

# Managing Water Levels and Flows in the Rainy River Basin

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A REPORT TO THE INTERNATIONAL JOINT COMMISSION

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Prepared by the  
INTERNATIONAL RAINY AND NAMAKAN LAKES RULE CURVES STUDY BOARD



International Rainy and Namakan  
Lakes Rule Curves Study Board





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FINAL REPORT - JUNE 2017

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## ACKNOWLEDGEMENTS

The International Rainy and Namakan Lakes Rule Curves Study Board is pleased to submit this final report, ***Managing Water Levels and Flows in the Rainy River Basin***. From the start, the Study Board's work has been a cooperative effort involving many individuals and organizations on both sides of the Canada-United States border. The planning, research, analysis and review that went into this report would not have been possible without their ideas, energy and shared commitment to working together to address the challenge of managing water levels and flows in the basin.

The Study Board expresses its sincere appreciation to the following groups and individuals for their contributions in support of the development of this report. Annex 4 provides a list of the individual members of several of these groups:

- Ryan Maki of **Voyageurs National Park**, who managed the Plan of Study for the IJC for several years in preparation for the Rule Curve Study, and who provided key summaries of Study conclusions.
- Community members from **First Nation** communities, the **Red Lake Band of Chippewa Indians**, **Métis Council** representatives and staff at **Grand Council Treaty #3**. The Study Board is grateful for the face-to-face meetings and dedication of time from these groups that enriched our understanding of issues and concerns to communities and the message that ongoing communication is key to working together on water regulation in the future.
- Members of the **Rule Curve Public Advisory Group**, their US co-chair Tim Snyder and Canadian co-chair Jeff Wieme. This group was invaluable in providing on-the-ground insights into the impacts of water level regulation and innovative ideas for consideration in this review.
- Members of natural resource agencies who either served on the **Resources Advisory Group** or as additional on-call experts. The resource knowledge and wealth of expertise of these individuals directly contributed to making this review comprehensive and inclusive.
- The **International Joint Commission** advisors who have guided our Study Board since its inception in August 2015: Mark Colosimo, Mark Gabriel, Nick Heisler and Wayne Jenkinson.
- Members of the **Technical Working Group**, whose extensive modelling and technical analysis formed the foundation of the report: Jean Morin and William Werick.
- Members of the **Independent Review Group**, who provided insightful peer review comments throughout the Study that greatly strengthened the analysis and final report: Elizabeth Bourget and Ted Yuzyk.
- Technical Writer, **Tom Shillington**, who ensured each version of the report improved in its consistency and completeness and was thoroughly edited and submitted on schedule.
- Members of the community who served on the **Adaptive Rule Curve Committee** and the **Rainy River group**. The technical and local expertise on these two groups provided valuable insight for the review.

- Members of the **International Rainy-Lake of the Woods Watershed Board**, especially members of the Board's **Water Levels Committee** and its **Community Advisory Group** and **Industry Advisory Group**, many of whom participated in meetings and reviewed documents throughout the process.
- Members of the public who attended public meetings, our practice and draft decision workshops and webinars and who submitted comments throughout the process.
- Finally, we would like to gratefully acknowledge the **International Joint Commission** for the opportunity to serve on the Study Board and work together to address this important challenge.

## **INTERNATIONAL RAINY AND NAMAKAN LAKES RULE CURVES STUDY BOARD**

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Kelli Saunders



## EXECUTIVE SUMMARY

***Managing Water Levels and Flows in the Rainy River Basin*** is the final report of the International Rainy and Namakan Lakes Rule Curves Study Board (Study Board) to the International Joint Commission (IJC).

The report is the product of several years of planning, science, analysis and consultations with residents of northwestern Ontario and northern Minnesota about the future management of the water levels and flows in the boundary waters of the Rainy River basin.

In preparing this final report, the Study Board has taken into consideration the comments received during a 30-day period of public review and comment on a draft of the report.

flows for the two lakes. The current rules have been in place since 2000. At that time, the IJC stated it would review those rules in 15 years, taking into account the most recent scientific information about the effects of water levels and flows in the system.

In the fall of 2015, the IJC established the Study Board, charging it “to *evaluate options for regulating levels and flows in the Rainy-Namakan Lakes system in order to benefit affected interests and the system as a whole in a manner that conforms to the requirements of the Treaty.*”

In the Rainy-Namakan Lakes system, these interests include: protecting shoreline properties and communities from flooding and erosion; ensuring sufficient water levels for hydroelectricity generation; protecting the rich and complex natural environment of the basin; protecting shoreline cultural and archeological sites and resources from erosion; maintaining seasonal water levels to allow for boating and other recreational uses and associated tourism; and protecting water quality.

### THE CHALLENGE

The Rainy River basin straddles the international border west of Lake Superior, a vast stretch of territory dense with large lakes, rivers and wetlands. The outlets of the two main lakes of the basin, Rainy and Namakan, have been controlled by dams for more than 100 years. Since 1949, Canada and the United States, through the IJC, have jointly established formal rules for regulating water levels and

### STUDY APPROACH

#### Scope of the Study

The geographic scope of the Study covers those areas of the Rainy River basin directly affected by dam operations at the outlets of Rainy Lake and Namakan Lake. This area consists of:

- the Namakan Chain of Lakes<sup>1</sup>;
- Rainy Lake;
- Rainy River; and
- the associated riparian (shoreline) zones of these waters.

#### Study objectives

The Study was led by a six-person Study



PATRICE NELSON

<sup>1</sup> The Namakan Chain of Lakes refers to the five lakes (Namakan Lake, Lake Kabetogama, Crane Lake, Sand Point Lake, and Little Vermilion Lake) that have water levels influenced by the dam operations at the outlet of Namakan Lake.

## Rainy-Namakan Lakes Rule Curves Review Study Area

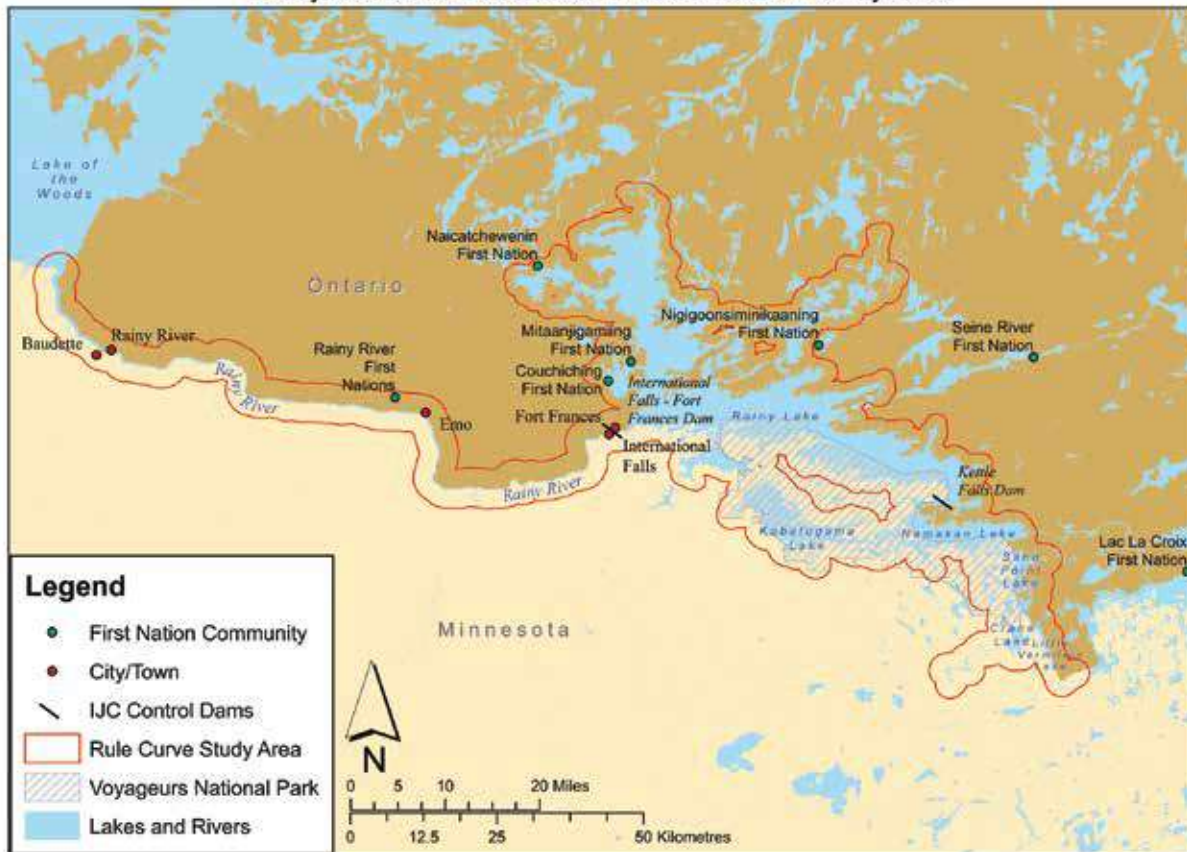


Figure Ex-1 Study area

Board, with members drawn equally from Canada and the United States and with experience with water management issues. After extensive consultation with the many interests in the basin regarding its Study Strategy, the Study Board established three key objectives to address the challenge of managing future water levels and flows in the Rainy-Namakan Lakes system:

1. *To evaluate the performance of the 2000 Rule Curves in comparison to the 1970 Rule Curves and State of Nature, considering a range of ecological, social, economic and environmental conditions that may be affected by water level regulation.*
2. *To develop and evaluate additional regulation alternatives that reflect concerns of stakeholders in the study area and to compare the performance of these alternatives to that of regulation*

*under the 1970 and 2000 Rule Curves.*

3. *To evaluate all regulation alternatives for performance under a range of climate and water supply conditions.*

### Rule Curves

Rule curves are the primary regulatory tool for managing water levels of Namakan Lake and Rainy Lake. They provide a target range, known as the band, for the level of the lake for every day of the year. The IJC has used rule curves for managing levels of these two lakes since 1949. The most recent versions were adopted in 2000 and, as a result, are known as the 2000 Rule Curves.

### Study methodology

To address these objectives in a scientifically rigorous and open manner, the Study



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Board adopted a two-part methodology for undertaking the analysis:

**1. Weight of Evidence (WOE)**

This approach involved an evaluation by the Study Board of the results of a series of studies to determine whether a specific issue in the basin under consideration (e.g., Walleye population or the economic impacts on the resort industry) has improved, worsened or not been affected by the adoption of the 2000 Rule Curves. Results of these individual assessments then were brought together in a simple matrix to assess the full range of effects of the 2000 Rule Curves.

**2. Shared Vision Planning (SVP)**

Shared Vision Planning aims to provide a comprehensive, participatory and transparent evaluation process. Through a series of practice decision workshops, supported by computer modelling, interested parties were able to evaluate various criteria and learn about the possible effects of changes in water levels and flows on the interests in the study area under different regulation plans.

**ENGAGEMENT AND OUTREACH IN THE STUDY**

Recognizing the many interests concerned with the future of water levels and flows in the basin, the IJC established a strong engagement and outreach component from the outset of the Study. The process sought to: make the public aware of the Study; provide opportunities to participate; identify and consider the public's views; and ensure that the study process was open, inclusive and fair.

The Study Board also recognized that Tribes, First Nations and Métis within the study area have a unique, intimate knowledge and relationship with the watershed. It sought to directly engage early with these communities to seek their input and involvement in the rule curves evaluation.

The IJC's Directive for Communication and

Public Outreach Activities established a Rule Curve Public Advisory Group (RCPAG) to assist the Study Board in its outreach activities. The RCPAG consisted of 32 individuals who live or operate businesses within the study area. They represented a range of perspectives in the basin, including: lake/property owners' associations; navigation interests; environmental organizations; First Nations and Tribes; tourism and recreation interests; and hydroelectric companies. RCPAG members were drawn from throughout the study area in both Canada and United States.

In addition, the Study Board established a separate advisory group of federal, state and provincial agency employees in the watershed that are responsible for natural resource management or environmental protection. This Resources Advisory Group (RAG) reviewed analyses and recommendations made by the Study Board for their potential effects on natural resources or the environment in the study area.

Over the course of the Study, the Study Board convened more than 45 public and advisory group meetings throughout the study area. The meetings included in-person meetings in communities, as well as webinars and teleconferences, recognizing that many interested parties live in rural or remote areas and were unable to attend in-person meetings.

The engagement and outreach plan developed and implemented by the Study Board resulted in important benefits to the Study: a better understanding of the concerns of the key interests in the basin; a strengthened report, thanks to public comments on the Study's overall approach, analysis and findings; and enhanced public understanding of water regulation and the hydrological makeup of the study area, which can support future outreach efforts on water management challenges in the basin.

## PERFORMANCE OF THE 2000 RULE CURVES

### Comparison of the 2000 Rule Curves and 1970 Rule Curves

In 2000, following an extensive review of the 1970 Rule Curves, the IJC established a new set of rule curves for Rainy Lake and Namakan Lake. The most significant change involved a reduction in the over-winter drawdown for Namakan Lake by approximately 1 m (3.28 ft), as well as the earlier refill of Namakan Lake in the spring. For Rainy Lake, the rule curve revisions were relatively minor. Figure Ex-2 illustrates the 1970 and 2000 Rule Curves for both lakes.

In addressing the Study's first key objective, the Study Board compared the 1970 and 2000 Rule Curves in seven key subject areas: fish; wildlife; economic impacts; cultural/archeological sites; aquatic riparian vegetation; invertebrates; and water quality. Table Ex-1 presents a summary of the analysis of whether the 2000 Rule Curves resulted in a *better*, *neutral* or *worse outcome* for the subject compared to the 1970 Rule Curves.

The Study Board concluded that the 2000 Rule Curves generally performed as expected, compared to the 1970 Rule Curves. These expected results included both positive and negative expected outcomes.

*Positive expected outcomes* confirmed by the Study included:

- improvements in fish population and spawning habitat of several key species;
- improved conditions for wildlife;
- increased tourism benefits as a result of improvements to navigation and dock access in the spring on the Namakan Chain of Lakes;
- improved preservation of cultural/archeological sites along the shorelines of Namakan and Rainy Lakes;
- benefits to wetland vegetation, emergent vegetation and submerged plants in the Namakan Chain of Lakes;
- increased over-winter survival of invertebrates in the Namakan Chain of Lakes as a result of the reduction in over-winter drawdown; and
- improvements in water quality in Black Bay on Rainy Lake.

*Negative expected outcomes* confirmed by the Study included:

- decreased potential for hydropower production as a result of reductions in available storage; and
- increases in flood damage on both Namakan Lake and, particularly, Rainy Lake, as a result of the decrease in available storage on Namakan Lake in advance of the spring freshet.



JEFF KANTOR JCK PHOTOS

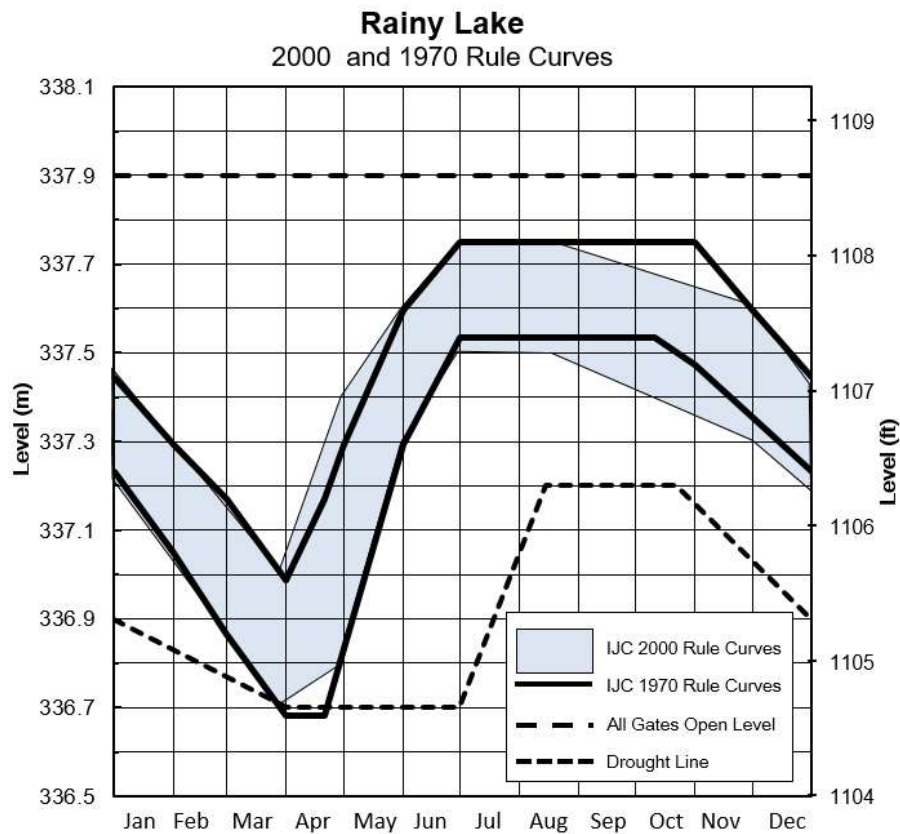
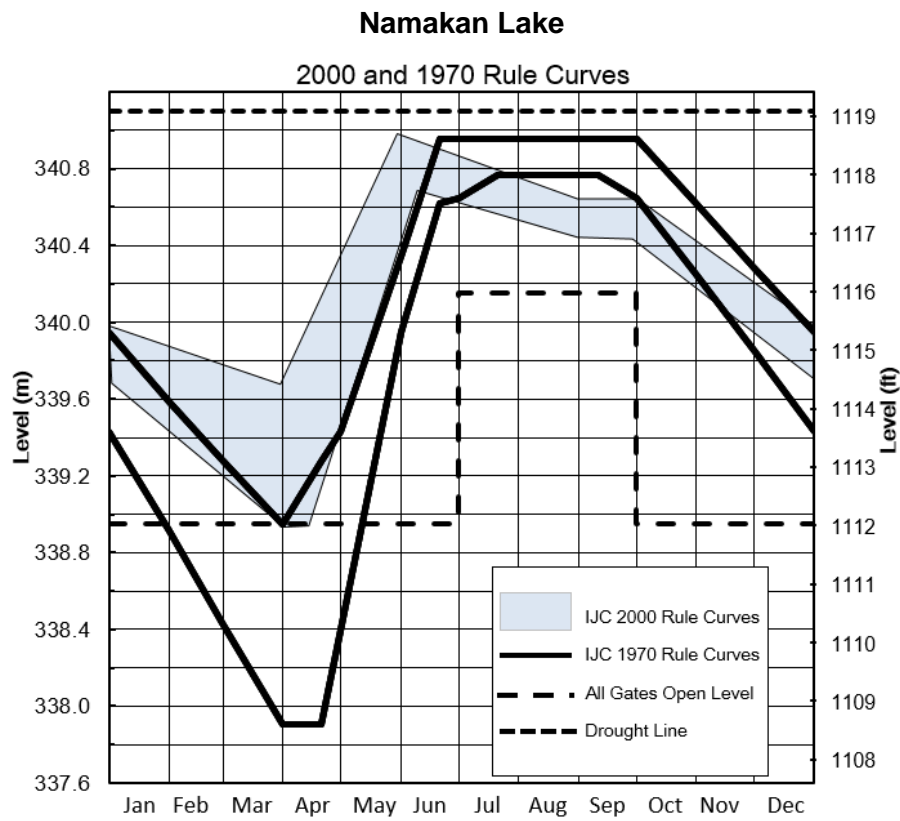


Figure Ex-2 2000 and 1970 Rule Curves for Namakan Lake and Rainy Lake



**Table Ex-1 Summary of Study Board assessment of 2000 Rule Curves vs 1970 Rule Curves**

Question: Did regulation under the 2000 Rule Curves result in a better, neutral or worse outcome for the Study subject?

(Note: blank entries mean either that the results were inconclusive or that no data were available on which to make a conclusion)

○ better outcome

✗ worse outcome

● neutral outcome

Study themes and subjects	Namakan Chain of Lakes	Rainy Lake
<b>1. Fish</b>		
Northern Pike population	○	○
Northern Pike young of year	○	●
Northern Pike nursery and young of year habitat	○	○
Walleye population	-	-
Walleye young of year	○	○
Walleye spawning habitat	○	●
Yellow Perch population	●	○
Yellow Perch young of year	○	○
Lake Sturgeon population	-	-
Lake Sturgeon spawning habitat	-	-
Lake Whitefish population	-	-
Lake Whitefish spawning habitat	○	●
Yellow Perch young of year mercury concentration	-	-
<b>2. Wildlife</b>		
Beaver population	○	●
Habitat for birds and herptiles	-	-
Common Loon reproductive success	○	●
Muskrat lodge winter viability	●	○
<b>3. Economic impacts</b>		
Power production	n/a	✗
Flooding	✗	✗
Ice damage	-	-
Resort industry	○	-
<b>4. Archeological resources</b>		
Condition of resources	○	○
<b>5. Vegetation</b>		
Cattail invasion	●	●
Wetland vegetation	○	-
Emergent vegetation - wet meadow	✗	○
Submerged plants	○	●
Wild Rice	●	●

Study themes and subjects	Namakan Chain of Lakes	Rainy Lake
<b>6. Invertebrates</b>		
Invertebrate community	○	●
Mussels	-	-
<b>7. Water quality</b>		
Trophic state	○	○
Lake water phosphorous concentrations	●	●

One significant finding of the performance of the 2000 Rule Curves compared to the 1970 Rule Curves was not expected. Despite the general ecosystem benefits of the 2000 Rule Curves, the modelling indicated that the expansion of the invasive Hybrid Cattail in Rainy Lake and the Namakan Chain of Lakes is a continued threat to Wild Rice habitat. The steady water levels that result from regulation under the 2000 Rule Curves have provided excellent conditions for the expansion of invasive cattail.

Limited information exists concerning the impacts of the 2000 Rule Curves on the Rainy River. Background studies undertaken as part of the Study were unable to assess the impacts of the 2000 Rule Curves on archeological resources, benthic invertebrates, and municipal and fish hatchery water use. However, other studies found no change to the condition of the river's Lake Sturgeon population as a result of the implementation of the 2000 Rule Curves. As well, modelling results suggested that the 2000 Rule Curves have improved the conditions for Walleye and Lake Sturgeon spawning habitat on Rainy River downstream of the international dam at the outlet of Rainy Lake.

#### **Comparison of the 2000 Rule Curves and the State of Nature**

The second part of the evaluation of the

2000 Rule Curves considered how the rule curves compared with conditions under the hypothetical State of Nature (SON) conditions, using the results of modelling. The SON refers to a basin configuration where it is assumed that the dams limiting or regulating flow out of Namakan Lake and Rainy Lake do not exist. This allows for the modelling of flows from these lakes in a pre-dam condition – a best estimate of the system under natural, unregulated conditions. This comparison provided the Study Board with a second baseline against which to compare the 2000 Rule Curves, and one that is, in theory, much closer to the natural state conditions of the system than the 1970 Rule Curves.

Table Ex-2 presents a summary of the comparison under the study subject themes.

In general, the 2000 Rule Curves had mixed results when compared with the hypothetical natural conditions of the SON. The modelling indicated that, overall, the SON generally would provide more favorable conditions for many ecological interests, though some interests, such as the Common Loon, fare best under regulated conditions. However, compared to the SON, the 2000 Rule Curves resulted in reduced flood risk and damages to riparian interests (as would be expected under regulation) and increased tourism benefits as a result of improved navigation in low water years. Finally, as the dams would

Table Ex-2 Summary of Study Board assessment of 2000 Rule Curves vs State of Nature

Study theme	State of Nature Conditions compared to 2000 Rule Curves
<b>Fish</b>	<p>Increase in Walleye on Namakan Lake and a decrease on Rainy Lake</p> <p>Increase in Northern Pike on both lakes</p> <p>Greater variation in Lake Whitefish population over the years on Namakan Lake and a decrease on Rainy Lake</p>
<b>Wildlife</b>	<p>Common Loon nests are less successful on both lakes</p> <p>Muskrats are more likely to thrive over the winter period more frequently on both lakes</p>
<b>Economic impacts</b>	<p>Increase in the amount of damage to docks and shoreline structures on both lakes</p> <p>Poor navigation conditions on both lakes throughout the boating season</p>
<b>Archeological resources</b>	<p>Extreme water levels during high water events would likely threaten archeological sites that are currently protected by regulation</p>
<b>Aquatic vegetation</b>	<p>Overall, a more diverse aquatic vegetation community on Namakan and Rainy Lakes</p> <p>Expansion of the invasive Hybrid Cattail impeded on both lakes</p> <p>Wild Rice likely to produce more successful crops, more frequently</p> <p>Increase in wet meadows and shrubby swamps on both lakes</p> <p>Emergent vegetation more variable on both lakes</p> <p>Areas of low- and high-density vegetation reduced on both lakes</p>
<b>Rainy River</b>	<p>Increase in the extent of suitable Walleye spawning habitat on Rainy River in most years</p> <p>Rainy River Lake Sturgeon spawning habitat increased for most years</p>



**Four alternatives  
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not be present under the SON conditions, any comparison of impacts on hydropower production was not relevant.

### **Formulation and evaluation of alternative rule curves**

In addressing the Study's second key objective, the Study Board worked to formulate and evaluate alternative rule curves that have the potential for providing improved performance over the 2000 Rule Curves. This work focused on two key objectives:

- addressing concerns about flooding, particularly on Rainy Lake; and
- improving ecological outcomes over the 2000 Rule Curves.

In practice, the formulation of alternative rule curves involved the iterative process of testing, refining and re-testing dozens of alternatives, and was informed by a series of decision workshops with the RCPAG and RAG.

Four alternatives (in addition to the existing 2000 Rule Curves) were selected and tested for detailed computer modelling and analysis. The objectives and key features of the four alternatives (named **B**, **C**, **D** and **E**) are summarized in Table Ex-3. (Note that in this evaluation, the 2000 Rule Curves were referred to as **Alternative A**.)

The alternatives were evaluated, through modelling, in terms of their effects on: fish; wildlife; the economy; archeological resources; aquatic vegetation; and Rainy River interests. Table Ex-4 summarizes the results of the evaluation of the four alternatives.

### **Summary of evaluation of alternatives**

Based on the analysis, the Study Board made the following key findings:

- **Alternative B** would be an improvement over the existing 2000 Rule Curves as it provides some flood damage reduction on Rainy Lake in most flood springs, with some negative ecological impacts

when a flood is incorrectly forecasted;

- **Alternative C** would be an improvement over the existing 2000 Rule Curves, as it provides many ecological benefits, despite some negative economic impacts;
- **Alternative D** would not improve upon the existing 2000 Rule Curves. The minor benefits to economic interests on Namakan Lake and Rainy Lake do not offset the negative ecological and archeological impacts; and
- **Alternative E** would not be an improvement over the existing 2000 Rule Curves as the negative impacts on economic interests, including flooding, on Rainy and Namakan Lake are too great.

### **Addressing climate variability and change**

In addressing the Study's third key objective, the Study Board considered the impacts of climate variability and change on the rule curve alternatives under consideration. Climate change could affect the quantity and timing of water flowing into the Namakan Chain of Lakes and Rainy Lake, and the temperature of the water and hence ice cover and evaporation.

The Study Board tested the 2000 Rule Curves and **Alternatives B** and **C** under a wide range of future climate conditions, including both extreme wet and dry scenarios. (**Alternatives D** and **E** were not evaluated further because they did not perform well even when tested against historical water supplies.) The performance of all the alternatives was affected similarly by greater extremes in inflows. However, none was markedly better or worse. Flood damages increased substantially for all alternatives in the wettest scenario and decreased substantially in the driest scenarios. Boating conditions on both Namakan and Rainy Lakes were more resistant to dry scenarios, as levels returned

Table Ex-3 Summary of selected alternative rule curves

Alternative	Objectives	Key features
<b>B</b>	<p>Retain the benefits of the 2000 Rules Curves</p> <p>No changes to Namakan Lake 2000 Rule Curve</p> <p>Reduce flood damages on Rainy Lake without major impacts to other interests.</p>	<p>Retains existing 2000 Rule Curves for both Namakan and Rainy Lakes</p> <p>In years when risk of spring flooding is considered to be high, the rule curve for Rainy Lake is altered so that the refill of the lake begins at the end of April and the target range from May through early July is lower; the lake then returns to the 2000 Rule Curve band in early July</p>
<b>C</b>	<p>Retain the benefits of the 2000 Rules Curves and reduce the potential for flooding on Rainy Lake, while enhancing some ecological conditions for fish and fur-bearers</p>	<p>Revised 2000 Rule Curve targets in fall and winter to reduce winter drawdown</p> <p>Includes conditional flood reduction option of Alternative B for Rainy Lake in high flood risk springs</p>
<b>D</b>	<p>Improve late summer navigation on Namakan Lake</p> <p>Reduce Rainy Lake flooding</p>	<p>2000 Rule Curve for Namakan Lake, except constant higher target levels from June 1-Oct 1</p> <p>2000 Rule Curve for Rainy Lake</p>
<b>E</b>	<p>Enhance ecological conditions by increasing the variability in seasonal water levels over the years</p>	<p>Series of three rule curves sets for each lake: lower, medium and higher to be alternately used over years</p> <p>All three sets of curves for each lake contain features that aim to improve ecological interests, such as the reduced over-winter drawdown to encourage Muskrat survival, and the rapid refill in early spring to benefit Walleye spawning</p>

Table Ex-4 Summary of evaluation of the alternative rule curves, compared to 2000 Rule Curves

Study theme	Alternative B	Alternative C	Alternative D	Alternative E
<b>Fish</b>	Spring spawning fish can be negatively affected on Rainy Lake in years where a flood is forecasted and the flood curve reduction rule is implemented	<p>Increase in Walleye, Northern Pike and Lake Whitefish spawning habitat on Namakan Lake, Northern Pike on Rainy Lake</p> <p>Spring spawning fish can be negatively affected on Rainy Lake in years where a flood is forecasted and the flood curve reduction rule is implemented</p>	<p>No change in Walleye production in most years on either lake</p> <p>Increase in Northern Pike spawning habitat on Namakan Lake (though the extent remains extremely low) and no change on Rainy Lake</p> <p>Minor decrease in Lake Whitefish production in most years on Namakan Lake and only small changes on Rainy Lake</p>	Increase in production of Walleye, Northern Pike and Lake Whitefish populations as a result of more favorable spawning conditions on both lakes
<b>Wildlife</b>	<p>Some negative impacts to Common Loon nest viability on Rainy Lake in years when flood curve reduction rule is implemented</p> <p>No impact on likelihood of over-winter survival of Muskrats on Rainy Lake</p>	<p>Existing conditions for Common Loon nesting maintained</p> <p>Increase in likelihood of Muskrat over-winter survival on both Namakan and Rainy Lakes</p>	Minor negative and positive impacts in some years on wildlife on both lakes	<p>Improved conditions for loon nesting in most years on both lakes</p> <p>Increase in the probability of over-winter survival of Muskrats on both lakes</p>
<b>Economy</b>	<p>Reduction in flood damages on Rainy Lake</p> <p>Negative impact on early season boating when the lake is lowered and no flood occurs</p> <p>Modest improvement in minimum power production</p>	<p>Reduction in flood damages on Rainy Lake</p> <p>Possible reduction in late-season boating reliability on Namakan Lake</p> <p>Potential decrease in hydropower production</p>	<p>Slight increase in flood damage on Namakan Lake and a decrease on Rainy Lake</p> <p>Minor improvement to the late-season boating conditions on Namakan Lake</p>	<p>Increase in flood damages average annual flood damages</p> <p>Reduction in boating reliability on Namakan Lake</p> <p>Negative impact on hydropower production</p>



Study theme	Alternative B	Alternative C	Alternative D	Alternative E
<b>Archeological resources</b>	Increased protection of erosion of archeological sites on Rainy Lake	Increased protection to archeological sites on both lakes from erosion, as a result of greater variability in water levels	Likely to result in loss of existing protection and cause additional damages	Increased protection from erosion to archeological sites on Namakan Lake, but decreased protection on Rainy Lake
<b>Aquatic vegetation</b>	<p>Decrease in aquatic plant diversity on Rainy lake</p> <p>Hybrid Cattail invasion is worsened on Rainy Lake, resulting in a decrease in suitable habitat for Wild Rice</p> <p>Increase in the amount of suitable habitat for wet meadows, and a decrease for shrubby swamps</p>	<p>Hybrid Cattail invasion is worsened on Rainy Lake, resulting in a decrease in suitable habitat for Wild Rice. May be countered by improved muskrat populations (interaction not modelled)</p> <p>Increase in suitable habitat for wet and a decrease in habitat for shrubby swamps on both lakes</p> <p>Increase in suitable habitat for emergent plants on Rainy Lake</p> <p>Decrease in suitable habitat for low- and high-density submerged vegetation on both lakes</p>	<p>Hybrid Cattail invasion worsened on Namakan Lake and results in a decrease suitable area for Wild Rice</p> <p>Suitable area for wet meadows and shrubby swamps is decreased on Namakan Lake</p> <p>Minor decrease in submerged vegetation on Namakan Lake</p>	<p>Reduction in the amount of habitat available for cattail invasion, which results in an increase in the amount of habitat available for Wild Rice growth</p>
<b>Rainy River interests</b>	No change in the amount of suitable habitat for Walleye and Lake Sturgeon spawn on Rainy River	No change in the amount of suitable habitat for Walleye and Lake Sturgeon spawn on Rainy River	Little or no change in the amount of suitable habitat for Walleye and Lake Sturgeon spawn on Rainy River	<p>Little or no change in the amount of Walleye spawning habitat on Rainy River</p> <p>Decrease in amount of habitat for Lake Sturgeon spawning, in most years</p>

**The 2000  
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most measures  
investigated.**

to rule curve levels at year's end under even the longest drought. In no case did the relative performance of one alternative shift dramatically compared to that of the others, based on the climate scenario.

Therefore, the Study Board concluded that the alternative rule curves cannot be ranked based on differences in their performance with respect to climate variability and change. Future climate change could substantially affect water levels in the basin, regardless of the rule curve in use, since levels in both lakes cannot be controlled under extremely high or low inflows.

## **STUDY BOARD FINDINGS AND RECOMMENDATIONS**

Based on the results of the studies and analyses described in this report, the Study Board presents the following findings and recommendations:

### **Performance of the 2000 Rule Curves**

The 2000 Rule Curves performed as expected across most measures investigated.

The Study Board concluded that the 2000 Rule Curves generally performed as expected. Compared to the 1970 Rule Curves, the 2000 Rule Curves provided the expected results with respect to many of the Study's theme areas, including: improvements in fish population and spawning habitat of several key species; increased tourism benefits along the Namakan Chain of Lakes as a result of improvements to navigation and dock access; decreased potential for hydropower production as a result of reductions in available storage; and increases in flood damage on both Namakan Lake and, particularly, Rainy Lake, as a result of the decrease in available storage on Namakan Lake in advance of the spring freshet.

The analysis also found that the expansion of the invasive Hybrid Cattail in Rainy Lake

and the Namakan Chain of Lakes is a continued threat to Wild Rice habitat. This was an area not given consideration in the development of the 2000 Rule Curves. The steady water levels that result from regulation under the 2000 Rule Curves have provided excellent conditions for the expansion of invasive Hybrid Cattail at the expense of Wild Rice.

### ***The 2000 Rule Curve for the Namakan Chain of Lakes has local support.***

The Study Board heard consistent support from interests on the Namakan Chain of Lakes for the 2000 Rule Curve. The benefits to navigation in the early tourist season were strongly supported. The gradual summer drawdown of the lakes introduced with the 2000 Rule Curves was not opposed, though suggestions of having lower levels than this were not supported due to concerns about navigation in the late summer. Specifically, concerns were raised about access to Loon River and difficulties for canoeists if lake levels were decreased during this season.

### **Opportunities for improving water level management through new Rule Curves**

#### ***Dam operations cannot prevent most floods.***

No alternative rule curve evaluated in the review substantially reduced flooding damages, because the discharge of water from the lakes is physically limited by the outlet characteristics upstream of the dam. The Study Board concluded that construction of the dams did not introduce this constraint, and modelling results indicated that extremely high water levels experienced occasionally since dam construction would have occurred in a State of Nature. The dams did, however, raise normal water levels, flooding areas that in a natural state would not have been regularly inundated.

#### ***Conditional changes to the Rainy Lake Rule Curve may reduce flood peaks.***

The Study Board's analysis indicated that

**The Study Board examined rule curve options that would increase the variability of summer water levels by changing the summer target range from one year to the next.**

even small increases in flood peaks can result in large increases in damage costs, primarily to docks. The WOE analysis confirmed that such increases resulted from the implementation of the 2000 Rule Curves, and that this was due primarily to the loss in storage capacity in the Namakan Chain of Lakes in the spring. A modification of the 2000 Rule Curves could result in Rainy Lake peak elevations in flood years that are similar to those that would occur under the 1970 Rule Curves. This modification delays the refill of Rainy Lake from April until May, resulting in the passing of additional outflows during April. It also has a lower target range through May and June to allow for some storage capacity for anticipated high inflows. Targeting this lower range only in springs deemed to have a high flood risk would reduce the negative effects of lower spring water levels on fish spawning.

Modifications to over-winter drawdown of both lakes could result in multiple ecological benefits.

A reduction in the water level drawdown over the winter may provide improvements for a number of ecological subjects, including the over-winter survival of benthic invertebrates, spawning success for fall-spawning fish such as Whitefish, as well as improved over-winter survival for Muskrat, which have very low survival rates on Rainy Lake and near zero survival on the Namakan Chain of Lakes. Muskrat are a consumer of Invasive Hybrid Cattail, which has expanded its range in this system, particularly in Rainy Lake and Lake Kabetogama. Improving Muskrat populations could help to reduce the spread of Invasive Hybrid Cattail.

***Inter-annual variability in summer water levels has broad ecological benefits.***

Under normal inflow conditions, the operators of the dams at the outlet of Rainy Lake are able to consistently hold the levels of the lakes in the middle range of the Rule Curve during the summer.

Consequently, summer levels under the existing Rule Curves result in little variability over the years. This reduced variability, while achieving the balances implied in the rule curve design, loses the ecological benefits that a wider range of water levels provides, such as promotion of diverse plant, amphibian and fish communities. The Study Board examined rule curve options that would increase the variability of summer water levels by changing the summer target range from one year to the next, ensuring that the system experienced a range of summer water levels every few years, including low and high levels. However, given the increase in flood risk associated with intentionally higher levels and the navigation issues associated with intentionally lower levels, the Study Board does not regard this option as viable.

***Support for Rainy Lake flood damage reduction is strong but qualified.***

Support from the public for **Alternative B**, a modification to the Rainy Lake 2000 Rule Curves to allow for lower spring targets in years with high risk of flooding, was heard during practice decisions, webinars and at public meetings and in formal comments received after the Draft Decision Workshop in March of 2017. Support for the general concept was qualified, though, by specific concerns over potential effects on the Walleye fishery.

Several property owners' associations expressed support for the use of flood forecasting to lower lake targets on Rainy Lake, but also called for the Namakan Lake Rule Curve to be held flat in June and July at a higher elevation, as was the case in the 1970 Rule Curves, rather than targeting a gradual decline. Modelling indicated that this approach would increase flood damages slightly on Namakan and reduce them slightly on Rainy Lake. Property owners and representatives of the tourism businesses did not support lowering Rainy Lake below



the current rule curve range during boating season, even though doing so could reduce flooding damages, because it would also make navigation more difficult.

***Sustainable fisheries are important for ecological and economic reasons.***

Many individual participants in the public meetings and decision workshops voiced opinions that reflected their combined interests as business operators, riparian property owners, fishers and environmentalists. More than once, the Study Board was told of concerns that tourists might decide to summer elsewhere if negative fishing, boating or flooding experiences were persistent. In particular, the Study Board heard that the status of the Walleye population in these lakes is of high importance to these interests.

***There was broad support for enhancing broader ecological benefits.***

**Alternative C** (Figure Ex-3), produced late in the Study following several months of refinement, had broad support from the RCPAG and RAG following a webinar in April 2017 to describe the alternative and its performance, and in the Study's Final Decision Workshop in June 2017. Concerns over this alternative were raised by the dam owners due to potential impacts to hydropower generation and their operations at the Namakan dams in winter. This alternative modified the Namakan and Rainy 2000 Rule Curves to allow for reduced over-winter drawdown more similar to a natural lake level decline for several

ecological benefits, including improved winter survival of Muskrat and benthic invertebrates and improved spawning success of fall spawning species. This alternative also includes the lower spring target option introduced in **Alternative B**.

***The effect of future climate scenarios is consistent across Rule Curve alternatives.***

The alternative rule curves cannot be ranked based on differences in their performance with respect to climate variability and change. Future climate change could substantially affect water levels in the basin, regardless of the rule curve in use, since levels in both lakes cannot be controlled under extremely high or low inflows. This finding reinforces the importance of putting in place a comprehensive adaptive management program to help identify and respond to emerging climate change conditions.

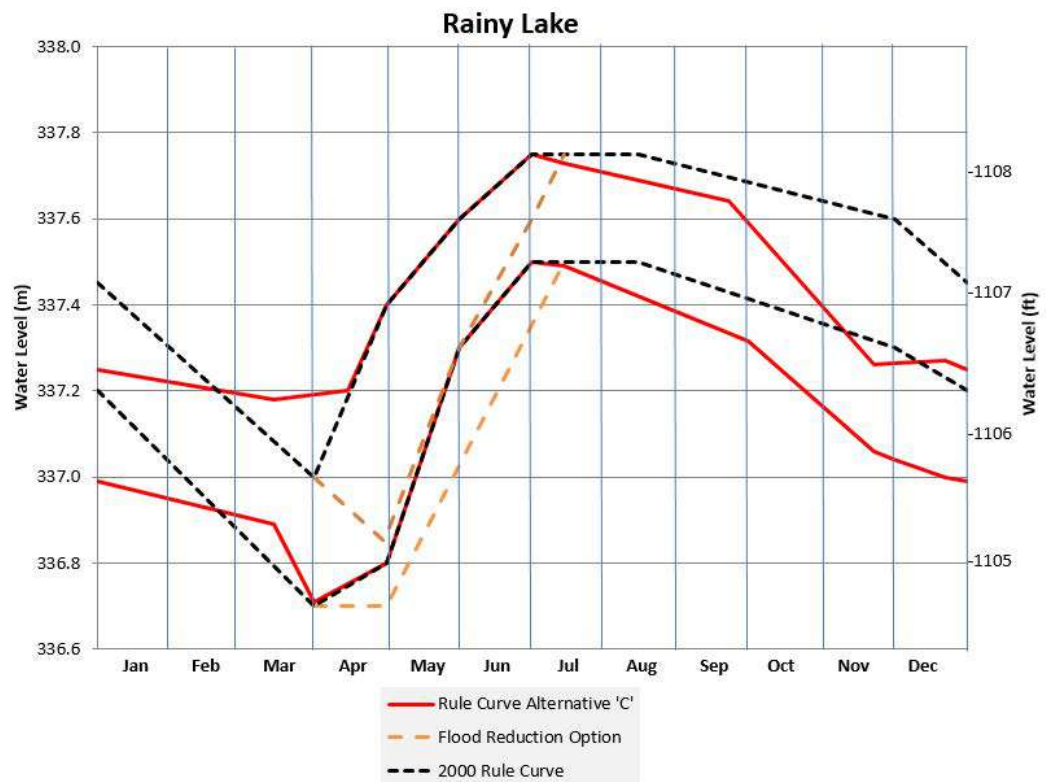
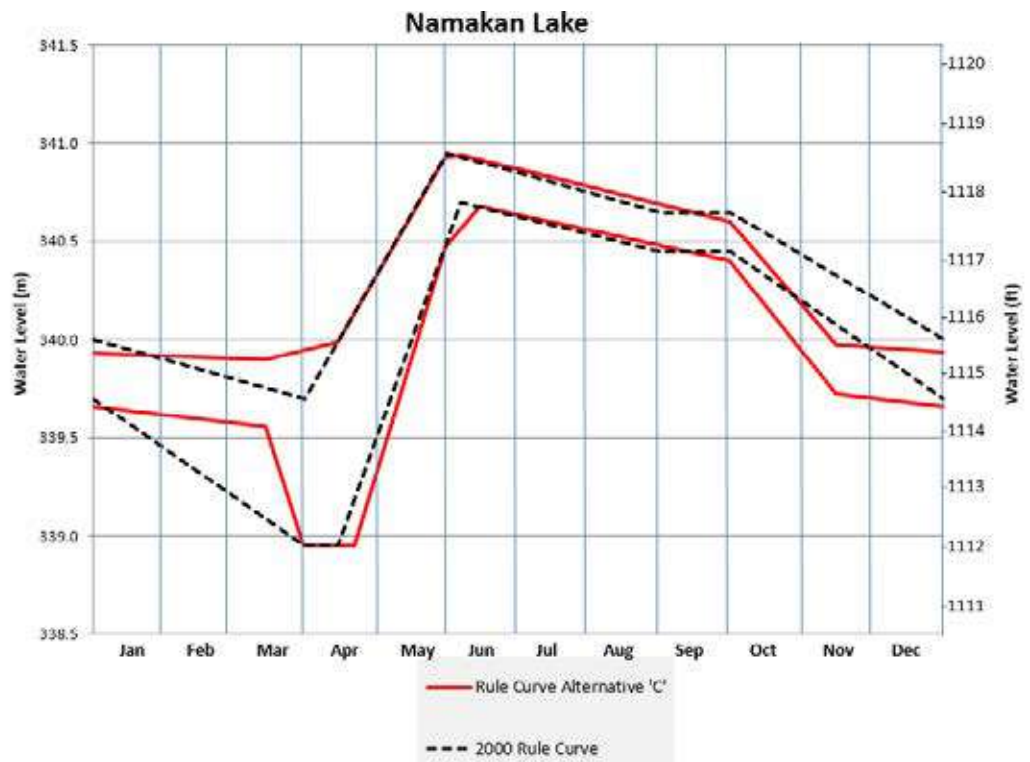
***Changes to the outflow profile from Rainy Lake, both through revised Rule Curves and operational policies, would affect downstream interests not considered in this study.***

Downstream interests at Lake of the Woods and the Winnipeg River are affected by the timing and magnitude of flows released into the Rainy River. This could have the potential to affect operations for downstream dams as well as stakeholders in these areas. This Study focused solely on potential effects of Rule Curve and operational changes on interests within the study area.

**Recommendation 1:  
Adopt Rule Curve Alternative C**

The Study Board recommends that the 2000 Rule Curves be replaced with Rule Curve **Alternative C**, providing conditional spring flood reduction targets for Rainy Lake in years with high spring flood risk and reducing over-winter drawdown for broad ecological benefits in both lakes.

Should the IJC determine that the changes to winter water level targets in Rule Curve **Alternative C** are not acceptable, the Study Board recommends that the conditional spring flood reduction component for Rainy Lake be implemented (Rule Curve **Alternative B**).



**Figure Ex-3 Rule Curve Alternative C and the 2000 Rule Curves**

**Alternative C** is designed to maximize ecological benefit in several areas each year while meeting constraints of high and low levels for flood protection and navigation.

***More flexible targeting within the 2000 Rule Curve band could provide additional benefit.***

Under the 2000 Rule Curves, the dam operators are required to normally target the middle portion of the Rule Curves. The rationale for targeting the middle portion of the band is that it provides some buffer in case hydrological conditions change quickly, either wetter or drier. The Study Board finds that more flexible operation within the Rule Curve bands may allow for additional benefits. For example, allowing lower targets in the spring if inflow conditions are already

high provides some buffer in case of higher flows, while holding the level higher in dry conditions would provide some drought resilience. In years where the Wild Rice crop is promising, ensuring relatively stable water levels throughout the growth period can protect the crop until harvest.

Development of Operational Guidelines, which cover these and other issues such as minimizing impacts to the Rainy River during flow changes and the current Rainy River Sturgeon Protocol, would provide a reference for these aims for the Water Levels Committee and stakeholders.

**Recommendation 2:**

**Promote flexible operation to improve outcomes**

The Water Levels Committee should be empowered and encouraged to actively target specific areas of the Rule Curve band to benefit various interests as the opportunity arises, in full consideration of trade-offs that would result. To support this approach, the Study Board recommends the development and regular updating of a set of Operational Guidelines that summarize water level management best practices that can benefit specific interests on both lakes and the Rainy River.

**Operations**

***The Water Levels Committee could benefit from having Terms of Reference.***

Under the IJC's 2001 Consolidated Order and the Directive for the International Rainy-Lake of the Woods Watershed Board, the Water Levels Committee of that board is charged with monitoring the hydrological conditions in the basin and the actions of the dam companies, and is

given the power to direct the companies in the operation of their discharge facilities. Beyond these responsibilities, there are no terms of reference specifying such matters as decision-making processes, record management, provision of data or operational information to the public or the duties of the committee's members and its engineering advisors. In addition, there are no written protocols for operating during emergency conditions.

**Recommendation 3:**

**Provide the Water Levels Committee with Terms of Reference**

Terms of Reference should be developed that detail the Water Levels Committee's operational procedures and responsibilities.

***The current process for deviating from the Rule Curves is inefficient.***

The 2001 Consolidated Order allows for the Water Levels Committee to deviate outside of the Rule Curve range if extremely high or low inflow conditions are anticipated,

with the permission of the IJC. The IJC's permission is granted through the issuance of Temporary Orders. The time from a request for a Temporary Order to its issuance by the IJC can result in operational problems and may limit the effectiveness of the intended deviation.

**Recommendation 4:**

**Empower the Water Levels Committee to direct targets outside of the Rule Curve range**

The IJC should consider empowering the Water Levels Committee to direct targets outside of the Rule Curve range under certain conditions, such as responding to imminent emergency, or to allow for more flexible spring refill of the lakes in timing with the freshet.

***Impacts to Rainy River water levels are not given regular consideration in current operations.***

The Study Board found that many interests engaged with the Rainy River believe that the 2000 Rule Curves are used to optimize conditions on Rainy Lake without regard for the Rainy River. The Study Board recognizes that many users of the river would benefit

from a reduction in the frequency of large flow changes from Rainy Lake that quickly and substantially raise or lower the river level, and would also benefit from being better informed when flow changes are planned. However, the Study Board also recognizes that fluctuations of the water levels in the Rainy River are affected only in part by the releases from the dam at International Falls, MN-Fort Frances, ON.

**Recommendation 5:**

**Examine practical operational approaches to benefitting Rainy River interests while meeting Rule Curve requirements**

As part of Operational Guidelines (Recommendation 2), the Water Levels Committee should identify best practices for limiting large flow changes from Rainy Lake while still respecting lake level requirements and operational requirements of the dam operators.

The IJC should consider developing an approach for notifying interested individuals along the Rainy River of planned changes in Rainy Lake outflow and associated changes in water levels, as well as the importance of the flow changes on the river level relative to other natural flows.

***Improved data collection could support improved inflow and lake level forecasting***

The Water Levels Committee currently uses an operational inflow forecasting model that relies on regular input of meteorological,

hydrometric, and hydrological data. Improvements in data collection in any of these areas could aid in producing more accurate inflow and lake level forecasts.



## **Recommendation 6:**

### **Review data monitoring sources to support inflow forecasting by the Water Levels Committee**

The IJC should direct a review of the available monitoring data to identify areas where additional monitoring would improve inflow forecasting. Specific areas of investigation should include snow-pack measurements, remotely-sensed snow-water content, precipitation monitoring stations and streamflow monitoring stations.

***There is broad support for better communication between the public and the Water Levels Committee concerning lake level management.***

Early in the Study, the Study Board raised the idea of having some form of community input process with the Water Levels Committee ahead of the spring freshet. This would benefit both the community participants through better understanding of the analyses

the Water Levels Committee is considering in planning for spring, and the Water Levels Committee by hearing local observations and concerns about spring conditions.

There was broad support for this idea from the RCPAG, and in 2017 the Water Levels Committee convened an informal meeting of this type with First Nations representatives, local organizations and resource agencies.

## **Recommendation 7:**

### **Formalize pre-spring engagement by the Water Levels Committee**

A formal process should be developed to engage the Water Levels Committee with key groups in the watershed affected by water level regulation ahead of the spring freshet. This recommendation is of particular importance should **Alternative B** or **Alternative C** Rule Curves be adopted, as a conditional decision on spring water level targets would need to be made each winter ahead of freshet.

### **Other water management considerations**

***Adaptive management could help improve water management outcomes in the basin.***

Adaptive management is a systematic, iterative approach for improving future management outcomes by learning from past outcomes—“learning by doing.” A collaborative, binational regional approach to adaptive management for the Rainy River basin could build on the experience, relationships and knowledge gained through the Study. It could address ongoing challenges such as integrated monitoring, modelling and risk assessment in response

to changing or uncertain conditions and emerging opportunities for action.

Participants in the Study's Final Decision Workshop in June 2017 endorsed the concept of adaptive management and expressed interest in how it could be implemented in the basin.

In reviewing options for an adaptive management framework for the basin, the Study Board believes that the concept of an Adaptive Management Committee is worth exploring. Such a committee could draw its membership primarily from the International Rainy-Lake of the Woods Watershed Board (IRLWWB) in a manner like the International Water Levels Committee. This committee

would consist of leads from the IRLWWB, with support and participation from the resource agencies in the watershed.

The Study Board emphasizes the importance of continued long-term monitoring along the Namakan Chain of Lakes and Rainy Lake of, at minimum, the following to support adaptive management:

- adult (gill netting) and young of year (seining) gamefish and adult Lake Whitefish (deep water gill netting);
- Wild Rice distribution;
- Hybrid Cattail distribution;
- Muskrat abundance;
- Common Loon reproductive success;
- Benthic community health;
- mercury content of young of year yellow perch;

- impacts of climate change; and
- water quality monitoring.

Over the course of the Study, resource agencies identified other possible monitoring needs to assess ecological impacts and these should be discussed further by any adaptive management committee established. All these adaptive management elements require financial and resource commitments in implementing a successful plan.

Finally, the Study Board notes the importance of monitoring the spread of Hybrid Cattail, as this is an area in which water level management can play a role, either directly through introduction of greater inter-annual variability, or indirectly through increasing Muskrat population.

#### **Recommendation 8: Investigate adaptive management**

The IJC should explore the use of a formal adaptive management process for the long-term evaluation of the effectiveness of the Rule Curves. The implementation of an adaptive management process is of particular importance should Rule Curve **Alternative C** be implemented as it would allow the Water Levels Committee to evaluate whether the changes to the winter water level targets result in the intended ecological effects.

#### ***There is some interest in investigating outlet modification for Rainy Lake to reduce flooding.***

The Study Board heard calls for a modification of the natural outlet constrictions, between Ranier, MN and Fort Frances, ON to reduce the severity of high water events. The Study Board recognizes that evaluating outlet modification would be a complex undertaking, with many environmental, economic, and political considerations. However, it also notes that significant reductions in flood peaks on Rainy Lake are not possible through operational changes or modification of the Rule Curves.

The Study Board notes that this is not a matter that the IJC can investigate on its own initiative, but would require direction from the governments of Canada and the United States. Based on feedback received from a variety of interests on this question, it recommends that the IJC advise the two governments that this is a subject of interest and controversy in the watershed.

### **Recommendation 9:**

#### **Advise the Governments of interest and concern over Rainy Lake outlet modification**

The IJC should advise the US and Canadian governments that modification to the outlet of Rainy Lake is a subject of interest in the watershed, with some support and some opposition.

#### **Engaging First Nations, Métis and Tribes**

Improved, ongoing communication with First Nations, Métis and Tribal communities would benefit the work of the Water Levels Committee and the Watershed Board.

From meetings, workshops and community visits, the Study Board learned the importance of ongoing, sustained interaction and communication in promoting the

involvement of Indigenous community members in IJC projects. The Study Board heard that engagement on only a project-by-project basis is not effective and that there would be great benefit to ongoing communication regarding work on water issues. This would help to establish relationships and partnerships that would later support and benefit individual projects as well as supporting water level regulation.

### **Recommendation 10:**

#### **Examine approaches for developing and sustaining improved relationships and communications with First Nations, Métis and Tribes on water issues**

The IJC should examine options for making meaningful improvements in relationships with Indigenous communities in the watershed. Ongoing communication is key to addressing the concerns of these communities and to improving the ability of the International Rainy-Lake of the Woods Watershed Board and its Water Levels Committee to inform its work with the benefit of both Aboriginal Traditional Knowledge and Western science.

#### ***The relationship between water levels and some key areas of Aboriginal Traditional Knowledge in this basin could not be adequately explored during this Study.***

While the rule curve review did provide analyses of the impacts of varying water level regulation scenarios on Wild Rice, fish, archeological resources and vegetation, First Nation communities also voiced concern over the impacts of regulation on burial grounds, pictographs and medicinal plants. The Study Board learned a great deal about the importance of these values to

communities in the study area but there were no data or research for pre- and post-2000 Rule Curves to incorporate these values into the review. However, the Study Board believes that research and resources are needed to address these important factors.

**Recommendation 11:****Consider sponsoring research projects to improve understanding of relationship between water levels and areas of Aboriginal Traditional Knowledge**

The IJC should consider sponsoring International Watersheds Initiative projects in communities that would help develop the understanding of the connection between water level management and key Aboriginal Traditional Knowledge subjects, such as medicinal plants and pictographs. This understanding could help inform the work of the Water Levels Committee, adaptive management efforts and future reviews of the Rule Curves.

**SUMMARY OF STUDY BOARD RECOMMENDATIONS**

1. Adopt Rule Curve **Alternative C**
2. Promote flexible operation to improve outcomes
3. Provide the Water Levels Committee with Terms of Reference
4. Empower the Water Levels Committee to direct targets outside of the Rule Curve range
5. Examine practical operational approaches to benefitting Rainy River interests while meeting Rule Curve requirements
6. Review data monitoring sources to support inflow forecasting by the Water Levels Committee
7. Formalize pre-spring engagement by the Water Levels Committee
8. Investigate adaptive management
9. Advise the Governments of interest and concern over Rainy River outlet modification
10. Examine approaches for developing and sustaining improved relationships and communications with First Nations, Métis and Tribes on water issues
11. Consider sponsoring research projects to improve understanding of relationship between water levels and areas of Aboriginal Traditional Knowledge



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## LIST OF ACRONYMS

The following is a list of acronyms used in the report:

ENSO	El Niño Southern Oscillation
IBI	Index of Biotic Integrity
IERM	Integrated Ecological Response Model
IJC	International Joint Commission
IRG	Independent Review Group
IRLBC	International Rainy Lake Board of Control
IRLWWB	International Rainy-Lake of the Woods Watershed Board
MNDNR	Minnesota Department of Natural Resources
OMNRF	Ontario Ministry of Natural Resources and Forestry
PCA	Packaging Corporation of America
PIs	Performance Indicators
RAG	Resources Advisory Group
RCPAG	Rule Curve Public Advisory Group
SON	State of Nature
SVM	Shared Vision Model
SVP	Shared Vision Planning
TWG	Technical Working Group
WLC	Water Levels Committee of the IRLWWB
WOE	Weight of Evidence
YoY	Young of Year



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# 1. INTRODUCTION

The Rainy River basin straddles the international border west of Lake Superior, a vast stretch of territory dense with large lakes, rivers and wetlands. For thousands of years, these waters and lands have been home to Indigenous peoples. The last 100 years have seen the growth of important industries in the region, such as pulp and paper production and mining. Today, the area is recognized as an outstanding recreational destination, with hundreds of thousands of seasonal residents and visitors enjoying camping, fishing, recreational boating and backcountry canoeing.

The outlets of the two main lakes of the basin, Rainy and Namakan, have been controlled by dams for more than 100 years. Since 1949, Canada and the United States, through the International Joint Commission (IJC), have jointly established formal rules for regulating water levels and flows for the two lakes. The current rules have been in place since 2000. At that time, the IJC stated it would review those rules in 15 years, taking into account the most recent scientific information about the effects of water levels and flows in the system.

This report presents the conclusions and recommendations of that review. It addresses the fundamental question of regulating water levels and flows: *what is the most effective approach to balancing the needs of different — and at times, competing — interests in the basin?* In the Rainy River basin, these interests include: protecting shoreline properties and communities from flooding and erosion; ensuring sufficient water levels for hydroelectricity generation; protecting the natural environment of the basin; protecting shoreline cultural and archeological sites and resources from

erosion; maintaining seasonal water levels to allow for boating and other tourism uses; and protecting water quality.

Underlying these concerns is the emerging challenge of regulating future water levels and flows under the uncertain conditions of a changing global climate.

## The International Joint Commission

Under the *Boundary Waters Treaty of 1909* (the Treaty), the governments of the United States and Canada established the basic principles for managing many water related issues along their shared international boundary. The Treaty established the IJC as a permanent international organization to advise and assist the governments on a range of water management issues. The IJC has two main responsibilities: regulating shared water uses; and investigating boundary water issues and recommending solutions.

## 1.1 Purpose of the report

In 2015, the IJC established the **International Rainy and Namakan Lakes Rule Curves Study Board** (the Study Board) to examine the challenges of regulating future water levels and flows in Rainy Lake and Namakan Chain of Lakes system<sup>2</sup>. The Study Board was tasked with rigorously evaluating regulation options and proposing scientifically-supported recommendations for the IJC's consideration, taking into account a wide range of hydrological, hydraulic, cultural, economic and environmental factors (Annex 1).

***Managing Water Levels and Flows in the Rainy River Basin*** is the final report of the

<sup>2</sup> The Namakan Chain of Lakes refers to the five lakes (Namakan Lake, Lake Kabetogama, Crane Lake, Sand Point Lake, and Little Vermilion Lake) that have water levels influenced by the dam operations at the outlet of Namakan Lake.

**The geographic scope of the Study covers those areas of the Rainy River basin directly affected by dam operations at Rainy Lake and Namakan Lake.**

Study Board to the IJC. It is the product of several years of planning, science, analysis and consultations with residents of northwestern Ontario and northern Minnesota about the future management of the water levels and flows in the boundary waters of the Rainy River basin. In preparing this final report, the Study Board has taken into consideration the comments received during a 30-day period of public review and comment on a draft version of the report.

The report has been prepared at the direction of the IJC. It also will be of interest to all parties concerned about the future of water levels and flows in the study area, many of whom have made significant contributions to the development of this report. These interests include provincial and state resource management agencies, year-round and seasonal residents, Tribes, First Nations and Métis, tourism and recreational services operators, and industries operating in the study area.

## **1.2 Study setting**

### **1.2.1 Study scope**

At a regional level, the physical setting and context for the study is the Rainy River basin (the basin), which extends from the watershed divide with Lake Superior to the east to the outlet of Rainy River into Lake of the Woods in the west.<sup>3</sup> The basin is also bounded by the English River drainage basin to the north, and the Mississippi River basin to the south.

The basin drains about 54,900 km<sup>2</sup> (21,200 mi<sup>2</sup>) of territory in northwestern Ontario and northeastern Minnesota. The portion of the basin above the outlet of Rainy Lake has a total drainage area of about 38,600 km<sup>2</sup> (14,900 mi<sup>2</sup>), of which 58 percent is in Canada.

The Rainy River, about 130 km (80 mi) long, is the boundary between Canada and the

United States from Rainy Lake to Lake of the Woods. The waters that leave the basin flow north through Lake of the Woods and the Winnipeg River, eventually flowing into Hudson Bay.

The basin has three distinct sub-basins:

- the *Namakan Lake sub-basin*, which includes the Namakan Chain of Lakes, and upstream lakes and rivers, the largest of which are Lac La Croix and Basswood Lake;
- the *Rainy Lake sub-basin*, which receives tributary flows from the Namakan Lake sub-basin as well as flows from the Seine River watershed and the Turtle River; and
- the *Rainy River sub-basin*, which receives all flow out of Rainy Lake in addition to a sizeable watershed that includes the Big Fork and Little Fork Rivers in Minnesota and additional drainage from smaller tributaries in Ontario.

The geographic scope of the Study covers those areas of the Rainy River basin *directly affected by dam operations at Rainy Lake and Namakan Lake*. This area consists of:

- the Namakan Chain of Lakes, with a combined surface area of about 270 km<sup>2</sup> (104 mi<sup>2</sup>);
- Rainy Lake, with a surface area of about 894 km<sup>2</sup> (344 mi<sup>2</sup>);
- Rainy River; and
- the associated riparian (shoreline) zones of these waters.

Figure 1-1 illustrates this study area within the larger basin.

### **1.2.2 Physical setting**

#### **Surface geology**

The surface geology of the basin region is

3 This section based on: International Rainy Lake Board of Control (IRLBC), 1999; International Lake of the Woods and Rainy River Watershed Task Force, 2011; Lake of the Woods Water Sustainability Foundation, 2014; and Minnesota Pollution Control Agency Rainy River Basin Information, available at: <https://www.pca.state.mn.us/sites/default/files/bid-rainyriver.pdf>.



## Rainy-Namakan Lakes Rule Curves Review Study Area



Figure 1-1 Study area

glacial in origin, the product of the advance and retreat of four great ice sheets about two million years ago. The lower, western part of the basin was once the bed of a large glacial lake, Lake Agassiz, which covered much of the region following the last period of glaciation for about 5,000 years, up to about 7,500 years ago.

The basin is characterized by streams in well-defined channels connecting numerous lakes. The land surface is characterized by heavily wooded rocky terrain, with only a limited soil cover.

### **Climate**

The basin's climate is characterized by short, hot summers and long, severe winters. Lakes typically freeze up in early December and break up near the end of April. Mean annual precipitation is 680 mm (about 27

inches), of which about 30 percent falls as snow. December through March typically are the driest months, while June, July and August are the wettest. Inflow of streams into the lakes is typically highest in May and June, as a result of a combination of snowmelt and rainfall. However, heavy rains at any time during the rainy season can cause runoff and flooding.<sup>4</sup>

Climate trends in recent decades include increasing average temperatures and rainfall, longer frost-free seasons, a decline in winter precipitation and an increase in the length of the ice-free season on the larger lakes in the basin.

### **1.2.3 Socio-economic setting**

The study area's year-round population is concentrated in the two largest urban

<sup>4</sup> IRLBC (1999), p.3

**Indigenous peoples ... rely on the land, waters and rich natural resources of the area for their economic and spiritual wellbeing.**

settlements in the basin: the towns of Fort Frances, ON (population about 8,000, as of the 2011 census) and International Falls, MN (about 6,400, as of 2010), on either side of the Rainy River at the outlet of Rainy Lake. Other settlements along waterways in the study area include Baudette, MN (1,100), Emo, ON (1,250) and Rainy River, ON (850). There are numerous seasonal homes in shoreline areas and along some roadways in the study area, and the area's population increases considerably during the summer tourist season.

Indigenous peoples have occupied the area since long before the period of European exploration and settlement. They rely on the land, waters and rich natural resources of the area for their economic and spiritual wellbeing. They traditionally harvest Wild Rice, timber, berries and medicinal plants, and engage in fishing, hunting and trapping. Within and near the study area itself are seven First Nations (Figure 1-1). The First Nations in the study area are members of Grand Council Treaty #3, the traditional government of the Anishinaabe Nation in the region. Grand Council Treaty #3's territory extends from west of Thunder Bay, ON to north of Sioux Lookout, ON, along the international border to near the Manitoba-Ontario provincial border. It is made up of 28 First Nation communities with a total population of about 25,000.<sup>5</sup> In addition, the Métis Nation of Ontario has community councils scattered throughout the greater watershed. Its Sunset Country Council is located in the study area. In the United States, the Bois Forte Band and Red Lake Band of Chippewa Indians have lands within the greater basin region, but no actual communities within the study area.

Historically, logging, sawmills and pulp and paper production were key components of the region's economy. While these remain

important activities, many communities in the region increasingly are looking towards water-based tourism and recreation to support their economic base. Fishing, recreational boating, ecotourism and shoreline property ownership are important activities in the study area. The US Voyageurs National Park includes portions of the waters and shorelines of Rainy, Namakan and other lakes in the study area (Figure 1-1). Much of the national park is accessible only by boat or, in winter, by snowmobile, ski or snowshoe. In 2016, more than 240,000 people visited the park.<sup>6</sup>

### 1.3 Report organization

The rest of the report is organized into the following chapters:

- **Chapter 2** provides an overview of current regulation of water levels and flows in the basin and a summary of the key interests likely to be affected by changes in water levels and flows in the study area;
- **Chapter 3** summarizes the approach to the Study undertaken by the Study Board, including study objectives, organization and methodology;
- **Chapter 4** presents an overview of the comprehensive engagement and outreach plan developed and implemented over the course of the Study by the Study Board, as well as a summary of the priority concerns about water levels that have been raised in the Study by members of the public and by Tribes, First Nations and Métis;
- **Chapter 5** presents an analysis of the performance of the 2000 Rule Curves in comparison to the 1970 Rule Curves and State of Nature conditions;
- **Chapter 6** summarizes the Study

<sup>5</sup> Website of Grand Council Treaty #3, <http://www.gct3.ca/>

<sup>6</sup> US National Parks Service Visitor Use Statistics; <https://irma.nps.gov/Stats/Reports/National>



Board's approach to developing alternative rule curves that address concerns of stakeholders in the study area with respect to flooding and ecological impacts;

- **Chapter 7** presents a detailed evaluation of the modelled performance of the selected alternative rule curves;
- **Chapter 8** summarizes the Study Board's approach to evaluating the performance of the selected alternative rule curves under a range of climate and water supply conditions;
- **Chapter 9** discusses the potential for adaptive management to improve water regulation outcomes in the study area; and
- **Chapter 10** presents the Study Board's

findings and recommendations.

**References** and a **Glossary** are provided at the end of the report.

A separate Annex to the Study provides: background materials on the Study's directives and terms of reference; a list of the members of the Study Board and its advisory groups; a description of the performance indicators used in the Study; a summary of the Weight of Evidence analysis of study subjects; details on the selected alternative rule curves; and sample operational guidelines.

The Study Board has placed extensive materials related to the Study on its website ([http://ijc.org/en\\_/RNLRCBSB](http://ijc.org/en_/RNLRCBSB)), including background reports, fact sheets on key topics, videos and presentations from public information meetings.



JEFF KANTOR JCK PHOTOS

## 2. REGULATING WATER LEVELS AND FLOWS IN THE RAINY RIVER BASIN

**Chapter 2** provides an overview of current regulation of water levels and flows in the basin by the International Joint Commission (IJC). It also presents a summary of the key interests in the basin likely to be affected by changes in water levels and flows in the basin.

### 2.1 Overview of current regulation

#### 2.1.1 Control structures

The *Rainy Lake Convention*, signed by Canada in 1938 and the United States in 1940, gave the IJC the regulatory authority over the discharge of water from the outlet facilities at Namakan Lake and Rainy Lake. These are the only existing control structures in the basin that fall under the authority of the IJC.

##### **Namakan Lake**

The principal outlet of Namakan Lake includes two dams, built in 1914 and located approximately 500 m (1,640 ft) apart on either side of Kettle Island. One dam, at Kettle Falls, spans the Canada-US border and is jointly operated by the Packaging Corporation of America (PCA) (formerly Boise Paper) and H2O Power LP. The other dam, at Squirrel Falls, is entirely within Canada and is operated by H2O Power LP.

Flow leaves Namakan Lake through these structures and directly enters Rainy Lake. There are also much smaller, unregulated flows out of Gold Portage and Bear Portage if the level of Namakan Lake is sufficiently high. Each dam has five sluices with stop logs to adjust the flow, as well as a smaller fishway. The maximum rate of flow through the dams is a function of the lake level above the dam; the higher the level, the greater the maximum flow rate. There are no

hydroelectric facilities at these structures.

##### **Rainy Lake<sup>7</sup>**

The regulation of Rainy Lake levels is accomplished by the international dam at Fort Frances-International Falls (Figure 2-1). Completed in 1909, the dam spans the Rainy River at the site of the former Koochiching Falls, approximately 4 km (2.5 mi) downstream from the natural outlet of Rainy Lake at Ranier Rapids, between Ranier MN and Seven Oaks/Point Park in Fort Frances, ON. Water is conveyed past the dam into the lower Rainy River through the hydroelectric turbines in powerhouses on either side of the river or through sluice gates on the Canadian side of the dam. The powerhouses are owned by PCA on the International Falls side, and H2O Power LP in Fort Frances.

There are 15 sluice gates, ten near the center of the dam and five along a canal at the north end of the dam. The canal was originally constructed for navigation, though it was never used for that purpose. Under extremely high water levels, the center of the dam has a spillway to allow the passage of additional flow.

The natural outlet of Rainy Lake, at Ranier Rapids, is the principal hydraulic feature that limits the maximum rate of flow out of the lake under normal lake level conditions. Generally, the higher the lake level, the higher the flow through this constriction. As a result, the number of open gates needed to pass the maximum flow rate out of Rainy Lake varies according to the lake level.

#### 2.1.2 Regulation history

In 1941, the IJC formed the International Rainy Lake Board of Control (IRLBC) and charged it with developing recommendations

In 1949, following extensive study and public hearings, the IJC issued the first Order establishing regulation by rule curves for Rainy Lake and Namakan Lake.

<sup>7</sup> For more information, see the Study Board's fact sheet #3: Control of Outflow from Rainy Lake, available at: [http://ijc.org/en/\\_/RNLRCBS](http://ijc.org/en/_/RNLRCBS)



**Figure 2-1 International Dam at Fort Frances-International Falls**

on regulation. In 1949, following extensive study and public hearings, the IJC issued the first Order establishing regulation by rule curves for Rainy Lake and Namakan Lake. The IRLBC was given the supervisory authority over the implementation of the rule curves by the dam operators.

The 1949 Rule Curves provided single target levels for each day of the year. They were designed to balance hydropower concerns (Fort Frances and International Falls were relatively young industry towns whose prosperity depended on the mill industry) and riparian interests (the area had recently experienced an increase in the number of cottage and resort properties and the area was one of the earliest focuses of the US conservationist movement).

Over the next few years, emergency conditions due to high water occurred several times, including in the late spring of 1950, when lakes in the basin reached historically high levels due to extremely high inflows from rain and melting snowpack. In 1957, following a review of the rule curves by the IRLBC, the IJC issued a Supplementary Order revising the Rule Curve for Namakan Lake to include a target range, rather than a specific target, to address concerns over high water risks.

High and low water conditions in the subsequent ten years again prompted a review of the rule curves. In 1970, revised rule curve ranges were established for both Rainy Lake and Namakan Lake by Supplementary Order, with new requirements for maximizing discharge from both lakes



## Rule Curves

Rule curves are the primary regulatory tool for managing water levels of Namakan Lake and Rainy Lake. They provide a target range, known as the band, for the level of the lake for every day of the year (Figure 2-2). The IJC has used rule curves for managing levels of these two lakes since 1949. The most recent versions were adopted in 2000 and, as a result, are known as the 2000 Rule Curves.

once the water level reaches a certain high level (known as the “All Gates Open” level), as well as minimum discharge requirements for low water conditions.

### 2.1.3 The 2000 Rule Curves

In 1993, an independent group, called the Rainy Lake and Namakan Reservoir Water Level International Steering Committee, raised concerns about the 1970 rule curve regulations (Rainy Lake and Namakan Reservoir Water Level International Steering Committee, 1993). These concerns focused largely on ecological effects and navigation concerns in the Namakan Chain of Lakes. The following year, the then-owner of the Namakan and Rainy dams, Boise Cascade Corporation, submitted its own report to the IJC in response to the recommendations from the steering committee. The IJC initiated a review of the rule curves in response to these submissions. This review took place from 1996 to 1999, and involved extensive investigation of the changes proposed by the steering committee.

In 2000, the IJC issued a Supplementary Order, revising the 1970 Rule Curves and incorporating some, though not all, of the changes suggested by the steering committee. The most significant change involved a reduction in the over-winter drawdown for Namakan Lake by approximately 1 m (3.28 ft), as well as the earlier refill of Namakan Lake in the spring. For Rainy Lake, the rule curve revisions were relatively small. Figure 2-2 illustrates the 1970 and 2000 Rule Curves for both lakes.

In 2013, the IJC created a new watershed board, the International Rainy-Lake of the Woods Watershed Board (IRLWWB), which replaced the IRLBC and the International Rainy River Water Pollution Board. The duties and powers of the former IRLBC were assigned to the Water Levels Committee (WLC) of the IRLWWB. Membership of the WLC is made up of an equal number of Canadian and US federal officials and local residents.

The hydroelectric generating companies and the WLC monitor water flow and level conditions and forecasts on a daily basis. Under the 2000 Rule Curves, the companies are required to adjust flows out of the two lakes to target the middle portion of the rule curve band. To provide for flexibility in response to changing circumstances, the WLC has the authority to direct the companies to target elsewhere within the bands (*i.e.*, higher or lower than the middle portion). In exceptional cases of unusually high or low inflows, the IJC may issue a temporary Supplemental Order to allow for water level targets outside the rule curve bands.

## 2.2 Interests in the basin

In evaluating the performance of the rule curves, the Study Board must consider the effects on all interests likely to be affected by changes in water levels and flows in the system. The IJC's Directive on Communications and Outreach to the Study Board (Annex 3) identifies a range of groups that may be interested in or affected by the rule curve review.

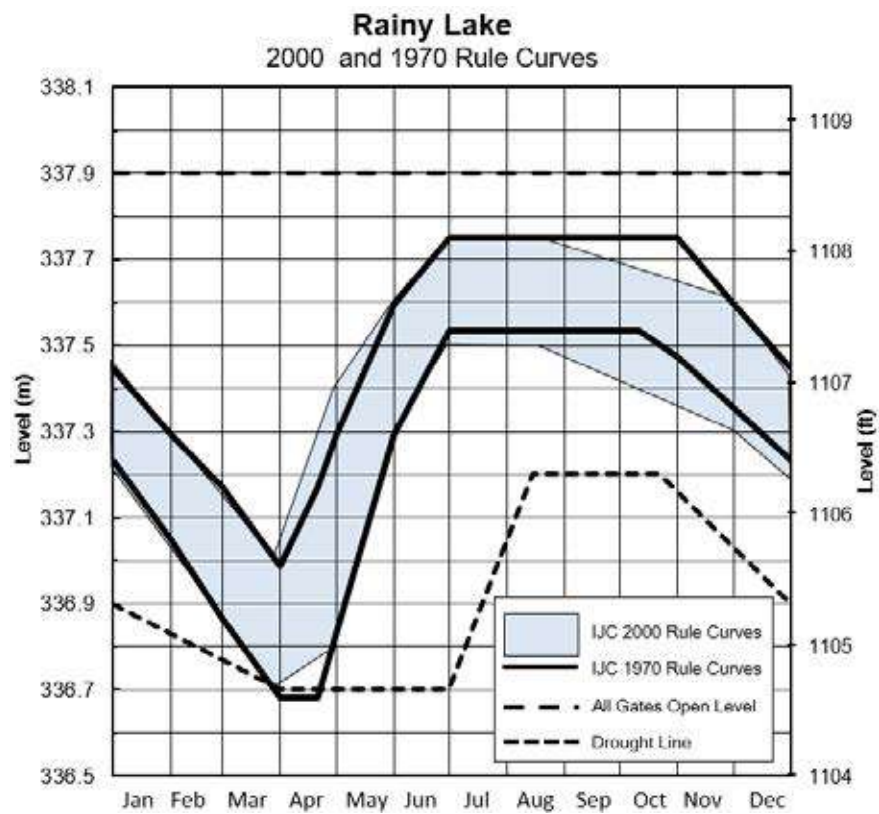
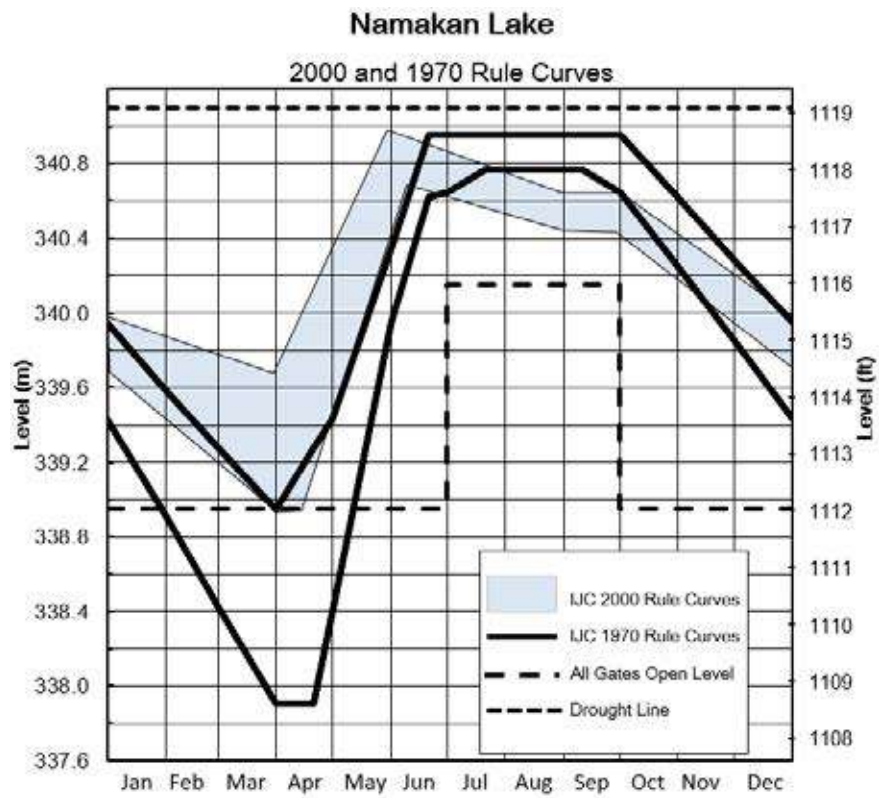


Figure 2-2 2000 and 1970 Rule Curves for Namakan Lake and Rainy Lake

The interests considered in the study are organized under the following five categories. Some specific parties (such as cottage owners) or ecological components (such as Wild Rice) may be under more than one interest:

1. Riparian interests;
2. Hydropower;
3. Ecosystems;
4. Cultural/archeological interests; and
5. Recreational boating and tourism.

## 2.2.1 Riparian interests

### Overview

Riparian interests include individuals and organizations with a direct interest in the property along the shorelines of Rainy River, Rainy Lake and the Namakan Chain of Lakes — that is, both upstream and downstream of the control structures at the outlet of Rainy Lake.

These parties include:

- First Nation, Tribal and Métis communities;
- individual year-round and seasonal residents;
- several lake property owners and fishing associations (including the Rainy Lake Property Owners Association, the Rainy Lake Sportfishing Club, the Border Lakes Association, the Rainy Lake Conservancy and the Kabetogama Lake Association);
- municipalities;
- recreational business owners; and
- Voyageurs National Park, a US National Park, part of which is located along the shorelines of lakes and rivers in the study area.

### Implications of changing water levels and flows

Shoreline properties, including homes and cottages, docks and boat houses, are

vulnerable to flooding during high water events. Damage to such structures during high water events may be amplified by wave action caused by high winds. Low water during open water season can interfere with boat access to docks, as well as create navigational hazards.

Erosion is an important concern, particularly along the Rainy River but also along the lakes in the study area. Shoreline erosion can introduce sediment into the lakes and river, thereby negatively affecting water quality, and expose archeological resources preserved in soils along banks.

Ice damage to shoreline property can occur in spring, fall and winter. During spring break-up, winds can move an ice pack onto shore, damaging not only structures within the water but those alongside the shoreline, as well. Fall water levels also can result in damage to riparian structures after freeze-up due to ice build-up. Finally, as lake levels are lowered throughout the winter, ice thickness increases and the weight of hanging ice can pull down docks.

In general, water levels do not affect domestic water supplies for riparian interests in the study area. However, water quality is an issue for both upstream and downstream riparian interests, as Rainy Lake, the Namakan Chain of Lakes and Rainy River are sources of drinking water for many private residences and cottages, resorts, First Nation communities and municipalities.

## 2.2.2 Hydropower

### Overview

Hydropower interests in the study area are the two hydroelectric generating stations at the international dam spanning the Rainy River. The stations are owned by PCA, in International Falls, MN and H2O Power LP in Fort Frances, ON.

Combined, these two power plants have an annual hydropower production of approximately 104,000 MWh. The PCA



**Key biological components considered in the study include aquatic vegetation, fish, invertebrates, shore and marsh nesting birds and riparian furbearers.**

station, with a capacity of 14.4 MW, produces electricity to power the company's mill operations. The mill's demand for electricity exceeds the station's generation capacity, and the company purchases additional electricity on the open market. The H2O Power LP station, with a capacity of 10MW, is connected to the provincial electrical grid.

### **Implications of changing water levels and flows**

The amount of energy produced from the hydropower plants generally increases with higher lake elevations and greater releases, so long as those releases pass through the generating turbines. Water flows in excess of the capacity of the turbines is considered "spill" — water flow that will not produce power from the plants. In general, moderately high Rainy Lake water levels throughout the summer and early fall provide ideal conditions for hydroelectric generation.

Peaking and ponding are methods used by dam operators to maximize power yield during times of high demand. These practices can lead to frequent large variations in dam outflow (Study Fact Sheet #8 on website).

## **2.2.3 Ecosystems**

### **Overview**

The ecosystems interest includes the biological components of the natural environment in the study area. Key biological components considered in the study include aquatic vegetation, fish, invertebrates, shore and marsh nesting birds and riparian furbearers.

### **Implications of changing water levels and flows**

#### ***Aquatic vegetation***

##### *Aquatic plants*

Aquatic plants provide food and shelter

for invertebrates, fish and wildlife. In an unregulated environment, rivers and lakes experience large fluctuations in water levels over the course of a year (within-year variability) in response to snowmelt and rainfall events. Similarly, sustained wet and dry periods result in large variations in mean water levels from year to year (inter-annual variability). These variations in water levels promote species diversity. Important considerations for maintaining a healthy aquatic vegetation community in a managed system include: within-year and inter-annual variability of water levels to encourage a balanced aquatic vegetative community; stable water levels during the growing season; and limiting exposure to dry, freezing conditions during the over-winter drawdown period.

##### *Wetlands and emergent plants*

In general, water level variability promotes emergent vegetation, shrubby swamps, and wet meadows. These habitats are essential components of the ecosystem and are involved in the biological cycles of numerous wildlife species, including Northern Pike, Yellow Perch, Muskrat and ducks and other marsh birds. High and stable water levels can affect the habitat of many emergent plant species. High water levels throughout the growing season result in more area remaining underwater, promoting submerged vegetation. Stable water levels during the growing season reduce the surface area where wet-dry cycles occur and thus reduce emergent vegetation habitat. Over the years, higher water levels will set the lower limit for trees and shrubs, and lower water levels will set the higher limit of submerged plants. Greater variability in water levels from year to year, with lower and higher levels, increases diversity in these habitats.

##### *Hybrid Cattails*

The dominance of the invasive Hybrid Cattail in many wetlands of the Rainy-Namakan Lakes system is a nuisance to many species.

**Walleye fishing is an important economic and sporting activity for the region, representing about 60 percent of the total fishing effort in the area.**

Hybrid Cattails lower biodiversity, as they form dense monospecific stands, choking wetlands and limiting the connectivity between open water and shallow areas that is essential to many fish species, such as the Northern Pike. After several years of stable water levels, Hybrid Cattails can form monotypic stands that are even more competitive for other plant species, including Wild Rice. Once the cattails are present in such a large extent, it is difficult to remove them by using water-level control only. Complete flooding or drying enabled by water-level variations of several meters maintained for a few years would be required. Among-year variations of the mean water level during the growing season can slow Hybrid Cattail expansion.

#### *Wild Rice*

Wild Rice is an economically and culturally important resource in the area. Wild Rice also provides good cover and brood rearing habitat for ducks, while rice beds can be important nursery areas for other aquatic vertebrates. This annual plant is sensitive to water-level variations during two stages of its life cycle: the germination-submerged stage; and the floating stage. Stable water levels during the germination and floating stage, combined with variable water levels from year to year, are the most suitable option for Wild Rice growth. The former enhances Wild Rice survival, while the latter provides more areas with limited vegetation cover, favoring Wild Rice establishment.

Wild Rice favors similar habitat to other wetland plants such as cattail. Certain cattail species, such as the invasive Hybrid Cattail, are present within the Rainy River watershed. As noted above, this species spreads through its root system, allowing it to out-compete Wild Rice, which re-seeds itself annually.

#### ***Fish***

Approximately 50 fish species are found in the study area. For many species, the

survival rate of their eggs and young is extremely sensitive to fluctuation in water levels. This sensitivity has further implications on larger predator fish that depend on smaller fish as a source of food. Higher water levels during the spawning period generally provide greater area of spawning habitat, while large increases or decreases in levels during the egg incubation period can cause harm. Declining water levels over the late summer and fall allow for wave action that cleans substrate at various elevations along the shoreline for spawning the following spring.

Concerns about the effects of regulation of lake levels and river discharge on fish generally have focused on Lake Sturgeon, Walleye, Northern Pike, and Lake Whitefish. Yellow Perch is also an important species, as it is a food source for larger predator species.

#### *Walleye*

Walleye fishing is an important economic and sporting activity for the region, representing about 60 percent of the total fishing effort in the area. In the ecosystem, Walleye is a top predator influencing fish community structure. Walleye spawn in both rivers and lakes and require clean gravel or cobble (low sediment) areas to shelter eggs. In general, higher water levels during the spawning period (two or three weeks after ice-out) provide more spawning habitat for Walleye. However, within lakes, the cleaning of substrate used for spring spawning is achieved through wave action. Therefore, within-year and inter-annual variability of water levels promotes the persistence of widespread walleye spawning habitat.

A successful spawn requires stable water levels from the onset of spawning until eggs hatch to ensure that eggs are maintained in a suitable incubation environment. Large fluctuations in water level on the lakes or river during the egg incubation period can decrease egg survival.



COURTESY OF TOTEM RESORTS

### *Lake Sturgeon*

The Lake Sturgeon population in the study area is listed as threatened under the *Ontario Endangered Species Act* and a *species of special concern* in Minnesota.<sup>8</sup> Lake Sturgeon are found in both Rainy Lake and the Namakan Chain of Lakes, though the most significant fishery is in the Rainy River. Lake Sturgeon spawn in fast-flowing waters, usually below waterfalls, rapids, dams or headwaters, and clean gravels or cobbles. The timing of spawning and egg incubation of Lake Sturgeon varies with water temperature but usually occurs between the end of May and late June in Rainy River. Lake Sturgeon eggs and larva are sensitive

to water level changes during the incubation period. Decreases in water levels can expose eggs and cause them to dry out. In a riverine setting, a sudden pulse of flow can cause eggs to detach from substrate. Water levels and flow in the Rainy River during the Lake Sturgeon spawning season may be affected not only by releases from the International dam but also by large fluctuations in flows coming out of the Little and Big Fork Rivers.

### *Northern Pike*

Northern Pike use wetland vegetation as spawning habitat and protection of larva and young. The impacts of water level variations (for example, through drought

<sup>8</sup> <https://www.ontario.ca/page/lake-sturgeon-species-risk>; [http://www.dnr.state.mn.us/minnaqua/speciesprofile/lake\\_sturgeon.html](http://www.dnr.state.mn.us/minnaqua/speciesprofile/lake_sturgeon.html)

**Wild Rice is particularly vulnerable to water level fluctuations during the floating leaf stages, as the plant establishes its roots.**

events or water level drawdowns) include loss of suitable spawning habitat and shelter availability around the lake edge. Large water level variations can determine the depth and distribution of aquatic plants, and thus have an indirect effect on Northern Pike (and other species). High water levels in early spring that flood wet meadows and shrubby swamps promote good Northern Pike production. A successful Northern Pike spawn requires water levels to be highest at the end of the spawning period and remain relatively stable during incubation to ensure that eggs hatch and mobile larvae are able to follow the receding water. Submerged plants are utilized by pike larvae and young fish for foraging and sheltering.

#### *Lake Whitefish*

Lake Whitefish has been an important component of the commercial fisheries in the Rainy-Namakan Lakes system. Contrary to many other commercially harvested species, Lake Whitefish spawn in fall and larvae hatch the following spring, making it sensitive to the over-winter water levels. In general, to maximize Lake Whitefish egg survival to incubation, water levels should remain stable from the onset of spawning (mid-November) until eggs hatch in early spring to ensure that eggs are maintained in a suitable incubation environment.

#### ***Lake bottom organisms and invertebrates***

Lake bottom organisms and invertebrates are an important source of food for many species of fish, birds and other wildlife. The stranding of organisms and exposure to air and ice cover by declining water levels can reduce or alter these benthic communities.

#### ***Shore and marsh nesting birds***

Shore and marsh nesting birds, such as loons and grebes, are most susceptible to water level fluctuations during nesting season, typically from May to July, when nests are at risk of being flooded out or stranded due to fluctuations in water levels.

Stable or gradually decreasing water levels for the entire nesting season are most favorable for nesting success of these birds.

#### ***Aquatic furbearers***

Muskrats and Beaver within the Rainy River watershed once played an important economic role in the region as furbearing species. Although trapping remains an important cultural activity to many area residents, the number of animals harvested has declined significantly since its peak in the 1960's. Nevertheless, these species remain important to the Namakan and Rainy Lake system. Muskrats that build their shelters on the lakes will forage on nearby wetland vegetation and create channels through these wetlands. These channels act as important spawning habitat and shelter for several fish species, including Northern Pike and Yellow Perch. Muskrats are important consumers of Hybrid Cattails and may play a vital role in limiting the expansion of cattails in the system.

Muskrats and Beaver are affected by the over-winter drawdown of water levels. Large declines in water levels over winter months can cause Beaver houses and Muskrat lodges to be cut off from their food source and can expose the furbearers to increased predation.

### **2.2.4 Cultural/archeological interests**

#### **Overview**

Cultural/archeological interests include the history, customs, practices and resources of Indigenous peoples in the study area. These interests include:

- archeological sites, such as burial sites and pictographs; and
- Wild Rice, an important food source for Indigenous communities within the study area that also holds important cultural value.

The US National Park Service recognizes 446 archeological sites within Voyageurs

National Park. Of these, 140 are found within Rainy Lake, while 299 are found in the Namakan Chain of Lakes. The remaining archeological sites within the park were excluded from the Study because they are located in the backcountry, away from potential lakeshore impacts.

These archeological sites contain buried artifacts and remnants of structures related to the area's rich cultural history and demonstrate the occupation of the area for at least the last 10,700 years. They include important historical resources dating from the fur trade era, which started locally in the early 18th Century.

### **Implications of changing water levels and flows**

Archeological sites can be adversely affected by water level regulation. Burial locations can be compromised by intense wave actions and bank erosion. Pictographs found on rock faces may be removed through persistent wave action.

As noted previously, Wild Rice is particularly vulnerable to water level fluctuations during the floating leaf stages, as the plant establishes its roots. In addition, navigation access during the Wild Rice harvest requires adequate water levels.

## **2.2.5 Recreational boating and tourism**

### **Overview**

The recreational boating and tourism interest includes pleasure boating and fishing, houseboat companies, full-service marinas, wilderness canoeing and kayaking interests and guides and outfitters with accommodations.

As noted in Section 1.2, part of the Voyageurs National Park is located in the study area. More than 240,000 people visited the park in 2016. As well, an estimated 16,000 anglers visit the Canadian side of Rainy Lake each year, according to the Ontario Ministry of Natural Resources and Forestry (OMNRF).

In addition to the thousands of individual recreationists who live in or travel to the area every year, there are dozens of businesses in the study area that rely predominantly on water-based recreation.

### **Implications of changing water levels and flows**

Navigation and dock access have major implications for residents, recreationists and tourism, including houseboat rentals and resorts on Rainy Lake and the Namakan Chain of Lakes. For example, water levels are particularly important during the open-water fishing season, typically from mid-May to September. Navigation and dock access on Rainy Lake are particularly challenging for keeled boats at lower water levels.

The health of the tourism industry is strongly linked to the health of the sport fish populations. In addition, water levels that expose beaches are favorable for tourism.

Finally, water quality is important to recreational activities such as fishing and swimming. Water level fluctuations can influence nutrient concentration in lakes by controlling the volume of water available for nutrient dilution. This is especially important in shallow bay areas that are prone to the development of harmful algal blooms. Such blooms can threaten the health of humans and wildlife, limit sport fishing and force the closure of beaches.



### 3. STUDY APPROACH

**Chapter 3** summarizes the approach that the **International Rainy and Namakan Lakes Rule Curves Study Board** (Study Board) used to undertake the Study. It presents the Study's objectives, organization and methodology. For more detailed information on the approach, see the Study Strategy (International Rainy and Namakan Lakes Rule Curves Study Board, 2016).

#### 3.1 Background

The International Joint Commission's (IJC) Order establishing the 2000 Rule Curves included a requirement that the Order be subject to review 15 years following its adoption. This review was required to consider, at minimum, "monitoring information collected by natural resource management agencies and others during the interim that may indicate the effect of the changes to the rule curves."

To support the review of the 2000 Rule Curves, the IJC formed a Rule Curve Assessment Workgroup in 2007 to develop a plan of study. Completed in 2009, this plan identified priority studies and data requirements and the appropriate parties to collect the data and undertake the analyses (Kallemeyn *et al.*, 2009). The plan of study recommended that the rule curves be evaluated by means of a "weight of the evidence approach" (WOE) in which an expert panel applies a simple matrix of positive, negative or neutral indicators for each monitored outcome.

The IJC then sponsored 21 studies as part of the review to assess the changes in hydrology, hydraulics, flooding and other impacts due to the changes from the 1970 to the 2000 Rule Curves in Rainy Lake and the Namakan Chain of Lakes. In subsequent years, additional studies were added and numerous related studies undertaken by other agencies and groups in the basin

were reviewed. Several of these studies were sponsored by the IJC's International Watersheds Initiative.

In 2014, as many of the studies were nearing completion, a group of scientists and interested parties met to take stock of the results obtained to date. They concluded that while the WOE approach would provide many insights into the effect of the 2000 Rule Curves, some studies did not provide clear evidence that an observed change since 2000 was a result of regulation under the new rule curves as opposed to outside influences (such as, for example, the increased frequency of years with high inflow in the spring since 2000 [WLC, 2015]). Additionally, the WOE approach was intended only for the analysis of the changes observed due to the implementation of the 2000 Rule Curves under observed historical conditions. The approach would not allow for the analysis of other potential rule curves and could not be used to evaluate existing or proposed rule curves under other water supply scenarios, including future climate change scenarios or other hypothetical extreme water flow scenarios.

The group considered the feasibility of applying a shared vision planning (SVP) approach in developing a rule curve evaluation study (Palmer *et al.*, 2013). The SVP approach had been successfully employed in the IJC's International Upper Great Lakes Study and the Lake Ontario-St. Lawrence River Study (International Upper Great Lakes Study Board, 2012; International Lake Ontario-St. Lawrence River Study Board, 2006). The group concluded that such an approach was essential, and recommended its use in the evaluation of the Rainy and Namakan Lakes Rule Curves.

In light of this recommendation, the IJC adjusted the original study scope as outlined

To support the review of the 2000 Rule Curves, the IJC formed a Rule Curve Assessment Workgroup in 2007 to develop a plan of study.



in the 2009 plan of study and re-allocated study resources to facilitate this revised approach. In 2015, the IJC issued a directive (Annex 1) and terms of reference (Annex 2) establishing the Study Board and its mandate.

### 3.2 Study objectives and scope

The primary goal of the Study was “to evaluate options for regulating levels and flows in the Rainy-Namakan Lakes system in order to benefit affected interests and the system as a whole in a manner that conforms to the requirements of the Treaty” (IJC, 2015).

In its Study Strategy, submitted to the IJC in February 2016, the Study Board established three key objectives to achieve this overarching goal:

1. *To evaluate the performance of the 2000 Rule Curves in comparison to the 1970 Rule Curves and State of Nature,<sup>9</sup> considering a range of ecological, social, economic and environmental conditions that may be affected by water level regulation.*
2. *To develop and evaluate additional regulation alternatives that reflect concerns of stakeholders in the study area and to compare the performance of these alternatives to that of regulation under the 1970 and 2000 Rule Curves.*
3. *To evaluate all regulation alternatives for performance under a range of climate and water supply conditions.*

As noted in **Chapter 1**, the scope of the study area is limited to those areas directly affected by water level regulation in the Rainy River basin, including the Namakan Chain of Lakes, Rainy Lake and Rainy River and the associated riparian zones. As a result, the Study did not directly evaluate the effects of the 2000 Rule Curves or other alternatives

on Lake of the Woods or waters within the Rainy River basin that are not affected by the operation of the dams at the outlets of Rainy and Namakan Lakes. However, the Study Board did seek comment on its draft recommendations from downstream interests at Lake of the Woods and the Winnipeg River.

Recognizing the many interests concerned with the future of water levels and flows in the basin, the IJC established a strong engagement and outreach component from the outset of the Study, through its Directive for Communication and Public Outreach Activities (Annex 3).

**Chapter 4** of the report provides a comprehensive overview of the engagement and outreach activities undertaken by the Study Board over the course of the Study.

### 3.3 Study governance and organization

The organization of the study consisted of a Study Board, a Technical Working Group (TWG), two advisory groups and an independent review group (Figure 3-1). Annex 4 provides a list of the members of these groups.

#### Study Board

A six-person Study Board was responsible for:

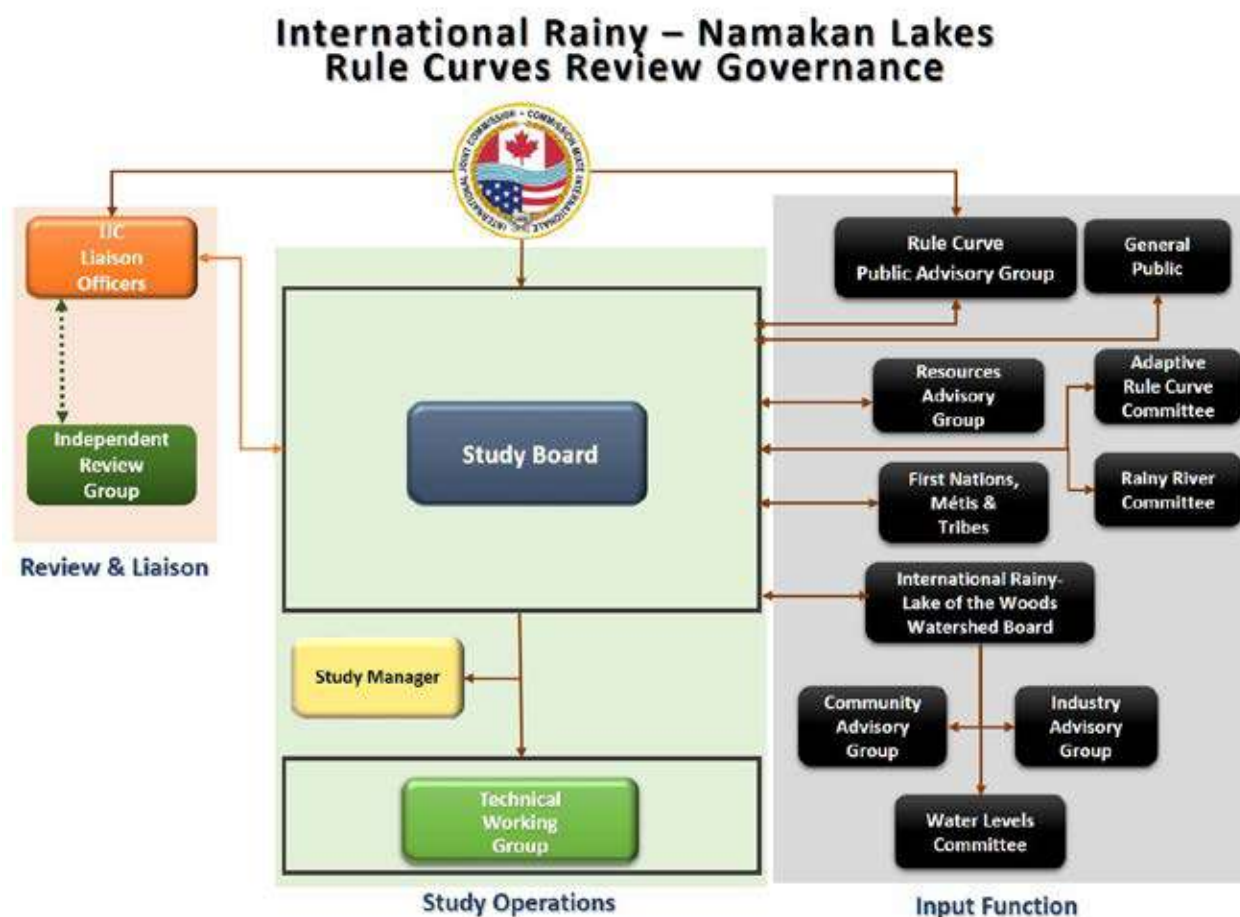
- overall direction and management of the Study;
- planning and managing the Study's outreach and engagement activities, including ensuring ongoing liaison with the International Rainy-Lake of the Woods Watershed Board (IRLWWB), the Study Board's advisory groups and Tribes, First Nations and Métis organizations in the study area;
- reporting formally to the IJC on a regular basis; and

<sup>9</sup> For the purposes of this study, the term State of Nature refers to a hypothetical basin configuration where the structures which limit or regulate flow out of Namakan Lake (Squirrel Falls and Kettle Falls dams) and Rainy Lake (the International Dam at Fort Frances-International Falls) are removed, allowing modelling of flows from these lakes in a pre-dam condition. Due to the absence of pre-dam data in these areas, it is necessarily an approximation of actual pre-dam conditions.

- preparing the draft and final versions of its report to the IJC.

Study Board members were drawn equally from Canada and the United States, and included experts from federal government

agencies and individuals with extensive knowledge of and experience with water level issues. All participants served in their personal and professional capacities, and not as representatives of their agencies, organizations or other affiliations.



**Figure 3-1 International Rainy and Namakan Lakes Rule Curves Review governance**

#### Technical working group and study manager

The Study Board was supported by a two-person TWG and a study manager. The TWG led the technical analysis that was the foundation of the Study Board's investigations, including modelling work, rule curve scenario simulations and development of technical recommendations.

A study manager was responsible for the Study's day-to-day operations, including coordination and liaison with the advisory

groups, community groups and residents.

#### Advisory groups

The IJC's Directive for Communication and Public Outreach Activities established a Rule Curve Public Advisory Group (RCPAG) to assist the Study Board in its outreach activities. The Study Board also established a separate advisory group, the Resources Advisory Group (RAG), for federal, state and provincial agencies in the watershed that are responsible for natural resource management or environmental protection.

See **Chapter 4** for more information on the roles of the RCPAG and RAG.

Over the course of the Study, the Study Board also met with other resource experts to discuss specific aspects of the project and solicit their expert advice. It established two ad hoc groups to focus on the concerns and interests on the Rainy River and on possible options for development of an adaptive rule curve approach.

### **Independent expert review**

The IJC recognized that there was a need to ensure that the Study was scientifically credible and transparent, given the complexity of many of the scientific and engineering studies involved and the range of interests concerned about water levels and flows in the basin. As a result, the IJC established an Independent Review Group (IRG) separate from the Study Board to provide additional, independent scrutiny and advice throughout the Study, from the scoping stage to the completion of the final report. The IRG's primary function was to evaluate the appropriateness and sufficiency of the studies and models used to inform the Study Board's conclusions related to possible changes in the rule curves.

## **3.4 Methodology**

### **3.4.1 Overview**

The Study Board adopted a two-part complementary methodology for undertaking the analysis: WOE and SVP. The methodology evolved over the course of the Study based on suggestions in the workshops and webinars, always with the goal of producing more useful summaries of the impacts of different rule curves.

As noted in Section 3.1, the WOE approach involves an evaluation, by an expert panel (in this case, the Study Board), of the results of a series of studies to determine whether a specific issue in the basin under consideration (e.g., Walleye population

or the economic impacts on the flooding damages) has improved, worsened, or not been affected by the adoption of the 2000 Rule Curves. Results of these individual assessments then are brought together in a simple matrix to display the full range of effects of the rule curves.

SVP aims to provide a comprehensive, participatory and transparent evaluation process. It is designed to evaluate rule curve alternatives with any water supply scenario, not limited by historical data. Through a series of practice decisions, interested parties, including the RCPAG and RAG, were able to become familiar with the approach. They helped improve the decision criteria and were able to learn about the possible effects of changes in water levels and flows on the interests in the study area under various rule curve alternatives.

The SVP approach allowed the Study Board to consider:

- whether the 2000 Rule Curves performed as expected when tested with the full historical record against the 1970 Rule Curves;
- what benefits and negative impacts may have resulted from the 2000 Rule Curves relative to likely impacts of the 1970 Rule Curves;
- what benefits and negative impacts would result from a "state of nature" (SON) operating plan;
- what benefits and negative impacts would result from various alternative rule curves; and
- how changing climatic conditions could affect water levels, flows and the performance of the different rule curve alternatives.

### **3.4.2 Shared vision planning process**

The main products of the SVP approach are two computer model tools. The first is

a numerical model called the Integrated Ecological Response Model (IERM). The IERM is a highly detailed model of the Rainy-Namakan system including the Rainy River. It is able to simulate the movement of water in the system, including important features such as wave action. The model then simulates how this water movement affects various ecological subjects, such as spawning areas. It produces quantified estimates of the impacts to a variety of plants and animals that result from the use of different rule curves.<sup>10</sup>

The second tool is a Shared Vision Model (SVM). It is designed to interpret results from the IERM, integrate results from other sources and develop evaluation metrics that can be used to compare rule curve alternatives. Each individual SVM simulation generates water levels and flows in mean quarter-monthly values for a specified number of years for a particular rule curve alternative and water supply sequence (e.g., drier climate scenario).

Figure 3-2 shows the flow of information in the SVP process:

- the SVM calculates a time series of water levels and flows for a selected rule curve and water supply sequence;
- studies, including some used in the WOE, provide information used to design algorithms relating water levels and flows to performance outcomes;
- time series of water levels and flows from the SVM are used in the IERM to simulate environmental outcomes from a rule curve alternative; and
- outputs from the IERM are processed through the SVM to populate a spreadsheet that displays outcomes from the SVM and IERM in tables and graphs. (The spreadsheet, informally called “SVM Light,” is a tool developed during the Study to provide the RCPAG and the RAG with an easily accessible summary of SVM results. It is not a model.)

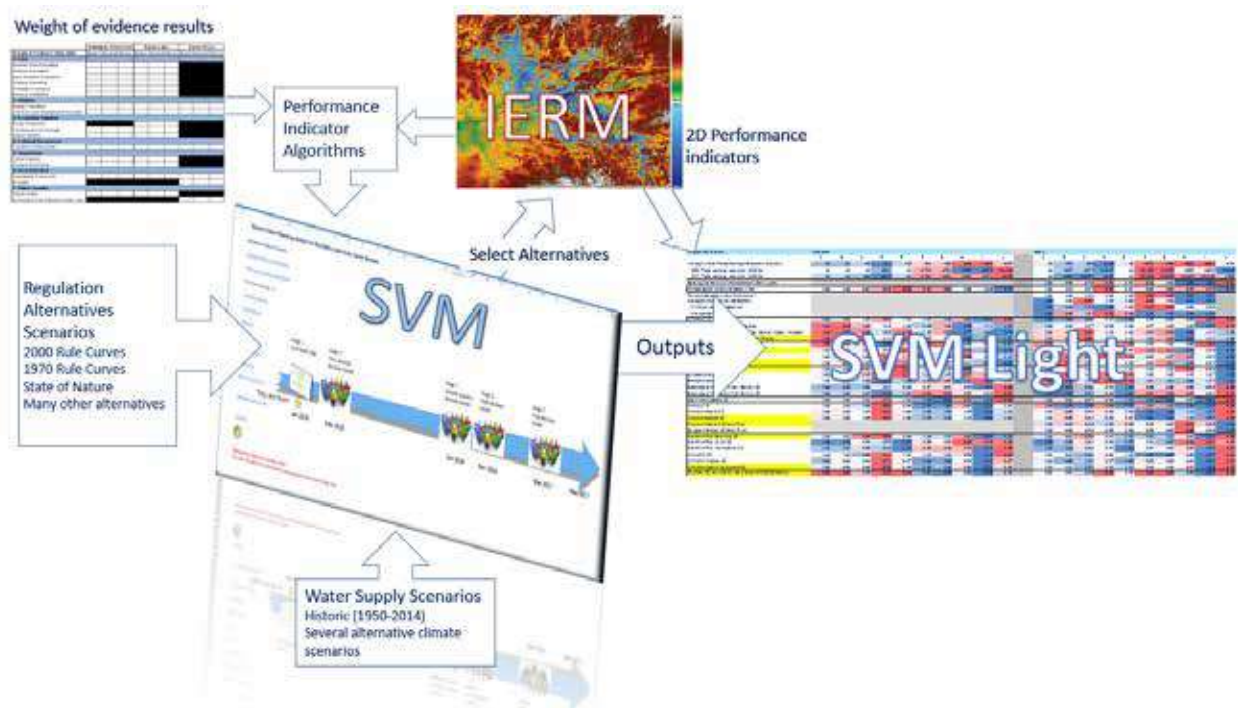


Figure 3-2 Shared vision planning process

<sup>10</sup> A full description of the IERM is provided in reference studies 19 and 21 (see Annex 6).

Methods for considering the possible effects of climate change on future water supply conditions have evolved considerably over the past 20 years.

The SVM was used to evaluate the performance of:

- the existing 2000 Rule Curves;
- the 1970 Rule Curves that had been in effect prior to 2000;
- a hypothetical SON natural flow regime; and
- more than two dozen alternative rule curves.

Chapter 6 presents more information on the objectives and key features of the alternative rule curves selected for detailed evaluation.

### 3.4.3 Water supply sequences

A water supply sequence is a quantification of the amount of water that enters a system over a period of time from sources such as runoff, tributary inflow and precipitation on the lake or river. Future water supplies are uncertain, and may differ considerably from those of the past due to changes in climate. Accordingly, the rule curve alternatives considered in the Study were evaluated for their performance under a range of possible water supply sequences including: historical conditions and possible future climate conditions.

#### Historical water supply sequence

The first water supply sequence is the actual inflows recorded from 1950 to 2014. This flow sequence allows for the comparison of alternatives based on water supplies that actually occurred. The historical water supply sequence serves two purposes:

- *Validation of model-generated water levels and flows:* The resultant modelled levels and dam releases can be compared to the appropriate segments of the actual levels and flows under the various rule curve regimes in place over this period to help validate the model.
- *Comparison of rule curve alternatives:* The historical supplies, which include major floods and dry periods, are then

used to evaluate specific outcomes from various rule curve alternatives.

Using the historical supplies is a good test for alternative rule curves, because it shows how real events might have changed with a different rule curve. But no historical supply set is certain to contain the floods and droughts or flow sequences that the future may bring, so alternative water supply sets were developed.

### Climate change water supply sequences

Given that the hydrology of the next few decades is unknown, the Study Board considered various plausible hydrology test data, including water supply sequences considered to be likely under climate change. Alternative water supply sequences to account for climate change were developed by applying available research on climate change in the basin.

Methods for considering the possible effects of climate change on future water supply conditions have evolved considerably over the past 20 years. The Study Board used an approach called “decision scaling” to test how well alternative rule curves for Rainy Lake and Namakan Lake will perform under a wide array of possible future water supply sequences representing different plausible climate change conditions. Decision scaling was first applied in the IJC’s International Upper Great Lakes Study (International Upper Great Lakes Study Board, 2012) and is based on a range of climate research and modelling. It derives its name from its perspective on starting with how a changed climate could affect important outcomes influenced by the decision, then testing regulation plans with plausible water supply series.

Ten alternative water supply sequences were developed that reflected the plausible changes in hydrology suggested by climate research, expert advice and the objectives for managing these lakes.

### 3.4.4 Hydrological metrics and performance indicators

For a given rule curve alternative and water supply sequence, the SVM and IERM each simulate a quarter-monthly time series of water levels and outflows for Namakan Lake and Rainy Lake, and flows and levels for Rainy River downstream of the Rainy Lake dam. In the SVM, the existing rule curves are replaced with the alternative rule curves, and if the alternative also includes new instructions on when or how to use the new curves, then those instructions also are programmed into the SVM. The next step is to evaluate how these hydrological outcomes (*i.e.*, water levels and flows) correspond quantitatively to other derived outcomes of importance, such as the frequency of high water events, loon nesting success, fish spawning success and flooding damages. In this way, each of these derived outcomes can be quantified. Together, they represent the *evaluation metrics* applying to each scenario.

This critical step allows the outcomes of different rule curve-water supply scenarios to be compared with one another, as they will all use the same evaluation metrics. These metrics fall into two general categories: *hydrological metrics*; and *performance indicators* (PIs).

#### Hydrological metrics

These metrics are straightforward statistics on measurable water data, such as frequency of emergency conditions or percentage of time the water level is within the rule curve range. An initial set of hydrological metrics were developed by the Study Board based on past studies and discussions with stakeholders in the study region. The SVM was programmed to measure the performance of all rule curve alternatives according to these metrics. The metrics aided in the gradual development of alternative rule curve options.

#### Performance indicators

While hydrological metrics are specific to simulated water levels and flows, PIs are used to quantify other outcomes that are a function of them. For example, a PI for navigation may be defined as “the percentage of the boating season for which preferred navigation depths are available.”

A key aspect of such indicators is that they are quantitatively related to the simulated water levels or flows that the models compute. Because they follow from a direct mathematical relationship to the water levels and flows, they may be modelled.

Each PI is computed uniquely, based on the relationship of the subject to the water level and flows. The best available scientific information was used in the development of the PIs calculated by the SVM and IERM. However, PIs are not available for all study subjects evaluated in the WOE analysis. In some cases, this is due to a lack of scientific information or an inability to establish a clear relationship between water levels or lake releases to the performance of a particular interest. For example, it is difficult to draw a direct relationship between adult fish populations and water levels due to numerous influencing factors that cannot be adequately modelled at the present time, such as water quality, disease, and sport fishing regulations.

Table 3-1 presents a list of PIs calculated by the SVM and IERM, grouped by study theme, that were used to compare each alternative rule curve to the 1970 and 2000 Rule Curves on Namakan and Rainy Lakes. Annex 5 presents details on how each PI is calculated.

#### Interpretation of PI performance

The IERM output presented in **Chapters 5 and 7** represents time-series of yearly performance of a particular PI over the modelling period, which may vary by PI. The



Table 3-1 Summary of performance indicators, by study theme

Study theme	PIs
1. Fish	1.1 Walleye Egg Survival Probability 1.2 Walleye Spawning Success 1.3 Northern Pike Spawning Suitable Habitat 1.4 Northern Pike Larval Suitable Habitat 1.5 Northern Pike Young of Year Suitable Habitat 1.6 Lake Whitefish Egg Survival Probability 1.7 Lake Whitefish Spawning Success
2. Wildlife	2.1 Common Loon Probability of Nest Viability 2.2 Muskrat Over-Winter Survival
3. Economy	3.1 Flood Damage Reduction 3.2 Boating Reliability 3.3 Hydropower Production
4. Archeological resources	4.1 Archeological Resource Protection
5. Aquatic vegetation	5.1 Hybrid Cattail Invasion 5.2 Wild Rice Success 5.3 Wet Meadows Suitable Habitat 5.4 Shrubby Swamps Suitable Habitat 5.5 Emergent Plants Suitable Habitat 5.6 Submerged Plants Suitable Habitat

environmental evaluations used in the analysis were labeled one- and two-dimensional evaluation metrics. The one-dimensional (1D) metrics tracked lake water surface patterns and compared them to known relationships between water levels and survival or breeding success. For example, Muskrat survival over the winter improved if levels did not drop or rise by much.

Two-dimensional (2D) metrics involved more complex calculations. These included

mapping where land was covered with water at different elevations as well as the characteristics of the covered land. 2D analysis required several layers of data in a Geographic Information System (GIS), including land elevations, soil types, and data and modelling used to determine light intensity on lake bottom, water and air temperatures, ice-out dates and wave heights.

More information on 1D and 2D modelling is available in the Study's background report 21

(available on the Study Board website: [http://ijc.org/en/\\_/RNLRCBSB](http://ijc.org/en/_/RNLRCBSB)).

Some PIs, such as the Muskrat over-winter survival PI, are presented as a probability and scored on a scale of zero (0) to one (1.0). In this case, a score of zero indicates that all Muskrats that build lodges on the lake will die as a result of lodge flooding (excessive water level rise) or freezing (excessive water level fall). A score of 1.0 indicates that over-winter water level conditions are ideal for Muskrat lodges; no lodges are at risk of flooding or freezing.

Other IERM-generated PIs are presented as an amount of suitable area (in hectares). As an example, the Wild Rice PI is presented as the total area of the lake where conditions are suitable for the successful growth of Wild Rice.

SVM results are presented in summary tables and, in most cases, represent the average outcome of a particular PI over the entire modelling period. Since the 2000 Rule Curves are the reference set, all scores for it are 1.0 or, in the case of flooding damage reduction, \$0. SVM scores for the other rule curves are relative to the 2000 Rule Curves. A full description of all PIs is provided in Annex 5.

### **Model limitations**

Both the IERM and SVM are modelling tools. By design, models are approximations of the real world, and have errors and uncertainty associated with them. The Study Board recognizes that models are not able to fully capture the complexities of a natural system like the Rainy River watershed and it must consider such limitations when interpreting PI outcomes. Error and uncertainty arise in

approximating the hydrology (e.g., inflow estimations), operations (capturing how operators would adjust flows) and the environment (complex interactions, such as increased Hybrid Cattail consumption due to Muskrat population increases simply are not able to be captured).

The degree of uncertainty associated with a particular PI depends upon the inherent complexity of this subject and the information available to produce a model of it (e.g., supporting research studies). The Study Board, in evaluating the performance of different rule curves (see **Chapter 7**), takes these uncertainties into account based on its knowledge of the supporting data, information and validation results<sup>11</sup> of each model.

However, there are no specific measures of uncertainty or error associated with any of the PIs used in the Study. For this reason, the Study Board considers the comparison of outcomes for individual PIs under different alternative rule curves to be more reliable and informative than comparing the outcomes between different PIs. Consider, for example, a hypothetical modelling of a new rule curve alternative that shows improvements in PI scores for wetland vegetation compared to the 2000 Rule Curves but decreases in Northern Pike spawning success. The Study Board, based on its knowledge of the models and science that supported the model development, may be confident in concluding that both changes are significant, but be less confident in asserting which is more important. Instead, the Study Board must consider the full range of PI results and make an overall judgment, similar to the approach taken in the WOE evaluation.

<sup>11</sup> The comparison of observed data with a model's projections to ensure the validity of the model.

## 4. ENGAGEMENT AND OUTREACH IN THE STUDY

### Chapter 4 presents details on the comprehensive engagement and outreach plan developed and implemented over the course of the Study.

**Chapter 4** presents details on the comprehensive engagement and outreach plan developed and implemented over the course of the Study by the **International Rainy and Namakan Lakes Rule Curves Study Board** (Study Board), with the support and advice of the Rule Curve Public Advisory Group (RCPAG) and the Resources Advisory Group (RAG). The chapter describes:

- the Study Board's approach, including objectives, the use of advisory groups and activities;
- public concerns about issues relating to water levels in the study area;
- the perspectives of Tribes, First Nations and Métis communities in the study area; and
- how engagement and outreach contributed to the Study.

### 4.1 Study approach

#### 4.1.1 Objectives

Recognizing the many interests concerned with the future of water levels and flows in the basin, the International Joint Commission (IJC) established a strong outreach and engagement component from the outset of the Study. The IJC's **Directive for Communication and Public Outreach Activities** (Annex 3) states that the key objectives of the Study's public participation process were to:

- make the public aware of the Study and provide opportunities to participate;
- identify and consider the public's views of the principal issues, questions and study objectives;
- explain the decision-making process of the Study;
- ensure that the study process is open, inclusive and fair;

- identify and consider the public's priorities and preferences;
- identify and utilize local expertise and information;
- enhance public understanding of the causes of problems related to fluctuating water levels and of the consequences of proposed solutions;
- broadly disseminate study findings as they become available; and
- encourage the public to assist in disseminating study findings.

The communications directive also instructed the Study Board to "directly engage early with Aboriginal peoples including but not limited to, First Nations, Métis and Native American Tribes in the basin to seek their input in the Rule Curve evaluation and their involvement in the Rule Curve Public Advisory Group."

#### 4.1.2 Advisory groups

Two advisory groups assisted the Study Board in planning and carrying out its engagement and outreach efforts. Annex 4 provides a list of the members of these two advisory groups.

##### 1. Rule Curve Public Advisory Group

The Directive for Communication and Public Outreach Activities established the RCPAG to assist the Study Board in its outreach activities. The RCPAG consists of 32 members who put their names forward after a widespread call for participation was made early in the study process. Members were appointed by the IJC and live or operate businesses within the study area. They represent a range of interests in the basin, including: lake/property owners' associations; navigation interests; environmental organizations; First Nations and Tribes; tourism and recreation interests;

Throughout the Study, the Study Board maintained a website to serve as the primary tool for posting reports and other materials related to the Study...

and hydroelectric companies.

The RCPAG was responsible for:

- reviewing and providing comment on various Study Board reports and products;
- advising the Study Board on the responsiveness of the study process to public concerns;
- advising the Study Board on public consultation, involvement and information exchange; and
- serving as a conduit to public input to the study process and for public dissemination of study outcomes.

## **2. Resources Advisory Group**

In addition to having input from the RCPAG, the Study Board established a separate Resources Advisory Group (RAG) of federal, state and provincial agencies in the watershed that are responsible for natural resource management or environmental protection. The RAG reviewed analyses and recommendations made by the Study Board for their potential effects on natural resources or the environment in the study area. Members also advised the Study Board on the responsiveness of the study process to resource agency concerns and provided access to other resource experts on specific topics, as needed.

### **4.1.3 Engagement and outreach activities**

In developing the engagement and outreach plan, the Study Board recognized that the study setting presented several challenges for informing and engaging the full range of interests likely to be affected by changes in the water levels. The study area covers a large rural area. A relatively small permanent population is located in several towns and a number of smaller and remote communities. In addition, the population of the region is highly seasonal in nature, with hundreds of

thousands of additional people arriving in the summer months as either seasonal residents or visitors.

In response to these challenges, the Study Board used a variety of approaches over the course of the Study to ensure that information was easily accessible and that all interested parties had an opportunity to express their concerns.

### **1. Study Board website**

Throughout the Study, the Study Board maintained a website to serve as the primary tool for posting reports and other materials related to the Study and for publicizing notices of public meetings (<http://ijc.org/en/RNLRCBSB>). The information on the website included: the IJC's directives establishing the Study and the outreach program; the Study Board's terms of reference; the Study Strategy and an Addendum; a list of members of the Study Board, RCPAG and RAG; copies of webinar presentations and recorded meetings; event notices and press releases; background documentation and research studies; and specialized information products (see below).

### **2. Specialized information products**

Over the course of the Study, the Study Board prepared and made available on its website several specialized information products.

A series of fact sheets was prepared to address specific questions or issues that had been raised by the public. These fact sheets covered, for example, the operational management of lake levels, basin monitoring and forecasting in the study area.

Through its ad hoc experts Adaptive Rule Curve Committee, the Study Board prepared a series of newsletters to facilitate a more thorough and collaborative effort to consider alternatives to the current 2000 Rule Curves. The newsletters focused on modelling and other technical issues related to the evaluation of alternative rule curves.

The Study Board also prepared and posted on the website animation videos explaining, in non-technical language, how the dam at International Falls-Fort Frances can be used to regulate the level of Rainy Lake, and how natural features of the system limit this regulation.

### **3. Information distribution**

In addition to the website, the Study Board used a variety of methods to distribute information within the study area, recognizing the remoteness of some communities. These methods included flyers, radio spots and display ads in local newspapers.

### **4. Public and advisory group meetings**

Over the course of the Study, the Study Board convened more than 45 public and advisory group meetings throughout the study area, including meetings with the RCPAG and the RAG at key decision-making points in the Study (see Table 4-1).

The meetings were structured to present information on the objectives and approach of the Study, respond to questions, receive public comments, present preliminary findings, explore options through practice decisions and discuss the final decision and recommendations. Members of the RCPAG assisted with the organization, publicity and facilitation of several of these meetings.

### **5. Meetings with Indigenous communities**

The Study Board held several meetings with First Nations and Métis representatives in the study area to provide information on the Study and learn of the concerns and priorities of these communities (Section 4.5, below). In addition, the RCPAG included a representative of the Red Lake Band of Chippewa Indians, a representative of Grand Council Treaty #3 and representatives of two First Nation communities.

### **6. Networking with other organizations**

Finally, the Study Board took advantage of

existing networking opportunities in the study area for reaching out to various interests. Study Board members participated in the annual Rainy-Lake of the Woods Watershed Forum in March 2016 and March 2017, presenting on the Study during the technical symposium and hosting workshops and public and advisory group meetings during the same week as the Forum.

As well, the Study Board connected with local and community groups to distribute announcements to their members and held several in-person meetings at different locations within the study area to promote public awareness and engagement in the Study.

The Study Board also kept the International Rainy-Lake of the Woods Watershed Board (IRLWWB) and the IRLWB's Water Levels Committee informed of progress on the Study at all stages.

## **4.2 Public concerns and priorities**

Public engagement and transparency have been guiding principles of the Study from the start. As outlined above, the Study Board sought to understand and respond to public concerns about water levels and flows in the study area on an ongoing basis over the course of the Study.

A summary of these public concerns and the corresponding responses from the Study Board are presented in a separate document, available through the Study's website: [http://ijc.org/en/\\_/RNLRCBSB](http://ijc.org/en/_/RNLRCBSB).

Public concerns and priorities about water levels and flows in the study area are summarized here.

### **1. Preference for greater flexibility in regulating water levels**

A key area of public concern was the desire for greater flexibility in regulating water levels in the study area to allow for more effective adaptation to changing conditions,



Table 4-1 Public and advisory group meetings

Event/Activity	Date	Location
Stakeholder Webinar	September 25, 2015	Online/Teleconference
Public Meeting	September 29, 2015 (3 meetings)	International Falls, MN
Public Meeting	September 30, 2015 (2 meetings)	Fort Frances, ON
Update to IRLWWB	October 2, 2015	Teleconference
Update to Community Advisory Group	November 17, 2015	Teleconference
RCPAG Webinar	January 20, 2016	Online/Teleconference
RAG Meeting	January 29, 2016	Online/Teleconference
Update to Industry Advisory Group	February 2, 2016	Teleconference
RCPAG Webinar	February 17, 2016	Online/Teleconference
RAG Webinar	March 4, 2016	Online/Teleconference
RCPAG Meeting	March 8, 2016	International Falls, MN
Practice Decision Workshop #1	March 8, 2016	International Falls, MN
Public Meeting	March 8, 2016	International Falls, MN
Update to IRLWWB	March 15, 2016	Teleconference
Rainy River Group	April 5, 2016	Teleconference
Update to Community Advisory Group	June 3, 2016	Teleconference
Update to Industry Advisory Group	July 25, 2016	Teleconference
RCPAG Meeting	July 26, 2016	International Falls, MN
Public Meeting	July 26, 2016	Rainy River, ON
Public Meeting	July 26, 2016	Kabetogama Lake, MN
Public Meeting	July 27, 2016	Rainy River First Nation, ON
Rainy River Group Meeting	July 27, 2016	Fort Frances, ON
Public Meeting	July 27, 2016	International Falls, MN
Public Meeting	July 28, 2016	Nigigoonsiminikaaning First Nation
Public Meeting	July 28, 2016	Crane Lake, MN
RAG	July 28, 2016	International Falls, MN
Adaptive Rule Curve Group	July 28, 2016	International Falls, MN
Public Meeting of IRLWWB	August 10, 2016	Kenora, ON
Update to Community Advisory Group	August 10, 2016	Kenora, ON
Meeting with IRLWWB	August 11, 2016	Kenora, ON
Practice Decision Workshop #2	November 2, 2016	International Falls, MN
Public Meeting	November 2, 2016	Fort Frances, ON
RAG	November 3, 2016	International Falls, MN
Update to Community Advisory Group	December 5, 2016	Teleconference
RCPAG Webinar	December 15, 2016	Online/Teleconference
Update to IRLWWB	January 10, 2017	Teleconference
Update to Industry Advisory Group	February 1, 2017	Teleconference
RCPAG Webinar	February 8, 2017	Online/Teleconference
Meeting with Water Levels Committee	February 16, 2017	Teleconference
Draft Decision Workshop	March 7, 2017	International Falls, MN
Update to Community Advisory Group	March 7, 2017	International Falls, MN
Public meeting	March 7, 2017	International Falls, MN
Webinar to review Alternative C	April 13, 2017	Online/Teleconference
Final Decision Workshop	June 13, 2017	Fort Frances, ON (also by webinar)
Quarterly meetings of International Multi-Agency Arrangement	2015-2017	Teleconference, International Falls, MN

**Public concerns  
were expressed  
about possible  
impacts of  
water levels on  
navigation and  
boater safety in  
the study area.**

particularly emergency conditions due to high water levels. For example, it was suggested that the requirement for the dam operators to target the middle portion of the rule curve range can be a concern in early spring in years with a higher potential for significant runoff due to conditions such as significant snowpack and/or late snowmelt. In addition, the 2000 Rule Curves target the highest level of the year at the time of year when inflow tends to be the highest.

Members of the public also expressed support for allowing the dam operators to target the lower band on Rainy Lake in the summer, so as to improve conditions for Wild Rice and recreational access to beaches. Similarly, there were calls to delay the summer drawdown on Namakan Lake to July rather than June to improve conditions for navigation in July and early August and to decrease the flood risk on Rainy Lake.

## **2. Focus on reduced Rainy Lake flooding**

Throughout the Study, attention was drawn by members of the RCPAG and a lake property owners' association to the desire for reduced flooding on Rainy Lake during high inflow periods. It was generally acknowledged that Rule Curve and operational changes cannot prevent most flood situations, but that efforts should be made by the Study Board to identify ways to reduce the frequency, duration and severity of flooding where possible, including revisions to the Rule Curves and in the management within the Rule Curves.

## **3. Impacts on fisheries**

Members of the public expressed concerns that any changes in regulation must consider impacts on the fishery and tourism, and specifically, that any changes in the rule curves should not adversely affect fish populations. They suggested that reduced fluctuations in water levels on the Rainy River during the spawning season be considered to help protect Lake Sturgeon eggs from

drying out due to water levels being reduced. In addition, there were calls for the issue of mercury contamination in fish to be included in the Study's weight of evidence (WOE) analysis, and suggestions that, to the extent possible, mercury contamination be controlled through water level regulation.

## **4. Climate change**

A number of public comments urged the Study Board to ensure that sound climate change science be incorporated into the Study's analysis and recommendations, so as to better address the possible impacts of future climate change on the basin's water levels and flows.

## **5. Impacts on Wild Rice**

Members of the public urged the Study Board to consider the possible effects on Wild Rice harvesting and whether a new rule curve can accommodate the water levels needed for Wild Rice growth in the spring. For example, they suggested that lower levels in spring could increase yields.

## **6. Impacts on navigation**

Public concerns were expressed about possible impacts of water levels on navigation and boater safety in the study area. There were calls to consider access to docks and launch sites for sail boats, and in particular the need to avoid low water levels on Rainy Lake that require sail boats to be pulled out early due to the risks of hull damage.

## **7. Impacts to Rainy River**

The Study considered effects of rule curves within the study area, with Rainy River being the furthest downstream area considered in the analysis. To better understand the perspective of riparian interests along the river, the Study Board conducted an informal online survey. Survey responses showed a common perspective that the 2000 Rule Curves do not give adequate consideration to the impacts of Rainy Lake outflows to Rainy River ecology, property, and recreation and that, as

a result, large flow fluctuations have negative consequences in all three areas.

Concerns were also raised during public engagement of the effect of Rainy Lake outflow on areas downstream of Rainy River. These, however, were outside of the Study area and not investigated as part of the Study.

### 4.3 Perspectives of Tribes, First Nations and Métis

The Study Board recognized that Tribes, First Nations and Métis within the study area hold intimate knowledge of their surrounding environment. It made a focused effort to establish lines of communication and build relationships with these communities so that their interests were properly considered in the rule curves review process.

Table 4-2 lists the meetings held with Anishinaabe Nation of Treaty #3 and Métis communities. On the US side, the Study Board contacted the Bois Forte Band to inform Band members of the Study and to invite their comments and participation.

In September 2016, the Study Board and Grand Council Treaty #3 co-hosted

a Learning Forum in the Round House at Nigigoonsiminikaaning First Nation to provide the Anishinaabe Nation of Treaty #3 First Nations communities within the study area with information on the rule curve review, the role of the IJC and the goals and progress to date of the Study Board. The Forum also allowed the Study Board to listen to Anishinaabe community members and gather feedback about their concerns and important considerations for the Study. Representatives from the following communities attended the Learning Forum: Nigigoonsiminikaaning First Nation; Couchiching First Nation; Rainy River First Nation; Seine River First Nation; and Naicatchewenin First Nation.

During the Forum, representatives of Grand Council Treaty #3 provided the Study Board with an overview of the differences and commonalities between Western science and Aboriginal Traditional Knowledge (ATK). ATK is the knowledge and values that have been acquired through direct experience with and observation from the land or from spiritual teachings, and handed down from one generation to another.<sup>12</sup> ATK is essentially qualitative and holistic in its

**Table 4-2 Study meetings with Anishinaabe of Treaty #3 and Métis communities**

Event/Activity	Date	Location
Mitaanjigamiing First Nation and Lac La Croix First Nation Meeting	July 27, 2016	Fort Frances, ON
Mitaanjigamiing First Nation Meeting	September 12, 2016	Conference Call
Learning Forum with Treaty #3 and Communities	September 29, 2016	Nigigoonsiminikaaning First Nation Round House
Meeting with Mitaanjigamiing First Nation Elders	October 12, 2016	Mitaanjigamiing First Nation
Métis Nation of Ontario, Region 1	November 1, 2016	Fort Frances, ON

<sup>12</sup> Government of Northwest Territories Policy 53.03 <http://www.enr.gov.nt.ca/node/3069>

**The various engagement and outreach activities gave the Study Board a better understanding of the concerns and priorities regarding water levels of the key interests in the study area.**

approach, viewing all life as interdependent. It seeks to promote reciprocity and decisions made for the social good.

In addition to the Learning Forum, the Study Board and members of the Technical Working Group met with the Mitaanjugamiing and the Lac La Croix First Nation communities, and representatives of the Métis Nation of Ontario.

Through these meetings, the Study Board was made aware of a range of concerns regarding the potential or existing impacts of water level regulation on:

- Wild Rice growth and quality;
- shoreline erosion;
- the threat of flooding to infrastructure, including docks, access roads and waste water treatment plants;
- degradation of pictographs and burial grounds;
- mercury contamination of fish;
- portage and canoe routes; and
- climate change impacts.

Other concerns that could not be directly linked to water level regulation were also noted, including: aquatic and terrestrial medicinal and edible plants; invasive aquatic and terrestrial species; mercury contamination of birds of prey; the quality of fur from fur-bearing animals, such as Beaver; water quality; and fish health.

During the forum and community meetings, the Study Board learned the importance of one-on-one meetings for sharing of information and was able to better understand community concerns in this way. The Study Board also heard that the exchange of information between researchers and Indigenous communities can be challenged by language barriers, such as the use of overly technical terminology, and by a perception that the scientific community does not always give

credibility to ATK or any other knowledge not gathered using the Western scientific method.

#### **4.4 Engagement and outreach benefits**

The engagement and outreach plan developed and implemented by the Study Board resulted in important benefits to the Study.

##### ***1. A better understanding of the concerns of the key interests***

The various engagement and outreach activities gave the Study Board a better understanding of the concerns and priorities regarding water levels of the key interests in the study area. The advisory groups, community meetings and extensive opportunities for dialogue helped the Study Board identify areas of consensus among the various interests and better address areas of uncertainty and disagreement.

As a result, the Study Board can provide the IJC with a high level of confidence that the Study's findings accurately and fairly reflect the concerns of the many interests affected by water levels and flows in the Rainy River basin.

##### ***2. An improved Study***

The Study Board's engagement and outreach activities and the advice of the RCPAG contributed to improvements in the Study's overall approach, analysis and report. The ongoing feedback provided at key milestones in the Study continued to inform the Study Board as it carried out its evaluation of the 2000 Rule Curves and possible alternative rule curves. For example, written feedback after various workshops and webinars helped identify areas where the Study Board needed to make a special effort to provide additional information or clarify a particular question or issue, such as the role of adaptive management and the possibility of improving flood forecasting.





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### ***3. An enhanced understanding of water regulation in the basin***

At the start of the Study, the RCPAG and other members of the public delivered a clear message to the Study Board: water regulation and the Study's objectives are extremely complicated issues. As a result, public participation in the Study would be difficult without a sound understanding of the Rainy-Namakan Lakes system and how water is regulated. In response, the Study Board committed to preparing specialized information products in the form of fact sheets and videos. These products targeted critical questions that consistently arose

at public meetings and that demanded focused attention if the project was to proceed with a good foundation.

These tools enhanced the public's understanding of water regulation and the hydrological makeup of the study area. This understanding proved to be of immediate help to the Study Board in its ongoing meetings with its advisory groups and the public. The longer term legacy of this enhanced understanding could be in how it supports future engagement and outreach efforts with interest groups and the public in the basin.



## 5. PERFORMANCE OF THE 2000 RULE CURVES

**Chapter 5** summarizes the approach of the **International Rainy and Namakan Lakes Rule Curves Study Board** (Study Board) to addressing the first key objective set out in its Plan of Study:

*To evaluate the performance of the 2000 Rule Curves in comparison to the 1970 Rule Curves and State of Nature, considering a range of ecological, social, economic and environmental conditions that may be affected by water level regulation.*

The chapter compares the performance of the 2000 Rule Curves using both monitoring study results and computer simulated results. The rule curves are compared by considering their impacts under seven key study themes:

1. Fish;
2. Wildlife;
3. Economy;
4. Archeological resources;
5. Aquatic vegetation;
6. Invertebrates; and
7. Water quality.

Within each theme, several study subjects are evaluated (see Table 3-1 for a complete list of the study subjects). For example, Walleye and Northern Pike are study subjects evaluated under subject theme 1: Fish. In addition, the impacts of the rule curves on interests in the Rainy River are addressed separately.

### 5.1 Study approach

#### Weight of evidence

The weight of evidence (WOE) approach involves an evaluation by the Study Board of the results of a series of studies to determine whether a specific subject in the basin under consideration has improved, worsened, or not been affected since the

adoption of the 2000 Rule Curves, when compared to the 1970 Rule Curves. For some study subjects, data from before and after the implementation of the 2000 Rule Curves were unavailable or else insufficient to make a determination as to the effect of the Rule Curves. Where possible in these cases, computer simulations, using the Integrated Ecological Response Model (IERM) (see Section 3.4) were used to make an assessment of the effect of the 2000 Rule Curves. This involved simulating operation of the Rainy and Namakan dams according to the 1970 Rule Curves using the historical inflows from 1950-2013 and then comparing these results to simulation for the same period but with operations according to the 2000 Rule Curves.

The collective results of these individual assessments, both empirical and modelled, were then brought together in a simple matrix to display the full range of effects of the rule curves.

#### Background studies

The Study Board reviewed 52 scientific reports, including 21 from the IJC's 2009 Plan of Study, to evaluate whether the condition of a particular study subject improved, worsened or was not affected by implementation of the 2000 Rule Curves. Most of these studies involved evaluation of data collected in the study area.

A list of the 52 scientific studies is available in Annex 6.

#### External feedback

In addition to the Study Board's evaluation, feedback on the Study Board's assessment of each study subject was solicited from the investigators of the Weight of Evidence (WOE) studies, as well as from the Rule Curve Public Advisory Group (RCPAG) and the Resources Advisory Group (RAG).

The chapter compares the performance of the 2000 Rule Curves using both monitoring study results and computer simulated results.

## Expected results of the 2000 rule curves

Wherever possible, the Study Board established what the expected outcome of the 2000 Rules Curves had been at the time of implementation. This information was collected from the studies reviewed, as well as from a number of reports submitted to the IJC during the previous rule curve review process (International Rainy Lake Board of Control, 1999).

As noted in **Chapter 2**, the greatest changes between the 1970 and 2000 Rule Curves were seen on the Namakan Chain of Lakes. Revisions to the Namakan Rule Curve were intended to address concerns over the ecological effects of the existing rule curve regulation and navigation concerns for the Namakan Chain of Lakes. Modifications to the Rainy Lake Rule Curve, which were minor, were expected to result in only limited habitat improvements for the aquatic plant community with consequent benefits to wildlife.

The 2000 Rule Curves were also expected to produce some negative impacts. These expected outcomes included, for example, a reduction in the potential for hydroelectric power generation and an increased risk of flood damage on both Rainy and Namakan Lakes.

Finally, most downstream interests on Rainy River were not expected to be affected by the implementation of the 2000 Rule Curves, with the exception of the general ecosystem health of the Rainy River (further discussed in Section 5.2.8).

## 5.2 Comparison of the 2000 Rule Curves and 1970 Rule Curves

This section presents a summary of the Study Board's findings regarding the performance of the 2000 Rule Curves compared to the 1970 Rule Curves. The findings are presented under each of the seven subject themes, based on study and IERM model results.

A detailed description of the research used and the Study Board's conclusion for each study subject and water body identified in the WOE matrix is presented in Annex 6.

In the following analysis, two tables are presented for each of the seven themes: one summarizes the expected outcome for each study subject; and a second presents the results of the WOE analysis.

For both tables, an option is selected among "better", "neutral" or "worse," reflecting the judgment of the Study Board in answering the following question: *Did regulation of Rainy Lake and Namakan Lake under the 2000 Rule Curves result in a better, neutral, or worse outcome for the study subject?* It is important to note that the Study was specifically examining the effect of the 2000 Rule Curves, not just whether any change in the condition of a study subject occurred since 2000.

For the Expected Outcomes tables, a "No projection made" is listed where no documentation from the last Rule Curve review process exists that supports an anticipated outcome for a given subject.

For the WOE Results tables, where the available information was insufficient to select one of the three outcomes (i.e., better, neutral, worse), "Study Results Inconclusive" is noted.

Inconclusive is distinct from Neutral in these tables. The former refers to a lack of sufficient data to answer the question; the latter refers to a conclusion, supported by data and/or simulations, that the 2000 Rule Curves did not change the outcome for the study subject.

### 5.2.1 Fish

The following tables summarize the expected outcomes and the WOE results for fish on Namakan and Rainy Lakes due to the implementation of the 2000 Rule Curves. Further details on each study subject are provided in Annex 6.

Expected Outcomes	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>1. Fish</b>						
Northern Pike Population	✓			<i>No projection made</i>		
Northern Pike Young of Year	✓				✓	
Northern Pike Nursery and Young of Year Habitat	✓			✓		
Walleye Population	<i>No projection made</i>			<i>No projection made</i>		
Walleye Young of Year	✓			<i>No projection made</i>		
Walleye Spawning Habitat	✓			✓		
Yellow Perch Population	<i>No projection made</i>			<i>No projection made</i>		
Yellow Perch Young of Year	<i>No projection made</i>			<i>No projection made</i>		
Lake Sturgeon Population	✓			✓		
Whitefish Population	✓				✓	
Whitefish Spawning Habitat	✓				✓	
Young of Year Yellow Perch Mercury Concentration	<i>No projection made</i>			<i>No projection made</i>		

Weight of Evidence Results	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>1. Fish</b>						
Northern Pike Population	✓			✓		
Northern Pike Young of Year	✓				✓	
Northern Pike Nursery and Young of Year Habitat	✓			✓		
Walleye Population	<i>Study Results Inconclusive</i>			<i>Study Results Inconclusive</i>		
Walleye Young of Year	✓			✓		
Walleye Spawning Habitat	✓				✓	
Yellow Perch Population		✓		✓		
Yellow Perch Young of Year	✓			✓		
Lake Sturgeon Population	<i>Study Results Inconclusive</i>			<i>Study Results Inconclusive</i>		
Whitefish Population	<i>No Study Available</i>			<i>Study Results Inconclusive</i>		
Whitefish Spawning Habitat	✓				✓	
Young of Year Yellow Perch Mercury Concentration	<i>Study Results Inconclusive</i>			<i>Study Results Inconclusive</i>		

### 1. Northern Pike

An improvement to the conditions for Northern Pike was an expected outcome for Namakan Lake as the 2000 Rule Curve provides higher spring levels that expand spawning habitat. Also, increased flooding on Namakan and Rainy Lakes under the 2000 Rule Curves was expected to promote the growth of wet meadows and shrubby swamps that provide food and shelter for Northern Pike larva and young of year (YoY).

The studies reviewed as part of this analysis have shown that Northern Pike adult and YoY populations have increased since the implementation of the 2000 Rule Curves.

Although no prediction had been made for

the adult Northern Pike population on Rainy Lake, data provided to the Study Board by the Minnesota Department of Natural Resources (MNDNR) indicated an increase in population following the implementation of the 2000 Rule Curves. As spring water levels on Rainy Lake were relatively unaffected by the adoption of the 2000 Rule Curve, no change was expected. Although the YoY population on Rainy Lake was found to increase after 2000, investigators could not confidently relate this change to water level management under the new Rule Curves.

### 2. Walleye

No projections were made regarding the impact of the 2000 Rule Curves on the adult

...the Study Board concluded that there was no change in Walleye spawning habitat on Rainy Lake due to the implementation of the 2000 Rule Curves based on the results of the IERM simulation.

Walleye population. In addition, monitoring data provided to the Study Board by the MNDNR were not able to provide any conclusive evidence of a decreasing, stable or increasing population. YoY populations and Walleye spawning habitat, however, were expected to improve as a result of the adoption of the 2000 Rule Curves on both the Namakan Chain of Lakes and Rainy Lake. Higher spring water levels, particularly on Namakan Lake, were expected to provide better access to substrate and more suitable water levels throughout the incubation period. A study investigating the influence of water level fluctuation on the production of YoY Walleye in northern lakes showed that the YoY population increased on both lakes (Study 32, Annex 6). Another study (Study 16, Annex 6) determined that the 2000 Rule Curves resulted in an increase of available spawning habitat on Namakan Lake; this conclusion was supported by IERM simulation. The study did not examine habitat availability on Rainy Lake. Therefore, the Study Board concluded that there was no change in Walleye spawning habitat on Rainy Lake due to the implementation of the 2000 Rule Curves based on the results of the IERM simulation.

### **3. Yellow Perch**

No projections had been made regarding the impact of the 2000 Rule Curves on Yellow Perch in Namakan or Rainy Lakes. However, monitoring data provided to the Study Board by the MNDNR suggested that Yellow Perch adult populations have remained stable in Namakan Lake and increased in Rainy Lake since 2000. Several studies analyzing YoY Yellow Perch data have led the Study Board to conclude that the implementation of the 2000 Rule Curves improved conditions for YoY Yellow Perch.

### **4. Lake Sturgeon**

Lake Sturgeon were expected to increase under the 2000 Rule Curves as a result of more favorable water levels during the

spawning and incubation periods. However, none of the studies reviewed for this analysis provided information on the impact of the 2000 Rule Curves on the Rainy Lake and Namakan Lake Sturgeon populations.

### **5. Lake Whitefish**

As noted in Section 2.2, Lake Whitefish spawn in the fall and their eggs hatch in the spring. The reduction in the over-winter drawdown on Namakan Lake was expected to promote the survival of Lake Whitefish eggs and larvae by providing a stable protective ice cover and reducing exposure to freezing. An increase in egg and larva survival was expected to lead to an increase in adult population. No change was expected on Rainy Lake. The Ontario Ministry of Natural Resources' (OMNR) Summaries of Commercial Lake Whitefish Data (North Arm, Redgut, and South Arm) support the conclusion that the limited changes to the 2000 Rule Curve for Rainy Lake have not had a discernable effect on Lake Whitefish reproductive success.

Lake Whitefish spawning habitat was also expected to increase on Namakan Lake, as fall water levels under the 2000 Rule Curve were expected to provide better access to shallow waters with clean substrate and a gentle slope. The IERM was used to model the amount of suitable spawning habitat for Lake Whitefish in both lakes and was validated using biological observations and historical records from local fishermen. The IERM results suggest that the 2000 Rule Curves have improved the amount of suitable habitat for spawning on Namakan Lake. Conditions, as expected, were unchanged for Rainy Lake.

### **6. Mercury concentration in fish**

Data from several studies (the US Geological Survey, the US National Park Service and the University of Minnesota-Duluth) were used in the IERM to compare the effects of the 1970 and 2000 Rule Curves on YoY Yellow Perch

mercury concentration. The IERM showed an increase in mercury concentrations in Yellow Perch coincident with the change in Rule Curve in the Namakan Chain of Lakes. However, unpublished USGS modelling results suggest mercury concentrations would have been higher if the 1970 Rule Curve had been used from 2000 to 2014 on Sand Point and Crane Lakes and would have increased slightly on Kabetogama and Namakan Lakes. Similar patterns, however, have not been observed in larger species of fish that prey on smaller fish such as Yellow Perch. Data collected by MNDNR have shown large variability in the mercury concentrations of Northern Pike in Rainy Lake and Namakan Lake since 1970 and provided no clear evidence of correlation to water levels over time. Given the uncertainty in connecting water level regulation to the risks associated with mercury (see Fact Sheet 7 on Study Board website), the Study Board is not able to offer a conclusion with a high level of confidence regarding the effects of the 1970 and 2000 Rule Curves on YoY Yellow Perch mercury concentration.

## 5.2.2 Wildlife

The following tables summarize the expected outcomes and the WOE results for wildlife on Namakan and Rainy Lakes due to the

implementation of the 2000 Rule Curves. Further details on each study subject are provided in Annex 6.

The Study Board found that the 2000 Rule Curves met the general expectation that conditions would improve for wildlife study subjects in the Namakan Chain of Lakes.

### 1. Beavers

The reduced over-winter drawdown of the 2000 Rule Curve on Namakan Lake was expected to provide more favorable winter water level conditions at the lodge sites. An assessment of the effects of water level management on the American Beaver by the US National Park Service suggested this expectation was met (see Study 34, Annex 6). No change was expected or observed on Rainy Lake.

### 2. Birds and herptiles

No projections were made regarding the impact of the 2000 Rule Curves on bird and herptiles (reptiles and amphibians) on Namakan and Rainy Lakes. A study mapping the habitat for marsh nesting birds and herptiles in the Rainy Lake and Namakan Reservoir area did not produce conclusive results due to the confounding influences, including differences in imagery resolution

Expected Outcomes	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>2. Wildlife</b>						
Beaver Population	✓				✓	
Habitat for Birds and Herptiles	<i>No projection made</i>			<i>No projection made</i>		
Common Loon Reproductive Success	✓				✓	
Muskrat Lodge Winter Viability		✓			✓	

Weight of Evidence Results	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>2. Wildlife</b>						
Beaver Population	✓				✓	
Habitat for Birds and Herptiles	<i>Study Results Inconclusive</i>			<i>Study Results Inconclusive</i>		
Common Loon Reproductive Success	✓				✓	
Muskrat Lodge Winter Viability		✓		✓		



and water level conditions during the pre- and post-2000 assessment periods.

### 3. Common Loons

Common Loon nesting success is improved by stable water levels during the spring. As a result of the 2000 Rule Curves, the conditions for loons were expected to improve on the Namakan Chain of Lakes and remain unchanged on Rainy Lake. A study by the US Department of the Interior and the US Geological Survey concludes that implementation of the 2000 Rule Curves positively affected loon productivity (chicks hatched/territorial pair) on Namakan Lake, but had no effect on Rainy Lake.

### 4. Muskrats

There was no expectation of an improvement to the conditions favoring the over-winter survival of Muskrats on either Namakan or Rainy Lakes. Muskrats on Rainy Lake and the Namakan Chain of Lakes are subject to extremely high mortality as a result of the water level drawdown over the winter. The drop in water levels strands Muskrat huts, leaving the animals vulnerable to exposure and predation and cutting off access to aquatic plants for food. The changes implemented in the 2000 Rule

Curves, including the substantial reduction in the over-winter drawdown on Namakan Lake, were not expected to be sufficient to reduce Muskrat mortality. No studies on pre- and post-2000 Muskrat populations were available for the WOE analysis. Instead, the IERM (Study 21) was used to model Muskrat performance based on the effects of water-level variation in the Rainy-Namakan system over the winter.

Results showed a slight, yet unexpected, improvement in probability of Muskrat lodge viability survival on Rainy Lake and no impact on Namakan Lake.

### 5.2.3 Economy

The following tables summarize the expected outcomes and the WOE results for economic impacts on Namakan and Rainy Lakes due to the implementation of the 2000 Rule Curves. Further details on each study subject are provided in Annex 6.

#### 1. Hydroelectric generation effects

The potential for hydropower production was expected to decrease due to effects of the reduction in available storage in the winter that resulted from the Namakan Lakes Rule Curve modifications. The WOE analysis supports this conclusion.<sup>13</sup>

Expected Outcomes	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>3. Economic Impacts</b>						
Power Production						✓
Flooding			✓			✓
Ice Damage			✓			✓
Resort Industry	✓				✓	

Weight of Evidence Results	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>3. Economic Impacts</b>						
Power Production						✓
Flooding			✓			✓
Ice Damage						
Resort Industry	✓					

<sup>13</sup> The WOE analysis on hydropower was based on a report commissioned by H2O Power to assess the impacts to hydroelectric generation at both the Canadian and American powerhouses attributable to change in regulation from the 1970 Rule Curves to the 2000 Rule Curves. The key highlights of the report were shared with the IJC for the purposes of the Rule Curve evaluation, but the detailed report was not made available to the Study.

## 2. Flood damage effects

Another anticipated negative consequence of the 2000 Rule Curves was an increase in flood damage on both Namakan and Rainy Lakes as a result of decreased early spring storage on the Namakan Chain of Lakes and earlier refill. A study compared the relative flood impacts associated with the 1970 and 2000 Rule Curves and concluded that there was an increase in damage to lived-in and non-lived-in buildings, docks, and boathouses caused by flooding under the 2000 Rule Curves.

## 3. Ice damage effects

The 2000 Rule Curves were identified as having potential for increased damage to shoreline structures due to moving ice in the spring. However, it was also noted that the gradual reduction of water levels from June to early fall could reduce the risk that an early freeze-up occurs at the maximum water level, thereby reducing the risk of hanging ice. The Study Board had insufficient data to quantify a connection between ice damages and the 2000 Rule Curves.

## 4. Resort Industry

Improvements to navigation and dock access in the spring in the Namakan Chain of Lakes were expected outcomes of the 2000 Rule Curve, largely due to the earlier spring refill. These benefits are reflected in the improvement to the resort industry on Namakan Lake. The economic survey of resorts within the study area, undertaken as part of the Study, found that resort owners

on Namakan Lake were in favor of the changes to the rule curves, noting that there was a strong positive economic benefit to resorts in spring due to higher water levels (further details of this survey are provided in Study 10, Annex 6).

## 5.2.4 Archeological resources

The following tables summarize the expected outcomes and the WOE results for cultural/archeological sites on Namakan and Rainy Lakes due to the implementation of the 2000 Rule Curves. Further details on each study subject are provided in Annex 6.

As noted in Section 2.2, there are a number of Indigenous cultural/archeological sites and other historical sites related to the fur trade along the shores of Rainy Lake and the Namakan Chain of Lakes. These sites are threatened by the erosion of shorelines that expose artifacts preserved in soils along the shorelines of the lakes. The 1970 Rule Curves on Namakan and Rainy Lakes held summertime lake levels steady throughout the season, thereby prolonging the exposure of the shoreline to wave action at a given water level and increasing the likelihood of erosion. Therefore, the over-summer drawdown introduced on both lakes by the 2000 Rule Curves was expected to reduce the threat of erosion at archeological sites.

An assessment of the effects of water level management on archeological sites in Voyageurs National Park (along the Namakan Chain of Lakes and Rainy Lake), confirmed that operation under the 1970 Rule Curves

Expected Outcomes	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>4. Archeological Resources</b>						
Condition of Resources	✓			✓		

Weight of Evidence Results	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>4. Archeological Resources</b>						
Condition of Resources	✓			✓		

has a greater potential to cause erosion in both lakes than the 2000 Rule Curves.

Furthermore, elevations of several pictographs on Rainy Lake were provided by one First Nation community. It was determined that these pictographs are at elevations above the upper limit of the 2000 Rule Curves, and are therefore not subject to damage at targeted water levels under either the 1970 or 2000 Rule Curves.

### 5.2.5 Aquatic vegetation

The following tables summarize the expected outcomes and the WOE results

for aquatic vegetation on Namakan and Rainy Lakes due to the implementation of the 2000 Rule Curves. Further details on each study subject are provided in Annex 6.

The modifications that resulted in the 2000 Rule Curve for Namakan Lake included a slight summer drawdown and a significant reduction in the over-winter drawdown that were expected to improve the abundance and diversity of aquatic vegetation. No predictions had been made regarding the impacts of the 2000 Rule Curve on the aquatic vegetation of Rainy Lake.

Expected Outcomes	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>5. Vegetation</b>						
Cattail Invasion	<i>No projection made</i>			<i>No projection made</i>		
Wetland Vegetation	✓			<i>No projection made</i>		
Emergent Vegetation - Wet meadow	✓			<i>No projection made</i>		
Submerged Plants	✓			<i>No projection made</i>		
Wild Rice	✓			<i>No projection made</i>		

Weight of Evidence Results	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>5. Vegetation</b>						
Cattail Invasion		✓			✓	
Wetland Vegetation	✓			<i>Study Results Inconclusive</i>		
Emergent Vegetation - Wet meadow			✓	✓		
Submerged Plants	✓				✓	
Wild Rice		✓			✓	

#### 1. Hybrid Cattail invasion

The spread of invasive Hybrid Cattail was not an area of investigation during the review of Rule Curves in the 1990s, and therefore was not considered in the design of the 2000 Rule Curves. Nevertheless, the expansion of the invasive Hybrid Cattail has become a major concern on the lakes in recent years, as it threatens the habitat of native plant species, including Wild Rice.

The IERM (Study 21) was used to assess the impacts of the 2000 Rule Curves on the invasion of Hybrid Cattail. Findings suggested that the 2000 Rule Curve

provided equally favorable water level conditions for the survival of cattail on Rainy Lake as the 1970 Rule Curve. The extent of cattail invasion was not affected by the 2000 Rule Curve as a similar expansion would have occurred had regulation continued under the 1970 Rule Curve.

On the Namakan Chain of Lakes, however, the IERM suggested that the reduced winter drawdown of the 2000 Rule Curve produced water level conditions that are more favorable for the survival of Hybrid Cattail. However, model results also suggest that the extent of the area suitable for cattail

growth, as determined by a number of physical characteristics (see Annex 5), was reduced as a result of the 2000 Rule Curve. As such, the Study Board concluded that the 2000 Rule Curve did not affect the overall conditions for Hybrid Cattail invasion on the Namakan Chain of Lakes.

In general, water level conditions under both the 1970 and 2000 Rule Curves produced favorable conditions for the expansion of the invasive Hybrid Cattail on both lakes.

## 2. Wild Rice

As no assessment of Wild Rice pre- and post- 2000 was available, the Study Board relied on the IERM to compare the conditions for Wild Rice under the 2000 Rule Curves. The IERM takes into account the competition for habitat that exists between Hybrid Cattails and Wild Rice. Model results suggest that although an improvement in conditions was expected on Namakan Lake, the invasion of the Hybrid Cattail has prevented Wild Rice from growing in many areas. No changes to the condition for Wild Rice due to the 2000 Rule Curves were calculated by the IERM for either lake.

## 3. Wetland vegetation

The Study Board concluded that, as anticipated, there was a post-2000 Rule Curve improvement in the wetland vegetation in Namakan Chain of Lakes. Studies indicated that recovery was occurring to areas previously negatively affected by the 1970 Rule Curves. No change was noted for Rainy Lake.

## 4. Emergent vegetation

As no studies investigating the state of emergent vegetation pre- and post-2000 were available, the Study Board relied upon the IERM to make its assessment of this study subject. Model results showed that there was slightly less habitat suitable to emergent vegetation under the 2000 Rule Curve as compared to under the 1970 Rule Curve in the Namakan Chain of Lakes. On Rainy Lake, however a slight improvement was seen in the condition of emergent wet meadows, where wet meadows benefited from the increased frequency of flooding provided by the 2000 Rule Curve.

## 5. Submerged plants

A study investigating changes in wetland vegetation due to lake level management in Voyageurs National Park supported the conclusion that the change to the 2000 Rule Curve contributed to significant positive changes to the submerged aquatic vegetation community on the Namakan Chain of Lakes. No changes were noted on Rainy Lake.

### 5.2.6 Invertebrates

The two tables below summarize the expected outcomes and the WOE results for invertebrates on Namakan and Rainy Lakes due to the implementation of the 2000 Rule Curves. Further details on each study subject are provided in Annex 6.

The significant reduction in over-winter drawdown on Namakan Lake was expected to reduce exposure of benthic invertebrates, thereby increasing their

Expected Outcomes	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>6. Invertebrates</b>						
Invertebrate Community	✓				✓	

Weight of Evidence Results	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>6. Invertebrates</b>						
Invertebrate Community	✓				✓	

likelihood of over-winter survival. The over-winter drawdown on Rainy Lake remained relatively unchanged; therefore, no change was predicted on Rainy Lake as a result of the 2000 Rule Curve. Several studies investigating the impacts of the water level regulation on Namakan and Rainy Lakes indicated a shift toward a healthier benthic macroinvertebrate community in the Namakan Chain of Lakes after implementation of the 2000 Rule Curve. Changes on Rainy Lake were found to be insignificant.

### 5.2.7 Water quality

The following two tables summarize the expected outcomes and the WOE results for water quality on Namakan and Rainy Lakes due to the implementation of the 2000 Rule Curves. Further details on each study subject are provided in Annex 6.

#### 1. Trophic states

The 2000 Rule Curves produced an improvement to the trophic state (a measure of water quality), based on chlorophyll-a values, of Lake Kabetogama (part of the Namakan Chain of Lakes) and Black Bay on Rainy Lake. This was an expected result for Lake Kabetogama as the within-year water level fluctuation of Namakan Lake under the 2000 Rule Curve is closer to its natural fluctuation than the within-year water level fluctuation under the 1970 Rule Curve. The improvement in trophic state on Black Bay, however, was not expected. Although no changes in trophic

state were observed in the main bodies of Namakan and Rainy Lakes, the improvements to Lake Kabetogama and Black Bay represent positive ecosystem responses, as they are two of the more eutrophic<sup>14</sup> water bodies within the study area.

#### 2. Phosphorous concentrations

Based on modelling results of Kepner and Stottlemeyer (1988), an improvement in lake water phosphorous concentrations was expected for Namakan Lake following the implementation of the 2000 Rule Curve. It was surmised that the lower annual fluctuation for Namakan Lake under the 2000 Rule Curve reduced the amount of shoreline area that was dried and rewetted each year, thereby reducing nutrient loading. However, studies reviewed in this analysis indicated that no such improvements were detected.

### 5.2.8 Rainy River study subjects

The two tables below summarize the expected outcomes and the WOE results for study subjects on the Rainy River due to the implementation of the 2000 Rule Curves. Further details on each study subject are provided in Annex 6.

Study 3 (see Annex 6) investigated the effects of the 2000 Rule Curves on the Rainy River hydrology and hydraulic regime. The authors found that there was no strong evidence to suggest that Rainy River flow patterns after the 2000 Rule Curves implementation were

Expected Outcomes	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>7. Water Quality</b>						
Trophic State	✓				✓	
Lake Water Phosphorous Concentrations	✓				✓	

Weight of Evidence Results	Namakan Chain of Lakes			Rainy Lake		
	Better	Neutral	Worse	Better	Neutral	Worse
<b>7. Water Quality</b>						
Trophic State	✓			✓		
Lake Water Phosphorous Concentrations		✓			✓	

14 That is, rich in nutrients supporting abundant plant life that, in the process of decaying, depletes the oxygen supply in the water.



governed solely by the change in rule curve and that climate was a significant influencing factor. The authors did note that any differences observed in the Rainy River hydraulic regime decreased with distance downstream from the International Falls Dam as a result of the increasing influence of tributary inflows and backwater from Lake of the Woods.

### 1. Walleye

Although it was expected that the regulation of Rainy Lake under the 2000 Rule Curve would not positively or negatively affect spawning habitat for Walleye on Rainy River, the IERM showed an increase in spawning habitat after 2000. Research undertaken for the Study attributed this change to small variations in river discharge during the Walleye spawning and egg incubation periods between the 1970 and 2000 Rule Curves (Study 19, Annex 6).

### 2. Lake Sturgeon

Although it was expected that the regulation of Rainy Lake under the 2000 Rule Curve would not positively or negatively affect spawning habitat for Lake Sturgeon on Rainy River, the IERM showed an increase in suitable spawning habitat after 2000. As Walleye and Lake Sturgeon overlap in their spawning requirements, the variations in river discharge during the spawning and egg incubation periods between the 1970 and 2000 Rule Curves also benefited Lake Sturgeon.

Lake Sturgeon adult population estimates by the MNDNR and the OMNRF have shown that Rainy River Lake Sturgeon numbers have increased since the previous population studies in the 1990s. However, this trend is attributed to the continued recovery of the species. Lake Sturgeon

Expected Outcomes	Rainy River		
	Better	Neutral	Worse
<b>1. Fish</b>			
Walleye Spawning Habitat		✓	
Lake Sturgeon Population	<i>No projections made</i>		
Lake Sturgeon Spawning Habitat		✓	
Rainy River Index of Biotic Integrity	✓		
<b>4. Archeological Resources</b>			
Condition of Resources	<i>No projections made</i>		
<b>6. Invertebrates</b>			
Mussels	<i>No projections made</i>		
<b>7. Water Quality</b>			
Municipal & Fish Hatchery Use		✓	

Weight of Evidence Results	Rainy River		
	Better	Neutral	Worse
<b>1. Fish</b>			
Walleye Spawning Habitat	✓		
Lake Sturgeon Population		✓	
Lake Sturgeon Spawning Habitat	✓		
Rainy River Index of Biotic Integrity		✓	
<b>4. Archeological Resources</b>			
Condition of Resources	<i>Study Results Inconclusive</i>		
<b>6. Invertebrates</b>			
Mussels	<i>Study Results Inconclusive</i>		
<b>7. Water Quality</b>			
Municipal & Fish Hatchery Use	<i>Study Results Inconclusive</i>		

population had declined greatly in the 20th Century due to commercial exploitation and habitat degradation. Conservation efforts, including the implementation of the Lake Sturgeon Protocol,<sup>15</sup> have played a role in the preservation of Lake Sturgeon on Rainy River.

### 3. Index of Biotic Integrity (IBI)

A study by Fisheries and Oceans Canada (Study 15) on the Rainy River Index of Biotic Integrity (IBI) hypothesized that the 2000 Rule Curves would result in seasonally higher flows to the Rainy River and would therefore bring potential benefit to the aquatic community of the river. The IBI is a multi-metric index that evaluates community composition (*i.e.*, feeding guilds, spawning needs, sensitivity to disturbance), species richness, fish abundance and fish health as surrogates of riverine health. The study concluded that the 2000 Rule Curves did not have an impact (positive or negative) on the biotic integrity of Rainy River.

### 4. Archeological/cultural resources

No predictions had been made regarding the effect of the 2000 Rule Curves on archeological and cultural resources along the Rainy River. An assessment on the effects of water level on cultural resources at benchmark sites on the Rainy River (Study 13) concluded that most of the cultural sites were higher than the flood levels derived from operation under the 1970 and 2000 Rule Curves. Therefore, the impact of switching from the 1970 to the 2000 Rule Curves cannot be assessed.

### 5. Mussels

No predictions had been made regarding the effect of the 2000 Rule Curves on mussel assemblages in the Rainy River. A study investigating the relationship of Rainy River hydrology to distribution and abundance of freshwater mussels (Study 14) was not able to conclude whether there was an impact on mussels in Rainy River as a result of the 2000

Rule Curves due to a lack of pre-2000 data.

### 6. Municipal and fish hatchery use

No impact (positive or negative) to municipal and fish hatchery water use was expected as a result of the adoption of the 2000 Rule Curves. The impact of the 2000 Rule Curves on the domestic water treatment plants and fish hatchery on Rainy River could not be determined as further modelling is required to eliminate the effects of flow contribution downstream of the International Dam at the outlet of Rainy Lake.

### 5.2.9 Summary of the performance of the 2000 Rule Curves

Table 5-1 presents a summary of the Study Board's WOE assessment for the study subjects discussed above. In general, the WOE analysis shows that the 2000 Rule Curves performed as expected. Note that in the table:

- a green check mark ( ✓ ) indicates that the conclusion derived for a given study subject and water body was an expected result of the 2000 Rule Curves;
- a red "x" ( ✗ ) indicates that the conclusion was not anticipated; in this case, the outcome that had been expected is identified in the matrix;
- a solid black dot ( ● ) indicates that no particular conclusion (*i.e.*, better, neutral or worse) had been expected;
- results are listed as "inconclusive" where the change (or lack of change) in condition observed could not confidently be attributed to the implementation of the 2000 Rule Curves;
- areas of the matrix that are greyed out indicate that there was no study available to derive an assessment for the particular study subject and water body; and
- the "Index Nos" column identifies the studies that the Study Board used to produce the WOE analysis for a given study subject (see Annex 6).

<sup>15</sup> The Lake Sturgeon Protocol is an informal arrangement developed in 2012 to allow for coordination between local observers and the Water Levels Committee during the spawning season with an aim of preventing reductions in releases from the Rainy Lake dam that would dewater Lake Sturgeon eggs.

**Table 5-1 Study Board assessment of 2000 Rule Curves performance**  
(note: assessment based on combined monitoring and modelling results)

Weight of Evidence Summary			Result was as expected		Question Addressed: Did regulation of Rainy Lake and Namakan Chain of Lakes under the 2000 Rule Curves result in a better, neutral, or worse outcome for the study subject?												
			✓	✗	Namakan Chain of Lakes			Rainy Lake			Rainy River						
			Neutral	Worse	Inconclusive	Better	Neutral	Worse	Inconclusive	Better	Neutral	Worse	Inconclusive				
			Better	Worse	Inconclusive	Better	Neutral	Worse	Inconclusive	Better	Neutral	Worse	Inconclusive				
INDEX Nos	Weight of Evidence Study Subject	Better	Neutral	Worse	Inconclusive	Better	Neutral	Worse	Inconclusive	Better	Neutral	Worse	Inconclusive	Better	Neutral	Worse	Inconclusive
1. Fish																	
33	Northern Pike Population	✓				●											
8	Northern Pike Young of Year	✓				✓											
8, 21	Northern Pike Nursery and Young of Year Habitat	✓															
33	Walleye Population				●												
32	Walleye Young of Year	✓				●											
16, 19, 21	Walleye Spawning Habitat	✓				expected	✗										
33	Yellow Perch Population		●			●											
26, 30, 32	Yellow Perch Young of Year	●				●											
9, 40, 48, 49	Lake Sturgeon Population	expected			✗	expected									●		
9, 19	Lake Sturgeon Spawning Habitat	expected				expected								✗	expected		
46a-d	Whitefish Population	expected								expected							
*	Whitefish Spawning Habitat	✓					✓										
15	Rainy River Index of Biotic Integrity													expected	✗		
26, 30	Young of Year Yellow Perch Mercury Concentration				●												
2. Wildlife																	
34	Beaver Population	✓					✓										
6	Habitat for Birds and Herptiles				●												
4, 21, 31	Common Loon Reproductive Success	✓					✓										
21	Muskrat Lodge Winter Viability		✓			✗	expected										
3. Economic Impacts																	
**	Power Production																
11	Flooding			✓				✓									
11	Ice Damage			expected	✗			expected				expected					
10	Resort Industry	✓								expected							
4. Archeological Resources																	
12,13	Condition of Resources	✓				✓											●
5. Vegetation																	
21	Cattail Invasion		●				●										
1,28	Wetland Vegetation	✓															
21	Emergent Vegetation - Wet meadow	expected		✗		●											
21, 28	Submerged Plants	✓					●										
21	Wild Rice	expected	✗				●										
6. Invertebrates																	
7, 27a, 27b	Invertebrate Community	✓					✓										
14	Mussels																●
7. Water Quality																	
22,23	Trophic State	✓				✗	expected										
22, 23, 24	Lake Water Phosphorous Concentrations	expected	✗				✓										
17	Municipal & Fish Hatchery Use										expected				expected		✗

The IERM  
simulates  
the impact of  
water levels  
on Walleye,  
Northern  
Pike and Lake  
Whitefish  
spawning.

### 5.3 Comparison of the 2000 Rule Curves and the State of Nature

The second part of the evaluation of the 2000 Rule Curves considered how the rule curves compared with conditions under the hypothetical State of Nature (SON) conditions, using the results of modelling through the shared vision model (SVM) and IERM.

As noted in **Chapter 3**, the SON refers to a basin configuration where it is assumed that the dams limiting or regulating flow out of Namakan Lake and Rainy Lake do not exist. This allows for the modelling of flows from these lakes in a pre-dam condition – a best estimate of the system under natural conditions. Due to the absence of pre-dam data in these areas, however, such modelling was necessarily an approximation of actual pre-dam conditions.

The SON conditions provided the Study Board with a second baseline against which to compare the 2000 Rule Curves, and in this case a baseline that is, in theory, much closer to the natural state conditions of the system than the 1970 Rule Curves.

#### 5.3.1 Evaluation approach

As described in **Chapter 3**, the 1970 and 2000 Rule Curves and the SON were programmed into the SVM to produce water levels and releases based on the historical water supply sequence. The SVM also calculated performance indicators (PIs) for several key subjects (see Annex 5). The water levels and releases calculated for each lake by the SVM were imported into the IERM for the evaluation of ecological PIs. As observed data are not available to evaluate study subjects under a SON setting, the comparison of the 1970 and 2000 Rule Curves with the SON relies solely on model output.

As stated in **Chapter 3**, PIs are not available for all study subjects evaluated in the WOE analysis. A full list and description of PIs is presented in Annex 5.

### 5.3.2 Fish

The IERM simulates the impact of water levels on Walleye, Northern Pike and Lake Whitefish spawning. It is expected that an increase in the likelihood of successful spawning periods over several years would result in an increase in recruitment. Based on this assumption, IERM modelling suggests that the SON results in:

- an increase in Walleye on Namakan Lake and a decrease on Rainy Lake,
- an increase in Northern Pike on both lakes, and
- greater variation in Lake Whitefish population over the years on Namakan Lake and a decrease on Rainy Lake.

#### 1. Walleye

Figures 5-1 to 5-4 show IERM results for the Walleye Egg Survival Probability and Walleye Spawning Success PIs.

The IERM suggests that the probability of Walleye egg survival is increased under the SON for Namakan Lake. On Rainy Lake, however, regulation of water levels provides an increase in the survival probability of eggs on both lakes, as regulation provides consistent and stable water levels throughout the spawning and incubation periods. The SON conditions for Walleye eggs vary over the modelling period.

The Walleye Spawning Success PI takes into account factors such as the presence of clean and coarse substrate material for spawning. The fluctuation of water levels under the SON results in the cleaning of gravel beds at a variety of depths through wave action on the lake. On Namakan Lake, the SON provides a greater extent of habitat likely to provide a successful Walleye spawn than the 1970 and 2000 Rule Curves (Figure 5-3). On Rainy Lake, however, regulation under both the 1970 and 2000 Rule Curves provides a greater extent of suitable habitat than the SON (Figure 5-4).

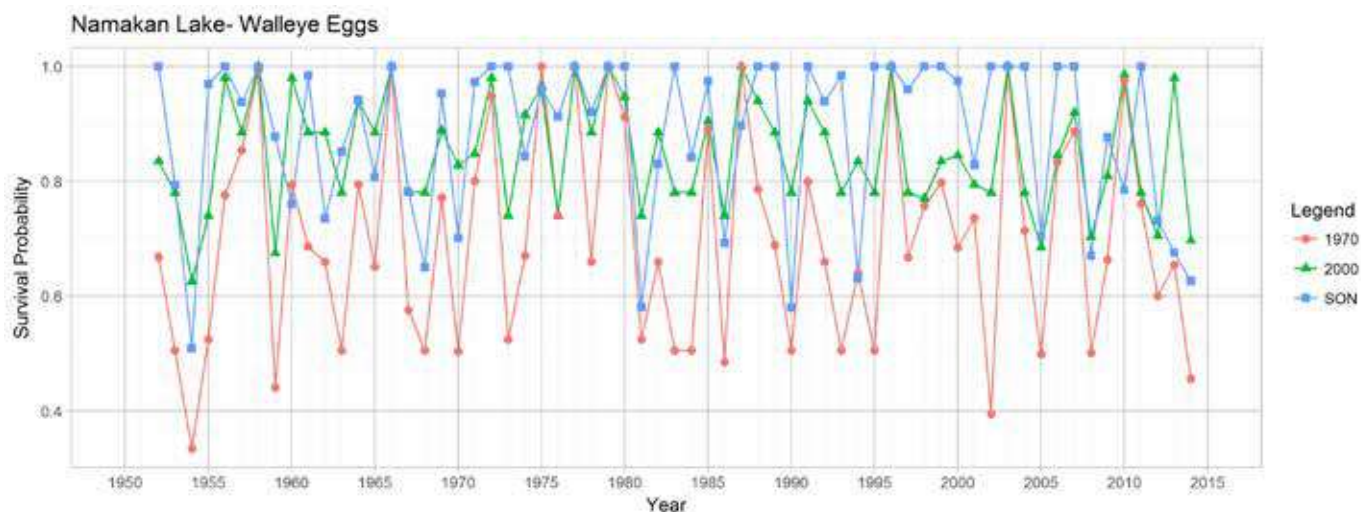


Figure 5-1 Probability of Walleye egg survival for Namakan Lake

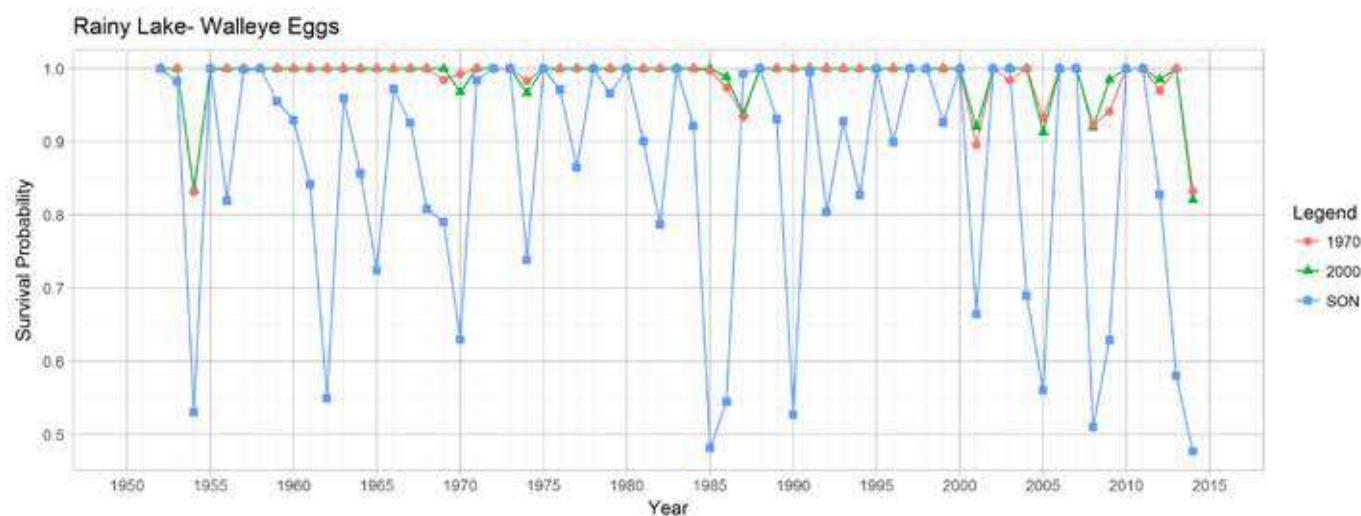


Figure 5-2 Probability of Walleye egg survival for Rainy Lake

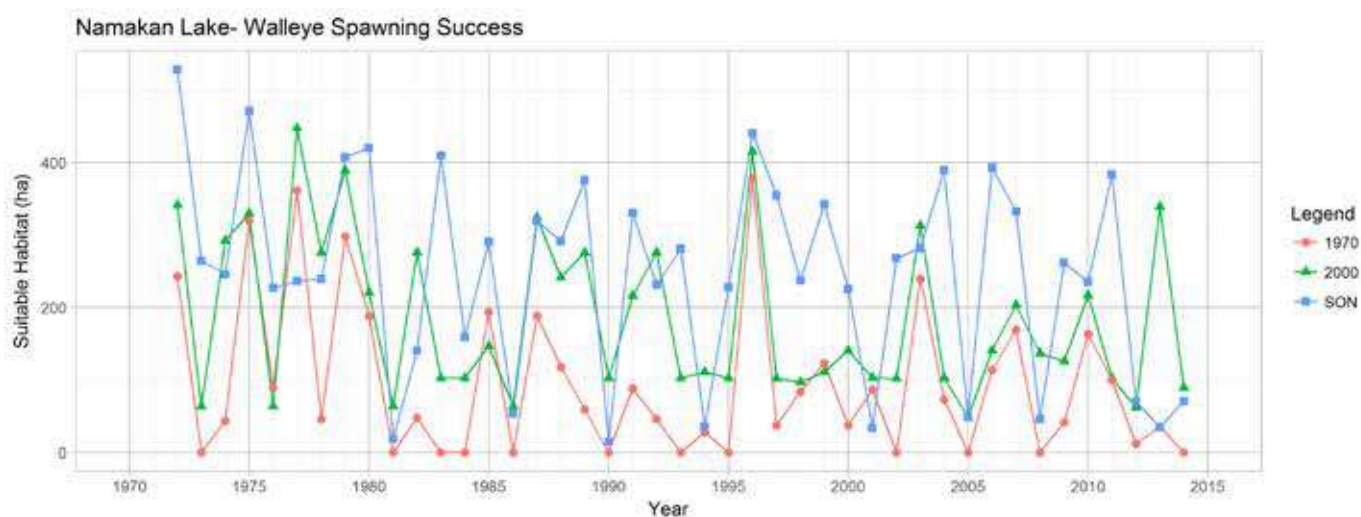


Figure 5-3 Area of suitable habitat for Walleye spawning success on Namakan Lake



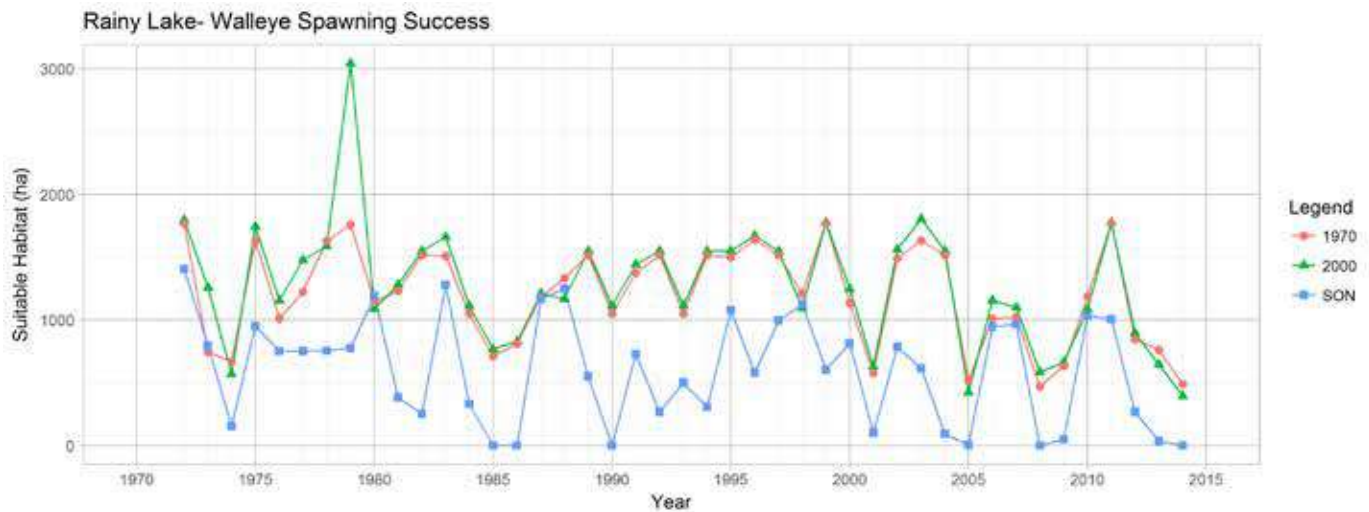


Figure 5-4 Area of suitable habitat for Walleye spawning success on Rainy Lake

## 2. Northern Pike

Figures 5-5 to 5-10 show IERM results for the Northern Pike Spawning Suitable Habitat, Larval Suitable Habitat and YoY Suitable Habitat Pls.

As discussed in Annex 5, although both high-quality and lower quality habitat are present within the lakes, high-quality spawning habitat is more sensitive to water level changes. Therefore, it best represents the impact of water level regulation on Northern Pike production. Figures 5-5 and 5-6 indicate that very little suitable high-quality habitat for Northern Pike spawning is available in either lake in most years under all conditions. In years with increased amounts of suitable spawning habitat, however, the SON provides a greater extent than the 1970 and 2000 Rule Curves. Research has shown that most

Northern Pike found in Namakan and Rainy Lakes are spawned in tributary rivers and shallow bays (Miller *et al.*, 2001).

IERM results suggest that the amount of suitable habitat for Northern Pike larva under the SON is higher in most years on Namakan Lake and lower in most years on Rainy Lake than under the 1970 and 2000 Rule Curves. On both lakes, however the amount of suitable habitat is most variable under SON.

Figures 5-9 and 5-10 indicate that the SON provides less habitat for Northern Pike YoY than the 1970 and 2000 Rule Curves. However, Morin *et al.* (2016, Study 19) point out that recruitment of Northern Pike in Namakan and Rainy Lakes is likely limited by low quantities of spawning habitat shown in Figures 5-5 and 5-6.

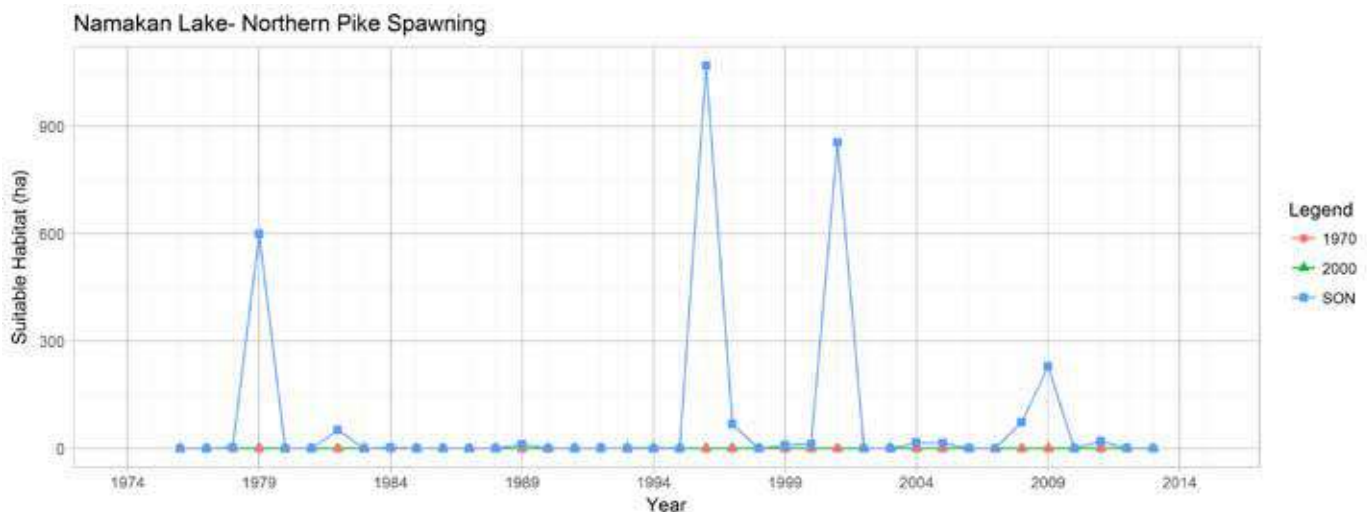


Figure 5-5 Area of suitable habitat for Northern Pike spawning on Namakan Lake



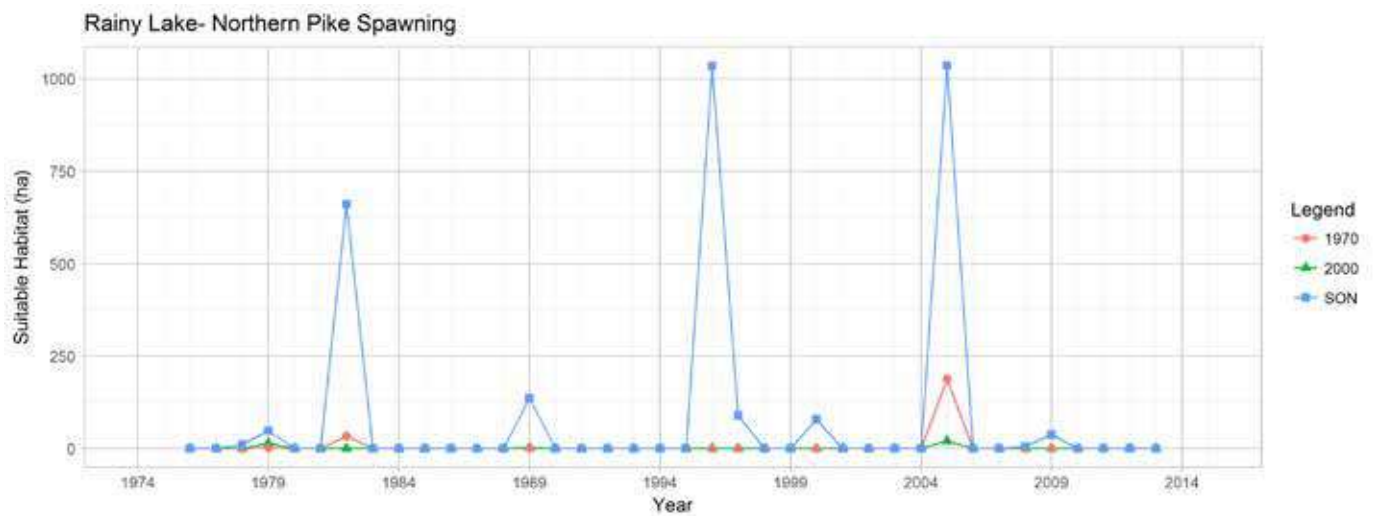


Figure 5-6 Area of suitable habitat for Northern Pike spawning on Rainy Lake

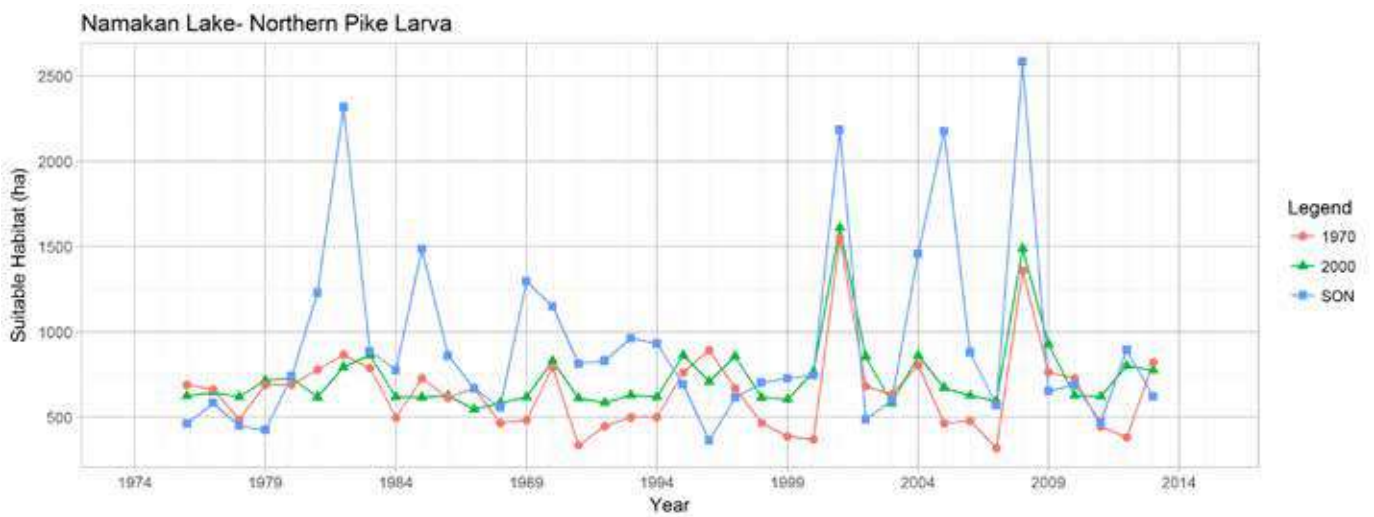


Figure 5-7 Area of suitable habitat for Northern Pike larval survival on Namakan Lake

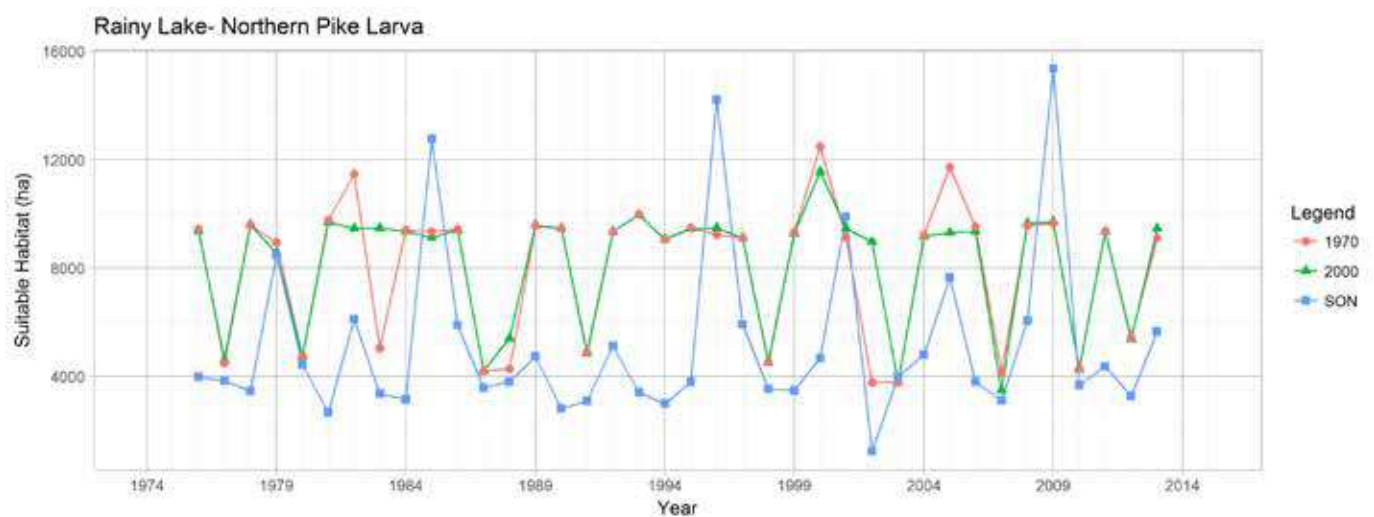


Figure 5-8 Area of suitable habitat for Northern Pike larval survival on Rainy Lake

### 3. Lake Whitefish

Figures 5-11 to 5-14 provide IERM results for the Lake Whitefish Egg Survival Probability and Spawning Habitat PIs.

The Lake Whitefish Egg Survival Probability indicates that the SON provides a greater variation in PI performance throughout the modelled time series. In many years, Lake Whitefish egg survival probability, especially on Namakan Lake, nears or equals 1 (*i.e.*, all eggs survive). However, in other years, the probability approaches zero (*i.e.*, no eggs survive). Regulation under the 2000 Rules

Curves provides the greatest likelihood of egg survival, most consistently.

The Lake Whitefish Spawning Success PI, however, takes in to account characteristics such as lake bottom slope and the presence of clean substrate. Although the SON conditions provide an increase in clean gravel beds for spawning, the 2000 Rule Curves provide the greatest extent of suitable spawning habitat for Lake Whitefish on Namakan Lake in most years. On Rainy Lake, both the 1970 and 2000 Rule Curves provide more suitable Lake Whitefish spawning habitat than the SON.

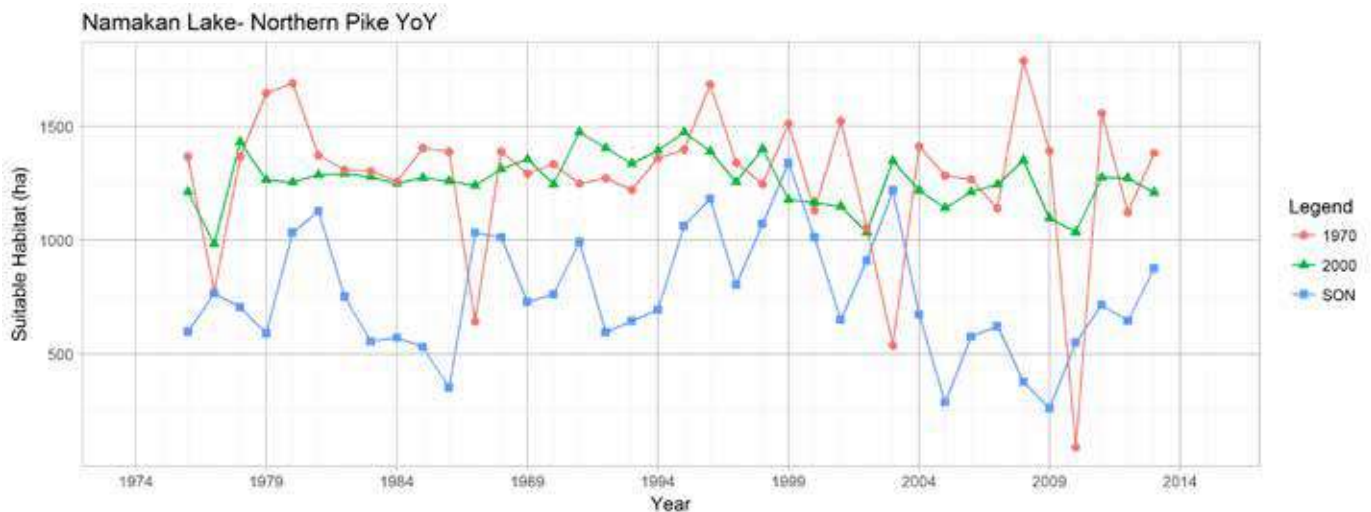


Figure 5-9 Area of suitable habitat for Northern Pike YoY survival on Namakan Lake

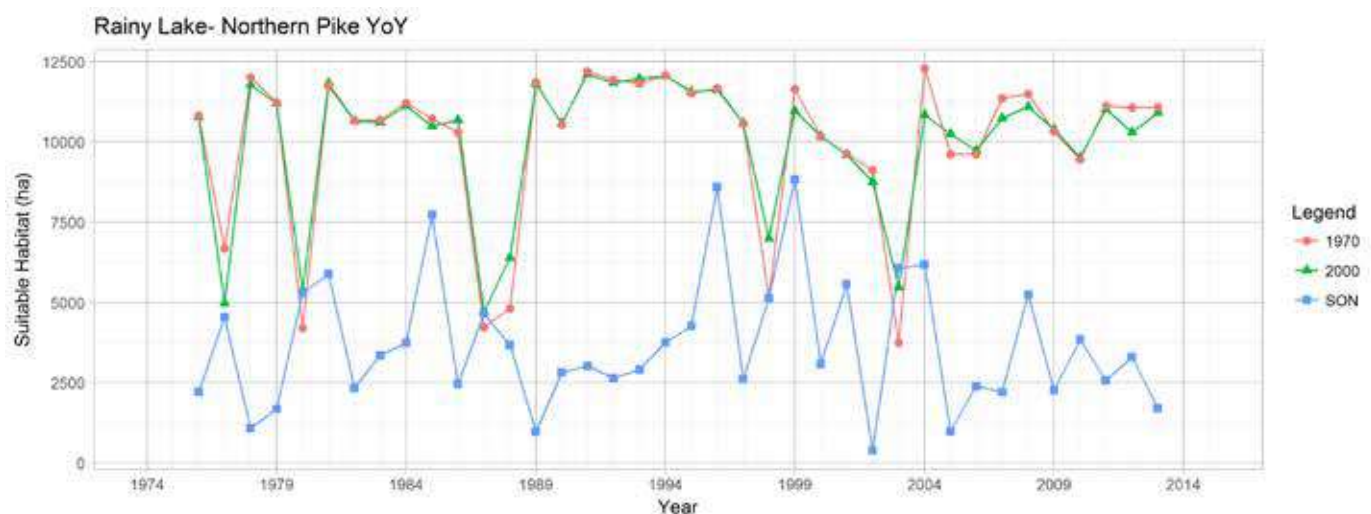


Figure 5-10 Area of suitable habitat for Northern Pike YoY survival on Rainy Lake

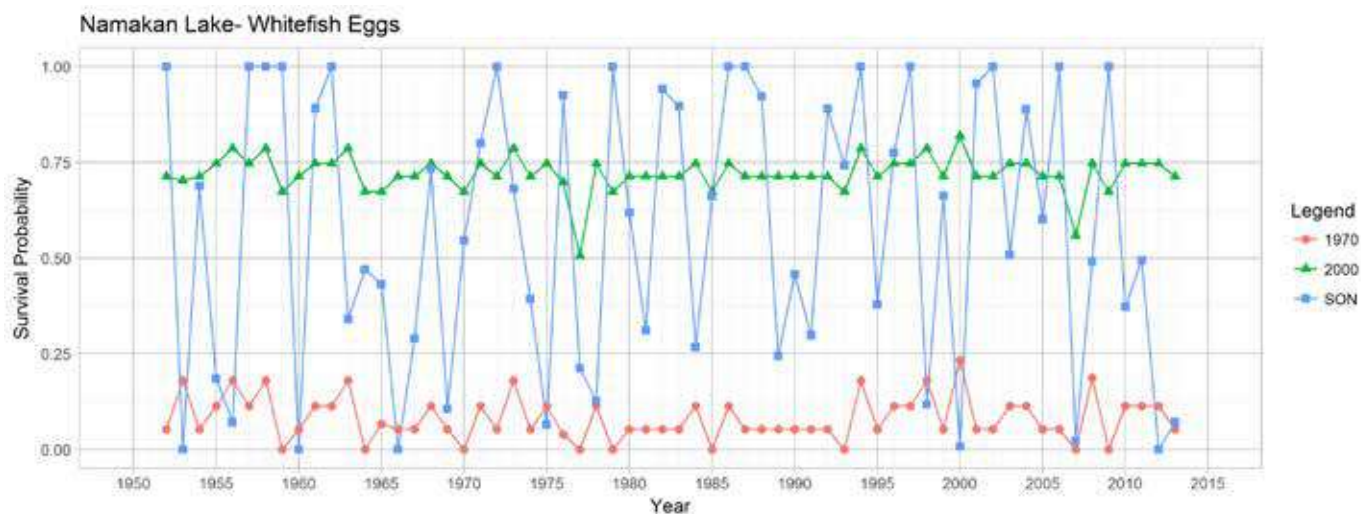


Figure 5-11 Probability of Lake Whitefish egg survival on Namakan Lake

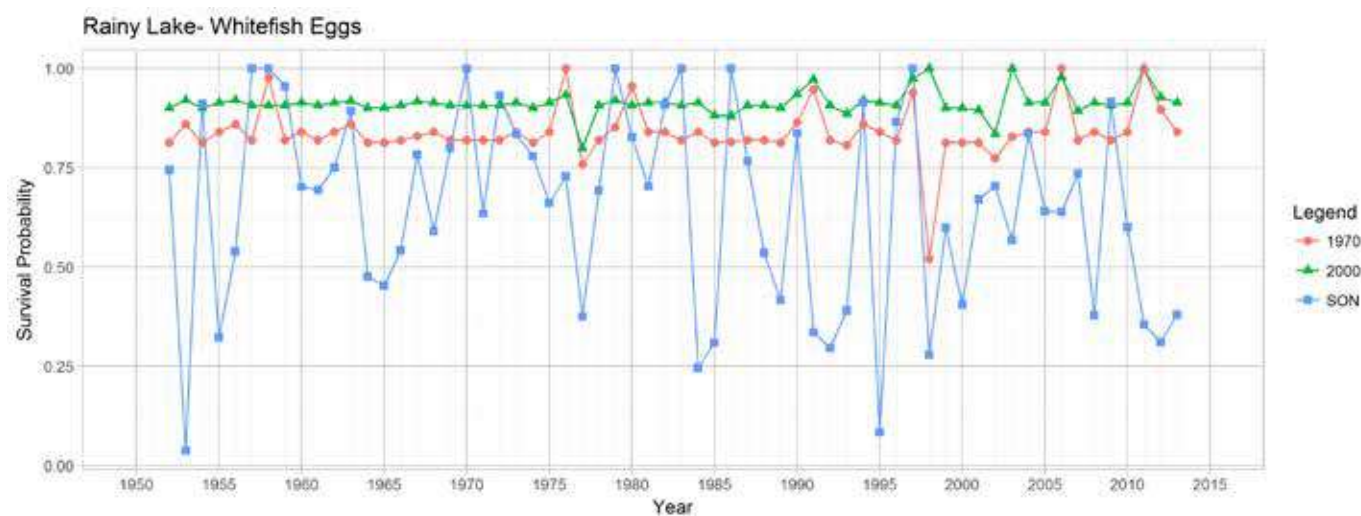


Figure 5-12 Probability of Lake Whitefish egg survival on Rainy Lake

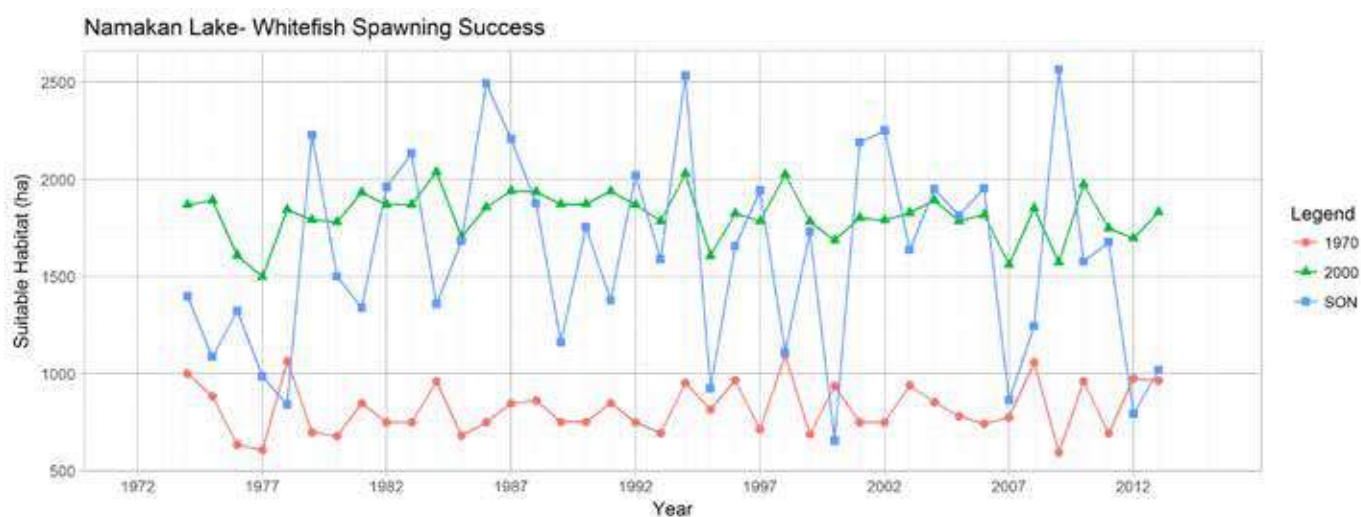


Figure 5-13 Area of suitable for Lake Whitefish spawning on Namakan Lake



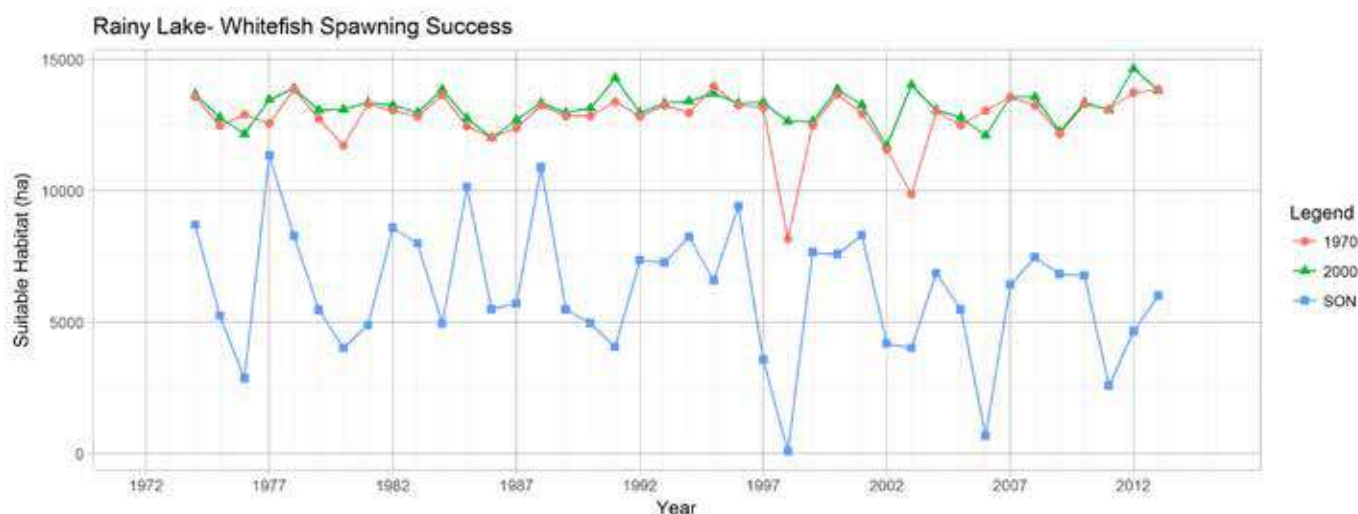


Figure 5-14 Area of suitable for Lake Whitefish spawning on Rainy Lake

### 5.3.3 Wildlife

The IERM includes models that predict the likelihood of over-winter survival of Muskrats and the likelihood of successful Common Loon nests in the spring. IERM results suggest that, under the SON conditions:

- Common Loon nests are less successful on both lakes; and
- Muskrats are more likely to thrive over the winter period more frequently on both lakes.

#### 1. Common Loon

Figures 5-15 and 5-16 show the IERM results for the Common Loon, indicating the Probability of Loon Nest Viability (PLNV). Model results indicate that Loon nests have

the greatest probability of survival under regulated conditions as a result of the reduced variations in water levels over the nesting season. On Namakan Lake, the 2000 Rule Curve produces the greatest likelihood of nest viability in most years.

#### 2. Muskrats

Figures 5-17 and 5-18 show the IERM results for the Muskrat Over-Winter Survival PI. On Namakan Lake, the 1970 and 2000 Rule Curves result in a probability of winter lodge viability of zero (*i.e.* no Muskrats survive). The SON, however, provides varying performance throughout the modelling period with many years where all Muskrat lodges are expected to survive on both lakes.

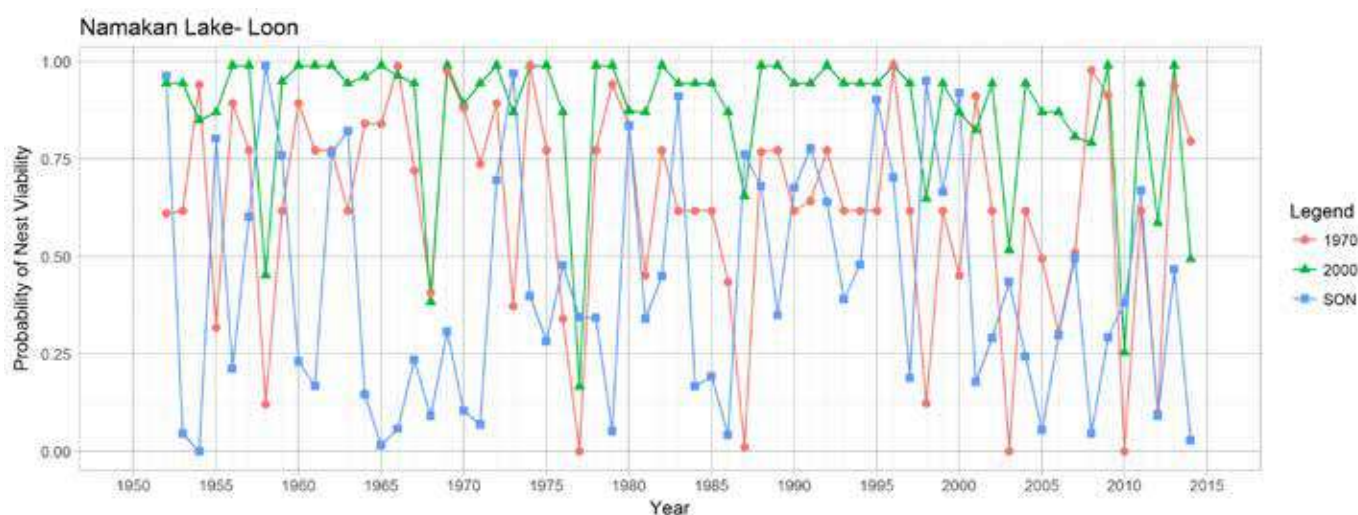


Figure 5-15 Probability of Loon nest viability on Namakan Lake

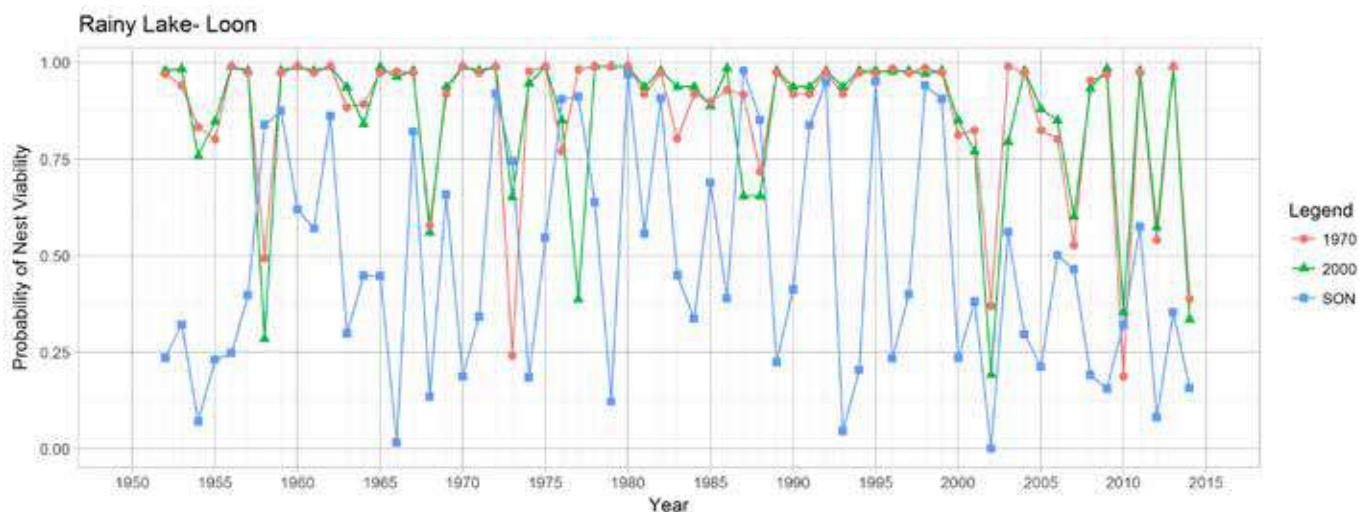


Figure 5-16 Probability of Loon nest viability on Rainy Lake

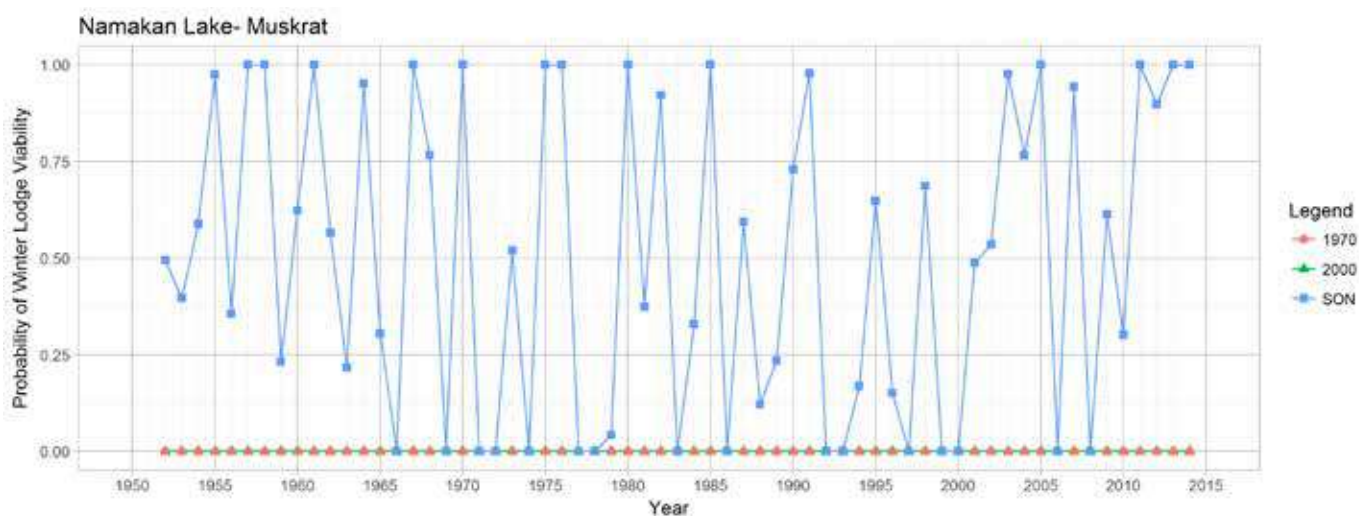


Figure 5-17 Probability of winter Muskrat lodge viability on Namakan Lake

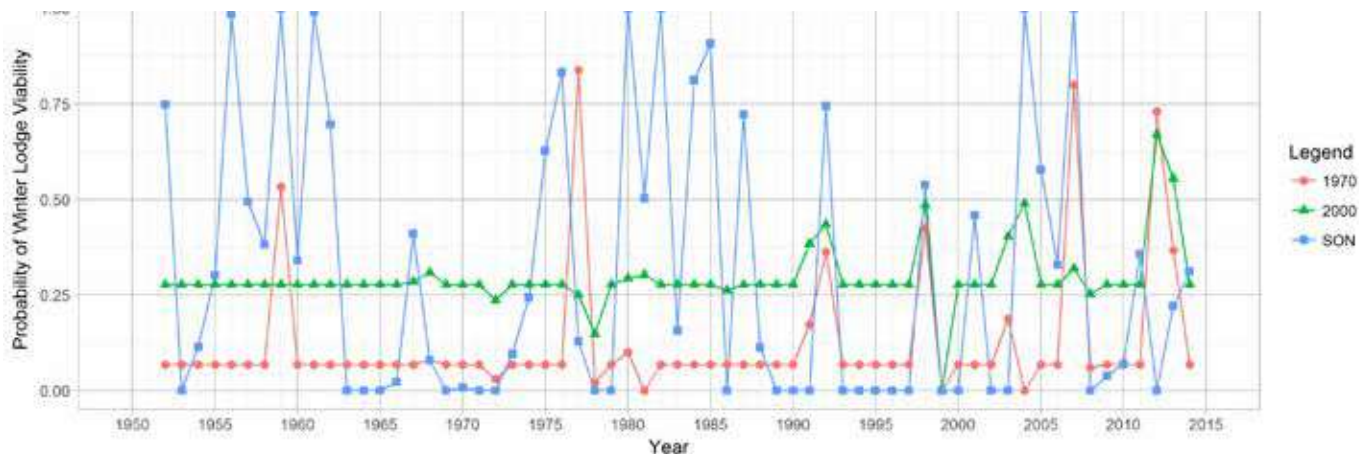


Figure 5-18 Probability of winter Muskrat lodge viability on Rainy Lake

### 5.3.4 Economy

The SVM estimates the impact of water levels on economic interests for Namakan and Rainy Lakes. SVM model output suggests that, under the SON conditions:

- there would be an increase in the amount of damage to docks and shoreline structures on both lakes; and
- poor navigation conditions would be sustained on both lakes throughout the boating season.

#### 1. Flood damages

As further explained in Annex 5, the SVM calculates the reduction in flood damages (compared to the 2000 Rule Curves)

provided by a regulation alternative. The SVM suggests that without the presence of the dams, the average annual flood damages on Namakan and Rainy Lakes would increase under the SON conditions (negative values indicate an increase in damages compared to the 2000 Rule Curves). As previously shown by the WOE analysis, the 1970 Rule Curves provide a reduction in the average annual flood damages, when compared to the 2000 Rule Curves. Similarly, the SVM also predicts that the SON conditions increase flood damages during major events such as the 1950 and 2014 floods, whereas the 1970 Rule Curves would reduce damages during such events, when compared to the 2000 Rule Curves.

**Table 5-2 Flood damages PI results**  
(net reductions in damages, in \$,000)

		2000 Rule Curves	1970 Rule Curves	State of Nature
Namakan	Average Annual Flood	\$0	\$17	-\$37
	1950 Flood	\$0	\$561	-\$1,469
	2014 Flood	\$0	\$217	-\$295
Rainy	Average Annual Flood	\$0	\$186	-\$54
	1950 Flood	\$0	\$1,547	-\$1,906
	2014 Flood	\$0	\$965	-\$535

#### 2. Navigation

The SVM calculates the boating reliability as the percentage of time that the level of each lake remains above a minimum elevation required for good navigation conditions for different periods of the boating season. This PI is further explained in Annex 5.

SVM results presented in Table 5-3 suggest that favorable boating conditions are only provided under regulated conditions and are generally better under the 2000 Rule Curves for the spring and summer time, particularly on Namakan Lake.

#### 3. Hydropower production

As the dams would not be present under the SON conditions, the SVM-calculated Hydropower Production PI is not relevant to this analysis.

### 5.3.5 Archeological resources

As described in Annex 5, the SVM estimates the likelihood of erosion due to prolonged exposure of archeological resources along the shoreline to the forces of wave action. This PI is indexed to the performance of the 2000 Rule Curves. The SVM suggests



**Table 5-3 Boating Depth Reliability**  
(percent of time minimum depth requirement is met)

	2000 Rule Curves %	1970 Rule Curves %	State of Nature %
<b>Namakan Lake</b>			
May-June	62	42	19
July-Aug	99	94	4
Late Season	31	95	2
<b>Rainy Lake</b>			
May-June	68	65	23
July-Aug	94	91	19
Late Season	95	95	2

that the 2000 Rule Curves offer the greatest protection from erosion to archeological sites on Namakan and Rainy Lakes. Under SON conditions, extreme water levels during high water events would likely threaten archeological sites that are currently

protected by regulation. The 1970 Rule Curves, however, provide more stable water levels throughout the year, which consistently exposes certain shoreline elevation bands to erosive wave action.

**Table 5-4 Archeological resources PI results**

	2000 Rule Curves	1970 Rule Curves	State of Nature
Namakan Lake	1.00	0.66	0.68
Rainy Lake	1.00	0.62	0.81

### 5.3.6 Aquatic vegetation

The IERM models the impact of water levels on Namakan and Rainy Lake on several types of aquatic vegetation. The IERM results presented below suggest that under the SON:

- the expansion of the invasive Hybrid Cattail would be impeded on both lakes;
- Wild Rice is likely to produce more successful crops, more frequently;
- there would be an increase in wet meadows and shrubby swamps on both lakes;
- emergent vegetation would be more variable on both lakes; and

- areas of low- and high-density vegetation would be reduced on both lakes.

Overall, the SON is expected to result in a more diverse aquatic vegetation community on Namakan and Rainy Lakes.

#### 1. Wild Rice and Hybrid Cattails

Wild Rice and Hybrid Cattails occupy similar habitat and benefit from the steady water levels provided by a regulated system. However, the invasive Hybrid Cattail present within the Namakan Chain of Lakes and Rainy Lake generally out-competes Wild Rice for habitat. As described in Annex 5, the IERM models this interaction between the

wetland species. It is therefore important to evaluate these two interests in parallel.

The IERM estimates the amount of area suitable for Hybrid Cattail invasion. The Cattail Total Invasion PI includes areas of rooted cattails, as well as monotonous stands of Hybrid Cattails that are likely to form floating mats. Figures 5-19 and 5-20 indicate that under SON condition, the expansion of

invasive cattails is greatly reduced in most years. The inter- and intra-annual variations of water levels under SON are sufficient to control the species. As a result, the SON also provides many years where the extent of area for successful Wild Rice growth far exceeds the conditions provided by water level regulation under the 1970 and 2000 Rule Curves (Figures 5-21 and 5-22).

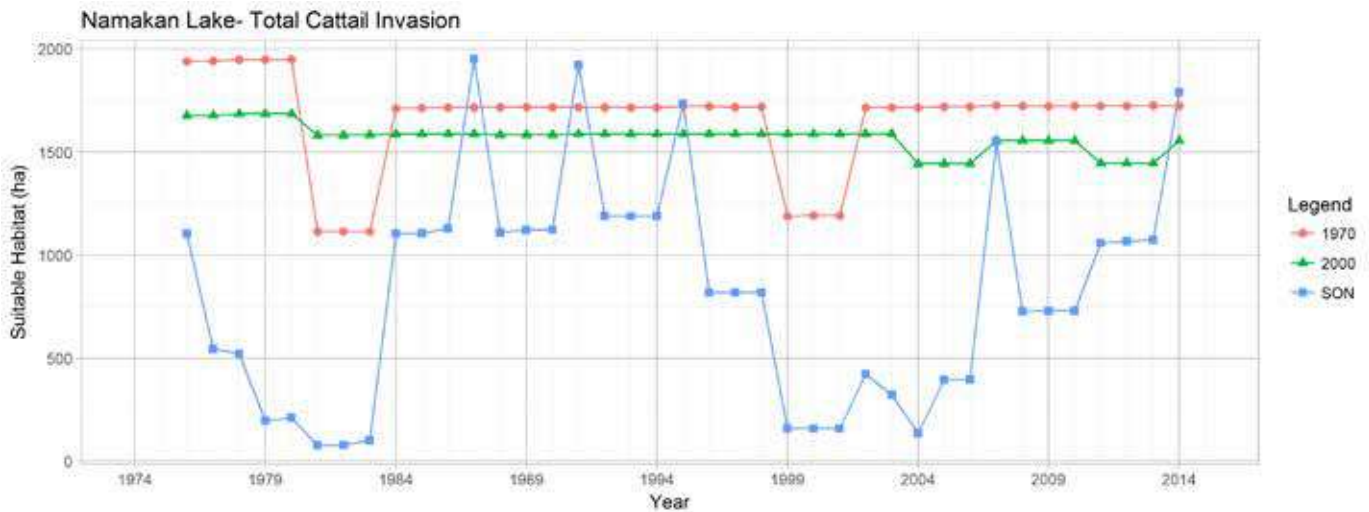


Figure 5-19 Area suitable for Hybrid Cattail invasion on Namakan Lake

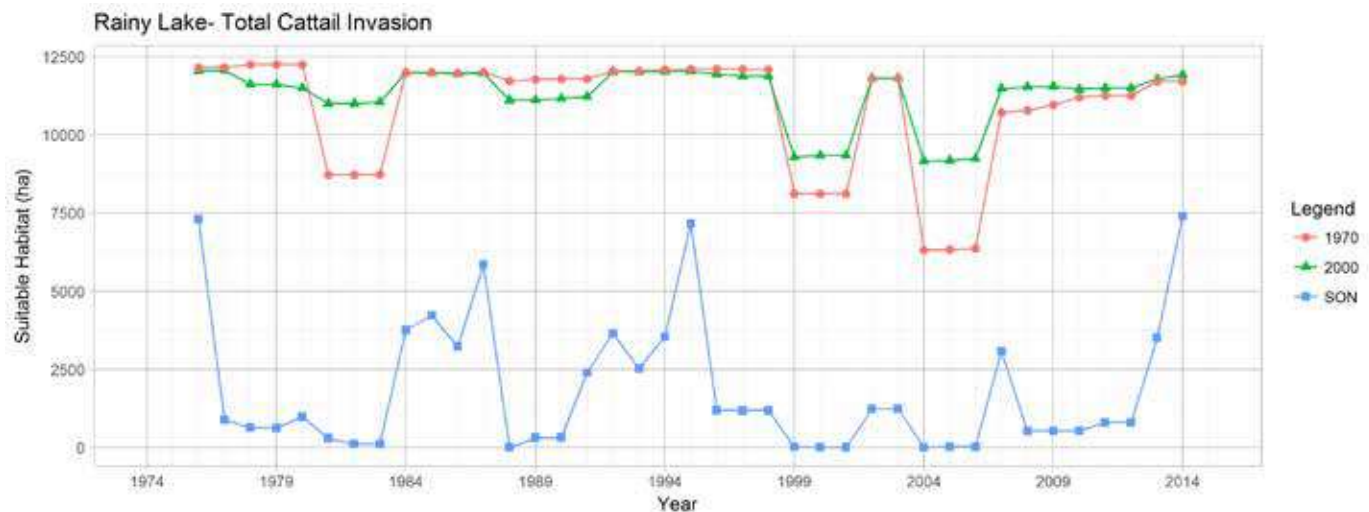


Figure 5-20 Area suitable for Hybrid Cattail invasion on Rainy Lake

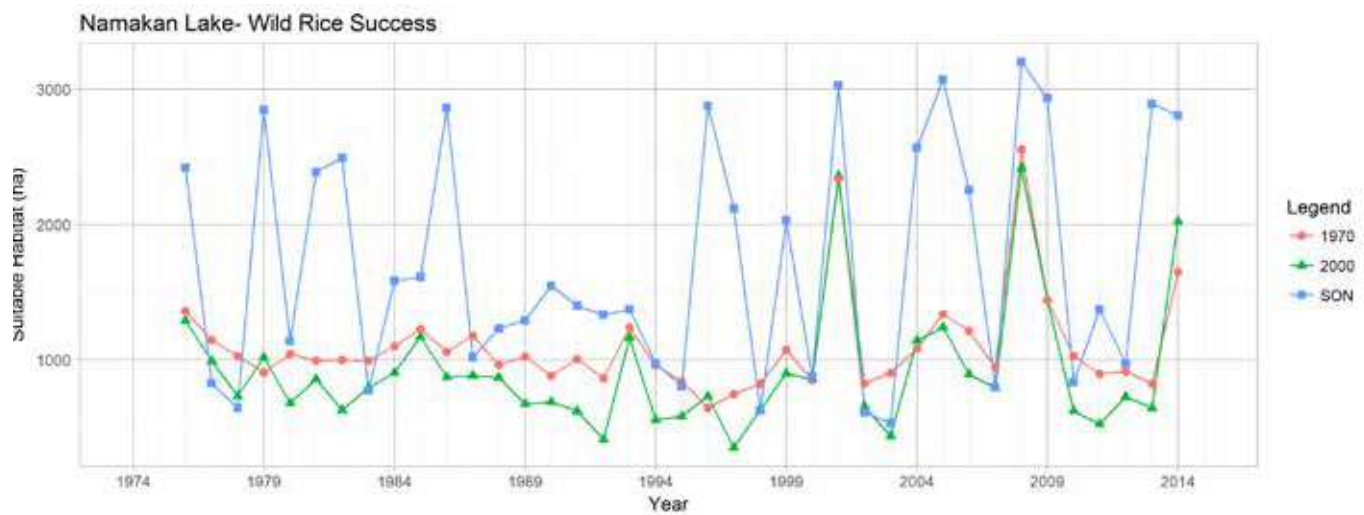


Figure 5-21 Area suitable for successful Wild Rice growth on Namakan Lake

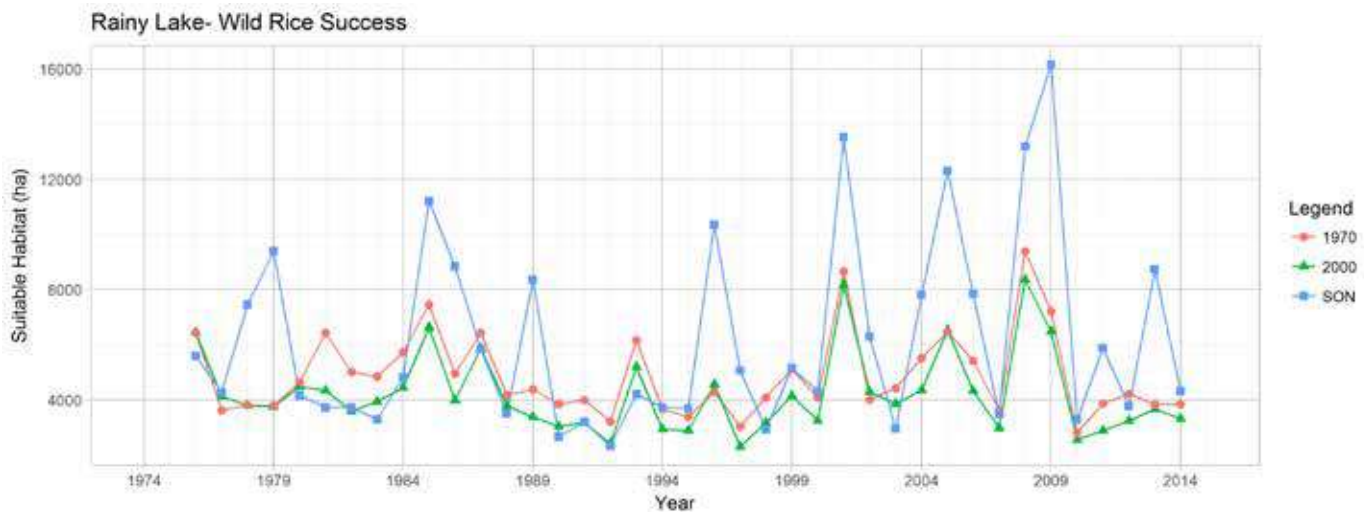


Figure 5-22 Area suitable for successful Wild Rice growth on Rainy Lake

## 2. Wet meadows and shrubby swamps

Figures 5-23 to 5-26 indicate the surface area of suitable habitat for wet meadows and shrubby swamps for a given year, as calculated by the IERM. The IERM suggests that, under the SON conditions, there is a greater extent of suitable habitat for wet meadows and shrubby swamps than

under regulated conditions. This is likely due to an increase in flooding that provides ideal conditions for these types of wetland vegetation. Shrubby swamps and wet meadows provide habitat for herptiles and marsh birds, as well as spawning habitat for Northern Pike. Therefore, an increase in their extent would likely promote an increase in wetland bio-diversity.

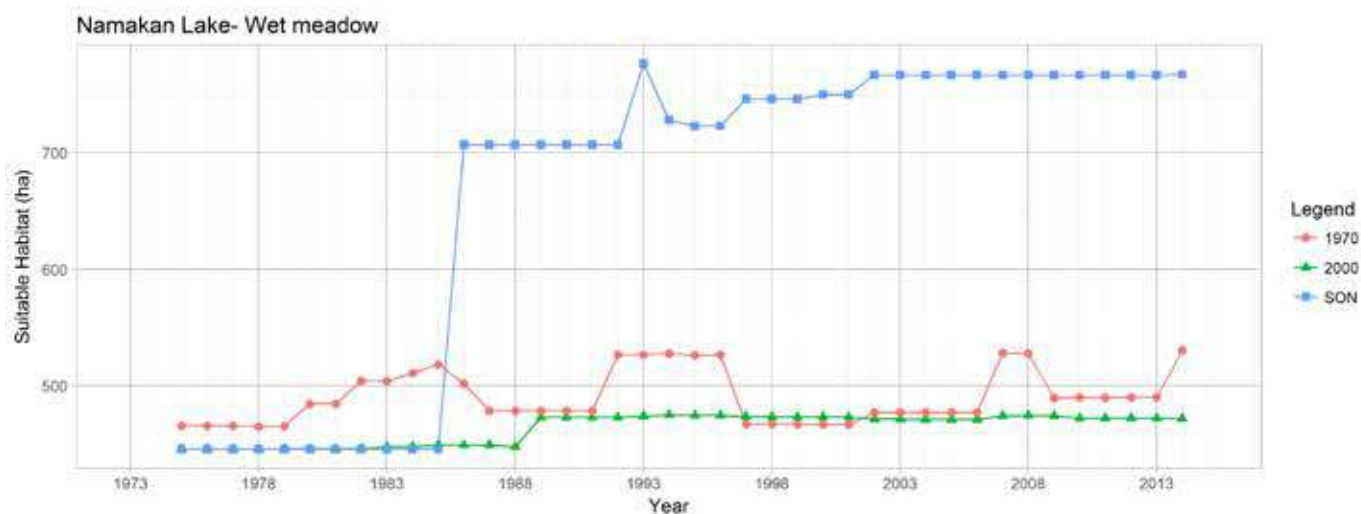


Figure 5-23 Area suitable for wet meadow growth on Namakan Lake

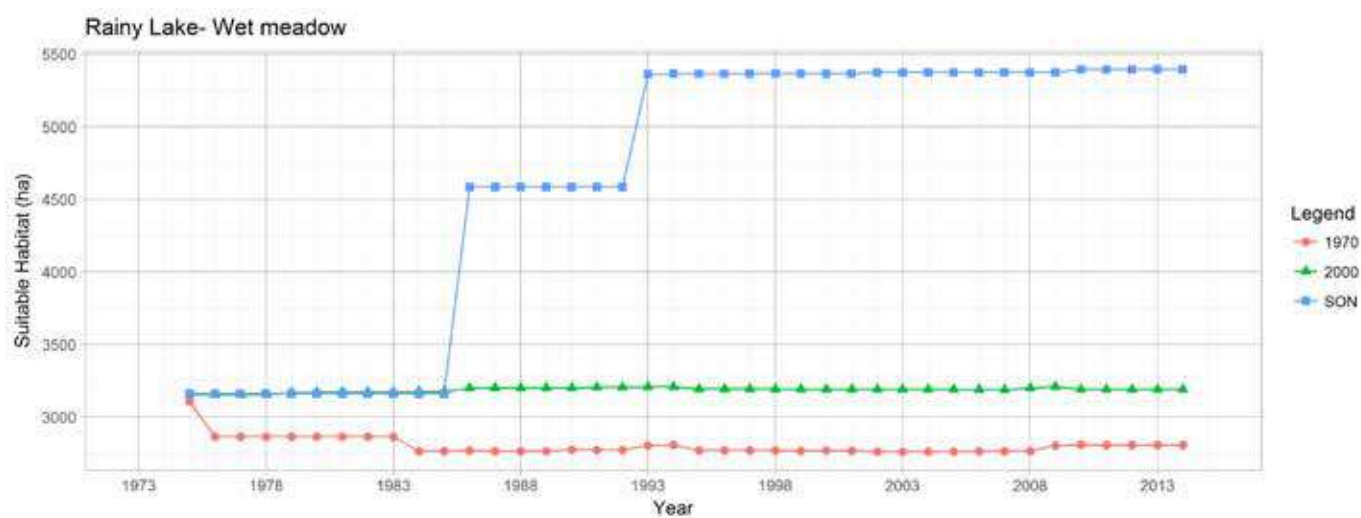


Figure 5-24 Area suitable for wet meadow growth on Rainy Lake

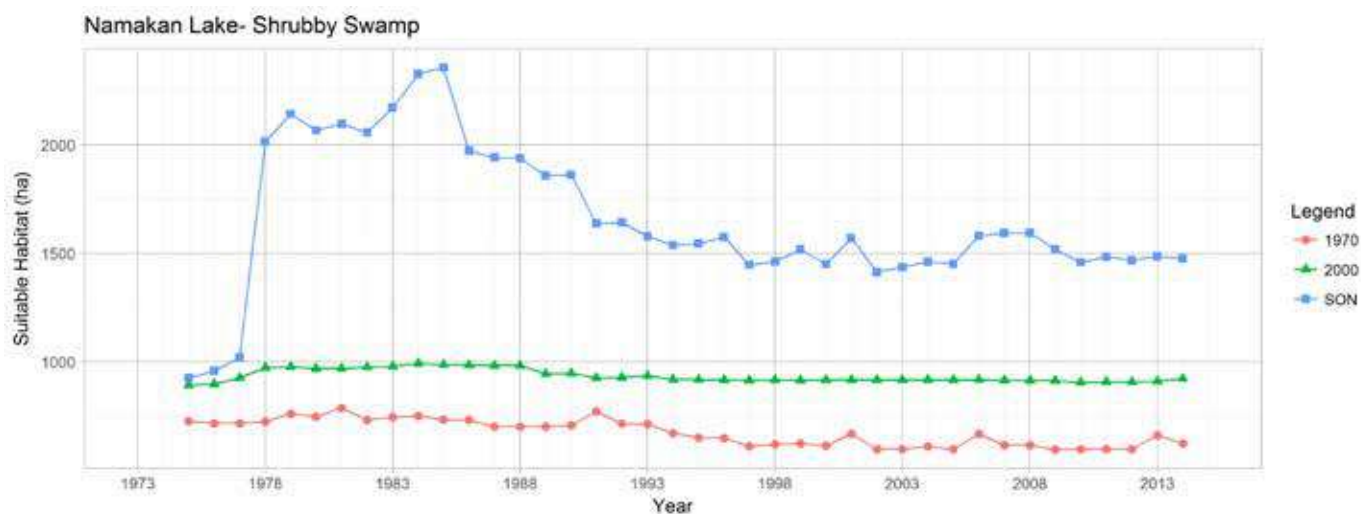


Figure 5-25 Area suitable for shrubby swamp growth on Namakan Lake

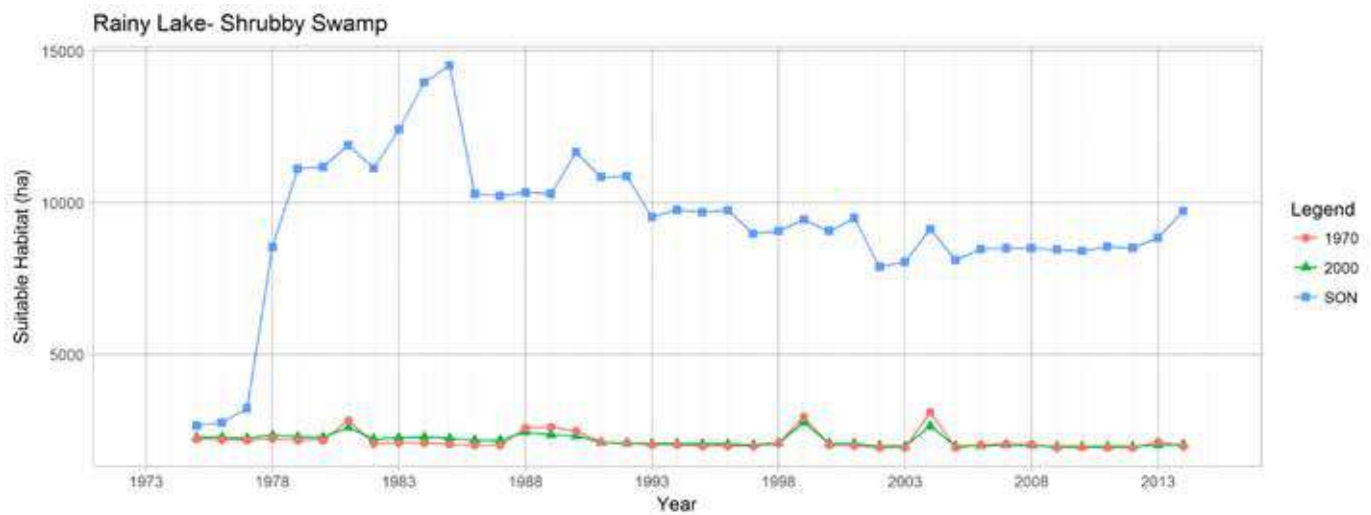


Figure 5-26 Area suitable for shrubby swamp growth on Rainy Lake

### 3. Emergent plants

Figures 5-27 and 5-28 show the IERM estimates of the area of suitable habitat for emergent plants on Namakan Lake and Rainy Lake, respectively. The IERM suggests that the SON provides a greater fluctuation in the amount of suitable habitat over time on both lakes.

Research undertaken for the Study (see Study 21, Annex 6) suggest that while emergent vegetation can support

populations of wetland birds and mammals, very dense emergent vegetation may become a nuisance to navigation and negatively affect some fish species. As such, a diverse emergent vegetation community, consisting of many species of emergent vegetation, is more desirable than an abundance of emergent vegetation. The water level variability provided by the SON is likely to support a more diverse plant population than regulated conditions.

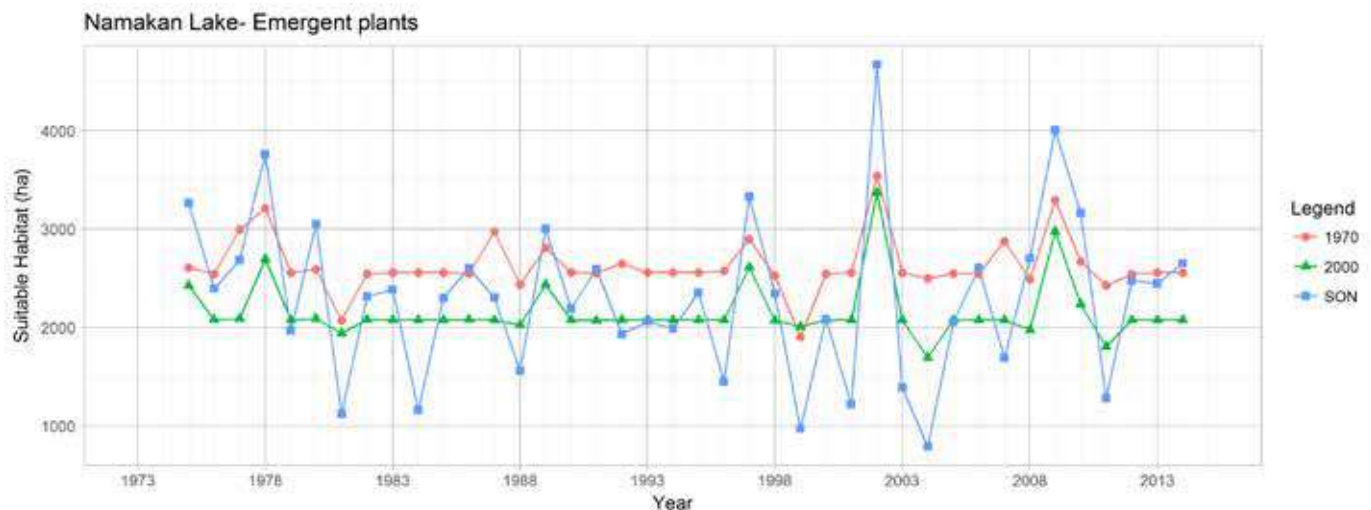


Figure 5-27 Area suitable for the growth of emergent plants on Namakan Lake



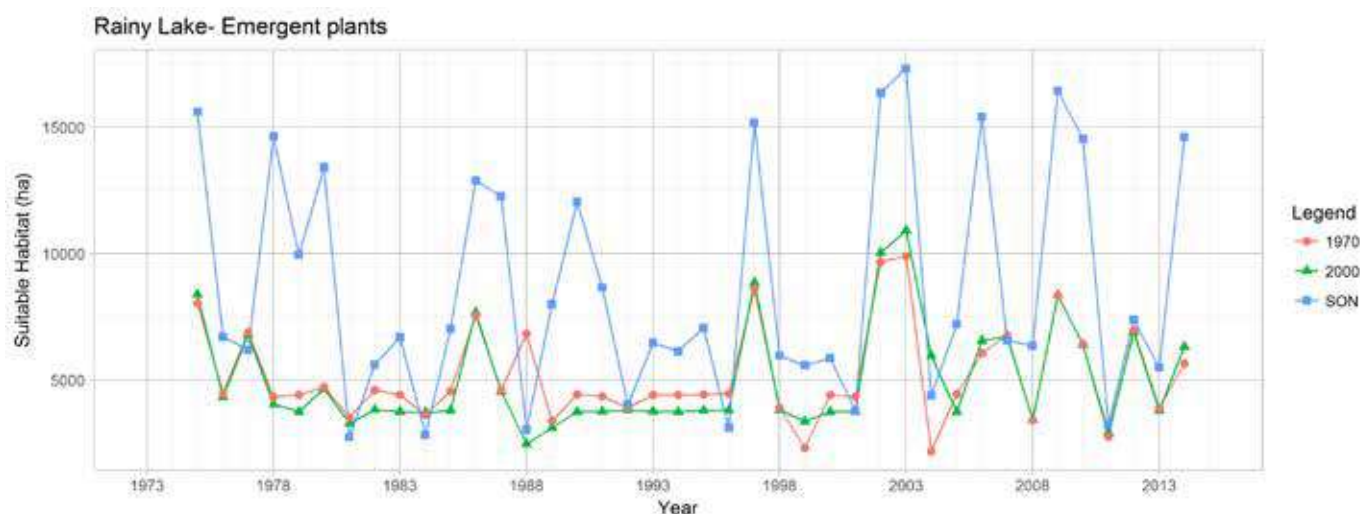


Figure 5-28 Area suitable for the growth of emergent plants on Rainy Lake

#### 4. Submerged plants

Figures 5-29 to 5-32 show the IERM estimates of the area of suitable habitat for submerged plants (low- and high-density) on Namakan Lake and Rainy Lake. The IERM suggests that the SON provides less area of suitable habitat for both low- and

high-density submerged plants for both lakes. As in the case of emergent vegetation, the diversity of submerged vegetation is more important than its quantity. Again, the variability in water level under the SON condition is likely to produce the most diverse submerged plant population.

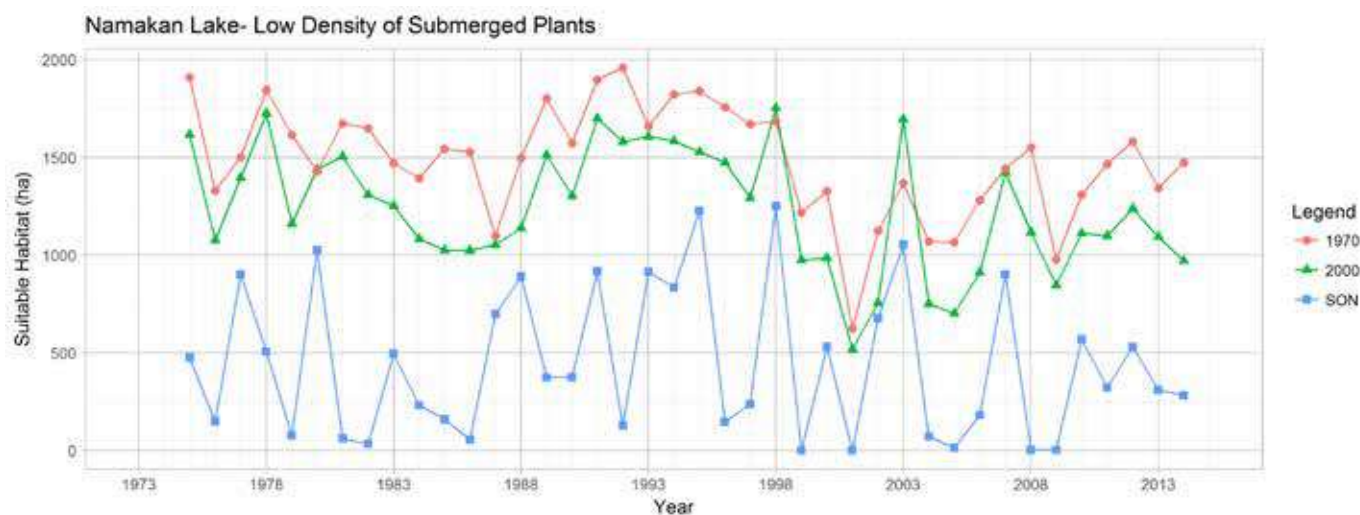


Figure 5-29 Area suitable for the growth of low-density submerged plants on Namakan Lake

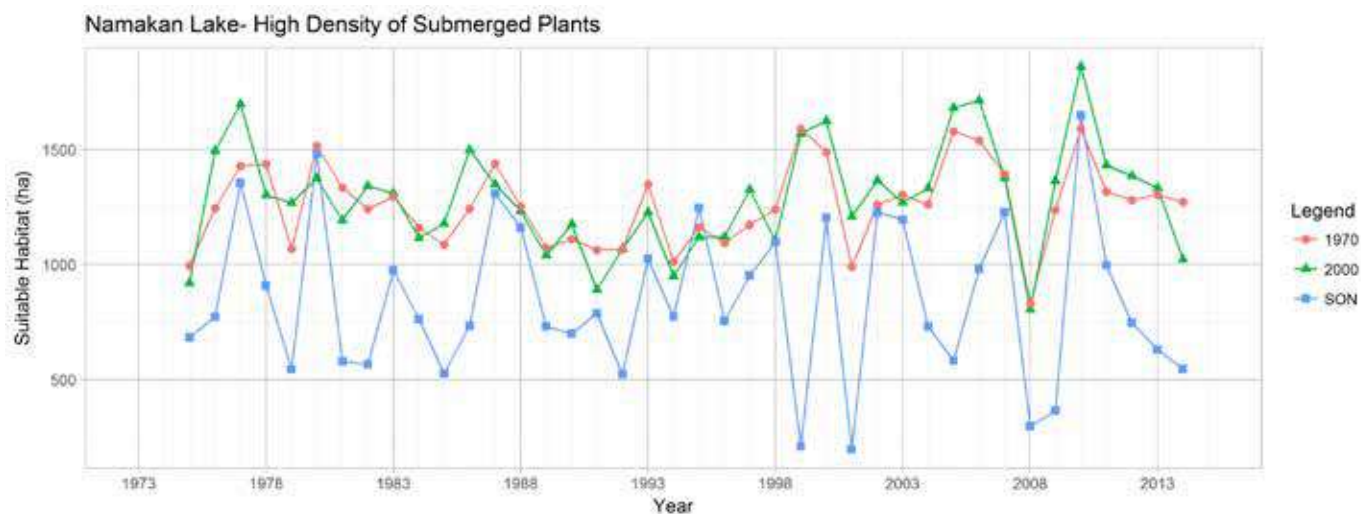


Figure 5-30 Area suitable for the growth of high-density submerged plants on Namakan Lake

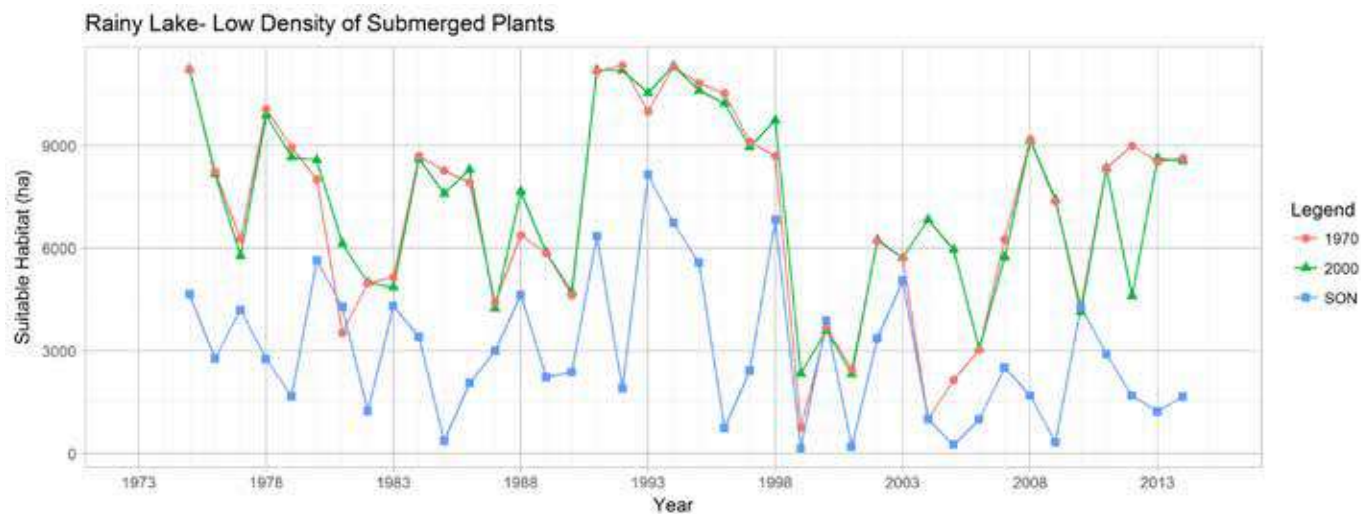


Figure 5-31 Area suitable for the growth of low-density submerged plants on Rainy Lake

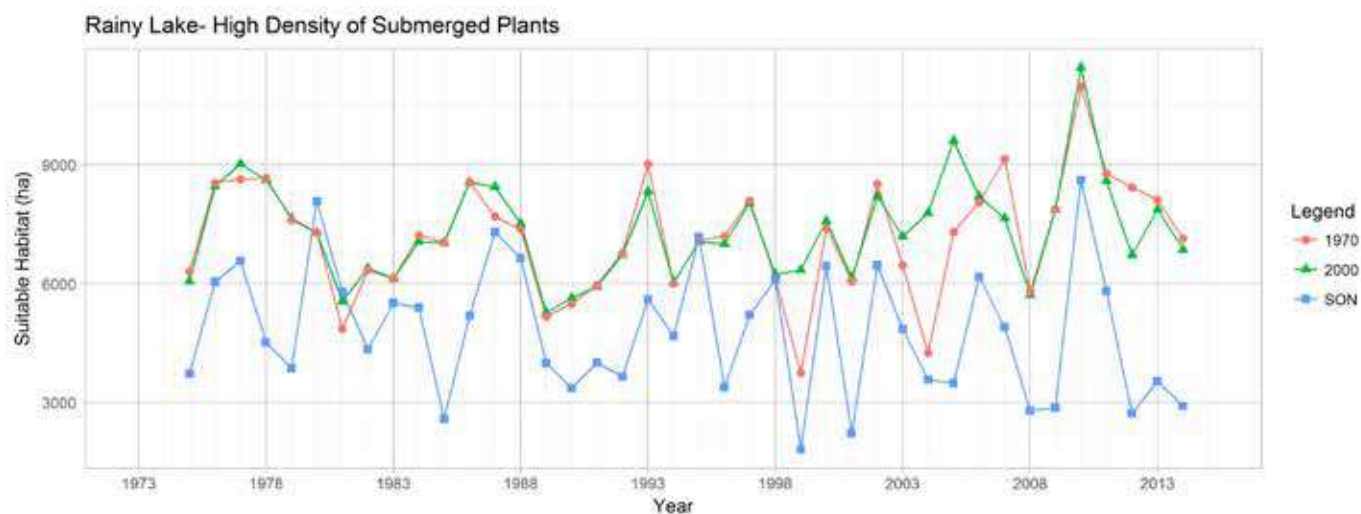


Figure 5-32 Area suitable for the growth of high-density submerged plants on Rainy Lake

### 5.3.7 Rainy River

The IERM estimates the amount of suitable habitat for Walleye and Lake Sturgeon spawning on Rainy River (Figures 5-33 and 34). The IERM suggests that the SON provides an increase in the extent of suitable

spawning habitat on Rainy River in most years. Rainy River Lake Sturgeon spawning habitat is also increased under the SON condition for many years throughout the modelling period.

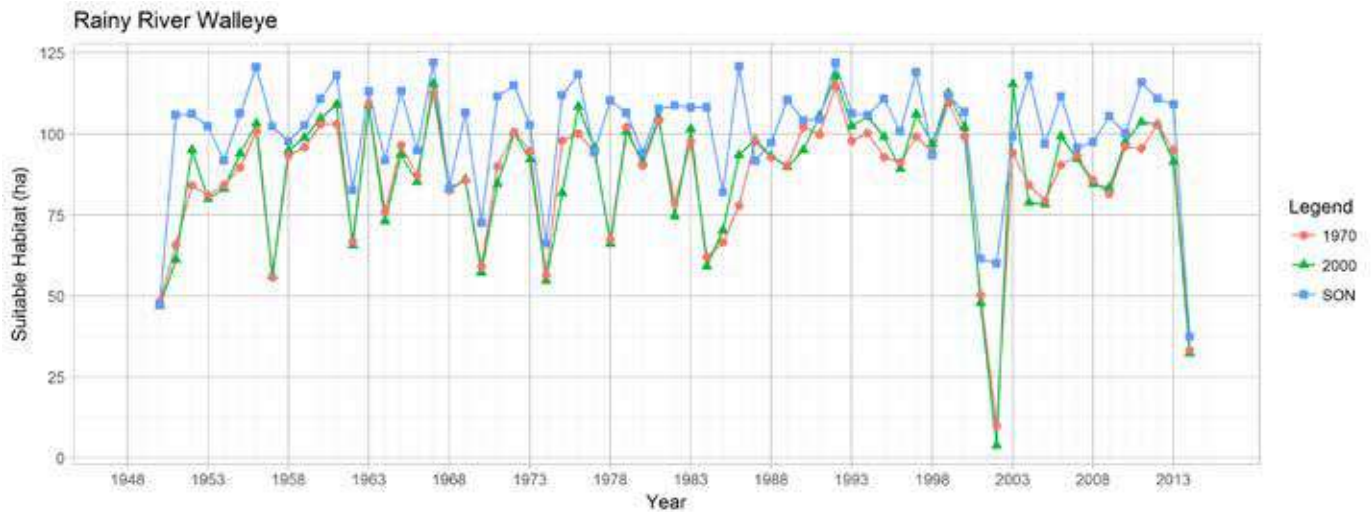


Figure 5-33 Area suitable for Walleye spawning on Rainy River

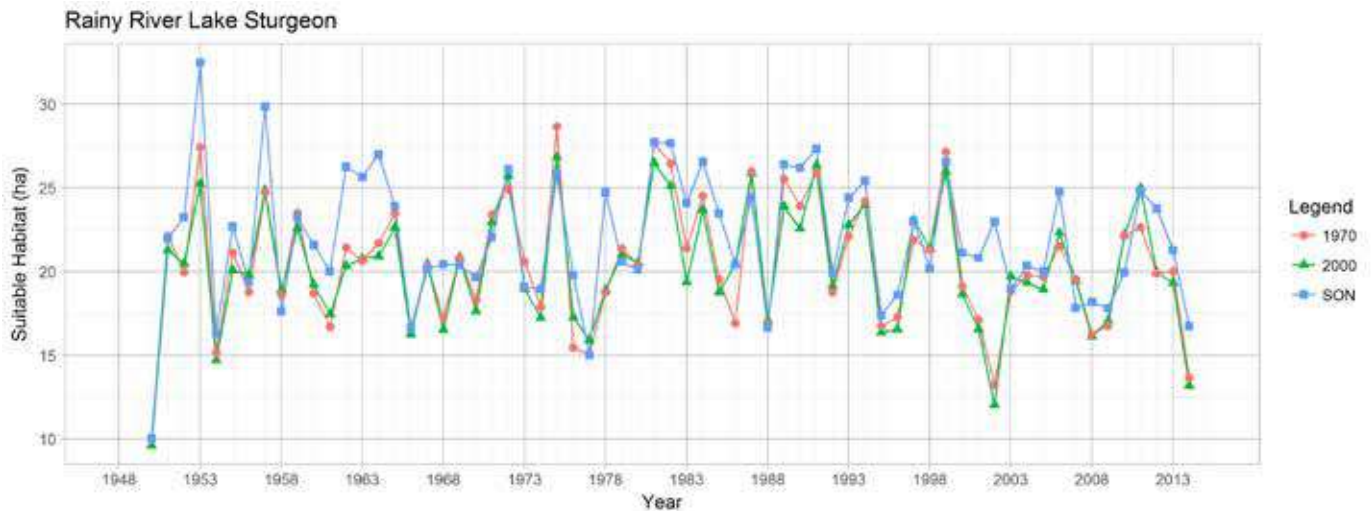


Figure 5-34 Area suitable for Walleye spawning on Rainy River

... research undertaken for the Study examined the historical impacts of water level management on lakes in Voyageurs National Park.

## Other considerations for SON conditions:

### *Invertebrates on Namakan and Rainy Lakes*

Although no models were developed to evaluate the condition of the invertebrate communities of the Namakan Chain of Lakes and Rainy Lake under SON conditions, the Study Board hypothesizes that an improvement would be achieved under natural conditions. This hypothesis is based on the improvements to ecosystem health as a whole under the SON, most notably the condition of aquatic vegetation that supports invertebrate habitat. A structurally diverse plant community such as exists in nearby unregulated Lac La Croix provides a patchy environment that contains both low-growth and upright growth forms that produce the best habitat for invertebrates (Wilcox and Meeker, 1992).

### *Water quality on Namakan and Rainy Lakes*

At this time, the Study Board is unable to compare the effects on water quality of the SON conditions to those of the 2000 Rule Curves using the IERM or SVM. However, research undertaken for the Study (Study 25, Annex 6) examined the historical impacts of water level management on lakes in Voyageurs National Park. The research analyzed diatoms from sediment cores of three lakes with dams (Rainy, Namakan and Kabetogama) and one undammed lake (Lac La Croix) to infer water quality, core geochemistry and sedimentation rates. Lac La Croix and Rainy Lake showed little variability in inferred water quality during the last 300 years. In contrast, Namakan Lake increased in total phosphorus and conductivity following damming, possibly in relation to inundation and several large fires. Kabetogama Lake also increased in

conductivity and had a slight decrease in total phosphorus.<sup>16</sup>

## 5.4 Key findings

Based on the Study Board's analysis summarized in this chapter, the following key points can be made regarding the performance of the 2000 Rule Curves compared to the 1970 Rule Curves and the SON:

- ◆ The 2000 Rules Curves generally performed as expected. Compared to the 1970 Rule Curves, the 2000 Rule Curves provided the expected results with respect to many of the Study's subject areas.

*Positive expected outcomes* confirmed by the Study included:

- improvements in fish population and spawning habitat of several key species;
- improved conditions for wildlife;
- increased tourism benefits as a result of improvements to navigation and dock access in the spring on the Namakan Chain of Lakes;
- improved preservation of cultural/ archeological sites along the shorelines of Namakan and Rainy Lakes;
- benefits to wetland vegetation, emergent vegetation and submerged plants in the Namakan Chain of Lakes;
- increased over-winter survival of invertebrates in the Namakan Chain of Lakes as a result of the reduction in over-winter drawdown; and
- improvements in water quality in Black Bay on Rainy Lake.

*Negative expected outcomes* confirmed

<sup>16</sup> Conductivity is useful as a general measure of water quality. "Significant changes in conductivity may indicate that a discharge or some other source of pollution has entered the aquatic resource. Generally, human disturbance tends to increase the amount of dissolved solids entering waters which results in increased conductivity." (<https://www.epa.gov/national-aquatic-resource-surveys/indicators-conductivity>)





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by the Study included:

- decreased potential for hydropower production as a result of reductions in available storage; and
  - increases in flood damage on both Namakan Lake and, particularly, Rainy Lake, as a result of the decrease in available storage on Namakan Lake in advance of the spring freshet.
- ◆ One significant finding of the performance of the 2000 Rule Curves compared to the 1970 Rule Curves was not expected: Despite the general ecosystem benefits of the 2000 Rule Curves, the modelling indicated that the expansion of the invasive Hybrid Cattail in Rainy Lake and the Namakan Chain of Lakes is a continued threat to Wild Rice habitat.
- The steady water levels that result from regulation under the 2000 Rule Curves have provided excellent conditions for the expansion of invasive cattail.
- ◆ The 2000 Rule Curves had mixed results when compared with the hypothetical natural conditions of the SON. The modelling indicated that, overall, the SON generally would provide more favorable conditions for many ecological interests, though some interests, such as the Common Loon, thrive best under regulated conditions. However, compared to the SON, the 2000 Rule Curves resulted in reduced flood risk and damages to riparian interests, as would be expected, and increased tourism benefits as a result of improved navigation in low water years.



## 6. FORMULATION OF ALTERNATIVE RULE CURVES

The second principal aim established in the Study Strategy of the **International Rainy and Namakan Lakes Rule Curves Study Board** (Study Board) was:

*To develop and evaluate additional regulation alternatives that reflect concerns of stakeholders in the study area and to compare the performance of these alternatives to that of regulation under the 1970 and 2000 Rule Curves.*

**Chapter 6 describes the development of additional regulation alternatives that have the potential for providing improved performance over the 2000 Rule Curves.**

**Chapter 6** describes the development of additional regulation alternatives that have the potential for providing improved performance over the 2000 Rule Curves. The chapter builds on the work detailed in **Chapter 5**, which summarizes how the 2000 Rule Curves performed compared to the 1970 Rule Curves and the State of Nature (SON) conditions. The approach involved formulating and testing a large number of potential rule curves and then narrowing the selection down to a small number of alternatives for analysis, comparison and, ultimately, recommendation, as described in subsequent chapters.

Based on the results of the Weight of Evidence (WOE) analysis, the Study Board determined that continuing to operate under the 2000 Rule Curves was a viable recommendation option. For the purposes of comparing Rule Curve options, the 2000 Rule Curves were denoted as **Alternative A** and the performance of all other alternative Rule Curves developed was compared to the baseline provided by this **Alternative A** (Figure 6-1).

### 6.1 Study approach

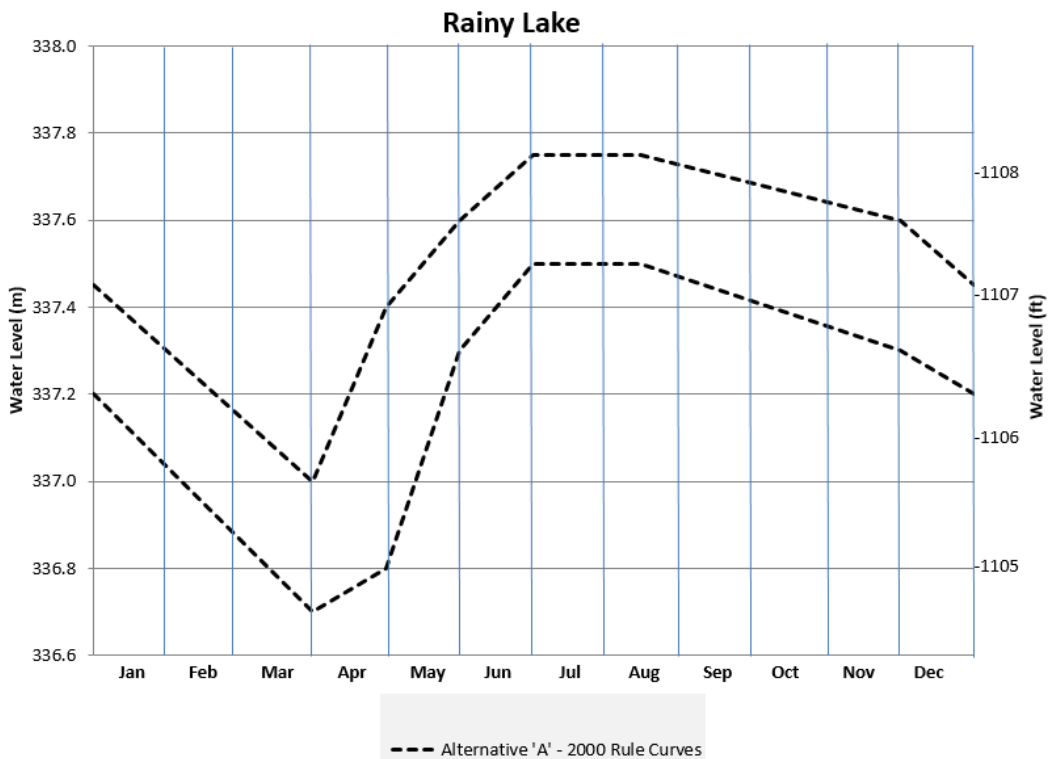
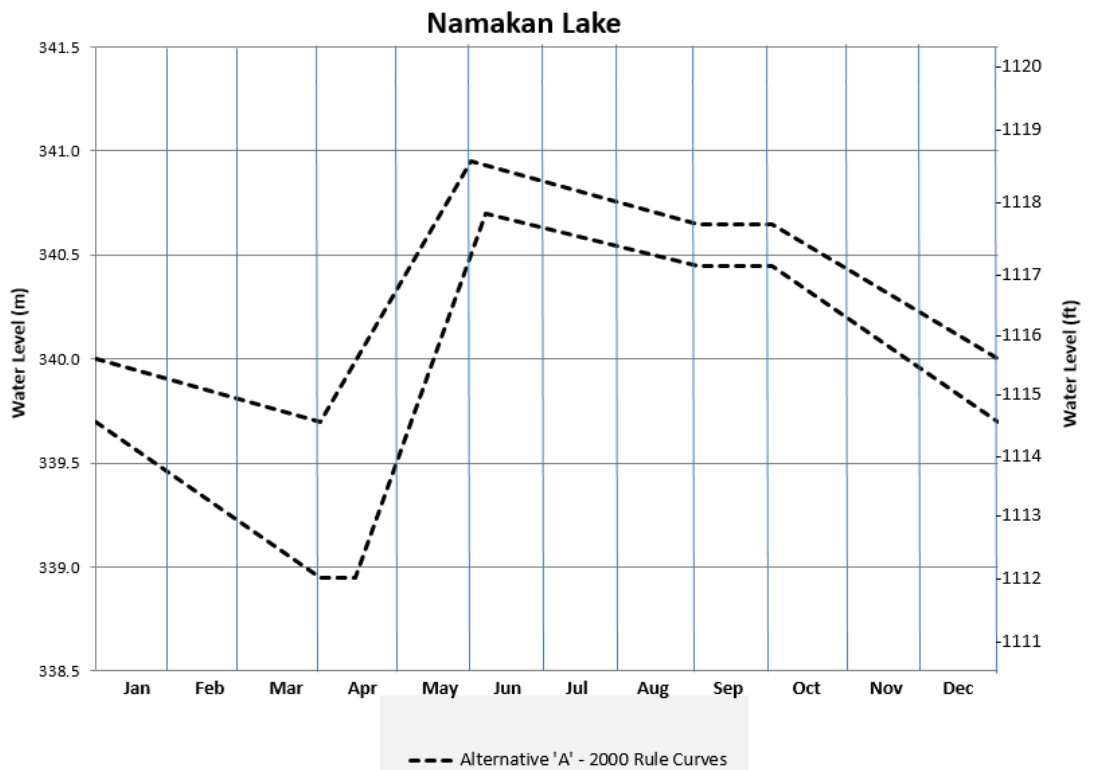
Early in the Study, the Study Board sought opinions from the general public, the Rule Curve Public Advisory Group (RCPAG) and the Resources Advisory Group (RAG) on the merits and limitations of regulation of Rainy

Lake and Namakan Chain of Lakes under the 2000 Rule Curves. **Chapter 4** summarizes the key public and indigenous concerns with respect to water level regulation in the study area. A detailed summary of comments received by the Study Board is presented in a separate document, available through the Study's website: [http://ijc.org/en\\_/RNLRCBSB](http://ijc.org/en_/RNLRCBSB).

These comments covered broad areas of suggestions or concerns regarding regulation of Rainy Lake and the Namakan Chain of Lakes. While there were many suggestions for improving operations by the dam operators and the Water Levels Committee (e.g., more flexibility at various times of the year within the rule curves, improved data collection and forecasting) as well as communications with the public, few suggestions related specifically to altering the Rule Curves themselves.

The areas where alterations to the Rule Curves were suggested — flood reduction and ecological concerns — were investigated by the Study Board and are described below. Comments were also received noting the importance of several areas that should not be adversely affected by any changes to the Rule Curves. These included navigational levels, impacts to fish spawning, erosion of archeological sites and Wild Rice growth. These and other areas were all considered in the development and evaluation of potential alternatives to the 2000 Rule Curves (**Chapter 7**).

As noted in Section 3.4, the Study's methodology was based on a participatory and transparent evaluation process known as Shared Vision Planning (SVP). Over the course of the Study, potential alternative rule curves reflecting concerns about flood control and ecological concerns were developed, refined, and tested in the



**Figure 6-1 Rule Curve Alternative A: the 2000 Rule Curves**

Continued use of the 2000 Rule Curves was considered a viable option. Evaluation of all subsequent alternatives developed used the performance of the 2000 Rule Curves as a baseline.

**A second broad area identified early in the Study as a potential area for Rule Curve modification related to a variety of potential ecological subjects investigated as part of the Plan of Study.**

Shared Vision Model (SVM) and Integrated Ecological Response Model (IERM). Progress on these efforts was shared in a series of practice decision workshops and webinars with the RCPAG and the RAG. Feedback from these groups informed the development of the primary alternatives to the 2000 Rule Curves considered by the Study Board described later in this chapter.

### **6.1.1 Flood reduction**

Concerns about the 2000 Rule Curves centered largely on the increased risk of flooding on Rainy Lake that resulted from the changes in the Namakan Rule Curve in the adoption of the 2000 Rule Curves. This was a recognized drawback of the 2000 Rule Curves by the International Rainy Lake Board of Control that recommended the rule curves (International Rainy Lake Board of Control, 1999).

The increased risk resulted from a reduction in the over-winter drawdown of Namakan Lake, leaving less storage room for excessive inflow in the spring. A contributing factor was the shift to an earlier refill of the lake to summer levels by the start of June, commonly a very wet time of year in the area, compared to early July under the 1970 Rule Curves.

Suggestions for changes to the 2000 Rule Curves included restoring a later refill to Namakan Lake, and restoring stable, higher water levels on Namakan Lake in the summer.

### **6.1.2 Ecological concerns**

A second broad area identified early in the Study as a potential area for Rule Curve modification related to a variety of potential ecological subjects investigated as part of the Plan of Study. These included water level effects on invasive Hybrid Cattail, Muskrat populations, Wild Rice and Northern Pike spawning success, as well as the ecosystem

impacts of reduced inter-annual water level variability that typically occurs in regulated lakes.

Suggestions for changes to the 2000 Rule Curves in this category included reducing lake level drawdown between lake freeze-up and freshet, and having variable targets from year to year.

## **6.2 Formulation of alternative rule curves: flood reduction**

The first focus of formulating alternative rule curves was on addressing concerns about flooding on Rainy Lake.

### **6.2.1 Understanding the limits of regulation**

To investigate possible ways to address the issue of increased Rainy Lake flooding risk under the 2000 Rule Curves, the Study Board programmed and tested a variety of curves and dam operational scenarios in the SVM. Some of these modelled scenarios involved unrealistic modifications to the 2000 Rule Curves. For example, some potential alternatives targeted the drought line each spring to create storage room for spring flows; others included unrealistic forecasting capabilities, such as assuming perfect spring flood forecasts available on January 1 each year.

These simulation exercises are referred to as “fencepost” plans, as they set the boundaries for what reductions are possible. These plans demonstrated that, even with perfect foreknowledge of spring flood conditions at the start of the year (not possible with current science), coupled with aggressive lowering of the lake throughout the winter, high water conditions cannot be avoided on Rainy Lake in springs with high inflow. This is because the natural outlet of the lake, 4 km (about 2.5 mi) upstream of the dam, limits the rate of flow out of the lake. When flooding occurs, it is because water enters the lake (for example, from tributaries

and rainfall) at a greater rate than it can flow out. In such situations, the lake level rises, regardless of actions taken at the dam downstream.

At best, a modest reduction in flood peak reduction, and associated flood damage costs, may be possible at Rainy Lake in some years. This can be accomplished if the level of Rainy Lake is lowered ahead of spring freshet and the dam is operated to match the natural release rate from the lake for the given water level. The simulation exercises had peak water level reductions in the range of several centimetres compared to the standard 2000 Rule Curve operation (which targets the middle portion of the 2000 Rule Curve band throughout the spring). In general, the lower the lake level when high inflows to the lake develop, the lower the peak lake level.

With this context, the SVM was used to evaluate the potential flood reduction possible using 2000 Rule Curves, but targeting lower in the Rule Curve range every spring. The simulated flood reductions achieved from these approaches were negligible. Therefore, the Study Board did not explore them further.

As the SVM was developed, new performance indicators (PIs) (see Section 3.4 for details) were included for ecological subjects. Simulation results for these PIs showed that targeting lower spring levels to reduce flood risk resulted in reduced performance for spring spawning fish. In most years, flooding does not occur. Given this, and given the negative effects of lower spring water levels, the Study Board explored whether a reasonably accurate method of assessing spring flood risk could

be developed that would allow for the use of lower spring targets when the risk was high, but otherwise would allow for continued operation under the 2000 Rule Curve targets in years where the risk was deemed to be low.

### 6.2.2 Flood risk indicators

The Study Board, together with its Technical Working Group and Adaptive Rule Curve Committee, examined several possible indicators of spring flooding risk that could be available each year by early March, a criterion considered by the Study Board to be necessary to allow sufficient time to adjust lake levels ahead of the spring freshet. These indicators included:

- basin hydrological conditions prior to freeze-up;
- winter temperature and precipitation;
- Rainy Lake ice-out date forecast; and
- measures of several well-described climate phenomena that could affect weather patterns in the basin (e.g., the El Niño Southern Oscillation<sup>17</sup> [ENSO] and the Pacific Decadal Oscillation<sup>18</sup>).

A computer simulation was used to find the best combination of these flood indicators. The simulation ran thousands of times, each time applying different weights to each category (e.g., ENSO, snow) then using the weighted indicator to determine whether to lower water levels in anticipation of a flood. Each simulation applied the forecasts to the 1950-2014 hydrology to determine how often the indicator:

- correctly forecasted a flood;
- issued a false alarm;
- failed to warn of a flood; and
- correctly indicated there would be no flood.

<sup>17</sup> The El Niño Southern Oscillation is the term given to the phenomena of irregular changes in air and sea temperatures over the eastern Pacific Ocean that can last several months. Changes, whether to cooler or warmer than normal, can influence the jet stream and weather patterns over North America.

<sup>18</sup> The Pacific Decadal Oscillation is "a climate index based upon patterns of variation in sea surface temperature of the North Pacific from 1900 to the present.... (It) is well correlated with many records of North Pacific and Pacific Northwest climate and ecology, including sea level pressure, winter land-surface temperature and precipitation, and stream flow." (<https://www.nwfsc.noaa.gov/research/divisions/fe/estuarine/oeip/ca-pdo.cfm>)

Some concern was raised regarding late summer navigation levels under the 2000 Rule Curves in certain areas along the Namakan Chain of Lakes.

Of these, a combination of measured snowfall through the end of February and an average departure of the ENSO temperature of -0.5 C or more below normal for the immediately prior December through February period was the most promising indicator of the risk of Rainy Lake flooding the following spring.

### 6.2.3 Flood risk reduction approach

This snow-ENSO flood forecast indicator was used as the basis for developing and testing of novel rule curves for Namakan Lake and Rainy Lake that would provide for:

- a delay in the beginning of refill of the lakes from April to May; and
- a water level target range on Rainy Lake, or both Rainy Lake and Namakan Lake, that would delay refill of the lakes by several weeks and lower the target level range below the 2000 Rule Curves through May and early June.

Combining a risk assessment mechanism with lower spring lake targets is referred to as the flood risk reduction approach. Early testing of the flood reduction approach using the revised curves for both lakes indicated that the overall flood reduction on Rainy Lake was not improved by the delayed refill on Namakan Lake. Therefore, future testing of the flood reduction approach centered on revising the Rainy Lake target only. This is referred to as Rule Curve **Alternative B** (Figure 6-2).

Two other alternative rule curves were proposed to address concerns related to flooding.

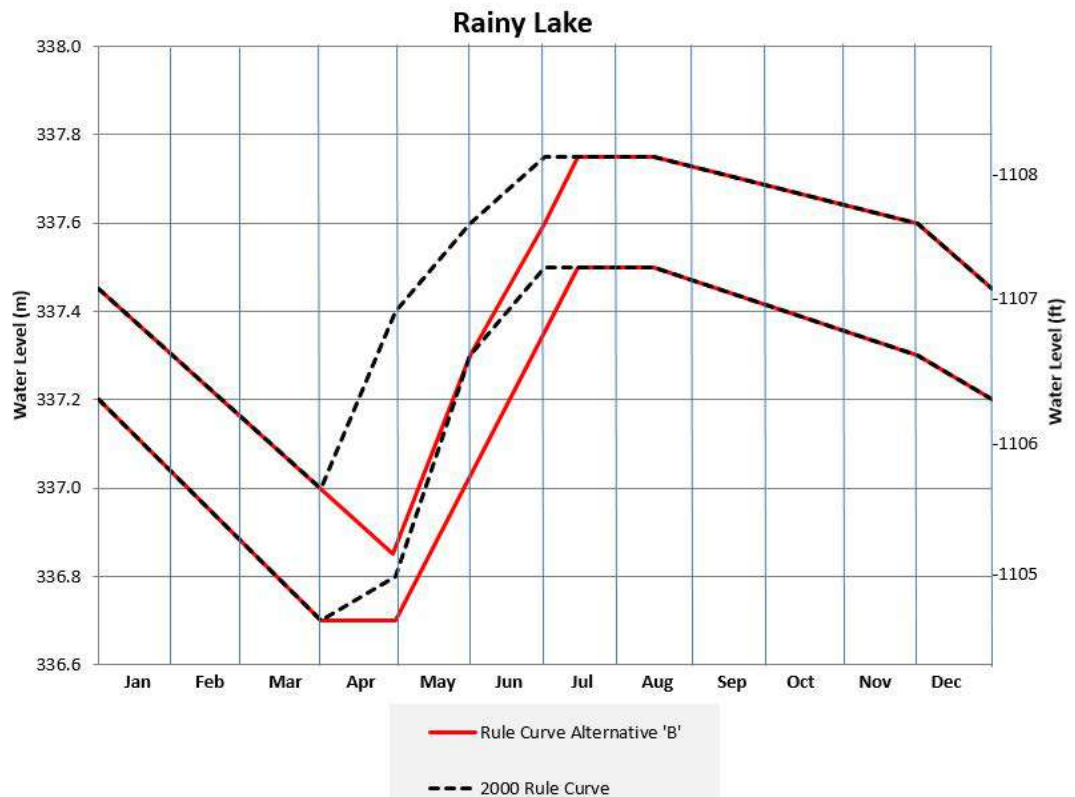
The first involved the closely coordinated operation of the dams at the outlets of both Namakan Lake and Rainy Lake. The RCPAG suggested to the Study Board that frequent adjustments to the outflow from both lakes in response to shifting forecasts and precipitation in the spring could result in substantial flood risk reduction. However, in

the testing phase of various flood reduction rule curves described earlier, results indicated that, short of substantial lowering of spring targets at Namakan similar to that required under the 1970 Rule Curve, the possible gains in storage volume in the Namakan Chain of Lakes under a coordinated lake management scheme would be insufficient to reduce flood damages on Rainy Lake. As a result, this alternative was not pursued.

The second alternative examined was to modify the 2000 Rule Curve for Namakan Lake. Under the 2000 Rule Curve, a gradual decline of the rule curve begins in June and continues until September. This was introduced to allow for cleaning of gravel substrate through wave action at various levels over the summer to expand suitable spawning habitat the following spring. In contrast, the 1970 Rule Curve was flat from late June to early October. The Study Board received feedback that the decline in the 2000 Rule Curve target range for Namakan in June and early July was considered a contributing factor to higher inflows to Rainy Lake and higher flood peaks there. As well, some concern was raised regarding late summer navigation levels under the 2000 Rule Curve in certain areas along the Namakan Chain of Lakes. In particular, the Loon River, which is used for navigation between Little Vermilion Lake and Lac La Croix, as well as access to Loon Lake in the upper watershed, can become difficult when water levels at Kettle Falls fall below 340.50 m. Under the 2000 Rule Curve, the lower Rule Curve falls slightly below this level, to 340.45 m, in late August and throughout September.

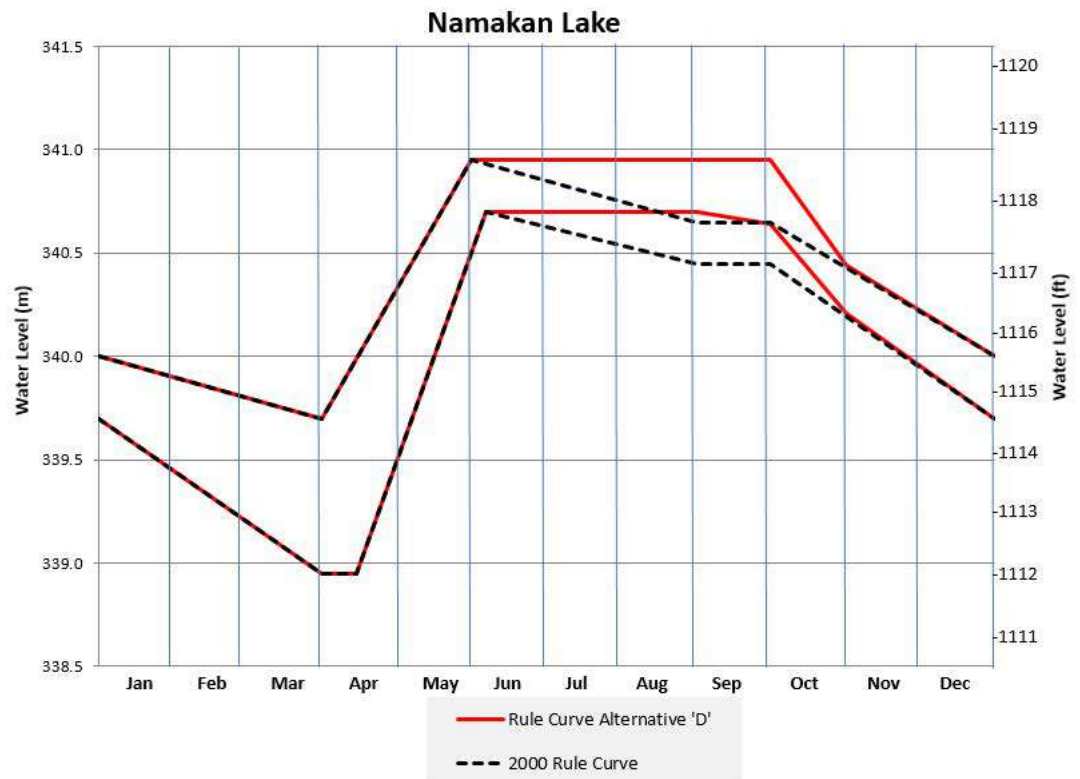
The Study Board developed **Alternative D** for Namakan Lake to examine these concerns (Figure 6-3). This alternative maintains targets of the 2000 Rule Curve for most of the year, but provides stable, higher level targets in the summer and early fall period, as under the 1970 Rule Curve.





**Figure 6-2 Rule Curve Alternative B and the 2000 Rule Curve for Rainy Lake**

**Alternative B** maintains the 2000 Rule Curve targets on Namakan Lake, and on Rainy Lake in most years. However, in years where spring flood risk is deemed to be heightened, the target range is shifted to delay refill and maintain additional storage room from April to mid-July.



**Figure 6-3 Alternative Rule Curve D and the 2000 Rule Curve for Namakan Lake**

**Alternative D** holds the target range on Namakan Lake flat from the start of June to the end of September with the aim of reducing flooding downstream on Rainy Lake (by holding water upstream) and improving navigation conditions in late summer and early fall on the Namakan Chain of Lakes.

### 6.3 Formulation of alternative rule curves: ecological concerns

The second area of focus for the formulation of alternative rule curves was on improving ecological outcomes over the 2000 Rule Curves. The Study Board developed two alternative rule curves to address ecological concerns, incorporating results from the IERM investigations for the WOE.

#### 6.3.1 Improving within-year ecological outcomes

The first ecologically-focused alternative rule curve was developed to provide an optimized balance of outcomes for the following ecological components on an annual basis: Wild Rice; invasive Hybrid Cattail; Muskrats; Northern Pike spawning habitat; and submerged vegetation.

The Study Board developed individual optimal rule curves for each of these subjects. It then aggregated them into one optimized curve that provided the best balance for each outcome based on the IERM results. Through an iterative process of simulation, followed by rule curve refinement to address unacceptable performance scores, particularly with respect to flood damages, **Alternative C** was developed (Figure 6-4).

This alternative was designed to permit more stable levels on both Rainy Lake and the Namakan Chain of Lakes over the winter period, by allowing for a faster drawdown before lake freeze-up in November, and a reduced drawdown through the winter period until April. The reduced lake level drop during the core winter period (mid-November to late March) was aimed at the following improvements:

**1. Muskrat survival** – under the 1970 Rule Curves and 2000 Rule Curves, the decline in lake level over the winter following freeze-up results in very high mortality rates for Muskrats, as their houses are left without

access to the water, exposing the animals to lower temperatures and reducing access to vegetation. As a result, very few Muskrats survive the winter on these lakes in most years and populations are low as a result. Increasing muskrat winter survival could result in increased population, and with it, improved wetland conditions, as Muskrats provide important ecological services such as consuming Hybrid Cattail (with resulting improved conditions for Wild Rice) and creating channels through wetland areas to improve access to spawning areas for Northern Pike.

#### 2. Success of fall spawning fish –

Eggs of fall spawning fish, such as Lake Whitefish and Cisco, are vulnerable to large drawdowns of lake levels that can expose eggs. Reduced drawdown would likely improve overall spawning success.

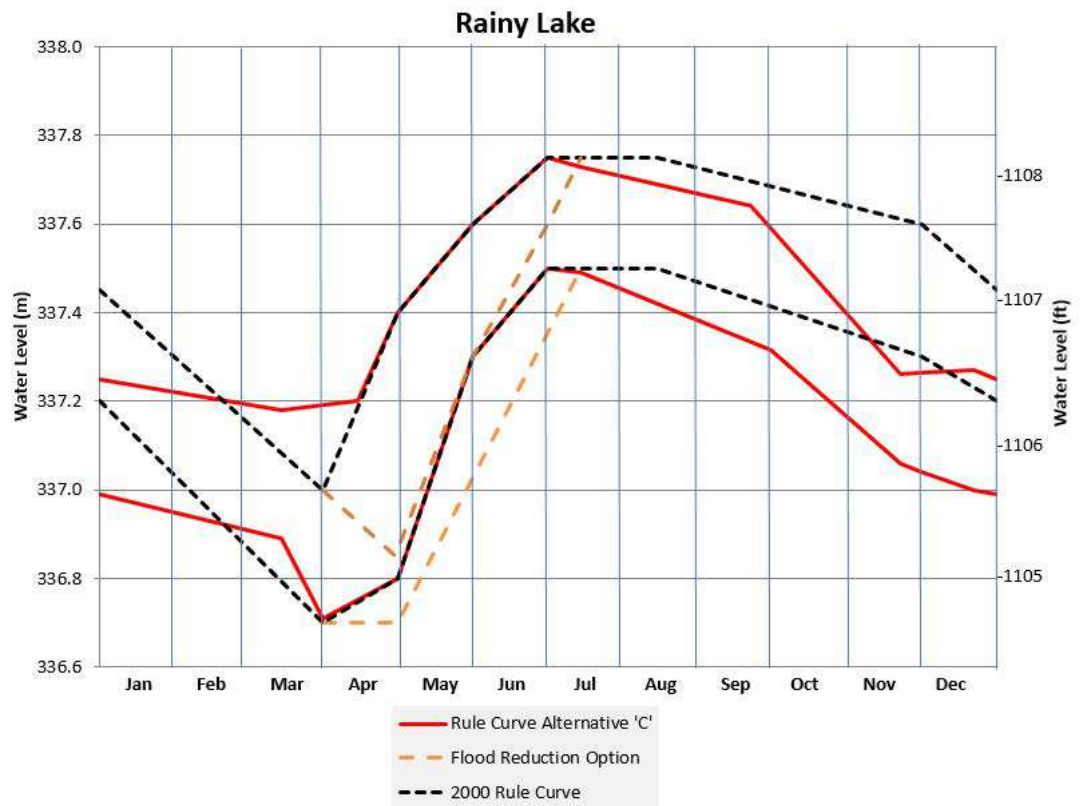
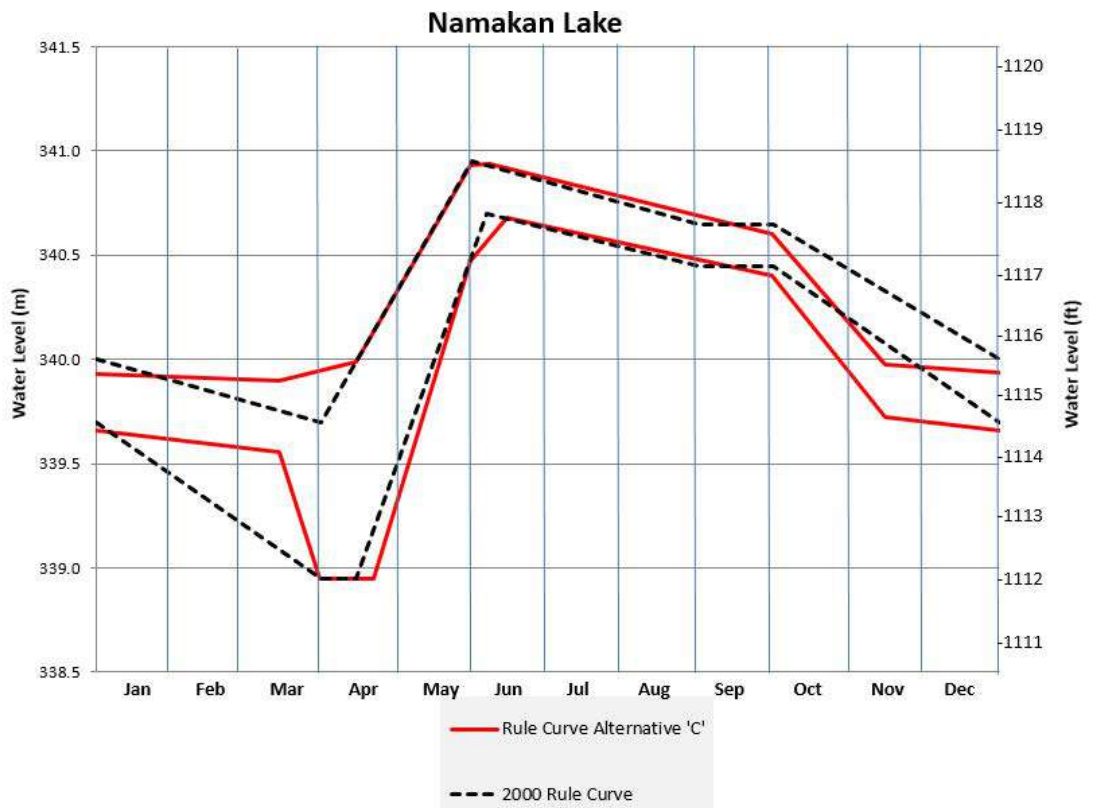
**3. Benthic invertebrate survival** – Benthic invertebrates in shoreline areas are also susceptible to exposure due to water level declines over the winter.

For the purposes of the analysis of alternatives, Muskrat and Lake Whitefish models were developed in the SVM or IERM. The benefits to other fall spawning fish and to benthic invertebrates were not explicitly evaluated.

To reduce spring flood damage on Rainy Lake, the conditional flood reduction target used in **Alternative B** was also incorporated.

#### 6.3.2 Increasing inter-annual variability for ecological benefits approach

Lake level regulation under the 2000 Rule Curves requires the dam operators to target the middle portion of the Rule Curve bands. Under normal inflow conditions, the dam operators do this effectively. As a result, summer levels vary little from year to year, except when flows in the watershed are extremely high or low.



**Figure 6-4 Rule Curve Alternative C and the 2000 Rule Curves**

**Alternative C** is designed to maximize ecological benefit in several areas each year while meeting constraints of high and low levels for flood protection and navigation.

Water depth,  
duration at  
particular  
levels and flood  
frequency  
influence the  
composition of  
the overall plant  
community.

However, this reduced variability, while meeting the ideal targets defined by the Rule Curves, results in loss of ecological benefits that a wider range of water levels can provide. Wetlands normally have a variety of plant communities that are influenced by water level variation from year to year. Water depth, duration at particular levels and flood frequency influence the composition of the overall plant community. Greater variation over the years supports more diverse plant communities at all water depths, while the converse is true — constant water levels over the years encourage less diversity, often benefitting invasive plant species such as Hybrid Cattail. The benefits of more diverse plant communities extend to changes in vertebrates, amphibians and bird communities that make use of these niches.

The Study Board developed an approach where the customary single Rule Curve band is replaced by a series of three Rule Curve bands for each lake, aimed at providing lower, moderate or higher water levels in different years. The SVM and IERM vary the choice of which Rule Curve to use for each simulation year, such that a range of higher, lower and moderate water levels occurs over the years. Initial modelling results with this approach showed the large variation in levels over the years had excellent responses in several ecological areas, but produced water levels that were not reasonable with respect to flooding damage and navigation. These rule curve sets were then refined to narrow the ranges to respect upper and lower bounds consistent with past Rule Curves for these lakes. Rule Curve **Alternative E** (Figure 6-5) shows the resulting series of Rule Curve sets produced from this effort.

Two different ways of determining which rule curves to apply each year were tested. The first approach randomly assigned a rule curve at the beginning of the year; the

second assigned a rule curve based on the average departure from normal ENSO temperatures for October, November and December. In these cases: the high curve was assigned if ENSO were cool; the low curve if ENSO were warm; and the middle curve in neutral ENSO years.

#### 6.4 1970 Rule Curves and State of Nature

For comparative purposes, the 1970 Rule Curves and water levels under the hypothetical SON conditions were included in the SVP analysis. As neither of these were alternatives under consideration for possible recommendations, they are referred to hereafter as **Reference F** (the 1970 Rule Curves, Figure 6-6) and **Reference G** (the results of the SON simulation).

#### 6.5 Summary

- ◆ As set out in its objectives, the Study Board worked to formulate alternative rule curves that have the potential for providing improved performance over the 2000 Rule Curves. This work focused on two key objectives:
  - addressing concerns about flooding, particularly on Rainy Lake; and
  - improving ecological outcomes over the 2000 Rule Curves.
- ◆ In practice, the formulation of alternative rule curves involved the iterative process of testing, refining and re-testing dozens of alternatives, and was informed by a series of decision workshops with the RCPAG and RAG.
- ◆ Table 6-1 provides a summary of the five alternative rule curves and two reference plans that were tested with the SVM and IERM. The results of these tests and the Study Board's analysis are presented in **Chapter 7**.

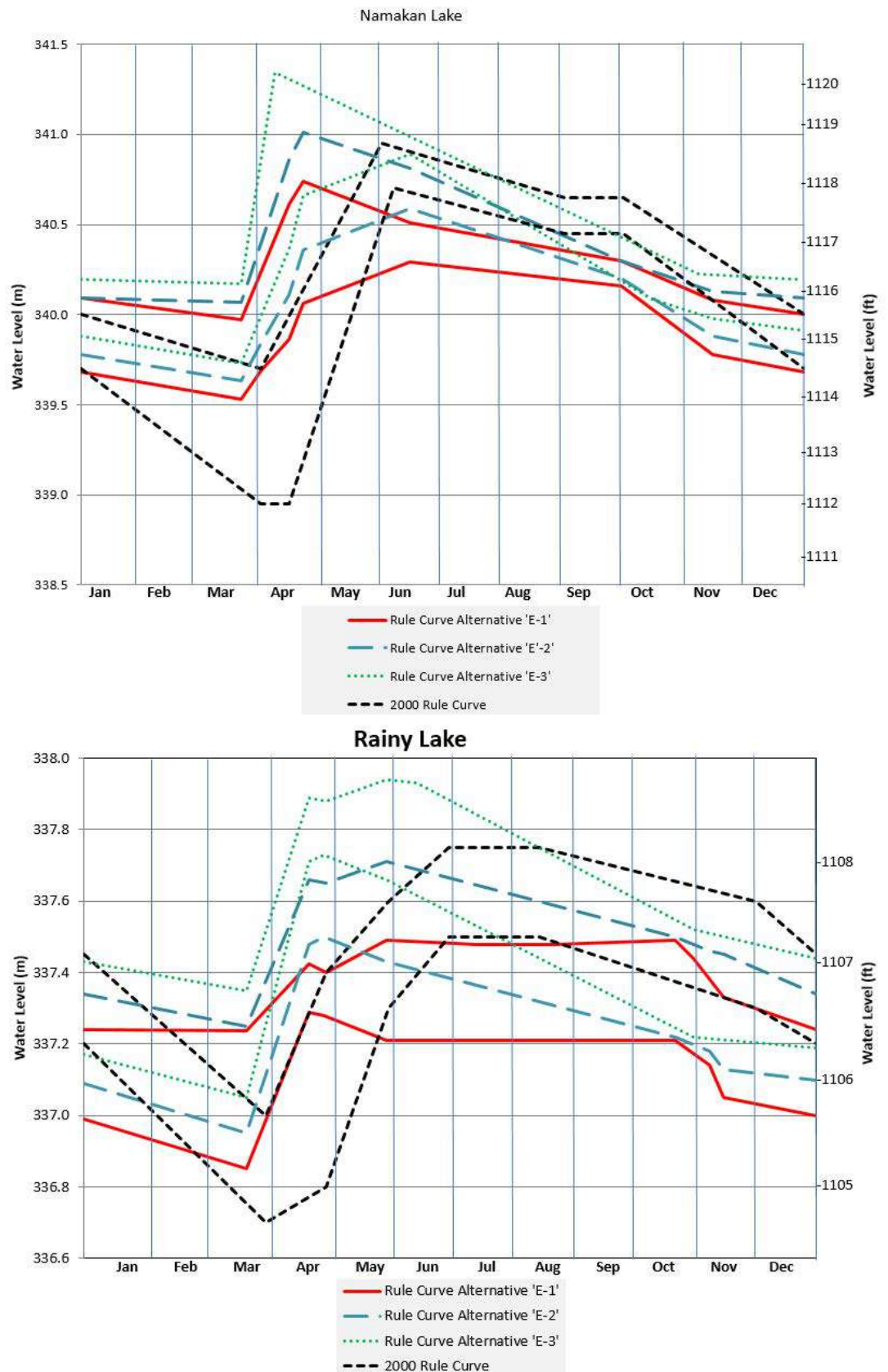
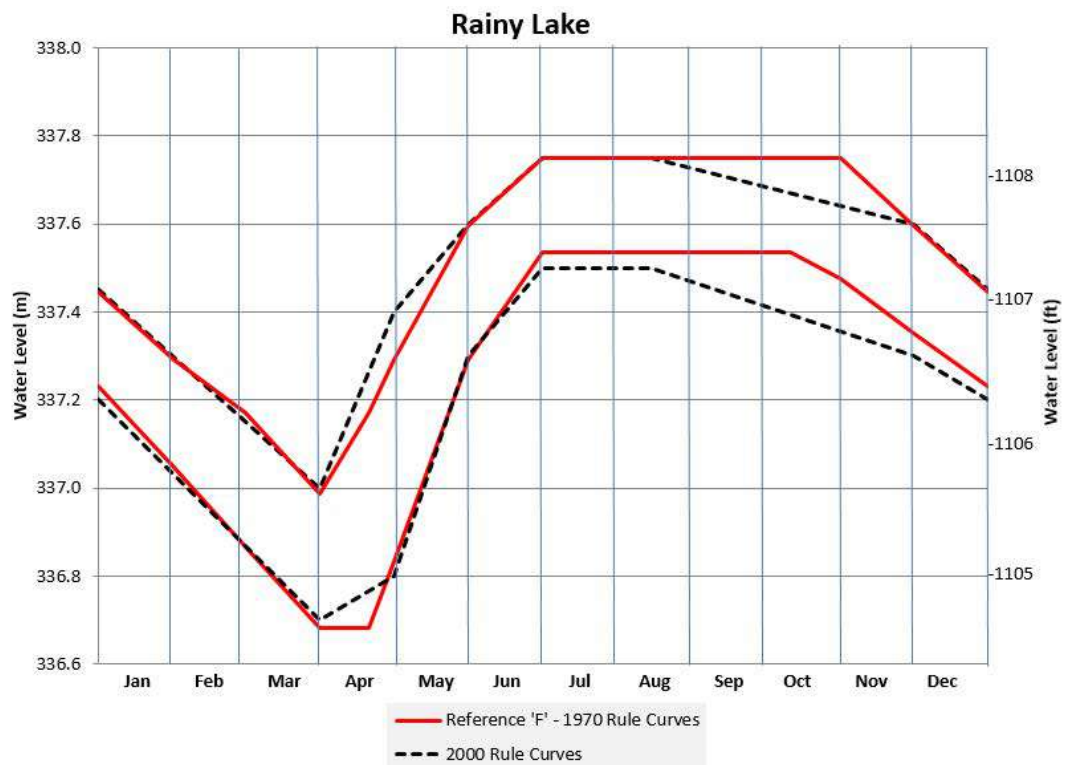
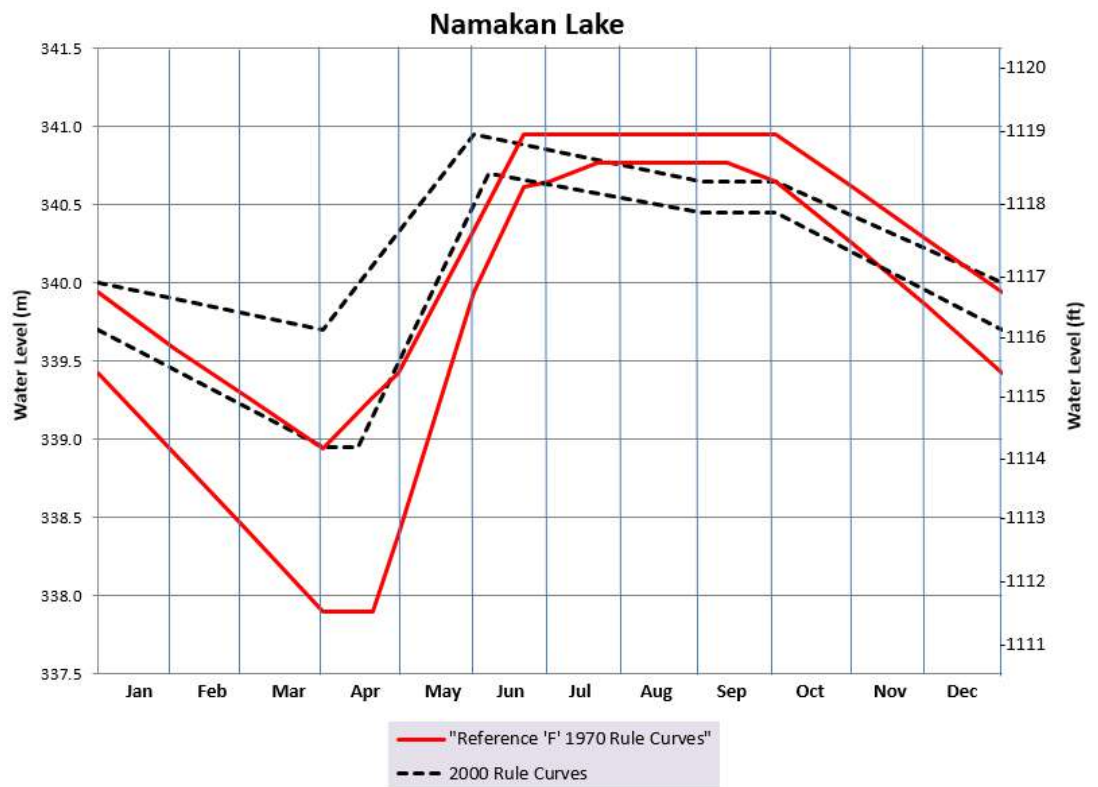


Figure 6-5 Rule Curve Alternative E and the 2000 Rule Curves

**Alternative E** is designed to increase inter-annual variability in water levels for ecological benefits. Under this approach, there are three sets of curves, and each year a different set is selected.





**Figure 6-6 Reference Curve F and the 2000 Rule Curves**

The 1970 Rule Curves are included in the SVM analysis for context, though they were not considered as a viable alternative given the results of the WOE analysis (**Chapter 5**).

Table 6-1 Summary of Alternative Rule Curves and Reference Plans modelled in the SVM and IERM

Alternative/ Reference	Description	Namakan Chain of Lakes	Rainy Lake
<b>A</b>	Existing Rule Curves Baseline for comparing other rule curves Viable option based on WOE Analysis	2000 Rule Curve	2000 Rule Curve
<b>B</b>	Conditional spring flood reduction for Rainy Lake Lower target range if high risk of flooding	2000 Rule Curve	2000 Rule Curve year-round if flood risk not high Lower target from April 1-July 31 if high risk of flooding, 2000 Rule Curves remainder of year
<b>C</b>	Alternative designed for ecological benefit in several areas each year while meeting constraints of high and low levels for flood protection and navigation.	Revised 2000 Rule Curve targets in fall and winter to reduce winter drawdown.	Revised 2000 Rule Curve targets in fall and winter to reduce winter drawdown Includes conditional flood reduction option of <b>Alternative B</b> for Rainy Lake in high flood risk springs
<b>D</b>	Hybrid 1970-2000 Rule Curve for Namakan for improved late summer navigation, reduced Rainy Lake flooding	2000 Rule Curve, except similar to 1970 Rule Curve from June 1-Oct 1 (constant higher target)	2000 Rule Curve
<b>E</b>	Alternative designed for increased inter-annual variability for broad ecological benefit	Series of 3 Rule Curves Sets, lower, medium and higher to be alternately used over years	Series of 3 Rule Curve Sets, lower, medium and higher to be alternately used over years
<b>F</b>	1970 Rule Curves, included as reference to compare results of <b>Alternatives A-E</b> , not considered a viable alternative based on WOE Analysis	1970 Rule Curve	1970 Rule Curve
<b>G</b>	State of Nature, included as reference to compare results of <b>Alternatives A-E</b> , not considered a viable alternative	Maximizes natural outflow year-round as if no dam	Maximizes natural outflow year-round as if no dam

## 7. EVALUATION OF ALTERNATIVE RULE CURVES

**Chapter 7** summarizes the approach taken by the **International Rainy and Namakan Lakes Rule Curves Study Board** (Study Board) to address the second part of the second key objective set out in its Study Strategy:

*To develop and evaluate additional regulation alternatives that reflect concerns of stakeholders in the study area and to compare the performance of these alternatives to that of regulation under the 1970 and 2000 Rule Curves.*

The chapter presents the results of the detailed evaluation of the four alternative Rule Curves (**B**, **C**, **D**, and **E**) described in **Chapter 6** in comparison to the 2000 Rule Curves (**Alternative A**) and reference plans **F** (1970 Rule Curves) and **G** (State of Nature). It also discusses how the Study Board addressed the issue of climate change and variability in assessing the alternative rule curves.

### 7.1 Study approach

As described in **Chapter 3**, the alternatives and reference plans, **A** through **G** were programmed into the Shared Vision Model (SVM) to produce water levels and releases based on the historical water supply sequence. The SVM also calculated performance indicators (PIs) for several key subjects (see Annex 5). The water levels and releases calculated for each lake by the SVM were imported into the Integrated Ecological Response Model (IERM) for the evaluation of ecological PIs. The following sections describe the Study Board's interpretation of SVM and IERM outputs for **Alternatives B-E** relative to the performance of **Alternative A**, the 2000 Rule Curves:

- **Alternative B:** Conditional spring flood reduction for Rainy Lake (Section 7.2);
- **Alternative C:** Within-year ecosystem improvements (Section 7.3);

- **Alternative D:** Hybrid 1970-2000 Rule Curve for Namakan for improved late summer navigation, reduced Rainy Lake flooding (Section 7.4); and
- **Alternative E:** Increased Inter-annual Variability for Ecosystem Benefit (Section 7.5).

Technical details on the four selected alternative rule curves are presented in Annex 7.

Note that in the analysis in this chapter, the discussion of effects for *Namakan Lake* generally will be applicable to the entire *Namakan Chain of Lakes* (the five lakes that have water levels influenced by the dam operations at the outlet of Namakan Lake — Namakan Lake, Lake Kabetogama, Crane Lake, Sand Point Lake, and Little Vermillion Lake).

### 7.2 Alternative B: Conditional spring flood reduction for Rainy Lake

#### 7.2.1 Overview

##### Objective

Implementation of the 2000 Rule Curves resulted in slightly higher peak water levels during flood periods on Rainy Lake, largely due to loss in storage room in the Namakan Chain of Lakes that was available under the 1970 Rule Curves (see **Chapter 5**). This was a recognized trade-off in the adoption of the 2000 Rule Curves. **Alternative B** aims to reduce peak flood levels on Rainy Lake without changes to the Namakan Lake Rule Curve, thereby retaining all the benefits of the 2000 Rule Curves for the Namakan Chain of Lakes confirmed by the WOE analysis (**Chapter 5**).

##### Key features

The existing 2000 Rule Curves are retained for Namakan and Rainy Lakes. In years when

The chapter presents the results of the detailed evaluation of the four alternative Rule Curves...

This alternative is expected to reduce flood damages on Rainy Lake without major impacts to other interests.

Model results presented in this section were developed by applying an ENSO-based flood forecast as described in **Chapter 6**. The models show no change in PIs for Namakan Lake as the rule curve for this lake is not modified under this alternative. The following discussion focuses solely on the model results for Rainy Lake and Rainy River.

### Forecast limitations

As described in **Chapter 6**, the SVM uses an ENSO-based forecast to indicate the risk of Rainy Lake spring flooding. Within the model, a decision is made on March 1st whether to use the existing 2000 Rule Curve on Rainy Lake or to use the Flood Reduction Rule Curve. As with any forecast, the predictions are imperfect. There are years where the model:

- correctly forecasts a flood (*hit*);
- correctly indicates there would be no flood (*correct rejection*);
- fails to warn of a flood (*miss*); or
- warns of a flood when none occurs (*false alarm*).

As shown in the table below, over the 65-year modelling period, the ENSO-based forecasts produced:

- a **hit** 11 years (17 percent);
- a **correct rejection** 39 years (60 percent);
- a **miss** 3 years (5 percent); and
- a **false alarm** 12 years (18 percent).

The performance of the flood forecast can affect the PI outcomes. Therefore, it is important to consider the success rate of the forecasting system in the evaluation of this alternative.

Hit
Correct Rejection
Miss
False Alarm
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
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Hit
Correct Rejection
Miss
False Alarm
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1996
1997
1998
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2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014

## 7.2.2 Fish: Alternative B

The IERM suggests that, in years where a flood is forecasted and the Flood Curve Reduction Rule is implemented on Rainy Lake, fish PIs can be negatively affected.

### 1. Walleye

Figures 7-1 and 7-2 show IERM results for the Rainy Lake Walleye Egg Survival Probability and Walleye Spawning Success PIs, further detailed in Annex 5.

Model output suggests that in most years **Alternative B** results in similar conditions for Walleye egg survival when compared to the 1970 and 2000 Rule Curves, (Figure 7-1). The amount of suitable habitat for a successful Walleye spawn (Figure 7-2), however, is negatively affected in years when the SVM lowers Rainy Lake water levels based on the ENSO forecast, but no flood occurs (false alarm). The Resources Advisory Group (RAG) agreed that although Walleye spawning success can be expected to vary from year to year, poor production over three to five consecutive years could be detrimental to the population.

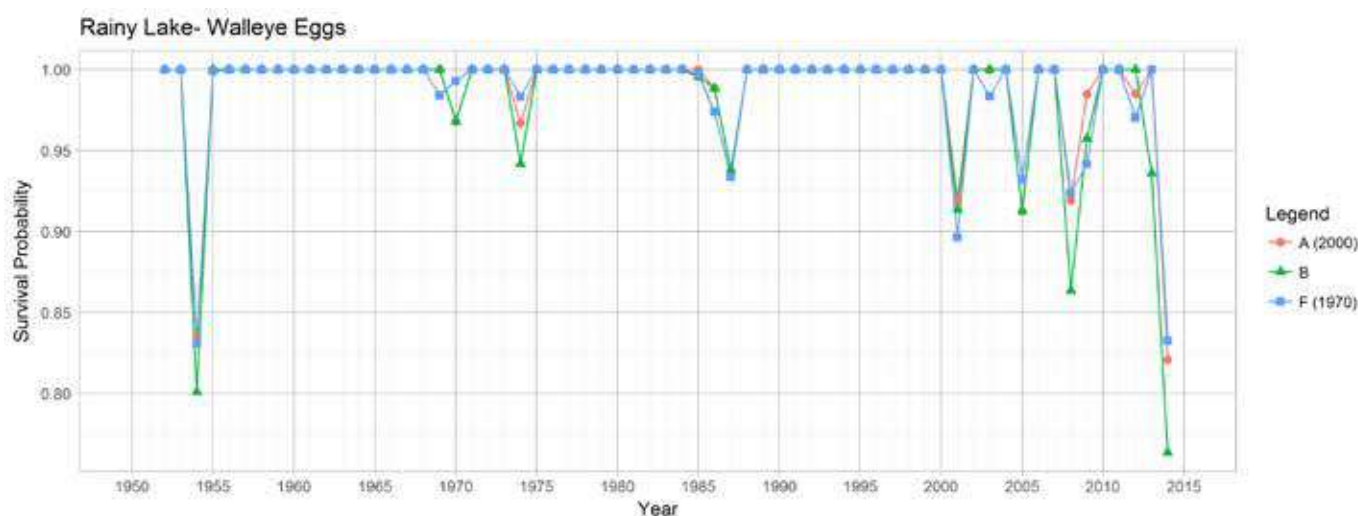


Figure 7-1 Probability of Walleye egg survival for Rainy Lake, Alternative B

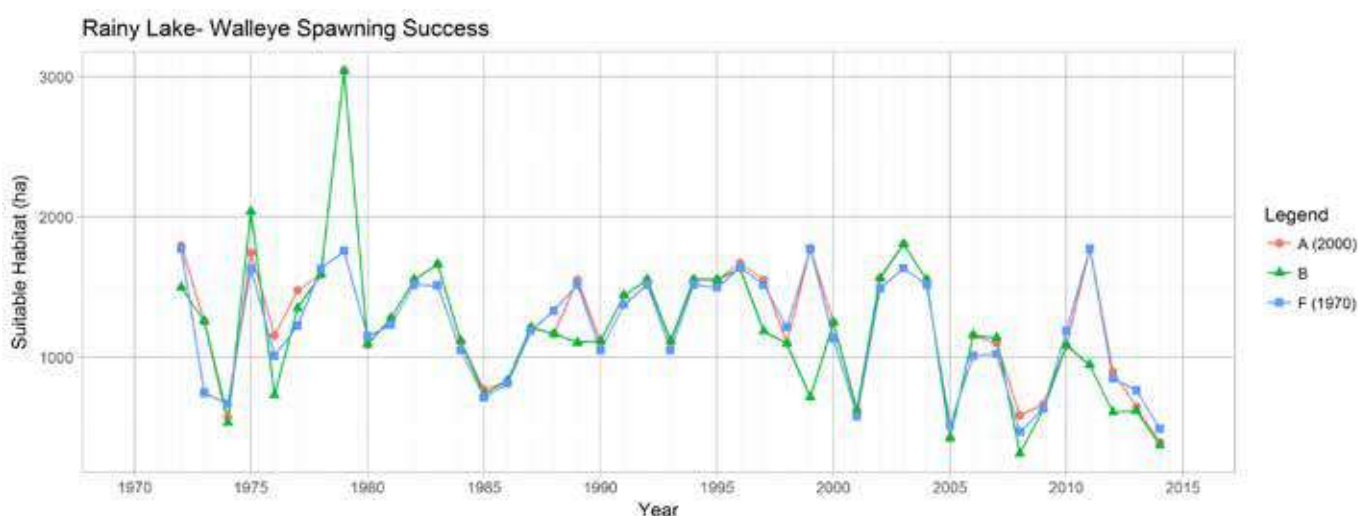


Figure 7-2 Suitable habitat for Rainy Lake Walleye spawning, Alternative B



## 2. Northern Pike

Figures 7-3 to 7-5 show IERM results for Rainy Lake Northern Pike Spawning Suitable Habitat, Larval Suitable Habitat and Young of Year (YoY) Suitable Habitat PIs.

As discussed in **Chapter 5**, most Northern Pike spawning occurs on tributary rivers. As with the 1970 and 2000 Rule Curves, the amount of high-quality habitat suitable for Northern Pike spawning is extremely low on Rainy Lake. The amount of suitable habitat for larval survival (Figure 7-4) and Northern Pike YoY (Figure 7-5) under **Alternative B** is similar to the 1970 and 2000 Rule Curves.

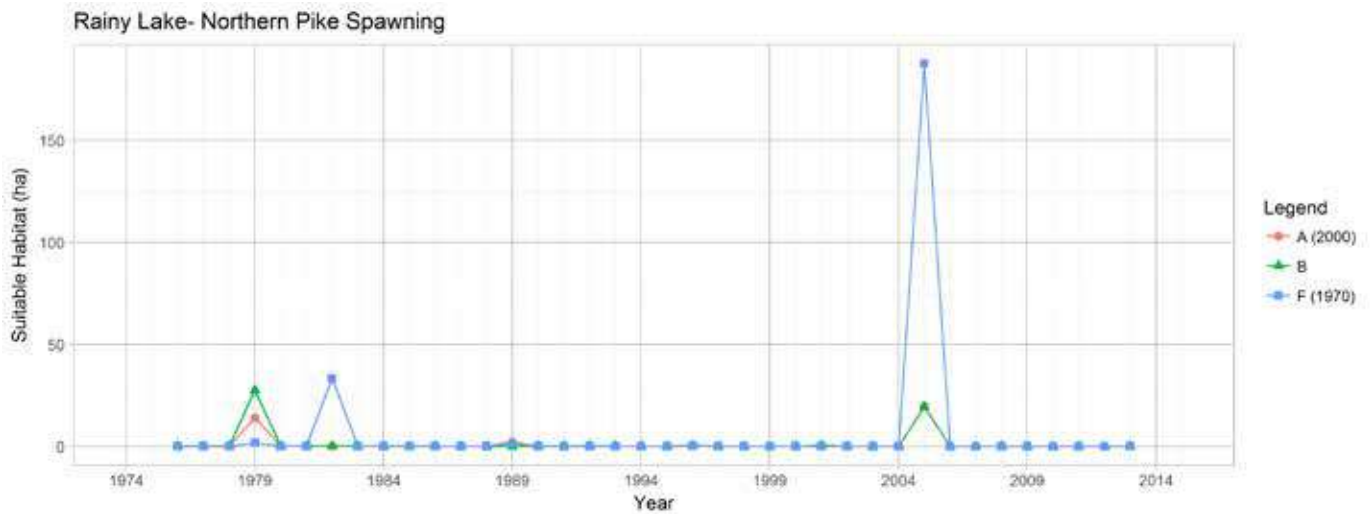


Figure 7-3 Suitable habitat for Rainy Lake Northern Pike spawning, Alternative B

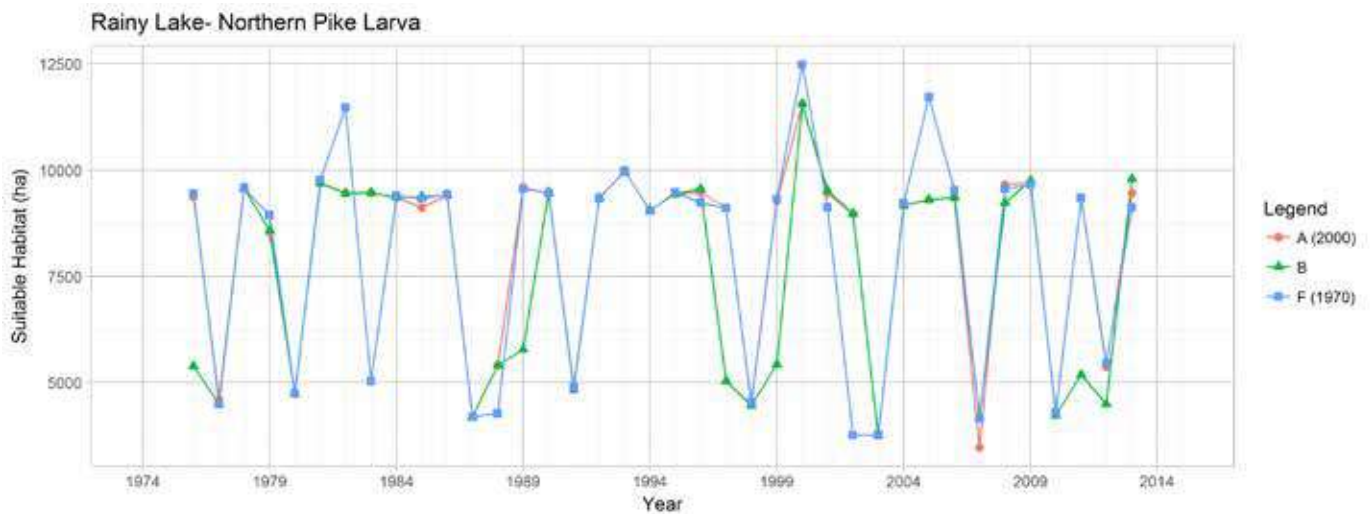


Figure 7-4 Suitable habitat for Rainy Lake Northern Pike larva, Alternative B

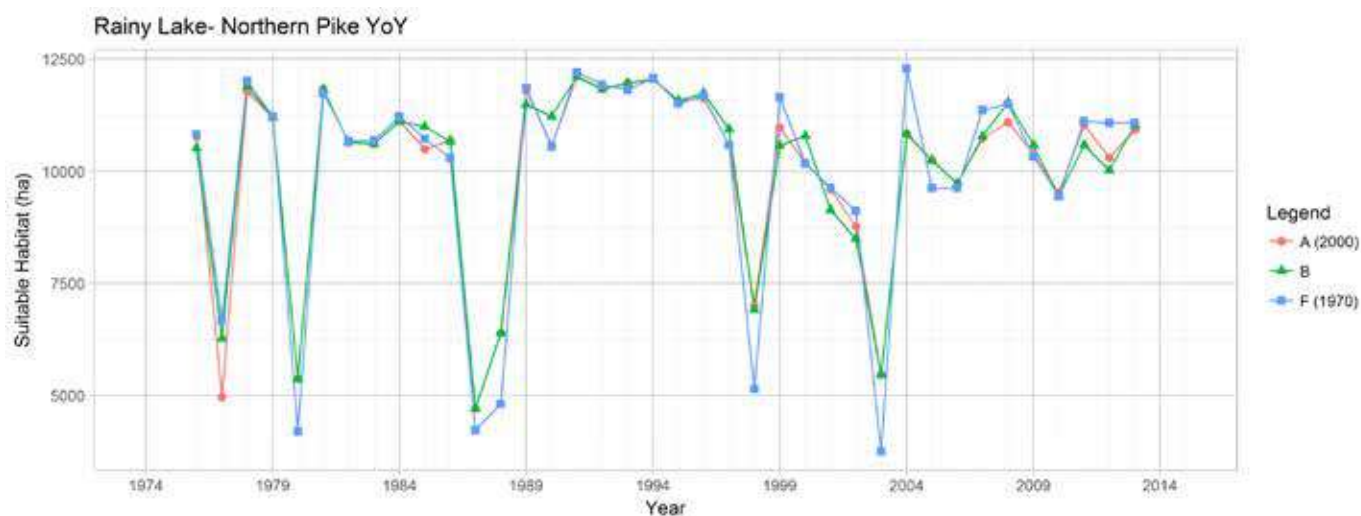


Figure 7-5 Suitable habitat for Rainy Lake Northern Pike Young of Year, Alternative B

### 3. Lake Whitefish

Figures 7-6 and 7-7 provide IERM results for the Rainy Lake Whitefish Egg Survival Probability and Spawning Habitat PIs.

The IERM suggests that **Alternative B** provides less favorable water levels for the survival of Lake Whitefish eggs on Rainy Lake in most years where the SVM predicts a flood will occur; whether the forecast is correct or issued a false alarm. This occurs as a result of an increase in the water level drop over the spawning and incubation period of Lake Whitefish eggs (beginning mid-November and ending after ice-out).

As with the Lake Whitefish Spawning Success PI, which takes into account water levels as well as other environmental variables and physical characteristics, the extent of suitable spawning habitat available for a successful spawn under **Alternative B** is also reduced in years where a flood is predicted.

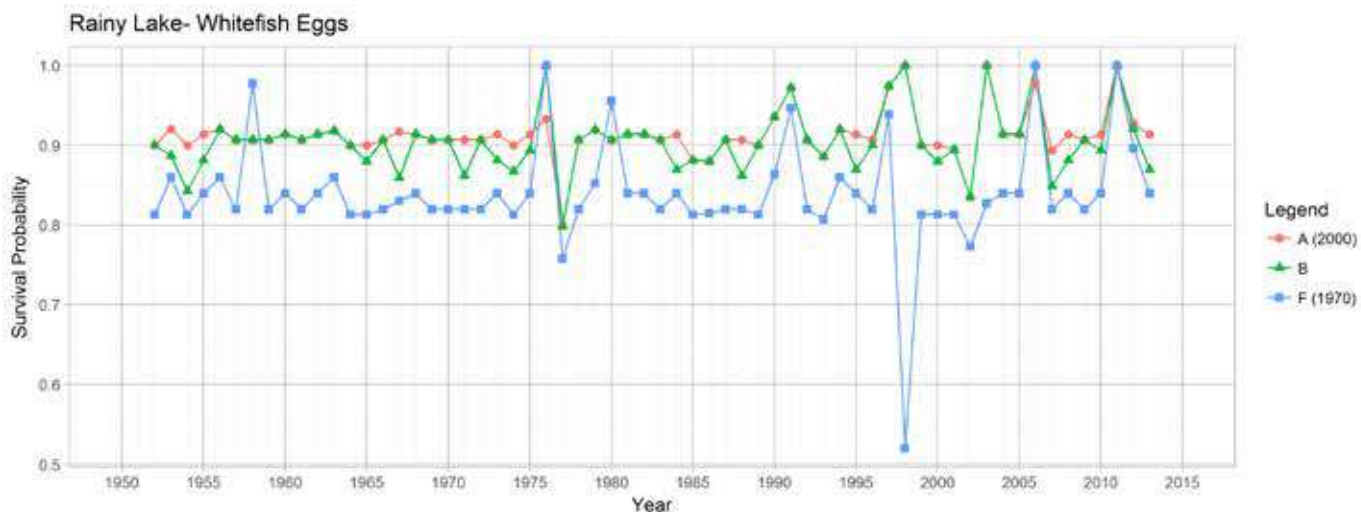


Figure 7-6 Probability of Lake Whitefish egg survival for Rainy Lake, Alternative B

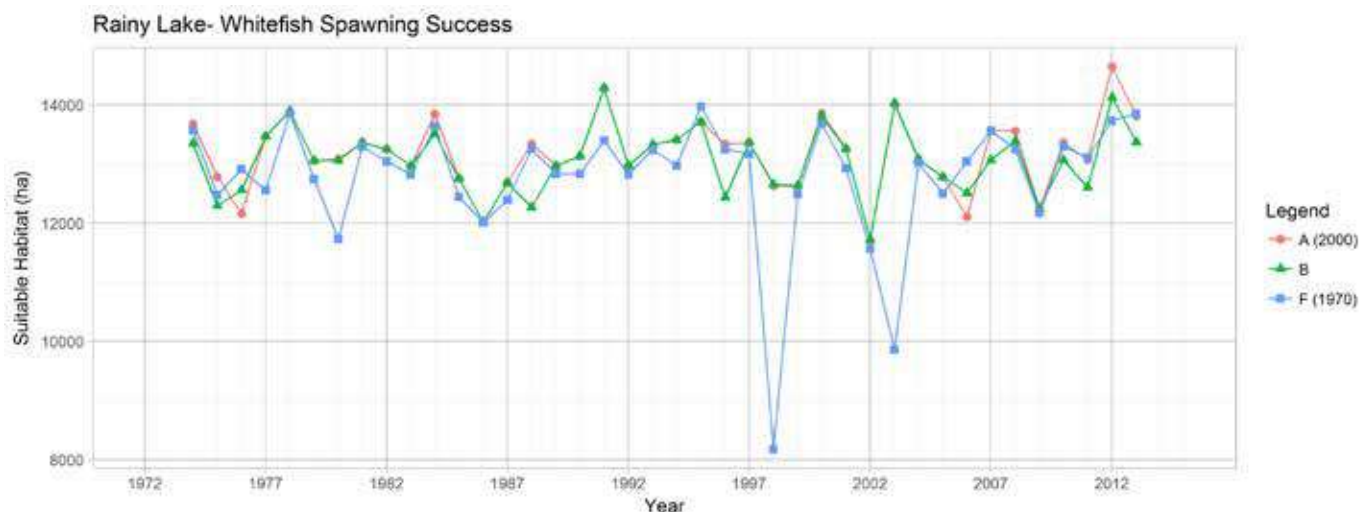


Figure 7-7 Suitable habitat for Lake Whitefish spawning, Rainy Lake, Alternative B

### 7.2.3 Wildlife: Alternative B

The IERM suggests that **Alternative B** has no impact on the likelihood of over-winter survival of Muskrats on Rainy Lake and some negative impacts to Common Loon nest viability in years when this alternative is implemented.

#### 1. Common Loon

The IERM estimates that the probability of nest viability on Rainy Lake under **Alternative B** is reduced in years when the SVM forecasts a flood based on the ENSO forecast, whether a flood occurs or not. As loons are only able to tolerate a water level rise of 15 cm over the nesting and incubation period (approximate 5 quarter-months), the steep rise of the **Alternative B** curve from May to mid-July results in a higher degree of nest failures.

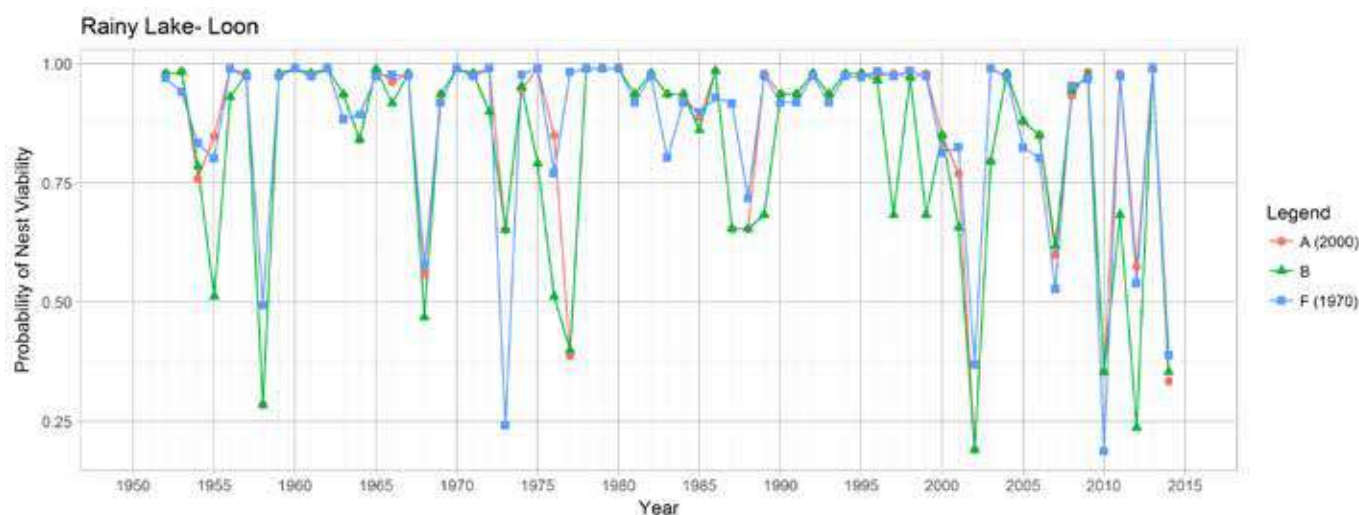


Figure 7-8 Probability of Common Loon nest viability on Rainy Lake, Alternative B

#### 2. Muskrats

The IERM shows that Alternative B provides nearly identical conditions for Muskrat over-winter survival on Rainy Lake compared to the 2000 Rule Curve.

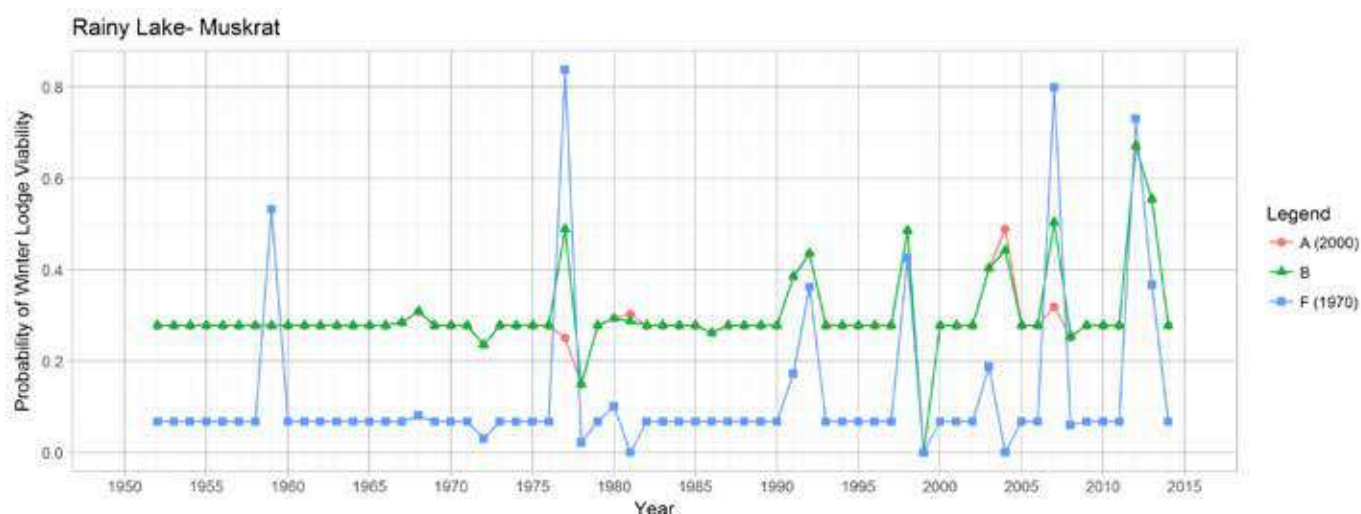


Figure 7-9 Probability of Muskrat winter lodge viability, Alternative B

#### 7.2.4 Economy, Alternative B

The SVM suggests that Alternative B produces both negative and positive impacts to economic interests on Rainy Lake, when compared to the 2000 Rule Curve. For example:

- average annual flood damages are reduced, and flood peaks are slightly lowered;
- early season boating can be negatively affected in years when the lake is lowered and no flood occurs (false alarm); and
- the average annual spill is decreased, likely resulting in an increase in hydropower production.

##### 1. Flood damages

Table 7-2 shows the estimated average annual reduction in flood damages on Rainy Lake under Alternative B, compared to the 2000 Rule Curve. The SVM estimates are for 1950 and 2014, the two highest flood years on record. Table 7-3 compares the reduction in Rainy Lake flood peak elevation for key flood years for three simulations:

1. **Alternative B** where the target level is the middle of the flood reduction rule curve band;

2. **Alternative B** where the target level is the bottom of the flood reduction rule curve band; and
3. **Reference F**, the 1970 Rule Curves.

In general, **Alternative B** provides an improvement over the 2000 Rule Curve in reducing the peak flood water levels on Rainy Lake; this benefit is greatest when the lower end of the target range is targeted. The benefit of **Alternative B** relative to the 1970 Rule Curve varies depending on the year, ranging from slightly better to slightly worse. This variation is a function of the timing of the inflow peak in a given year. If the inflow peak is in May, the **Alternative B** Rule Curve allows for additional storage room to be created by keeping Rainy Lake lower. If it comes in early April, however, no additional storage has been gained on Rainy Lake compared to the 2000 Rule Curve and little benefit results. In contrast, under the 1970 Rule Curve the additional storage in the Namakan Chain of Lakes is available each spring. Additionally, **Alternative B** only provides protection in years where a flood is correctly forecast. Years where the model incorrectly forecasts no flooding will follow the 2000 Rule Curves and have no additional flood reduction benefit.

**Table 7-2 Flood damage reduction on Rainy Lake for Alternative B**  
(net reductions in damages compared to 2000 Rule Curve, in \$,000)

	Alternative A 2000 Rule Curve	Alternative B	Reference F 1970 Rule Curve
Average Annual Flood Damage Reduction	\$0	\$68	\$186
1950 Flood	\$0	\$847	\$1,547
2014 Flood	\$0	\$965	\$965

**Table 7-3 Flood peak reduction on Rainy Lake for Alternative B (mid-band and lower curve targets) and 1970 Rule Curve**

	Reduction in Rainy Lake Flood Peak Water Level Compared to 2000 Rule Curve (cm)		
Year	Alternative B mid-band target	Alternative B lower curve target	Reference F 1970 Rule Curve
1950	2	4	4
1954	3	7	7
1968	4	5	4
1974	1	5	6
1985	6	7	1
1996	2	5	7
2001	0	2	4
2005	0	2	8
2008	2	4	2
2009	1	2	3
2013	7	10	7
2014	4	6	4

## 2. Navigation

The SVM computes the percentage of time preferred minimum water level is met throughout the boating season (details provided in Annex 5).

The SVM suggests that **Alternative B** provides less reliable May/June boating depths for Rainy Lake compared to the 2000 Rules Curves as the lake is intentionally held at a lower level in the spring in years where the model predicts a flood will occur. When no flood occurs (false alarm), this PI is negatively affected. Navigation throughout the remainder of the boating season is the same as under **Alternative A**.

**Table 7-4 Boating depth reliability on Rainy Lake for Alternative B**  
(percentage of time minimum depth requirement is met)

Boating Season Period	Alternative A 2000 Rule Curve %	Alternative B %
May-June	68	59
July-Aug	94	94
Late Season	95	95



### 3. Hydropower production

SVM results indicate that **Alternative B** results in a slight reduction in spill from Rainy Lake when compared to operations under the 2000 Rule Curve (details on the spill PI are provided in Annex 5). The 1970 Rule Curve provides the least average spill, consistent with the results of the WOE analysis which showed a reduction in hydropower production between the 1970 and 2000 Rule Curves.

Table 7-5 Hydropower spill reduction under Alternative B

	Alternative A 2000 Rule Curve (baseline)	Alternative B	Reference F 1970 Rule Curve
Reduction in Average Annual Spill	1.00	1.01	1.09

### 7.2.5 Archeological resources: Alternative B

As described in Annex 5, the SVM estimates the likelihood of erosion due to prolonged exposure at a given water level to the forces of wave action. The SVM predicts that **Alternative B** reduces the threat of erosion of archeological sites on Rainy Lake when compared to the 2000 Rule Curve.

Table 7-6 Archeological resources PI results for Alternative B: protection of archeological sites from erosion

	Alternative A 2000 Rule Curve (baseline)	Alternative B	Reference F 1970 Rule Curve
Rainy Lake	1.00	1.02	0.62

### 7.2.6 Aquatic vegetation: Alternative B

The IERM suggests that, under **Alternative B**, aquatic plant diversity may slightly decrease. For example:

- Hybrid Cattail invasion is increased in most years;
- the amount of suitable habitat for Wild Rice is generally decreased;
- there is a small increase in the amount of suitable habitat for wet meadows, and a decrease for shrubby swamps; and
- the amount of suitable habitat for emergent plant, and low- and high-density submerged vegetation is unchanged.

#### 1. Wild Rice and Hybrid Cattails

Wild Rice and Hybrid Cattails occupy similar habitat and benefit from the steady water levels provided by a regulated system. However, the invasive Hybrid Cattail present within

the Namakan Chain of Lakes and Rainy Lake generally out-competes Wild Rice for habitat. As described in Annex 5, the IERM models the impact of Hybrid Cattails on Wild Rice. It is therefore important to evaluate these two interests together.

Figure 7-10 shows the total area of Rainy Lake invaded by Hybrid Cattails under **Alternative B** and the 1970 and 2000 Rule Curves, as estimated by the IERM. In most years, the IERM predicts that **Alternative B** results in a greater extent of cattail invasion than the 2000 and 1970 Rule Curves. The flood protection offered under **Alternative B** also provides steadier water level conditions that benefit Hybrid Cattail growth.

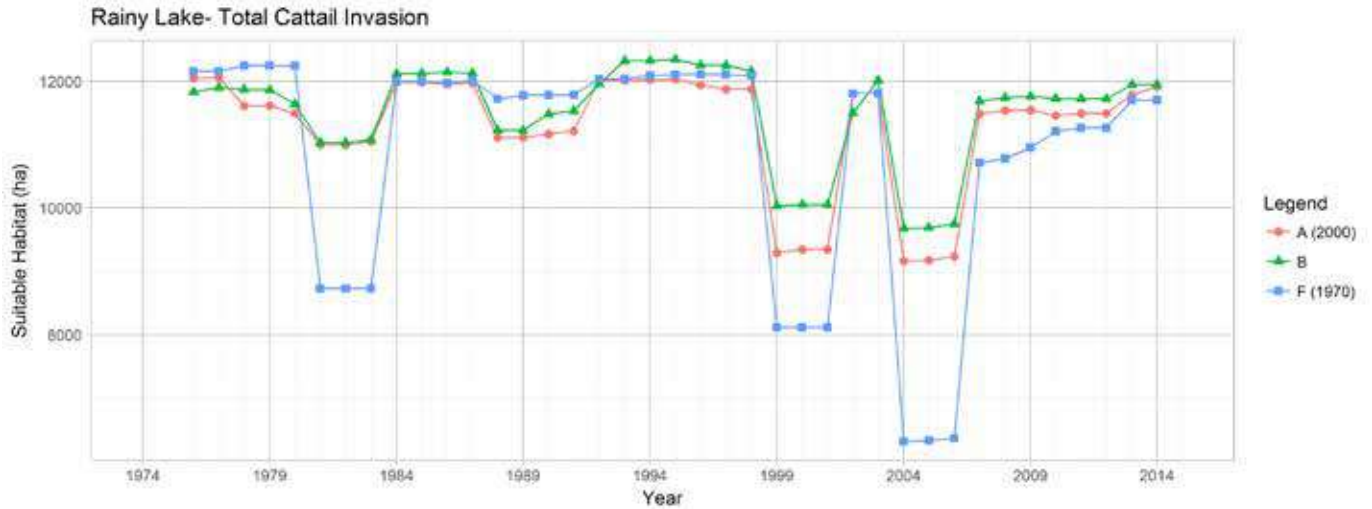


Figure 7-10 Area suitable for Hybrid Cattail invasion, Rainy Lake, Alternative B

Given the increase in presence of Hybrid Cattail under **Alternative B**, the IERM estimates that the number of hectares where Wild Rice can successfully grow is reduced under this alternative compared to the 2000 Rule Curve (Figure 7-11).

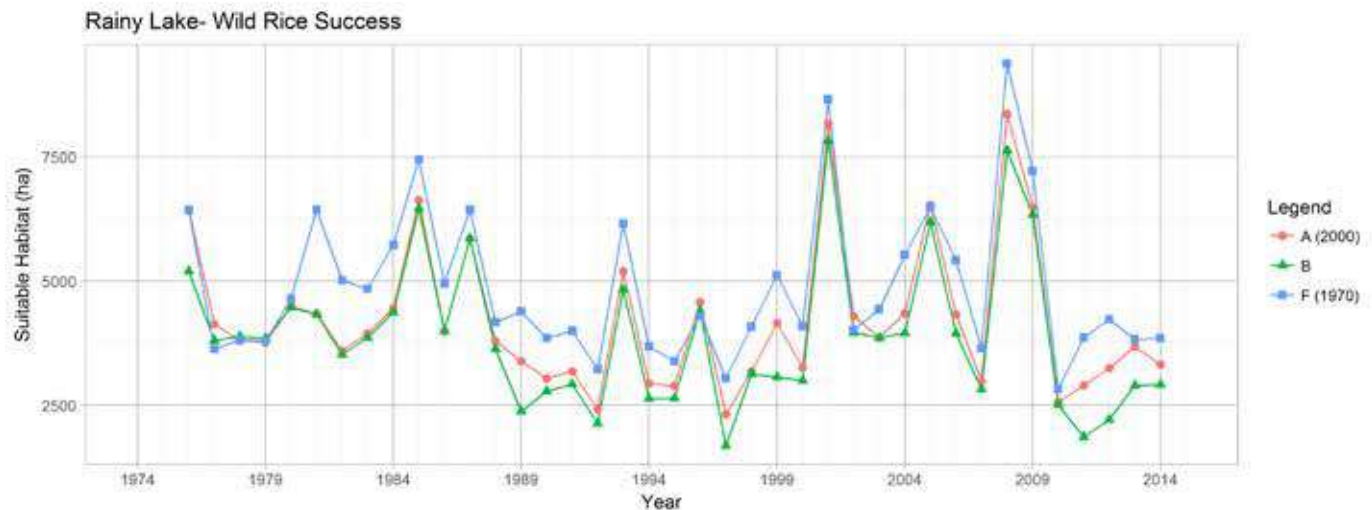


Figure 7-11 Area suitable for Wild Rice, Rainy Lake, Alternative B

## 2. Wet meadows and shrubby swamps

The IERM suggests that **Alternative B** results in an increase in wet meadows and a decrease in shrubby swamps when compared to the 2000 Rule Curves. These wetland vegetation types are sensitive to the proportion of time an area is flooded and wet-dry cycles within a year. Drought years result in a decrease in the amount of area suitable to wetland vegetation. For example, in Figure 7-12, wet meadows under the 1970 Rule Curve are adversely affected by extremely low water levels in 1976 and 1977. Water levels under the 2000 Rule Curve and **Alternative B** are higher on Rainy Lake during this period.

Furthermore, shrubby swamps occur at higher elevations than wet meadows and require higher flood peaks to provide water to these areas. Shrubby swamps are less likely to be flooded under **Alternative B** as a result of the reduction in flood peak shown in Table 7-3.

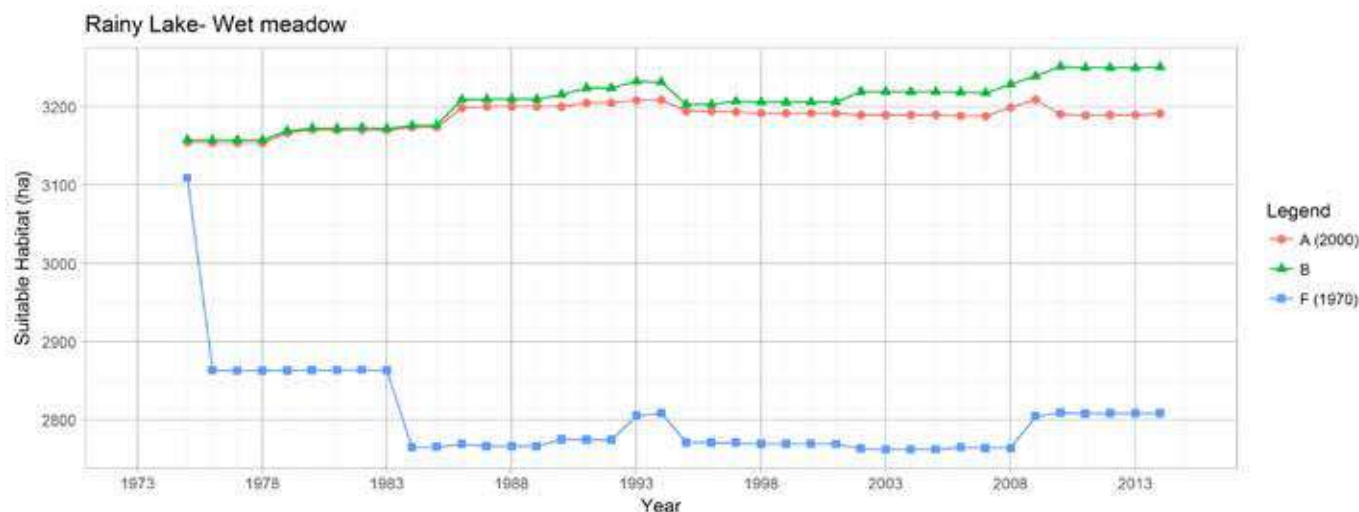


Figure 7-12 Area of suitable habitat for wet meadows on Rainy Lake, Alternative B

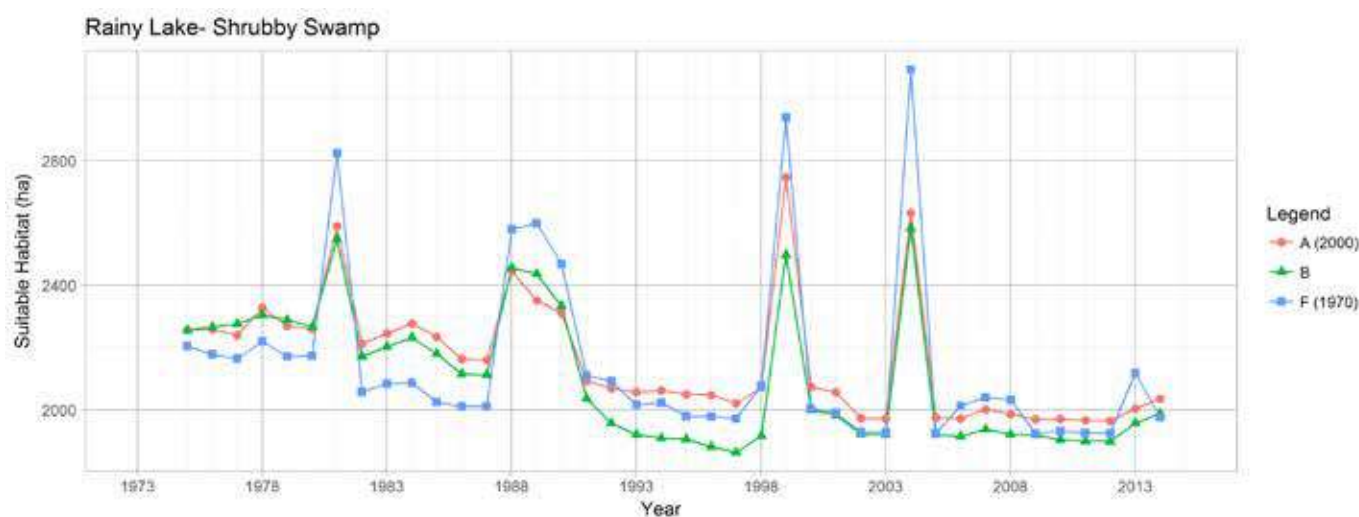


Figure 7-13 Area of suitable habitat for shrubby swamps on Rainy Lake, Alternative B

### 3. Emergent plants

The amount of suitable area for emergent plants is unchanged in most years under **Alternative B** when compared to the 2000 Rule Curves.

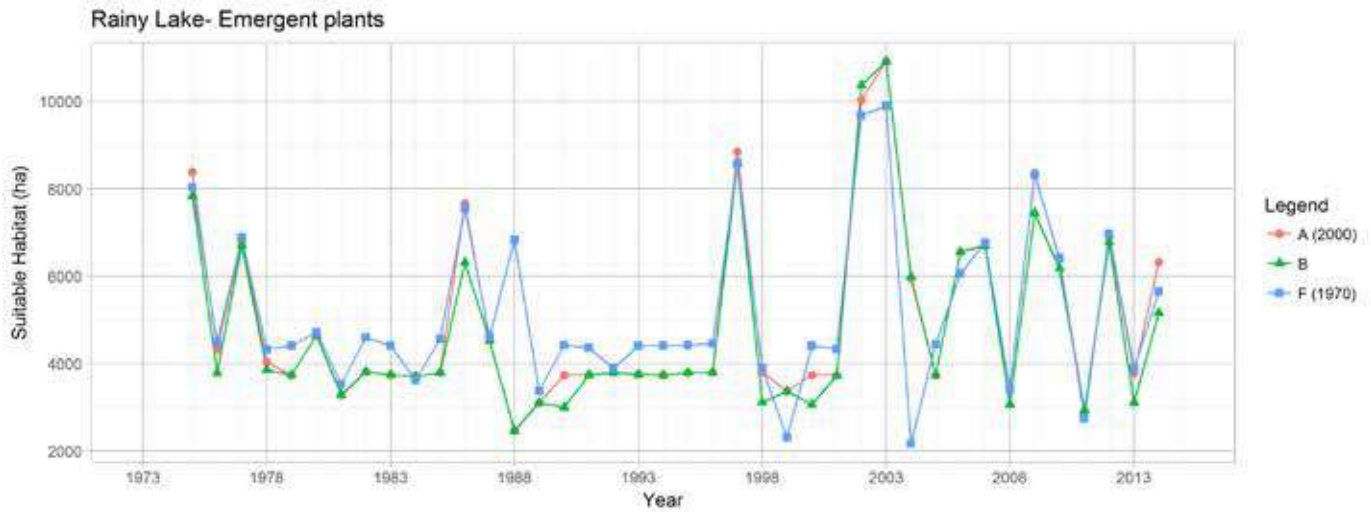


Figure 7-14 Area of suitable habitat for emergent plants on Rainy Lake, Alternative B

### 4. Submerged vegetation

The amount of suitable area for low- and high-density submerged plants is unchanged in most years under **Alternative B** when compared to the 2000 Rule Curve.

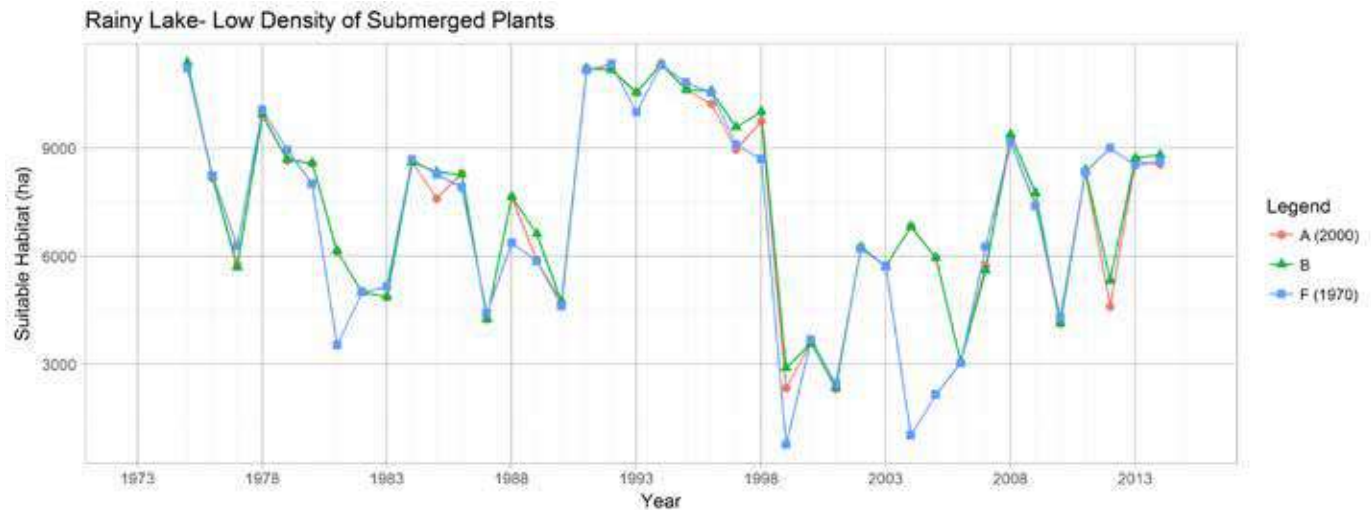


Figure 7-15 Area of suitable habitat for low-density submerged plants on Rainy Lake, Alternative B

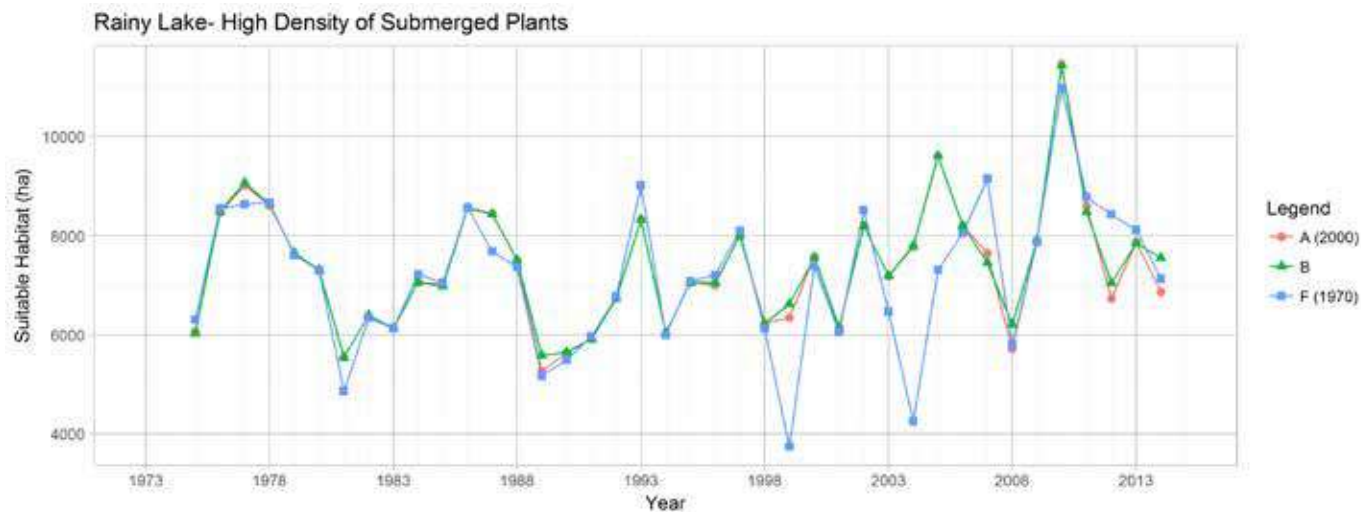


Figure 7-16 Area of suitable habitat for high-density submerged plants on Rainy Lake, Alternative B

### 7.2.7 Rainy River: Alternative B

The IERM suggests the amount of suitable habitat for Walleye and Lake Sturgeon Spawn on Rainy River under **Alternative B** is consistent with the 2000 Rule Curves.

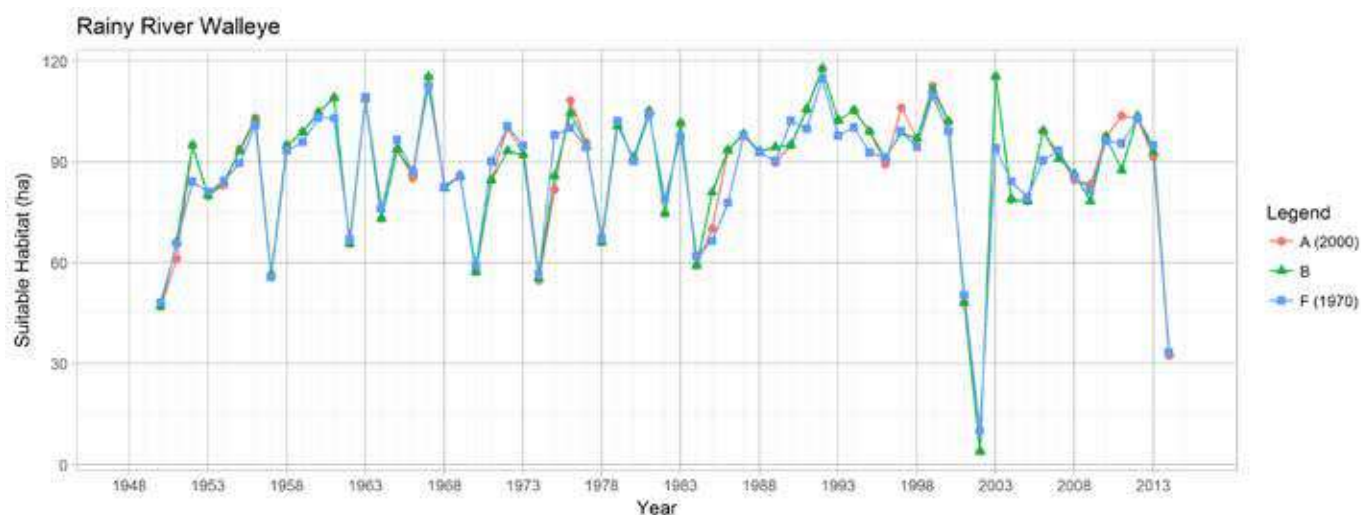


Figure 7-17 Area of suitable habitat for Walleye spawning on Rainy River, Alternative B

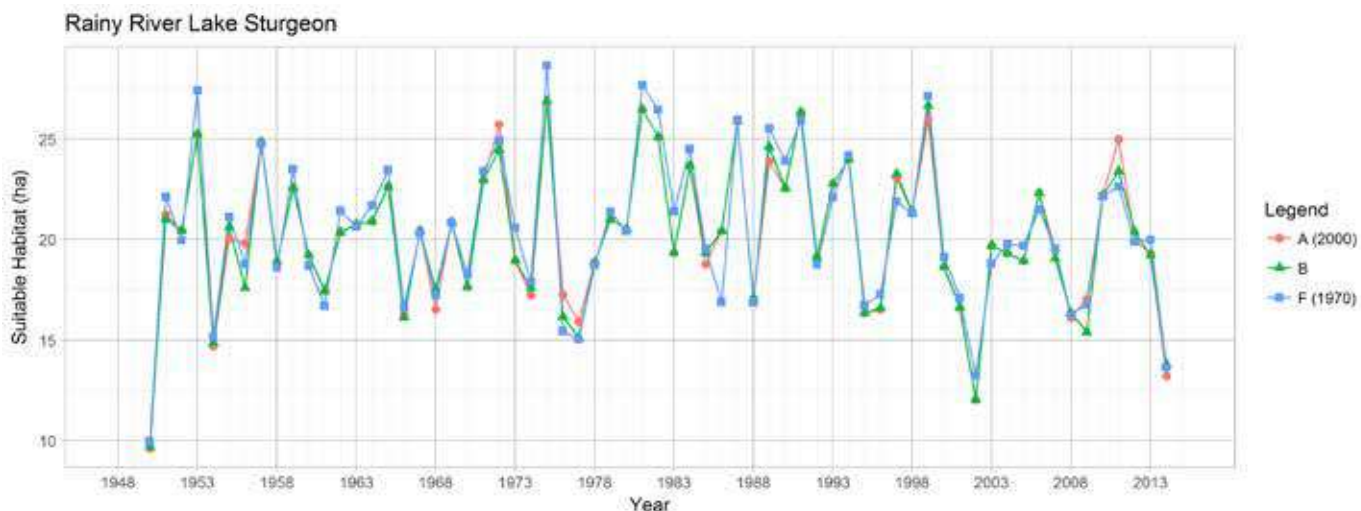


Figure 7-18 Area of suitable habitat for Lake Sturgeon spawning on Rainy River, Alternative B



### 7.3 Alternative C: Improving within-year ecological outcomes

#### 7.3.1 Overview

##### Objective

This alternative aims to retain the benefits of the 2000 Rules Curves and reduce the potential for flooding on Rainy Lake (as demonstrated by **Alternative B**), while enhancing some ecological conditions for fish and fur-bearers.

##### Key features

This alternative includes modifications to both the Namakan Lake and Rainy Lake Rule Curves that result in a reduced over-winter drawdown from late November to late March. In years when flood conditions are projected, the lower target range for Rainy Lake included in **Alternative B** is followed from April to mid-July.

This rule curve is designed to benefit Muskrat survival by ensuring their lodges are built at water levels that allow for continued access to aquatic vegetation over the winter. As described in Section 2.2, Muskrats play a vital role in the control of Hybrid Cattail expansion and create channels through cattail beds that benefit many fish species.

#### Summary of model results

Model output shows that **Alternative C** provides a number of ecological benefits to Muskrats, fish and aquatic vegetation, however some negative impacts are seen in years when a flood is incorrectly forecasted.

**Alternative C** also provides similar flood reduction benefits as **Alternative B**, though other economic interests may be negatively affected.

#### 7.3.2 Fish: Alternative C

**Alternative C** produces a positive change for fish on Namakan Lake and for some species on Rainy Lake. **Alternative C** results in:

- an increase in Walleye, Northern Pike and Lake Whitefish spawning habitat on Namakan Lake; and
- a comparable amount of suitable habitat for Walleye on Rainy Lake to the 2000 Rule Curve, though this is negatively affected in some years.

##### 1. Walleye

The IERM suggests that the probability of Walleye egg survival on Namakan Lake is unchanged under **Alternative C** when compared to the 2000 Rule Curve (Figure 7-19a). On Rainy Lake, small deviations from the 2000 Rule Curve, both positive and negative, occur in some years (Figure 7-19b).

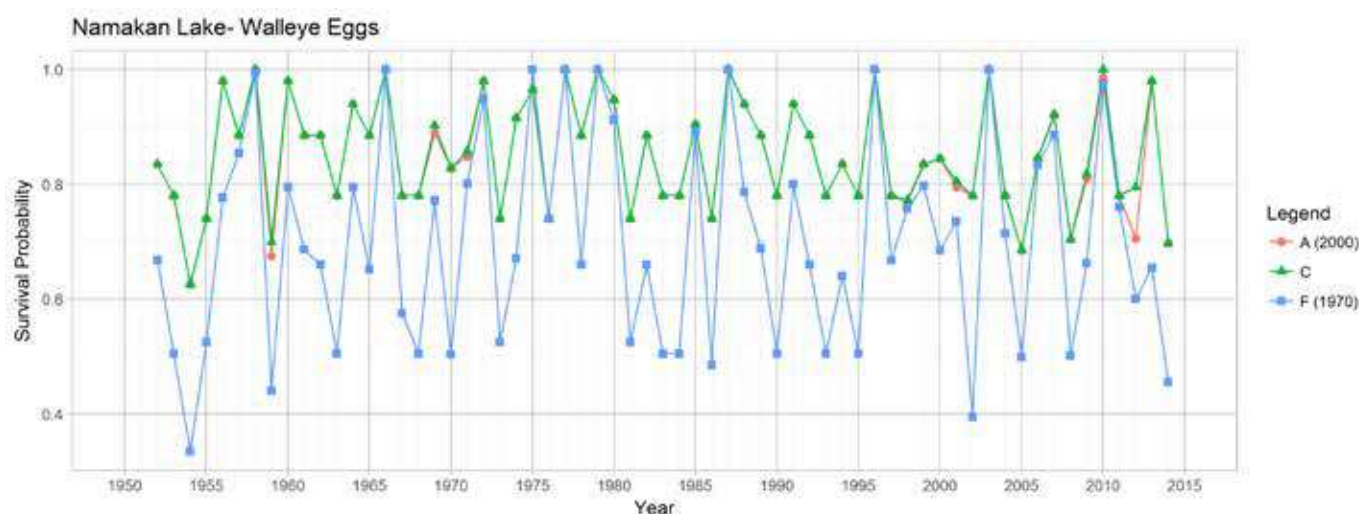


Figure 7-19a Probability of Walleye egg survival on Namakan Lake, Alternative C

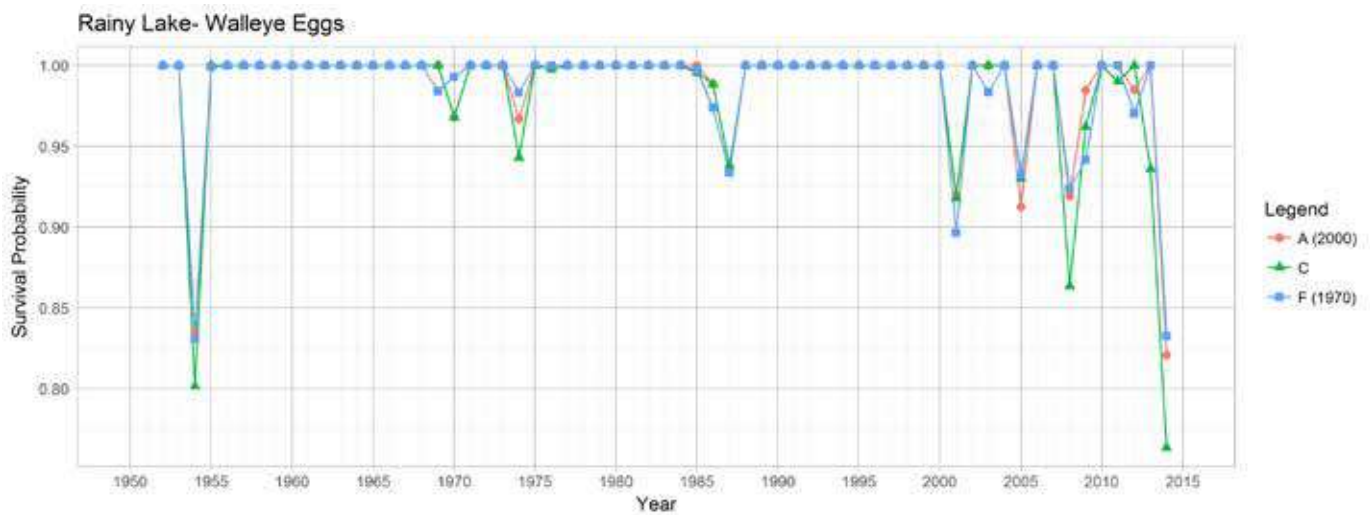


Figure 7-19b Probability of Walleye egg survival on Rainy Lake, Alternative C

The amount of suitable habitat for Walleye spawning on Namakan Lake is similar in most years, with occasional peak years where **Alternative C** produces slightly more suitable area (Figure 7-20a). On Rainy Lake, however, years where the SVM predicts a flood but none occurs (false alarm), Walleye spawning habitat is negatively affected (Figure 7-20b).

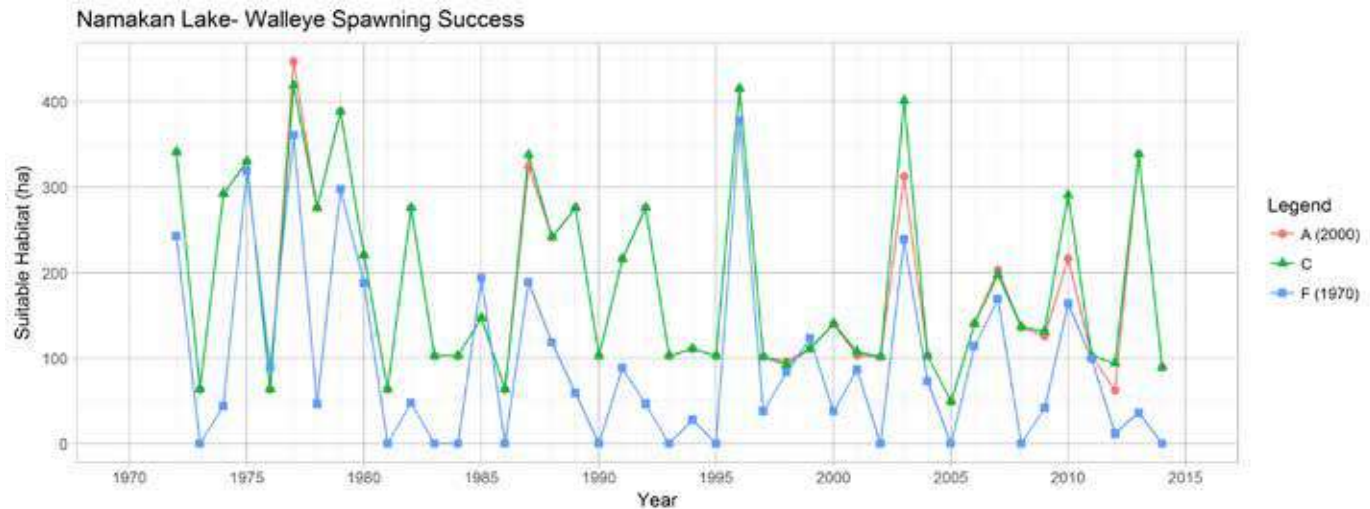


Figure 7-20a Area of suitable habitat for successful Walleye spawning on Namakan Lake, Alternative C

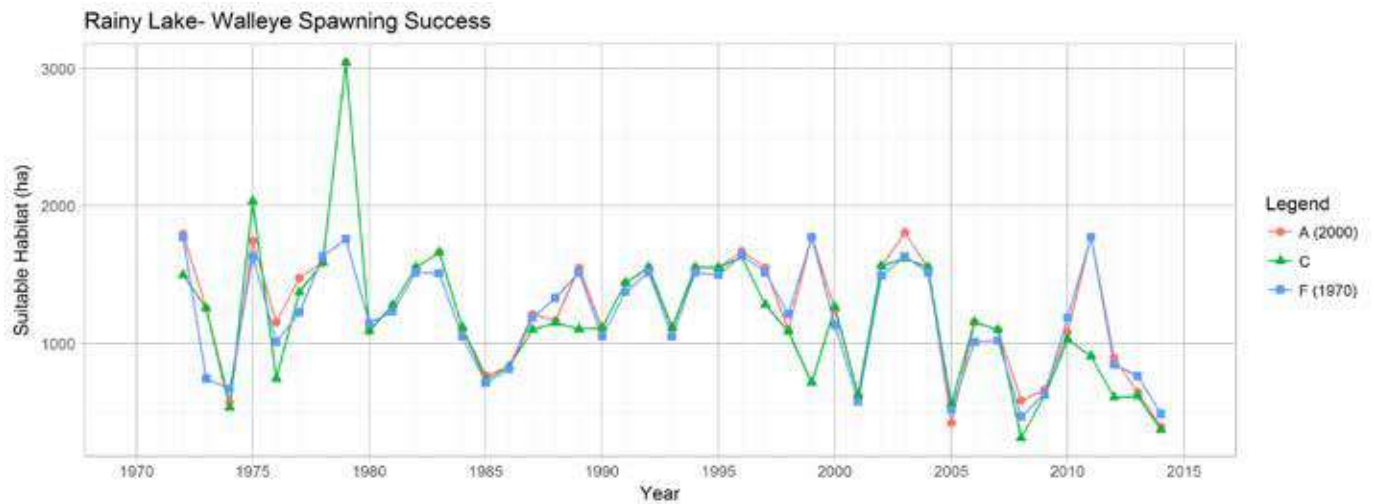


Figure 7-20b Area of suitable habitat for successful Walleye spawning on Rainy Lake, Alternative C

## 2. Northern Pike

The amount of Northern Pike spawning habitat on Namakan Lake increases in most years under **Alternative C** (Figure 7-21a), but remains extremely low on both lakes (Figure 7-21b).

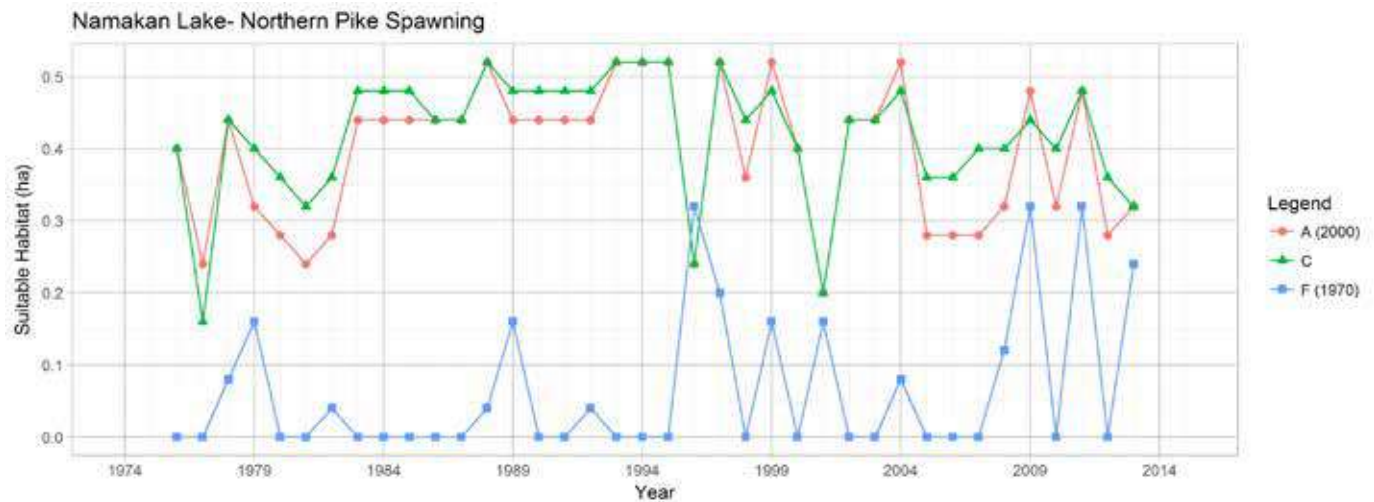


Figure 7-21a Area of suitable habitat for Northern Pike spawning on Namakan Lake, Alternative C

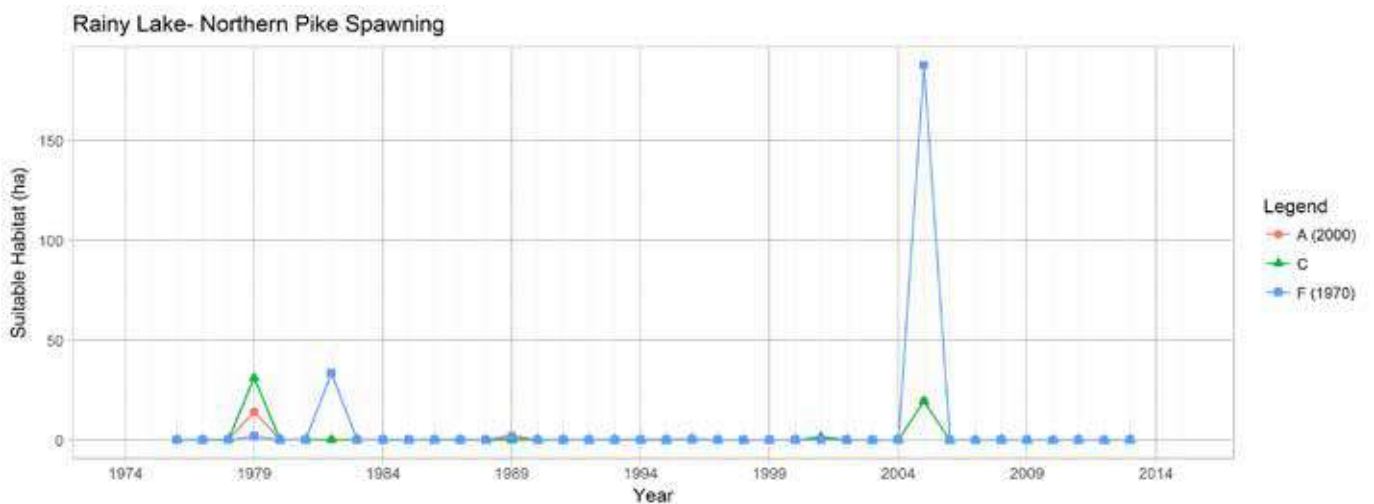


Figure 7-21b Area of suitable habitat for Northern Pike spawning on Rainy Lake, Alternative C

The amount of suitable habitat for Northern Pike larval survival under **Alternative C** is similar in most years to the 2000 Rule Curves (Figures 7-22a and 7-22b). The amount of suitable habitat for Northern Pike YoY, however, is decreased on both lakes on most years (Figures 7-23a and 7-23b). The amount of Northern Pike spawning habitat remains the limiting factor in Northern Pike production on the lakes, since in most years the amounts of suitable habitat for larva and YoY far exceed the amount of suitable spawning habitat.

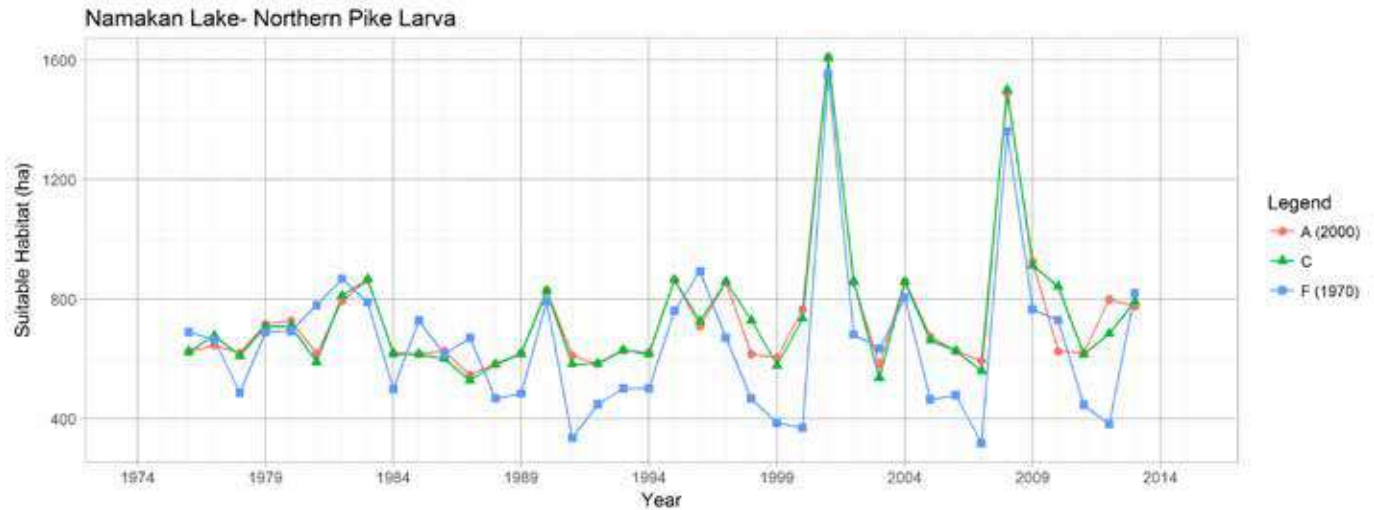


Figure 7-22a Area of suitable habitat for Northern Pike larval survival on Namakan Lake, Alternative C

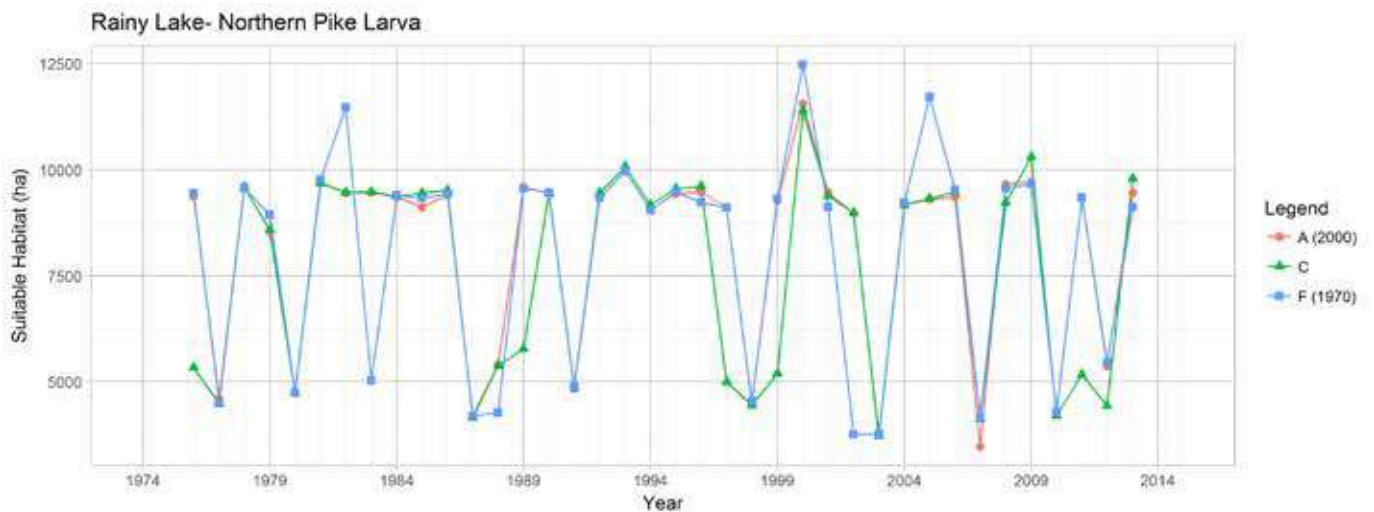


Figure 7-22b Area of suitable habitat for Northern Pike larval survival on Rainy Lake, Alternative C



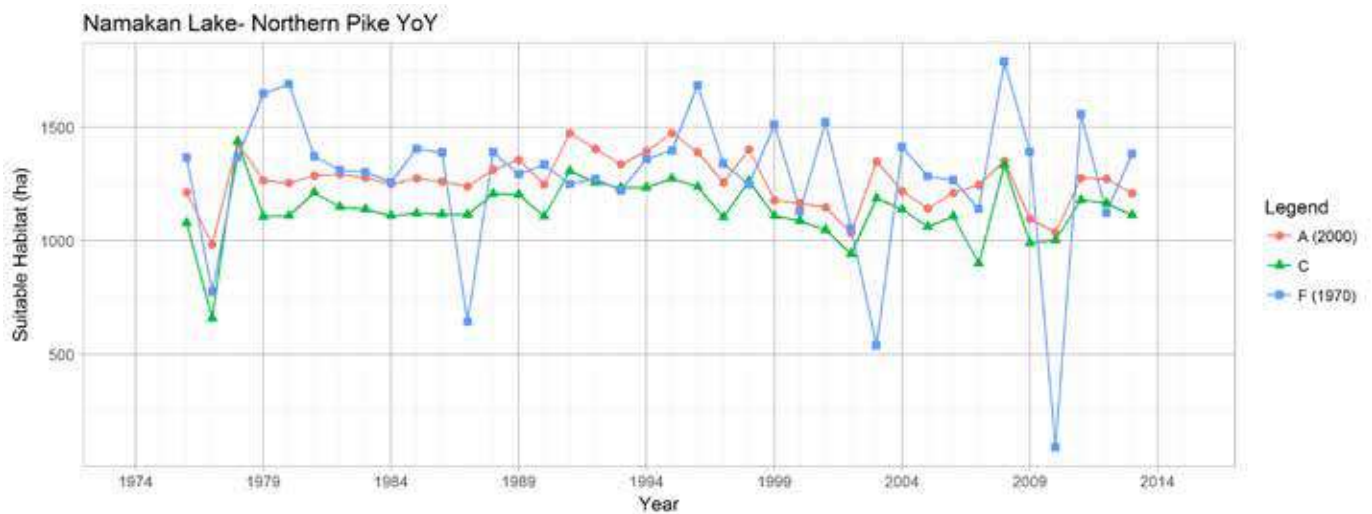


Figure 7-23a Area of suitable habitat for Northern Pike YoY on Namakan Lake, Alternative C

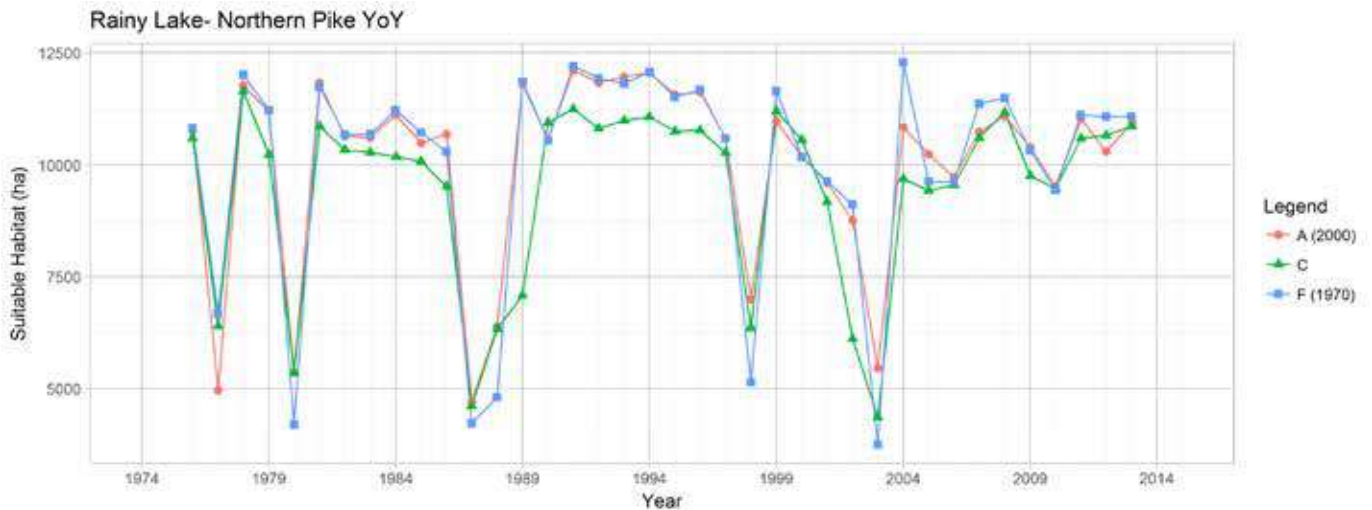


Figure 7-23b Area of suitable habitat for Northern Pike YoY on Rainy Lake, Alternative C

### 3. Lake Whitefish

Figures 7-24a to 7-25b suggest that **Alternative C** provides benefits to Lake Whitefish egg survival probability and spawning habitat on both Namakan and Rainy Lakes. The reduction in over-winter drawdown provides improved conditions for Lake Whitefish eggs throughout the spawning and incubation periods.



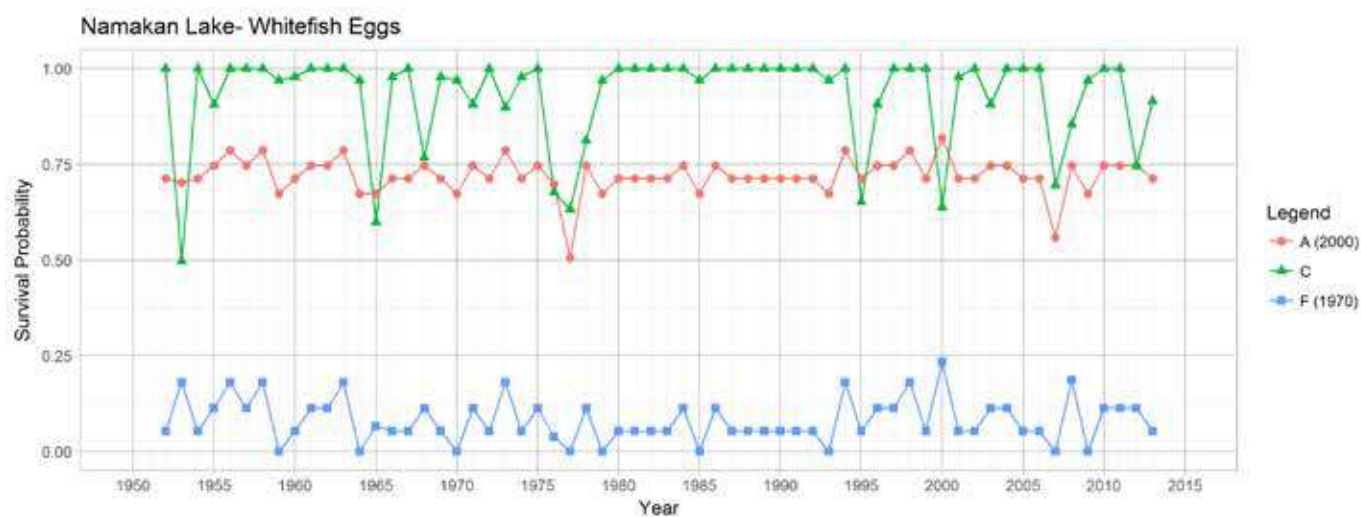


Figure 7-24a Probability of Lake Whitefish egg survival on Namakan Lake, Alternative C



Figure 7-24b Probability of Lake Whitefish egg survival on Rainy Lake, Alternative C

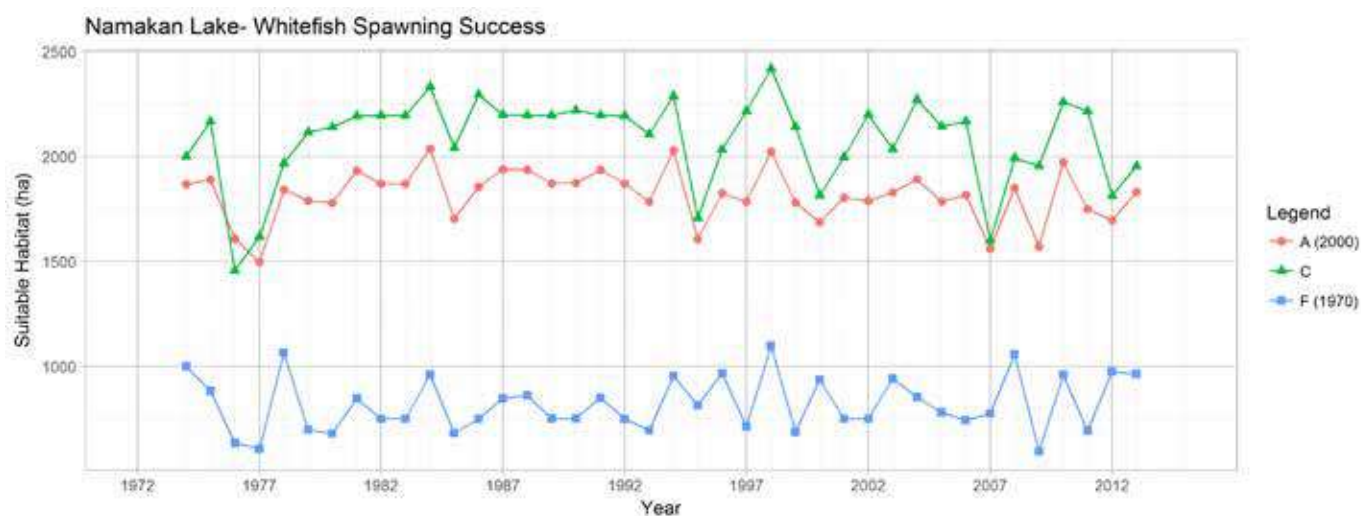


Figure 7-25a Area of suitable habitat for successful Lake Whitefish spawning on Namakan Lake, Alternative C



Figure 7-25b Area of suitable habitat for successful Lake Whitefish spawning on Rainy Lake, Alternative C

### 7.3.3 Wildlife: Alternative C

**Alternative C** provides an increase in likelihood of Muskrat over-winter survival on both Namakan and Rainy Lakes, while maintaining the conditions for Common Loon nesting provided by the 2000 Rule Curves.

#### 1. Common Loon

Figures 7-26a and 7-26b suggest that the probability of Common Loon nest viability on Namakan and Rainy Lakes under **Alternative C** remains similar to the performance under the 2000 Rule Curves.

#### 2. Muskrats

The IERM suggests that **Alternative C** increases the likelihood of over-winter survival of Muskrats on both Namakan and Rainy Lakes, as it estimates a zero probability of winter lodge viability under both **Alternative A** and **Reference F**.

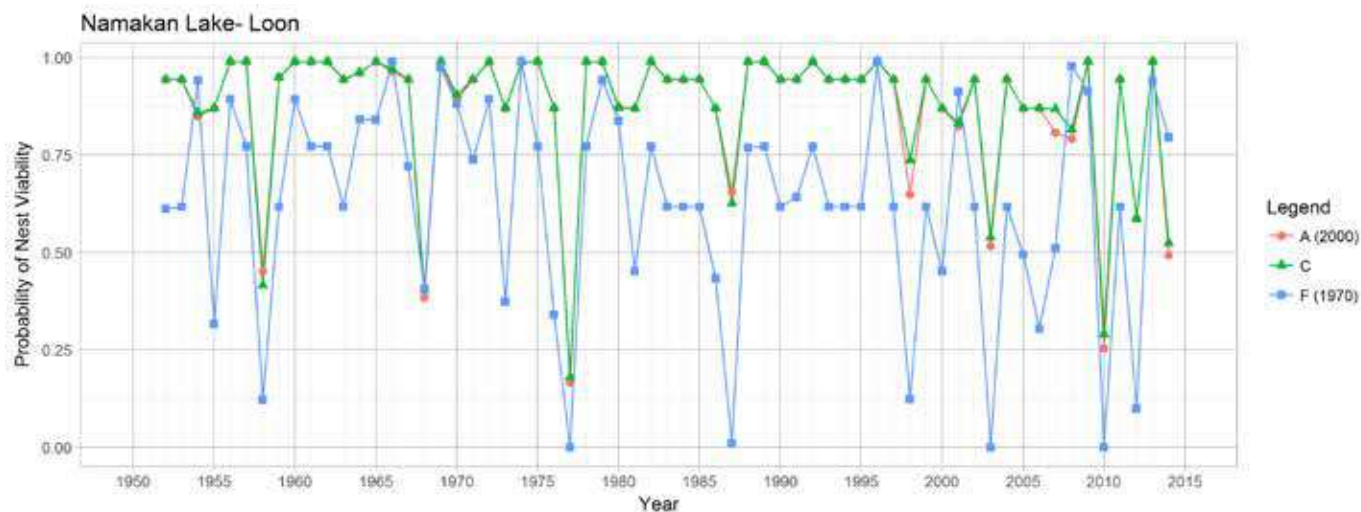


Figure 7-26a Probability of Common Loon nest viability on Namakan Lake, Alternative C

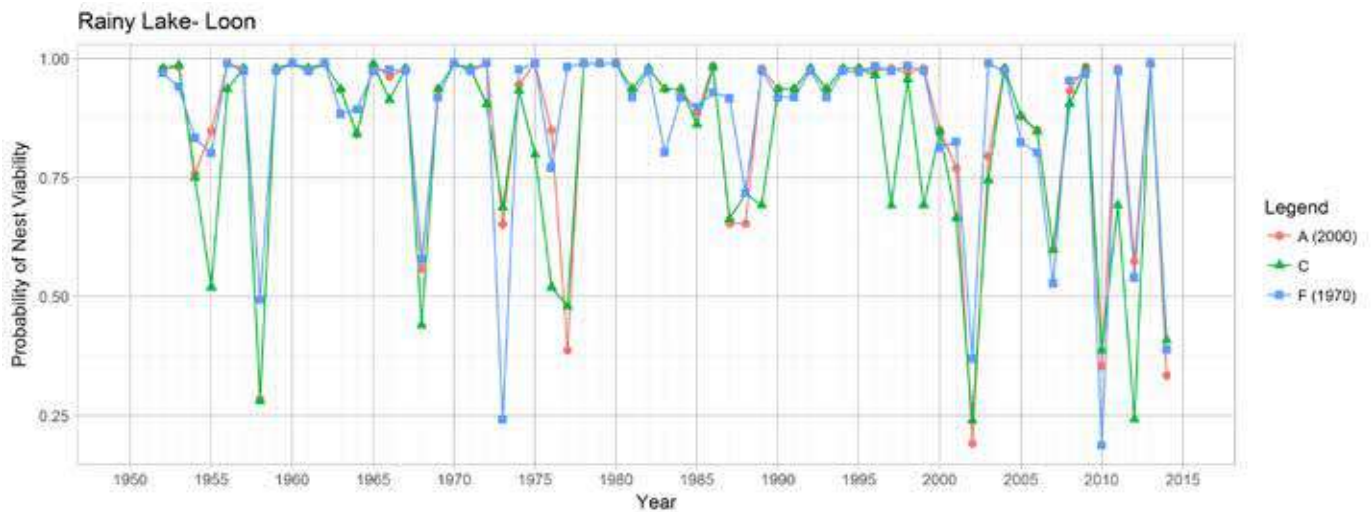


Figure 7-26b Probability of Common Loon nest viability on Rainy Lake, Alternative C

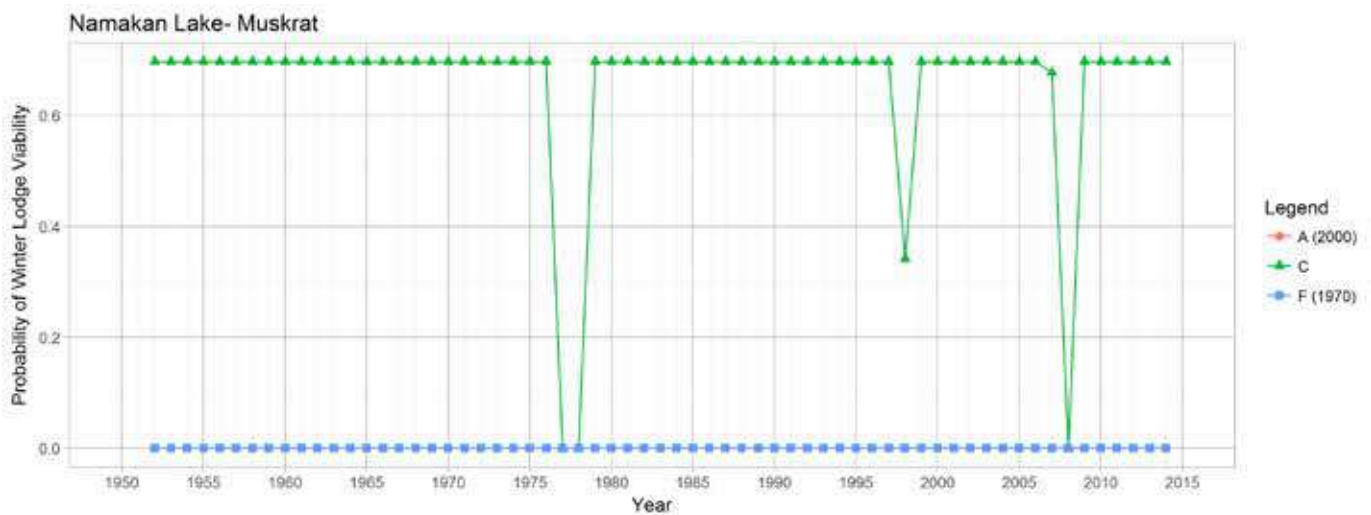


Figure 7-27a Probability of Muskrat winter lodge viability on Namakan Lake, Alternative C

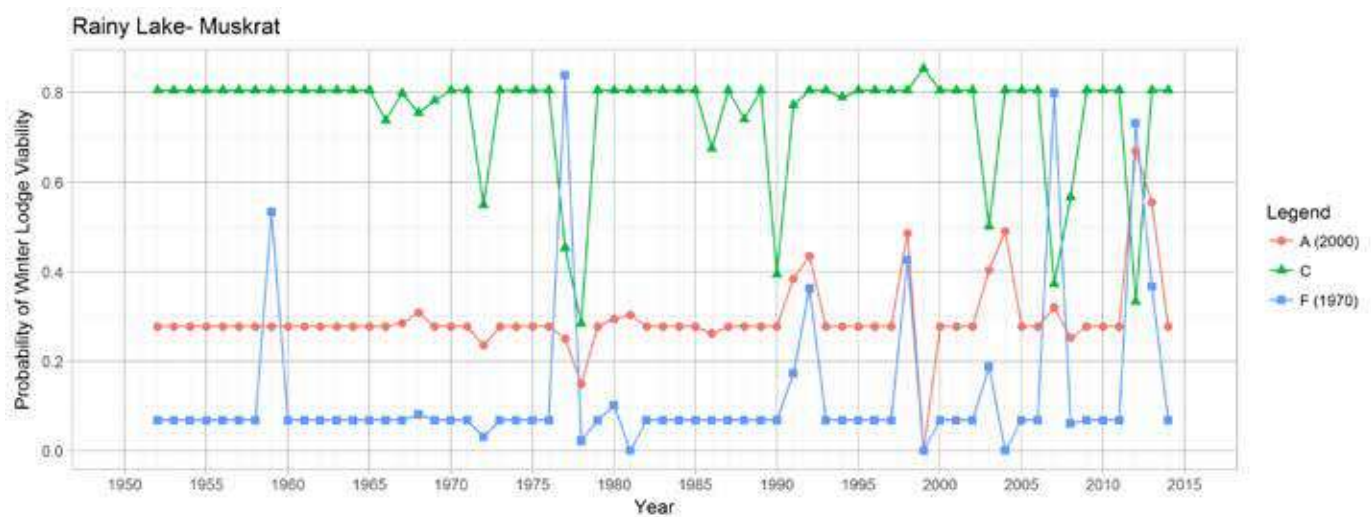


Figure 7-27b Probability of Muskrat winter lodge viability on Rainy Lake, Alternative C

### 7.3.4 Economy: Alternative C

The SVM suggests that **Alternative C** results in both positive and negative economic impacts, including:

- a reduction in flood damages on Rainy Lake;
- a reduction in late-season boating reliability on Namakan Lake; and
- a potential decrease in hydropower production from Rainy Lake.

#### 1. Flood Damages

**Alternative C** results in some changes in annual flood damage reduction on Namakan Lake, but does not affect major flood events such as the 1950 and 2014 floods. On Rainy Lake, however, the use of the ENSO-based forecast to lower water levels in anticipation of a flood event results in a reduction in average annual flood damages.

**Alternative C** also reduces the flood damages in major flood years, when compared to the 2000 Rule Curves. It provides similar benefits to **Alternative B**.

**Table 7-7 Flood damage reduction for Alternative C**  
(net reductions in damages compared to 2000 Rule Curves, in \$,000)

	Alternative A 2000 Rule Curves (baseline)	Alternative C	Reference F 1970 Rule Curves
<b>Namakan Lake</b>			
Average Annual Flood Damage Reduction	\$0	-\$1	\$17
1950 Flood	\$0	\$0	\$561
2014 Flood	\$0	\$0	\$217
<b>Rainy Lake</b>			
Average Annual Flood Damage Reduction	\$0	\$65	\$186
1950 Flood	\$0	\$847	\$1,547
2014 Flood	\$0	\$965	\$965

#### 2. Navigation

Under **Alternative C**, a sharp drawdown period on Namakan Lake begins in early October in order to reduce water levels in advance of freeze-up. The SVM shows that this drawdown period negatively affects the late-season boating period on Namakan Lake.

Similarly, on Rainy Lake, the steeper summer drawdown proposed under **Alternative C** also affects July-August boating reliability, though to a lesser extent.

**Table 7-8 Boating Depth Reliability for Alternative C**  
(percentage of time minimum depth requirement is met)

Boating Season Period	Alternative A 2000 Rule Curves %	Alternative C %
<b>Namakan Lake</b>		
May-June	62	62
July-Aug	99	99
Late Season	63	49
<b>Rainy Lake</b>		
May-June	68	62
July-Aug	94	91
Late Season	95	95

### 3. Hydropower production

The SVM suggests that **Alternative C** increases the average annual spill from Rainy Lake, suggesting that a negative impact to hydropower is expected under this alternative, when compared to the 2000 Rule Curves.

**Table 7-9 Hydropower Spill Reduction under Alternative C**

	Alternative A 2000 Rule Curve (baseline)	Alternative C	Reference F 1970 Rule Curve
Reduction in Average Annual Spill	1.00	0.96	1.09

### 7.3.5 Archeological resources: Alternative C

**Alternative C** provides greater variability in water levels throughout the open-water period on both lakes. As a result, the SVM suggests that **Alternative C** offers an increase in protection to archeological sites on both lakes from erosion.

**Table 7-10 Archeological resources PI for Alternative C: protection of archeological sites from erosion**

	Alternative A 2000 Rule Curves (baseline)	Alternative C	Reference F 1970 Rule Curves
Namakan Lake	1.00	1.20	0.66
Rainy Lake	1.00	1.08	0.62



### 7.3.6 Aquatic vegetation: Alternative C

The IERM suggests that **Alternative C** results in some impacts to aquatic vegetation. For example:

- Hybrid Cattail invasion is worsened on Rainy Lake, resulting in a decrease in suitable habitat for Wild Rice;
- suitable habitat for wet meadows is increased and habitat for shrubby swamps is decreased on both lakes;
- suitable habitat for emergent plants is increased on Rainy Lake; and
- suitable habitat for low- and high-density submerged vegetation is decreased on both lakes.

#### 1. Wild Rice and Hybrid Cattails

The IERM suggests that **Alternative C** has almost no impact on the Hybrid Cattail invasion or Wild Rice growth on Namakan Lake (Figures 7-28a and 7-29a). On Rainy Lake, however, the cattail invasion is worsened throughout most of the modelled time series, resulting in a negative impact to Wild Rice under **Alternative C** (Figures 7-28b and 7-29b). However, it should be noted that a substantial increase in the probability of Muskrat over-winter survival on both lakes is expected to impede the expansion of Hybrid cattail, thereby increasing the amount of suitable area for Wild Rice. This interaction between Muskrat, Hybrid Cattail and Wild Rice is not captured by the IERM.

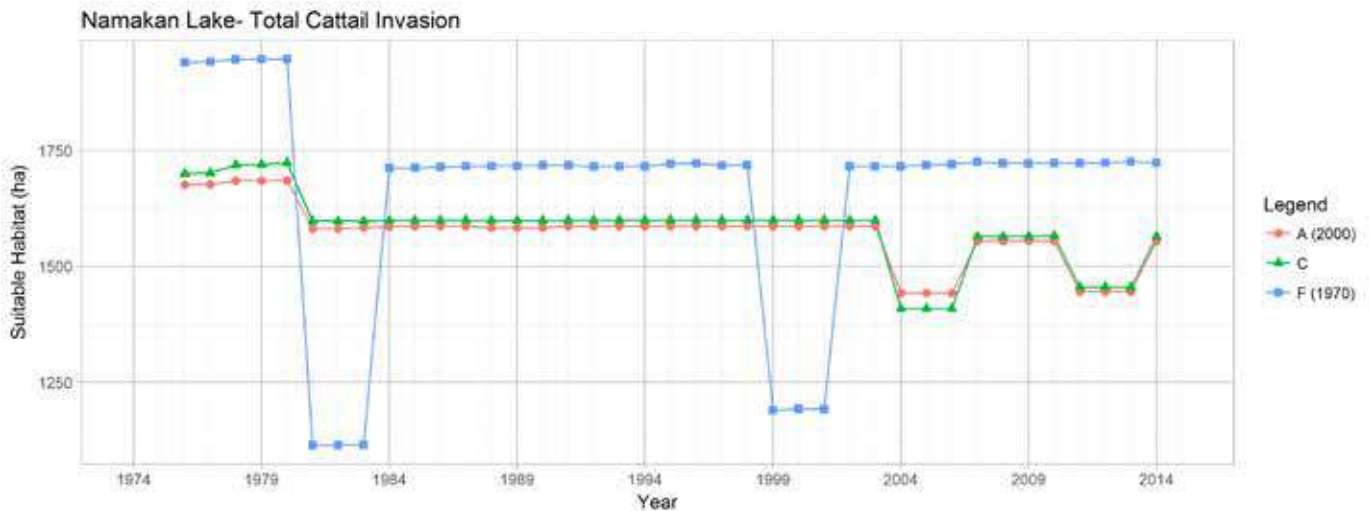


Figure 7-28a Area suitable for Hybrid Cattail invasion on Namakan Lake, Alternative C

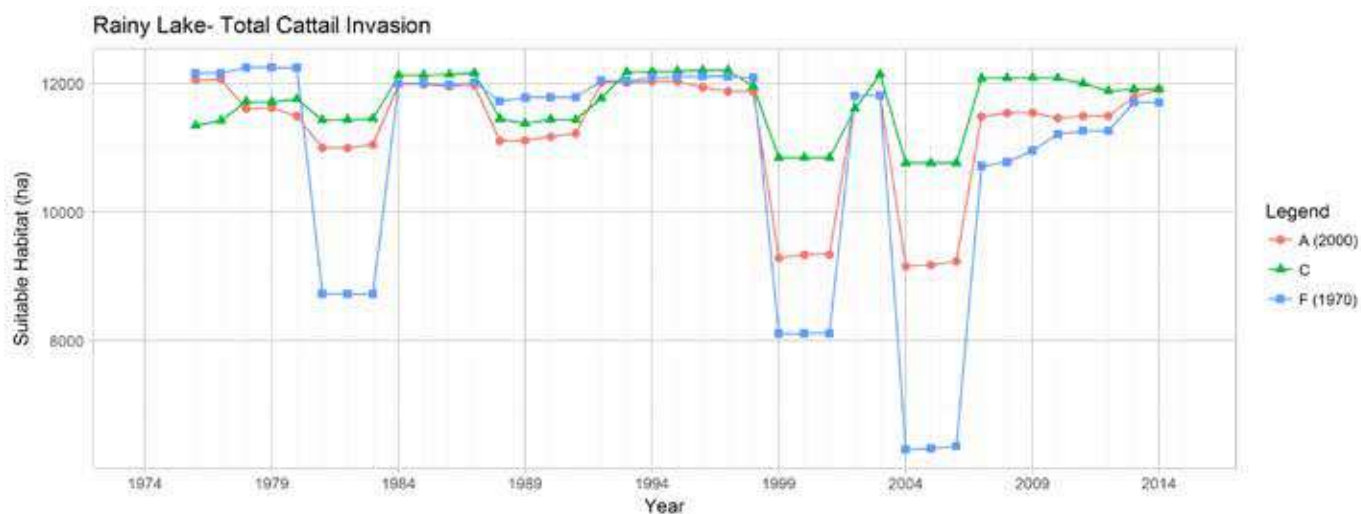


Figure 7-28b Area suitable for Hybrid Cattail invasion on Rainy Lake, Alternative C

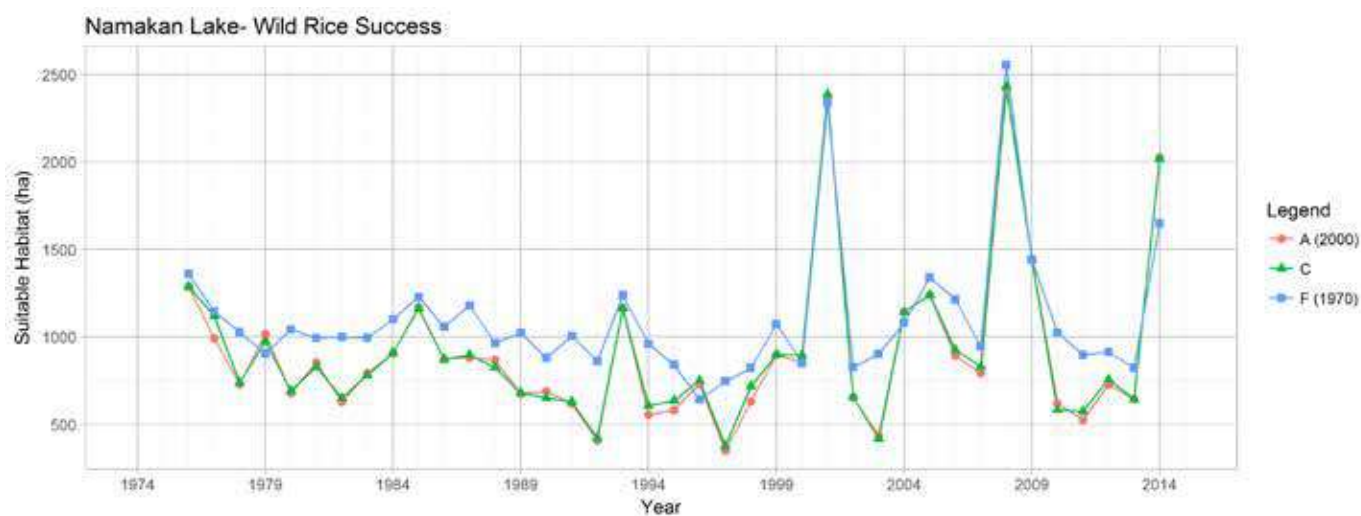


Figure 7-29a Area suitable for the successful growth of Wild Rice on Namakan Lake, Alternative C

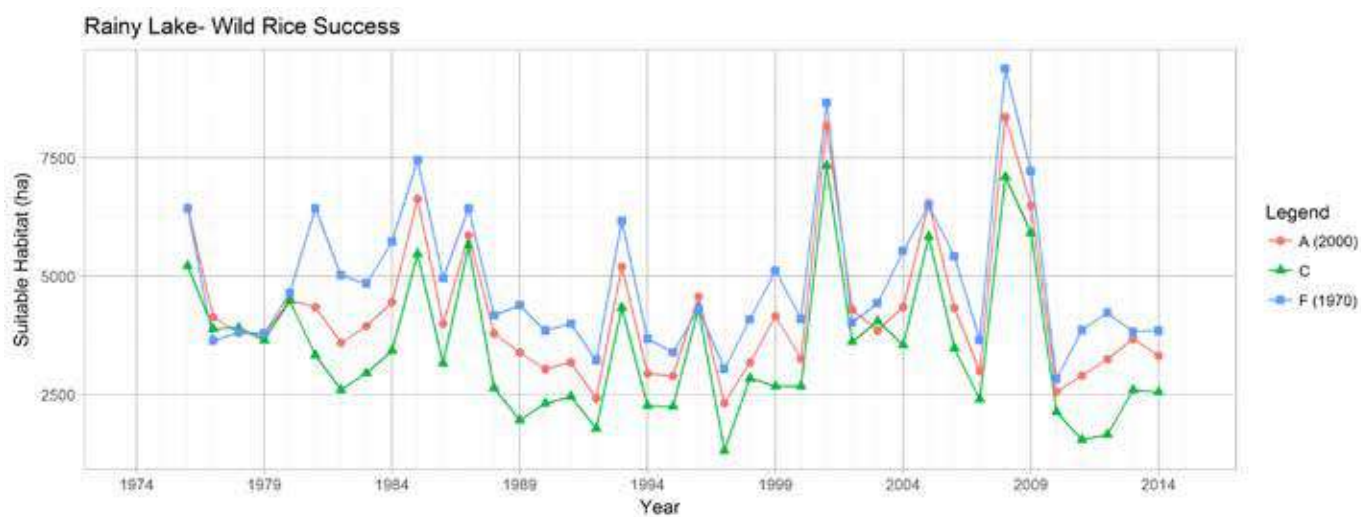


Figure 7-29b Area suitable for the successful growth of Wild Rice on Rainy Lake, Alternative C

## 2. Wet meadows and shrubby swamps

The IERM suggests that **Alternative C** results in an increase in wet meadows (Figures 7-30a and 7-30b) and decrease in shrubby swamps (Figures 7-31a and 7-31b) on both Namakan and Rainy Lakes. These wetland vegetation types are sensitive to the proportion of time an area is flooded and wet-dry cycles within a year. Shrubby swamps are located at higher elevations than wet meadows.

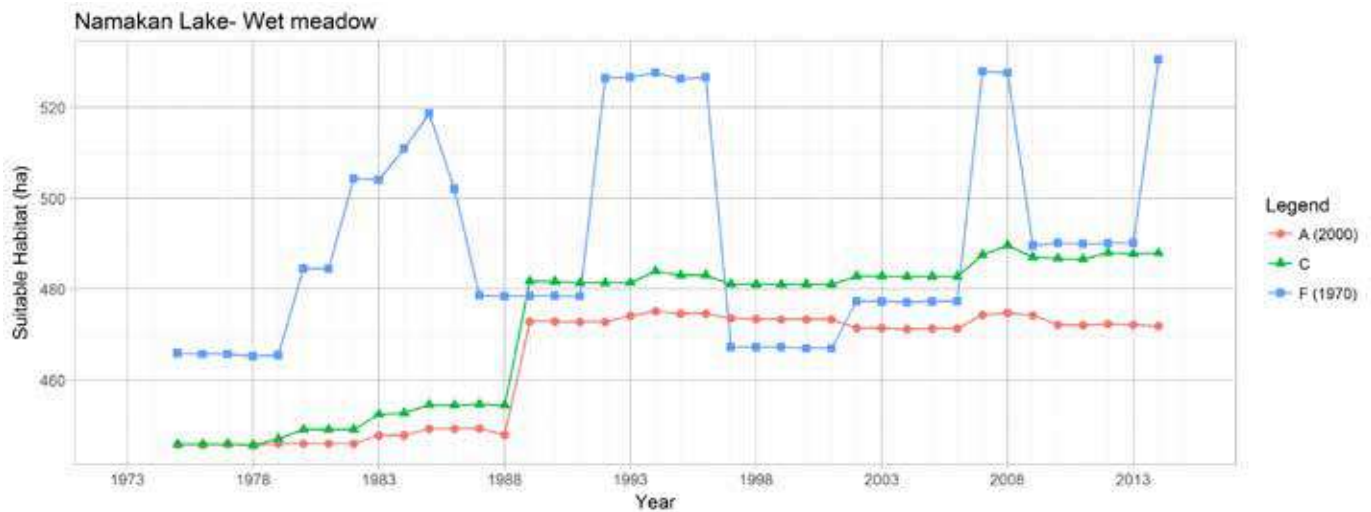


Figure 7-30a Area suitable for wet meadows on Namakan Lake, Alternative C

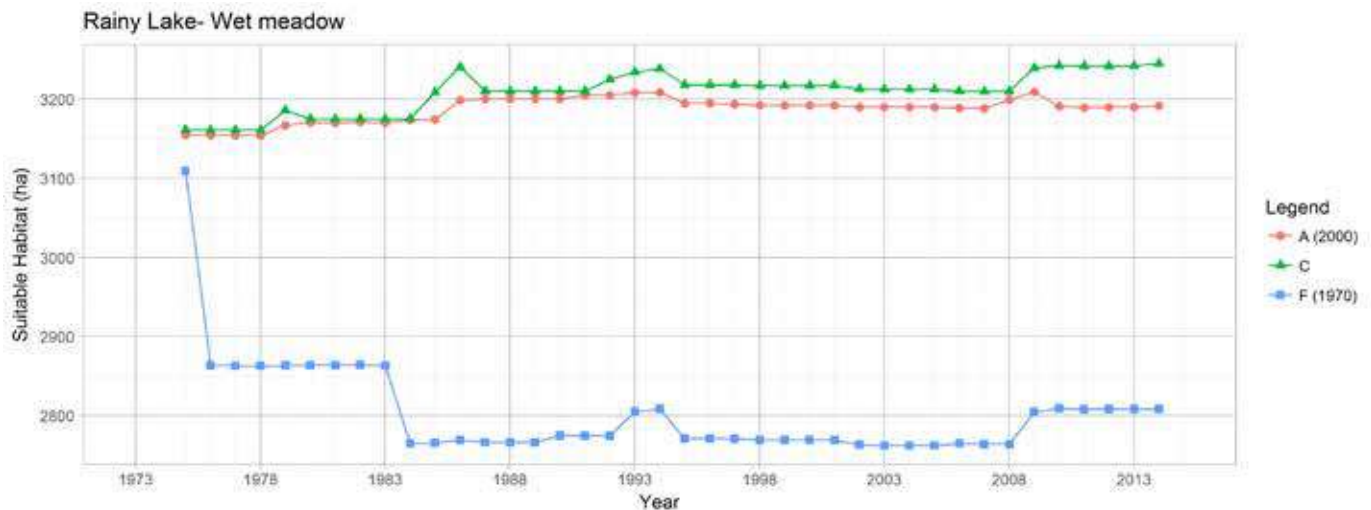


Figure 7-30b Area suitable for wet meadows on Rainy Lake, Alternative C

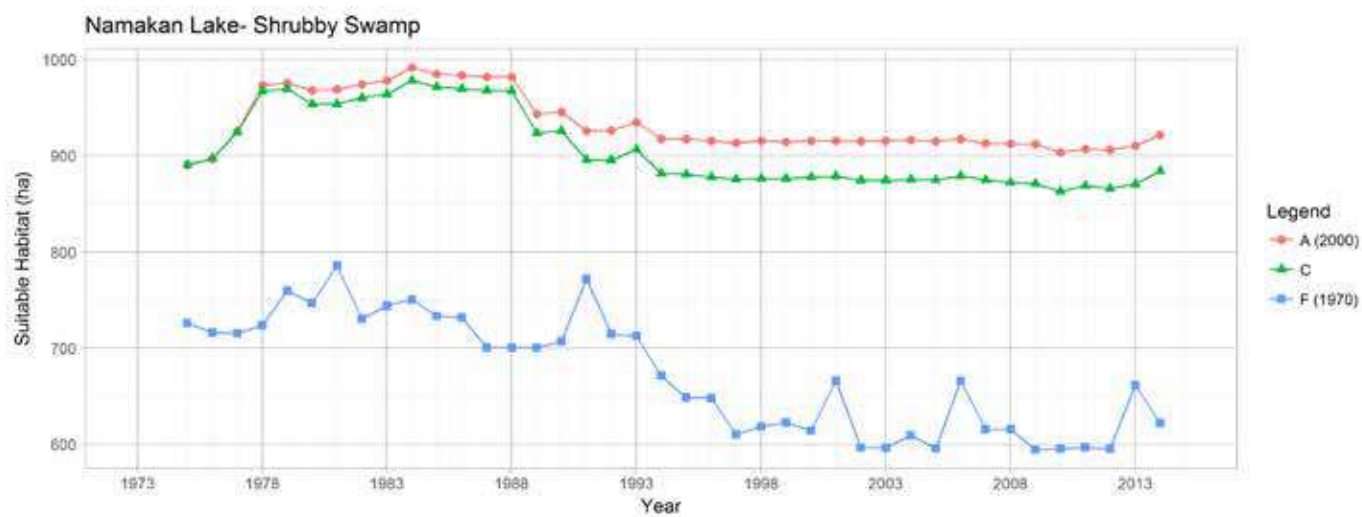


Figure 7-31a Area suitable for shrubby swamps on Namakan Lake, Alternative C

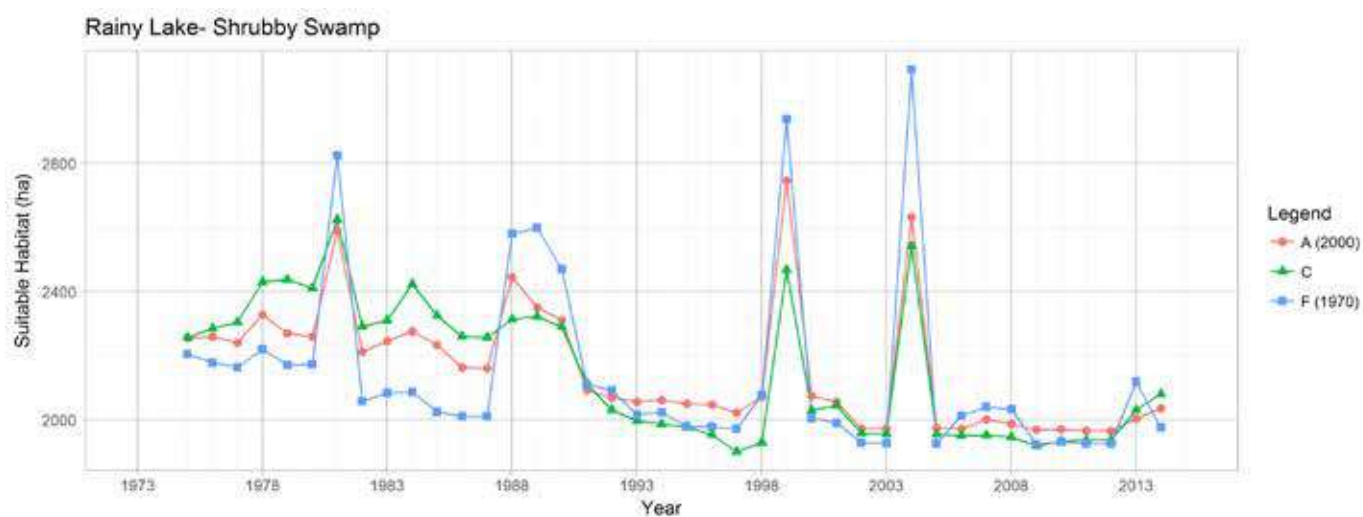


Figure 7-31b Area suitable for shrubby swamps on Rainy Lake, Alternative C

### 3. Emergent plants

The IERM suggests that **Alternative C** results in similar conditions for emergent plants on Namakan Lake (Figure 7-32a) when compared to the 2000 Rule Curve, and an increase in the amount of suitable habitat on Rainy Lake (Figure 7-32b). The steepened summer drawdown on Rainy Lake provided by **Alternative C** means that areas that previously supported submerged vegetation spend less time under water and become more suited to emergent plants.

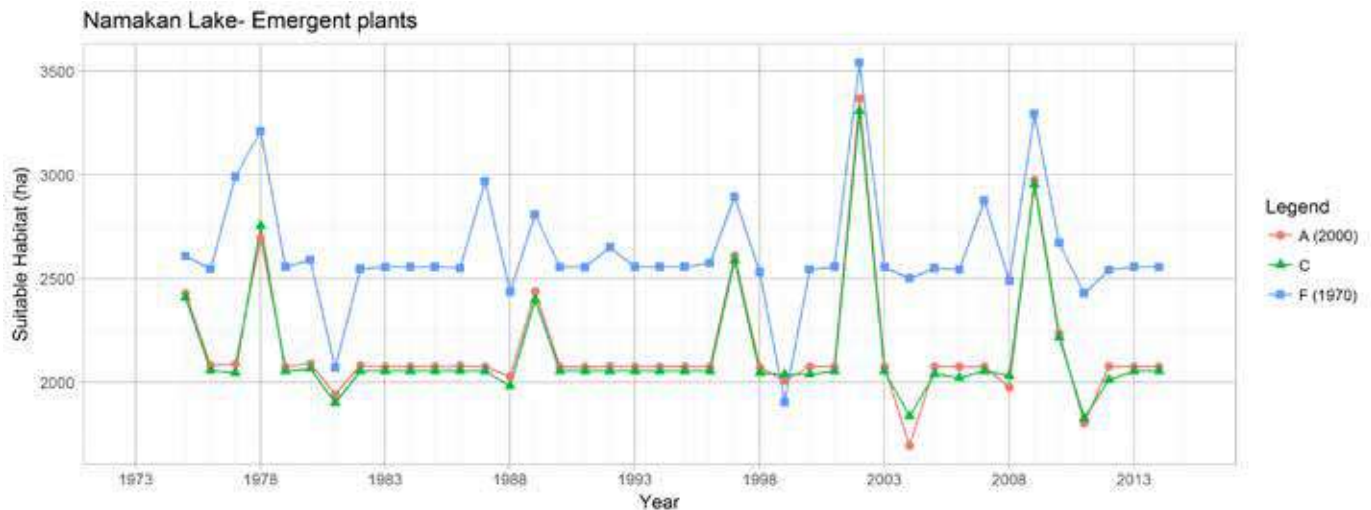


Figure 7-32a Area suitable for emergent plants on Namakan Lake, Alternative C

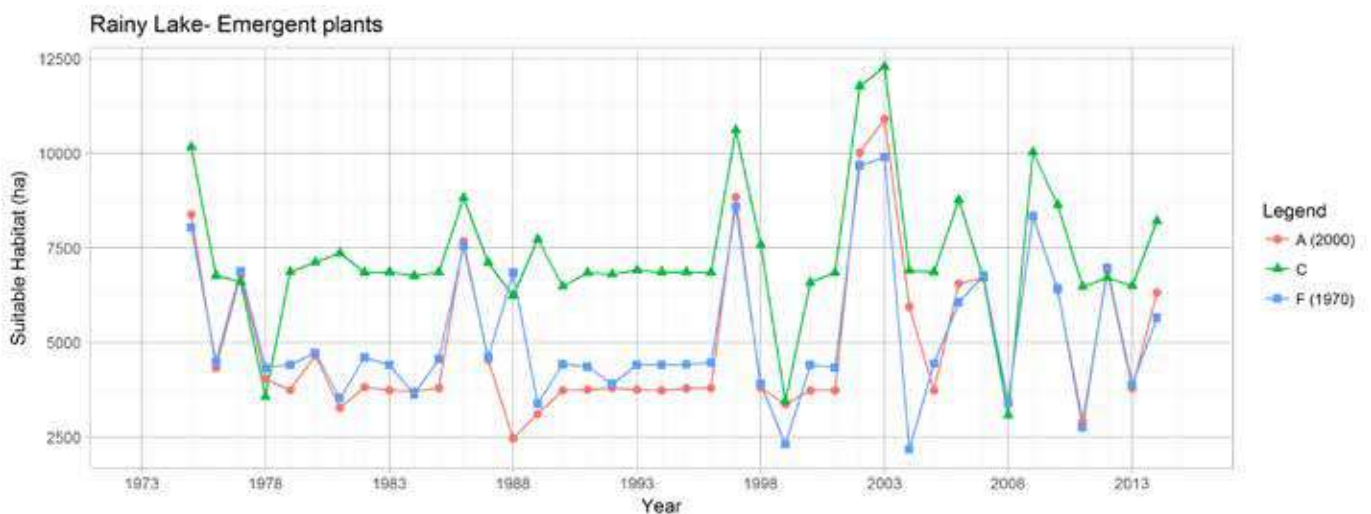


Figure 7-32b Area suitable for emergent plants on Rainy Lake, Alternative C

### 4. Submerged vegetation

Under **Alternative C**, the IERM predicts that the amount of habitat for low- and high-density vegetation would decrease on both Namakan and Rainy Lakes in most years.



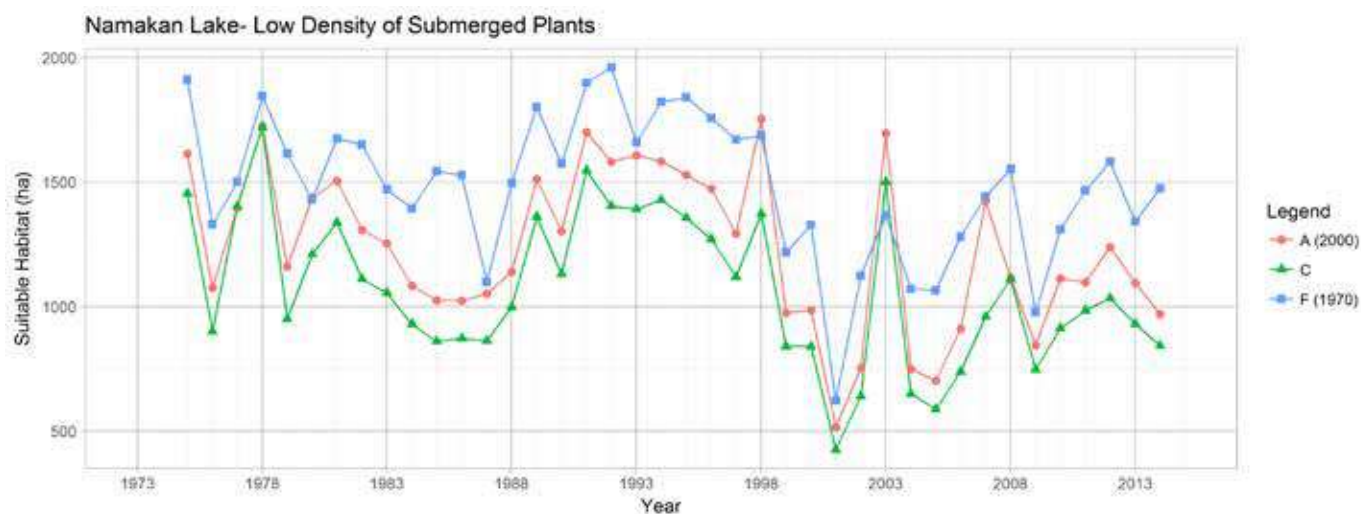


Figure 7-33a Area suitable for low-density submerged plants on Namakan Lake, Alternative C

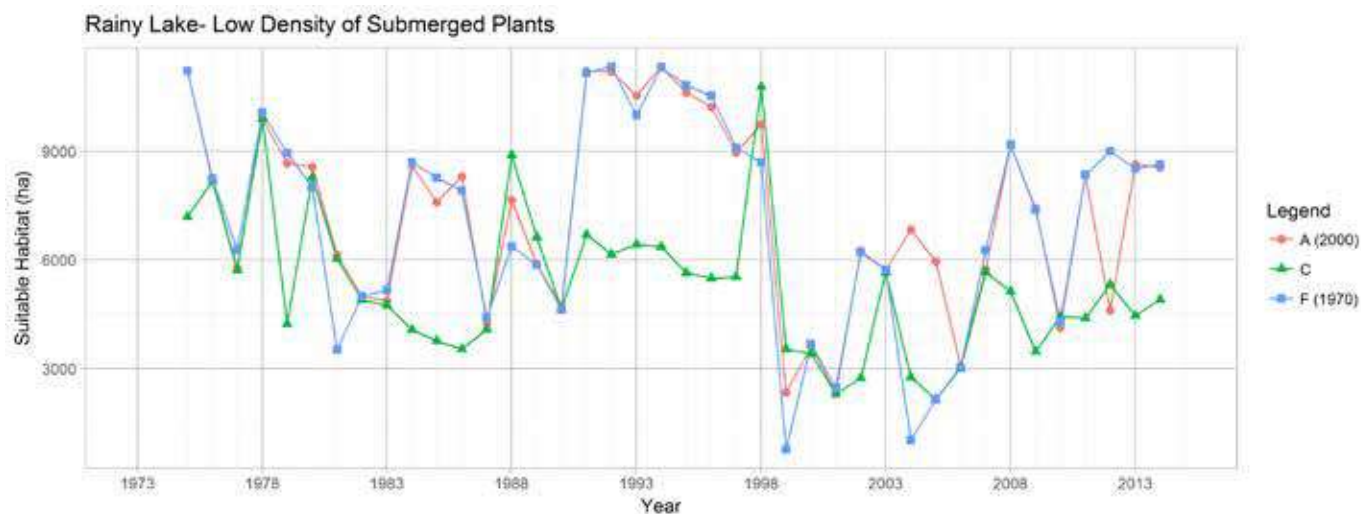


Figure 7-33b Area suitable for low-density submerged plants on Rainy Lake, Alternative C

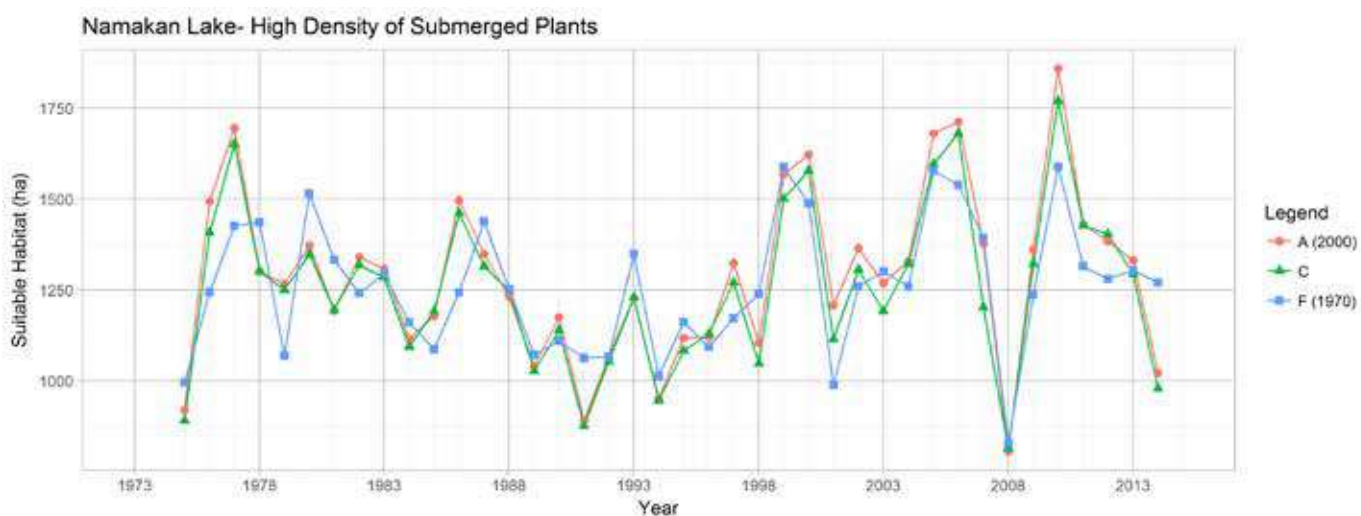


Figure 7-34a Area suitable for high-density submerged plants on Namakan Lake, Alternative C

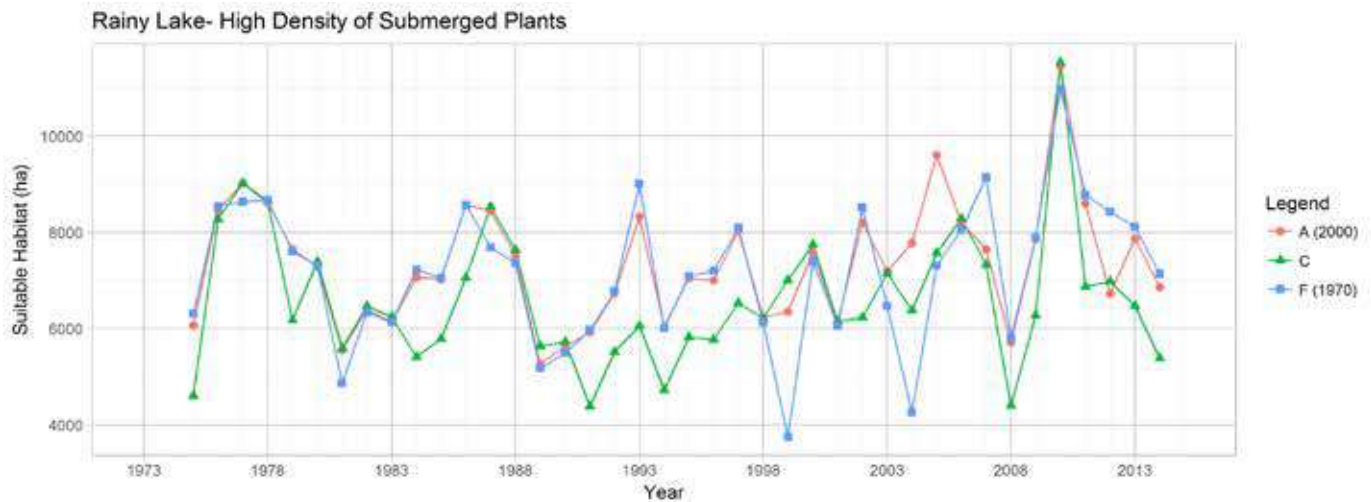


Figure 7-34b Area suitable for high-density submerged plants on Rainy Lake, Alternative C

### 7.3.7 Rainy River: Alternative C

The IERM suggests that the amount of suitable habitat for Walleye (Figure 7-35) and Lake Sturgeon spawning (Figure 7-36) on Rainy River remains relatively unchanged under **Alternative C**, when compared to the 2000 Rule Curve.

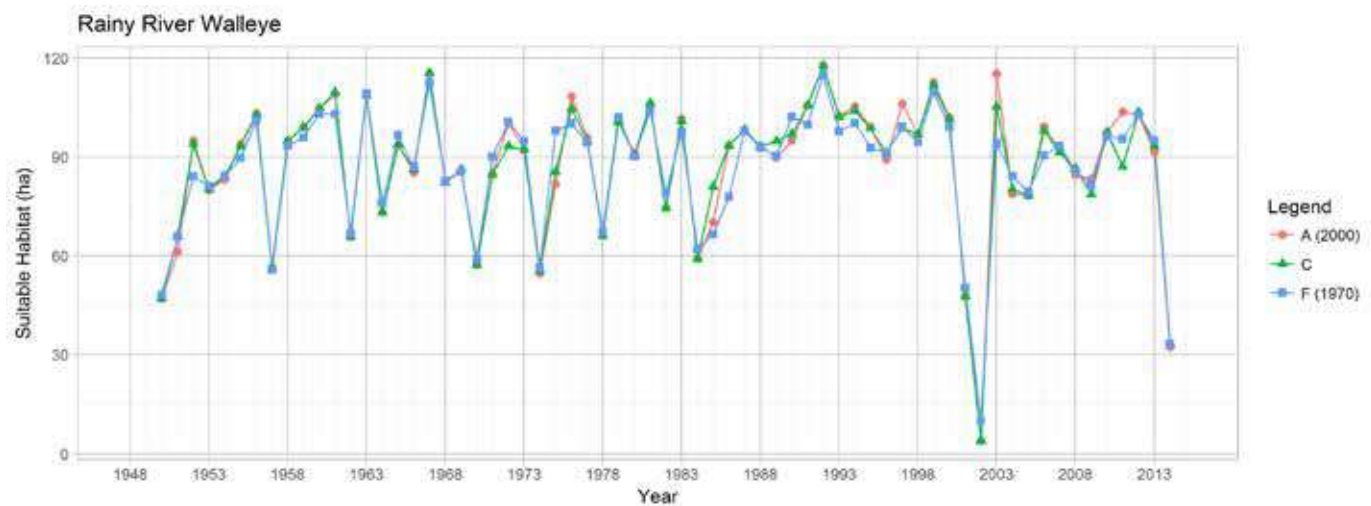


Figure 7-35 Area suitable for Walleye spawning on Rainy River, Alternative C

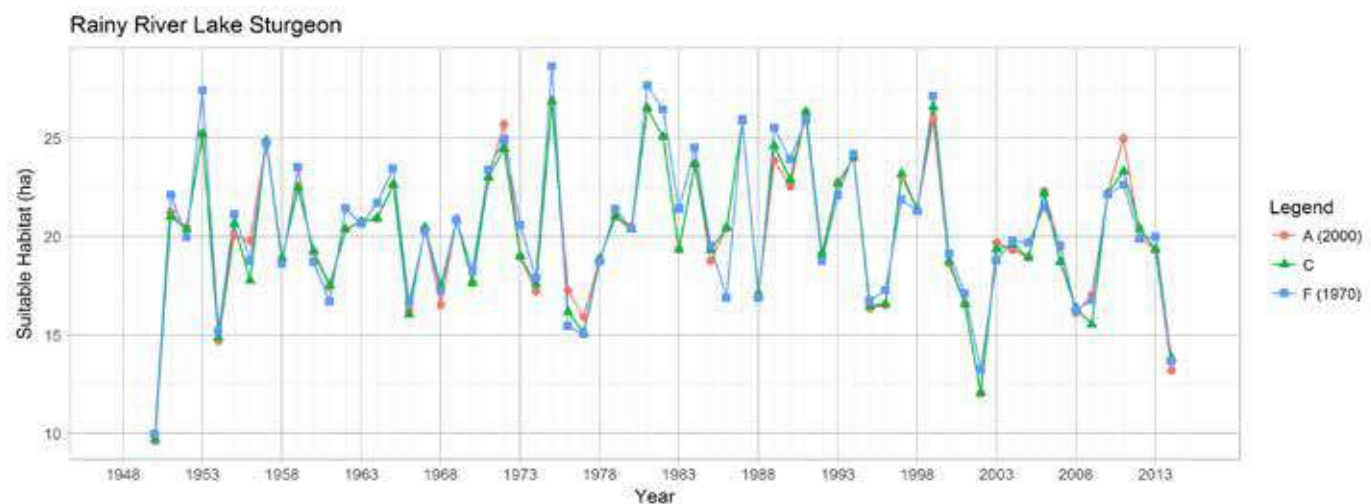


Figure 7-36 Area suitable for Lake Sturgeon spawning on Rainy River, Alternative C

## 7.4 Alternative D: Hybrid 1970-2000 Rule Curves for Namakan Lake

### 7.4.1 Overview

#### Objective

This alternative provides stable level targets on Namakan Lake from June 1 to October 1, similar to the 1970 Rule Curve (*i.e.*, eliminates gradual summer drawdown), but retains the 2000 Rule Curve for the remainder of the year. No modifications are made to the 2000 Rule Curve for Rainy Lake.

#### Key features

This alternative was expected to provide the following benefits:

- provide Rainy Lake with additional flood protection in late spring and early summer by reducing discharge from Namakan Lake while Rainy Lake is still refilling; and
- improve navigation over the summer period on Namakan Lake by maintaining a higher lake level throughout the boating season.

#### Summary of model results

Model results indicate that **Alternative D** does not provide the intended level of flood reduction benefits on Rainy Lake and that it reverses some benefits gained by 2000

Rule Curve summer drawdown on Namakan Lake, as discussed in **Chapter 5**.

### 7.4.2 Fish: Alternative D

The IERM is able to model the impact of water levels on Walleye, Northern Pike and Lake Whitefish spawning. It is expected that an increase in the likelihood of successful spawning periods over several years would result in an increase in recruitment. Based on this assumption, IERM model results suggest that **Alternative D** results in:

- no change in Walleye production in most years on either lake;
- an increase in Northern Pike spawning habitat on Namakan Lake (though the extent remains extremely low) and no change on Rainy Lake; and
- a minor decrease in Lake Whitefish production in most years on Namakan Lake and small changes (both positive and negative) on Rainy Lake.

#### 1. Walleye

As shown in Figures 7-37a to 7-38b, the IERM suggests that **Alternative D** does not produce any change to the likelihood of Walleye eggs survival or the extent of suitable habitat for Walleye spawning on either lake when compared to the 2000 Rule Curves.

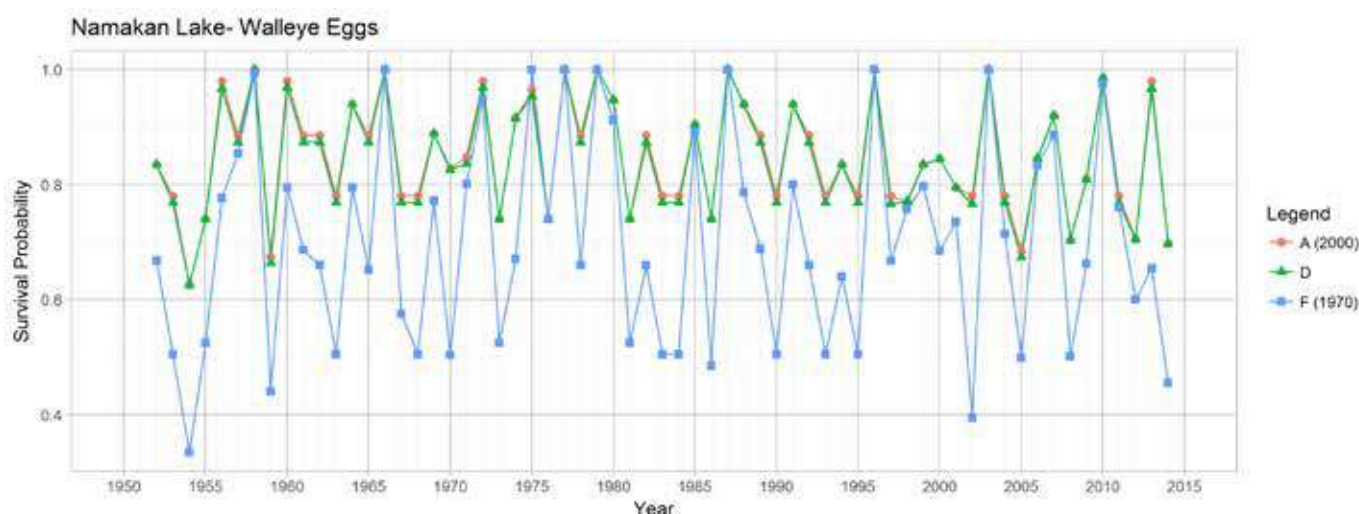


Figure 7-37a Probability of Walleye egg survival on Namakan Lake, Alternative D

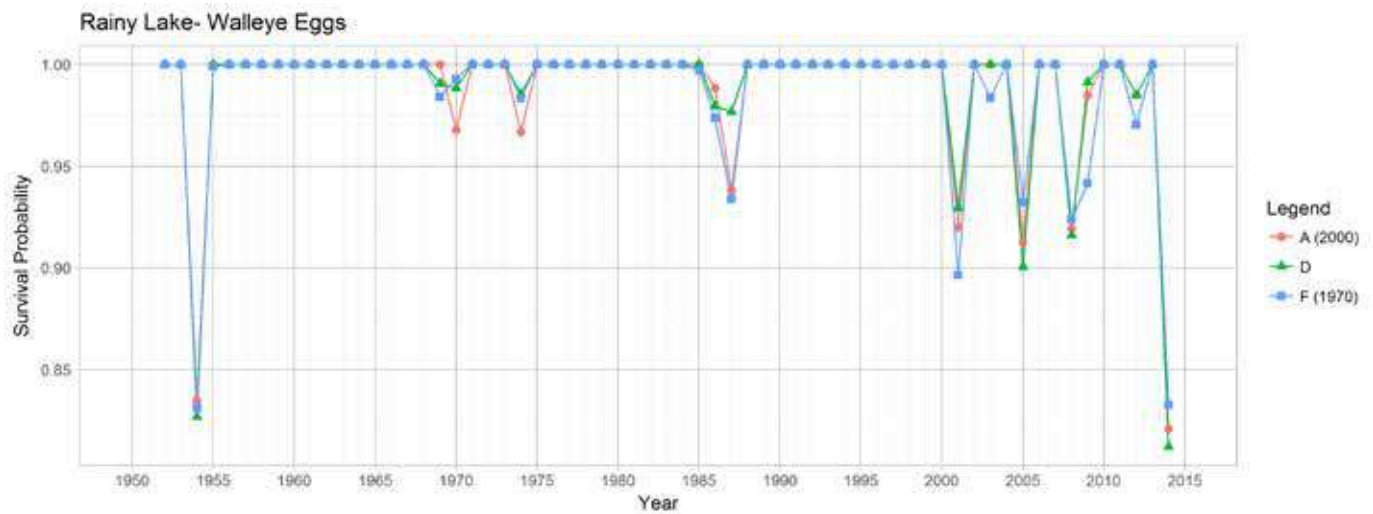


Figure 7-37b Probability of Walleye egg survival on Rainy Lake, Alternative D

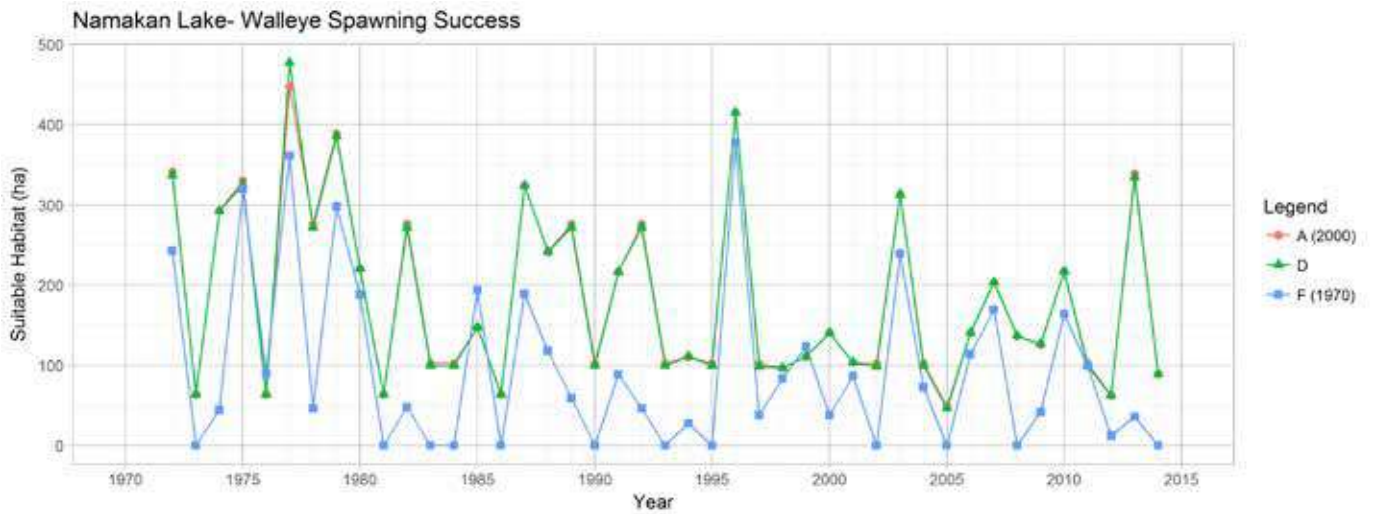


Figure 7-38a Area of suitable habitat for successful Walleye spawning on Namakan Lake, Alternative D

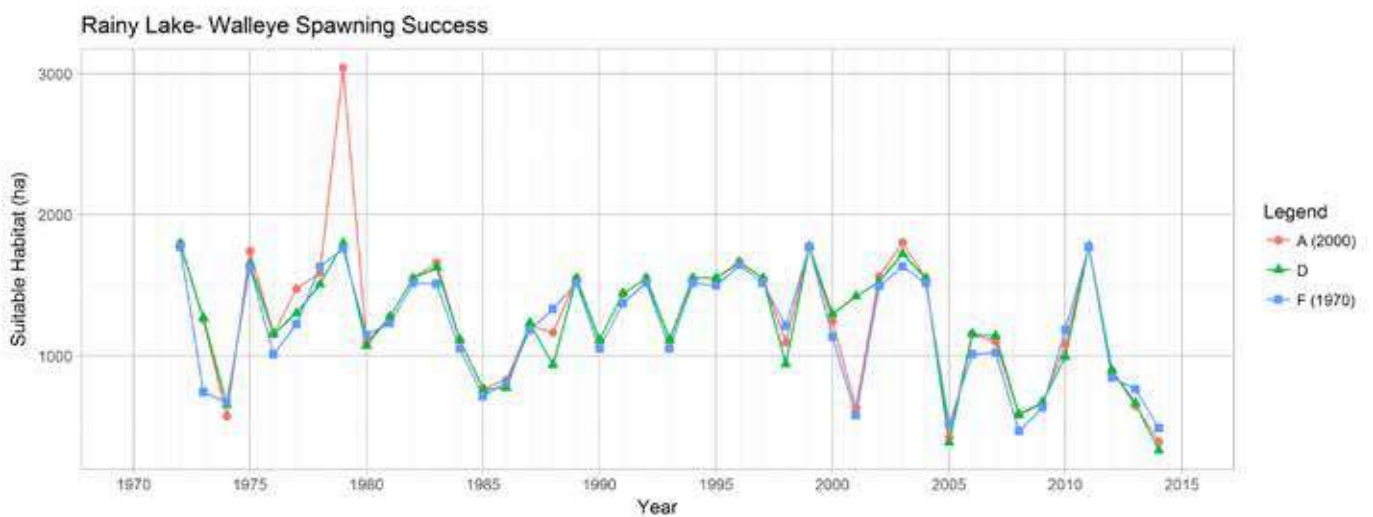


Figure 7-38b Area of suitable habitat for successful Walleye spawning on Rainy Lake, Alternative D



## 2. Northern Pike

Figure 7-39a indicates that the IERM predicts an increase in the amount of Northern Pike spawning habitat on Namakan Lake under **Alternative D** when compared to the 2000 Rule Curve. Nevertheless, suitable high-quality habitat area remains extremely low and continues to be the limiting factor in Northern Pike production in Namakan and Rainy Lakes.

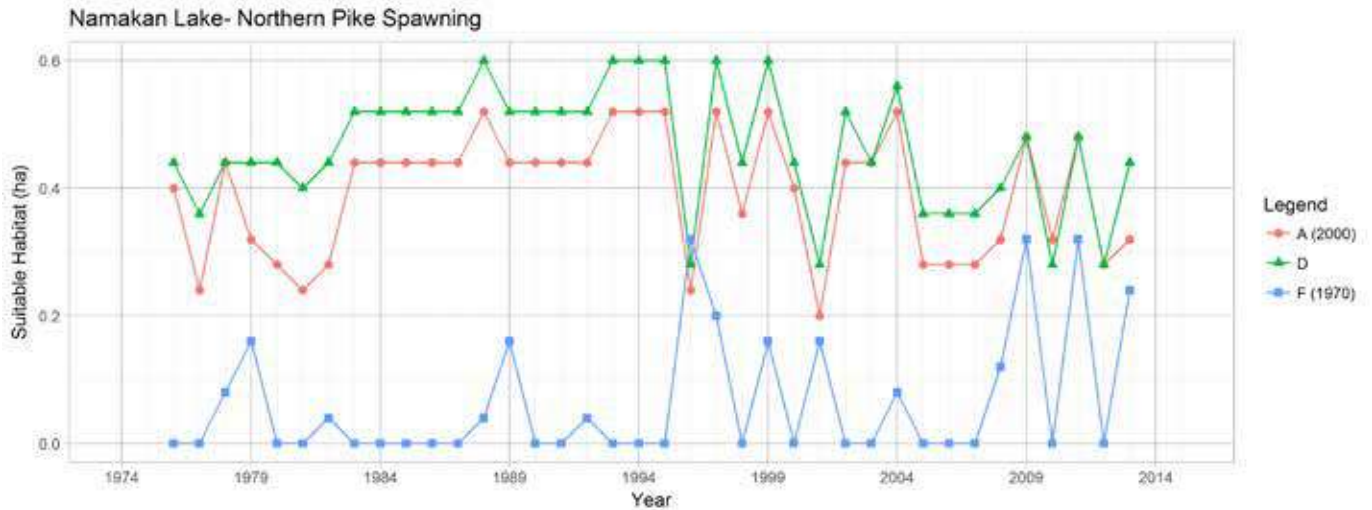


Figure 7-39a Area of suitable habitat for Northern Pike spawning on Namakan Lake, Alternative D

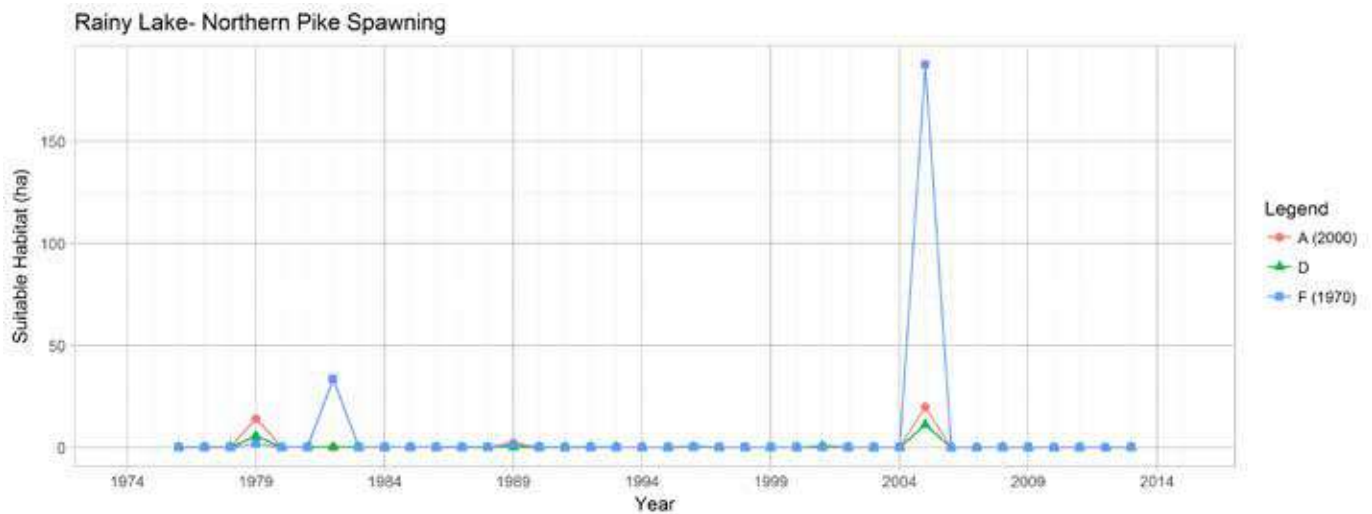


Figure 7-39b Area of suitable habitat for Northern Pike spawning on Rainy Lake, Alternative D



The IERM predicts that in many years **Alternative D** produces less suitable habitat for Northern Pike larva on Namakan Lake when compared to the 2000 Rule Curve (Figure 7-40a). The amount of habitat on Rainy Lake is unchanged (Figure 7-40b).

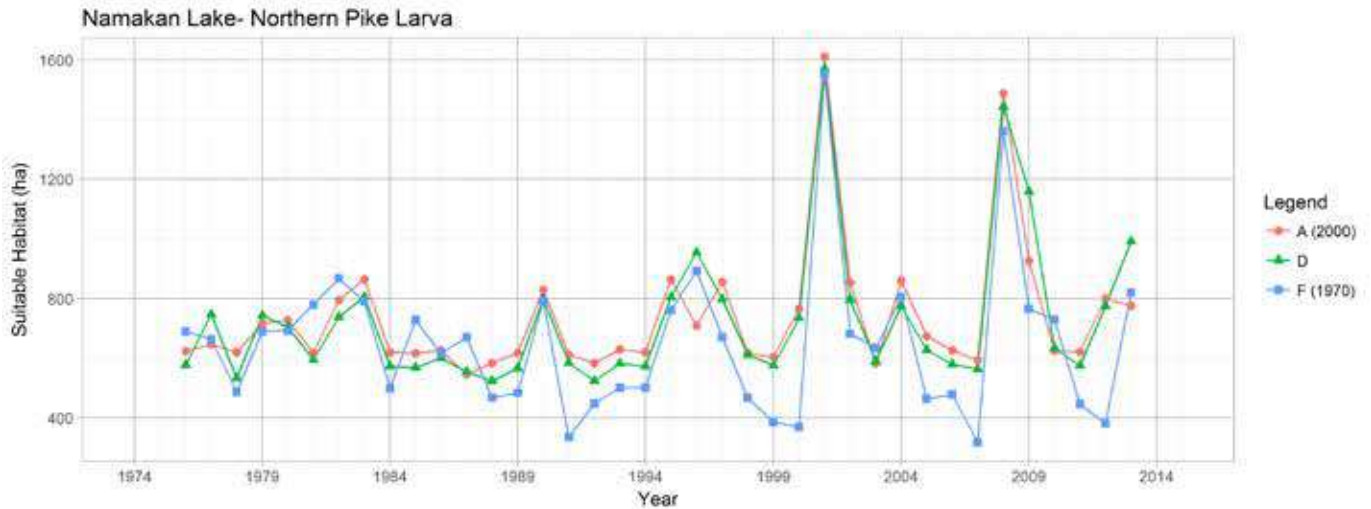


Figure 7-40a Area of suitable habitat for Northern Pike larval survival on Namakan Lake, Alternative D

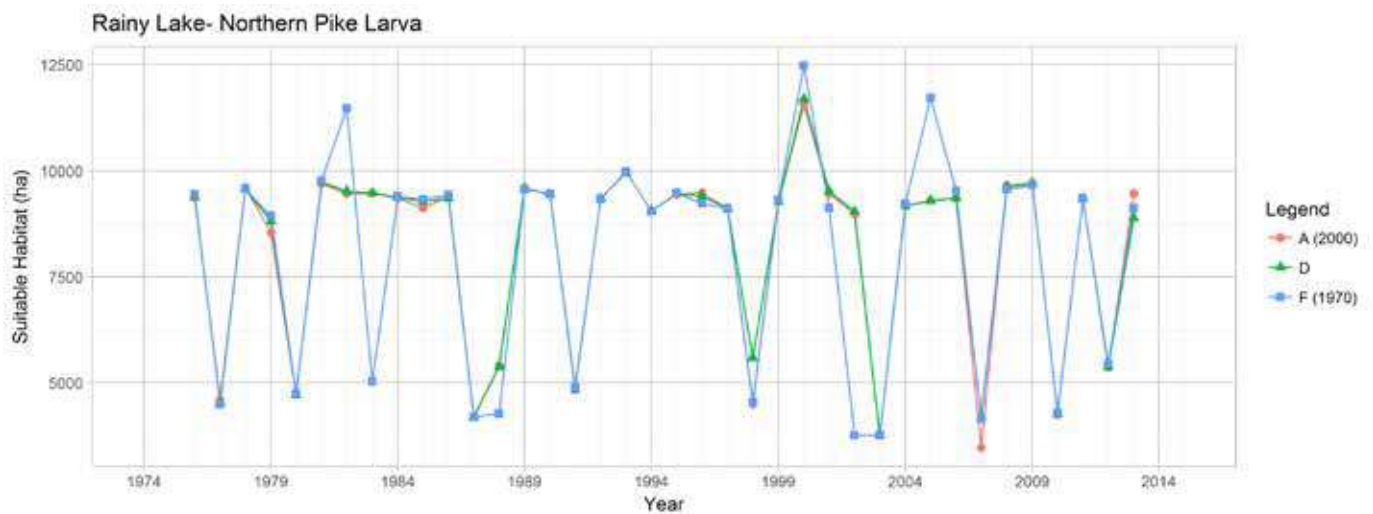


Figure 7-40b Area of suitable habitat for Northern Pike larval survival on Rainy Lake, Alternative D

The IERM predicts that in many years **Alternative D** produces less suitable habitat for Northern Pike YoY on Namakan Lake when compared to the 2000 Rule Curve (Figure 7-41a). The amount of habitat on Rainy Lake is unchanged (Figure 7-41b).

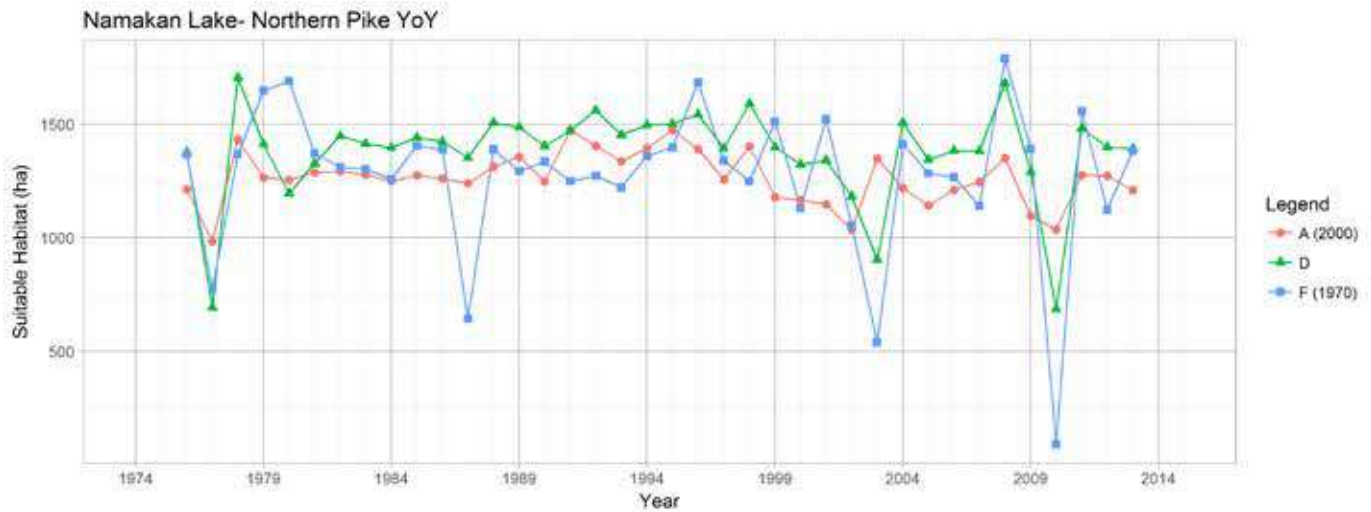


Figure 7-41a Area of suitable habitat for Northern Pike YoY on Namakan Lake, Alternative D

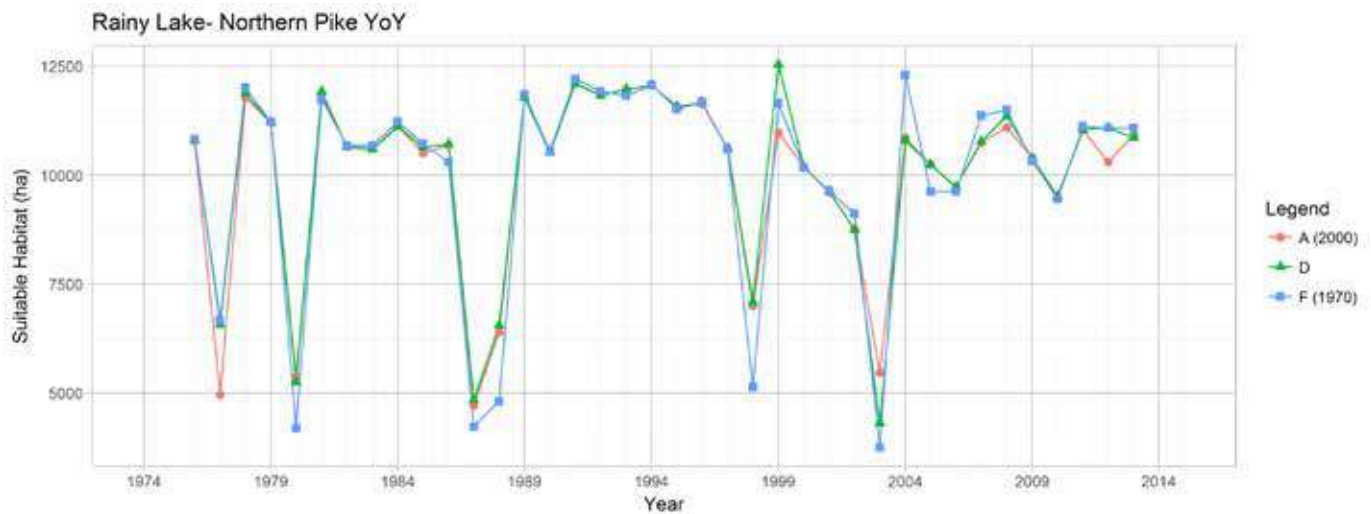


Figure 7-41b Area of suitable habitat for Northern Pike YoY on Rainy Lake, Alternative D

### 3. Lake Whitefish

As **Alternative D** does not impact water levels during the Lake Whitefish spawning and incubation period (mid-November to a few weeks after ice-out), the likelihood of survival of Lake Whitefish eggs on Namakan and Rainy Lakes is effectively unchanged compared to the 2000 Rule Curves.

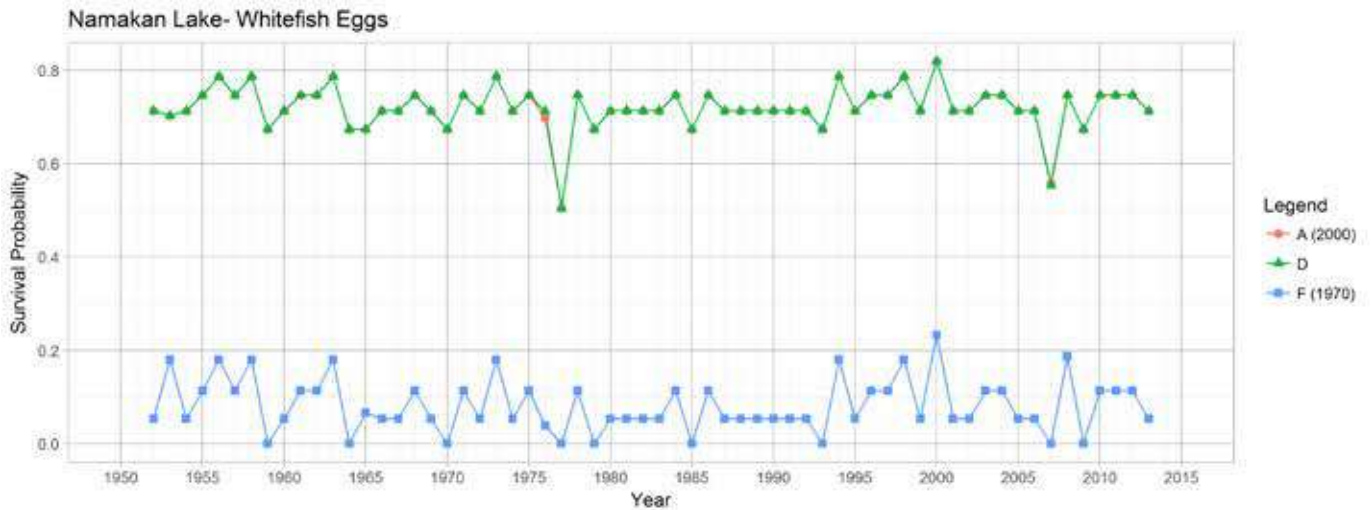


Figure 7-42a Probability of Lake Whitefish egg survival on Namakan Lake, Alternative D

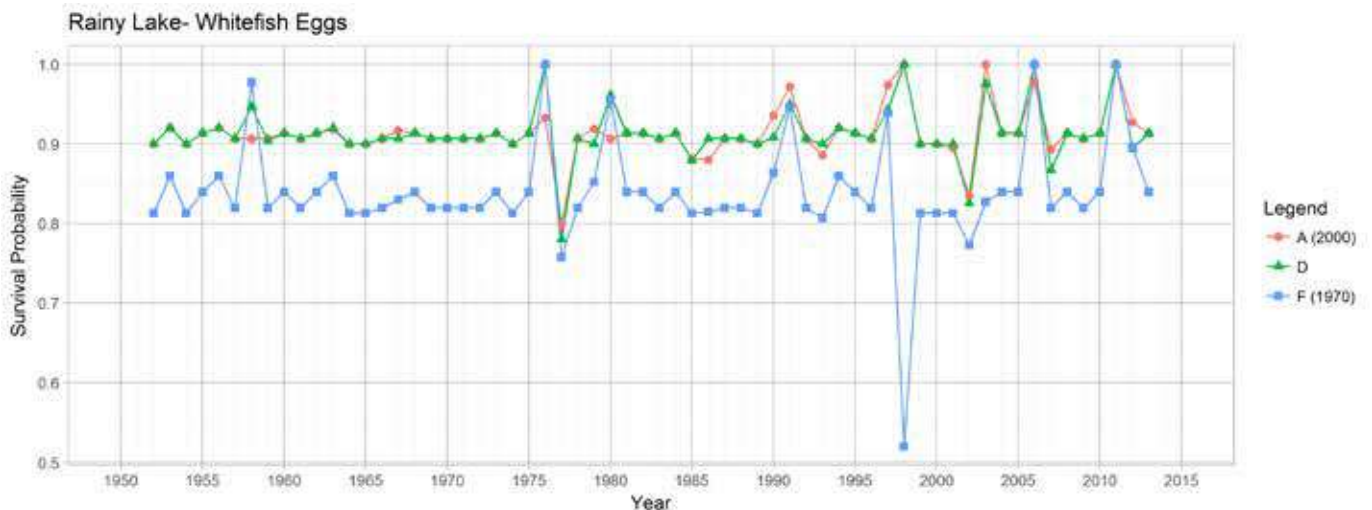


Figure 7-42b Probability of Lake Whitefish egg survival on Rainy Lake, Alternative D

The IERM suggests that the area of suitable habitat for Lake Whitefish spawning is decreased in some years on Namakan Lakes (Figure 7-43a). These small variations from the 2000 Rule Curves are likely due to the stabilization of water levels over the summer period, resulting in fewer substrate beds (used for spawning) at various elevations being cleaned by wave action.

On Rainy Lake, the amount of suitable habitat for Lake Whitefish spawning shows small deviations, both positive and negative, from the 2000 Rule Curve in some years (Figure 7-43b).

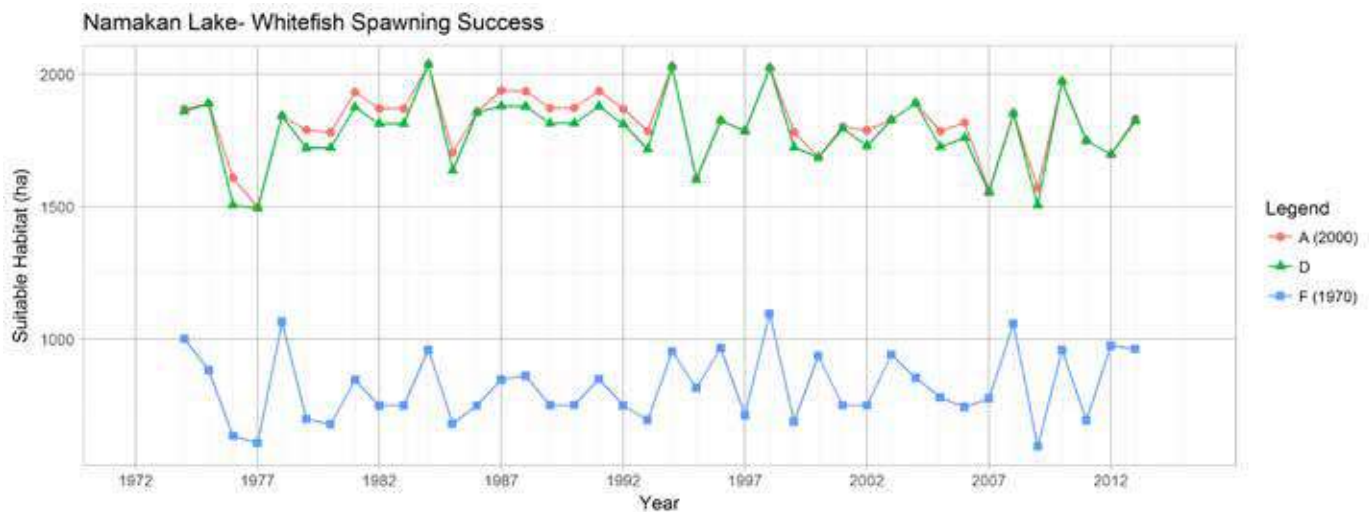


Figure 7-43a Area of suitable habitat for successful Lake Whitefish spawning on Namakan Lake, Alternative D

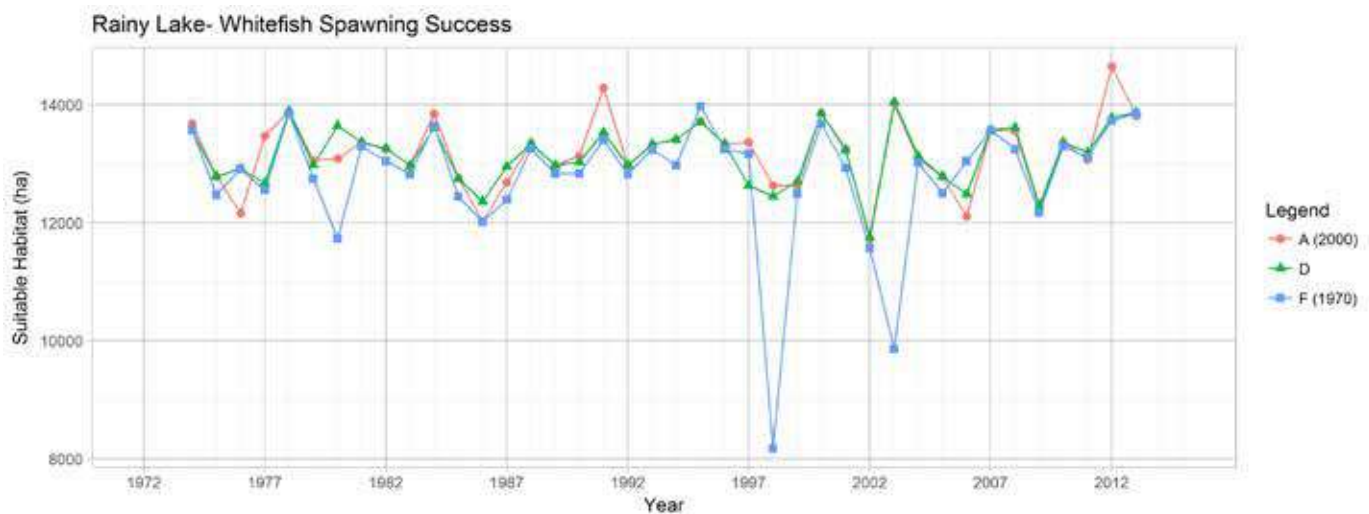


Figure 7-43b Area of suitable habitat for successful Lake Whitefish spawning on Rainy Lake, Alternative D

### 7.4.3 Wildlife: Alternative D

The IERM suggests that **Alternative D** results in small impacts in some years on wildlife on both Namakan and Rainy Lakes, including:

- occasional decreases in loon nest viability on Namakan Lake, with an increase in viability in the same years on Rainy Lake; and
- no change in the conditions to Muskrats on Namakan Lake and a reduction in the likelihood of over-winter survival on Rainy Lake in some years.

#### 1. Common Loon

The IERM suggests that **Alternative D** results in no change to probability of Common Loon nest viability on Namakan Lake in most years, though years with low probability are amplified when compared to the 2000 Rule Curve (Figure 7-44a). This is the result of increased flooding during the nesting season that results when keeping Namakan Lake steady throughout the nesting season. In years where loons on Namakan Lake are negatively affected, loons on Rainy Lake see an increase in the probability of nest viability as flood peaks are reduced by holding water back in Namakan Lake (Figure 7-44b).

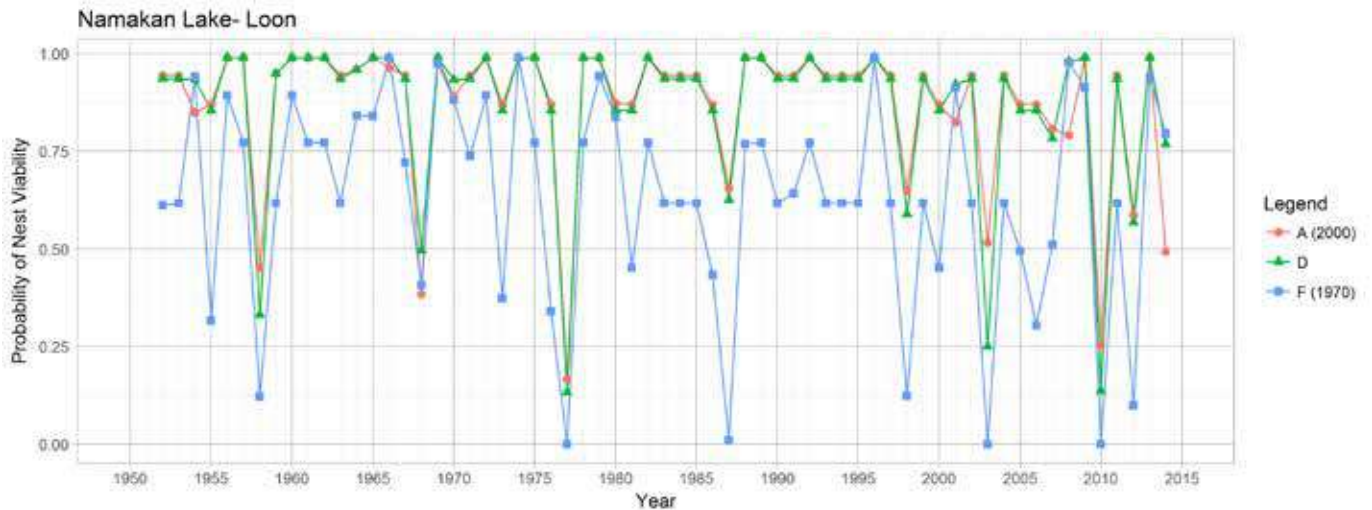


Figure 7-44a Probability of Common Loon nest viability on Namakan Lake, Alternative D

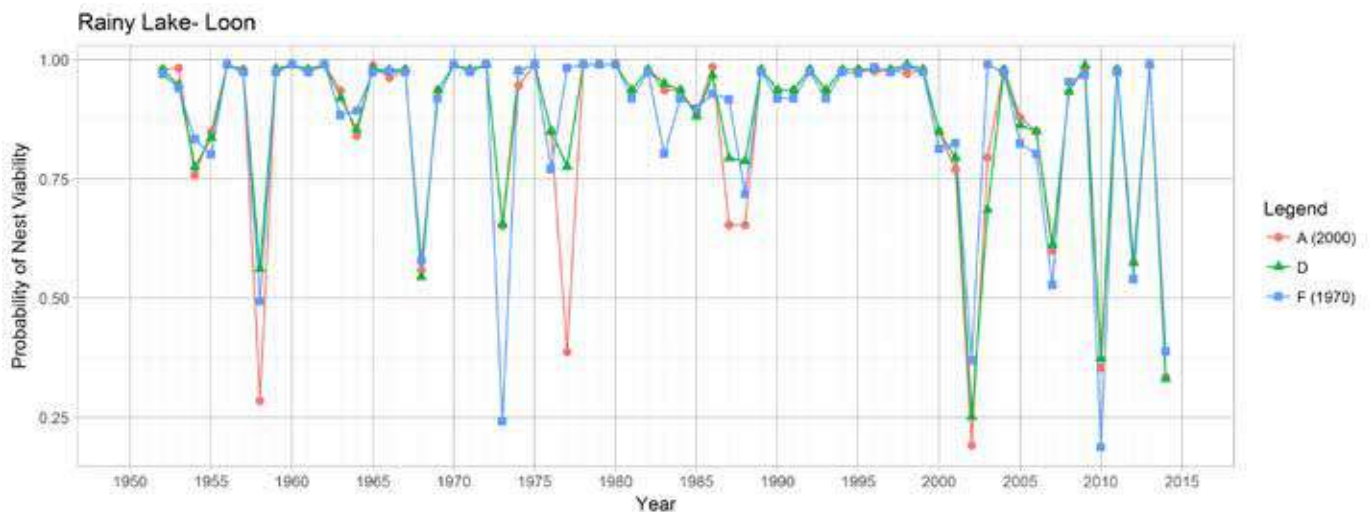


Figure 7-44b Probability of Common Loon nest viability on Rainy Lake, Alternative D



## 2. Muskrats

Figure 7-45a shows that the probability of Muskrat over-winter survival on Namakan Lake remains at zero under **Alternative D**. On Rainy Lake, however, the probability of survival is reduced in some years (Figure 7-45b). This can be explained by the impact of the change in Namakan Lake releases to Rainy Lake under this alternative. As water is held back in Namakan Lake over the summer, more water must be released in the fall in order to achieve the steeper drawdown. This results in higher fall water levels on Rainy Lake, when Muskrats are building their lodges, and therefore a greater difference between the fall and spring Rainy Lake water levels. As a result, the IERM predicts a greater likelihood of Muskrat lodge failure under **Alternative D**.

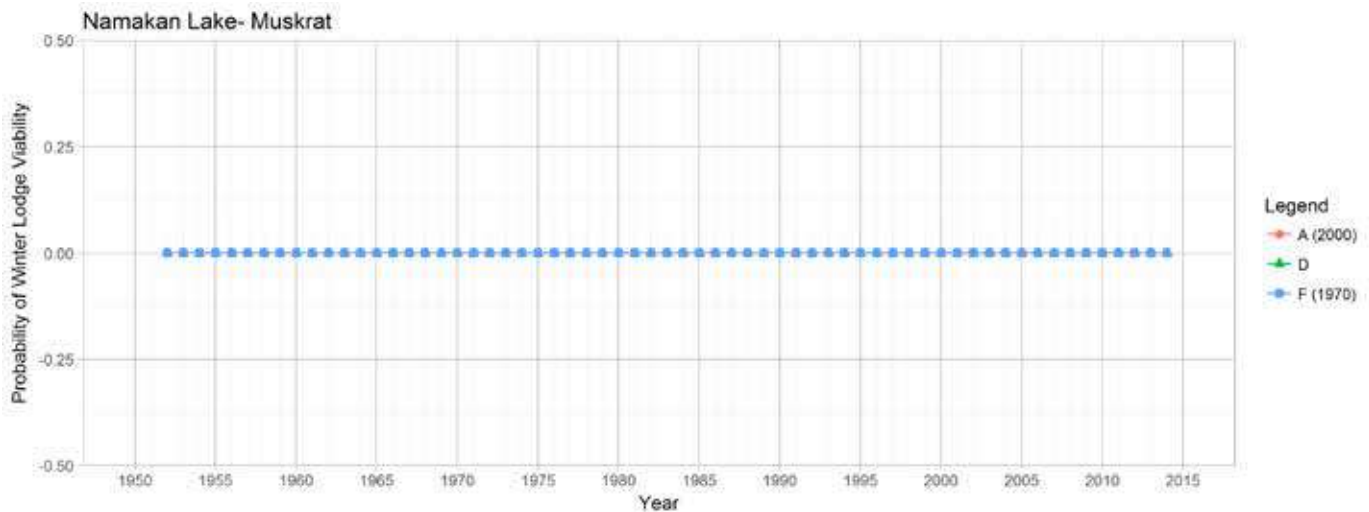


Figure 7-45a Probability of Muskrat winter lodge viability on Namakan Lake, Alternative D

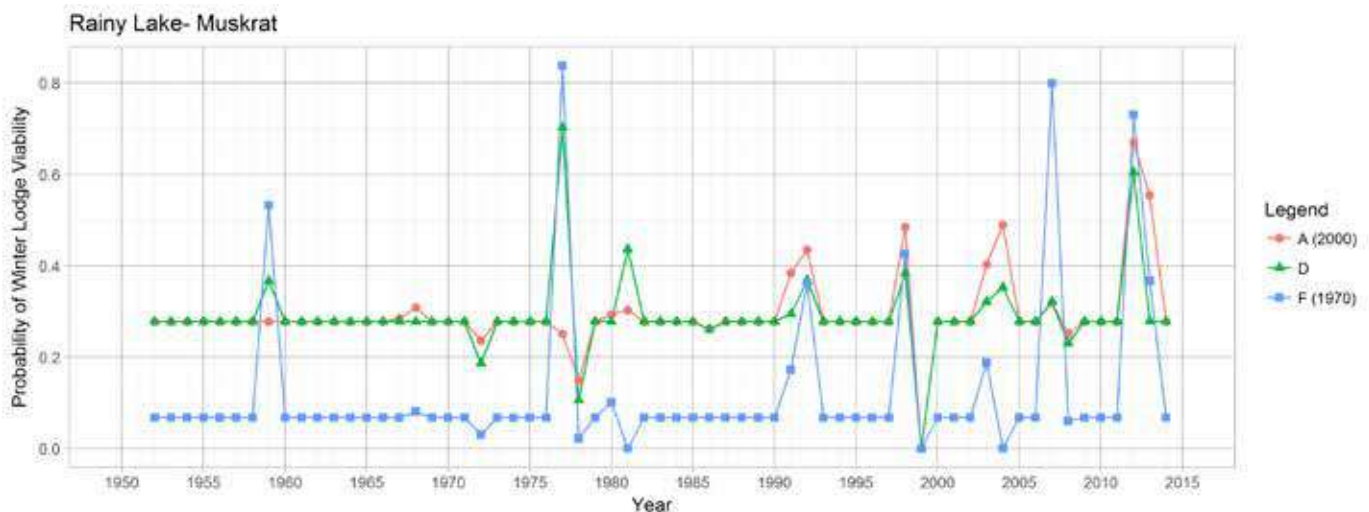


Figure 7-45b Probability of Muskrat winter lodge viability on Rainy Lake, Alternative D

#### 7.4.4 Economy: Alternative D

The SVM suggests that **Alternative D** has relatively minor economic impacts when compared to the 2000 Rule Curves. These include:

- an increase in average annual flood damage on Namakan Lake and a decrease on Rainy Lake;
- an improvement to the late-season boating conditions on Namakan Lake; and
- a small decrease in average annual spill from Rainy Lake.

##### 1. Flood damages

**Alternative D** provides a minor increase in flood damages on Namakan Lake (as indicated by the negative value in Table 7-7) and a minor decrease in flood damages on Rainy Lake. This rule curve alternative provides no additional protection from major events, such as the 1950 and 2014 events, to Namakan or Rainy Lakes when compared to the 2000 Rule Curves.

**Table 7-11 Flood damage reduction for Alternative D**  
(net reductions in damages compared to 2000 Rule Curves, in \$,000)

	<b>Alternative A 2000 Rule Curves (baseline)</b>	<b>Alternative D</b>	<b>Reference F 1970 Rule Curves</b>
<b>Namakan Lake</b>			
Average Annual Flood Damage Reduction	\$0	-\$7	\$17
1950 Flood	\$0	\$0	\$561
2014 Flood	\$0	\$0	\$217
<b>Rainy Lake</b>			
Average Annual Flood Damage Reduction	\$0	\$9	\$186
1950 Flood	\$0	\$0	\$1,547
2014 Flood	\$0	\$0	\$965

## 2. Navigation

**Alternative D** improves late-season boating reliability on Namakan Lake as water levels are kept uniform throughout most of the mid- to late boating season. A minor reduction to July/ August boating period on Rainy Lake results from holding water back in Namakan Lake over this period.

**Table 7-12 Boating depth reliability for Alternative D**  
(percentage of time minimum depth requirement is met)

Boating Season Period	Alternative A 2000 Rule Curves %	Alternative D %
<b>Namakan Lake</b>		
May-June	62	62
July-Aug	99	100
Late Season	63	99
<b>Rainy Lake</b>		
May-June	68	68
July-Aug	94	93
Late Season	95	95

## 3. Hydropower production

The SVM estimates that **Alternative D** can result in a decrease in annual spill in some years, when compared to the 2000 Rule Curves.

**Table 7-13 Hydropower spill reduction under Alternative D**

	Alternative A 2000 Rule Curve (baseline)	Alternative D	Reference F 1970 Rule Curve
Reduction in Average Annual Spill	1.00	1.01	1.09

### 7.4.5 Archeological resources: Alternative D

The SVM suggests that **Alternative D** increases the threat of erosion to archeological sites on Namakan Lake, and to a lesser extent on Rainy Lake, when compared to the 2000 Rule Curves. The PI score for Namakan Lake is lower than **Reference F** (the 1970 Rule Curve), indicating that **Alternative D** not only reverses the benefits to archeological sites provided by the 2000 Rule Curve on Namakan Lake, but is likely to cause additional damage.

**Table 7-14 Archeological resources PI for Alternative D: protection of archeological sites from erosion**

	<b>Alternative A 2000 Rule Curves (baseline)</b>	<b>Alternative D</b>	<b>Reference F 1970 Rule Curves</b>
Namakan Lake	1.00	0.50	0.66
Rainy Lake	1.00	0.97	0.62

### 7.4.6 Aquatic vegetation: Alternative D

IERM results suggest that **Alternative D** results in some changes to aquatic vegetation species on Namakan Lake, and to a lesser extent on Rainy Lakes. For example:

- Hybrid Cattail invasion is worsened on Namakan Lake and results in a decrease in suitable area for Wild Rice;
- the amount of suitable area for wet meadows and shrubby swamps is decreased on Namakan Lake; and
- there is small decrease in submerged vegetation on Namakan Lake.

**Alternative D** is likely to reduce diversity of the aquatic vegetation community on Namakan Lake, compared to the 2000 Rule Curve.

#### 1. Wild Rice and Hybrid Cattails

The IERM shows that the stabilized summer-time water levels on Namakan Lake result in an increase in Hybrid Cattail invasion (Figure 7-46a), which results in a decrease in area of suitable habitat for Wild Rice (Figure 7-47a) in some years.

On Rainy Lake, there is a small reduction in Hybrid Cattail invasion in some years (Figure 7-46b) and an increase in Wild Rice habitat in most years (Figure 7-47b).

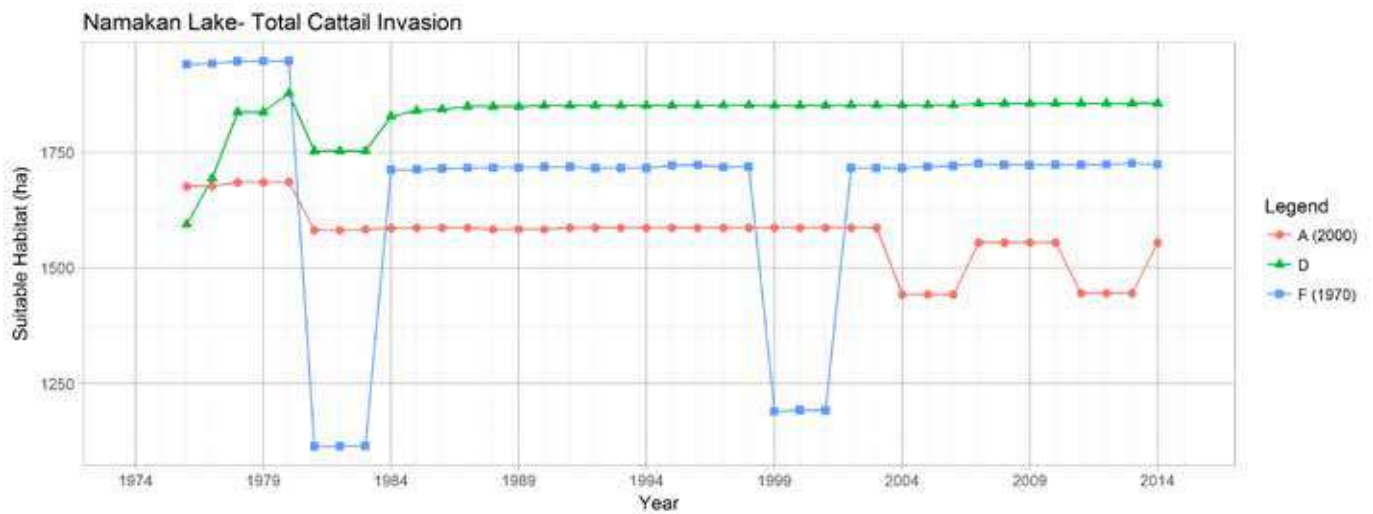


Figure 7-46a Area suitable for Hybrid Cattail invasion on Namakan Lake, Alternative D

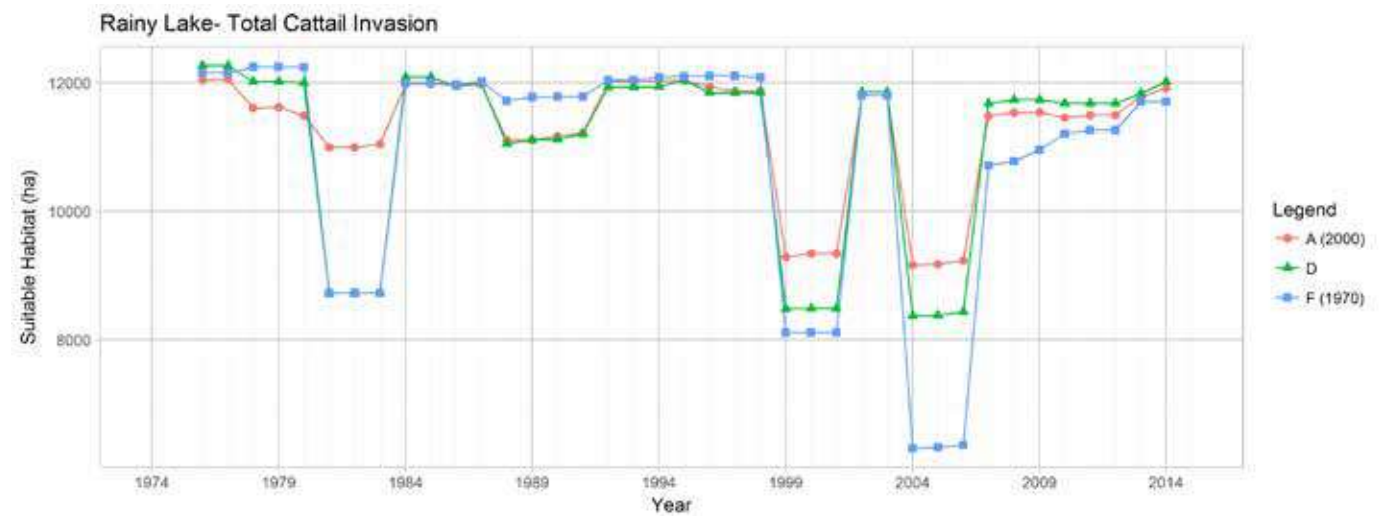


Figure 7-46b Area suitable for Hybrid Cattail invasion on Rainy Lake, Alternative D

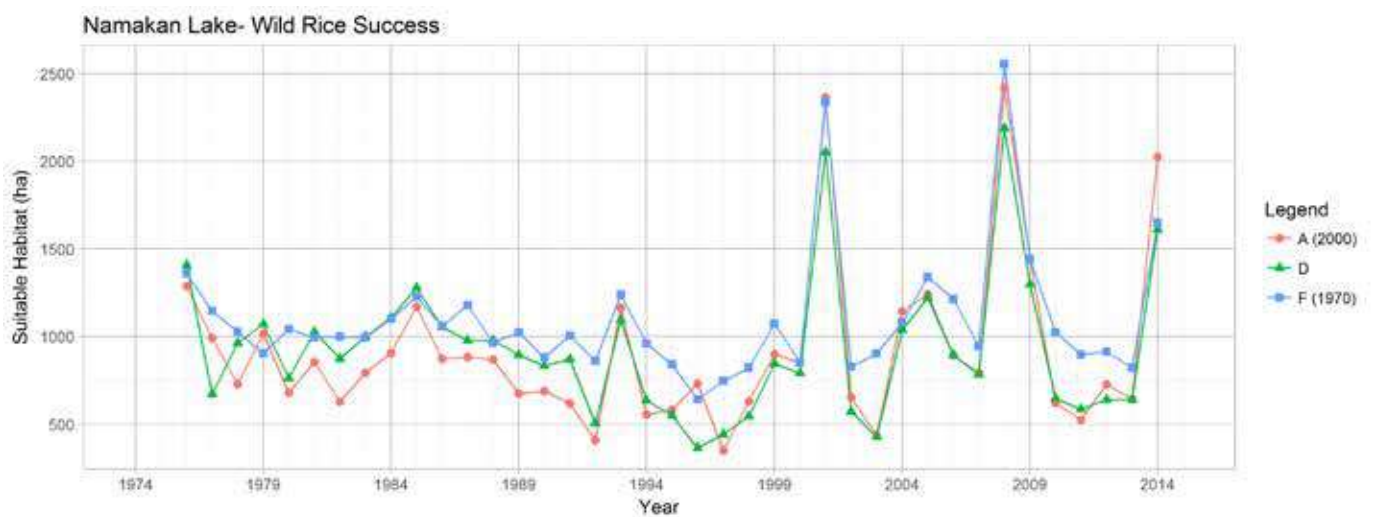


Figure 7-47a Area suitable for the successful growth of Wild Rice on Namakan Lake, Alternative D



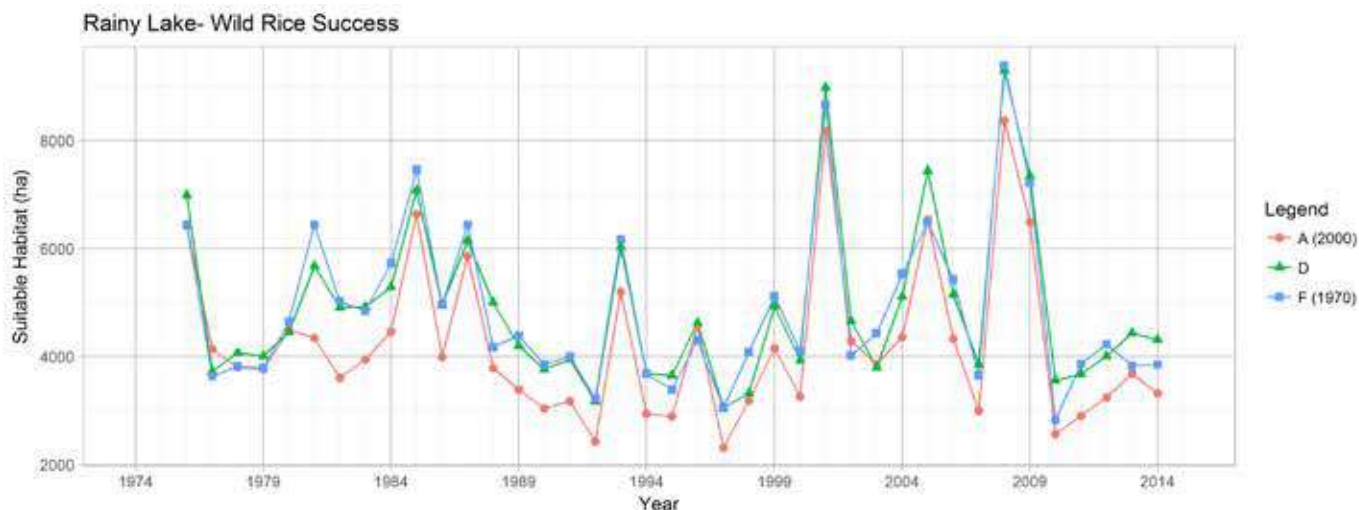


Figure 7-47b Area suitable for the successful growth of Wild Rice on Rainy Lake, Alternative D

## 2. Wet meadows and shrubby swamps

The IERM suggests that amount of suitable habitat for wet meadows and shrubby swamps are reduced under **Alternative D** when compared to the 2000 Rule Curves. The stable water levels throughout the summer increase the amount of time these areas are flooded, making them more suitable to other aquatic vegetation types, such as emergent plants.

On Rainy Lake, the IERM suggests that **Alternative D** results in a minor increase in wet meadows and a decrease in shrubby swamps in some years. This is the result of reduced water levels on Rainy Lake that result from holding water back on Namakan Lake: the shrubby swamps, which exist at higher elevations, are not flooded as frequently and are therefore less likely to thrive.

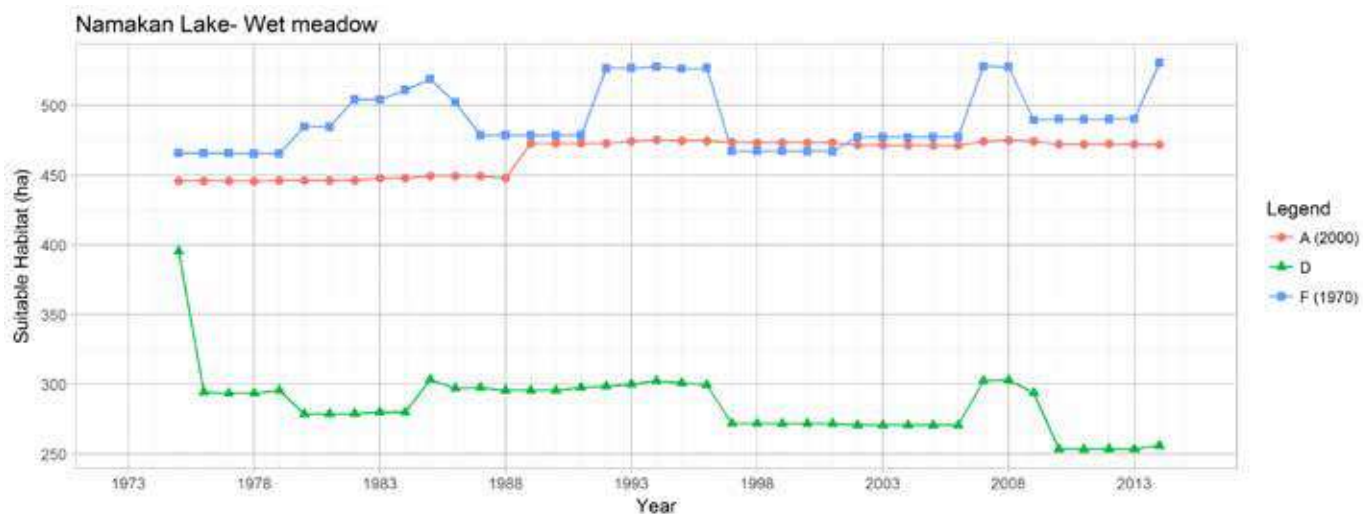


Figure 7-48a Area suitable for wet meadows on Namakan Lake, Alternative D

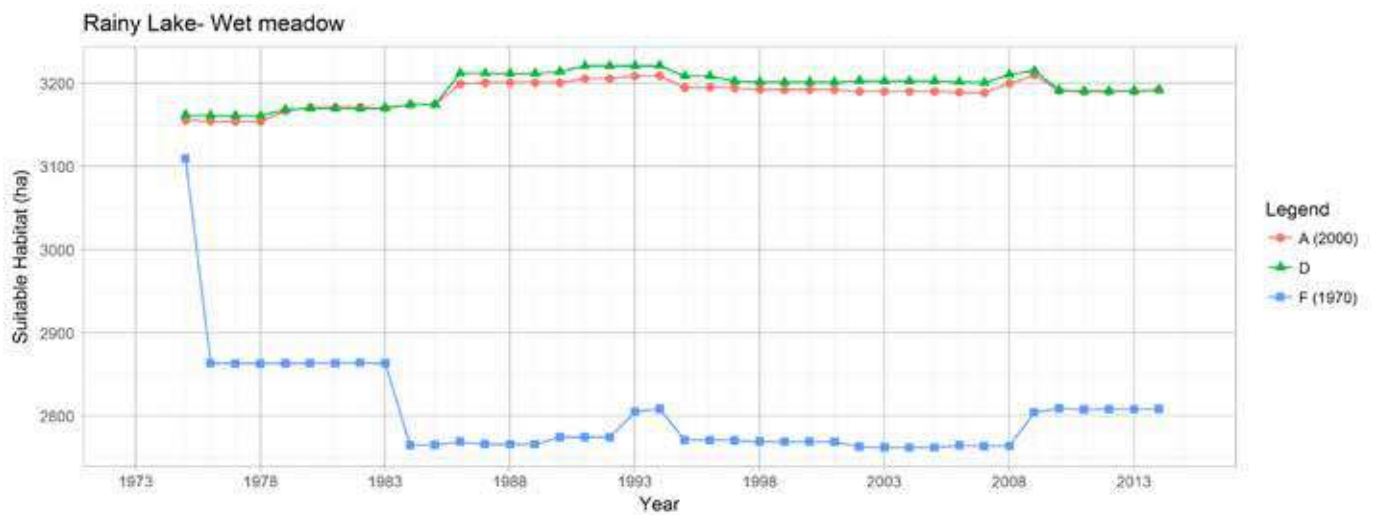


Figure 7-48b Area suitable for wet meadows on Rainy Lake, Alternative D

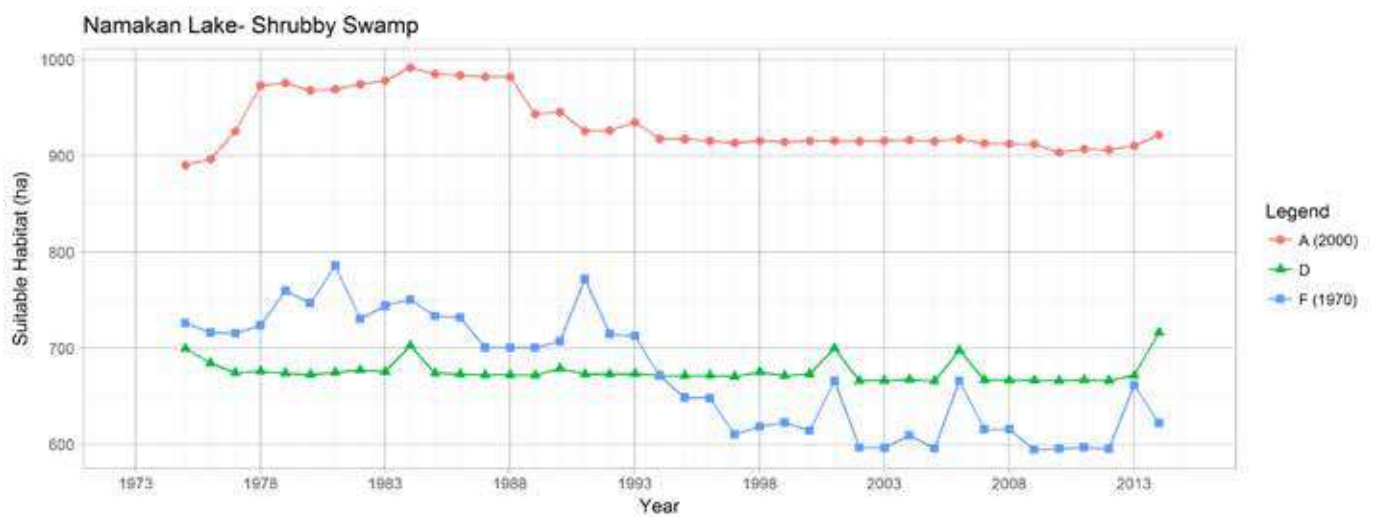


Figure 7-49a Area suitable for shrubby swamps on Namakan Lake, Alternative D

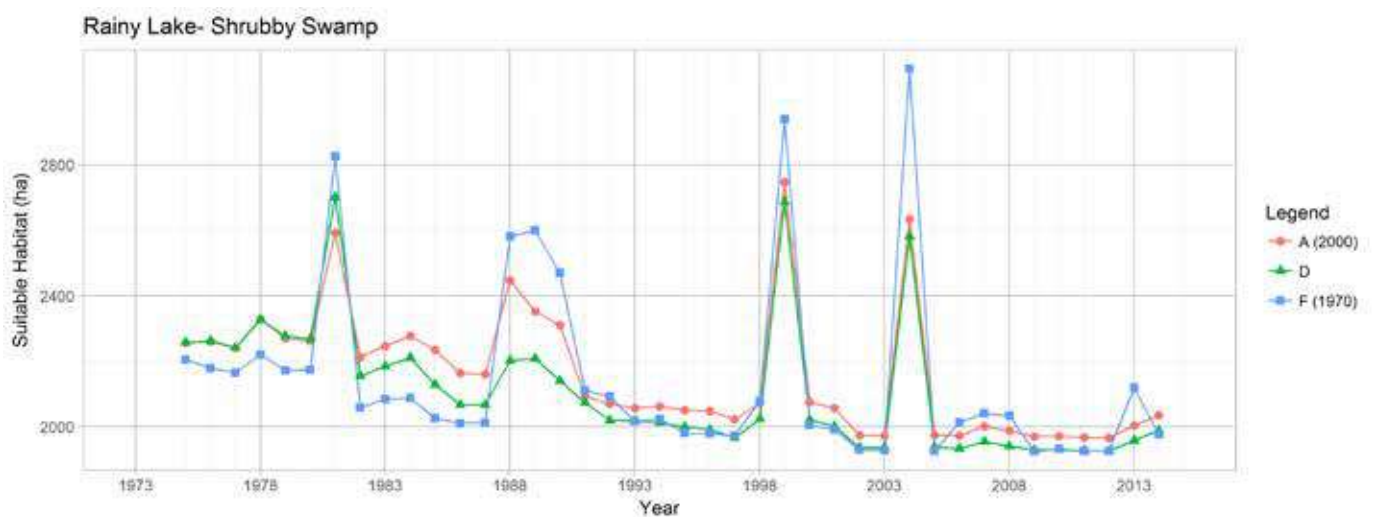


Figure 7-49b Area suitable for shrubby swamps on Rainy Lake, Alternative D

### 3. Emergent plants

The IERM suggests that **Alternative D** increases the amount of suitable habitat for emergent vegetation on Namakan Lake (Figure 7-50a) but has no impact on Rainy Lake (Figure 7-50b).

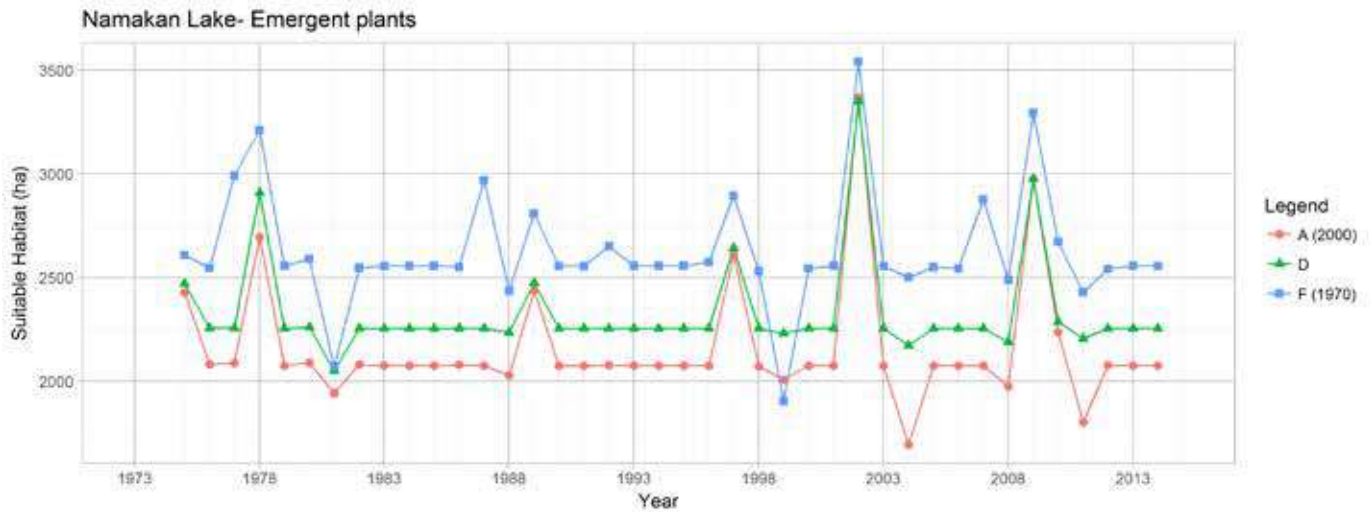


Figure 7-50a Area suitable for emergent plants on Namakan Lake, Alternative D

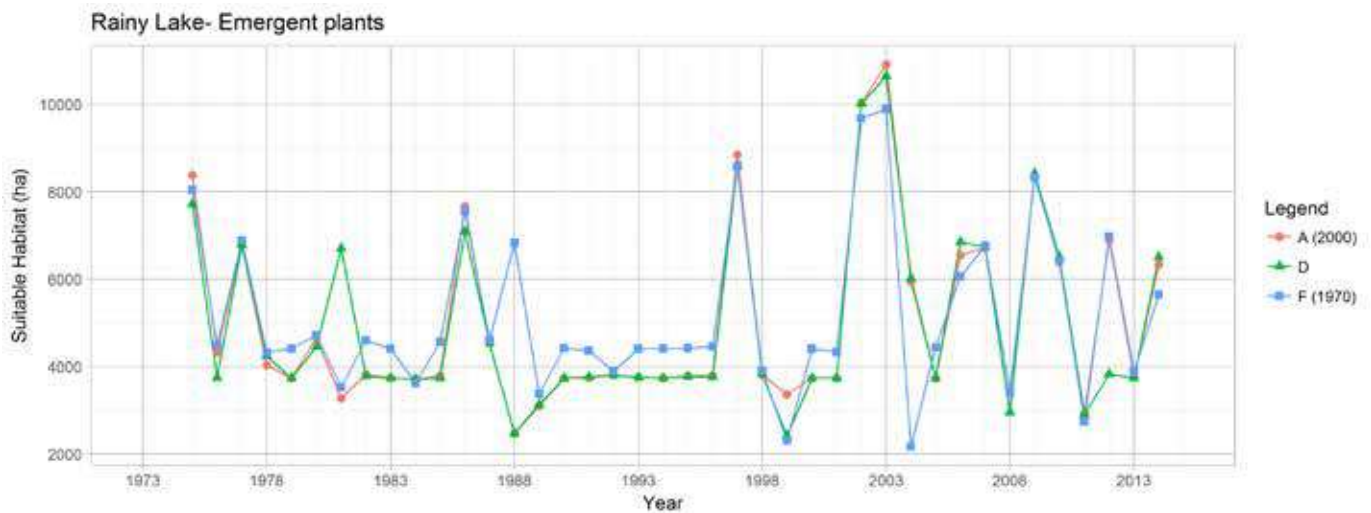


Figure 7-50b Area suitable for emergent plants on Rainy Lake, Alternative D

#### 4. Submerged vegetation

The IERM suggests there is a small decrease in high-density submerged vegetation on Namakan Lake as a result of **Alternative D** (Figure 7-52a), but no change on Rainy Lake in most years (Figures 7-51b and 7-52b).

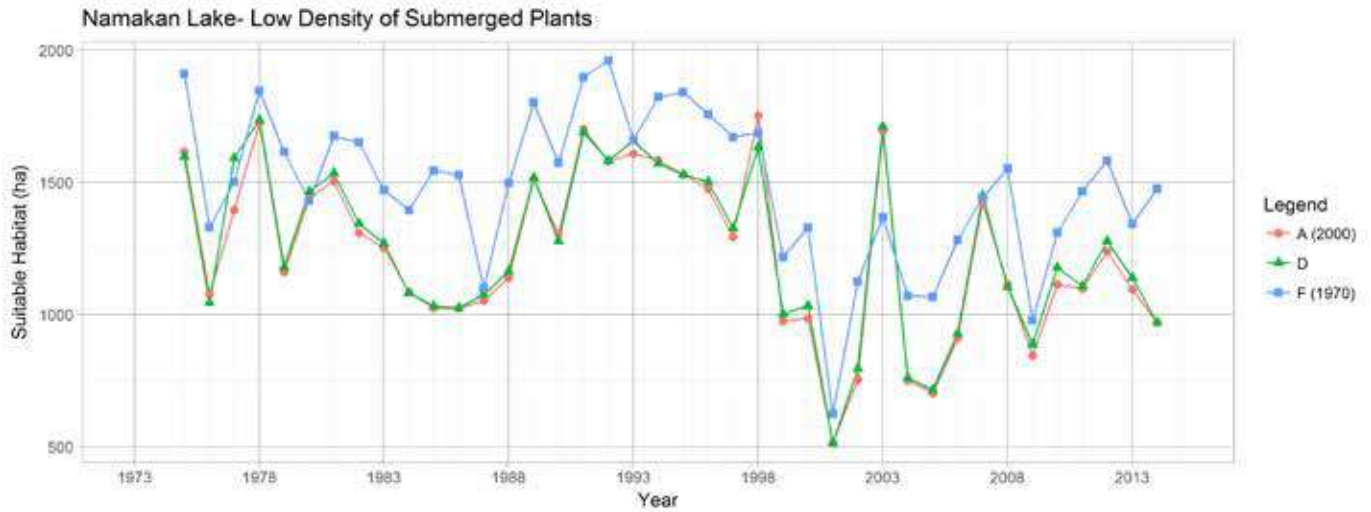


Figure 7-51a Area suitable for low-density submerged plants on Namakan Lake, Alternative D

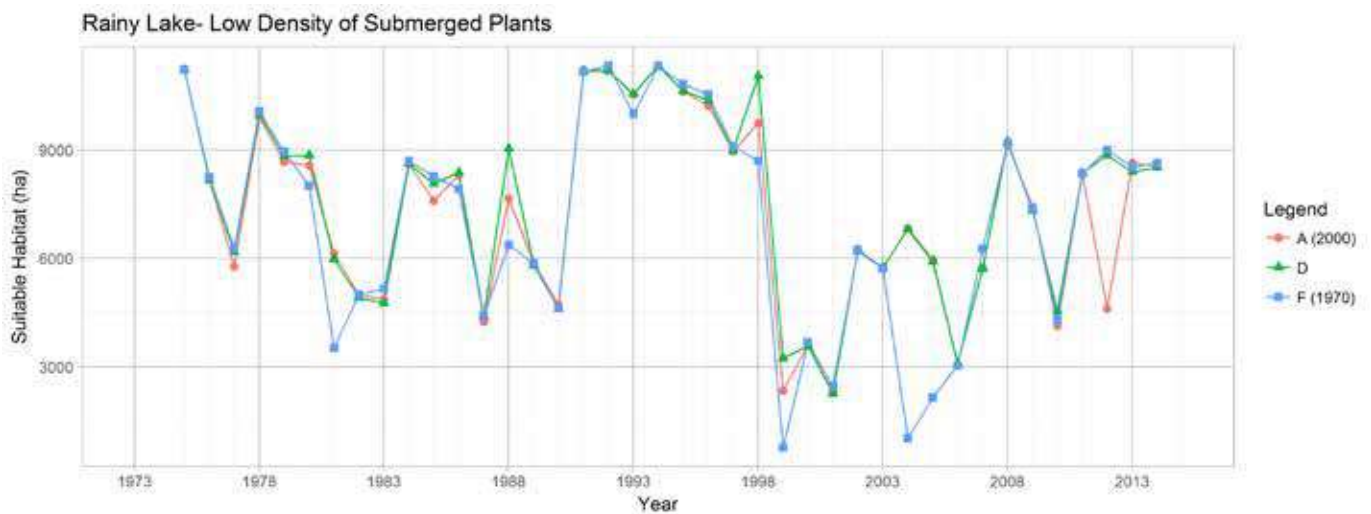


Figure 7-51b Area suitable for low-density submerged plants on Rainy Lake, Alternative D



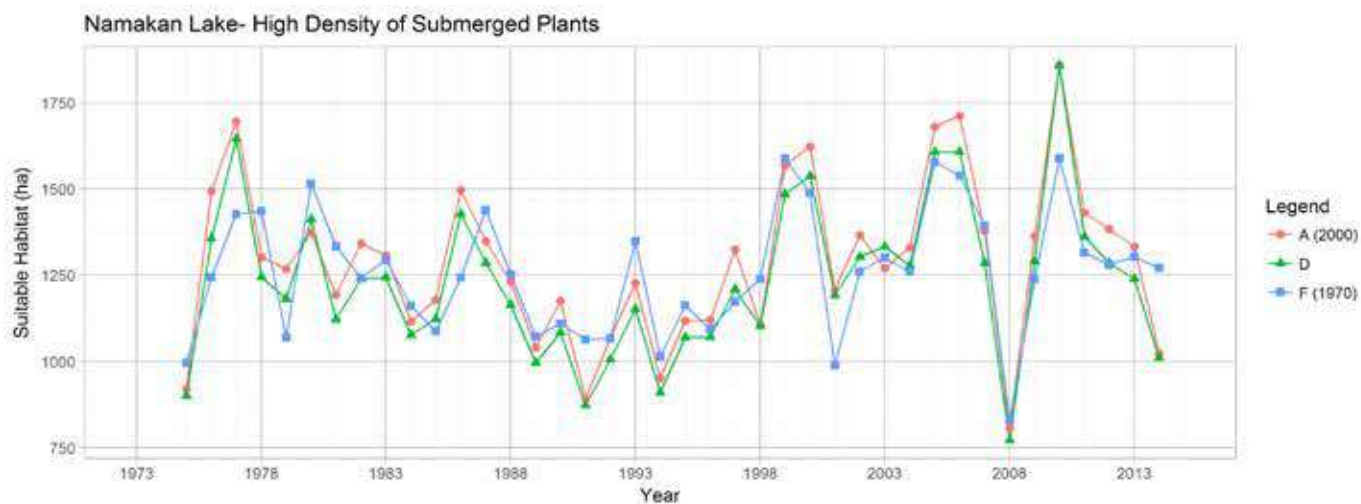


Figure 7-52a Area suitable for high-density submerged plants on Namakan Lake, Alternative D

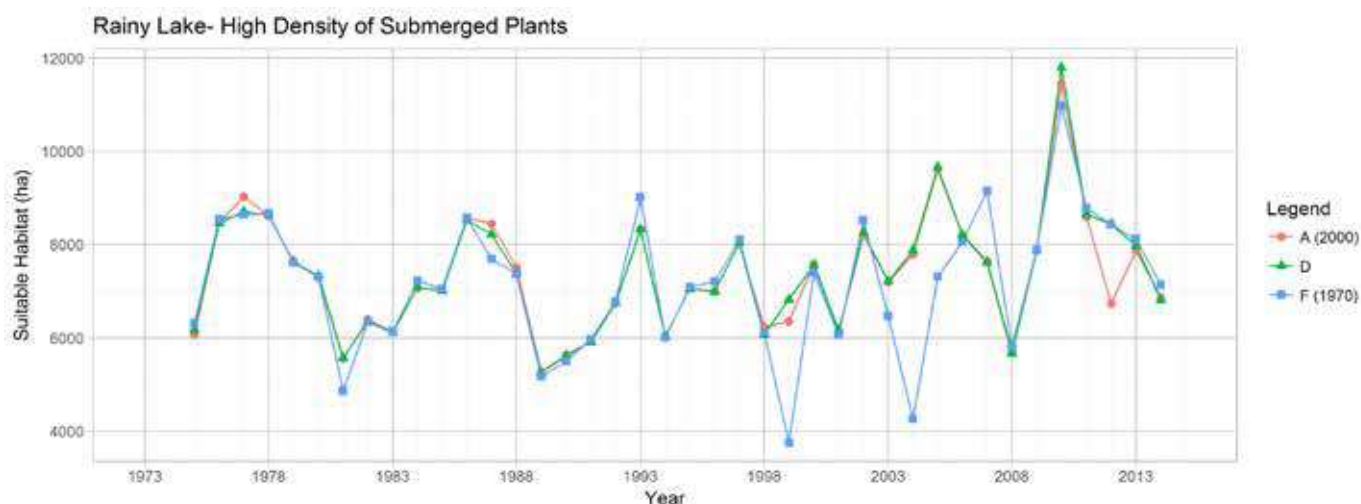


Figure 7-52b Area suitable for high-density submerged plants on Rainy Lake, Alternative D

#### 7.4.7 Rainy River: Alternative D

The IERM suggests that there is little impact to the amount of suitable habitat for Walleye or Lake Sturgeon spawning on Rainy River as a result of **Alternative D** (Figures 7-53 and 7-54).

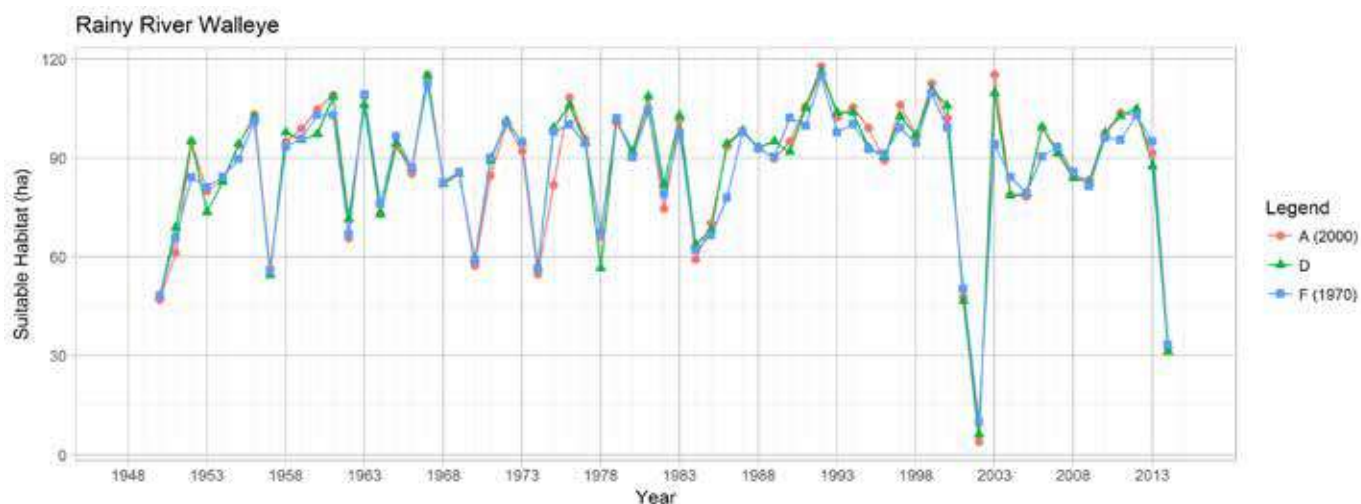


Figure 7-53 Area suitable for Walleye spawning on Rainy River, Alternative D



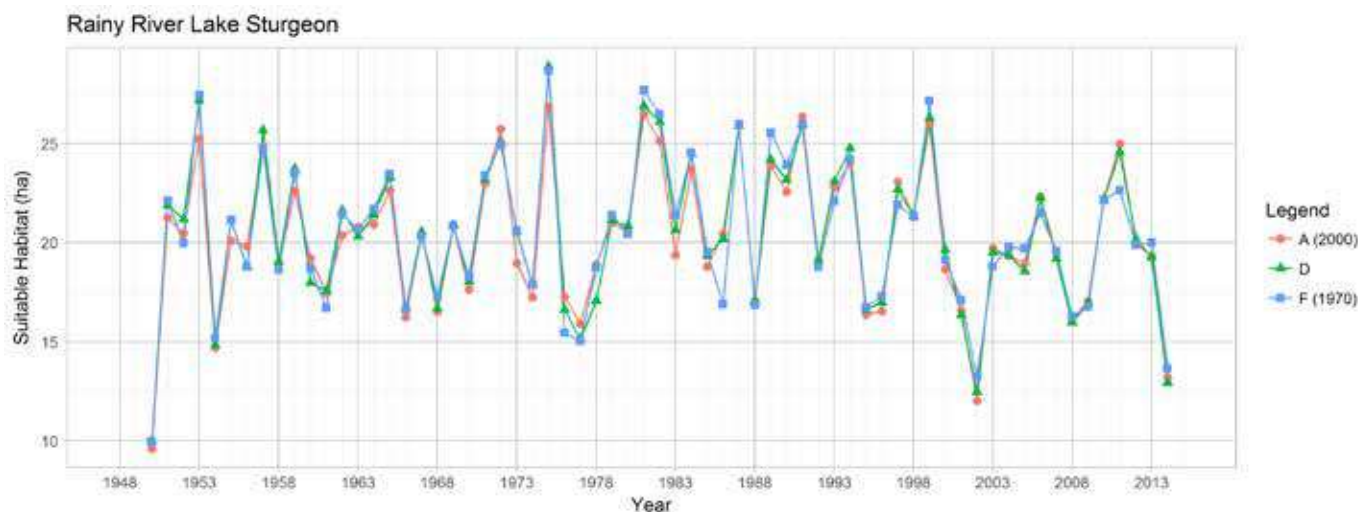


Figure 7-54 Area suitable for Lake Sturgeon spawning on Rainy River, Alternative D

## 7.5 Alternative E: Increased inter-annual variability

### 7.5.1 Overview

#### Objective

This alternative is designed to enhance ecological conditions by increasing the variability in seasonal water levels over the years.

#### Key features

This alternative consists of three sets of rule curves for each lake. The SVM is forced to target a low, normal or high using an ENSO-based projection of basin conditions. All three sets of curves for each lake contain features that aim to improve ecological interests, such as the reduced over-winter drawdown to encourage Muskrat survival, and the rapid refill in early spring to benefit Walleye spawning.

#### Summary of model results

**Alternative E** provides many of the expected benefits to ecological interests such as fish and wildlife, but produces negative impacts on economic interests on both lakes and archeological interests on Rainy Lake.

### 7.5.2 Fish: Alternative E

The IERM shows that **Alternative E** would likely increase the production of Walleye, Northern Pike and Lake Whitefish populations as a result of more favorable spawning conditions on both lakes when compared to the 2000 Rule Curves.

#### 1. Walleye

The IERM suggests that **Alternative E** provides an increase in the likelihood of Walleye egg survival in all years on Namakan Lake and in most years on Rainy Lake (Figures 7-55a and 7-55b). Years where the SVM produces a false alarm are negatively affected. As a result, Figures 7-56a and 7-56b show that the amount of suitable habitat for Walleye spawning is increased on both lakes under **Alternative E**, when compared to the 2000 Rule Curves.

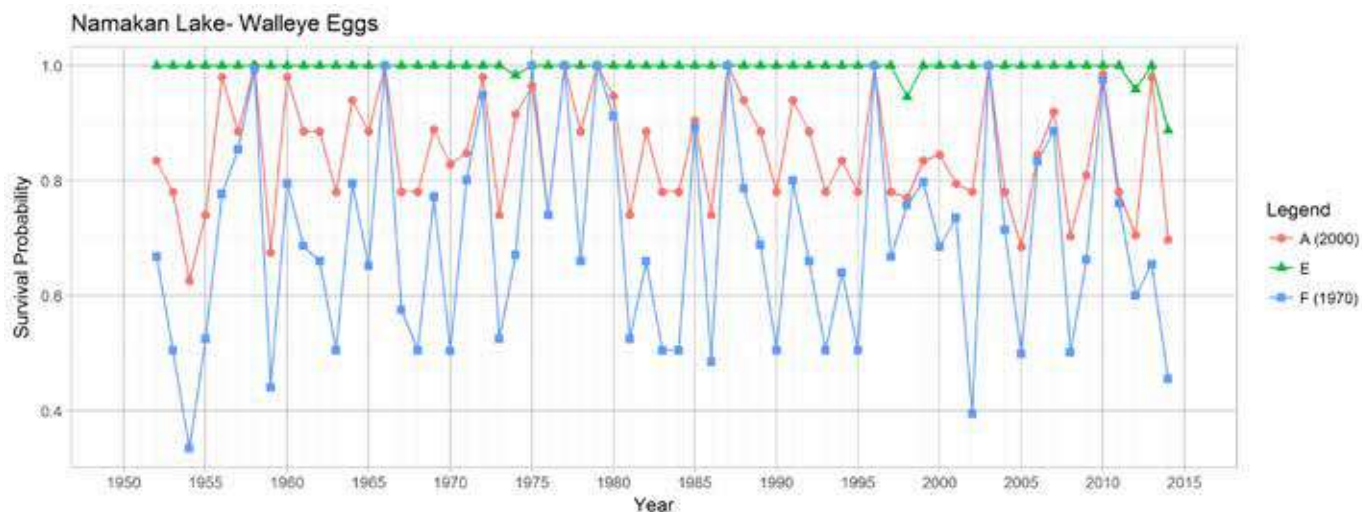


Figure 7-55a Probability of Walleye egg survival on Namakan Lake, Alternative E

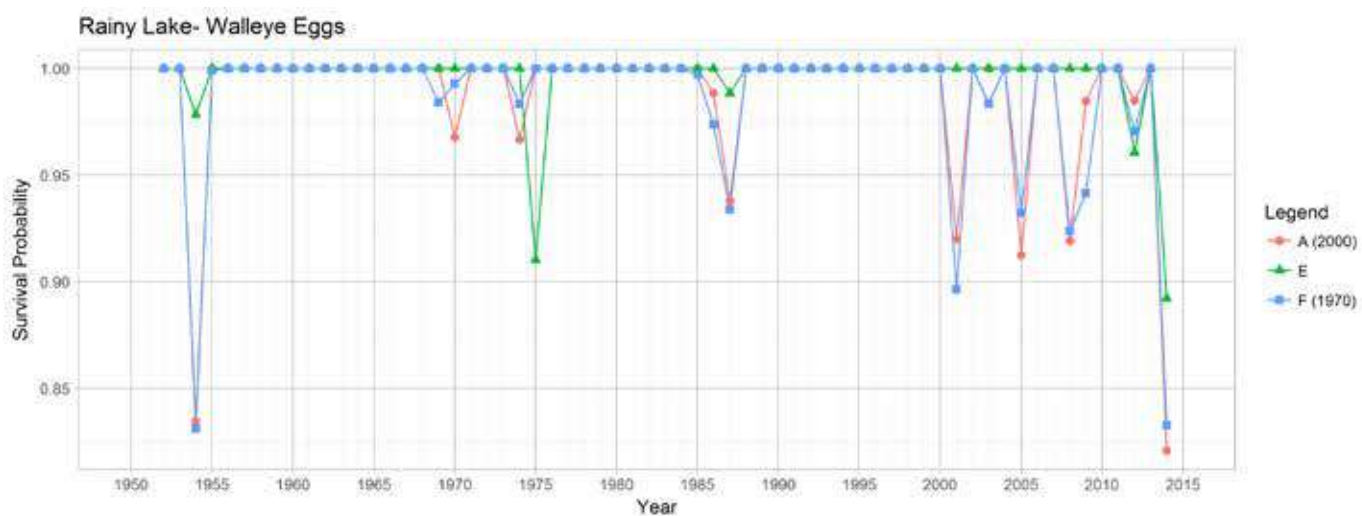


Figure 7-55b Probability of Walleye egg survival on Rainy Lake, Alternative E

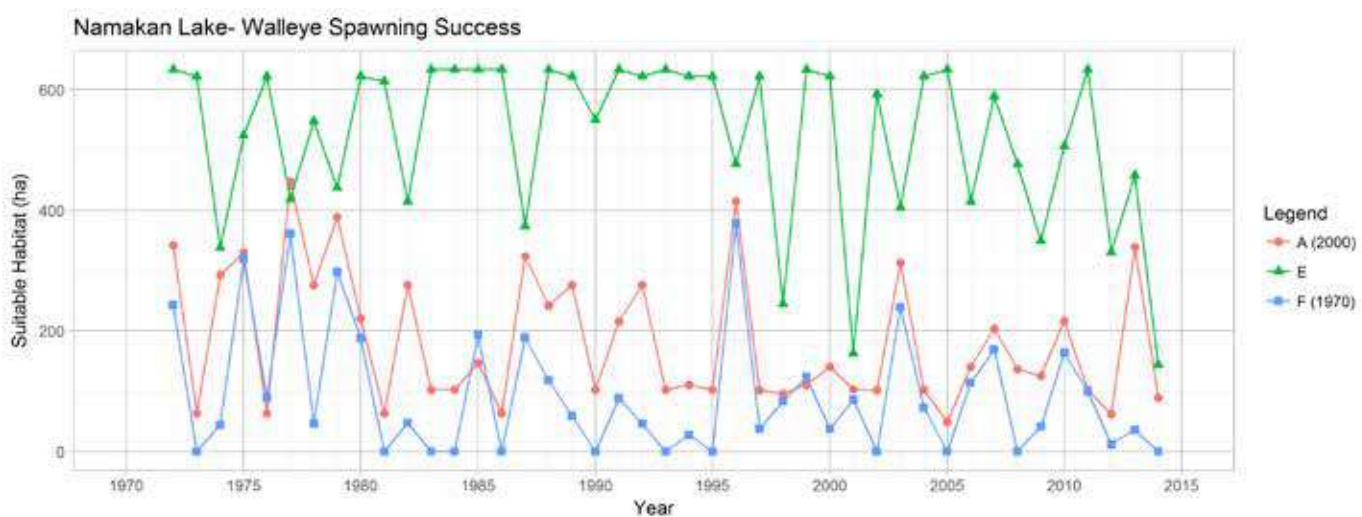


Figure 7-56a Area of suitable habitat for successful Walleye spawning on Namakan Lake, Alternative E

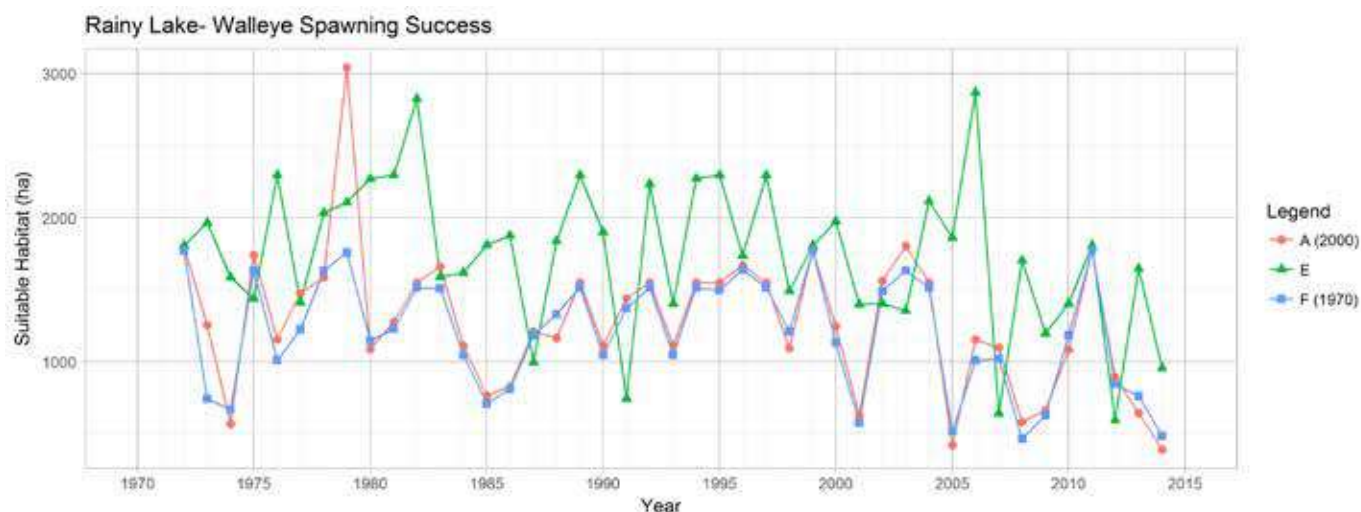


Figure 7-56b Area of suitable habitat for successful Walleye spawning on Rainy Lake, Alternative E

## 2. Northern Pike

The IERM predicts that **Alternative E** produces the greatest amount of high-quality spawning habitat for Northern Pike on both Namakan and Rainy Lakes (Figures 7-57a and 7-57b). The amount of suitable habitat for Northern Pike larva (Figures 7-58a and 7-58b) and YoY (Figures 7-59a and 7-59b) is also increased on Namakan Lake. Nevertheless, spawning habitat remains the limiting factor for Northern Pike production on both lakes, as the amount of habitat suitable for larva and YoY far exceeds the amount of high-quality spawning habitat.

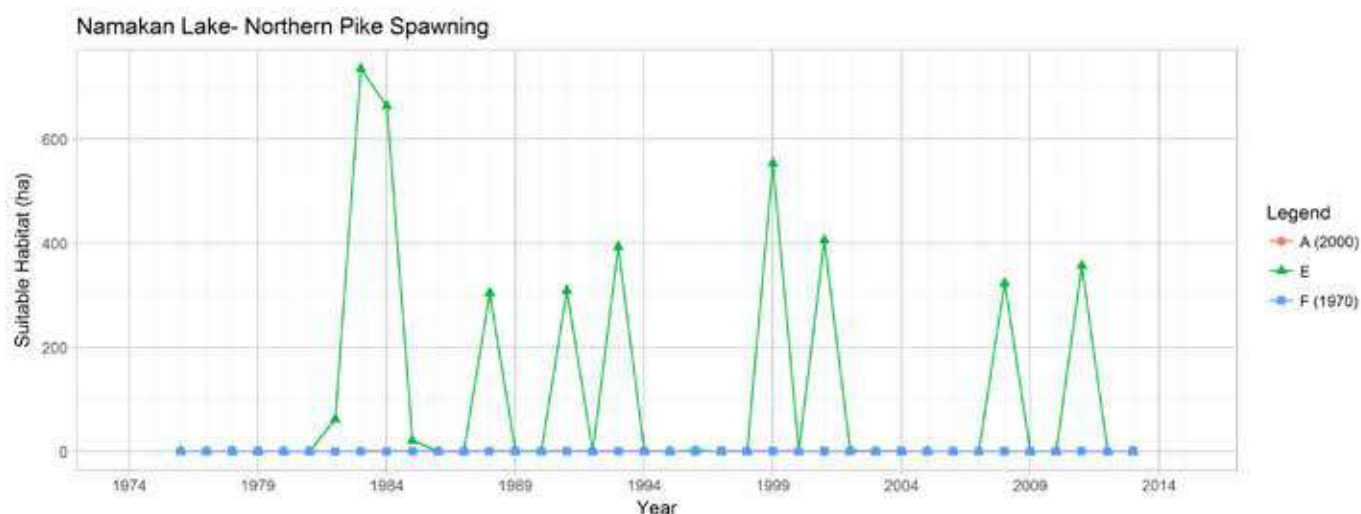


Figure 7-57a Area of suitable habitat for Northern Pike spawning on Namakan Lake, Alternative E

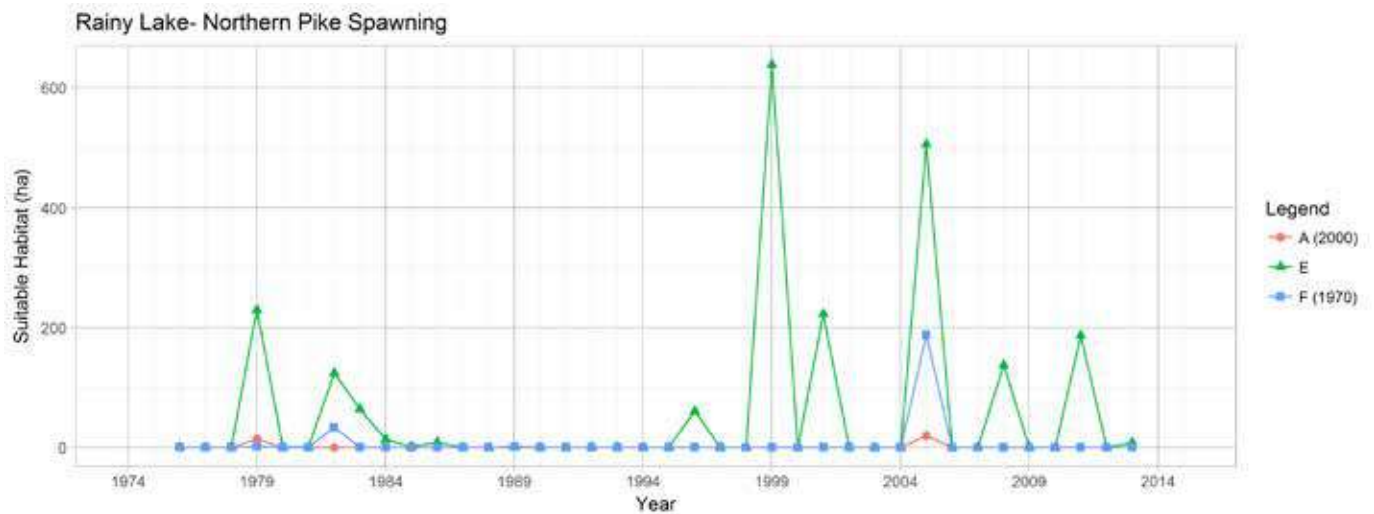


Figure 7-57b Area of suitable habitat for Northern Pike spawning on Rainy Lake, Alternative E

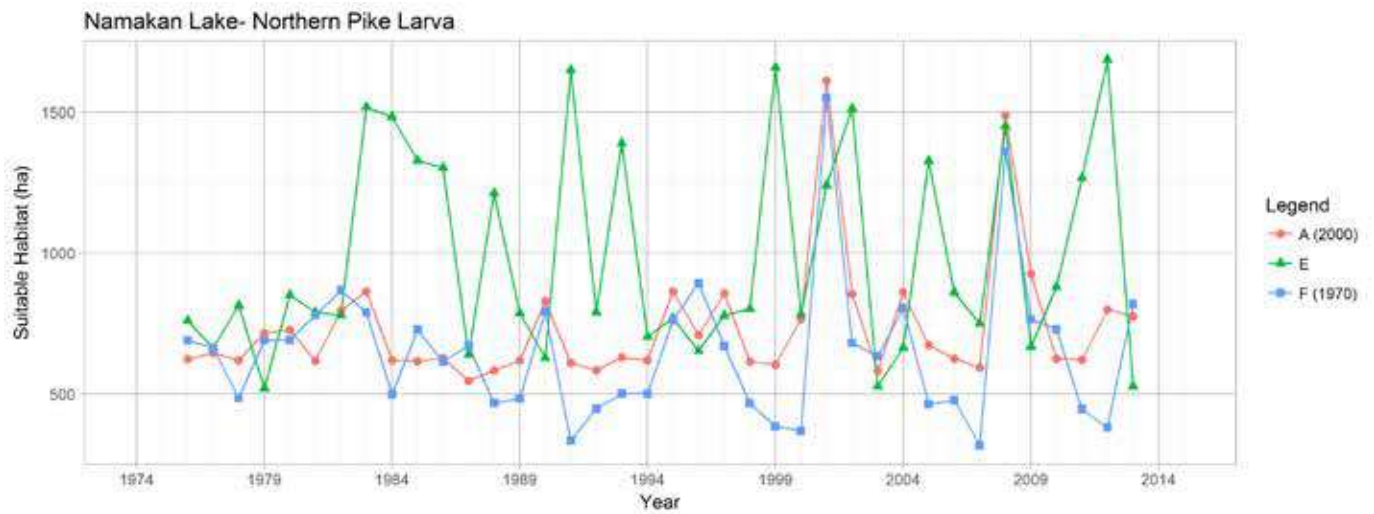


Figure 7-58a Area of suitable habitat for Northern Pike larval survival on Namakan Lake, Alternative E

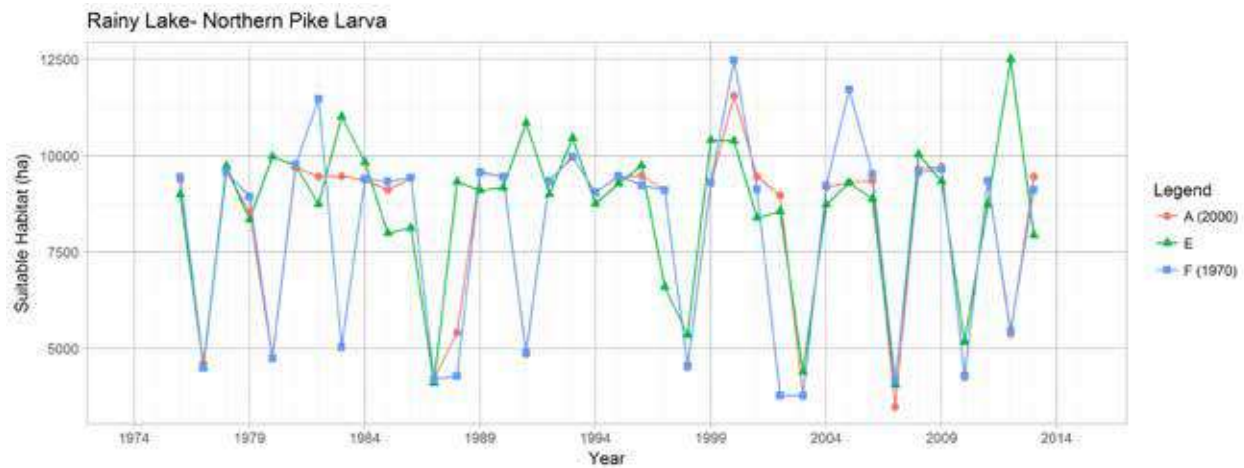


Figure 7-58b Area of suitable habitat for Northern Pike larval survival on Rainy Lake, Alternative E



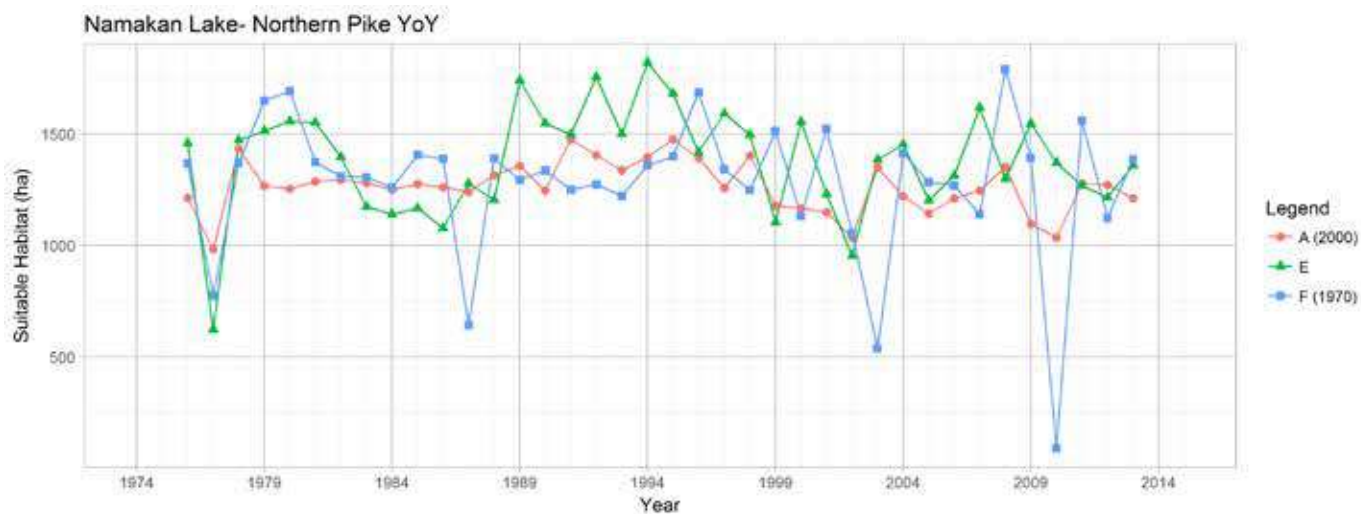


Figure 7-59a Area of suitable habitat for Northern Pike YoY on Namakan Lake, Alternative E

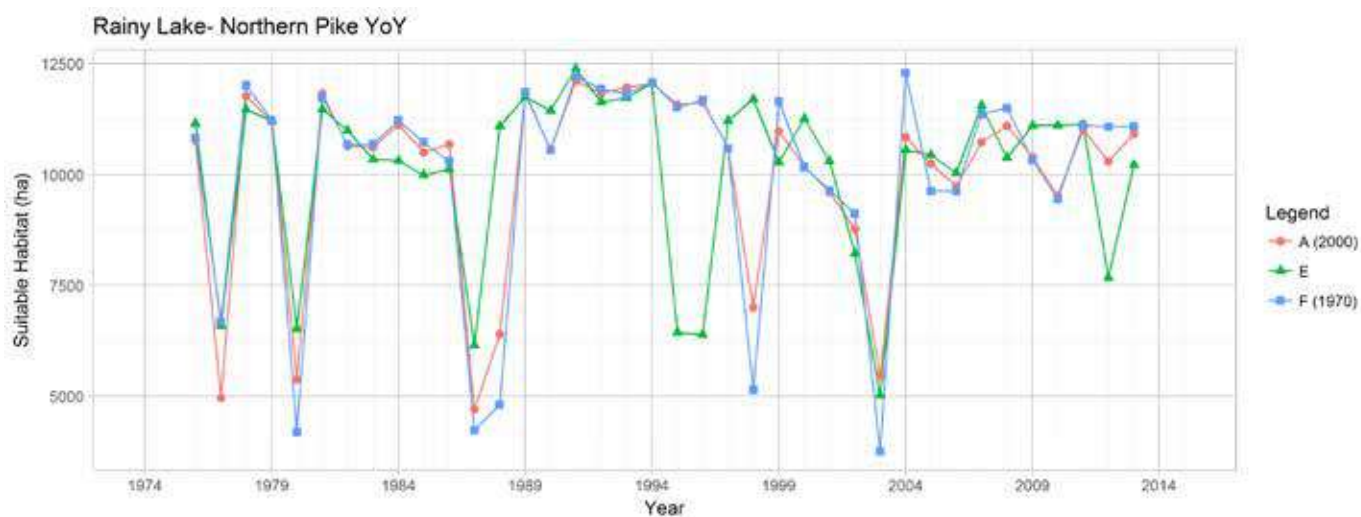


Figure 7-59b Area of suitable habitat for Northern Pike YoY on Rainy Lake, Alternative E



### 3. Lake Whitefish

The IERM suggests that likelihood of Lake Whitefish eggs survival (Figures 7-60a and 7-60b) and the amount of suitable habitat for Lake Whitefish spawning (Figures 7-61a and 7-61b) are increased on both lakes under **Alternative E**, when compared to the 2000 Rule Curves.

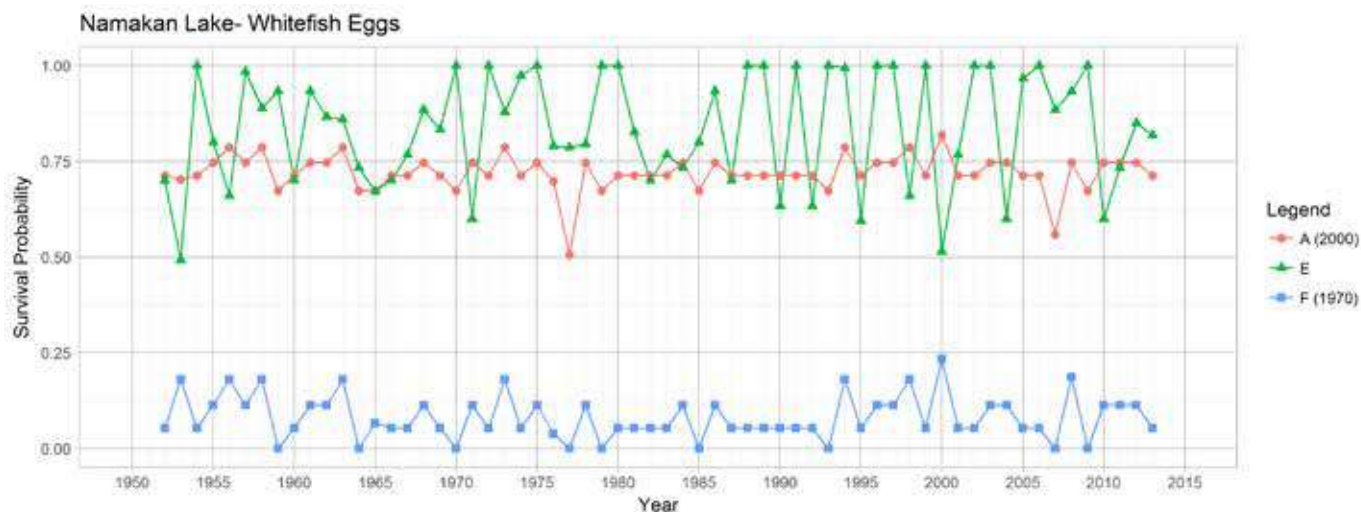


Figure 7-60a Probability of Lake Whitefish egg survival on Namakan Lake, Alternative E



Figure 7-60b Probability of Lake Whitefish egg survival on Rainy Lake, Alternative E

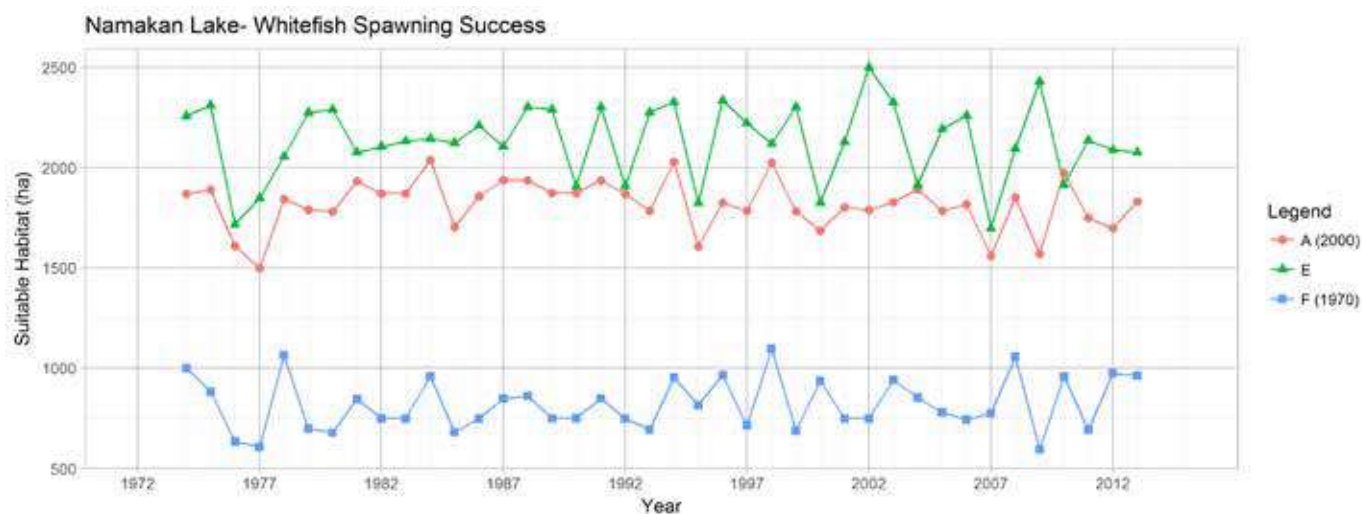


Figure 7-61a Area of suitable habitat for successful Lake Whitefish spawning on Namakan Lake, Alternative E

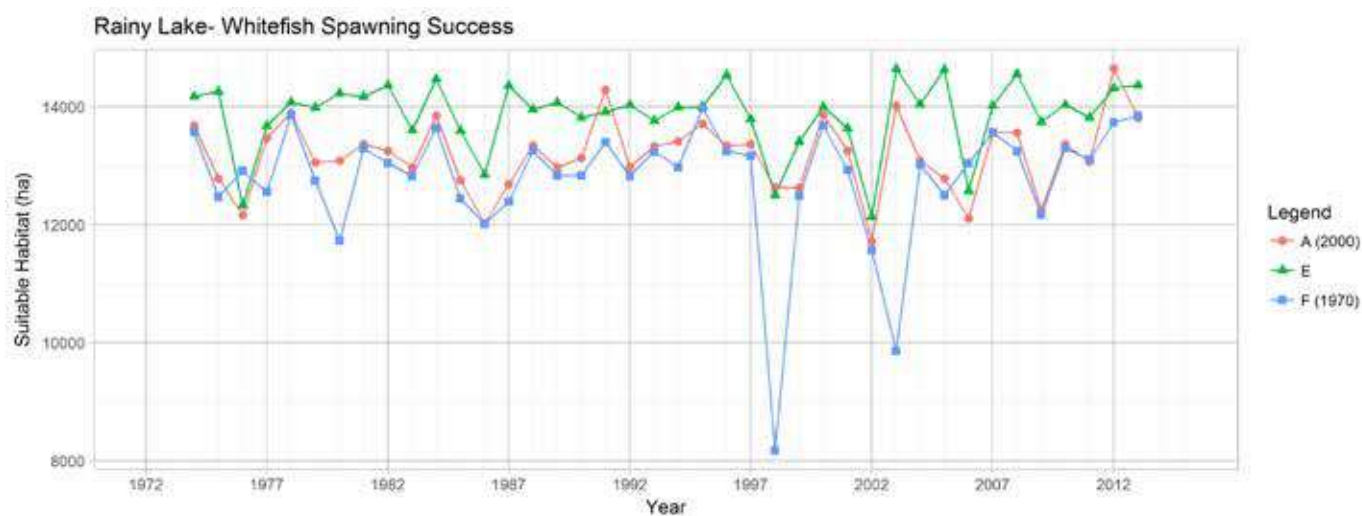


Figure 7-61b Area of suitable habitat for successful Lake Whitefish spawning on Rainy Lake, Alternative E

### 7.5.3 Wildlife: Alternative E

The IERM shows that **Alternative E** benefits wildlife interests on Namakan and Rainy Lakes.

#### 1. Common Loon

The IERM suggests that **Alternative E** provides improved conditions for loon nesting in most years on Namakan Lake and Rainy Lake (Figures 7-62a and 7-62b).

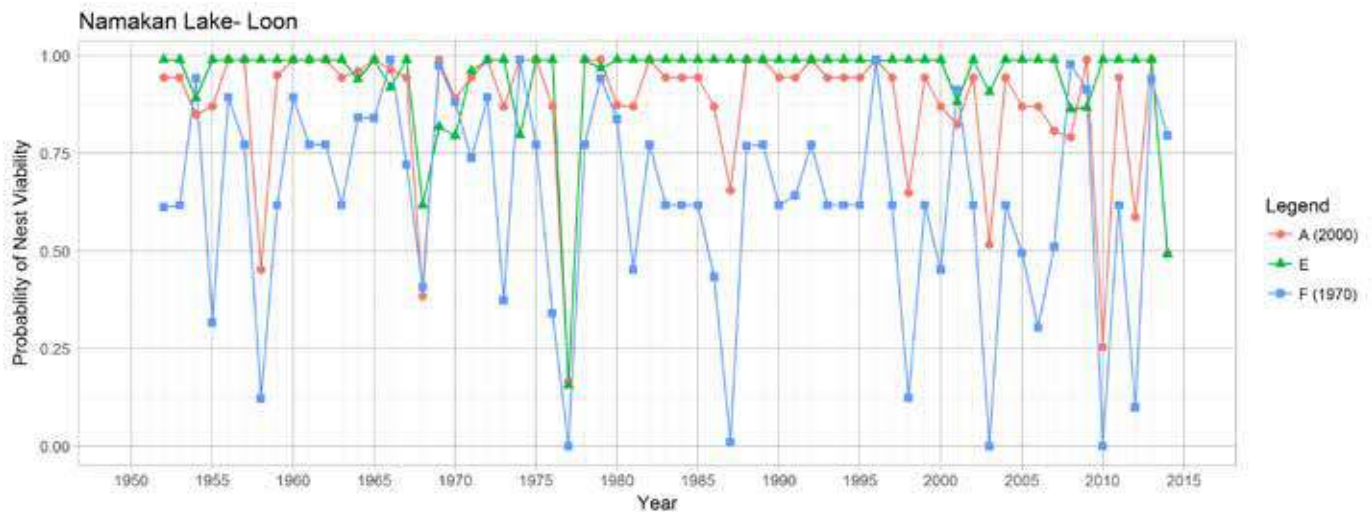


Figure 7-62a Probability of Common Loon nest viability on Namakan Lake, Alternative E

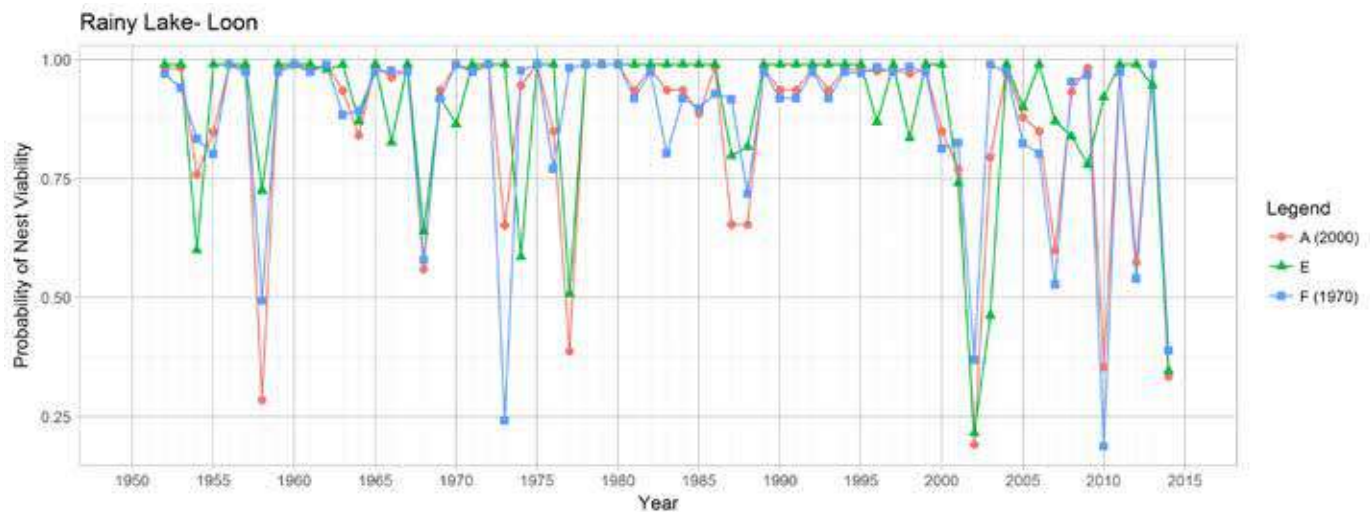


Figure 7-62b Probability of Common Loon nest viability on Rainy Lake, Alternative E

## 2. Muskrats

The IERM suggests that **Alternative E** results in an increase in the probability of over-winter survival of Muskrats on both lakes (Figures 7-63a and 7-63b). In most years, this alternative produced the highest scores when compared to all other alternatives and reference rule curves evaluated in this section. The IERM estimates a zero probability of winter lodge viability under **Alternative A** and **Reference F**.

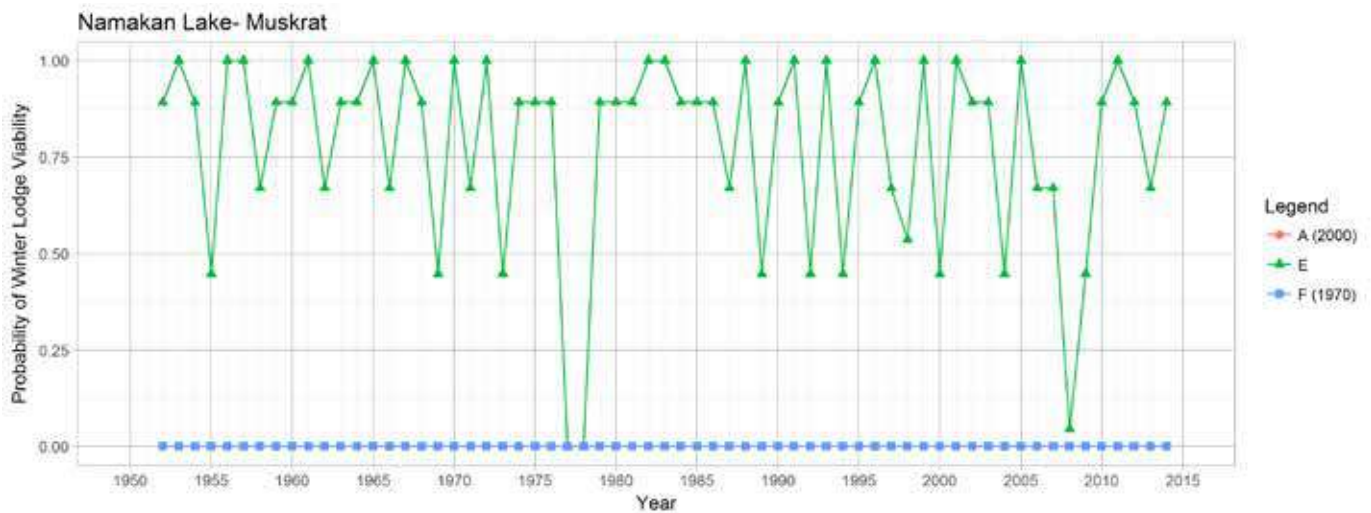


Figure 7-63a Probability of Muskrat winter lodge viability on Namakan Lake, Alternative E

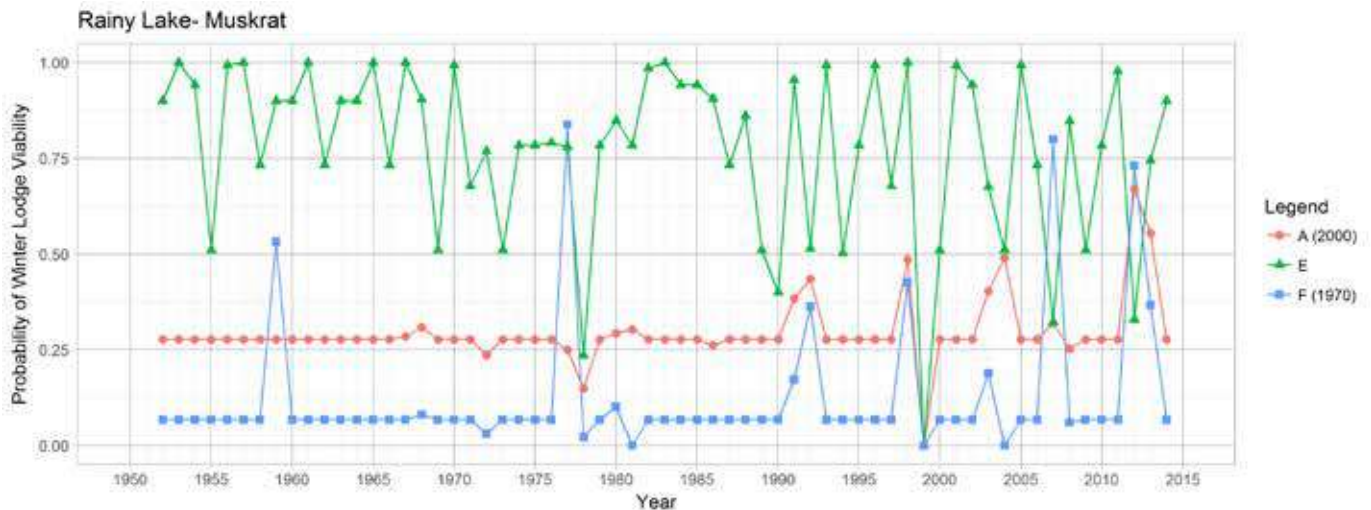


Figure 7-63b Probability of Muskrat winter lodge viability on Rainy Lake, Alternative E

#### 7.5.4 Economy: Alternative E

The SVM suggests that **Alternative E** negatively affects economic interests on Namakan and Rainy Lakes. For example:

- average annual flood damages are increased;
- boating reliability on Namakan Lake is reduced; and
- hydropower production is negatively affected by an increase in spill.

##### 1. Flood damages

The SVM suggests that **Alternative E** greatly increases the average annual flood damages on Namakan and Rainy Lakes (as shown by the negative values in Table 7-15).

**Table 7-15 Flood damage reduction for Alternative E**  
(net reductions in damages compared to 2000 Rule Curves, in \$,000)

	Alternative A 2000 Rule Curves (baseline)	Alternative E	Reference F 1970 Rule Curves
<b>Namakan Lake</b>			
Average Annual Flood Damage Reduction	\$0	-\$64	\$17
1950 Flood	\$0	\$975	\$561
2014 Flood	\$0	-\$231	\$217
<b>Rainy Lake</b>			
Average Annual Flood Damage Reduction	\$0	-\$552	\$186
1950 Flood	\$0	-\$355	\$1,547
2014 Flood	\$0	-\$2,263	\$965

##### 2. Navigation

Under **Alternative E**, boating conditions on Namakan Lake are negatively affected during the July-August and late-season periods (Table 7-16).

**Table 7-16. Boating Depth Reliability for Alternative E**  
(percentage of time minimum depth requirement is met)

Boating Season Period	Alternative A 2000 Rule Curves %	Alternative E %
<b>Namakan Lake</b>		
May-June	62	69
July-Aug	99	51
Late Season	63	8
<b>Rainy Lake</b>		
May-June	68	62
July-Aug	94	96
Late Season	95	95



### 3. Hydropower production

The SVM suggests that **Alternative E** increases the average annual spill from Rainy Lake, suggesting that a negative impact to hydropower is expected under this alternative, when compared to the 2000 Rule Curve (Table 7-17).

Table 7-17 Hydropower Spill Reduction under Alternative E

	Alternative A 2000 Rule Curve (baseline)	Alternative E	Reference F 1970 Rule Curve
Reduction in Average Annual Spill	1.00	0.80	1.09

### 7.5.5 Archeological resources: Alternative E

The SVM suggests that **Alternative E** offers an increase in protection from erosion to archeological sites on Namakan Lake, but reduces it on Rainy Lake (Table 7-18).

Table 7-18 Archeological resources PI for Alternative E: protection of archeological sites from erosion

	Alternative A 2000 Rule Curves (baseline)	Alternative E	Reference F 1970 Rule Curves
Namakan Lake	1.00	1.24	0.66
Rainy Lake	1.00	0.83	0.62

### 7.5.6 Aquatic vegetation: Alternative E

**Alternative E** has varying results on the aquatic vegetation community on Namakan and Rainy Lakes. Most notable, however, is the reduction in the amount of habitat available for cattail invasion, which results in an increase in the amount of habitat available for Wild Rice growth.

#### 1. Wild Rice and Hybrid Cattails

The SVM suggests that the large inter-annual variability of water levels provided by **Alternative E** reduces the expansion of Hybrid Cattail on both lakes, thereby increases the amount of suitable habitat for Wild Rice growth. As previously noted, however, the IERM does not model the impacts of Muskrat survival on Hybrid Cattail. Therefore, it is expected that **Alternative E** would provide even greater benefits to the reduction of Hybrid Cattail invasion and Wild Rice growth than shown in Figures 7-64a to 7-65b.

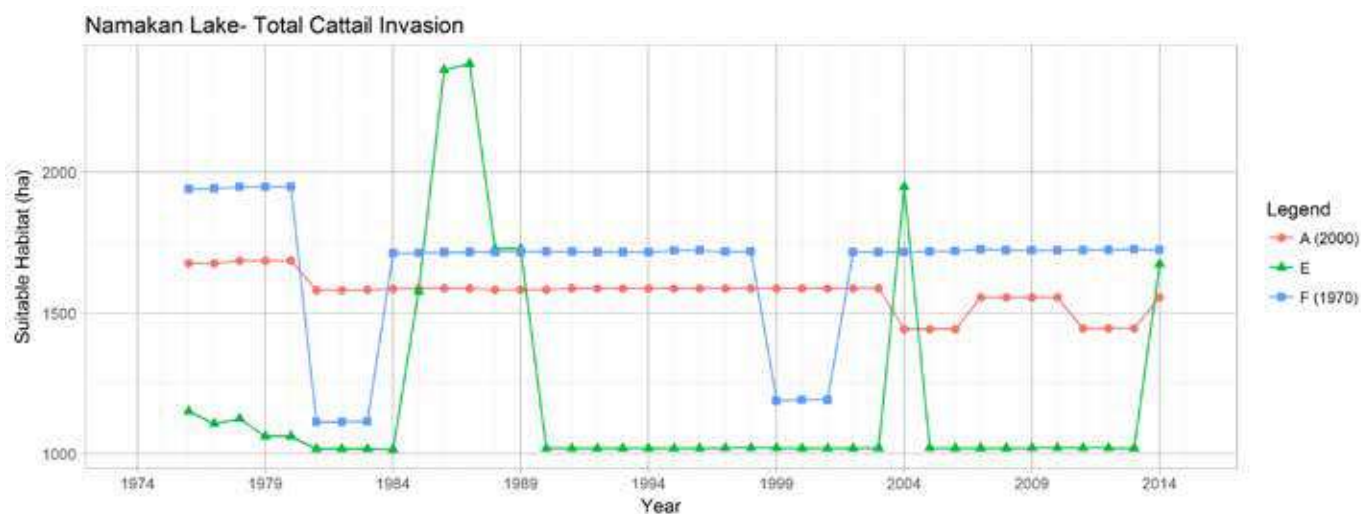


Figure 7-64a Area suitable for Hybrid Cattail invasion on Namakan Lake, Alternative E

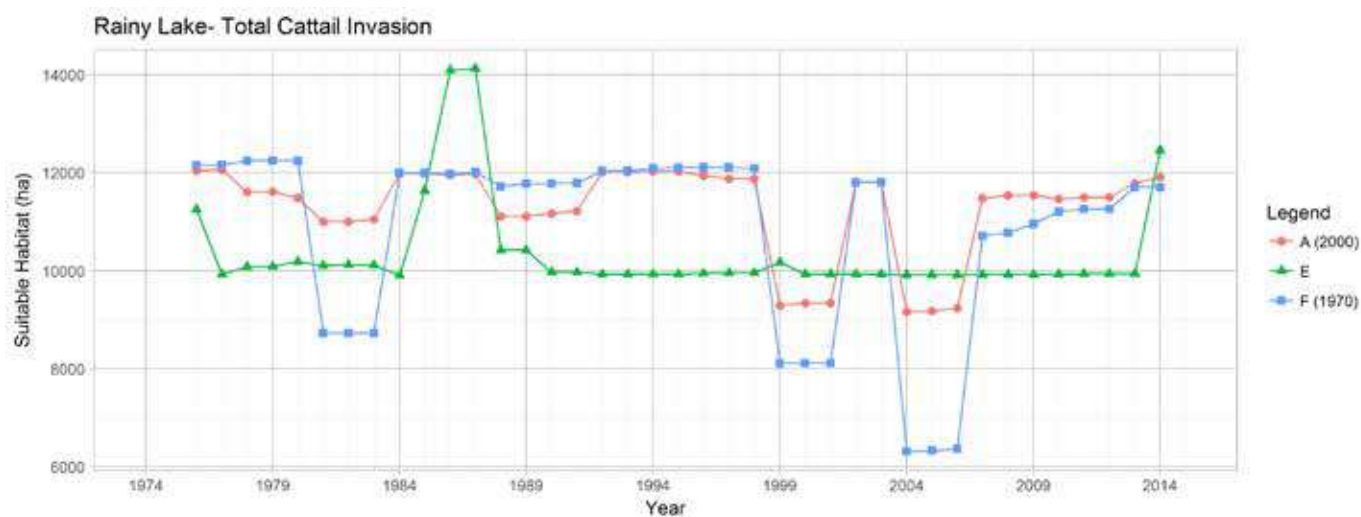


Figure 7-64b Area suitable for Hybrid Cattail invasion on Rainy Lake, Alternative E

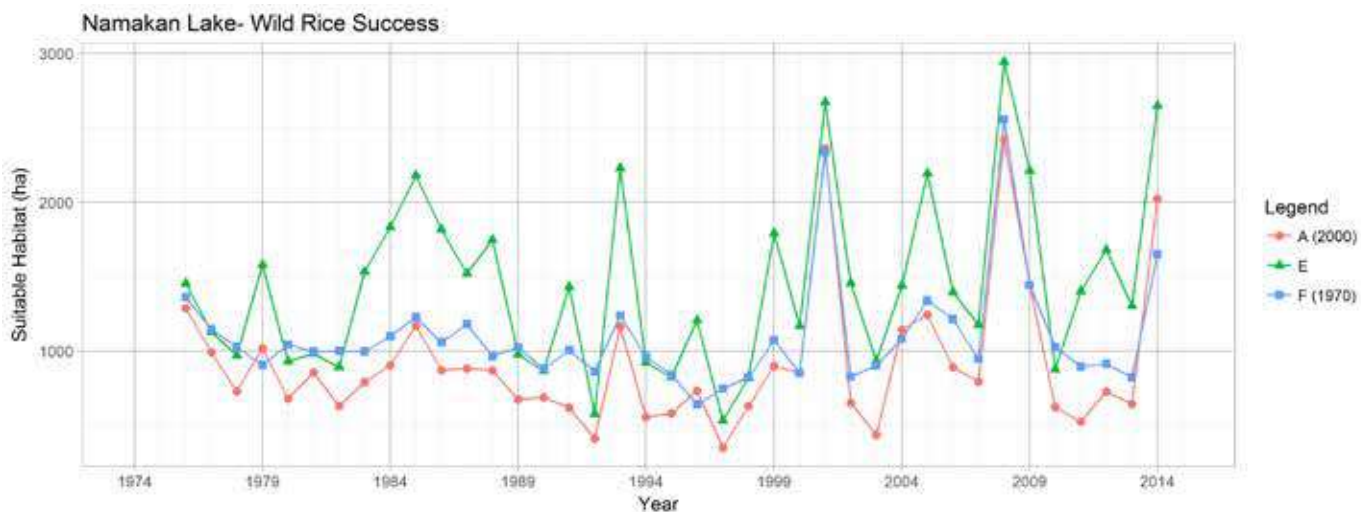


Figure 7-65a Area suitable for the successful growth of Wild Rice on Namakan Lake, Alternative E

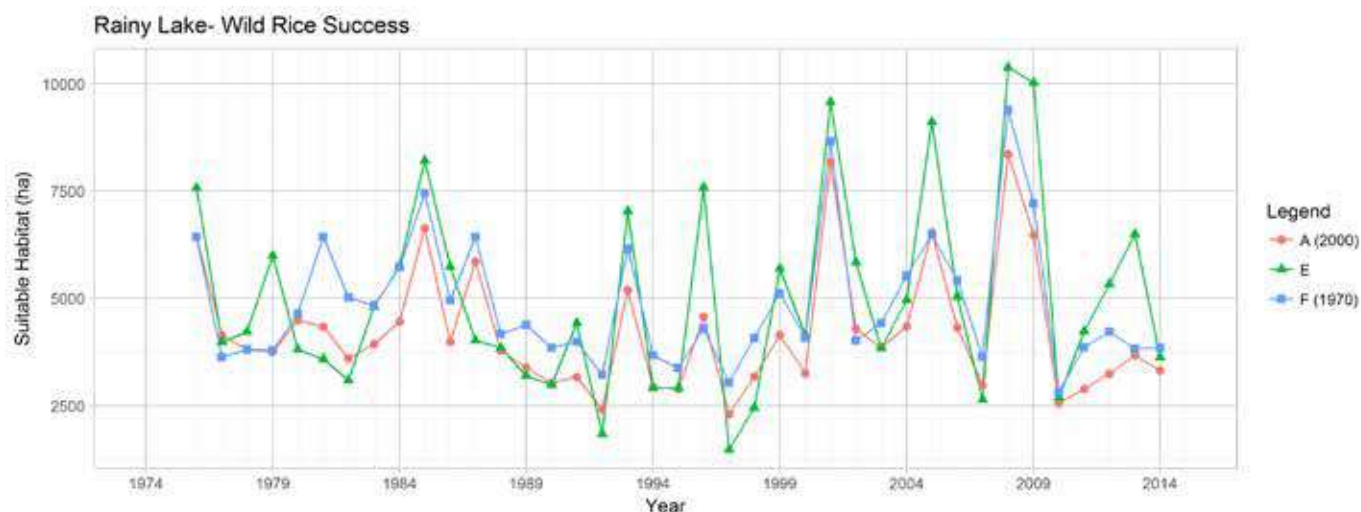


Figure 7-65b Area suitable for the successful growth of Wild Rice on Namakan Lake, Alternative E

## 2. Wet meadows and shrubby swamps

The IERM suggests that **Alternative E** increases the amount of habitat suitable for wet meadows in most years on Namakan Lakes (Figure 7-66a), and reduces it most years on Rainy Lake (Figure 7-66b), when compared to the 2000 Rule Curves. The reverse is seen for shrubby swamps, where the amount of suitable habitat is reduced in most years on Namakan Lake (Figure 7-67a) and increased in most years on Rainy Lake (Figure 7-67b).

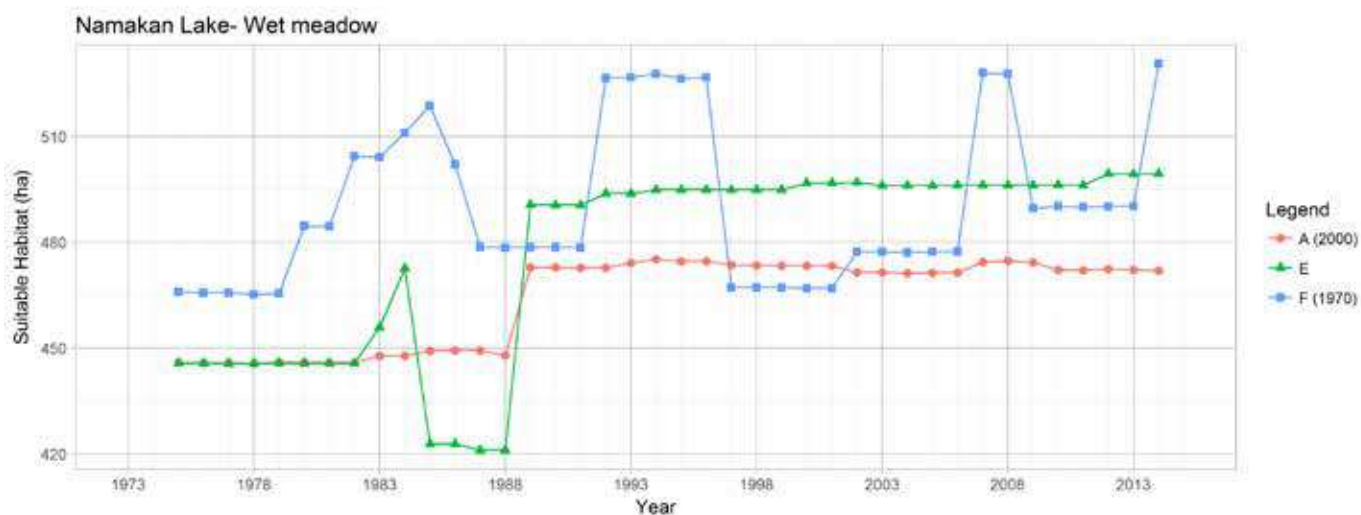


Figure 7-66a Area suitable for wet meadows on Namakan Lake, Alternative E

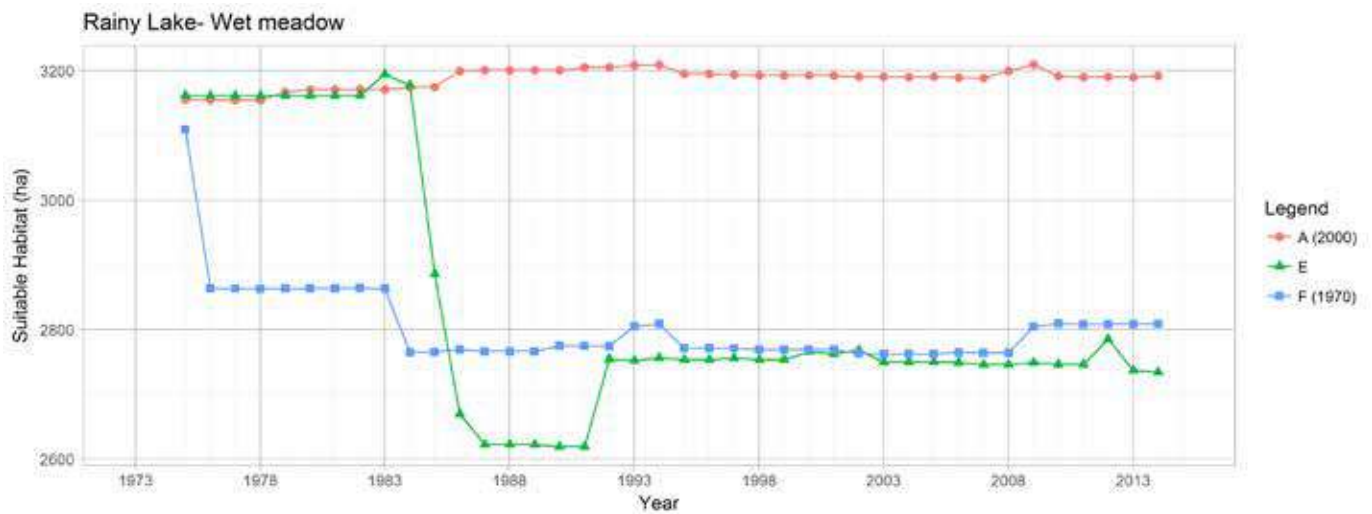


Figure 7-66b Area suitable for wet meadows on Rainy Lake, Alternative E

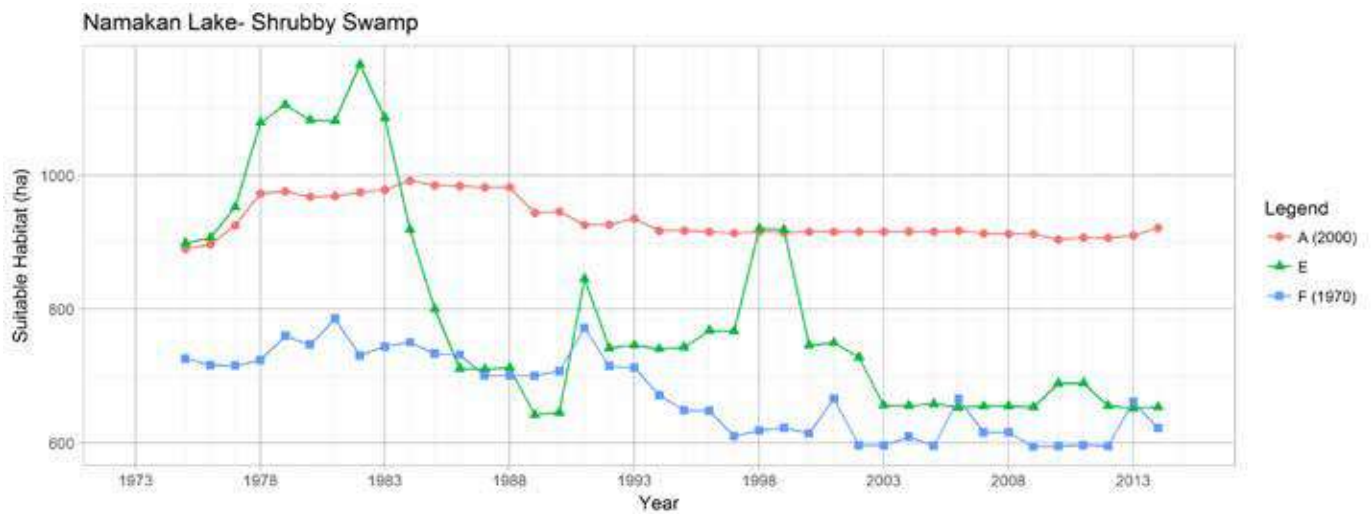


Figure 7-67a Area suitable for shrubby swamps on Namakan Lake, Alternative E

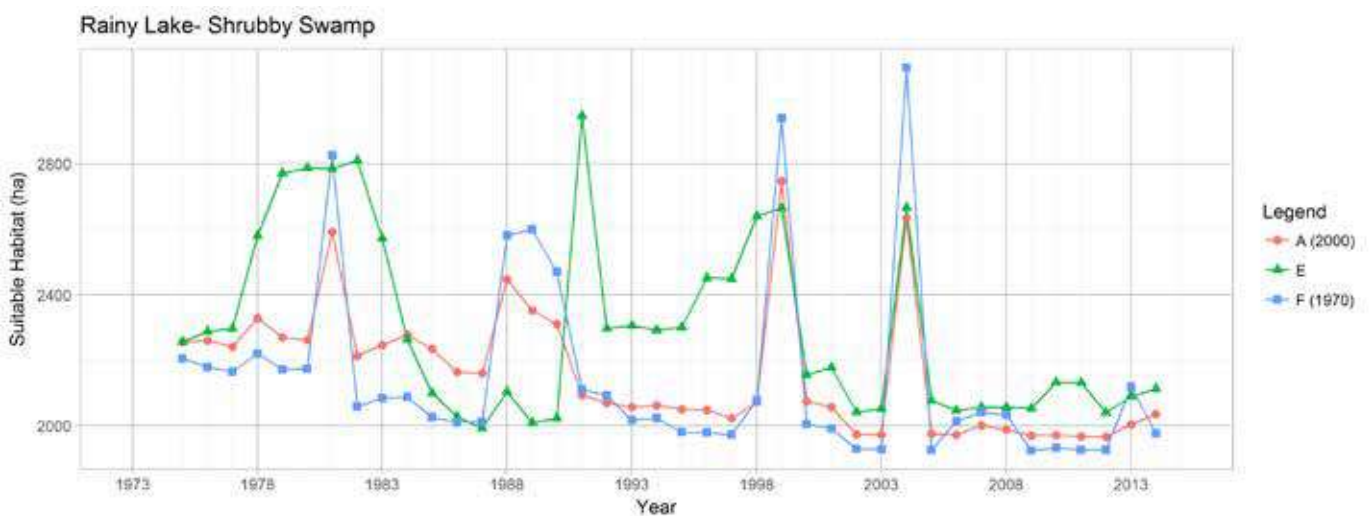


Figure 7-67b Area suitable for shrubby swamps on Rainy Lake, Alternative E

### 3. Emergent plants

The amount of suitable habitat for emergent plants is consistently lower under **Alternative E**, when compared to the 2000 Rule Curve on Namakan Lake (Figure 7-68a). On Rainy Lake, however, the amount of suitable habitat for emergent plants is increased in most years (Figure 7-68b).

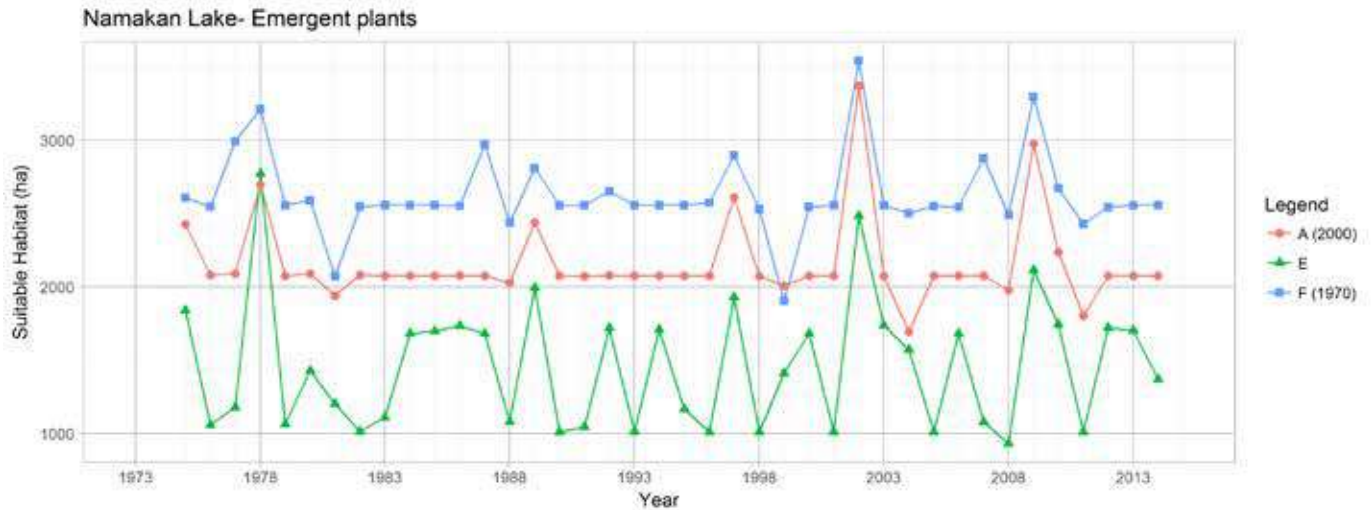


Figure 7-68a Area suitable for emergent plants on Namakan Lake, Alternative E

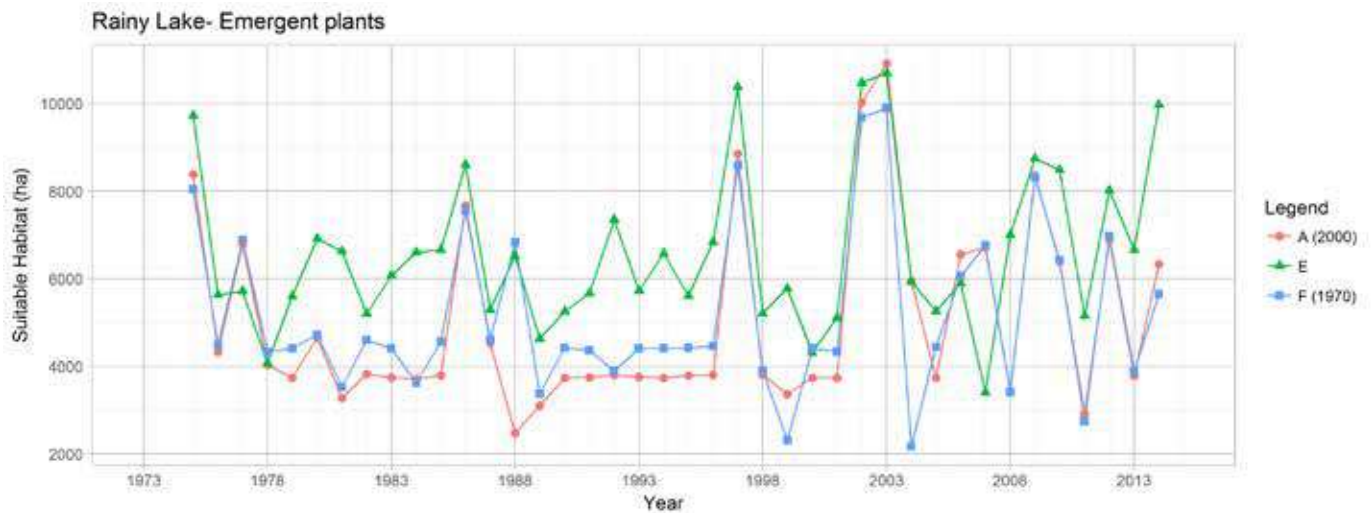


Figure 7-68b Area suitable for emergent plants on Rainy Lake, Alternative E



#### 4. Submerged vegetation

Under **Alternative E**, low-density submerged vegetation is reduced on Namakan and Rainy Lakes in most years (Figures 7-69a and 7-69b). However, the amount of habitat suitable to high-density submerged vegetation is comparable to the 2000 Rule Curves (Figures 7-70a and 7-70b).

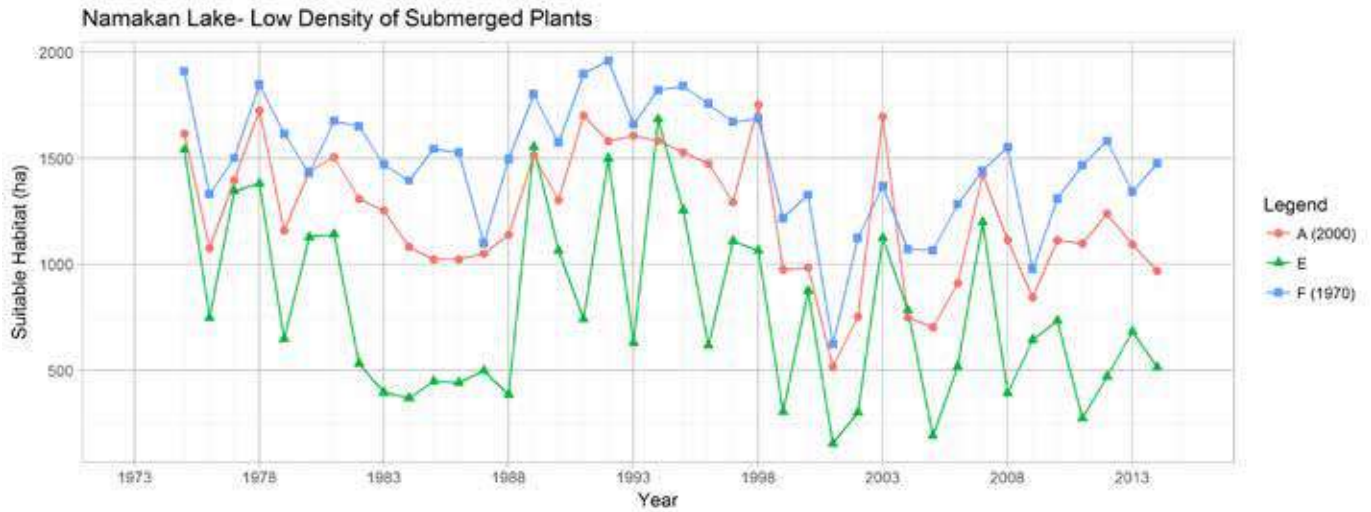


Figure 7-69a Area suitable for low-density submerged plants on Namakan Lake, Alternative E

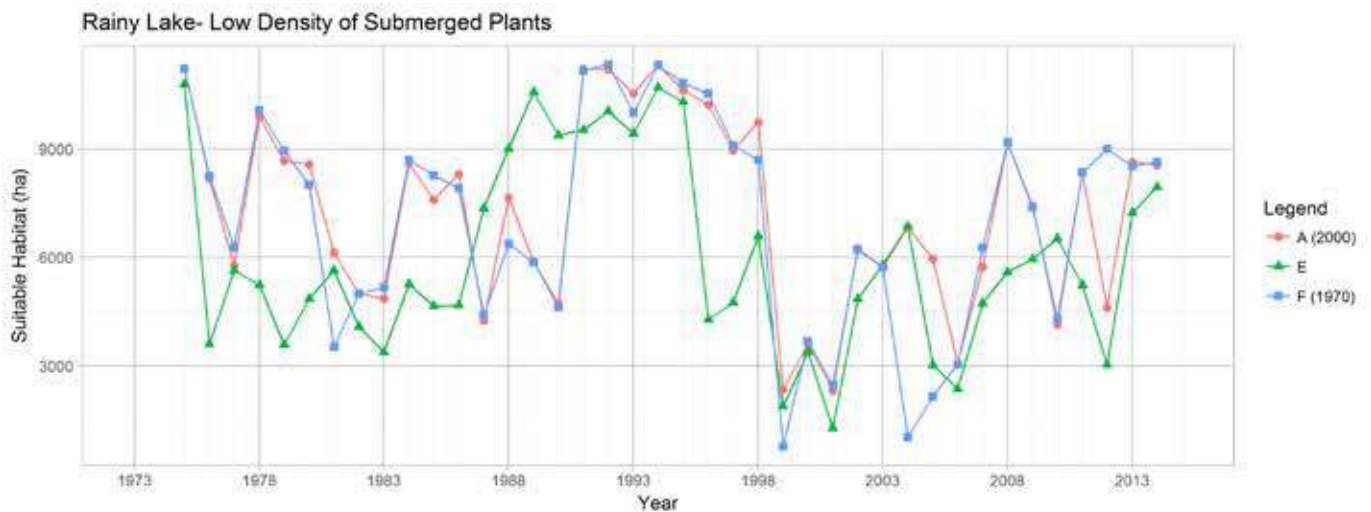


Figure 7-69b Area suitable for low-density submerged plants on Rainy Lake, Alternative E

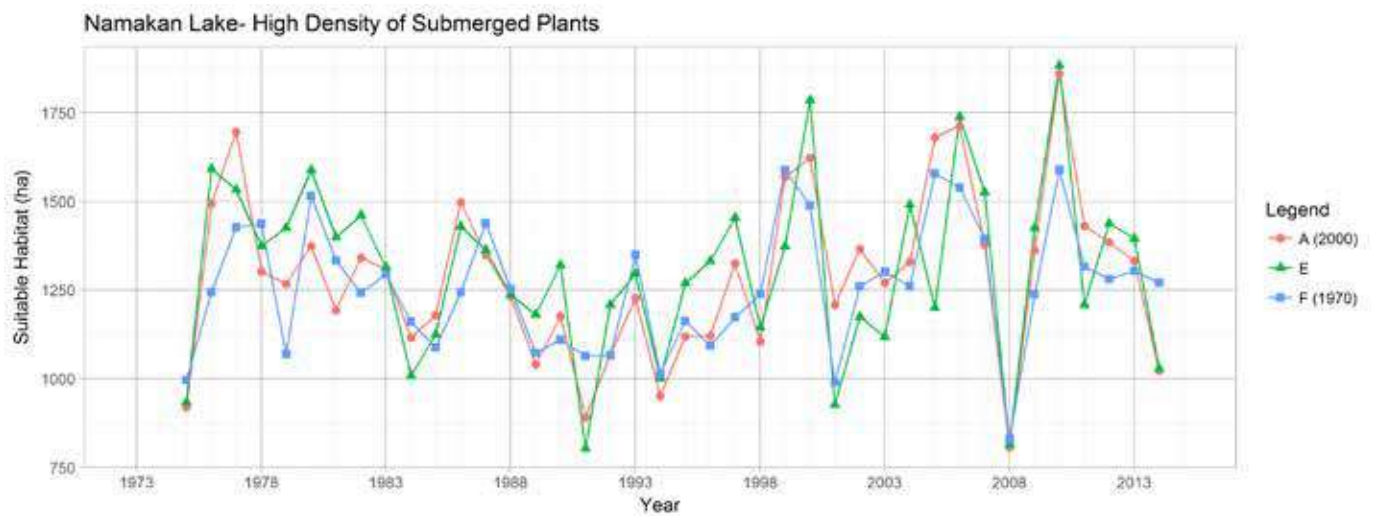


Figure 7-70a Area suitable for high-density submerged plants on Namakan Lake, Alternative E

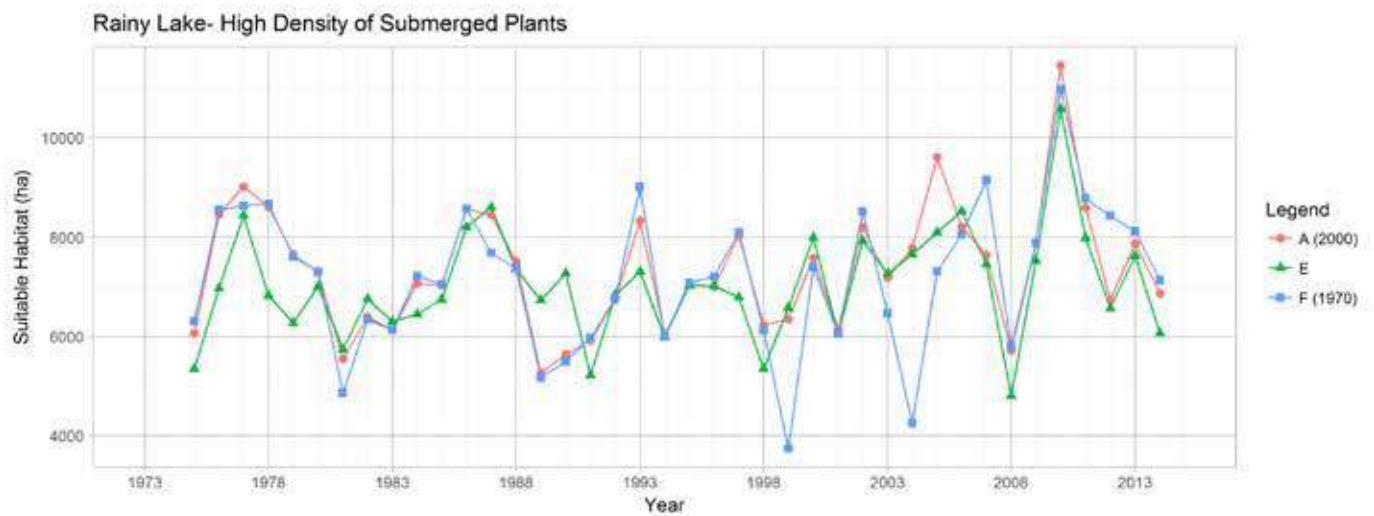


Figure 7-70b Area suitable for high-density submerged plants on Rainy Lake, Alternative E

### 7.5.7 Rainy River: Alternative E

The IERM suggests that the amount of Walleye spawning habitat on Rainy River under **Alternative E** is similar to the 2000 Rule Curves, though more variable (Figure 7-71). The amount of habitat for Lake Sturgeon spawning, however, is reduced in most years (Figure 7-72).

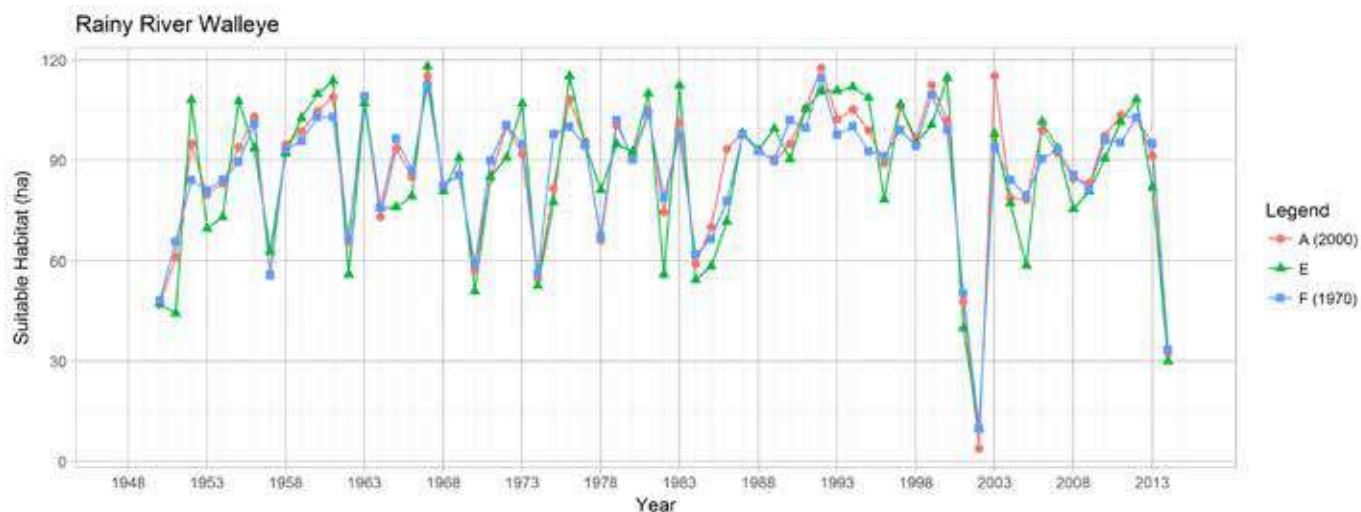


Figure 7-71 Area suitable for spawning on Rainy River, Alternative E

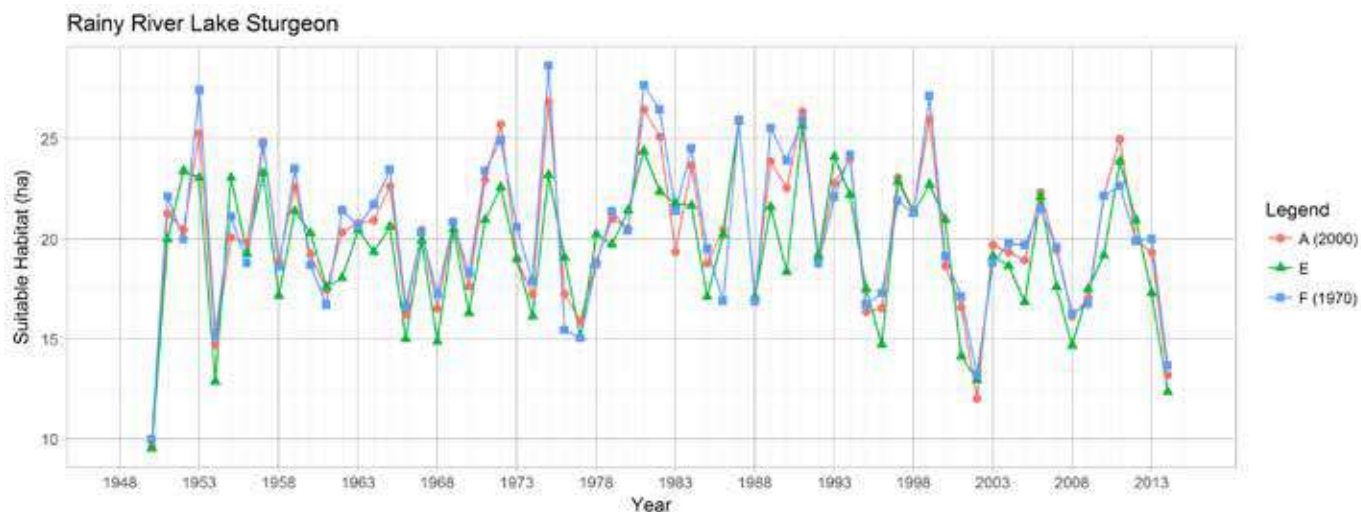


Figure 7-72 Area suitable for Lake Sturgeon spawning on Rainy River, Alternative E

**The Study Board finds Alternative B to be an improvement over the existing 2000 Rule Curves as it provides economic benefits, with only some negative ecological impacts when forecasting tools fail.**

## 7.6 Key findings

Figures 7-73 and 7-74 provide a summary of IERM and SVM results of the comparison of Rule Curve **Alternatives A to E** and **References F and G** for both Rainy Lake and the Namakan Chain of Lakes. Details of model evaluations for each PI are provided in Annex 5. Individual PI scores are annotated where they exceed the scale of the figure or are zero.

Based on the analysis of SVM and IERM model output, the Study Board makes the following key findings:

### Alternative B (Conditional spring flood reduction for Rainy Lake)

- ◆ The analysis of **Alternative B** showed that:
  - this alternative has no impact on Namakan Lake;
  - using an ENSO-based flood forecast, flood peaks on Rainy Lake can be reduced by several centimetres in most flood years;
  - the performance of this alternative is contingent on the performance of the flood forecast; negative impacts to ecological and economic interests can occur as a result of false alarms or missed floods; and
  - Rainy River interests are not likely affected.

- ◆ The Study Board finds **Alternative B** to be an improvement over the existing 2000 Rule Curves as it provides economic benefits, with only some negative ecological impacts when forecasting tools fail.

### Alternative C (Within-year ecosystem improvements)

- ◆ The analysis of **Alternative C** showed that:
  - as with **Alternative B**, flood peaks on

Rainy Lake can be reduced by several centimetres in most flood years using an ENSO-based flood forecast;

- late-season boating reliability is reduced on Namakan Lake;
  - hydropower production is likely reduced under this alternative as a result of increased spill;
  - archeological sites on Namakan and Rainy Lakes are better protected from erosion;
  - **Alternative C** provides a number of ecological benefits to Muskrats, fish and aquatic vegetation on both Namakan and Rainy Lakes;
  - the performance of this alternative is contingent on the performance of the flood forecast; negative impacts to ecological and economic interests can occur as a result of false alarms or missed floods; and
  - Rainy River interests are not likely affected.
- ◆ The Study Board finds **Alternative C** to be an improvement over the existing 2000 Rule Curves, as it provides many ecological benefits, despite some negative economic impacts.

### Alternative D (Hybrid 1970-2000 Rule Curve for Namakan)

- ◆ The analysis of **Alternative D** showed that:
  - this alternative improves late-season boating conditions on Namakan Lake;
  - this alternative does not provide the intended level of flood reduction benefits on Rainy Lake;
  - **Alternative D** reverses some benefits of the summer drawdown on Namakan Lake that were achieved by the implementation of the 2000 Rule Curve; protection to archeological resources is reduced and aquatic



vegetation is negatively affected;

- increase in fall outflow from Namakan Lake in some years can negatively affect over-winter survival of Muskrats on Rainy Lake; and
- Rainy River interests are not likely affected.

- ◆ The Study Board finds that **Alternative D** does not improve upon the existing 2000 Rule Curves. The minor benefits to economic interests on Namakan Lake and Rainy Lake do not offset the negative ecological and archeological impacts.

#### **Alternative E (Increased inter-annual variability for ecosystem benefit)**

- ◆ The analysis of **Alternative E** showed that:
  - this alternative produces the greatest benefits to ecological interests, including the highest probability of over-winter survival of Muskrats and the greatest amount of spawning habitat for Walleye, Northern Pike and Lake Whitefish of all the alternatives evaluated;

- all economic interests on Namakan Lake and Rainy Lake are adversely affected by this alternative;
- the protection of archeological sites from erosion on Namakan Lake is increased, but decreased on Rainy Lake;
- the inter-annual variability provided by this alternative can, to some degree, control the rate of Hybrid Cattail expansion, thereby benefitting Wild Rice;
- the amount of Walleye spawning habitat on Rainy River under **Alternative E** is similar to that under the 2000 Rule Curves, though more variable; and
- the amount of habitat for Lake Sturgeon spawning, however, is reduced in most years.

- ◆ The Study Board does not find **Alternative E** to be an improvement over the existing 2000 Rule Curves as the negative impacts on economic interests on Rainy and Namakan Lake are far too great.



JEFF KANTOR, JCK PHOTOS



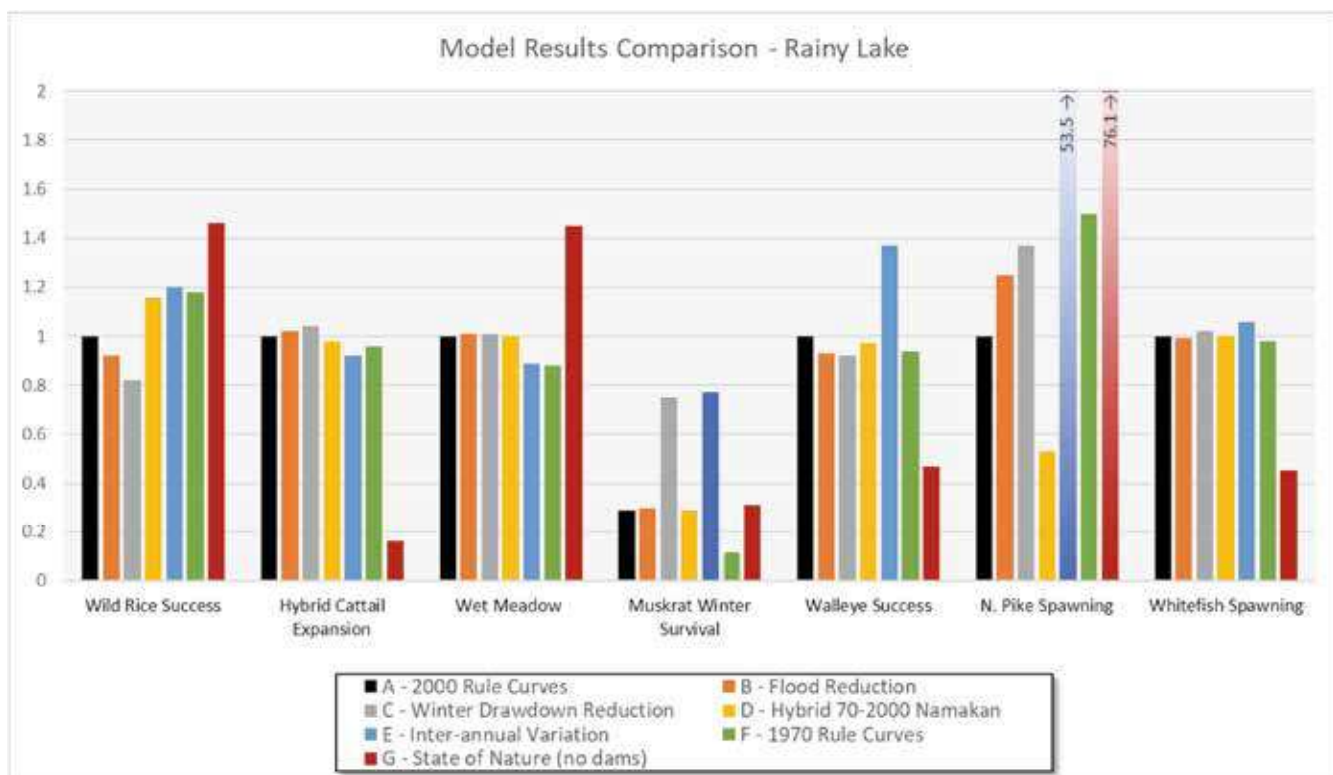
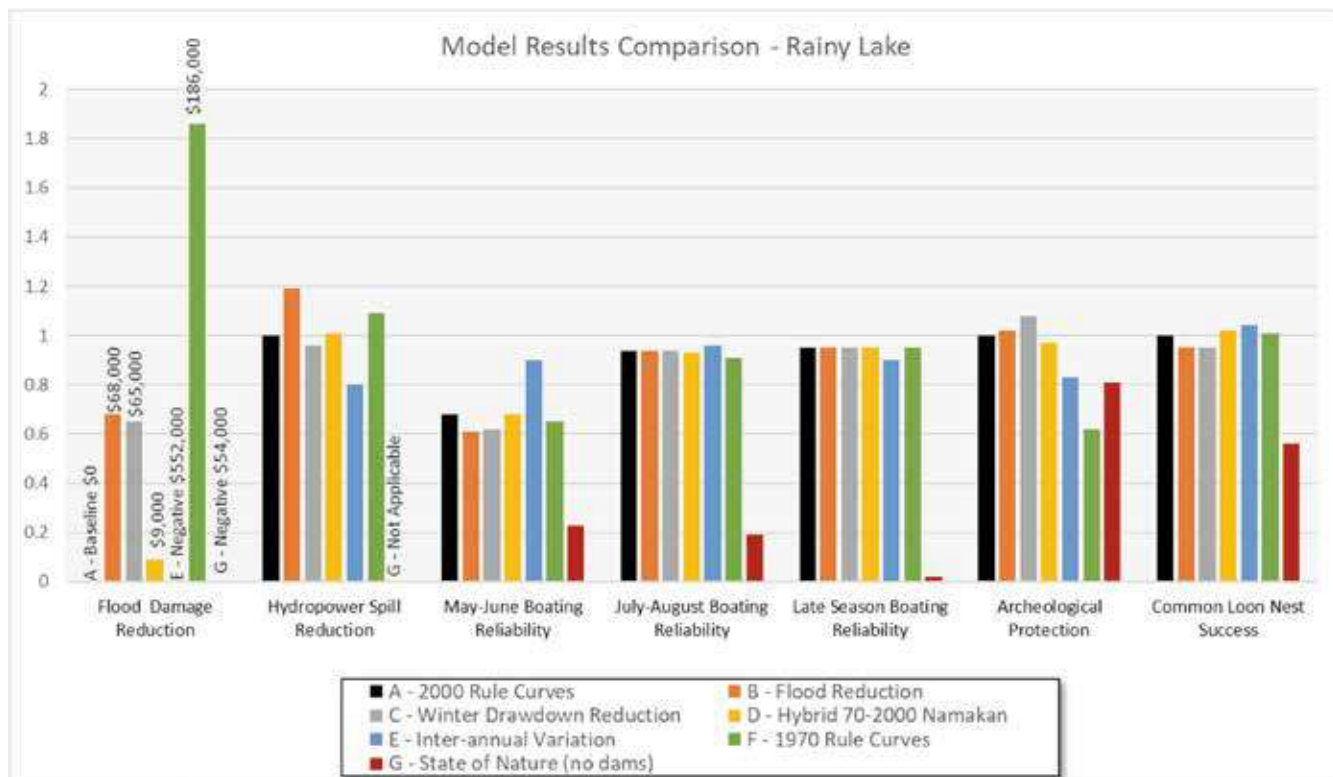


Figure 7-73 Summary of comparison of alternatives, Rainy Lake

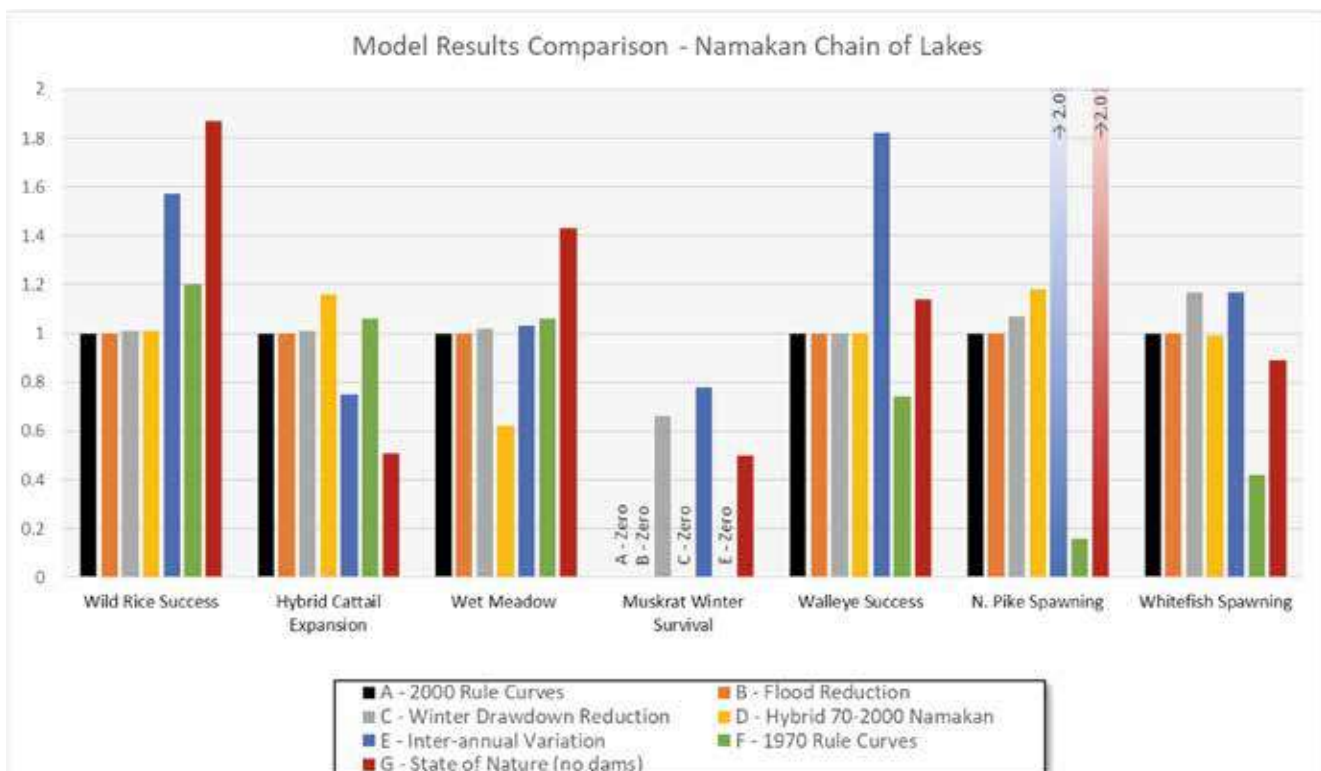
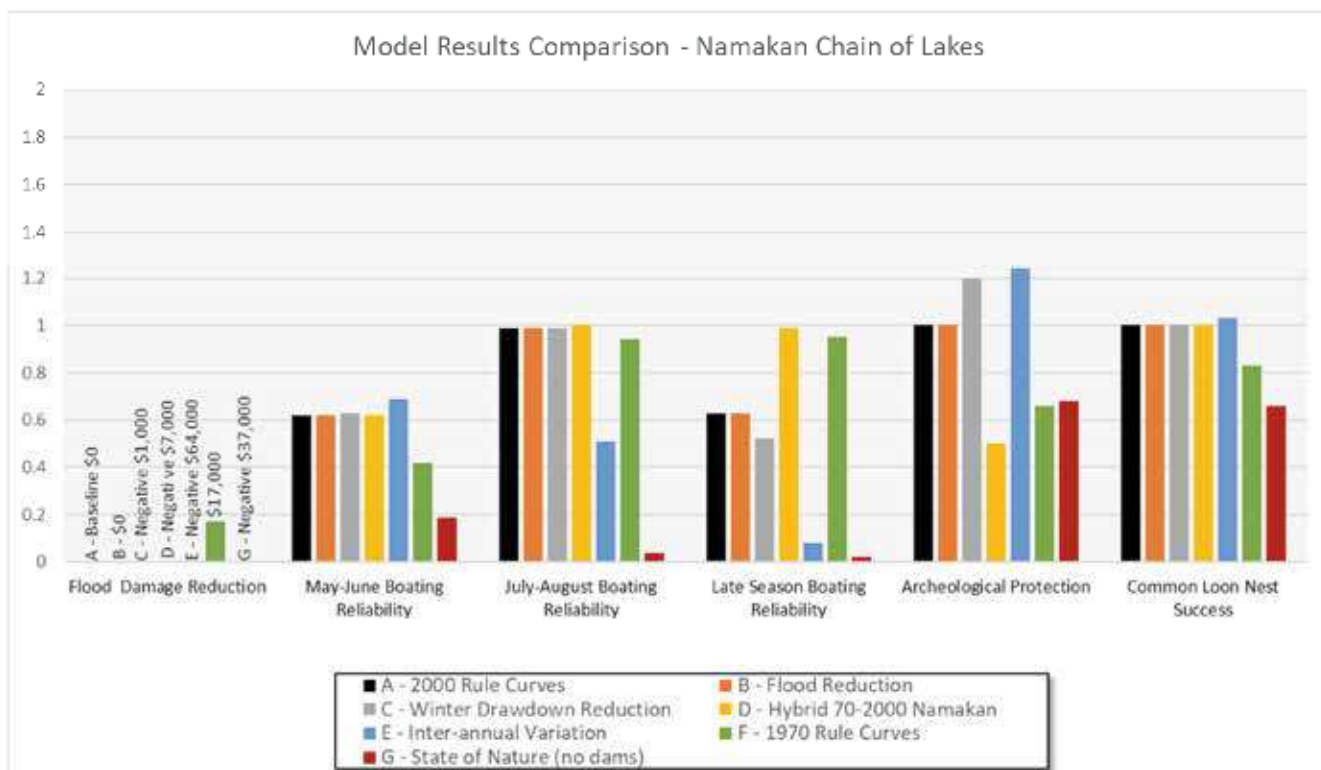


Figure 7-74 Summary of comparison of alternatives, Namakan Chain of Lakes

## 8. ADDRESSING CLIMATE VARIABILITY AND CHANGE

**Chapter 8** summarizes the approach taken by the **International Rainy and Namakan Lakes Rule Curves Study Board** (Study Board) to address the third key objective set out in its Study Strategy:

*To evaluate all regulation alternatives for performance under a range of climate and water supply conditions.*

### 8.1 Background

Climate change could affect the quantity and timing of water flowing into the Namakan Chain of Lakes and Rainy Lake, and the temperature of the water and hence ice cover and evaporation. More severe storms could affect sediment runoff and water quality.

Climate change projections for North America suggest that average annual precipitation and average annual temperatures in the region will increase, with the projected percentages varying depending on the model used and future greenhouse gas emissions scenarios.<sup>19</sup> Precipitation increases are projected to be greater in winter and spring than in summer or fall. Temperature increases are projected to be greater in summer than winter.<sup>20</sup> Analysis of temperature records at International Falls, MN shows that winter temperatures have been increasing the fastest from 1909 to 2016. Warmer winters can change inflows because snow melts sooner in the year. This pattern is one of the possible future conditions modeled in the climate change inflows used to test the rule curve alternatives.

Peak discharges on rivers are expected to increase, but the effect on lake levels is less

clear. If average annual precipitation stays the same while the amount of water falling during individual precipitation events increases, then peak tributary flows will be higher, but the change in lake levels will be muted because of lower precipitation in other periods. Higher annual precipitation amounts can be expected to increase the average inflows, but the potential of those to raise lake levels could be offset by greater evaporation. Ice cover and the timing of the release of water from snow accumulations are also expected to change.

A comparative analysis of models conducted as part of the IJC's International Upper Great Lakes Level Study (International Upper Great Lakes Study Board, 2012) concluded that limitations in model projections of future hydroclimatic conditions result in significant uncertainty about whether Great Lakes levels will be higher or lower, depending on the relative influence of greater precipitation versus higher temperature and the attendant change in evaporation from the surface of the lakes.

The context for making lake level regulation decisions also could change. The current drivers affecting these decisions include hydropower production, flood damage reduction, recreation, the preservation of archeological sites and ecosystem management. Climate change could change the value of hydropower, change the relationship between hours of sunlight and water and air temperature, disturbing life cycles triggered by changes in sunlight and, in turn, changing the current expectations about ecosystem response to the rule curves. The timing of releases might be inappropriate for these new life cycles.

Warmer winters can change inflows because snow melts sooner in the year. This pattern is one of the possible future conditions modeled in the climate change inflows used to test the rule curve alternatives.

<sup>19</sup> See : NASA, <http://spaceref.com/earth/north-american-climate-change-in-the-coming-century.html> and ECCC, [http://www.cccma.ec.gc.ca/diagnostics/cgcm3-t47/animation\\_sresa1b\\_st\\_pcan.shtml](http://www.cccma.ec.gc.ca/diagnostics/cgcm3-t47/animation_sresa1b_st_pcan.shtml)

<sup>20</sup> Federal Highway Administration. [https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/climate\\_effects/effects03.cfm](https://www.fhwa.dot.gov/environment/sustainability/resilience/publications/climate_effects/effects03.cfm)

Warmer water also could affect fisheries. The balances within the current ecosystem could be upset by the migration of invasive species that cannot tolerate the current climate. Development pressures may increase as people abandon areas that have become too hot or dry and move to the study area as warmer temperatures extend the recreation season and winters become milder.

## 8.2 Study approach

To assess and manage the risks posed by climate change to the management of lake levels on Namakan Lake and Rainy Lake, the Study Board:

- considered how climate change might exacerbate problems or provide opportunities; the main concerns were changes in flooding, reliability of boating depths, and ecosystem impacts due to changes in the timing and magnitude of inflows;
- consulted various national sources for current information on how climate change would affect the region, including experts on regional climate change or related fields such as regional paleoclimatology;
- created alternative inflow datasets consistent with the projections of climate scientists and the issues in the basin; and
- tested three alternative rule curves with these datasets to determine the “robustness” of each alternative.

In this context, a *robust* rule curve is one that performs well relative to other alternatives, regardless of the assumptions regarding climate change and future water supplies.

To accommodate the different potential risks (wetter, drier, and seasonally redistributed), ten alternative inflow datasets were created by redistributing the historical timing and magnitude of flows into Namakan Lake and Rainy Lake to create wetter and drier

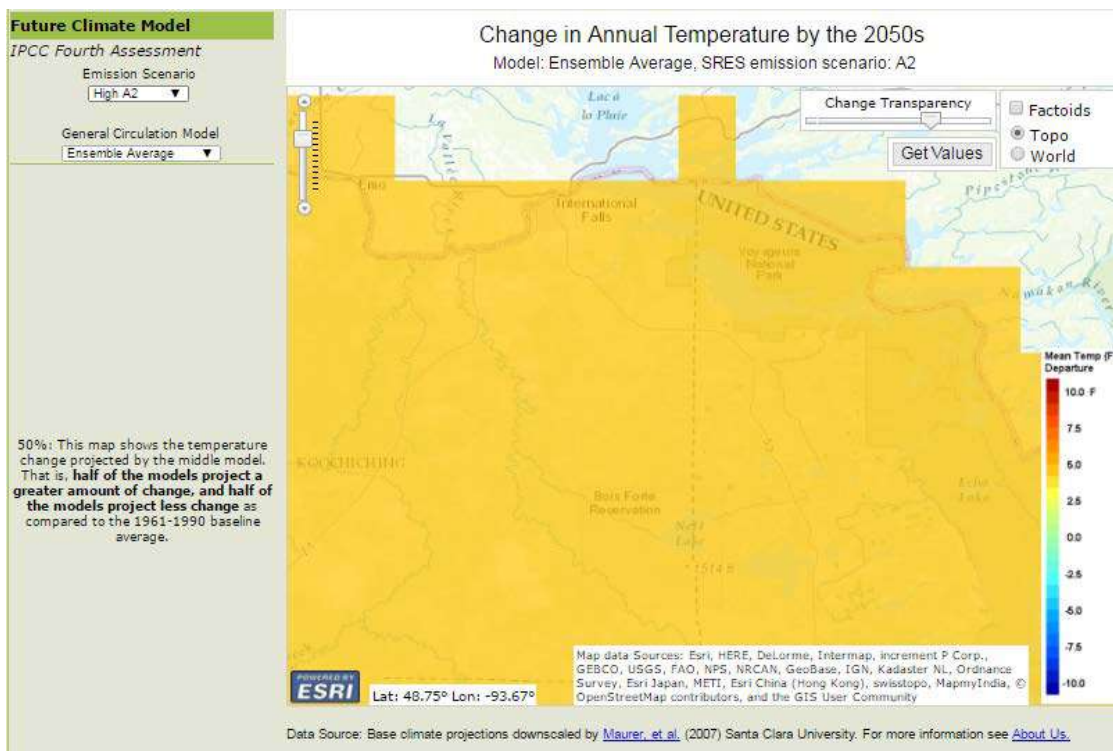
scenarios, as well as scenarios that simulate an earlier snow melt, creating higher late winter flows and lower spring flows.

The historical inflows were adjusted in steps to create the climate change dataset. Quarter-monthly flow rates were converted to volumes of water based on the length of the quarter-month, which were then added up to create the cumulative volume of water flowing into the lakes at the end of each quarter-month. The cumulative volumes for each quarter-month were then expressed as the percentage of the year’s inflow volume to date; for example, 10 percent of the 1955 inflow was received by the lake by quarter-month 4, and 12 percent by quarter-month 5.

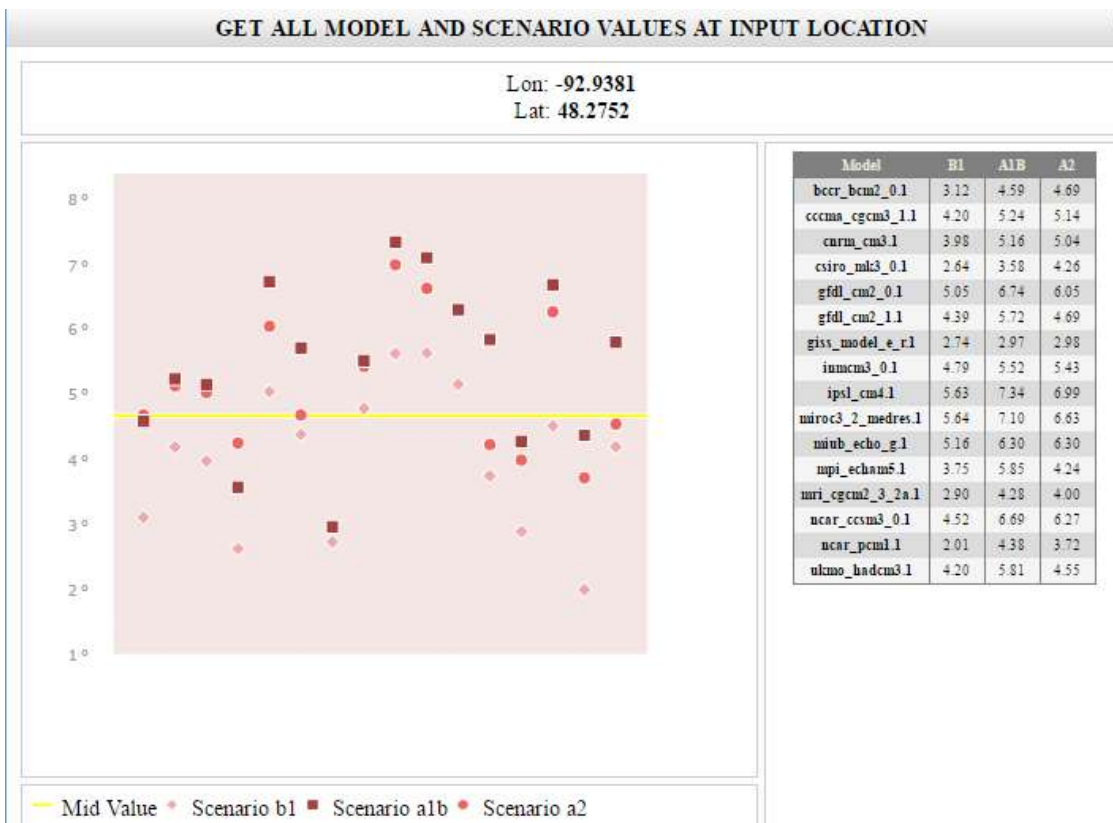
These percentages by quarter-month were then adjusted by factors designed to increase the beginning of year percentages slightly. This was done nine times using limited random adjustments to get slightly different patterns. The end results were then multiplied by random factors from 0.9 to 1.1 to create plausible scenarios of inflow datasets that represent drier and wetter periods than historically observed. This range reflects both the range of projections for temperature and precipitation and the uncertainty about how higher evaporation would counteract higher precipitation.

Two figures illustrate the range in climate model projections in the study area, in this case, for the increase in temperature by 2050:

- Figure 8-1 presents one forecast of the change in average annual temperature for the study area of about 2.8 degrees C (5 degrees F); and
- Figure 8-2 illustrates, in both graphic and tabular form, the individual model run results for projected temperature increases from 16 models and three emission scenarios varying from 1.1 C (2.01F) to 3.9 C (6.99 degrees F) that support the composite 2.8 degree change projection.



**Figure 8-1 Graphical representation of projected 2050 warming in the study area**  
 (source: Nature Conservancy Climate Wizard 2050)



**Figure 8-2 Scenario predictions for climate change in study area from different models and scenarios**

Note: Graph and table illustrate individual model run results for projected temperature increases in the study area from 16 models and three emission scenarios varying from 1.1 C (2.01 F) to 3.9C (6.99 F).



Each of the nine water supply scenarios is constructed to test the alternative rule curves under different conditions that can plausibly be expected in the future.

### 8.3 Water supply scenarios

Each of the nine water supply scenarios is constructed to test the alternative rule curves under different conditions that can plausibly be expected in the future. These conditions assume that: inflows will on net be reduced by greater evaporation; inflows on net will increase due to more severe storms and an increase in average annual precipitation; and dry conditions could persist longer.

Figure 8-3 shows the difference from the historical inflows by quarter-month of the year, based on the average of the inflow changes of Rainy and Namakan Lakes for each quarter-month.

Following are the key features of the water supply scenarios:

- Scenarios 1, 2, 3, 4 and 5 represent a drier future, with warmer temperatures substantially increasing winter snow melt and evaporation, with drier April, May and June inflows. Scenario 5 is identical to the historical conditions except that low flow periods in historical years 1961 and 1997 are extended an additional year to capture the potential for longer droughts in the future.
- Scenario 6 represents very slightly wetter overall supplies and assumes that warmer winters would slightly increase the volume of water that ran into the lakes during the winter, with higher temperatures slightly reducing the amount of water flowing into the lakes in April, May and June and late fall.
- Scenario 7 is the historical inflow.
- Scenario 8 represents a future in which annual flows are only slightly greater than current flows but with the somewhat greater inflows in April, May and June.
- Scenarios 9 and 10 reflect the concern that inflows would be wetter on average and that with greater storm severity,

flows in April, May and June would increase the most when the timing would have the greatest impact on flooding.

### 8.4 Testing the alternative rule curves for robustness

The 2000 Rule Curves (**Alternative A**), **Alternative B** and **Alternative C** were evaluated using the ten inflow datasets. **Alternatives D** and **E** were not evaluated further because they did not perform well even with the historical supplies. As indicated in Section 7.4, **Alternative D** does not provide the intended level of flood reduction benefit on Rainy Lake and also reverses some benefits gained by 2000 Rule Curve summer drawdown on Namakan Lake; **Alternative E** (Section 7.5) provides many of the expected benefits to ecological interests such as fish and wildlife, but produces negative impacts on economic interests on both lakes and archeological interests on Rainy Lake.

The SVM calculated ten sets of flood damages, boating indicators, spill estimates and archeological indicators for each of the three rule curve alternatives evaluated. The distribution of those scores was represented graphically and by ratios to the performance of the 2000 Rule Curves with historical supplies.

The analysis showed that:

- **Flooding** in wet scenarios is greater than historical and low levels in dry scenarios are lower no matter the alternative rule curve simulated (Figure 8-4 through 8-7). The number of flooding events causing \$1 million in damage on Rainy Lake varies from four in climate scenario 1 to ten in the historical or near-historical scenarios (5-6-7) to 11 in scenario 8 and 18 in scenario 10. In each climate scenario, the counts are the same for all plans, even as **Alternatives B** and **C** produce lower damages than **A**, except that in scenario 4, **Alternative A** causes

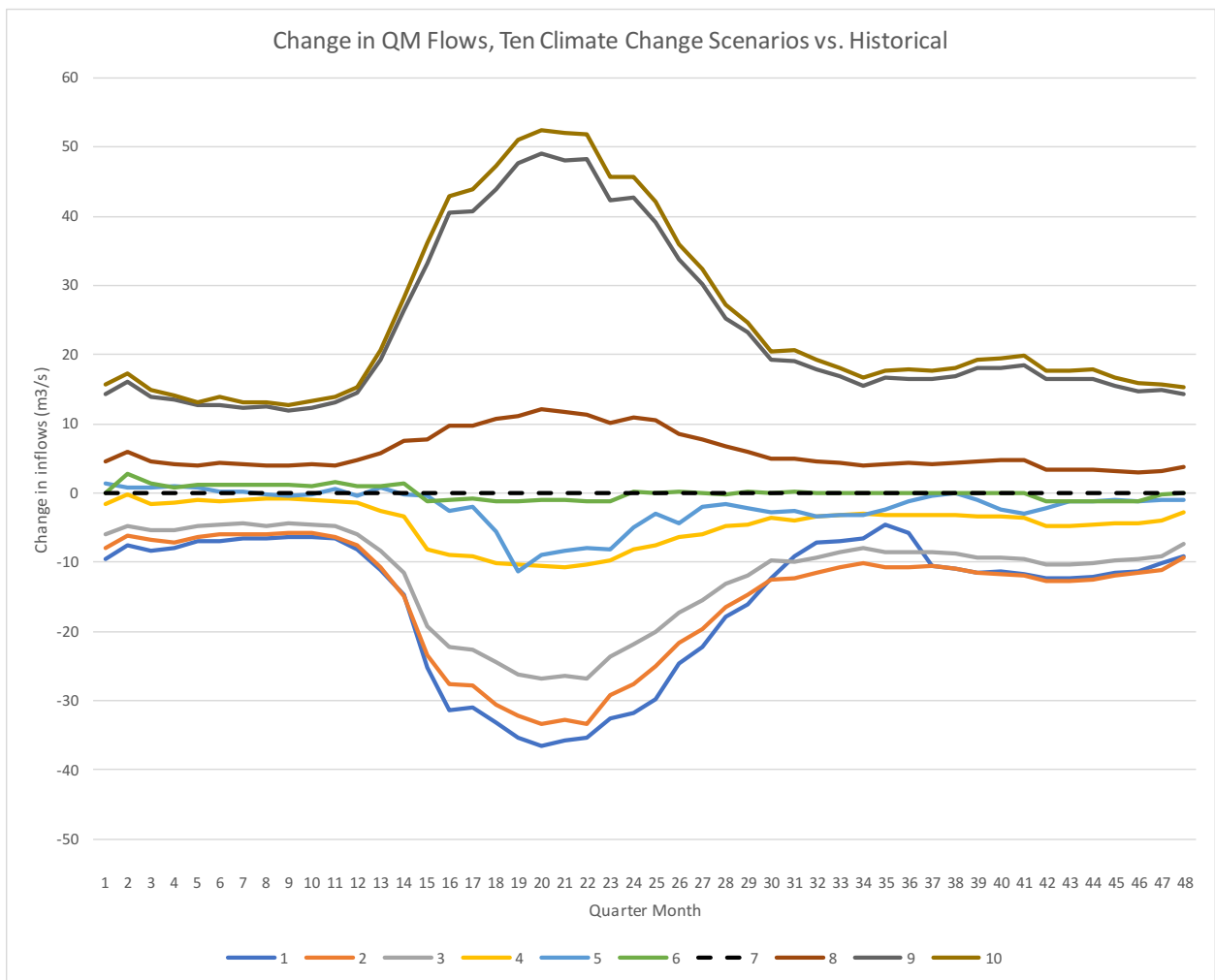


Figure 8-3 Inflow rate changes from the historical inflows by quarter-month, ten inflow scenarios

- five large floods, while **B** and **C** each cause four.
- Even in multi-year droughts, Rainy Lake returns to a level close to the rule curve band by the end of the year.
- Boating depths are more likely to suffer at the beginning and end of the boating season (Figures 8-8 through 8-13). However, no alternative rule curve performance deteriorates significantly more than the others.
- Although there are differences between the alternatives for archeological vulnerability (Figures 8-14 and 8-15), similar differences are observed over the ten climate scenarios.
- Walleye success rates (Figures 8-16 and 8-17) decline for all the alternatives under the wettest inflow scenarios but no alternative is more sensitive than the others to fast rising levels.
- Muskrat survival rates (Figures 8-18 and 8-19) are always much better for **Alternative C**, which has high rates no matter the inflows. **Alternatives A** and **B** have low rates no matter the scenario.
- Drought and minimum releases into the Rainy River increase in frequency in drier climate scenarios (Figure 8-20). Rainy River always maintains at least the minimum release, so the count of

low releases tracks the impact of dry climate scenarios on river flows under each alternative. In very dry scenarios, the relative performance of **Alternative C** versus **A** and **B** gets slightly worse. This could be monitored under adaptive management to determine if these small changes in frequency translate to noticeable impacts.

- Finally, none of the three alternatives evaluated performs much differently compared to the others with regard to the range of water levels produced, no matter the inflow scenario (Figure 8-21). Water levels on these lakes can vary greatly from May to July, but in the most extreme climate scenarios, each of the three alternatives performs about as well as any other, with expected differences in levels early and late in the year.

This is a limited test in that the Study Board did not attempt to estimate ecosystem impacts under warmer future conditions. Given the small changes in water levels between the three alternatives and the potential changes in the ecosystem, there is little confidence in the ability to rank the alternatives based on differences in the performance of ecosystem PIs. The flood forecasts used in **Alternatives B** and **C** are the same as was used for the historical analysis, even though the ENSO indicator may not predict floods as well under climate change. If a forecast (ENSO-based or not) works as well as the current forecast has worked, then the assessment of **Alternatives B** and **C** under climate change is sound. However, if climate change reduces the ability to predict flooding, then the performance of those alternatives would change in ways not tested in this analysis.

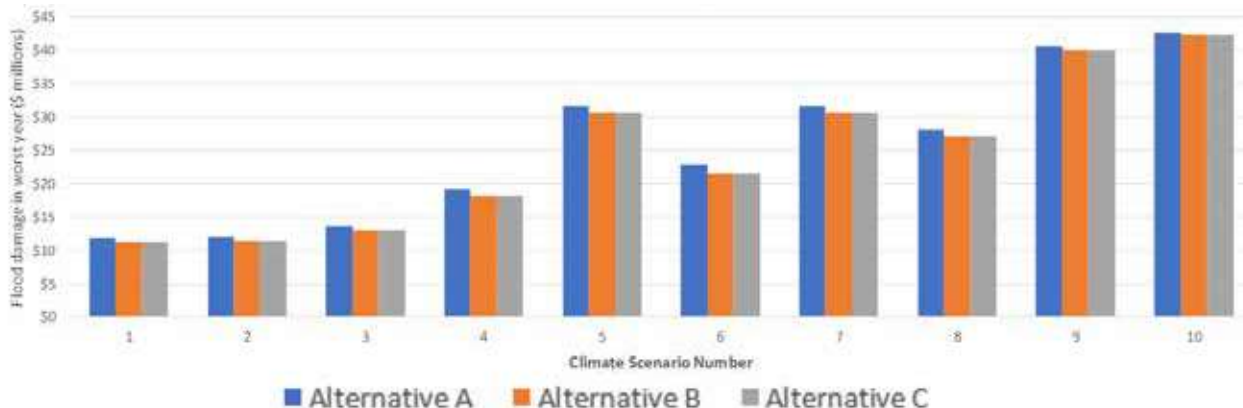


Figure 8-4 Rainy Lake flood damages in worst year: ten different inflow sequences, three alternatives, ten inflow scenarios

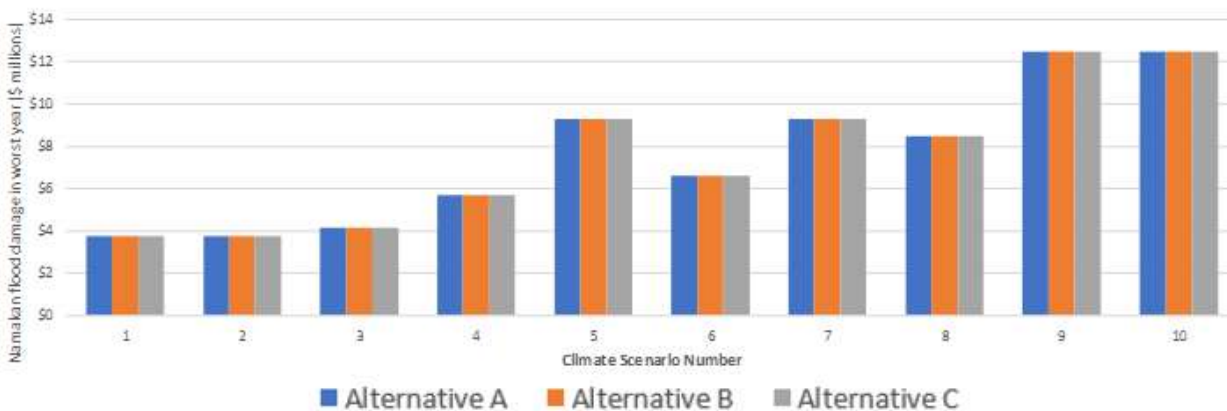


Figure 8-5 Namakan Lake flood damages in worst year: three alternatives, ten inflow scenarios

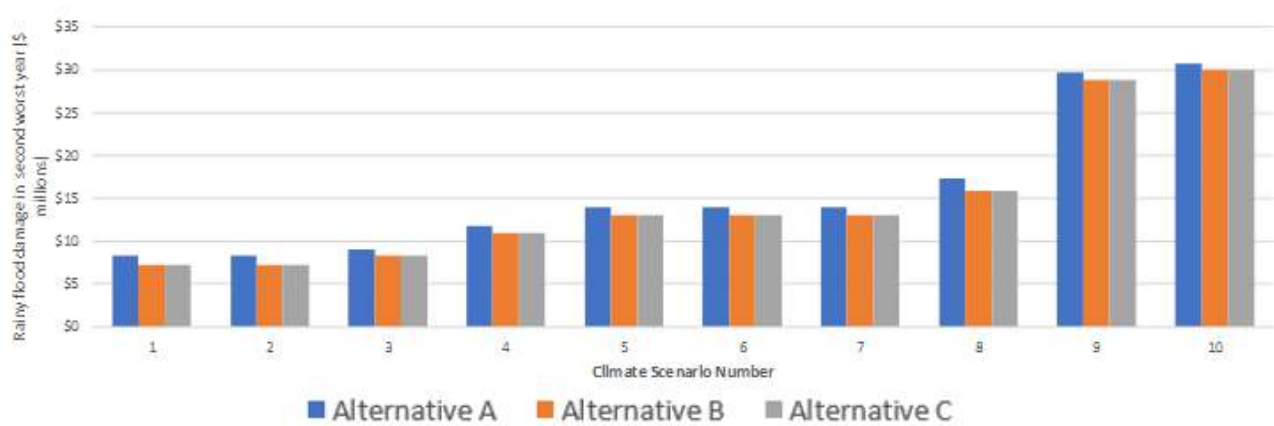


Figure 8-6 Rainy Lake flood damages in the second worst year: three alternatives, ten inflow scenarios

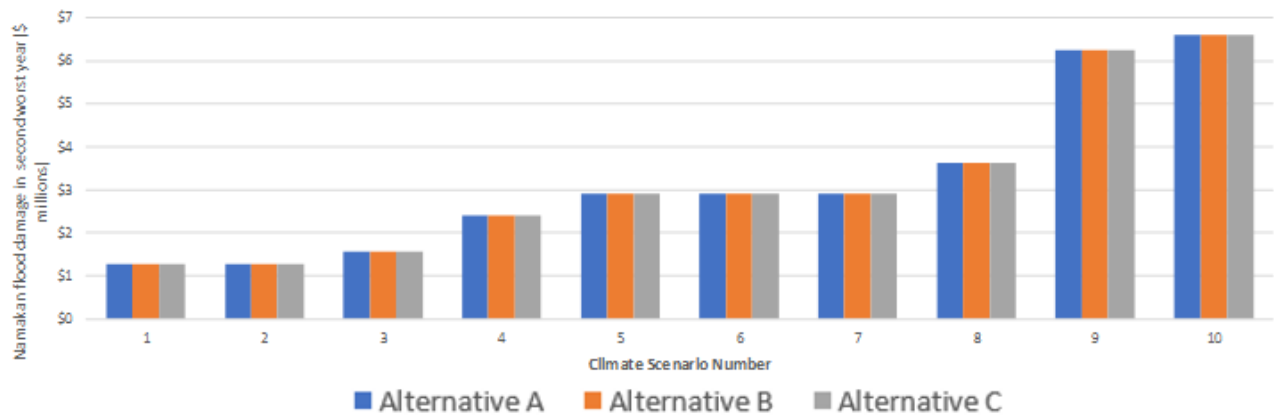


Figure 8-7 Namakan Lake flood damages in the second worst year: three alternatives, ten inflow scenarios

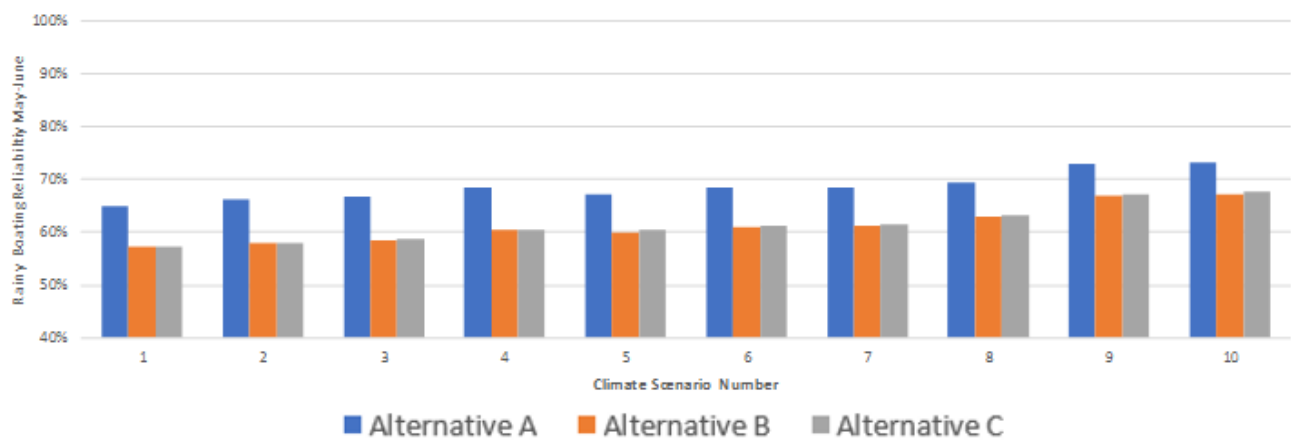


Figure 8-8 Boating reliability on Rainy Lake, May-June: three alternatives, ten inflow scenarios

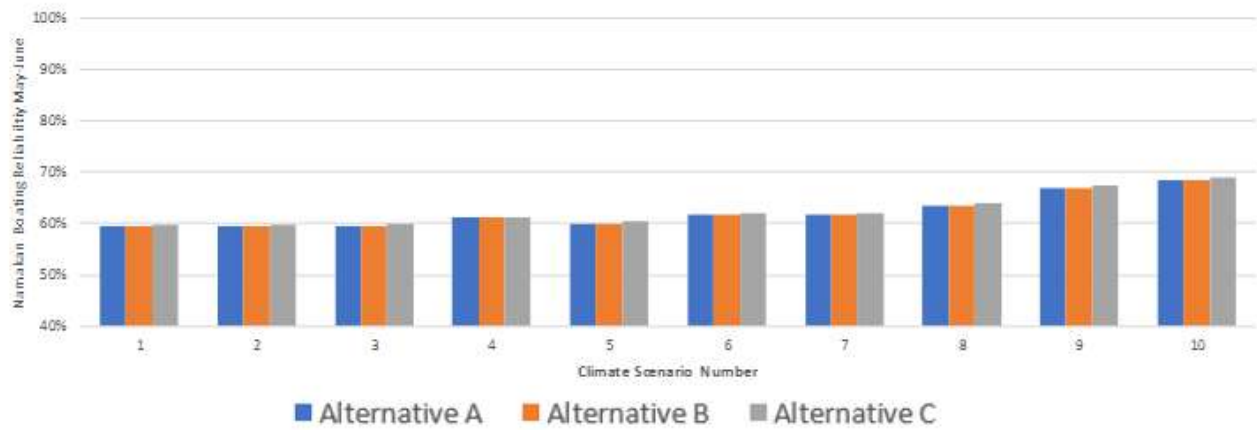


Figure 8-9 Boating reliability on Namakan Lake, May-June: three alternatives, ten inflow scenarios

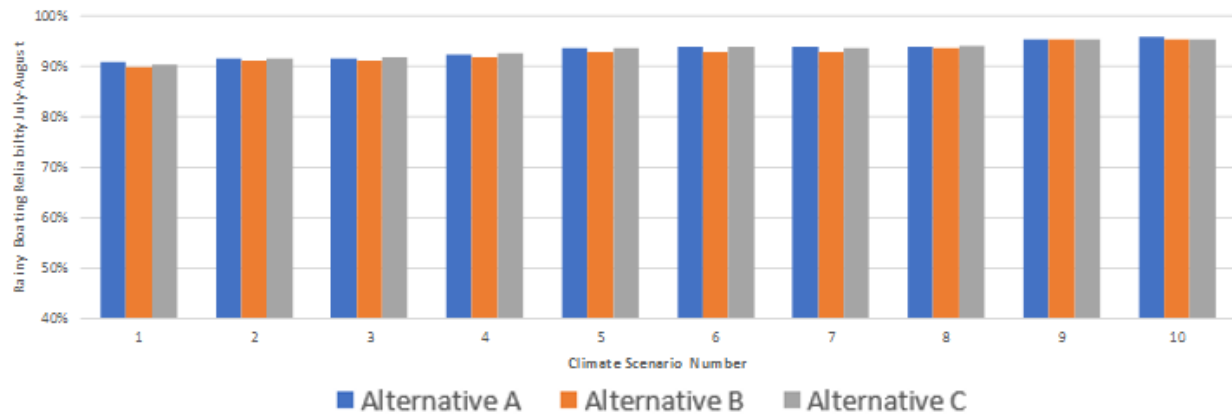


Figure 8-10 Boating reliability on Rainy Lake, July-August: three alternatives, ten inflow scenarios

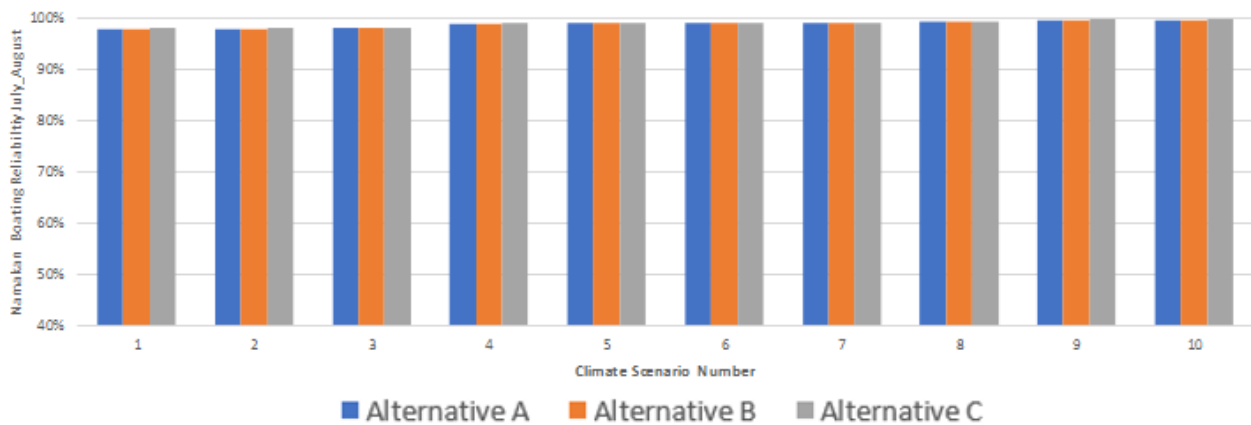


Figure 8-11 Boating reliability on Namakan Lake, July-August: three alternatives, ten inflow scenarios



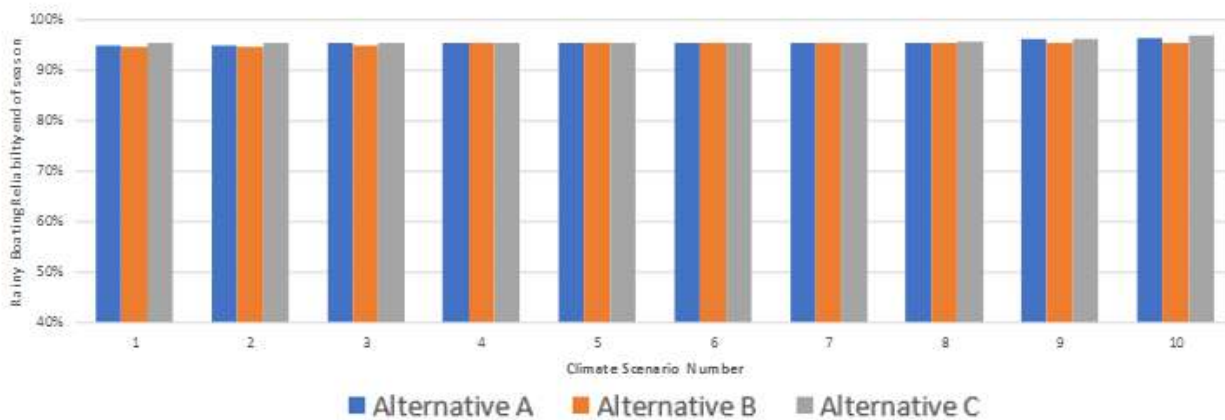


Figure 8-12 Boating reliability on Rainy Lake, end of season: three alternatives, ten inflow scenarios

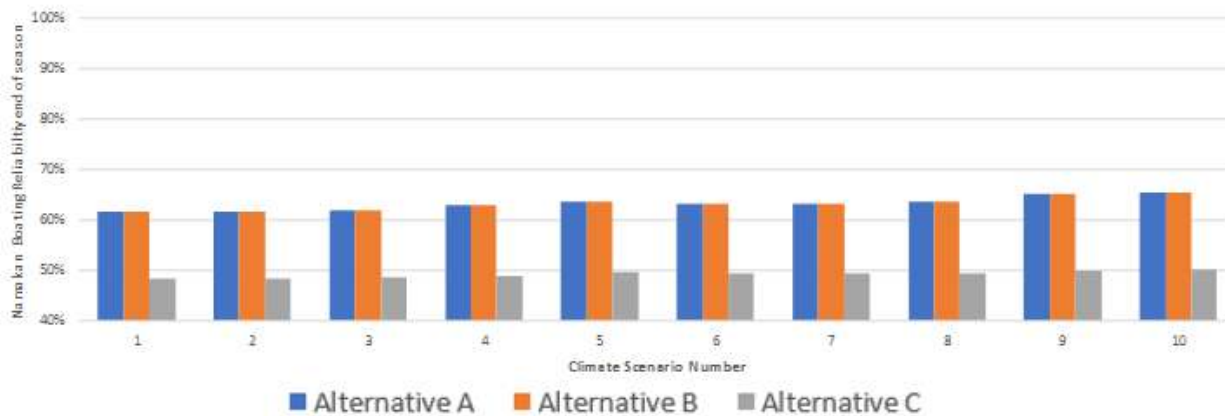


Figure 8-13 Boating reliability on Namakan Lake, end of season: three alternatives, ten inflow scenarios

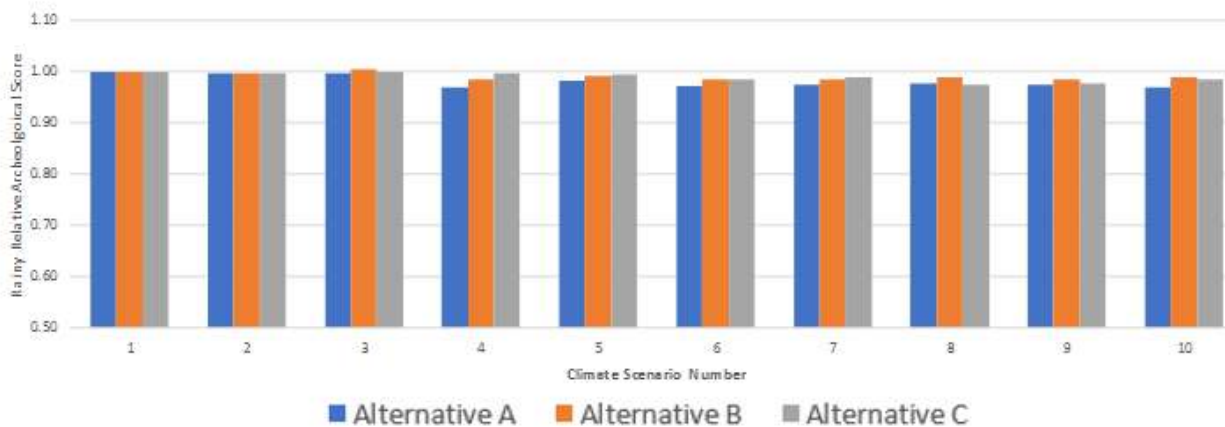


Figure 8-14 Variation in Rainy Lake archeological scores among ten inflow scenarios, as ratios to Scenario 1

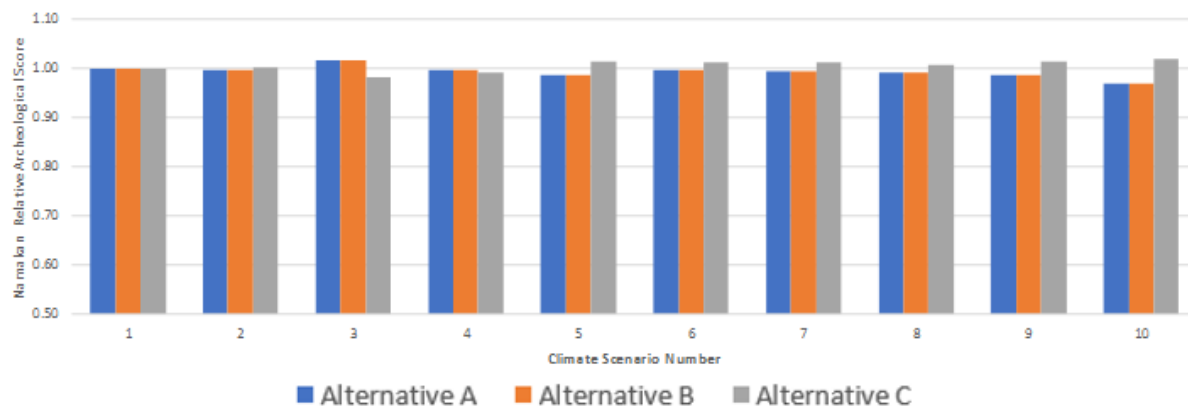


Figure 8-15 Variation in Namakan Lake archeological scores among ten inflow scenarios, as ratios to Scenario 1

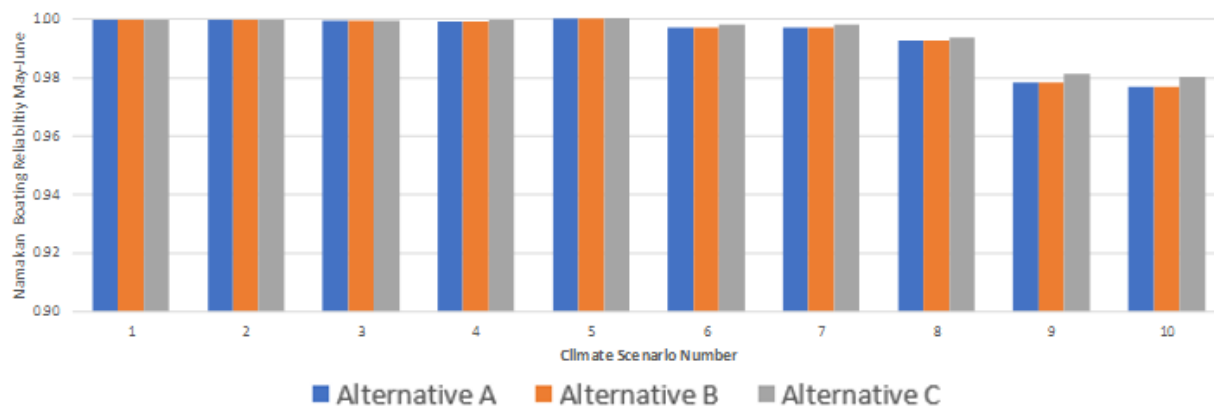


Figure 8-16 Walleye 1D success rates, Rainy Lake: three alternatives, ten inflow scenarios

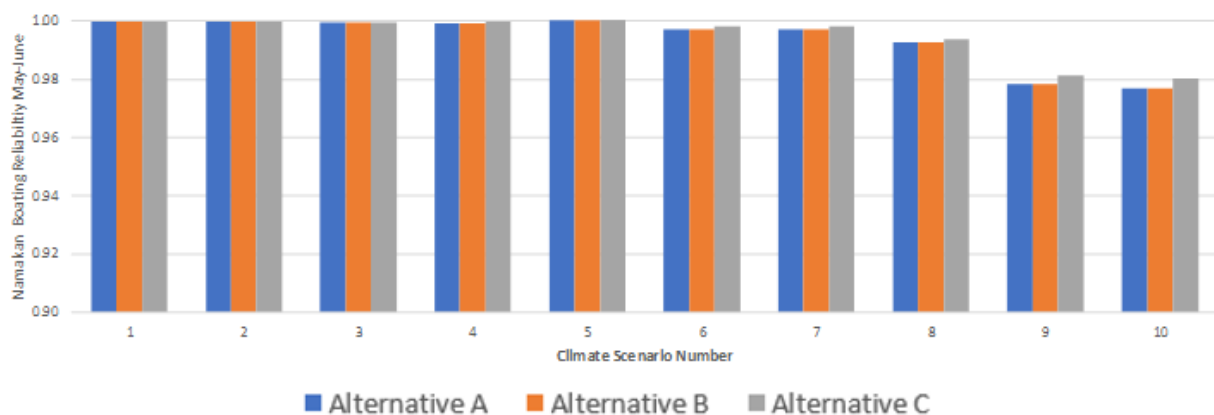


Figure 8-17 Walleye 1D success rates, Namakan Lake: three alternatives, ten inflow scenarios

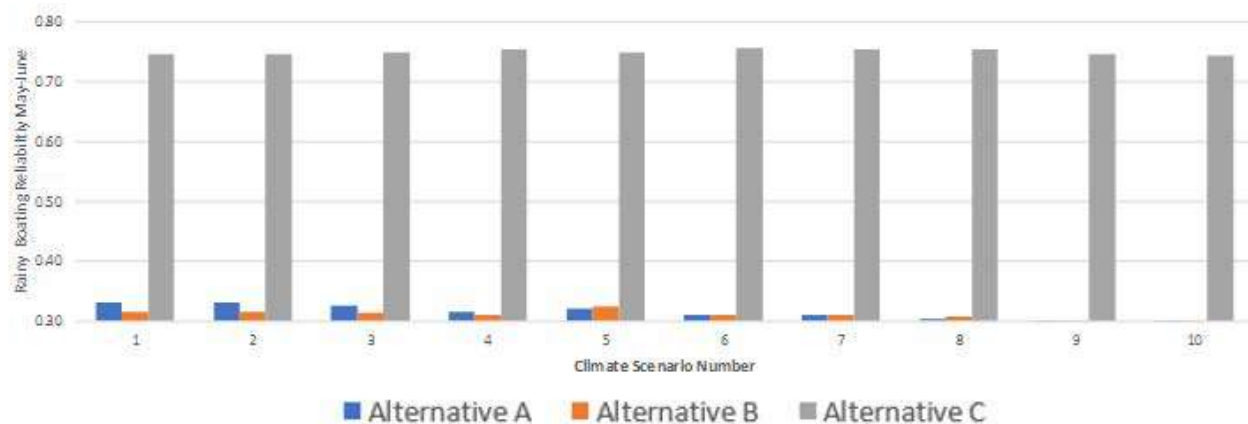


Figure 8-18 Average Muskrat Survival Rates, Rainy Lake: three alternatives, ten inflow scenarios

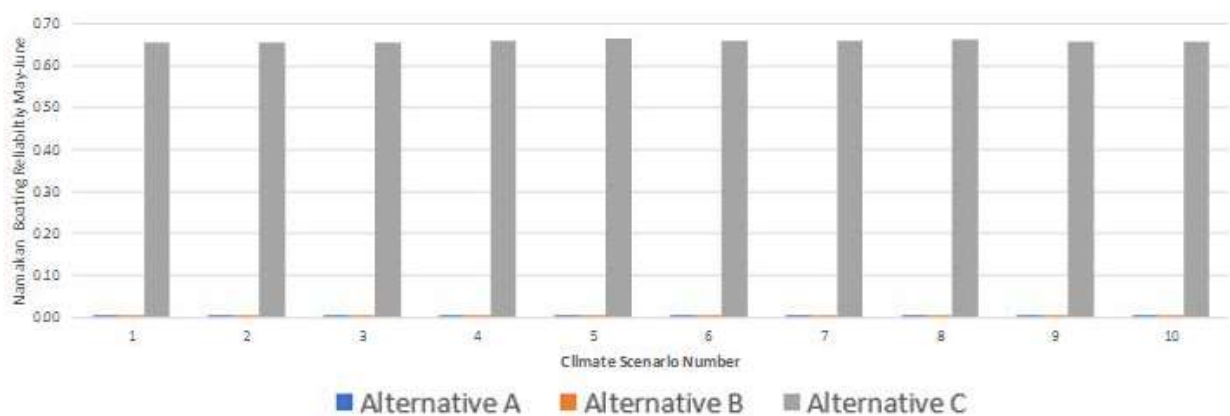


Figure 8-19 Average Muskrat Survival Rates, Namakan Lake: three alternatives, ten inflow scenarios

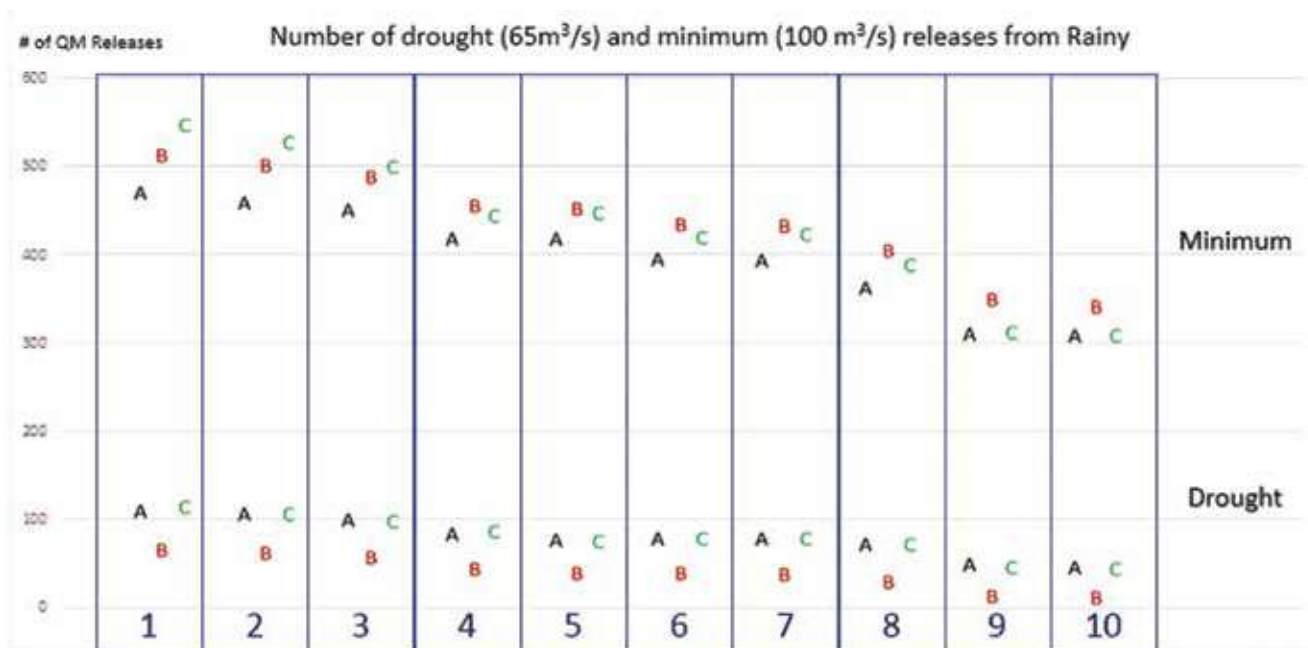


Figure 8-20 Number of drought and minimum releases from Rainy Lake: three alternatives, ten inflow scenarios

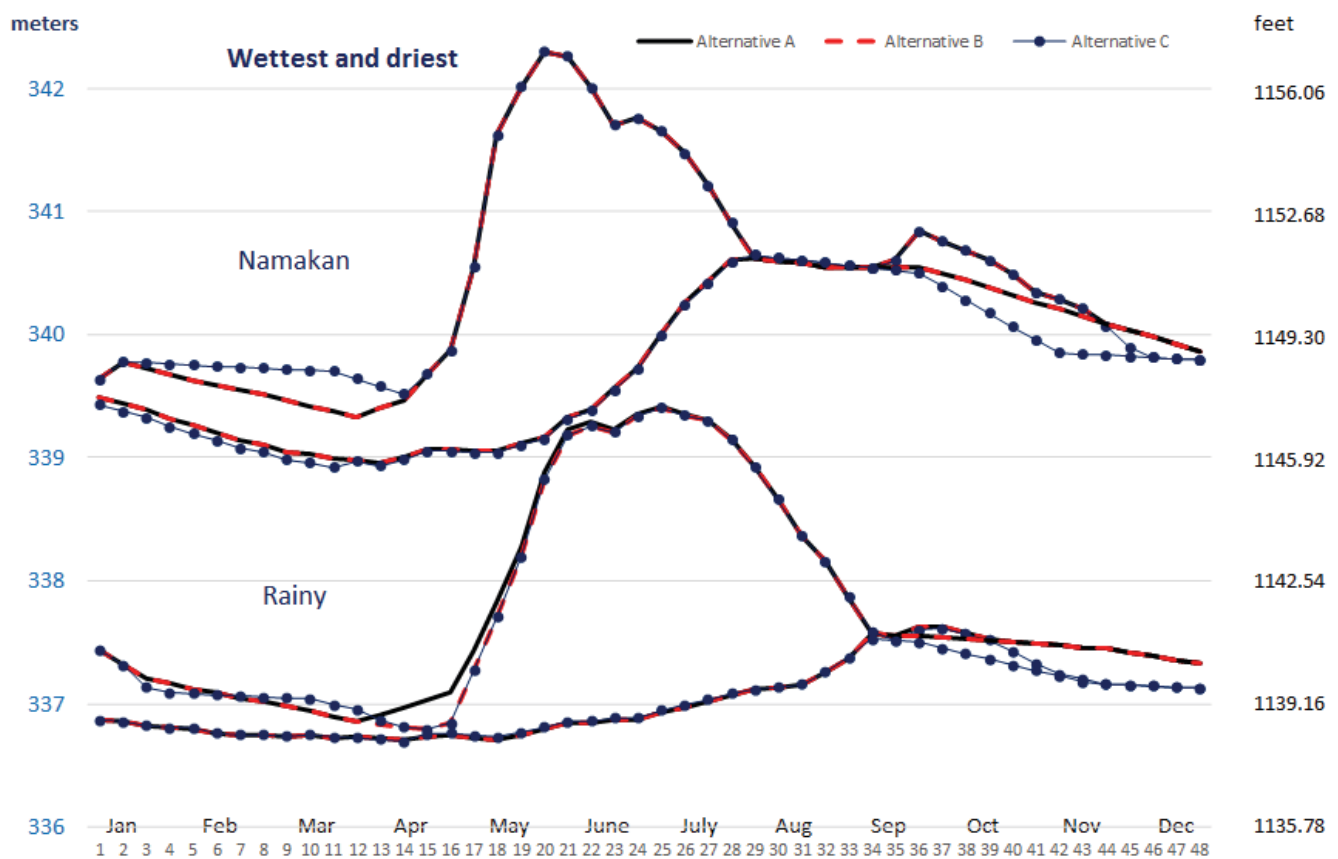


Figure 8-21 Range of Rainy and Namakan water levels: three alternatives, wettest and driest years from ten inflow scenarios

## 8.5 Key findings

Based on the analysis summarized in this chapter, the Study Board makes the following key findings:

- ◆ The Study Board tested three alternative rule curves under a range of future climate conditions, including both extreme wet and dry scenarios. The performance of all three alternatives was affected similarly by greater extremes in inflows. However, none was markedly better or worse. Flood damages increased substantially for all the alternatives in the wettest scenario and decreased substantially in the driest scenarios. Boating conditions on both Namakan and Rainy Lakes were more resistant to dry scenarios, as levels returned to rule curve levels at year's end under even the longest drought. In no case did the relative performance of one alternative rule curve shift dramatically compared to that of the others, based on the climate scenario.
- ◆ The Study Board concludes, therefore, that the alternative rule curves cannot be ranked based on differences in their performance with respect to climate variability and change. Future climate change could substantially affect water levels in the basin, regardless of the rule curve in use, since levels in both lakes cannot be controlled under extremely high or low inflows. This finding reinforces the importance of putting in place a comprehensive adaptive management program to help identify and respond to emerging climate change conditions (see **Chapter 9**).

## 9. THE ROLE OF ADAPTIVE MANAGEMENT

**Chapter 9** presents the assessment of the **International Rainy and Namakan Lakes Rule Curves Study Board** (Study Board) of the value of adaptive management in improving outcomes from water level management in the Rainy-Namakan system. It discusses the elements of adaptive management within the context of the review of the 2000 Rule Curves and notes the challenges involved in implementing adaptive management.

### 9.1 Overview

#### 9.1.1 The concept of adaptive management

Adaptive management is a systematic approach for improving future management outcomes by learning from past outcomes. The National Research Council (2004) defines adaptive management as a decision process with:

*“... flexible decision making that can be adjusted in the face of uncertainties as outcomes from management actions and other events become better understood. Careful monitoring of these outcomes both advances scientific understanding and helps adjust policies or operations as part of an iterative learning process.*

*It is not a ‘trial and error’ process, but rather emphasizes learning while doing.”*

A critical task in adaptive management is to monitor the results of a decision in those areas where the predictions were most uncertain and influential and then use those results to update the state of knowledge and even adjust the decision if the new understanding calls for change. For adaptive management to work, it must be done collaboratively, involving all those who can affect the outcomes in question. Figure

9-1 illustrates the iterative and collaborative framework of the concept.

Normally, projects such as a review of rule curves on a lake system would not be considered part of an adaptive management cycle, as they are not designed to allow for continual monitoring, review and iterative learning. In such situations, there is a discontinuity in data gathering, modelling and interpreting whether the objectives and targets are achieved.

However, as discussed in the following section, this was not the case for this Study; in fact, in the lead-up to this review process, decisions made in conjunction with the adoption of the 2000 Rule Curves included subsequent monitoring and research to assess their performance. Now, as follow up to this review process, the implementation of an institutional adaptive management process would likely improve the quality of decisions, while lowering the system uncertainties through modelling, observations and measurements. This is depicted in Figure 9-2.

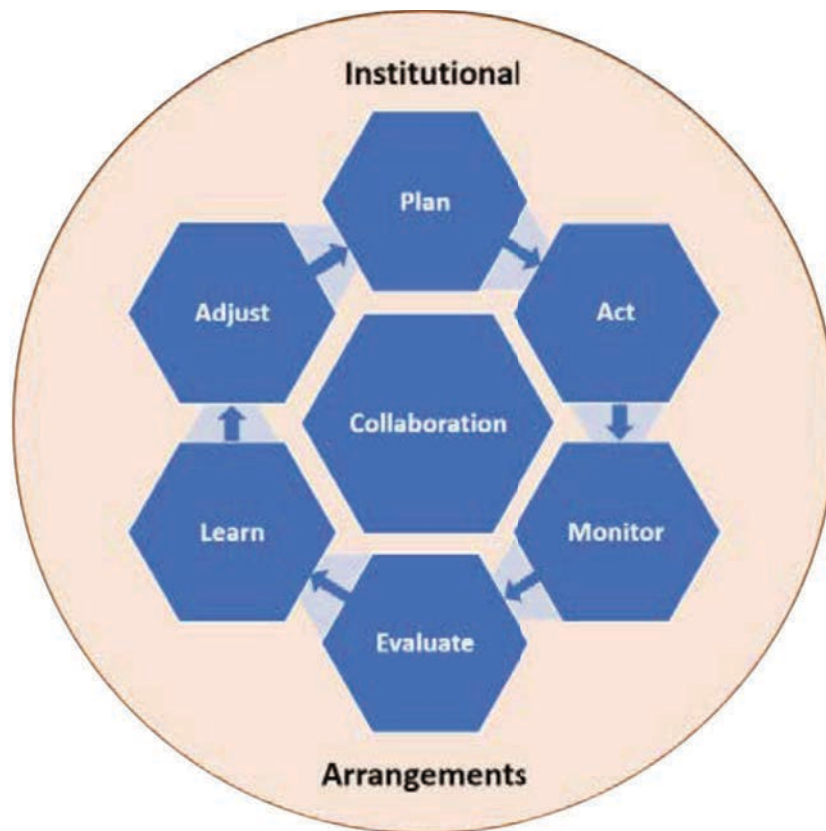
In fact, in the case of the review of the Rainy-Namakan system, adaptive management began when the rule curves were first investigated in the 1990s and was carried forward in the numerous studies, noted in previous chapters, to scientifically support the Study Board’s analysis.

#### 9.1.2 Rule curve review as an element of adaptive management cycle

While the Study Board was developing its Study Strategy, it did not place explicit emphasis on adaptive management. However, the fact that the 2000 Order called for a 15-year review, with a requirement to consider any information provided by the many interests, implicitly involves adaptive management. With the recommendations

Adaptive management is a systematic approach for improving future management outcomes by learning from past outcomes.





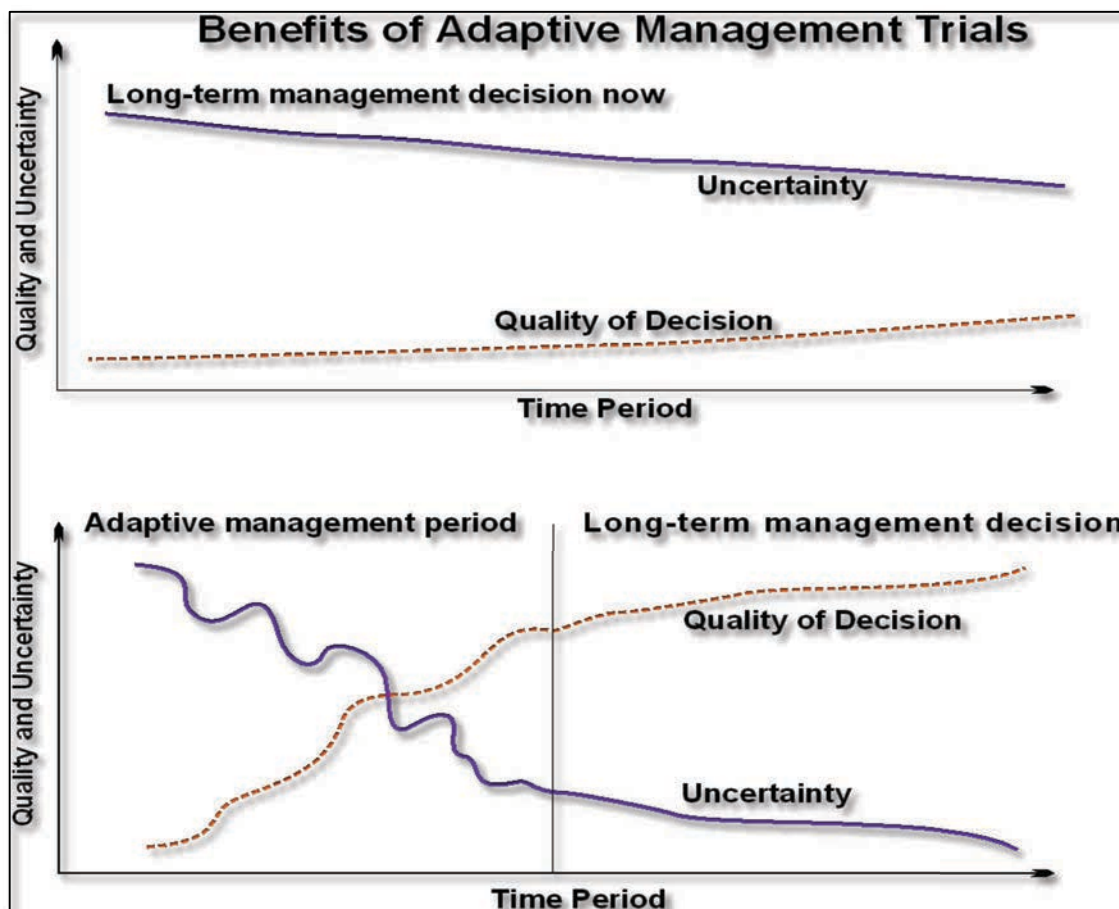
**Figure 9-1 Adaptive management conceptual framework**  
(from International Upper Great Lakes Study Board, 2012)

captured in this report, the International Joint Commission (IJC) will have completed one cycle of adaptive management relative to a water management decision on the revised rule curves.

Considering the adaptive management “wheel” shown in Figure 9-1, the implementation of the 2000 Rule Curves represents the *act* step. Following this was the *monitoring* step, with resource agencies convening a monitoring workshop in early 2000 to identify priority needs and then starting their monitoring. Every year, the IJC’s Rainy Lake Board of Control and Rainy River Water Pollution Board met with the resource agencies to assess progress on the monitoring and *learn* collaboratively and iteratively as part of the adaptive management “wheel.”

On the 15-year time frame for the review of the 2000 Rule Curves, the adaptive management process now is at the stage of *evaluating* the water management action (the rule curves) with all the parties collaborating to evaluate and learn. The Study Board is assessing whether adjustments are needed in the water management *plan*, the current version being the 2000 Rule Curves. Between implementation in 2000 and this review, the overarching institutional arrangements shown in the adaptive management “wheel” were ad-hoc, but effective. It is worth considering the value of formalizing the institutional arrangements, governance structure, supporting agencies and interests.

This is a good example of a successful international adaptive management model. The results noted in the Weight of Evidence



**Figure 9-2 Benefits of adaptive management in better decisions**  
(after Murray and Mamorek, 2003))

(WOE) matrix, and captured in **Chapter 5**, include lessons learned to apply in improving the quality of decisions in water management through the adaptive management of rule curves.

### 9.1.3 The potential benefits of adaptive management

Adaptive management is useful in addressing uncertainty in water management in two areas, sometimes referred to as *environmental variation* and *process uncertainty* (Groves, et al., 2008). The first includes uncertainty about what will happen in the world; the second includes uncertainty about conception of how the world works.

Environmental variations of concern in the Rainy Basin include climate variability and

change, large-scale impacts on species, including invasion and migration, and demand for water and quality of water supply. In the process uncertainty category, there is uncertainty about how robust the algorithms for flooding or suitable Walleye habitat are — to what extent do misconceptions in the models skew decisions and produce less desirable outcomes?

Adaptive management is a structured process for acquiring the evidence that can improve decisions and for applying that learning in the decision-making process. A case in point is the example of the change in the Namakan Rule Curve in 2000 to benefit fisheries. The evidence from monitoring and scientific studies since 2000 indicates

In the long term... Hybrid Cattails can encroach and occupy Northern Pike spawning grounds and other habitat, and threaten the population.

that the expected fisheries benefits were confirmed.

The Study Board's data seem rather to indicate that the 2000 Rule Curve changes provided enhanced conditions on Namakan for Hybrid Cattails post-introduction (as noted in **Chapter 5** — another good reason for monitoring and adaptive management). The Integrated Ecological Response Model (IERM) offers clear evidence that greater water level variability would help manage Hybrid Cattails. In the short term, that would also adversely affect tourism businesses because water level variability makes recreational boating more difficult. In the long term, though, Hybrid Cattails can encroach and occupy Northern Pike spawning grounds and other habitat, and threaten the population. Hybrid Cattails also out-compete Wild Rice, another cultural product. Challenges such as these provide the platform for recommending monitoring in support of adaptive management.

Adaptive management can encourage the development of better databases on Hybrid Cattail extent and Muskrat populations, allowing for the development of better conceptual models of their interrelationships. Those improved models, in turn, can support better informed trade-offs between short- and long-term impacts.

## 9.2 Challenges to adaptive management

### 9.2.1 Institutional challenges

The US Department of the Interior, which prepared one of the most comprehensive and authoritative guides to adaptive management (Williams and Brown, 2005), has concluded that despite the potential for adaptive management to improve the outcomes of water management, it “is infrequently implemented, even though many resource planning documents call for it and numerous resource managers refer to it.”

There are three important institutional issues that make it difficult to manage adaptively.

The first issue is *funding*. Funding to address significant water management issues is often provided in response to crises or disasters. Droughts and floods, for example, produce drought and flood studies. Those studies are scheduled and funded for a certain number of months or years, and when completed, their funding ends. Adaptive management, by its nature, is ongoing and requires a continuous, albeit more modest, funding stream.

The second issue is that most important water problems are managed by *multiple agencies* and *private bodies*, often in different geopolitical zones. Each agency has authority and funding to address specific components. However, often there is no connective or overarching institution to coordinate and prioritize their efforts. Any efforts to organize a coordinated approach often are resisted by those who suspect the organizing entity of “mission creep” — an attempt to passively expand authorized work and subsequently take over other agencies’ work (and associated resources).

The third issue is *maintaining institutional knowledge* throughout the adaptive management process. Individuals from agencies, nongovernment organizations, the private sector and other organizations who contribute significantly to various aspects of the adaptive management process retire or move on to other challenging career endeavors and no longer contribute to the adaptive management process. To overcome this discontinuity issue, collaborative group learning and more formalized institutional arrangements linked to specific organizations are needed to maintain and transfer knowledge over longer time scales.

### 9.2.2 Managing climate change concerns adaptively

Going forward, climate change and possibly

other factors like variability, intensity of storms and wind speeds, likely will change water inflow patterns and rates and the outcomes from any water level regime.

No climate change analysis, including the analysis done for this Study, can forecast such changes with any certainty. Some of this modelling and prediction uncertainty will resolve itself over time with added monitoring data and improvements in technology. Adaptive management can help ensure that improved future knowledge can be translated into better future lake levels and release decisions. The Study Board identified factors that will help it define the most important aspects of any adaptive management effort for the Rainy-Namakan system.

The robustness test used in the Study's analysis suggests three important considerations:

1. The alternative rule curves in final consideration by the Study Board perform about as well as one another under a wide range of inflow conditions; as a result, there is no obvious reason that concerns about climate change should change rankings of the alternatives;
2. The robustness test does not consider how climate change will or will not reduce the correlation between cool El Niño Southern Oscillations (ENSOs) and flooding in the Rainy Basin, so the reliability of the ENSO signal and the skill of flood forecasting needs to be monitored and reviewed; and
3. Some of the water supply sequences used in the robustness test show that to the extent that winter precipitation runs into the lakes sooner because of warmer temperatures, average flooding damages will be reduced. However, so too will the availability of deep water for boating be reduced. Therefore, it may be necessary to change the timing and

levels of the 2000 Rule Curves to adapt to the new inflow patterns and changed water supplies.

Using adaptive management, the models and studies developed for this review would be improved and updated through targeted monitoring programs. Using and updating the models and research will help decision makers, experts and stakeholders maintain their familiarity with the results of this review and train the future water managers and modellers, so that they build on that knowledge base. As any changes in climate and related impacts become clearer, uncertainty will be reduced in the model projections and they will become more useful guides to future changes in rule curves or operational guidelines.

## **9.3 Key findings**

### **9.3.1 Adaptive management in the Rainy Basin**

The IJC has institutionalized adaptive management in other settings by, for example, establishing the Great Lakes-St. Lawrence River Adaptive Management Committee (International Upper Great Lakes Study Board, 2012). That effort was based on scholarly and practical experience starting in the Lake Ontario (International Lake Ontario- St. Lawrence River Study Board, 2006) and Upper Great Lakes studies. Lessons learned from those initiatives can be applied to implement adaptive management in the Rainy Basin.

The IJC also has established adaptive management efforts in other basins associated with reviewing their Orders. This includes Osoyoos Lake, in the Okanagan Basin where the new Supplementary Order includes another clause requiring review of the Order within 25 years or sooner, as determined appropriate by the IJC (International Osoyoos Lake Board of Control, 2012). Adopting something similar

for the Rainy-Namakan system would provide an opportunity to institutionalize a formal adaptive management protocol.

Regardless of the Rainy-Namakan Lakes Rule Curves alternative eventually adopted by the IJC, there needs to be an ongoing effort for communication, monitoring, modelling and research to continue to assess risk, address uncertainties and changing conditions and identify appropriate adaptive actions. At this stage, the Study Board has not attempted to identify specific resource implications for implementing adaptive management beyond the fact that resource needs will depend upon the model adopted, support could be garnered from resource agencies, and synergies accrued from proactive management from the multiple interests in the basin. The International Rainy-Lake of the Woods Watershed Board (IRLWWB) and its Water Levels Committee could be requested to assess the resource requirements based on the commitments from the governments.

The Study Board sees benefit in an adaptive management process with the following core elements to address future water level extremes and uncertainties in the basin:

1. The network of experts, stakeholders and decision makers that was created before and during this review should be sustained. The Great Lakes experience provides practical ways for this to happen. For details, see [http://ijc.org/en\\_/GLAM](http://ijc.org/en_/GLAM). If there is a structured community engagement for flood forecasting, this could be part of the sustained relationships.
2. A binational Rainy-Namakan system hydroclimatic monitoring and modelling review should be conducted in support of the adaptive management process. This activity would include, for example, a gap analysis of station adequacy, areal coverage and tributary indicators. Based on the gap analysis and the

quality of available data, a list of the most important modelling and observation uncertainties would be identified.

3. Ongoing examination of key environmental resources is the cornerstone of good adaptive management practices. These should include the resources studied as part of this review, where needed, and additional ones identified by those involved in the adaptive management process. It is important to include binational monitoring of these resources and identified performance indicators in support of the adaptive management process. These monitoring programs should be placed in areas both upstream and downstream of the international dam. Most of the agencies that monitored environmental resources as part of this Rule Curve review cycle are interested in continuing their efforts; however, they have raised concerns about funding challenges if these monitoring efforts are to continue.
4. Ongoing risk assessment should be undertaken. The research needs underlying the identified uncertainties should be done in consultation with government researchers and agencies. This encourages grant programs to incorporate the objectives of the Rainy-Namakan system into grant requirements and university researchers to develop directed research to address those objectives.
5. Information management and outreach platforms, which play important roles in furthering the objectives of adaptive management, should be maintained by the IJC similar to the International Upper Great Lakes Study ([http://www.iugls.org/Decision\\_tree\\_tool](http://www.iugls.org/Decision_tree_tool)) and updated as required by the group if established as a result of the Study's recommendations.
6. The tools and processes for decision



**The Study Board considered several different options for addressing the organizational setup of an adaptive management framework for the Rainy-Namakan system.**

makers to evaluate their actions should be retained or enhanced. This Study leaves behind two operational models: the Shared Vision Model (SVM); and the Integrated Ecological Response Model (IERM). These models, along with the research and databases, should be maintained. Other data and information collected as part of the adaptive management exercise should be added to the model databases to keep them current and useful in forecasting mode.

7. A collaborative regional Rainy-Namakan system-wide management study for addressing water level extremes should be undertaken under the aegis of the adaptive management framework. These aspects were addressed in only a limited way in this cycle as part of the Study. Alternate stochastic water supplies and climate change flows were tested as limits for the rule curve evaluation of robustness of the system. The stochastic flows came from resampling of historical data and generally provide flow sequences not considerably different from the observed water supplies. The required testing is beyond this limited work. Virtual floods and droughts can be designed to test rule curve responses to extreme conditions. These “fire drills” help maintain readiness in the intervals between actual floods and droughts and help provide younger staff hands-on experience that introduces them to knowledge developed during special, limited studies such as the rule curve review.
8. It was evident from the participation of the Rule Curve Public Advisory Group (RCPAG) and the Resources Advisory Group (RAG) and the feedback at the Watershed Forum that there is an identified need for the integration of water quality and quantity modelling and activities through the SVM and IERM platforms to continually monitor

the performance of the Rule Curves on identified performance indicators and metrics.

9. It is important to link to the monitoring and scientific studies proposed by the governments in their binational approach to address nutrient loading and harmful algal blooms for the Lake of the Woods watershed, of which the Rainy River watershed is a part. Canada and the United States have initiated actions to address water quality issues in Lake of the Woods. For this four-year initiative, work began a year ago, and more scientific studies are planned that may be suitable for use in adaptive management by considering variables that link water quantity to water quality, such as the links between water levels and the release of mercury and the concentration of mercury in fish.
10. It is important to note that implied in these core adaptive management elements is the need for funding, agency collaboration, access to subject experts and forums for information exchange.
11. It will be important to consider a formal review of the results of any new rule curve, along with the associated adaptive management elements after a 15-year adaptive management cycle.

### **9.3.2 Proposed adaptive management framework**

The Study Board considered several different options for addressing the organizational setup of an adaptive management framework for the Rainy-Namakan system.

**Option 1** – This option involves an independent regional adaptive management body responsible not only for the Rainy Lake and Namakan Chain of Lakes but also Lake of the Woods and other system water bodies. This option would require the formation of a body in parallel to the IRLWWB, and therefore could be viewed as

being an overlapping organization. Therefore, this option was not pursued further.

**Option 2** – Under this option, the objectives of adaptive management would be integrated into the operations of the IRLWWB or its Water Levels Committee. The procedures could be modelled after the operations of the Canadian Lake of the Woods Control Board, where the decisions on targeting a water level in the system lakes and river flows are based on the input from a variety of interests. This option has worked with success, with the proviso that there is a dedicated secretariat that follows through the process that is binational and given appropriate resources. This option would require expanding the size of the IRLWWB beyond its current 24 members, by adding experts in resource fields and adaptive management. Therefore, it was not pursued further.

**Option 3** – A third organizational option is a compromise of the first two. A separate Adaptive Management Committee is proposed, with membership primarily drawn from the IRLWWB in a manner like the International Water Levels Committee. This committee would consist of leads from the IRLWWB, with support/participation from the resource agencies in the watershed.

The Study Board proposes **Option 3** for further consideration by the IJC.

Figure 9-3 illustrates a possible organizational structure for this third option, with an international adaptive management committee reporting to the IRLWWB. The terms of reference for the adaptive management committee would be developed based on the adopted setup of the organization.

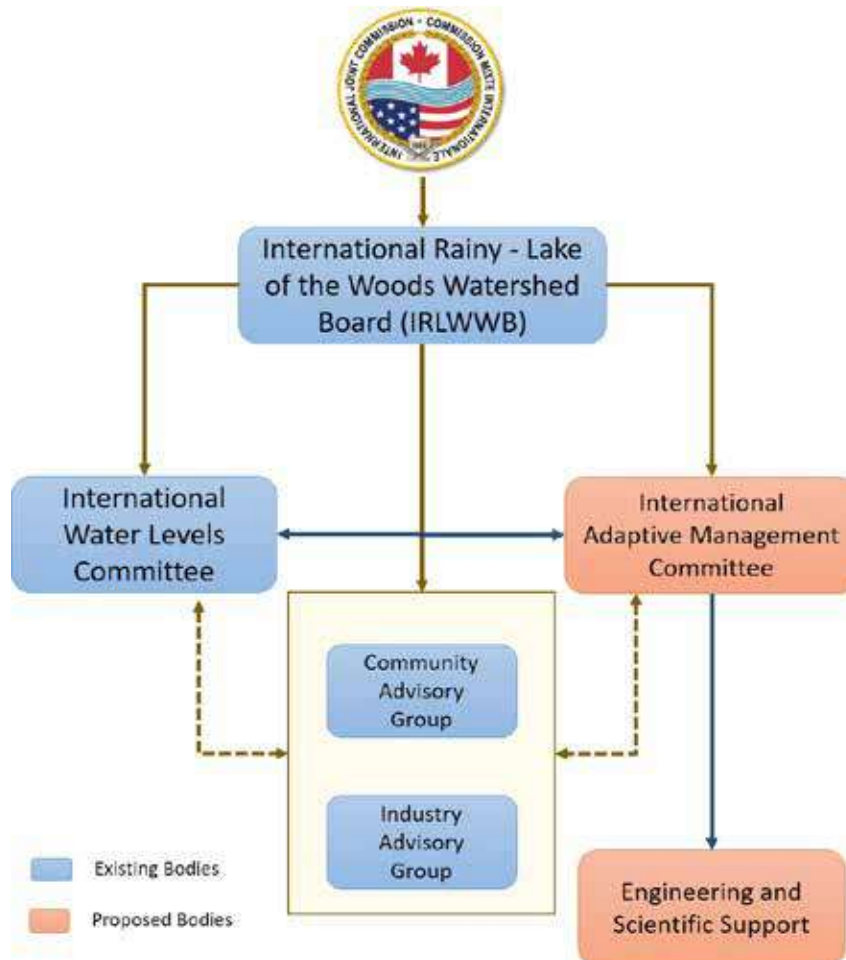


Figure 9-3 Option 3: Adaptive management committee organization

## 10. FINDINGS AND RECOMMENDATIONS

**Chapter 10** presents the findings and recommendations of the **International Rainy and Namakan Lakes Rule Curves Study Board** (Study Board).

### 10.1 The challenge

For more than 100 years, through the *Boundary Waters Treaty of 1909*, the governments of Canada and the United States have demonstrated their shared commitment to cooperatively managing the many water-related challenges along their shared border.

It is within that same spirit of cooperation that this joint US-Canadian Study has been undertaken to consider future regulation of the waters of the Rainy Lake-Namakan Chain of Lakes system of northwestern Ontario and northern Minnesota. These waters have been controlled by dams for more than 100 years. Over the past 70 years, through the IJC, the two countries have jointly established formal rules for regulating water levels and flows for the lakes. The existing rules, in the form of the 2000 Rule Curves, have been in place for more than 15 years.

When the 2000 Rule Curves went into force, the IJC stated its commitment to review those rules in 15 years' time, taking into account the most recent scientific information about the effects of water levels and flows in the system. In the fall of 2015, the IJC established the Study Board, charging it *"to evaluate options for regulating levels and flows in the Rainy-Namakan Lakes system in order to benefit affected interests and the system as a whole in a manner that conforms to the requirements of the Treaty."*

After extensive consultation with the many interests in the basin, the Study Board established three key objectives to achieve this overarching goal:

1. *To evaluate the performance of the 2000 Rule Curves in comparison to the 1970 Rule Curves and State of Nature, considering a range of ecological, social, economic and environmental conditions that may be affected by water level regulation.*
2. *To develop and evaluate additional regulation alternatives that reflect concerns of stakeholders in the study area and to compare the performance of these alternatives to that of regulation under the 1970 and 2000 Rule Curves.*
3. *To evaluate all regulation alternatives for performance under a range of climate and water supply conditions.*

The Study Board addressed these objectives in a comprehensive, scientifically rigorous and cooperative manner. It reviewed the best available scientific information to help build a solid understanding of how the many interests in the study area could be affected by changes in water levels and flows. From the start, it informed the many residents and interests in the study area through a wide variety of communication tools and at a large number of public venues. It engaged the direct involvement of the public through a Rule Curve Public Advisory Group (RCPAG) that communicated with area residents and provided feedback on the Study Board's analysis and preliminary findings. It ensured that natural resources were a key component of the decision making by establishing a Resources Advisory Group (RAG) and called upon additional resource experts as needed. Using a proven and transparent participatory approach to planning and evaluation, it evaluated the performance of the 2000 Rule Curves. It developed dozens of alternative rule curves and tested and modified and re-tested them in a series of "practice decision" workshops with representatives of the many interests in the basin.

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**What is the best way to regulate the waters of the system to benefit affected interests and the system as a whole in a manner that conforms to the requirements of the Treaty?**

Finally, the Study Board focused on a small number of alternative rule curves in an effort to answer the fundamental question of water regulation: *what is the best way to regulate the waters of the system to benefit affected interests and the system as a whole in a manner that conforms to the requirements of the Treaty?*

This report presents the Study Board's best efforts to answer this challenge.

## **10.2 Study Board findings and recommendations**

Based on the results of the studies and analyses described in this report, the Study Board presents the following findings and recommendations.

### **10.2.1 Performance of the 2000 Rule Curves**

#### ***Finding 1: The 2000 Rule Curves performed as expected across most measures investigated.***

The Study Board concluded that the 2000 Rule Curves generally performed as expected. This finding is based on the results of the Weight of Evidence (WOE) evaluation, supported by data and analysis from 52 scientific reports and monitoring data collected by resources agencies as well as feedback from the investigators of the WOE studies, the RCPAG, the RAG, the public and First Nation, Tribal and Métis community members.

Compared to the 1970 Rule Curves, the 2000 Rule Curves provided the expected results with respect to many of the Study's subject areas, including: improvements in fish population and spawning habitat of several key species; increased tourism benefits along the Namakan Chain of Lakes as a result of improvements to navigation and dock access; decreased potential for hydropower production as a result

of reductions in available storage; and increases in flood damage on both Namakan Lake and, particularly, Rainy Lake, as a result of the decrease in available storage on Namakan Lake in advance of the spring freshet.

The analysis also found that the expansion of the invasive Hybrid Cattail in Rainy Lake and the Namakan Chain of Lakes is a continued threat to Wild Rice habitat. This was an area not given consideration in the development of the 2000 Rule Curves. The steady water levels that result from regulation under the 2000 Rule Curves have provided excellent conditions for the expansion of invasive Hybrid Cattail at the expense of Wild Rice.

#### ***Fish***

The Study Board concludes that operations under the 2000 Rule Curves have provided a benefit for a variety of fish species on both the Namakan Chain of Lakes and Rainy Lake. With the exception of Lake Sturgeon population, where no conclusion on the effects of the Rule Curve change could be drawn, all expected areas of improvement in this category were substantiated by the evidence for the Namakan Chain of Lakes.

For Rainy Lake, few changes were expected given the limited modifications under the 2000 Rule Curve. One expected benefit, to Northern Pike young of year and nursery habitat, was supported by the evidence. Walleye spawning habitat did not change as a result of the rule curve changes, whereas some improvement was expected. Lake sturgeon data were insufficient to draw a conclusion on whether or not the 2000 Rule Curves provided an expected benefit. Several studies examining changes to indicators for Walleye, Northern Pike and Yellow Perch showed benefits due to operation under the 2000 Rule Curves, though these were not areas of expected improvement when the rule curves were adopted.

## **Wildlife**

Evidence supports the anticipated results of operation under the 2000 Rule Curves for wildlife on the Namakan Chain of Lakes, including benefits to the Beaver population and Common Loon nesting success. In addition, as expected, there was no change to the over-winter survival of Muskrats, which remains extremely challenging in most winters due to the magnitude of drawdown on the lake.

For Rainy Lake, Beaver and Common Loon were not affected by the switch to the 2000 Rule Curves, as expected. Modelling results show a very small increase in potential Muskrat winter survival. However, no improvement had been predicted for Muskrats, as the data are almost non-existent.

## **Economic Indicators**

### ***Flooding damage***

Flooding damage during high inflow springs was exacerbated on Rainy Lake, and to a lesser degree on Namakan Lake, by operation under the 2000 Rule Curves. As had been expected, computer modelling demonstrated that peak high water elevations during these events were several centimetres higher than they would have been had the lakes been managed under the 1970 Rule Curves.

The Study's flood damage investigation found that a large majority of structural damages due to high water levels involves docks and, to a lesser degree, boat houses. A relatively small proportion of higher value residential buildings, not designed for some degree of inundation, are affected by emergency high water conditions. The increase in damage for a particular event depends on the level and duration of high water. Monetary estimates of damage in high water events vary from several thousands of dollars to several millions (as was the

case in 2014), based on the flood damage investigation's stage-damage curves. These damage amounts are considered by the Study Board to be rough estimates, useful in comparing different rule curve and operational options.

Since the adoption of the 2000 Rule Curves, emergency conditions due to high water on Rainy Lake have occurred more frequently than was the case in the preceding 30 years. Results of modelling with the Shared Vision Model (SVM) and with the Rainy/Namakan Hydrologic Response Model (Study #2, Annex 6) indicate that most high water event peaks would have been reduced by several centimetres on Rainy Lake had the 1970 Rule Curves been followed. However, none of the events would have been avoided. The Study Board notes that the frequency of high water events experienced since 2000 is similar to that experienced in the 1950s and 1960s.

### ***Hydropower generation***

Hydropower generation declined under the 2000 Rule Curves, as anticipated. Citing concerns over sharing of proprietary and competitive data, the hydropower companies did not provide the Study Board with revenue data. As a result, the Study Board's conclusion is based on an independent engineering report commissioned by H2O Power LP in 2012 and SVM modelling of hydropower production indicators. The report provided by H2O Power was largely redacted, but estimated total reduction in annual hydropower due to the change in Rule Curves to be between 2140 MWh and 4000 MWh. The general approach of the SVM modelling was reviewed and supported by H2O Power LP.

### ***Tourism/resort impacts***

Under the 1970 Rule Curves, the additional winter drawdown often resulted in spring water levels on the Namakan Chain of Lakes being too low for resort operators.



The Study Board investigated changes to the 2000 Rule Curves that could potentially improve on the overall benefits that they provide.

The reduced drawdown under the 2000 Rule Curves improved this condition and benefitted tourism.

The Study Board found that it could not make a conclusion regarding the overall impact of the rule curve change on Rainy Lake resort operators, as the supporting report on tourism noted that there were benefits to operation within the Rule Curves, but complaints concerning the frequency of flooding.

#### **Cultural/Archeological Resources**

Cultural/archeological resources, including Indigenous burial areas, pictographs and fur-trade era sites, were found to have benefitted from the change to the 2000 Rule Curves. This was an expected result, as the gradual summer drawdown introduced on both lakes resulted in less frequent exposure to the erosive effects of stable water levels.

#### **Vegetation**

The Study Board found that the change to the 2000 Rule Curves benefitted wetland vegetation, wet meadow emergent vegetation and submerged plants on Namakan Lake. Wild Rice, which had been an area of expected improvement, was unchanged overall. This result was found to be consistent with subsequent modelling using the Integrated Ecological Response Model (IERM).

In summary, the 2000 Rule Curves provided broad ecological benefits and improved navigation and associated tourism for the Namakan Chain of Lakes, while resulting in negative impacts to flooding damage on Rainy Lake and hydropower production.

#### ***Finding 2: The 2000 Rule Curve for Namakan Chain of Lakes has local support.***

The Study Board heard consistent support from interests on the Namakan Chain of Lakes for the 2000 Rule Curve. The benefits to navigation in the early tourist season were

strongly supported. The gradual summer drawdown of the lakes introduced with the 2000 Rule Curve was not opposed, though suggestions of having lower levels than this were not supported due to concerns about navigation in the late summer. Specifically, concerns were raised about access to Loon River and difficulties for canoeists if lake levels were decreased during this season.

#### **10.2.2 Opportunities for improving water level management through new Rule Curves**

The Study Board investigated changes to the 2000 Rule Curves that could potentially improve on the overall benefits that they provide. Based on feedback received during the study, the principal aims in these investigations were to reduce spring flood peaks on Rainy Lake, and to enhance ecological conditions on some areas not considered in the development of the 2000 Rule Curves.

#### ***Finding 3: Dam operations cannot prevent most floods.***

Chapter 6 noted the use of “fencepost” plans to explore the limits of dam operation in mitigating against or preventing flooding on Rainy Lake during high inflow periods. The SVM was used to compare flooding under the 1970 and 2000 Rule Curves as well as under a variety of alternative rule curves that prioritized flood control over all other impacts and others that simulated lake levels if unrealistic, perfect prediction of floods months in advance were available.

This analysis found that no rule curve options substantially reduce flooding damages, because the release of water from the lakes is physically limited by the characteristics of the outlet of Rainy Lake upstream of the dam and at Kettle Falls and Squirrel Falls at the outlets of Namakan Lake. This limitation ensures that whenever water cannot be released from the lakes fast enough to keep

pace with inflows, uncontrolled lake level rise results. Lowering lake levels to provide storage room for high spring flows provides only limited benefit because the lower lake levels reduce the maximum flow that can be released from the lake. The construction of the dams did not introduce this constraint and SVM modelling results indicated that similar flooding would have occurred if the dams had not been constructed. That is, under the State of Nature conditions, extremely high peak water levels would still occur in flood years. However, modern 'normal' water levels experienced in the post-dam period are higher than would have occurred in a State of Nature, as the dams raised the water levels in both Rainy Lake and the Namakan Chain of Lakes.

These modelling results are consistent with observations found in various IJC reports from before the 1990s<sup>21</sup>, analyses conducted in the review of the 1970 Rule Curves in the 1990s (see *Final Report Review of the IJC Order for Rainy and Namakan Lakes*, International Rainy Lake Board of Control, 1999; "Rainy River 2D Hydrodynamic Modelling Study – Phase II" National Research Council Canada, 2011).

**Finding 4: Conditional changes to the Rainy Lake Rule Curve may reduce flood peaks.**

One of the drawbacks of the adoption of the 2000 Rule Curves was the small increase in peak water levels of Rainy Lake during flood periods. The SVM results, built on the data from the flood-damage study, indicate that even small increases in flood peaks may result in large increases in damage costs, primarily to docks, and that this is due primarily to the loss in storage capacity in the Namakan Chain of Lakes that was available under the 1970 Rule Curves.

The Study Board finds that the modification of the 2000 Rule Curves to Rule Curve **Alternative B**, presented in **Chapter 6**, would result in Rainy Lake peak elevations in flood years that are similar to those that would occur under the 1970 Rule Curves. **Alternative B** delays the refill of Rainy Lake from April until May, resulting in the passing of additional outflows during April. It also has a lower target range through May and June to allow for some storage capacity for anticipated high inflows. This option is predicated on the conditional use of the lower target only in those years where the flood risk for Rainy Lake is deemed to be high; otherwise the 2000 Rule Curves are used.

These lower level targets have the potential to reduce the availability of Walleye spawning areas in Rainy Lake as well as resulting in the earlier release of cold water to the Rainy River, potentially delaying spawning activity along the river. To balance potential trade-offs, in particular to spring spawning fish, the Water Levels Committee could consider monitoring data and expert opinions from resource managers on whether a potentially weaker year class (a cohort of fish born in the same year) that could result from targeting lower levels is a concern with respect to the overall health of a given fish population.

**Finding 5: Support for Rainy Lake flood damage reduction is strong but qualified.**

Support from the public for **Alternative B** was heard during practice decisions, webinars and at public meetings and in formal comments received after the Draft Decision Workshop in March of 2017. Support for the general concept was qualified, though, by specific concerns.

The Rainy Lake Property Owners' Association and the Border Lakes Association each wrote

<sup>21</sup> For example, see Report to the International Joint Commission by the International Rainy Lake Board of Control in the Matter of Regulation of the Level of Rainy Lake and of Other Boundary Waters in the Rainy Lake Watershed", 1969.

the Study Board in support of the use of flood forecasting to lower lake targets on Rainy Lake, but also called for the Namakan Rule Curve to be held flat in June and July at a higher elevation, as was the case in the 1970 Rule Curves, rather than targeting a gradual decline. SVM modelling indicated that this approach would increase flood damages slightly on Namakan and reduce them slightly on Rainy Lake. Discussions during the Draft Decision Workshop included concerns from property owners and resource managers about the impacts of flood damage reduction measures on Walleye spawning in individual years, and on the overall health of the Walleye population on Rainy Lake in the longer term if a flood risk reduction curve were put into practice.

There was no support from property owners or representatives of the tourism businesses at the decision workshops for lowering Rainy Lake below the current rule curve range during the summer, even though doing so could reduce flooding damages, because it would also make navigation more difficult.

The Study Board notes that some members of the public hold that flooding can be avoided or substantially reduced through changes to the Rule Curves or in the way that the dams are operated (e.g., through improved inflow forecasting or increased density of precipitation stations). This is contrary to the results of modelling conducted both in this study and in the rule curve review undertaken in the 1990s. The Study Board, working with the IJC, has produced public information factsheets and videos to help promote increased awareness of the limits of flood protection through dam operations.

***Finding 6: Modifications to over-winter drawdown of both lakes could result in multiple ecological benefits.***

Hybrid Cattail has expanded its range in this system, particularly in Rainy Lake and Lake

Kabetogama. The consistent summer water levels that rule curves tend to provide year after year favor Hybrid Cattail growth and propagation. As the Hybrid Cattails extend their range over time, the natural variability of wetland plant types is reduced, adversely affecting fisheries and exacerbating the problems that floating cattails pose. IERM results show that Hybrid Cattail could be controlled effectively through water level manipulations, whether by increasing water levels to completely submerge the plants or lowering them sufficiently to expose their root systems for a sufficient time. The Study Board views these water level extremes as presently untenable in this system due to the impacts to other interests. Increased variability from year to year, but within the general range of preferred levels, can result in stress to the plants that could help to slow their encroachment. Improved conditions for Muskrats, which feed on Hybrid Cattail, is another method that could help with control of this plant.

Muskrat mortality over the winter is very high on Rainy Lake and winter survival is not possible along the Namakan Chain of Lakes because of the steep drawdown of lake levels between late fall and the end of February. This drawdown exposes the Muskrats to freezing and predation. Rule Curve **Alternative C**, which combines the conditional flood reduction in the spring on Rainy Lake of **Alternative B** with reduced over-winter drawdown on both lakes, would potentially aid in increasing Muskrat populations in these lakes. Increased Muskrat abundance may result in a variety of ecological benefits, including natural removal of Hybrid Cattail by Muskrats, an associated increase in areas available for Wild Rice development due to decreased cattail competition, improved wetland qualities, and improved spawning habitat for Northern Pike.

This approach under **Alternative C**, however, also would result in reduced hydropower

Many individual participants in the public meetings and decision workshops voiced opinions that reflected their combined interests as business operators, riparian property owners, fishers and environmentalists.

production in the winter period in most years, as well as reduced fall water levels on both lakes, which could present navigation challenges late in the boating season.

The Study Board held a webinar with the RAG, RCPAG, and the International Rainy-Lake of the Woods Watershed Board (IRLWWB) in April, 2017 to explain **Alternative C**, and compare its performance to that of the 2000 Rule Curves and **Alternative B**. There was general support for **Alternative C** provided that, if implemented, an adaptive management approach be taken to monitor if expected improvements, such as in the Muskrat population, are occurring.

H2O Power and PCA, the owners of the dams, submitted comments on **Alternative C** related to concerns over the changes to winter drawdown. These concerns center on safety and dam accessibility issues in early winter at Namakan Lake if flow changes were necessary to stabilize the lake level after ice formation, and on reduced hydropower generation in the winter periods due to the reduced outflow from both lakes.

***Finding 7: Inter-annual variability in summer water levels has broad ecological benefits.***

Under normal inflow conditions, the dam operators are able to consistently follow the middle range of the Rule Curves during the summer. As a result, summer levels under the 2000 Rule Curves have limited variability over the years. This reduced variability, while achieving the balances implied in the Rule Curve design, diminishes the ecological benefits that a wider range of water levels provides. Wetlands normally have a variety of plant communities that are influenced by water level variation from year to year. Water depth, duration at particular levels, and flood frequency influence the composition of the overall plant community. Greater variation over the years supports more diverse plant communities at all

water depths, while the converse is true – constant water levels over the years encourage less diversity, often benefitting invasive plant species such as Hybrid Cattail. More diverse plant communities can lead to beneficial changes in vertebrates, amphibians and bird communities.

The Study Board examined rule curve options that would increase the variability of summer water levels by changing the summer target range from one year to the next, ensuring that the system experienced a range of summer water levels every few years, including low and high levels. **Alternative E** was presented at the Draft Decision Workshop as the candidate for consideration for this approach. However, based on feedback from the RCPAG concerning the increase in flood risk associated with intentionally higher levels and the navigation issues associated with intentionally lower levels, the Study Board does not regard this option as viable in its current form.

***Finding 8: Sustainable fisheries are important for ecological and economic reasons.***

Many individual participants in the public meetings and decision workshops voiced opinions that reflected their combined interests as business operators, riparian property owners, fishers and environmentalists. More than once, the Study Board was told of concerns that tourists might decide to summer elsewhere if adverse fishing, boating or flooding experiences were to occur for two or three years in a row. In particular, the status of the Walleye population in these lakes is of high importance to these interests.

***Finding 9: There was broad support for enhancing broader ecological benefits.***

**Alternative C**, produced late in the Study following several months of refinement, met with broad support from the RCPAG and RAG following a webinar in April 2017 to

The Study Board tested three alternative rule curves under a range of future climate conditions, including both extreme wet and dry scenarios.

describe the alternative and its performance and again during the Final Decision Workshop in June 2017. Concerns over this alternative were raised by the dam owners due to potential impacts to hydropower generation and their operations at the Namakan dams in winter. This alternative modified the Namakan and Rainy 2000 Rule Curves to allow for reduced over-winter drawdown more similar to a natural lake level decline for several ecological benefits, including improved winter survival of Muskrat and benthic invertebrates and improved spawning success of fall spawning species. This alternative also includes the lower spring target option introduced in **Alternative B**.

***Finding 10: The effect of future climate scenarios is consistent across Rule Curve alternatives.***

The Study Board tested three alternative rule curves under a range of future climate conditions, including both extreme wet and dry scenarios. The performance of all three alternatives was affected similarly by greater extremes in inflows. However, none was markedly better or worse. Flood damages increased substantially for all alternatives in the wettest scenario and decreased substantially in the driest scenarios. Boating conditions on both Namakan and Rainy Lakes were more resistant to dry scenarios, as levels returned to rule curve levels at year's end under even the longest drought. In no case did the relative performance of one alternative rule curve shift dramatically compared to that of the others, based on the climate scenario.

The Study Board concludes, therefore, that the alternative rule curves cannot be ranked based on differences in their performance with respect to climate variability and change. Future climate change could substantially affect water levels in the basin, regardless of the rule curve in use, since

levels in both lakes cannot be controlled under extremely high or low inflows. This finding reinforces the importance of putting in place a comprehensive adaptive management program to help identify and respond to emerging climate change conditions.

***Finding 11: Changes to the outflow profile from Rainy Lake, both through revised Rule Curves and operational policies, would affect downstream interests not considered in this study.***

Downstream interests at Lake of the Woods and the Winnipeg River are affected by the timing and magnitude of flows released into the Rainy River. This could have the potential to affect operations for downstream dams as well as stakeholders in these areas. This Study focused solely on potential effects of Rule Curve and operational changes on interests within the study area.

**Therefore, the Study Board recommends that:**

**Recommendation 1:  
Adopt Rule Curve Alternative C**

The Study Board recommends that the 2000 Rule Curves be replaced with Rule Curve **Alternative C**, providing conditional spring flood reduction targets for Rainy Lake in years with high spring flood risk and reducing over-winter drawdown for broad ecological benefits in both lakes.

Should the IJC determine that the changes to winter water level targets in Rule Curve **Alternative C** are not acceptable, the Study Board recommends that the conditional spring flood reduction component for Rainy Lake be implemented (Rule Curve **Alternative B**).



***Finding 12: More flexible targeting within the 2000 Rule Curve band could provide additional benefit.***

Under the 2000 Rule Curves, the dam operators are required to normally target the middle portion of the Rule Curves. The rationale for targeting the middle portion of the band is that it provides some buffer in case hydrological conditions change quickly, either wetter or drier.

For many years, the dam operators interpreted this target range as the mid-point between the upper and lower rule curves for the given date. However, in recent years, with direction from the Water Levels Committee, the “middle portion” has been interpreted as the 25-75 percent range.

The Study Board finds that more flexible operation within the Rule Curve bands may allow for additional benefits. For example, allowing lower targets in the spring if inflow conditions are already high provides some buffer in case of higher flows, while holding the level higher in dry conditions would provide some drought resilience. In years where the early Wild Rice crop is promising, targeting the lower portion of the Rule Curve may protect the crop until harvest.

Development of Operational Guidelines, which cover these and issues such as minimizing impacts to Rainy River during flow changes and the currently-used Rainy River Sturgeon Protocol, would provide a reference for these aims for the Water Levels Committee and stakeholders. Sample guidelines are provided in Annex 8.

In recent years, the Water Levels Committee has been more active in directing the dam operators to set different targets in response to certain conditions or interests. Developing more comprehensive guidelines that relate water levels to specific outcomes, while staying within the Rule Curves, could enhance the overall performance of the Rule Curves.

**Therefore, the Study Board recommends that:**

**Recommendation 2:  
Promote flexible operation to  
improve outcomes**

The Water Levels Committee should be empowered and encouraged to actively target specific areas of the Rule Curve band to benefit various interests as the opportunity arises, in full consideration of trade-offs that would result. To support this approach, the Study Board recommends the development and regular updating of a set of Operational Guidelines that summarize water level management best practices that can benefit specific interests.

### **10.2.3 Operations**

***Finding 13: The Water Levels Committee could benefit from having Terms of Reference.***

Under the IJC's 2001 Consolidated Order and the Directive for the International Rainy-Lake of the Woods Watershed Board, the Water Levels Committee is charged with monitoring the hydrological conditions in the basin and the actions of the dam companies, and is given the power to direct the companies in the operation of their discharge facilities. Beyond these responsibilities, there are no terms of reference specifying such matters as decision-making processes within the Committee (quorum requirements, for example), record management, provision of data or operational information to the public or the duties of the committee's members and its engineering advisors. In addition, the Water Levels Committee has no written protocol for operating under emergency conditions.

**Therefore, the Study Board recommends that:**

**Recommendation 3:  
Provide the Water Levels Committee  
with Terms of Reference**

Terms of Reference should be developed that detail the Water Levels Committee's operational procedures and responsibilities.

***Finding 14: The current process for deviating from the Rule Curves is inefficient.***

The 2001 Consolidated Order allows for the Water Levels Committee to authorize deviation outside of the Rule Curve range if extremely high or low inflow conditions are anticipated, with the permission of the IJC. The Directive to the International Rainy-Lake of the Woods Watershed Board further requires that the Water Levels Committee promptly notify the IJC of any necessary departure from the strict application of the Order, and must wait for approval. The IJC's approval is granted through the issuance of Temporary Orders. The time from a request for a Temporary Order to its issuance by the IJC could result in operational problems (e.g. emergency action to avoid turbine damage or mill flooding may require very fast response) and may limit the effectiveness of the intended deviation.

**Therefore, the Study Board recommends that:**

**Recommendation 4:  
Empower the Water Levels  
Committee to direct targets outside  
of the Rule Curve range**

The IJC should consider empowering the Water Levels Committee to direct targets outside of the Rule Curve range under certain conditions, such as responding to imminent emergency, or to allow for more flexible spring refill of the lakes in timing with the freshet.

***Finding 15: Impacts to Rainy River water levels are not given regular consideration in current operations.***

Results of an online survey by the Study Board of property owners, users and resource professionals engaged with the Rainy River showed a common opinion that the 2000 Rule Curves are used to optimize conditions on Rainy Lake without regard for the Rainy River. Indeed, the IJC's 2000 Consolidated Order makes no provision for considering the effects of flow changes on the Rainy River, except for minimum flow requirements during periods of drought.

The Study Board recognizes that many users of the river would benefit from a reduction in the frequency of large flow changes from Rainy Lake that quickly change the level of the river up or down, and would also benefit from being better informed when flow changes are planned. This would allow, for example, dock owners to make adjustments ahead of planned increases or decreases in the water level, or recreational users to adapt their plans to changing flow conditions.

The fluctuations of water levels in the Rainy River are affected only in part by the releases from the dam at International Falls-Fort Frances. Inflows from major tributaries (including the Big Fork and Little Fork Rivers) can affect levels both upstream and downstream from the confluence with Rainy River, and backwater effects from Lake of the Woods also can influence water levels along much of the river.

**Therefore, the Study Board recommends that:**

**Recommendation 5:  
Examine practical operational  
approaches to benefitting Rainy  
River interests while meeting Rule  
Curve requirements**

As part of Operational Guidelines

Early in the Study, the Study Board proposed the idea of having some form of community input process with the Water Levels Committee ahead of the spring freshet.

(Recommendation 2), the Water Levels Committee should identify best practices for limiting large flow changes from Rainy Lake while still respecting lake level requirements and operational requirements of the dam operators.

The IJC should consider developing an approach for notifying interested individuals along the Rainy River of planned changes in Rainy Lake outflow and associated changes in water levels, as well as the importance of the flow changes on the river level relative to other natural flows.

***Finding 16: Improved data collection could support improved inflow and lake level forecasting.***

One lake property owners' association requested that the Study Board recommend an increase in the number of precipitation monitoring stations in the Rainy-Namakan Lakes watershed. The association's rationale for this request was that rainfall events occurring in areas of the basin without rain gauges are either missed or poorly estimated by the dam operators or the Water Levels Committee. The association suggested that additional gauges would result in reduced reaction times in increasing outflow from the dams in years when flood risk is high, ultimately leading to lower flood peak water levels and decreased damage.

More broadly, the Study Board notes that the Water Levels Committee currently uses an operational inflow forecasting model that relies on regular input of meteorological, hydrometric, and hydrological data. Improvements in data collection in any of these areas could aid in producing more accurate inflow and lake level forecasts.

**Therefore, the Study Board recommends that:**

**Recommendation 6:  
Review data monitoring sources to support inflow forecasting by the Water Levels Committee**

The IJC should direct a review of the available monitoring data to identify areas where additional monitoring would improve inflow forecasting. Specific areas of investigation should include snow-pack measurements, remotely-sensed snow-water content, precipitation monitoring stations and streamflow monitoring stations.

***Finding 17: There is broad support for better communication between the public and the Water Levels Committee concerning lake level management.***

Early in the Study, the Study Board proposed the idea of having some form of community input process with the Water Levels Committee ahead of the spring freshet. This would benefit both the community participants through better understanding of the analyses the Water Levels Committee is considering in planning for spring, and the Water Levels Committee by hearing local observations and concerns about spring conditions.

There was broad support for this idea from the RCPAG, and in 2017 the Water Levels Committee convened an informal meeting of this type with First Nations representatives, local organizations and resource agencies.

**Therefore, the Study Board recommends that:**

**Recommendation 7:  
Formalize pre-spring engagement by the Water Levels Committee**

A formal process should be developed to

In reviewing options for an adaptive management framework for the basin, the Study Board believes that the concept of an Adaptive Management Committee is worth exploring.

engage the Water Levels Committee with key groups in the watershed affected by water level regulation ahead of the spring freshet. This recommendation is of particular importance should **Alternative B** or **Alternative C** Rule Curves be adopted, as a conditional decision on spring water level targets would need to be made each winter ahead of freshet.

#### 10.2.4 Other water management considerations

##### ***Finding 18: Adaptive management could help improve water management outcomes in the basin.***

Adaptive management is a systematic, iterative approach for improving future management outcomes by learning from past outcomes – “learning by doing.” A collaborative, binational regional approach to adaptive management for the Rainy River basin could build on the experience, relationships and knowledge gained through the Study. It could address ongoing challenges such as integrated monitoring, modelling and risk assessment in response to changing or uncertain conditions and emerging opportunities for action.

Participants in the Study’s Final Decision Workshop in June 2017 endorsed the concept of adaptive management and expressed interest in how it could be implemented in the basin.

In reviewing options for an adaptive management framework for the basin, the Study Board believes that the concept of an Adaptive Management Committee is worth exploring. Such a committee could draw its membership primarily from the IRLWWB in a manner like the International Water Levels Committee. This committee would consist of leads from the IRLWWB, with support/

participation from the resource agencies in the watershed.

The Study Board emphasizes the importance of continued long-term monitoring along the Namakan Chain of Lakes and Rainy Lake of, at minimum, the following to support adaptive management:

- adult (gill netting) and young of year (seining) gamefish and adult Lake Whitefish (deep water gill netting);
- Wild Rice distribution;
- Hybrid Cattail distribution;
- Muskrat abundance;
- Common Loon reproductive success;
- Benthic community health;
- mercury content of young of year yellow perch;
- impacts of climate change; and
- water quality monitoring.

Over the course of the Study, resource agencies identified other possible monitoring needs to assess ecological impacts and these should be discussed further by any adaptive management committee established. All these adaptive management elements require financial and resource commitments in implementing a successful plan.

Finally, the Study Board notes the importance of monitoring the spread of Hybrid Cattail, as this is an area in which water level management can play a role, either directly through introduction of greater inter-annual variability, or indirectly through increasing Muskrat population.

**Therefore, the Study Board recommends that:**

##### **Recommendation 8: Investigate adaptive management**

The IJC should explore the use of a

formal adaptive management process for the long-term evaluation of the effectiveness of the Rule Curves. The implementation of an adaptive management process is of particular importance should Rule Curve **Alternative C** be implemented as it would allow the Water Levels Committee to evaluate whether the changes to the winter water level targets result in the intended ecological effects.

***Finding 19: There is some interest in investigating outlet modification for Rainy Lake to reduce flooding.***

Emergency conditions due to high water on Rainy Lake occur periodically due to inflow conditions that exceed the natural outflow capacity of the lake. A 2016 report by the National Research Council of Canada (NRC, 2016) showed through modelling that an enlarged outlet would allow for higher maximum outflows at all lake levels.

The Study Board heard calls for modifying the natural outlet constrictions, between Ranier, MN and Fort Frances, ON to reduce the severity of high water events. The Study Board also heard concerns during the Study that outlet modifications could result in a higher risk of flooding of the riverfront in Fort Frances and also result in possible downstream issues along Rainy River and on Lake of the Woods. The Study Board recognizes that evaluating outlet modification would be a complex investigation, with many environmental, economic, and political considerations. However, it also notes that significant reductions in flood peaks on Rainy Lake are not possible through operational changes or modification of the Rule Curves.

The Study Board notes that this is not a matter that the IJC can investigate on its own initiative, but would require direction

from the governments of Canada and the United States. Based on feedback received from a variety of interests on this question, it recommends that the IJC advise the two governments that this is a subject of interest and controversy in the watershed.

**Therefore, the Study Board recommends that:**

**Recommendation 9:  
Advise the Governments of interest and concern over Rainy Lake outlet modification**

The IJC should advise the US and Canadian governments that modification to the outlet of Rainy Lake is a subject of interest in the watershed, with some support and some opposition.

**10.2.5 Engaging First Nations, Métis and Tribes**

***Finding 20: Improved, ongoing communication with First Nations, Métis and Tribal communities would benefit the work of the Water Levels Committee and the Watershed Board.***

From meetings, workshops and community visits, the Study Board learned the importance of ongoing, sustained interaction and communication in promoting the involvement of Indigenous community members in IJC projects. The Study Board heard that engagement on only a project-by-project basis is not effective and that there would be great benefit to ongoing communication regarding work on water issues. This would help to establish relationships and partnerships that would later support and benefit individual projects as well as supporting water level regulation.

**Therefore, the Study Board recommends that:**



**Recommendation 10:  
Examine approaches for developing  
and sustaining improved  
relationships and communications  
with First Nations, Métis and Tribes  
on water issues**

The IJC should examine options for making meaningful improvements in relationships with Indigenous communities in the watershed. Ongoing communication is key to addressing the concerns of these communities and to improving the ability of the International Rainy-Lake of the Woods Watershed Board and its Water Levels Committee to inform its work with the benefit of both Aboriginal Traditional Knowledge and Western science.

***Finding 21: The relationship between water levels and some key areas of Aboriginal Traditional Knowledge in this basin could not be adequately explored during this Study.***

While the rule curve review did provide analyses of the impacts of varying water level regulation scenarios on Wild Rice, fish, archeological resources and vegetation, First Nation communities also voiced concern over the impacts of regulation on burial grounds, pictographs and medicinal plants. The Study Board learned a great deal about the importance of these values to communities in the study area but there was no data or research for pre- and post-2000 Rule Curves to incorporate these values into the review. However, the Study Board feels these are important factors to take into consideration that will require research and resources to do so.

**Therefore, the Study Board recommends that:**

**Recommendation 11:  
Consider sponsoring research  
projects to improve understanding  
of relationship between water levels  
and areas of Aboriginal Traditional  
Knowledge**

The IJC should consider sponsoring International Watersheds Initiative projects in communities that would help develop the understanding of the connection between water level management and key Aboriginal Traditional Knowledge subjects, such as medicinal plants and pictographs. This understanding could help inform the work of the Water Levels Committee, adaptive management efforts and future reviews of the Rule Curves.



PATRICE NELSON

### 10.3 Summary of recommendations

1. Adopt Rule Curve **Alternative C**
2. Promote flexible operation to improve outcomes
3. Provide the Water Levels Committee with Terms of Reference
4. Empower the Water Levels Committee to direct targets outside of the Rule Curve range
5. Examine practical operational approaches to benefitting Rainy River interests while meeting Rule Curve requirements
6. Review data monitoring sources to support inflow forecasting by the Water Levels Committee
7. Formalize pre-spring engagement by the Water Levels Committee
8. Investigate adaptive management
9. Advise the Governments of interest and concern over Rainy River outlet modification
10. Examine approaches for developing and sustaining improved relationships and communications with First Nations, Métis and Tribes on water issues
11. Consider sponsoring research projects to improve understanding of relationship between water levels and areas of Aboriginal Traditional Knowledge

## REFERENCES

Following are the references cited in the main report. Additional background studies prepared or reviewed as part of the Study are listed in Annex 6 and are available on the Study Board's website: [http://ijc.org/en\\_/RNLRCBSB](http://ijc.org/en_/RNLRCBSB).

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## GLOSSARY

Following is a list of key technical terms used in the main report.

**ADAPTIVE MANAGEMENT** – A planning process that can provide a structured, iterative approach for improving actions through long-term monitoring, modelling and assessment. Through adaptive management, decisions can be reviewed, adjusted and revised as new information and knowledge becomes available or as conditions change.

**BASIN, RAINY RIVER** – The area of northwestern Ontario and northeastern Minnesota that drains the waters of the Namakan Lake, Rainy Lake and Rainy River systems, into Lake of the Woods.

**BOUNDARY WATERS TREATY OF 1909** – The agreement between the United States and Canada that established principles and mechanisms for the resolution of disputes related to boundary waters shared by the two countries. The International Joint Commission was created as a result of this treaty.

**CLIMATE** – The prevalent weather conditions of a given region (temperature, precipitation, wind speed, atmospheric pressure, etc.) observed throughout the year and averaged over a number of years.

**CLIMATE CHANGE** – A change of climate that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods.

**DIRECTIVE** – An IJC instruction to a new or existing Study Board specifying the study's terms of reference, including tasks and responsibilities.

**ECOSYSTEM** – A biological community in interaction with its physical environment, and including the transfer and circulation of matter and energy.

**ENSO (El Niño Southern Oscillation)** – The term given to the phenomena of irregular changes in air and sea temperatures over the eastern Pacific Ocean that can last several months. Changes, whether to cooler or warmer than normal, can influence the jet stream and weather patterns over North America.

**ENVIRONMENT** – Air, land or water; plant and animal life including humans; and the social, economic, cultural, physical, biological and other conditions that may act on an organism or community to influence its development or existence.

**FRESHET** – The sudden overflow or rise in level of a stream as a result of heavy rains or snowmelt.

**HABITAT** – The particular environment or place where a plant or an animal naturally lives and grows.

**INDEX OF BIOTIC INTEGRITY (IBI)** – A multi-metric index that evaluates community composition (*i.e.*, feeding guilds, spawning needs, sensitivity to disturbance), species richness, fish abundance and fish health as surrogates of riverine health.



**INTEGRATED ECOLOGICAL RESPONSE MODEL (IERM)** – A model that allows for quantifying each hydrological scenario based on different rule curves and allows for a ranking of rule curves in terms of their impacts on the different components of the ecosystem.

**INTER-ANNUAL VARIABILITY**– Variations in mean water levels from year to year.

**INTERESTS** – In the context of the report, groups, systems or activities served by water levels and flows of the Rainy River basin, such as riparian landowners, hydroelectric power generation, ecosystems, cultural/archeological interests and recreational boating and tourism.

**INTERNATIONAL JOINT COMMISSION (IJC)** – International independent agency formed in 1909 by the United States and Canada under the Boundary Waters Treaty to prevent and resolve boundary waters disputes between the two countries. The IJC makes decisions on applications for projects such as dams in boundary waters, issues Orders of Approval and regulates the operations of many of those projects.

**NAMAKAN CHAIN OF LAKES** – Part of the geographic scope of the Study, consisting of the five lakes (Namakan Lake, Lake Kabetogama, Crane Lake, Sand Point Lake, and Little Vermilion Lake) that have water levels influenced by the dam operations at the outlet of Namakan Lake.

**ORDERS OF APPROVAL** – In ruling upon applications for approval of projects affecting boundary or transboundary waters, such as dams and hydroelectric power stations, the IJC can regulate the terms and conditions of such projects through Orders of Approval to maintain specific targets with respect to water levels and flows in the lakes and connecting channels.

**PERFORMANCE INDICATOR** – A measure of economic, social or environmental health. In the context of the study, performance indicators relate to impacts on various interests of different water levels and flows in the Rainy River basin.

**PLAN FORMULATION METHOD** – A method involving a multi-objective, multi-stakeholder evaluation procedure used to evaluate factors in determining whether a revised operating plan performs better than an existing plan.

**REGULATORY STRUCTURES** – Adjustable structures, such as a gated dam, that can be raised or lowered to adjust water levels and flows both upstream and downstream.

**RESOURCES ADVISORY GROUP (RAG)** – An advisory group established by the Study Board, made up of federal, state and provincial agencies in the watershed that are responsible for natural resource management or environmental protection. It reviewed analyses and recommendations made by the Study Board for their potential effects on natural resources or the environment in the study area.

**RIPARIAN** – Relating to or found along a shoreline.

**RIPARIANS** – Persons residing on the banks of a body of water. Typically associated with private owners of shoreline property.

**RULE CURVE** - The primary regulatory tool for managing water levels of Namakan Lake and Rainy Lake. It provides a target range, known as the band, for the level of a lake for every day of the year. The most recent versions were adopted in 2000 and, as a result, are known as the 2000 rule curves.

**RULE CURVE PUBLIC ADVISORY GROUP (RCPAG)** – The group of volunteers from the United States and Canada that worked to assist the Study Board in its outreach and engagement activities, including serving as a conduit to public input to the study process and for public dissemination of study outcomes.

**SHARED VISION MODEL (SVM)** – A modelling tool used in the Shared Vision Planning process. In this Study, it is designed to interpret results from the IERM, integrate results from other sources and develop evaluation metrics that can be used to compare rule curve alternatives. Each individual SVM simulation will generate water levels and flows in mean quarter-monthly values for a specified number of years for a particular rule curve alternative and water supply set.

**SHARED VISION PLANNING (SVP)** – A comprehensive, participatory and transparent evaluation process used in the study. In this Study, it is designed to evaluate any chosen rule curve alternative and any water supply scenario, and is not limited by historical data. Through a series of practice decisions, interested parties are able to evaluate various criteria and learn about the possible effects of changes in water levels and flows on the interests in the study area under different regulation plans.

**SHORELINE EROSION** – The wearing away of a shoreline as a result of the action of water current, wind and waves.

**STATE OF NATURE** – For the purposes of the Study, the term refers to a hypothetical basin configuration where it is assumed that the structures that limit or regulate flow out of Namakan Lake and Rainy Lake do not exist. This allows for the modelling of flows from these lakes in a pre-dam condition – a best estimate of the system under natural conditions.

**STOCHASTIC SUPPLIES** – Randomly-generated sequences of water supply conditions, generated over many iterations, so as to reflect climate variability.

**WATER SUPPLY** – Water reaching a basin as a direct result of precipitation, minus evaporation from land and lake surfaces.

**WITHIN-YEAR VARIABILITY** – Variations in water levels over the course of a single year.

**WETLANDS** – An area characterized by wet soil and high biological productivity, providing an important habitat for waterfowl, amphibians, reptiles and mammals.

**YEAR CLASS** – A cohort of fish born in the same year.

**YOUNG OF YEAR (YoY)** – Fish born within the past year that have not yet reached one year of age.

# **Managing Water Levels and Flows in the Rainy River Basin**

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A REPORT TO THE INTERNATIONAL JOINT COMMISSION

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## **A N N E X E S**

Prepared by the  
INTERNATIONAL RAINY AND NAMAKAN LAKES RULE CURVES STUDY BOARD



International Rainy and Namakan  
Lakes Rule Curves Study Board







## LIST OF ANNEXES

1. Directive for the International Rainy-Namakan Lake Rule Curves Study Board
2. Terms of Reference for the Evaluation of the 2000 Rainy-Namakan Rule Curves
3. Directive for Communication and Public Outreach Activities for the Rainy-Namakan Lake Rule Curves Study
4. Study Organization Members and Participants
5. Performance Indicators
6. Weight of Evidence Analysis of Study Subjects
7. Rule Curve Alternatives
8. Sample Operational Guidelines



## DIRECTIVE FOR THE INTERNATIONAL RAINY-NAMAKAN LAKE RULE CURVES STUDY BOARD

1. Pursuant to the Boundary Waters Treaty of 1909 (Treaty), the International Joint Commission has an ongoing responsibility for assuring that projects it has approved continue to operate in a manner that is consistent with the provisions of the Treaty as interpreted by the Commission and the governments of Canada and the United States (governments).

In carrying out this responsibility, the Commission had prepared the Plan of Study (PoS) entitled ***Evaluation of the International Joint Commission (IJC) 2000 Order for Rainy and Namakan Lakes and Rainy River*** in 2009. Studies in support of the Rule Curve Review outlined in the PoS have been conducted since 2010. In preparation for the evaluation phase of the Rule Curve Review which includes consolidation of the findings of the PoS studies the Commission worked with the International Rainy Lake of the Woods Watershed Board to develop a ***Terms of Reference for the International Rainy-Namakan Lake Rule Curves Study Board*** (ToR) which outlines the objectives, scope and timeline of the rule curve evaluation.

2. This directive establishes the International Rainy-Namakan Lake Rule Curves Study Board (Study Board). The mandate of the Study Board is to undertake the studies required to develop a rule curve evaluation report providing the Commission with sufficient information required to evaluate options for regulating levels and flows in the Rainy-Namakan Lakes system in order to benefit affected interests and the system as a whole in a manner that conforms to the requirements of the Treaty, and the Study Board shall be guided by this mandate in pursuing its studies. The Study Board shall provide options and recommendations for the Commission's consideration. In carrying out this mandate, the Study Board is encouraged to integrate as many relevant considerations and perspectives into its work as possible, including those that have not been incorporated to date, to assure that all significant issues are adequately addressed.
3. The Commission will appoint an equal number of members from Canada and the United States to the Study Board, and the Commission will name a member from Canada and a member from the United States to be the co-chairs of the Study Board. The co-chairs of the Study Board shall convene and preside at meetings of the Study Board and shall jointly take a leadership role in planning and implementing the Study Board's work. The Co-chairs will also be responsible for coordinating with the IRLWWB (International Rainy Lake of the Woods Watershed Board) and its WLC (Water Levels Committee), the Study Board's TWG (Technical Working Group) and the other technical and advisory groups, and for coordinating with and reporting to the Commission.
4. The Commission will appoint a Study Manager to assist the Study Board on a full-time basis in performing the responsibilities assigned to it in this directive. The Study Manager will report to and take direction from the Study Board. The Study Manager shall work under the joint direction of the co-chairs of the Study Board and shall keep

fully abreast of the work of the study teams, committees, work groups and other advisory bodies, as well as the Rule Curve Public Advisory Group (RCPAG), which is established pursuant to the ***Directive for Communication and Public Outreach Activities for the Rainy-Namakan Lake Rule Curves Study***.

5. The Commission will appoint a Technical Working Group (TWG), consisting of two members, one from Canada and one from the United States. The TWG will report to and take direction from the Study Board. The TWG will support the Study Board and will be responsible for conducting scenario modeling for rule curve evaluation as directed by the Study Board.
6. The Study Board, after consultation with Commission, may establish study teams, committees, work groups and other advisory bodies to address the substantive areas identified in the ToR and assist it in carrying out its responsibilities. The Study Board shall normally appoint an equal number of persons from Canada and from the United States to each of these entities. Unless other arrangements are made, members of the Study Board, study teams, committees, work groups and other advisory bodies will make their own arrangements for reimbursement of necessary expenditures unless otherwise arranged with the Commission. The Commission seeks to ensure the inclusion of appropriate expertise in the membership of its boards, while drawing that expertise from a diversity of sources on a non-discriminatory basis. When identified by the Study Board, the Commission will pursue technical assistance from the two governments, the province of Ontario and the State of Minnesota.
7. The Study Board, study teams, committees, work groups and other advisory groups shall act as unitary bodies. The members of the Study Board, the study teams, work groups, other advisory bodies, and the co-managers shall serve the Commission in their personal and professional capacities, and not as representatives of their countries, agencies, organizations, or other affiliations.
8. The Study Board and the study teams, committees, and work groups shall endeavour to conduct all their work by consensus. The Study Board shall notify the Commission of any irreconcilable differences and shall refer promptly to the Commission any lack of clarity or precision in instructions or directives received from the Commission.

The Study Board shall carry out its work independent of the work of the International Rainy Lake of the Woods Watershed Board (IRLWWB) and its Water Levels Committee (WLC) and shall not take instructions from the IRLWWB or WLC. The Study Board, however, shall maintain liaison with the IRLWWB and WLC so that all may be aware of the others' activities that might be useful to it in carrying out its responsibilities. The Study Board will consult regularly with the IJC's IRLWWB Liaisons who shall be invited to all meetings of the Study Board.

9. The Study Board shall keep the Commission fully informed of its progress and direction. The Study Board shall also maintain an awareness of basin-wide activities and conditions and shall inform the Commission about any such activities or conditions that might affect its work. In addition to regular contact with designated Commission personnel, the Study Board shall meet with the Commission at each of its semi-annual meetings during the study period and shall submit written progress reports to the Commission at least three weeks in advance of those times and at other times

as deemed appropriate by the Study Board or as requested by the Commission. All progress reports will be shared with the IRLWWB, the WLC, the Industry Advisory Group (IAG) and the Community Advisory Group (CAG) at that time so that the IRLWWB can provide comments at its appearance before the Commission. The final study report shall discuss findings from the evaluation of Rule Curve alternatives. The final study report should include a discussion of the multiplicity of views provided by the RCPAG and explain how those views were considered in its final recommendations. The Study Board will also maintain such financial and other records as may be necessary to document the contributions of each country to the study effort.

10. The Commission emphasizes the importance of public outreach, consultation, and participation. In the conduct of its activities, the Study Board shall be guided by the ***Directive for Communication and Public Outreach Activities for the Rainy-Namakan Lake Rule Curves Study***. The Commission expects the Study Board to involve the public in its work to the fullest extent possible. The Study Board shall provide communication materials to the Secretaries of the Commission prior to their release. Public communications materials shall include but not be limited to: public meetings, press releases, and public statements. IJC Communications staff will assist the Study Board and its Study Manager in establishing and maintaining a public website, which will be a complete repository of all the Study Board's public documents. The Study Board shall solicit and make use of public input received prior to and during the study period and make it available on the IJC website. The final Study report should also include a summation of its public outreach activities.
11. The Study Board shall within two months of its creation submit for the Commission's approval an evaluation methodology report laying out activities and work to be conducted during the study, a list of RCPAG members and a comprehensive work plan with an associated schedule of activities, products and budget, all based on the ToR.
12. The Commission will administer, or coordinate, resource contributions from the two governments to support the activities of the Study Board, the study teams, committees, work groups, other advisory bodies, and the RCPAG.
13. The Study Board will start its work on August 10, 2015 and deliver its Final report to the Commission on March 31st, 2017. Some estimated dates of key milestones are:
  - a. **August 4, 2015** – IJC announce the structure, role and membership of the Study Board and TWG.
  - b. **Week of August 10, 2015** – study board convene an initial meeting separately and in conjunction with the IRLWWB annual meetings.
  - c. **November 1, 2015** – Evaluation Methodology Report to be sent to IJC
  - d. **March 2016** – International Lake of the Woods Science Forum – Study Board public information meetings.
  - e. **March 31, 2017** – Draft report submitted to the Commission.
  - f. **May 31, 2017** - Final draft report submitted to the Commission. Public hearings to be held as required.
14. An Independent Review Group (IRG) will be established to ensure independent technical review is being conducted and documented on appropriate study components and

documents, during the entire study process. The IRG will conduct, as well as manage this independent review. One Canadian and one U.S. representative shall Co-chair the IRG. All IRG members shall have practical experience evaluating multi-purpose water resource studies requiring analysis of trade-offs used for the purposes of public decision making. These members and the IRG Co-chairs shall not have participated in Plan of Study development nor be members of groups that report to the Study Board Co-chairs. IRG members should have backgrounds in economics, hydrology and hydraulics, environmental science, recreational boating and tourism, water use or plan formulation and evaluation.

## ANNEX 2

### TERMS OF REFERENCE FOR THE EVALUATION OF THE 2000 RAINY-NAMAKAN RULE CURVES

This document should be read in conjunction with Directive for the *International Rainy-Namakan Lake Rule Curve Study Board (IRNLRCSB)* and *Directive for Communication and Public Outreach Activities*. If there is a conflict in wording between the three documents, the Directives shall be authoritative.

#### SUMMARY

This Terms of Reference outlines the approach for the planned Rainy and Namakan Lake 2000 Rule Curve evaluation, including the planned study methodology, governance structure and public engagement strategy.

The 2000 Rainy and Namakan Lake Rule Curves were established in 2001 as part of a consolidated order, which stipulated a review of the 2000 Rule Curve in 2015. In 2009 a report outlining a Rule Curve review plan of study was issued and approved (Kallemeyn *et al.*, 2009). That plan called for 18 studies to investigate the wide range of hydrologic, hydraulic, cultural and environmental risk factors. The last of those and subsequently identified required studies is scheduled for completion in October 2015, barring possible extensions.

The objective of this rule curve evaluation study is to provide to the IJC with scientifically supported recommendations for the modification or retention of the 2000 Rainy and Namakan Lakes Rule curves, considering the aforementioned risk factors. The evaluation scope of the original 2009 plan has been expanded, based on review by the International Rainy Lake of the Woods Watershed Board (IRLWWB) in 2014, to now include a Shared Vision Model (SVM) component allowing for a more integrated comparison of rule curve options linking the hydrology and hydraulics to the other investigated risk factors. The geographic scope of this study comprises the Rainy and Namakan Lakes, the connecting channels and the Rainy River downstream of Rainy Lake to the Lake of the Woods, and the riparian areas adjacent to these water bodies.

As outlined in the Directive this evaluation study will be managed by a six -person Study Board, advised by a two-person technical working group (TWG) and supported by a Study Manager. The TWG will perform the numerical modelling and rule curve scenario simulations and provide options and technical recommendations to the Study Board. The Study Board will be responsible for informing and soliciting feedback from the public, stakeholders, the IRLWWB and their Water Levels Committee (WLC) throughout the study and will be responsible for forming a Rule Curve Public Advisory Group (RCPAG), consisting of members of riparian associations and stakeholders active in the basin. The Study Board will also be responsible for evaluating the recommendations from the TWG, considering feedback from stakeholders, and presenting a final report with recommendations to the IJC.

The project is anticipated to start in the fall of 2015 with an anticipated duration of one and one-half (1.5) years with an anticipated total cost of \$295,000.



## BACKGROUND

In 2001 the International Joint Commission (IJC) issued an Order prescribing the method of regulating the levels of the boundary waters of Rainy and Namakan lakes, consolidating and replacing a number of previous orders and supplementary orders (International Joint Commission 2001). This “Consolidated Order” was effective on February 28, 2001, and contained the following provision: “This order shall be subject to review 15 years following adoption of the Commission’s Supplementary Order of 5 January 2000, or as otherwise determined by the Commission. The review shall, at a minimum, consider monitoring information collected by natural resource management agencies and others during the interim that may indicate the effect of the changes contained in the Supplementary Order of January 5, 2000.”

In 2007, the IJC formed a six-member Rule Curve Assessment Workgroup to develop a plan of study (POS) in which the Workgroup would prioritize the monitoring and analyses required to review the IJC Order in 2015. Specifically, the POS was written to identify priority studies and describe information/data that remained to be collected, identify appropriate entities to collect the data and perform the studies, and to provide an estimate for the cost to accomplish this work by 2015. The Plan of Study (POS) for the Evaluation of the International Joint Commission (IJC) 2000 Order for Rainy and Namakan Lakes and Rainy River was completed in 2009 (Kallemeyn et al., 2009).

The Workgroup, in its 2009 report, suggested that an expert panel should judge the rule curves based on the review of a simple matrix of positive, negative or neutral indicators for each monitored outcome, called the “weight of the evidence approach”. A total of 18 studies were originally launched as part of this Rule Curve Review following from the 2009 report, to assess the changes in hydrology, hydraulics, flooding and other impacts due to the changes from the 1970 to the 2000 rule curves in the Rainy and Namakan reservoirs. Since the start of the Rule Curve Review study other needed studies have been added and others defunded, as the study team managed the study adaptively. The final list of studies in support of the Rule Curve Review is tabulated in Table 1. Additionally, IWI-funded studies may also provide results which could support the rule curve review, and these are listed in Table 2.

In 2014, as many of the studies were nearing completion, the scientists and stakeholders took stock of the results obtained to date. Questions were raised whether the expected results could lead to a definitive evaluation of the changes in the rule curve or reliably recommend alternative rule curves. The weight of the evidence approach originally outlined in the 2009 report is straightforward but has shortcomings. The original proposed approach would also be unable to evaluate rule curve performance in other plausible hydrologic scenarios, including those with climate change.

On March 11, 2014, scientists and stakeholders involved in this work met in International Falls to consider the feasibility of the shared vision approach (Palmer et al, 2013) in developing a rule curve evaluation study similar to what has been successfully employed in the IJC Upper Great Lakes Study and the Lake Ontario – St. Lawrence River Study (IJC, 2012; IJC, 2006). The scientists and stakeholders determined it was feasible and advisable, and they recommended the work described in a project proposal for the evaluation of the Rainy and Namakan Rule Curves, provided to the IJC in May 2014 through the International Rainy-Lake of the Woods Watershed Board. The recommendations introduced a plan for a Shared Vision Model.

In light of these recommendations, the IJC adjusted the original study scope as outlined in the 2009 report and re-allocated study resources to facilitate the anticipated SVM study approach, resulting in the addition of several new studies and the defunding of others that are no longer necessary.

This Plan of Study outlined the Rule Curve evaluation study employs much of the IRLWWB 2014 proposal with the above items fully addressed.

**Table 1 Rule Curve Review Studies**

<b>Study Index</b>	<b>Rule Curve Review Studies</b>
<b>1 / 2</b>	Reservoirs - develop reservoir hydrologic model & reservoir PHABSIM habitat model (1 - hydrologic, 2 - hydraulic)
<b>3</b>	Characterize the natural hydrology of Rainy River (HEC-RAS Model) vs. rule curves
<b>4</b>	Measure changes in benthic community in relation to curves, in the reservoirs
<b>5</b>	Aquatic vegetation (replicate Meeker and Harris 2009)
<b>6</b>	Reservoirs – northern pike spawning habitat and reproductive success
<b>7</b>	Rainy River – critical spawning and nursery habitats
<b>8</b>	Economic survey of impact of rule curves on tourist resorts on reservoirs
<b>9</b>	Relate rule curve changes to flooding and ice effects on reservoirs
<b>10</b>	Assess Effects of Water Level Fluctuation on Bioindicators Using Analytical Models
<b>11</b>	Detailed bathymetric mapping of the littoral zone of selected reservoir locations
<b>12</b>	Assess effects on cultural resources at a small number of sites on the reservoirs
<b>13</b>	Assess effects on cultural resources at benchmark sites on the Rainy River
<b>14</b>	Assess effects on reservoir habitats for marsh-nesting birds/herps at selected sites
<b>15</b>	Identify critical river benthic habitats at X-sections; model effects of curve change (defunded)
<b>16</b>	Measure Unionid (mussel) diversity and abundance in the Rainy River re: effects
<b>17</b>	Measure changes in fish community health (Index Biotic Diversity) re: effects
<b>18</b>	Measure critical spawning habitat for walleye on Namakan Reservoir re: effects
<b>19</b>	Examine municipal water treatment and hatchery data for Rainy River re: effects
<b>20</b>	Network Global Navigation Satellite System Surveys of Vertical Benchmarks
<b>21</b>	Development of a 2-D habitat model required to support Study No 7 “Rainy River – critical spawning and nursery habitats”
<b>22</b>	Collect bathymetric data for selected shallow areas to assist in the development of a digital elevation model for Rainy Lake and Namakan Reservoir

**Table 2 IWI Studies supporting or complementary to the Rainy Rule Curve Review**

<b>IWI Studies</b>
Seine River Temperature Study - Seine River First Nation
Cattails and Wild Rice Study - Seine River First Nation
Multi-year Rainy River Temperature Study
Namakan Pinch-Point Hydraulic Study

## **Public and Stakeholder Engagement**

Residents and businesses, including recreation and tourism, along the shores of Rainy and Namakan Lakes have a high interest and concern about water levels control. This fact makes it particularly important that the public engagement plan for the Rule Curve Review begin early in the process and maintain a high level of public and stakeholder engagement throughout the study.

As per the Directives the Study Board will be relying on IJC Communications staff, to assist it in organizing its communications and outreach program. These staff time costs are not included in the budget.

## **SCOPE AND OBJECTIVES**

### **Project Objectives**

The objective of this study is to provide to the IJC scientifically supported recommendations for the modification or retention of the 2000 Rainy and Namakan Lakes Rule curves, considering a wide range of hydrologic, hydraulic, cultural and environmental risk factors.

### **Project Scope**

This project study scope includes the evaluation of the 2000 Rule Curves for Rainy and Namakan Lakes and the identification of performance differences between the 1970 rule curves and estimated state-of-nature releases from those lakes. The geographic scope of this study comprises the Rainy and Namakan Lakes, the connecting channels and the Rainy River downstream of Rainy Lake to the Lake of the Woods, and the riparian areas adjacent to these water bodies. The rule curve evaluations will be conducted using a weight of evidence approach as outlined in Kallemeyn *et al.* (2009), as well as a shared vision modelling approach detailed below. The SVM approach will also evaluate the influence of the rule curves under various climate change scenarios, and provide recommended modifications to the existing 2000 Rule Curves if appropriate, through the testing of rule curve alternatives.

## **STUDY METHODOLOGY**

The TWG will conduct and execute two complimentary approaches to review the Rainy and Namakan Lake Rule Curves: the weight of evidence approach as outlined originally in Kallemeyn *et al.* (2009); and the added shared vision model (SVM) approach.

The TWG will develop a shared vision model using economic and environmental impact information from the already completed rule curve studies and based on an existing reservoir simulation model for Rainy and Namakan lakes and the existing hydrodynamic model of the Rainy River. The Rainy and Namakan lake model currently simulates lake levels and releases under the 1970 and 2000 Rule Curves using the historical water supplies and has been modified to consider other rules, in particular a “state of nature” release rules representing estimates of releases without the presence of hydraulic control structures or human influences.

A two-dimensional hydrodynamic model of the downstream Rainy River will be used to simulate the levels with the flows generated under the two Rule Curves and state of nature release rules as well as any other release rules developed. The shared vision model will thus include the Rainy River in an integrated simulation of the impacts of water levels throughout the system on economic and ecological indicators.

At the March 2014 review of the Kallemeyn approach, scientists involved in the Rule Curve Review studies, developed the list of performance indicators that could be prepared for programming into the modified reservoir simulation model including the Rainy River. They agreed that such programming would allow the evaluation of the impacts of any proposed new regulation approach on wetland evolution (cattails, wild rice and submerged plants), muskrat winter survival, loon nesting, and northern pike and walleye reproduction. Economic indicators, such as emergency conditions of flood and low levels, electric power production, and tourism, will also be programmed into the shared vision model (SVM). A list of the variables being considered for inclusion in the SVM is tabulated in Table 3.

Some indicators have no readily formulated algorithms that relate performance to water levels or flows. The TWG will present these indicators in the weight of evidence matrix to compare the 1970 and 2000 Rule Curves along with alternative curves for evaluation by the Study Board. An uncertainty analysis will attempt to determine the sensitivity of conclusions drawn about the rule curves to uncertainty about the future and our understanding of the relationship between impacts and water levels and flows. The weight of evidence matrix will be used in parallel to the SVM to improve the certainty and quality of the findings. It is anticipated that the matrix may improve the certainty of the findings with regard specifically to the comparison of the 1970 and 2000 Rule Curves.

### Project Oversight

The bi-national Study Board will oversee the evaluation work, manage outreach and stakeholder engagement, write reports and provide recommendations to the IJC. The Study Board will be responsible for study findings, recommendations and conclusions with their evaluation based on both the shared vision model simulations and the weight-of-evidence matrix.

**Table 3 Performance indicators for inclusion in the SVM**

<b>Proposed performance indicators for inclusion in the SVM</b>
Rainy Lake / Namakan Reservoir Northern Pike population; reproduction or recruitment
Rainy Lake / Namakan Reservoir Walleye population; reproduction or recruitment
Rainy Lake / Namakan Reservoir Northern Pike spawning and nursery habitat
Both Rainy River and Namakan Reservoir Walleye spawning habitat
Rainy River Lake Sturgeon spawning habitat
Rainy River Log perch spawning habitat
Rainy Lake / Namakan Reservoir yellow perch mercury concentration (important and doable)
Rainy Lake / Namakan Reservoir beaver population/health
Rainy Lake / Namakan Reservoir common loon reproductive success modeling
Rainy Lake / Namakan Reservoir muskrat population model
Power Production
Flooding and ice damage on Rainy Lake and Namakan Reservoir,
Rainy Lake / Namakan Reservoir resort industry economic impact (revenue, employment)
Cultural Resources (erosion index for threat to artifacts)
Rainy Lake / Namakan Reservoir Wetlands
Rainy Lake / Namakan Reservoir Wild Rice
Rainy Lake / Namakan Reservoir Invertebrate community; biomass or indicator
Rainy River Benthic macroinvertebrate habitat (IJC still assessing feasibility of this)

## **Shared Vision Model Development**

The TWG will collaboratively develop a shared vision model to determine:

- whether the 2000 Rule Curves worked as expected
- whether they are better than the 1970 Rule Curves and why
- what benefits and/or negative impacts may have resulted from the 2000 rule curves relative to likely impacts of the 1970 Rule Curves
- what benefits and negative impacts would result from a “state of nature” operating plan
- what benefits and negative impacts would result from a few alternative operating policies or plans
- what benefits and negative impacts would result from changed climate

The scientists working on each relevant study will develop an algorithm for each performance indicator (listed in Table 3) representing the impacts of the water levels of each applicable water body of the system. The TWG will be responsible for working with scientists and stakeholders to program the algorithms into the simulated water levels, creating the shared vision model (SVM). The TWG may rely on external technical expertise (e.g. postdoctoral fellows) to assist with the development of the SVM.

Two additional water supply data sets will be developed based on the historical supplies to test plausible and relevant concerns about how future supplies might expose weaknesses in any of these operating sets. The datasets will be created simply and cheaply by methods such as repeating a dry year to test the possibility of an extended drought or by redistributing historical annual supplies differently over the course of the year to represent the potential for earlier snow melt under climate change. The “state of nature” release rules will be programmed into the Rainy and Namakan lake model so that they can be applied to any water supply data set. The impacts of the resulting flows will be simulated in the Rainy River model.

The TWG will apply three water supply sets to the Shared Vision Model to discover how future water supplies may expose weaknesses, including the historical water supplies and two additional water supply sets based on the historical supply set.

## **Weight of Evidence Matrix Development**

The TWG will also complete a weight of evidence matrix for those indicators which have no readily formulated algorithms that relate performance to water levels or flows. All indicators will be included in the matrix to improve the certainty and quality of the SVM for use by the Study Board in its evaluation.

## **Rule Curve Options - Review and Evaluation**

The TWG may work with the WLC, RCPAG and other specialists and stakeholders as the Study Board sees fit, to develop alternative sets of rules curves. The alternatives will be programmed in the Rainy and Namakan lake model and the outflows simulated in the Rainy River model of the SVM. The number of alternatives will have to be limited given the overall study cost, but at least three alternatives will be formulated and modeled including variations such as:

1. 2000 Rule Curves, but with the target level set at the level that would result from the natural flow at that elevation rather than the mid-point of the upper and lower curves.
2. Modified shaping of the 2000 Rule Curves based on evidence from performance indicator scores from the evaluation of the 2000 Rule Curves.



3. 2000 Rule Curves, but with the target elevation shifted from the center by current data (soil moisture, temperature, snow pack, e.g.)

The SVM model will be used to run approximately 18 scenarios composed of:

1. Six operating plans (1970, 2000, State of Nature, 3 alternatives) times; and
2. Three water supply sets (historical, extreme, climate change)

The Study Board will oversee the work, review the results of the approximately 18 rule curve evaluations and will write a report, with assistance from the TWG, providing the summary of the analysis and results, and with recommendations to the IJC.

## **REVIEW PROCESS**

The Study Board and TWG will employ a peer review process at various stages of this study. A two- person review panel, one from the US and one from Canada, will be employed for this purpose at three points during the study. Once the Board and TWG produce an evaluation methodology the review panel will review the methodology and provide recommendations to the Board. Additionally the review panel will review both the draft and final reports. All of the review panel's reports will be made public.

The IRLWWB and its WLC, along with its two advisory boards (CAG and IAG) will be asked to review final reports and recommendations of the Study Board prior to submission to the IJC. Following this period of review the Study Board will consider the views of these groups in their deliberations in authoring the final study report.

It is anticipated the IJC will conduct its own review of the recommendations after the final board report. After its review, the IJC may go back to the Study Board for clarification or additional information to be included in the Board's final report.

## **REFERENCES**

International Joint Commission. 2001. In the Matter of Emergency Regulation of the Level of Rainy Lake and of other Boundary Waters in the Rainy Lake Watershed. Order Prescribing Method of Regulating the Levels of Boundary Waters. 16pp.

Kallemeyn, L., W.R. Darby, E. Eaton, K. Peterson, K Smokorowski, and J. Van den Broeck. 2009. Plan of study for the evaluation of the IJC 2000 Order for Rainy and Namakan Lakes and Rainy River.

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Palmer, R., Cardwell, H., Lorie, M., and Werick, W. "Disciplined planning, structured participation, and collaborative modeling – applying Shared Vision Planning to water resources." Journal of American Water Resources Association. Volume 49, Issue 3, pages 614–628, June 2013.

International Joint Commission, 2006. Options for Managing Lake Ontario and St. Lawrence River Water Levels and Flows. Final Report by the International Lake Ontario - St. Lawrence River Study Board.

International Joint Commission, 2012. International Upper Great Lakes Study, Lake Superior Regulation: Addressing Uncertainty in Upper Great Lakes Water Levels.

## ANNEX 3

### **DIRECTIVE FOR COMMUNICATION AND PUBLIC OUTREACH ACTIVITIES FOR THE RAINY-NAMAKAN LAKE RULE CURVES STUDY**

1. Public participation in the study will be objectives-driven. The principal objectives are to:
  - a. Make the public aware of the study and provide opportunities to participate;
  - b. Identify and consider the public's views of the principal issues, questions and study objectives
  - c. Explain the decision-making process of the study;
  - d. Insure that the study process is open, inclusive and fair;
  - e. Identify and consider the public's priorities and preferences;
  - f. Identify and utilize local expertise and information;
  - g. Enhance public understanding of the causes of problems related to fluctuating water levels and of the consequences of proposed solutions;
  - h. Broadly disseminate study findings as they become available; and
  - i. Encourage the public to assist in disseminating study findings.
2. The Study Board will directly engage early with Aboriginal peoples including but not limited to, First Nations, Metis and Native American Tribes in the basin to seek their input in the Rule Curve evaluation and their involvement in the Rule Curve Public Advisory Group (RCPAG, described below).
3. For purposes of the study, the "public will include everyone who is interested in the rule curve review, or who could be affected by it, including the following groups:
  - a. Governments at all levels;
  - b. Native Americans/Aboriginal Peoples, including but not limited to First Nations, Metis and Native American Tribes;
  - c. Upstream/downstream riparians.
  - d. Commercial navigation;
  - e. Environment;
  - f. General public;
  - g. Hydroelectric power;
  - h. Domestic water supply and sanitation; and
  - i. Recreational boating.
4. To facilitate public outreach and consultation, the Study Board shall make information related to the study as widely available as practicable, including white papers, data, reports of the Study Board or any of its subgroups, and other materials, as appropriate. The Study Board supported by the IJC Communications staff shall maintain a web-site as a means for disseminating information related to implementation of the Plan of Study, and will use the IJC website to encourage public discussion of such information. To the extent practicable, the Study Board shall make available on the web-site all documents that are available for public information under the Commission's Rules of Procedure, including public comment and other information made available by decision pursuant to the Rules of Procedure.

5. In carrying out its public participation activities, the Study Board will be assisted by a Rule Curve Public Advisory Group (RCPAG). This advisory group is to receive its direction from and directly liaise with the Study Board. The RCPAG should consist of no fewer than eight members to be appointed by the International Joint Commission (IJC or “the Commission”) after consultations with the Study Board, with an objective to include at least one member from the United States and Canada from each of the following groups, who also live or operate within the study geography (where possible):
  - a. Lake/property owners associations;
  - b. Navigation interests;
  - c. Environmental organizations;
  - d. First Nations, Metis and Tribes;
  - e. Tourism and recreation interests;
  - f. Hydro Power companies or organizations; and
  - g. Other interested groups identified by the Study Board that would have a vested interest in the Rainy and Namakan Lake Rule Curve evaluation.
6. The IJC shall appoint two co-chairs of the RCPAG, one from the United States and one from Canada. The members of the RCPAG will make their own arrangements for reimbursement of necessary expenditures unless otherwise arranged with the Commission. The RCPAG will meet in the basin, or by teleconference. Members will receive support for their travel to the RCPAG meeting but will not be compensated for their time. Secretarial support will be provided to RCPAG functions, such as distributing documents and organizing meetings, by the Study Manager.
7. IJC Communications staff will support the Study Board and RCPAG in its communication and outreach activities.
8. Discussion during RCPAG meetings is to be open, frank and free-flowing. All members of RCPAG have equal status during discussion and are expected to demonstrate fairness and a commitment to in-depth examination of matters under review. Advice from the RCPAG to the Study Board should not necessarily be censuses advice, but should reflect the multiplicity of views of its members, although it can weight its advice by noting where most or all members agree. Topics that do not fit within the mandate of the Study should not be discussed. Minutes of RCPAG meetings are prepared and certified for accuracy by the Co- Chairs. Minutes are kept to the minimum detail required to summarize effectively the proceedings and to reflect advice offered. There is no attribution of comments unless specifically requested by a member. RCPAG Co-chairs will be responsible for the approval and distribution of the minutes, with the assistance of the Study Manager. The minutes will be posted to the Study Board website, as authorized by the Study Board. The mission of the RCPAG is to:
  - a. Review and provide comment on Study Board reports and products as requested;
  - b. Advise the Study Board on the responsiveness of the study process to public concerns;
  - c. Advise the Study Board on public consultation, involvement and information exchange; and
  - d. Serve as a conduit for public input to the study process, and for public dissemination of study outcomes.

Members carry out the mandate of RCPAG by:

- a) Demonstrating preparedness for meetings;
  - b) Fostering and contributing to an open and collaborative climate;
  - c) Actively providing constructive input to the deliberations;
  - d) Drawing on their knowledge, contacts and experience to provide informed input into discussions; and
  - e) Maintaining a good attendance record.
9. In order to inform and provide context for the review of the rule curves, members of the Study Board, or others, as determined by the Study Board, will conduct outreach activities with the public at the beginning of the study to identify:
    - a. The public's views of the principal issues, questions and study objectives;
    - b. What information they already have that would be helpful, especially their knowledge of additional studies and other historical data and information;
    - c. How they think they can contribute to the study; and
    - d. Their future plans and activities that could potentially be affected by levels
  10. The Study Board will work with the RCPAG throughout the basin and conduct public participation activities at strategic points in the study to:
    - a. Identify and utilize local expertise and information;
    - b. Consult with the public on critical or potentially controversial study findings;
    - c. Disseminate plain language information to enhance public understanding of the Identify and consider the public' priorities and preferences, as well as those of Native American and Aboriginal Peoples, as alternatives are defined and optimized; and
    - d. Consult with the public, as well as Native American and Aboriginal Peoples, on Study Board findings, conclusions and before these study components have been finalized.
  11. Study Board meetings will be held at different locations within the study geography to encourage public consultation and meetings will be announced in advance. Opportunities for public observers to attend the meetings should also be announced in advance.
  12. Coordination of public outreach activities under the study with public outreach activities of the International Rainy Lake of the Woods Watershed Board (IRLWWB), and its Water Levels Committee (WLC) is encouraged to avoid confusion and to better inform the public.
  13. Information and findings generated by the study process will be made available to the WLC of the IRLWWB as they become available, but the mandate of the IRLWWB and WLC will remain unchanged unless amended by the IJC.
  14. The IJC may conduct its own public participation process related to the review of the Rule Curves during the study or after receiving the Study Board's report.

## A N N E X 4

### STUDY ORGANIZATION MEMBERS AND PARTICIPANTS

#### 1. International Rainy and Namakan Lakes Rule Curves Study Board

	Canada	United States
<b>Co-Chairs</b>	Matt DeWolfe, Environment and Climate Change Canada	Colonel Samuel Calkins, US Army Corps of Engineers Scott Jutila, US Army Corps of Engineers (Alternate)
<b>Members</b>	Syed Moin, Independent consultant Erika Klyszejko, Environment and Climate Change Canada	Larry Kallemeyn, Independent consultant Pam Tomevi, Koochiching County Soil and Water Conservation District
<b>Study Manager</b>	Kelli Saunders, Lake of the Woods Water Sustainability Foundation	

#### 2. Technical Working Group

- Jean Morin, Environment and Climate Change Canada
- William Werick, Independent consultant

#### 3. International Joint Commission Liaisons

- Mark Colosimo, Washington, DC
- Mark Gabriel, Washington, DC
- Nick Heisler, Ottawa, ON
- Wayne Jenkinson, Ottawa, ON



#### 4. Rule Curves Public Advisory Group

	Canada	United States
<b>Co-Chairs</b>	Jeff Wiume, Fort Frances, ON	Tim Snyder, Kabetogama Lake, MN
<b>Members</b>	Paul Anderson, Rainy Lake, ON Richard Boileau, Fort Frances, ON Francis DeBay Fort Frances, ON Kristie Duncan, Kenora, ON Deb Ewald, Rainy River, ON John Kabatay, Mine Centre, ON Jim Krag, Fort Frances, ON Ron Medina, Fort Frances, ON Travis Rob, Fort Frances, ON Kiley Shebagegit, Nestor Falls, ON John Spencer, Rainy Lake, ON	Bob Anderson, International Falls, MN Jack Bartlett, Rainy River/Lake MN Kayla Bowe, Red Lake, MN John Carlson, International Falls, MN Barbara Clark, Grand Marais, MN Tom Dougherty, Ranier, MN Georgia Growette, Ranier, MN Lee Herseth, Kabetogama Lake, MN Mike Hirst, Baudette, MN David Imes, Birchdale, MN Janice Imes, Birchdale, MN Tonia Kittelson, Duluth, MN Jerry Polhman, Crane Lake, MN Kelly Sjerven, International Falls, MN Kelly Voigt, Baudette, MN Alyse Walton, Baudette, MN Grant Walton, Baudette, MN Tyson Whitbeck, International Falls, MN Tom Worth, International Falls, MN

#### 5. Resources Advisory Group

- Bridget Antze, Ministry of Natural Resources and Forestry, Atikokan, ON
- Greg Chapman, Ministry of Natural Resources and Forestry, Fort Frances, ON
- Richard Gervais, Fisheries and Oceans Canada, Winnipeg, MB
- Mary Graves, Voyageurs National Park, MN
- Melissa Mosley, Ministry of Natural Resources and Forestry, Fort Frances, ON
- Kevin Peterson, Minnesota Dept. of Natural Resources, International Falls, MN

#### 6. Independent Review Group

- Elizabeth Bourget, Hudson, WI
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#### 7. Technical Writer

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## ANNEX 5

### PERFORMANCE INDICATORS

**Annex 5** presents a description of each Performance Indicator (PI) generated by the Shared Vision Model (SVM) and the Integrated Ecosystem Response Model (IERM) that were used in the Study to assess the performance of rule curve alternatives.

The following 21 PIs are described here:

#### **Study theme 1: Fish**

- 1.1 Walleye Egg Survival Probability
- 1.2 Walleye Spawning Success
- 1.3 Northern Pike Spawning Suitable Habitat
- 1.4 Northern Pike Larval Suitable Habitat
- 1.5 Northern Pike Young of Year Suitable Habitat
- 1.6 Lake Whitefish Egg Survival Probability
- 1.7 Lake Whitefish Spawning Success
- 1.8 Rainy River Walleye Spawning Habitat
- 1.9 Rainy River Lake Sturgeon Spawning Habitat

#### **Study theme 2: Wildlife**

- 2.1 Common Loon Probability of Nest Viability
- 2.2 Muskrat Over-Winter Survival

#### **Study theme 3: Economy**

- 3.1 Flood Damage Reduction
- 3.2 Boating Reliability
- 3.3 Hydropower Production

#### **Study theme 4: Cultural/archeological sites**

- 4.1 Archeological Resource Protection

#### **Study theme 5: Aquatic vegetation**

- 5.1 Cattail Invasion
- 5.2 Wild Rice Success
- 5.3 Wet Meadows Suitable Habitat
- 5.4 Shrubby Swamps Suitable Habitat
- 5.5 Emergent Plants Suitable Habitat
- 5.6 Submerged Plants Suitable Habitat

#### **Time step of model output**

It is important to note that the time step of model output is provided in quarter month (QM) time steps. The International Rainy-Lake of the Woods Watershed Board (IRLWWB) has adopted the following standard quarter month lengths:

- the first QM begins on the 1st and ends on the 8th of the month;
- the second QM begins on the 9th and ends on the 15th of the month;
- the third QM begins on the 16th and ends on the 22nd of the month; and
- the fourth QM begins on the 23rd and ends on the last day of the month.

There are 48 QMs in a year, as shown in the figure below:

JAN				FEB				MAR				APR				MAY				JUN				JUL				AUG				SEP				OCT				NOV				DEC			
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48

## STUDY THEME 1: FISH

### 1.1 Walleye Egg Survival Probability

The IERM predicts Walleye Egg Survival Probability (WESP) as a function of water level variations during the spawning and egg incubation period (beginning at ice-out, ending when water temperatures reach or exceed 11°C). The IERM assumes that Walleye eggs can safely tolerate a water level drop between 0.10 m (WESP = 1.00) and 1.00 m (WESP = 0.00). WESP for water level falling between 0.10 m and 1.00 m are linearly interpolated. The IERM also assumes that Walleye eggs can safely tolerate a water level rise of 0.50 m (WESP = 1.00) and 2.50 m (WESP of 0.0). WESP for water level rises between 0.50 m to 2.50 m are linearly interpolated.

The Walleye Egg Survival PI presented in this document represents the WESP score. Therefore:

- the PI is **equal to 1.00** indicates **perfect conditions for Walleye Egg Survival**; and
- a value **approaching 0.00** indicates **poor conditions for Walleye Egg Survival**.

### 1.2 Walleye Spawning Success

The IERM estimates the extent of suitable spawning and egg incubation habitat (SSEIH) during the spawning and egg incubation period. Preferred Walleye habitat is characterized by the presence of clean and coarse substrate material (gravels and cobbles). Due to the absence of a good substratum map for Namakan Lake and Rainy Lake, physical metrics, such as bottom slope and wind wave energy, were used as proxies for substrate composition. These variables were combined with water depths to identify SSEIH.

Once Walleye eggs are deposited on the lake bottom, they are sensitive to water movements that could move them beyond suitable depths. The IERM estimates the likelihood of egg mortality due to displacement of eggs to areas that are not suitable for incubation. Within the model, areas where the calculated shear stress on the lake bottom exceeds 0.125 m/s at least once during a QM of the spawning and incubation period are considered unsuitable for spawning success of Walleye.

The Walleye Spawning Success PI integrates the Walleye Egg Survival Probability PI with the SSEIH and the likelihood of egg mortality due to displacement. The Walleye Spawning Success PI represents the total area where all conditions are met to ensure a successful spawn. Therefore:

- an **increase** in PI value represents **better conditions for Walleye spawning**

(positive change); and

- a **decrease** in PI value represents **worsened conditions for Walleye spawning** (negative change).

### 1.3 Northern Pike Spawning Suitable Habitat

The IERM calculates the extent of high quality habitat suitable for Northern Pike spawning (wet meadows), where adequate water levels are maintained throughout the egg incubation period (three QMs following ice-out).

The Northern Pike Spawning Suitable Habitat PI represents the amount of suitable habitat calculated by the IERM. Therefore:

- an **increase** in PI value represents **better conditions for Northern Pike spawning** (positive change); and
- a **decrease** in PI value represents **worsened conditions for Northern Pike spawning** (negative change).

### 1.4 Northern Pike Larval Suitable Habitat

The IERM estimates Northern Pike larval success based on physical and environmental conditions during the larval stage (a period of four QMs that begins once water temperatures reach or exceed 12°C), including water depth, light intensity, lake bottom slope and curvature, wave energy and submerged plant density, as well as the presence of emergent plants and cattails during the previous and current years (as calculated by the IERM).

The Northern Pike Larval Suitable Habitat PI represents the amount of suitable habitat calculated by the IERM. Therefore:

- an **increase** in PI value represents **better conditions for Northern Pike larval survival** (positive change); and
- a **decrease** in PI value represents **worsened conditions for Northern Pike larval survival** (negative change).

### 1.5 Northern Pike Young of Year Suitable Habitat

The IERM estimates Northern Pike Young of Year (YoY) success based on physical and environmental conditions during the YoY stage (begins two QMs after the end of the larval stage and lasts five QMs), including water depth, light intensity, lake bottom slope and curvature, wave energy and submerged plant density, as well as the presence of emergent plants and cattails during the previous and current year (as calculated by the IERM).

The Northern Pike YoY Suitable Habitat PI represents the amount of suitable habitat calculated by the IERM. Therefore:

- an **increase** in PI value represents **better conditions for Northern Pike YoY survival** (positive change); and
- a **decrease** in PI value represents **worsened conditions for Northern Pike YoY survival** (negative change).

## 1.6 Lake Whitefish Egg Survival Probability

The IERM estimates the impact of water level variations on Lake Whitefish egg survival probability (LWESP) using a 1-D model. Within the IERM, a water level rise or fall greater than 2.00 m between the spawning (beginning mid-November) and the egg incubation periods (ending after ice-out) would result in total egg mortality (LWESP = 0.00). A water level fall or a rise of less than 0.50 m would result in total egg survival (LWESP = 1.00). Egg survival probability for water level variations between 0.50 m and 2.00 m are linearly interpolated.

The Lake Whitefish Egg Survival Probability PI represents the LWESP score. Therefore:

- the PI is **equal to 1.00** indicates **perfect conditions for Lake Whitefish Egg Survival**; and
- a value **approaching 0.00** indicates **poor conditions for Lake Whitefish Egg Survival**.

This 1-D model has been integrated in to the SVM.

## 1.7 Lake Whitefish Spawning Success

This IERM estimates the extent of suitable spawning and egg incubation habitat (SSEIH) necessary for the reproduction of Lake Whitefish. The IERM identifies areas within Namakan and Rainy Lakes during the fall spawning season (beginning mid-November) with suitable characteristics, including a gentle bottom slope, shallow water and clean substrate (determined by accumulated wave energy).

The Lake Whitefish Spawning Habitat PI integrates the Lake Whitefish Egg Survival Probability PI and the SSEIH to determine the amount of suitable habitat for successful Whitefish spawning. Therefore:

- an **increase** in PI value represents **better conditions for Lake Whitefish spawning** (positive change); and
- a **decrease** in PI value represents **worsened conditions for Lake Whitefish spawning** (negative change).

## 1.8 Rainy River Walleye Spawning Habitat

The IERM uses dam outflow data generated by the SVM and an estimated discharge time series for the Big Fork and Little Fork Rivers to estimate streamflow in the Rainy River. A 2-D hydraulic model of the river, from the International Falls dam to Manitou Rapids is used to simulate important variables such as water levels, depths, velocities and sheer stresses. The IERM estimates the extent and distribution of suitable spawning and egg incubation habitat for Walleye in Rainy River by identifying areas with suitable characteristics (such as river bottom slope, water depth and water velocity) during the spawning period. Within the IERM, the spawning and egg incubation period begins at ice-out and ends when hatching is completed (calculated based on cumulative degree days).

The Rainy River Walleye Habitat PI represents the total area of suitable spawning and egg incubation habitat for Walleye in Rainy River. Therefore:

- an **increase** in PI value represents **better conditions for Walleye spawning** on



Rainy River (positive change); and

- a **decrease** in PI value represents **worsened conditions for Walleye spawning** on Rainy River (negative change).

## 1.9 Rainy River Lake Sturgeon Habitat

The IERM estimates the extent and distribution of suitable spawning and egg incubation habitat (SSEIH) for Lake Sturgeon in Rainy River by identifying areas with suitable characteristics (such as river bottom slope, water depth and water velocity) during the spawning period. Within the IERM, the spawning and egg incubation period begins when mean daily water temperature reaches 8.5°C for five consecutive days and finishes when larvae drifting is completed (calculated based on cumulative degree days).

The Rainy River Lake Sturgeon Habitat PI represents the total area of suitable spawning and egg incubation habitat for Lake Sturgeon in Rainy River. Therefore:

- an **increase** in PI value represents **better conditions for Lake Sturgeon spawning** on Rainy River (positive change); and
- a **decrease** in PI value represents **worsened conditions for Lake Sturgeon spawning** on Rainy River (negative change).

## STUDY THEME 2: WILDLIFE

### 2.1 Common Loon Probability of Nest Viability

The IERM calculates the Probability of Loon Nest Viability (PLNV) as a function of water level variation during the nesting period. The nesting period begins three QMs after the ice-out and ends approximately ten QMs after the ice-out. Based on known clutching and incubation duration, nests were considered active for at least five QMs following the nest initiation QM. The IERM assumes that Common Loon nests can tolerate a maximum water level rises 0.15 m and a fall 0.30 m or less (PLNV=1.00). A water level rise larger than 0.40 m or a fall larger than 0.80 m during the nesting period will result in complete nest failure (PLNV=0.00). PLNV values for water level rises between 0.15 m and 0.40 m and falls between 0.30 and 0.80 m are linearly interpolated.

Common Loons with unsuccessful nests may re-attempt to nest up to two more times during the nesting season. Based on the literature review in Study 21, the IERM assumes that 48 percent of the loon pairs attempted to re-nest after the first failed attempt. After a second failed attempt, 14 percent of breeding pairs attempt a third nest.

The Common Loon PI represents the PLNV score. Therefore:

- a PI value **equal to 1.00** indicates **perfect conditions for Common Loon nesting**; and
- a PI value **approaching 0.00** indicates **poor conditions for Common Loon nesting**;

This 1-D model has been integrated in to the SVM.

## 2.2 Muskrat Over-Winter Survival

The IERM estimates the Probability of Muskrat Lodge Viability (PLV). Muskrats build lodges during the fall, and inhabit them throughout the cold season. Significant changes in water level after lodge construction can negatively impact Muskrats overwinter survival (e.g., flooding or freezing). Winter lodge building on Namakan and Rainy Lakes begins between mid-October and mid-November. Muskrat lodges can tolerate a water level rise or fall of up to 0.15 m (PLV=1.00). A water level rise greater than 0.33 m or a fall greater than 0.60 m results in the complete loss of lodges (PLV=0.00). PLV for water level rises between 0.15 m to 0.33 m, or water level falls between 0.15 m and 0.60 m, are linearly interpolated.

The Muskrat Over-Winter Survival PI is represented by the PLV score. Therefore:

- the PI is **equal to 1.00** indicates **perfect conditions for Muskrat Over-Winter Survival**; and
- a value **approaching 0.00** indicates **poor conditions for Muskrat Over-Winter Survival**.

This 1-D model has been integrated in to the SVM.

## STUDY THEME 3: ECONOMY

### 3.1 Flood Damage Reduction

The SVM estimates reduction in flood damages for Namakan and Rainy Lakes based on the findings of Study 11. That study used a detailed geospatial database that catalogued buildings, boathouses and dock structures along the shorelines of Rainy Lake and the Namakan Chain of Lakes. Flood-Damage Curves were established and used to estimate a dollar value associated with damages caused by a given water level. The number of structures flooded by a given water level can also be calculated by the SVM.

During high water events, significant damage can result from wave action. However, this model does not take this into account. The Flood Damage PI should be used only as a means of comparing relative damages that may occur under various rule curve alternatives.

The Flood Damage Reduction PI is presented in dollar amounts and uses the 2000 Rule Curves as a baseline. Therefore:

- the PI is **equal to \$0** for the **2000 Rule Curves**;
- a value **greater than \$0** represents a **reduction** in flood damage as a result of a rule curve alternative (*i.e.*, a positive change); and
- a value **less than \$0** represents an **increase** in flood damage as a result of a rule curve alternative (*i.e.*, a negative change).

### 3.2 Boating Reliability

The Boating Reliability PI was created based on feedback provided by the Rule Curve Public Advisory Group (RCPAG). The SVM assumes that water levels below a given reference level will limit access to docks and provide poor conditions for navigation. The reference level provided by the RCPAG for Rainy Lake is 337.27 m (1106.5 ft). This is the minimum

lake elevation required for launching and moving a five-foot draft boat out of the Rainy Lake Houseboat launch area.

The reference level selected for Namakan Lake was obtained from the 1993 Final Report and Recommendations of the Rainy Lake and Namakan Reservoir International Steering Committee. The report states that navigation problems on the Namakan Chain of Lakes are most troublesome at Loon Narrows and at “56 Rapids”, where passage is difficult until water levels reach 340.5 m (1117 ft). Therefore, 340.5 m (1117 ft) was selected as the minimum lake level for suitable boating conditions.

The SVM defines the boating season on Namakan Lake as the period for which the US Coast Guard maintains buoys and lighted buoys (May 7 to October 14, QMs 17 to 38). The boating season on Rainy Lake ends October 1st (QM 36) as the lift service for deep draft boats at the Rainy Lake Houseboat launch area end on that day. The SVM breaks down the boating season on each Lake into three periods:

- May/Jun (QMs 17 to 24)
- July/August (QMs 25 to 32)
- Late season (QMs 33 to 38 for Namakan Lake and QMs 33 to 36 for Rainy Lake)

For each QM during the boating period, the SVM determines whether the water level is below the identified reference level on each lake. The boating reliability score represents the percent of QMs within the period where the water level of a given lake is above the reference water level, averaged over the modelled period. Therefore:

- a PI equal to **0% indicates that conditions are never suitable** for navigation; and
- a PI equal to **100% indicates that conditions are always suitable** for navigation.

### 3.3 Hydropower Production

The SVM estimates the performance of a given alternative in relation to hydropower based on the average annual spill it produces. The spill is the amount of water released from Rainy Lake that does not pass through turbines to produce power.

The Spill PI is indexed to the average annual spill produced by the 2000 Rule Curves:

- the PI is **equal to 1.00 for the 2000 Rule Curves**;
- a value **greater than 1.00** represents a **reduction** in average spill (positive change for hydropower); and
- a value **less than 1.00** represents an **increase** in average spill (negative change for hydropower).

## STUDY THEME 4: CULTURAL/ARCHEOLOGICAL SITES

### 4.1 Archeological Resource Protection

This PI is based on information provided by Study 12 and uses the mean residence time of water levels as a metric for erosion effects on landforms. This assumes that prolonged exposure of a site to a given water level is directly related to the likelihood of erosion due to the forces of wave action.

The SVM defines elevation bands and, for a given alternative, determines the number of QMs over the modelling period that the mean water level falls within a given elevation band. The greatest number of occurrences within a single elevation band is identified.

According to experts within the Resource Advisory Group (RAG), the impacts of ice on archeological resources are not well defined. Therefore, the SVM only considers the open-water season for calculation of this PI (assumed to be QMs 15 to 44).

The Archeological Resource Protection PI is scored in relation to the 2000 Rule Curves and calculated as the greatest number of occurrences within a single elevation band for the 2000 Rule Curves divided by greatest number of occurrences within a single elevation band for a given alternative.

- the PI is **equal to 1.00 for the 2000 Rule Curves**;
- a value **greater than 1.00** represents an **increase** in the protection of archeological sites; and
- a value **less than 1.00** represents a **decrease** in the protection of archeological sites.

## STUDY THEME 5: AQUATIC VEGETATION

### 5.1 Cattail Invasion

The IERM estimates the Water-Level Suitability Index (WLSI) to represent the mean conditions during the cattail growing season (QMs 13 to 41). The IERM estimates that most cattails are established in areas with a water level depth of 0.50 m to 0.90 m, and can tolerate a water level rise or fall of up to 1.00 m (WLSI=1.00). It also assumes that cattails are completely eliminated when water levels rise or fall 1.50 m or more (WLSI=0.00).

The IERM estimates the total surface area of suitable habitat for Cattail Establishment (CEH) and Invasion (CIH) based on four hydrological variables: wave energy; water depth; light penetration; and number of cycle during the growing season.

The suitable habitat for CEH represents area where conditions have been favorable throughout three consecutive growing seasons. Cattail will become rooted along shorelines. Suitable conditions for the establishment of cattail are defined by: a predicted probability of presence greater than 0.60 (based on the result from a logistic regression); and water depth variations within -0.15 m to 1.00 m for more than six consecutive QMs of the growing season.

Areas of suitable habitat for CIH are created in areas where favorable conditions for cattail exist over long periods of time. Cattails form dense mats that choke out other vegetation (monotonic stands), such as Wild Rice. These invasive cattail mats may break off from shorelines and form floating mats. The IERM calculates CIH based on areas where suitable conditions for cattail establishment are present for ten consecutive years.

The Total Invasion PI is calculated as the sum of the areas of suitable habitat for CEH and CIH. Therefore:

- an **increase** in PI value represents an **expansion of Cattail habitat** (negative change); and
- a **decrease** in PI value represents a **reduction in Cattail habitat** (positive change).

## 5.2 Wild Rice Success

The Probability of Wild Rice Survival (PRS) is based on water level conditions during its most sensitive period (germination-submerged and floating stages). For each year, the IERM calculates the mean water level during the germination-submerged stage and assumes that wild rice can tolerate a water level rise or fall of 0.50 m or less (PRS = 1.00), and will be completely destroyed by a water level rise or fall of 1.20 m (PRS = 0.00) during the floating stage. PRS for water level variations between 0.50 m and 1.20 m is linearly interpolated.

The IERM also estimates the total surface area of suitable habitat for Wild Rice based on hydrological variables such as wave energy, water depth, light penetration and wave action during the germination-submerged and floating stages.

Based on the PRS, the amount of suitable area of habitat, and the presence of cattails, the IERM estimates the total surface area of where the survival/success of Wild Rice is possible.

This Wild Rice Success PI is calculated as a total area of suitable habitat. Therefore:

- an **increase** in PI value represents **better conditions for Wild Rice** (positive change); and
- an **decrease** in PI value represents **worsened conditions for Wild Rice** (negative change).

## 5.3 Wet Meadows Suitable Habitat

The IERM predicts the surface area of suitable habitat for wet meadows for a given year. This wetland type requires occasional flooding to provide conditions that are either too wet for terrestrial habitat, like forested swamps, or too dry for aquatic habitats like emergent marshes. The IERM uses the following variables to determine suitable habitat: proportion of time an area is flooded; number of wet-dry cycles in a year; mean depth; wind wave energy; and bottom slope and curvature. Since these environmental conditions need to be maintained over a certain period of years before they induce modification of wetland types, a succession model is included in the IERM.

The Wet Meadows PI represents the area of suitable habitat. Therefore:

- an **increase** in PI value represents an **increase in wet meadow habitat**; and
- a **decrease** in PI value represents a **decrease in wet meadow habitat**.

It is difficult to comment on whether a change in PI value represents a positive or negative change, as the diversity of aquatic vegetation is often more important than the success of any one species.

## 5.4 Shrubby Swamps Suitable Habitat

The IERM also calculates the surface area of suitable habitat for shrubby swamps for a given year. This wetland type also requires occasional flooding to provide conditions that are either too wet for terrestrial habitat, like forested swamps, or too dry for aquatic habitats like emergent marshes. The IERM uses the following variables to estimate suitable habitat: proportion of time an area is flooded, number of wet-dry cycles in a year, mean depth, wind wave energy, and bottom slope and curvature. Since these environmental conditions need to

be maintained over a certain period of time before they induce modification of wetland types, a succession model is included in the IERM.

The Shrubby Swamp PI represents the area of suitable habitat. Therefore:

- an **increase** in PI value represents an **increase in shrubby swamp habitat**; and
- a **decrease** in PI value represents a **decrease in shrubby swamp habitat**.

It is difficult to comment on whether a change in PI value represents a positive or negative change, as the diversity of aquatic vegetation is often more important than the success of any one species.

## 5.5 Emergent Plants Suitable Habitat

The IERM uses environmental variables (such as bottom slope and curvature, light penetration and water depth) from the three previous growing seasons to estimate the area of suitable habitat for emergent plants over time. The growing season for emergent plants is estimated to take place from QMs 13 to 41.

The Emergent Plants PI represents the area of suitable habitat. Therefore:

- an **increase** in PI value represents an **increase in emergent plant habitat**; and
- a **decrease** in PI value represents a **decrease in emergent plant habitat**.

It is difficult to comment on whether a change in PI value represents a positive or negative change, as the diversity of aquatic vegetation is often more important than the success of any one species.

## 5.6 Submerged Plants Suitable Habitat

The IERM uses environmental variables (such as lake bottom slope and curvature, light penetration, water depth, and wave action) to determine their spatial and temporal distribution of submerged plants. The model identifies three density categories: absence; low; and high. Results for the low and high density areas are presented in this document.

The Submerged Plants PI (low density) represents the area of suitable habitat. Therefore:

- an **increase** in PI value represents an **increase in low-density submerged plant habitat**; and
- a **decrease** in PI value represents a **decrease in low-density submerged plant habitat**.

Similarly, the Submerged Plants PI (high density) represents the area of suitable habitat. Therefore:

- an **increase** in PI value represents an **increase in high-density submerged habitat**; and
- a **decrease** in PI value represents a **decrease in high-density submerged habitat**.

It is difficult to comment on whether a change in PI value represents a positive or negative change, as the diversity of aquatic vegetation is often more important than the success of any one species.



## ANNEX 6

### WEIGHT OF EVIDENCE ANALYSIS OF STUDY SUBJECTS

**Annex 6** presents:

- A list of the 52 background study reports used in the analysis; the reports are available on the Study Board's website: [http://ijc.org/en\\_/RNLRCRB/Background\\_Reports](http://ijc.org/en_/RNLRCRB/Background_Reports); and
- the decision-making process behind the Weight of Evidence (WOE) table presented in Chapter 5. A description of the research used, the expected results, and the study's support to the Study Board's decision are summarized for each study subject.

#### **Background study reports**

#1 - Wetland vegetation monitoring: Voyageurs National Park. Natural Resource Technical Report (Meeker and Harris, 2009)

#2 - Rainy/Namakan Hydrologic Response Model (Thompson, 2015)

#3 - An Investigation of the Effects of the 2000 Rule Curve Change on the Rainy River Hydrologic and Hydraulic Regime (Luce and Metcalf, 2014)

#4 - Development of Models to Assess Effects of Water-Level Fluctuations on Reproductive Success of Common Loons (Gutreuter, Windels and Maki, 2013)

#5 - Rainy Lake and Namakan Reservoir Bathymetric Data. US National Park Service. (Data only)

#6 - Habitat Mapping for Marsh Nesting Birds and Herptiles in the Rainy Lake and Namakan Reservoir Area: Using GIS to Assess the Effects of the 2000 Rule Curve Changes (Grabas, Watton and Brett, 2013)

#7 - Sustained Changes in Rainy Lake and Namakan Reservoir: Benthic Macroinvertebrate Communities in Relation to the 2000 Rule Curve Changes (Ferrington and McEwen, 2015)

#8 - Water level change effects on northern pike spawning and nursery habitat and reproductive success in Rainy Lake and Namakan Reservoir, Minnesota (Timm and Pierce, 2015)

#9 - Effects of the 2000 Rule Curves on Upper Rainy River Spawning Critical Habitats and Characterization of the Food Web (Smith, Power and Smokorowski, 2014)

#10 - Economic Survey of Impact of Rule Curves on Tourist Resorts on Rainy Lake and Namakan Reservoir (Welle, 2015)

#11 - Flooding and Ice Damage: Evaluation of 1970 and 2000 Rule Curves (Shantz, 2016)

#12 - Evaluation of Shoreline Impacts and Long-term Monitoring of Shoreline Archeological Sites in Voyageurs National Park (Schilling, LaBounty, Barnett and Graves, 2016)

#13 - Assess Effects on Cultural Resources at Benchmark Sites on the Rainy River (Golder

Inc., 2016). Final report accepted by the IJC and is unavailable in view of culturally sensitive information.

#14 - Relationship of Rainy River Hydrology to the Distribution and Abundance of Freshwater Mussels (Minnesota Dept. of Natural Resources, 2016)

#15 - Rainy River Index of Biotic Integrity (Timusk, Smokorowski, Power and Gardner, 2014)

#16 - Study to Measure Critical Spawning Habitat for Walleye (*Sander vitreus*) on Selected Lakes in the Namakan Reservoir and Assess how this Habitat has been Affected by the International Joint Commission 2000 Rule Curve (Papenfuss, Cross and Venturelli, 2015)

#17 - Examining Municipal Water Treatment and Fish Hatchery Data to determine how these Facilities have been Impacted by the 2000 Rule Curve (Kenora Resource Consultants, 2015)

#18 - Network Global Navigation Satellite System Survey to Harmonize Water Surface Elevation Data for the Rainy River Basin (US Geological Survey, 2016)

#19 - Habitat Modeling of the Lake Sturgeon and Walleye Spawning Habitat of the Rainy River (Morin, Bachand, Richard, Champoux, Martin and Guenard, 2016)

#20 - Rainy Lake and Namakan Reservoir Bathymetric Data. US National Park Service. (Data only)

#21 - Modeling the Rainy Lake and Namakan Reservoir Ecosystem Response to Water Level Regulation (Morin, Bachand, Richard and Martin, 2016)

#22 - Trophic State in Voyageurs National Park Lakes Before and After Implementation of a Revised Water-level Management Plan (Christensen and Maki, 2015)

#23 - Effects of Changes in Reservoir Operations on Water Quality and Trophic-state Indicators in Voyageurs National Park, Northern Minnesota (Christensen, Payne, and Kallemeyn, 2004)

#24 - Evaluation of Internal Loading and Water Level Changes: implications for phosphorus, algal production, and nuisance blooms in Kabetogama Lake, Voyageurs National Park, Minnesota, USA (Christensen, Maki & Kiesling 2011 (report); Christensen, Maki & Kiesling 2013 (article))

#25 - Determining the historical impact of water level management on lakes in Voyageurs National Park (Edlund, Serieyssol, Kallemeyn and Engstrom, 2014)

#26 - Can mercury in fish be reduced by water level management? Evaluating the effects of water level fluctuation on mercury accumulation in yellow perch (*Perca flavescens*) (Larson, Maki, Knights and Gray 2014)

#27 - The effects of water-level manipulation on the benthic invertebrates of a managed reservoir (McEwen and Butler 2008 (a: report); McEwen and Butler 2011 (b: article))

#28 - Changes in Wetland Vegetation Associated with Lake Level Management, Voyageurs National Park (Meeker and Harris, 2011)

#29 - Impacts of Settlement, Damming and Hydromanagement in two boreal lakes: a

- comparative paleolimnological study (Serieyssol, Edlund and Kallemeyn, 2008)
- #30 - Relationship between Mercury Accumulation in Young-of-the-Year Yellow Perch and Water-Level Fluctuations (Sorensen, Kallemeyn and Sydor, 2013)
- #31 – Effects of Water Level Management on Nesting Success of Common Loon (Windels et. al., 2013)
- #32 - Do Water Level Fluctuations Influence Production of Walleye and Yellow Perch Young-of-Year in Large Northern Lakes? (Larson, Staples, Maki, Vallazza and Peterson, 2016). (report available by permission at <http://www.tandfonline.com/doi/full/10.1080/02755947.2016.1214645>)
- #33 - Are Walleye, Northern Pike and Yellow Perch increasing in abundance since the implementation of a new water level management regime in large lakes of the Rainy-Namakan system (MN, USA and ON, CA)? (USGS, MDNR, USNPS) Unavailable; in peer review.
- #34 - Impact of Water Level fluctuations on Beaver Lodge Occupancy and Population Abundance. Windels; in peer review
- #35 - Mercury and water level fluctuations in lakes of northern Minnesota (Larson , J., Maki, R., Christensen, V., Hlavacek, E., Sandheinrich, M., LeDuc, J., Kissane, C., and Knights, B.; in peer review)
- #36 - Seine River Temperature Project (Haines, 2016)
- #37 - Recovery of a Wild Rice Stand following Mechanical Removal of Narrowleaf Cattail (Dysievick, Lee and Kabatay, 2016)
- #38 - An analysis of water temperatures on the Rainy River in relation to critical fish spawning periods, with recommendations on peaking restrictions (Marshall and Foster, 2015)
- #39 - Namakan Chain of Lakes Pinch Point Modelling (Stevenson and Thompson, 2013)
- #40 - A Population Assessment of the Lake of the Woods – Rainy River Lake Sturgeon Population, 2014 (Heinrich and Friday, 2014)
- #41a-e - Fall Walleye Index Netting and Creel Survey technical reports (MNR)
- #42a - Population Characteristics and Adult Movement of Lake Sturgeon in the Lower Seine River System, 2011-2014 (Jackson and Godwin, 2015)
- #42b - Draft - Development of Juvenile Sturgeon Monitoring Protocol for Seine River System – Assessment of 2012-2014 data (Jackson, 2014)
- #43 - Fall Walleye Index Netting on Namakan and Sand Point Lakes, Ontario 2000 (Taillon, 2003)
- #44 - Fall Walleye Index Netting on Namakan Lake, Ontario 2005 (McLeod and Trembath, 2007)
- #45 - Summary of 2000-2014 Fall Walleye Index Netting (FWIN) on Namakan Lake, Ontario and Assessment of Walleye and Northern Pike Population Status (Jackson, 2016)

- #46 a-d Whitefish Data, Rainy Lake (4 reports) (Bisson, 2010)
- #47 - Roving Creel Surveys on Rainy Lake, Ontario 2010-2011 (McLeod and Denyes, 2012)
- #48 - Lake Sturgeon population attributes and reproductive structure in the Namakan Reservoir, Minnesota and Ontario (Shaw, Chipps, Windels, Webb, McLeod and Willis, 2012)
- #49 - Lake Sturgeon population characteristics in Rainy Lake, Minnesota and Ontario (Adams, Kallemeyn and Willis, 2006)
- #50 - Lake Sturgeon Biology in Rainy Lake, Minnesota and Ontario (Adams, 2004)
- #51 - Lake Sturgeon (*Acipenser fulvescens*) population attributes, reproductive structure and distribution in Namakan Reservoir, Minnesota and Ontario (Shaw, 2010)
- #52 - Vegetative substrates used by larval northern pike in Rainy and Kabetogama Lakes, Minnesota (Timm and Pierce, 2014)

## **1. FISH**

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- 2. Northern Pike Young of Year
- 3. Northern Pike Nursery and Young of Year Habitat
- 4. Walleye Population
- 5. Walleye Young- of-Year
- 6. Walleye Spawning Habitat
- 7. Walleye Spawning Habitat
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- 13. Lake Whitefish Population
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## 1. Northern Pike Population

**Water Body:** Namakan Chain of Lakes, Rainy Lake

### Study or Studies Referenced:

*Study 33*

Are Walleye, Northern Pike and Yellow Perch increasing in abundance since the implementation of a new water level management regime in large lakes of the Rainy–Namakan system? (*manuscript in review at journal, only dataset provided to Study Board*)

### Description of Research:

The dataset consists of MN DNR gillnetting data from Rainy Lake and Namakan Lakes as well as from two control lakes (Lake Vermilion and Lake of the Woods). The Study Board assed this dataset as well as year class strength information for Walleye, Northern Pike and Yellow Perch in Rainy Lake and the Namakan Chain of Lakes.

### Summary of results:

Based on this dataset, the Study Board determined that the Northern Pike Population has improved on both Namakan and Rainy Lakes as a result of the 2000 Rule Curves. The improvement was an expected result for Namakan Lake as the 2000 Rule Curve provides higher spring levels.

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## 2. Northern Pike Young of Year

**Water Body:** Namakan Chain of Lakes, Rainy Lake

### Study or Studies Referenced:

*Study 8*

Water level change effects on northern pike spawning and nursery habitat and reproductive success in Rainy Lake and Namakan Reservoir, Minnesota

### Description of Research:

The objectives of Study 8 were to:

1. determine if northern pike spawning and nursery habitat and reproductive success have changed due to the 2000 Rule Curves;
2. verify that larval and young of year (YoY) northern pike are using predicted improved spawning and nursery habitats resulting from the 2000 Rule Curves with further larval and YoY sampling, and
3. assess how well long-term seining data sets represent northern pike reproductive success in Rainy Lake and the Namakan Chain of Lakes by comparing catch rate and efficiency of light-trapping and seining methods.

### Summary of results:

For both Rainy Lake and the Namakan Chain of Lakes, mean annual seine catches were significantly higher under the 2000 Rule Curves (2000-2012) conditions when compared to the 1970 Rule Curves (1986-1999) conditions.

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### **3. Northern Pike Nursery and Young of Year Habitat**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

#### **Study or Studies Referenced:**

*Study 8*

Water level change effects on northern pike spawning and nursery habitat and reproductive success in Rainy Lake and Namakan Reservoir Minnesota

*Study 21*

Modelling the Rainy Lake and Namakan Reservoir Ecosystem Response to Water Level Regulation (Final Report to IJC)

#### **Description of Research:**

The objectives of Study 8 were to:

4. determine if northern pike spawning and nursery habitat and reproductive success have changed due to the 2000 RC;
5. verify that larval and YoY northern pike are using predicted improved spawning and nursery habitats resulting from the 2000 Rule Curves with further larval and YoY sampling, and
6. assess how well long-term seining data sets represent northern pike reproductive success in Rainy Lake and the Namakan Chain of Lakes by comparing catch rate and efficiency of light-trapping and seining methods.

Study 21 quantified the effects of water level regulations on wet meadows and shrubby swamps, two of the primary types of Northern Pike nursery and YoY habitat, using the IERM.

#### **Summary of results:**

For both Rainy Lake and the Namakan Chain of Lakes, mean annual seine catches were significantly higher under the 2000 Rule Curves (2000-2012) conditions when compared to the 1970 Rule Curves (1986-1999) conditions.

The IERM model results showed that the 1970 and 2000 Rule Curves produced very similar amounts of shrubby swamp coverage and that the 2000 Rule Curves provided more wet meadow habitat than the 1970 Rule Curves, especially in Namakan (although both amounts were substantially less than the amount produced by the natural water level series).

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### **4. Walleye Population**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

#### **Study or Studies Referenced:**

*Study 33*

Are Walleye, Northern Pike, and Yellow Perch increasing in abundance since the implementation of a new water level management regime in large lakes of the Rainy – Namakan system? (manuscript in review at journal, only dataset provided to Study Board)

**Description of Research:**

The journal peer review process was not completed for this paper as of the writing of this report. The USGS has not released a draft of the paper for the Study Board, so the paper is not summarized here. The dataset upon which this paper is developed has been delivered to the Study Board. The dataset consists of MN DNR gillnetting data from Rainy Lake and the Namakan Chain of Lakes as well as from two control lakes (Lake Vermilion and Lake of the Woods).

**Summary of results:**

Based on the dataset provided and an assessment of year class strength information, the Study Board determined that it is not possible to conclusively assess the effects of the 2000 Rule Curves on Walleye population in Namakan and Rainy Lakes.

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**5. Walleye Young- of-Year**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:**

*Study 32*

Does water level fluctuation influence production of Walleye and Yellow Perch young-of-year in large northern lakes?

**Description of Research:**

Long-term seine monitoring datasets from six northern Minnesota lakes were used to assess the effects of water level fluctuations on the abundance of YoY walleye and yellow perch. Rainy Lake and Kabetogama Lake saw a change in water level management in 2000 with the new Rule Curve.

**Summary of results:**

For both Rainy Lake and Lake Kabetogama, mean annual seine catches were significantly higher under the 2000 Rule Curves (2000-2012) conditions when compared to the 1970 Rule Curves (1986-1999) conditions.

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**6. Walleye Spawning Habitat**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:**

*Study 16*

Study to measure critical spawning habitat for walleye (*Sander vitreus*) on selected lakes in the Namakan Reservoir and assess how this habitat has been affected by the International Joint Commission 2000 Rule Curve

*Study 21*

Modeling the Rainy Lake and Namakan Reservoir Ecosystem Response to Water Level Regulation (Final Report to IJC)

**Description of Research:**

The objective of Study 16 was to assess whether the maintenance and availability of critical spawning habitat for walleye in Namakan have been affected by the 2000 Rule Curves. After identifying active walleye spawning sites, the authors used hydrological models, a digital elevation model and wave energy models to determine: 1. whether the 2000 Rule Curves are exposing the spawning sites to increased wave energy and ice scour which maintains the quality of spawning sites by cleaning them off; and 2. whether the 2000 Rule Curves have improved the extent to which walleye spawning habitat is adequately inundated during the spawning season.

Study 21 used the IERM to assess water level effects on conditions for Walleye reproduction, including the extent of habitat suitable to walleye spawning and egg incubation.

**Summary of results:**

Study 16 determined that the 2000 Rule Curves resulted in an increase of spawning habitat availability on Namakan. The IERM supported this conclusion through its 1-D and 2-D models, demonstrating that the 2000 Rule Curves provided better conditions for Walleye reproduction in Namakan than the 1970 Rule Curves.

For Rainy Lake, however the IERM showed that the 2000 Rule Curves did not improve conditions over the 1970 series.

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**7. Walleye Spawning Habitat**

**Water Body:** Rainy River

**Study or Studies Referenced:**

*Study 19*

Development of a 2-D habitat model required to support “Rainy River – critical spawning and nursery habitats” (Final Report to IJC)

**Description of Research:**

The objective of this study was to quantify the effects of historical water level regulations on Lake Sturgeon and Walleye in the Rainy River. The authors employed two dimensional habitat modelling to evaluate the impact of different water level management plans on Lake Sturgeon and Walleye to answer questions originally posed in Study 9, “Rainy River critical spawning and nursery habitat,” summarized above in this document.

**Summary of results:**

The authors concluded that spawning habitat improvements were evident for both Walleye and Lake Sturgeon under 2000 Rule Curve conditions as compared to under 1970 Rule Curve conditions. They note, however, that the models show that spawning conditions for both species would be at least marginally improved under unregulated conditions and write that a rule curve that more closely resembles natural conditions would benefit both species.

The authors point out that the variability of discharges at the Fort Frances / International

Falls dam during the spawning and egg incubation period is likely a major factor in the success of Walleye spawning. They note that large variations in discharge during the spawning and egg incubation period are detrimental to Walleye reproduction, while stable, low to medium discharge during the same period increase the amount of available habitat. They propose that spawning conditions could be improved for Walleye by maintaining stable, low to medium discharge during the Walleye spawning and egg incubation period.

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## **8. Yellow Perch Population**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

### **Study or Studies Referenced:**

*Study 33*

Are Walleye, Northern Pike, and Yellow Perch increasing in abundance since the implementation of a new water level management regime in large lakes of the Rainy–Namakan system? (manuscript in review at journal, only dataset provided to Study Board)

### **Description of Research:**

The journal peer review process was not completed for this paper as of the writing of this report. The USGS has not released a draft of the paper for the Study Board, so the paper is not summarized here. The dataset upon which this paper is developed has been delivered to the Study Board. The dataset consists of MN DNR gillnetting data from Rainy and Namakan as well as from two control lakes (Lake Vermilion and Lake of the Woods).

### **Summary of results:**

Based on the dataset provided and an assessment of year class strength information the Study Board determined that the 2000 rule curves had not improved the Yellow Perch population on the Namakan Chain of Lakes, but resulted in improved consistency in year class strength for Yellow Perch in Rainy Lake.

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## **9. Yellow Perch Young of Year**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

### **Study or Studies Referenced:**

*Study 32*

Does water level fluctuation influence production of Walleye and Yellow Perch young-of-year in large northern lakes?

### **Description of Research:**

Study 32 used a before-after-control-impact design to test whether Yellow Perch production has increased in Rainy and Kabetogama Lakes since implementation of the 2000 Rule Curves. The analysis was based on catch per unit effort (CPUE) data for YoY

Yellow Perch collected as part of a long term seining program and included four control lakes in addition to Rainy and Kabetogama.

**Summary of results:**

The study concluded that YoY Yellow Perch CPUEs were higher in Rainy Lake and Lake Kabetogama after 2000 (probability of increase = 87 percent and 97 percent, respectively). Although the authors pointed to the possibility that the increase is part of a regional trend, they identified a strong correlation between water levels and YoY Yellow Perch in Kabetogama Lake. Based on these findings, the Study Board concluded that the conditions for YoY Yellow Perch have improved in the Namakan Chain of Lakes and Rainy Lake as a result of the implementation of the 2000 Rule Curves.

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**10. Lake Sturgeon Population**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:**

*Study 48*

Lake Sturgeon Population Attributes and Reproductive Structure in the Namakan Reservoir, Minnesota and Ontario

*Study 49*

Lake Sturgeon Population Characteristics in Rainy Lake, Minnesota and Ontario

**Description of Research:**

Study 48 quantified the age, growth, mortality and reproductive structure of lake sturgeon collected in the US and Canadian waters of the Namakan Chain of Lakes.

Study 49 documented the population characteristics and movement of lake sturgeon in Rainy Lake. Age data were compared with water level metrics to determine if reproductive success was influenced by water level variation during the spring spawning season.

**Summary of results:**

On Rainy Lake there was a weak negative correlation between water levels and sturgeon year class strength for days of the year 100-160. On Namakan, the only significant relationship identified was that there was a positive relationship between total annual precipitation and year class strength. Neither of the studies provided information on the impact of the 2000 Rule Curves on the Lake Sturgeon populations of Rainy and Namakan.

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**11. Lake Sturgeon Population**

**Water Body:** Rainy River

**Study or Studies Referenced:**

*Study 40*

**Description of Research:**

The study was undertaken jointly by the Minnesota Department of Natural Resources (MNDNR) and the Ontario Ministry of Natural Resources and Forestry (OMNRF) to comply with a 10-year cycle of population estimates and assessment of size structure. The population estimates are part of recovery efforts for this species, which had declined greatly in the 20th century due to commercial exploitation and habitat degradation. The study did not investigate the role of the 2000 Rule Curves.

**Summary of results:**

Lake Sturgeon population has increased in the Lake of the Woods-Rainy River system since the previous population studies in the 1990s. The increase in the adult population suggests that this population is in a state of continuing recovery which demonstrates the resiliency of the species when perturbations are addressed and habitat remains intact.

While the data support the continued improvement of the Lake Sturgeon population in this area, no changes were expected with the adoption of the 2000 Rule Curves, and no contribution to the improvements is attributed to rule curve changes.

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## **12. Lake Sturgeon Spawning Habitat**

**Water Body:** Rainy River

**Study or Studies Referenced:**

*Study 9*

Rainy River critical spawning and nursery habitat (Final Report to IJC)

*Study 19*

Habitat Modeling of the Lake Sturgeon and Walleye Spawning Habitat of the Rainy River

**Description of Research:**

Study 9 provided the data necessary to develop a quantitative functional relationship between water levels or flows and fish spawning and nursery habitat. This relationship was programmed in to the IERM in Study 19 to produce a two-dimensional model to evaluate the impact of different water level management plans on the spawning habitat of these species.

**Summary of results:**

Results from the Lake Sturgeon spawning habitat model suggest that the 2000 Rule Curves increased the amount of suitable spawning habitat compared to the 1970 Rule Curves. Still, under natural conditions, the mean surface area of habitat suitable to spawning Lake Sturgeon would have been slightly higher than under any regulated time series. This suggests that closer to natural conditions would marginally increase the surface area of spawning habitat.

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### 13. Lake Whitefish Population

**Water Body:** Rainy Lake

**Study or Studies Referenced:**

*Study 46*

Ontario Ministry of Natural Resources' Summaries of Commercial Whitefish Data North Arm, Redgut and South Arm.

*Dataset only*

Minnesota Department of Natural Resources Fish Community Index Netting (FCIN) Program on Rainy and Namakan Lakes.

**Description of Research:**

Study 46 is a collection of resource management data on the Lake Whitefish population in these areas post-2000 Rule Curves from OMNR.

The Fish Community Index Netting (FCIN) program used to sample Lake Whitefish populations in Rainy and Namakan Lakes was first implemented after 2000. Multi-mesh monofilament nets are used to sample Lake Whitefish at numerous locations and depths. Results from the FCIN netting surveys are assessed using FCIN metrics and criteria established by the OMNR. The seven metrics are based on age, growth rates, relative abundance, and spatial distribution of the FCIN catch.

**Summary of results:**

Study 46 provides supporting evidence that the 2000 rule curve for Rainy Lake has not had a discernable effect on Lake Whitefish reproductive success. This was expected in that the 2000 Rule Curve had no significant shift from the 1970 Rule Curve for overwinter drawdown. Presence of multiple year classes and consistent harvests suggests reproduction is successful nearly every year.

The FCIN program was established to obtain a baseline against which future changes in the populations could be assessed. However, since it was not started until post-2000 no comparisons could be made with the status of the Lake Whitefish while the 1970 Rule Curves were in effect. The Rainy Lake FCIN sampling from recent years suggests the Lake Whitefish population is healthy. Sampling was carried out in a two of four year rotation resulting in seven years of sampling between 2003 and 2015. The catch rate of Lake Whitefish has been high and consistent in recent years. Overall, Lake Whitefish catch rates in Namakan Lake have been slightly lower in recent years than in the past. However, none of the other parameters show a clear pattern up or down and the magnitude of difference in gill net catch rates is not large. The Namakan Lake Whitefish population appears relatively stable and healthy based on the FCIN metrics.

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#### **14. Lake Whitefish Spawning Habitat**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:**

*No study number*

Do the past Rules Curves improve the conditions for the spawning of Lake Whitefish in Rainy Lake and Namakan Reservoir? [presentation at the 2017 Rainy-Lake of the Woods Watershed Forum. IJC-sponsored Study not yet published]

**Description of Research:**

The goal of this study was to develop an eco-hydraulic model of Lake Whitefish spawning habitat and reproductive success using the Rainy-Namakan IERM (Morin *et al.*, 2016). The study also attempted to quantify the impact of overwinter drawdowns on Lake Whitefish using different rule curve scenarios. Model results were verified through biological observations in November 2016, as well as documented observations from local fishermen.

**Summary of results:**

IERM results suggest that the 2000 Rule Curves increased the amount of suitable habitat for Lake Whitefish spawning in the Namakan Chain of Lakes, and had no effect on the conditions in Rainy Lake.

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#### **15. Rainy River Index of Biotic Integrity**

**Water Body:** Rainy River

**Study or Studies Referenced:**

*Study 15*

Rainy River Index of Biotic Integrity (Final Report to IJC)

**Description of Research:**

The index of biotic integrity (IBI), which was developed as a tool to assess the health of streams, is a multi-metric index that evaluates community composition (*i.e.*, feeding guilds, spawning needs, sensitivity to disturbance), species richness, fish abundance and fish health as surrogates of riverine health. Metrics are scored and the sum of the values, or IBI score, is compared to that obtained from regional expectations. The Minnesota Department of Natural Resources conducted an IBI Study on the Rainy River in 2002, following the implementation of the 2000 Rule Curves, which is taken as the pre-2000 Rule Curve baseline as the cumulative impacts of Rule Curve alternation are not expected to develop in a short period. Results of 2013 field work are contrasted with the results from 2002 to evaluate the impact of the 2000 Rule Curves.

**Summary of results:**

Based on the results of the IBI in 2002 and 2013, it does not appear that the health of the Rainy River fish community is being greatly impacted, either positively or negatively, by the 2000 Rule Curve.

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## 16. Young of Year Yellow Perch Mercury Concentration

**Water Body:** Namakan Chain of Lakes, Rainy Lake

### Study or Studies Referenced:

#### *Study 26*

Can mercury in fish be reduced by water level management? Evaluating the effects of water level fluctuation on mercury accumulation in yellow perch.

#### *Study 30*

Relationship between Mercury Accumulation in Young-of-the-Year Yellow Perch and Water-Level Fluctuations

#### *Fact Sheet*

Mercury in yellow perch as a performance index for water level management; information provided in Study Fact Sheet to be published on Study website ([http://ijc.org/en/\\_/RNLRCBSB](http://ijc.org/en/_/RNLRCBSB))

### Description of Research:

These studies examine the relationship between water level variation and mercury concentrations in yellow perch, the hypothesis being that temporal variation in mercury content of fish (YoY yellow perch) is linked to water level fluctuations through variation in sediment inundation.

The Rainy-Namakan rule curves review process asked for the development of a mercury-driven Performance Indicator for fish. The PI developed used data on total mercury concentration in YoY yellow perch that were collected between 1996 and 2015 in the Rainy-Namakan lake system.

### Summary of results:

Study 30 found positive correlations between mean and maximum water levels, and differences between the two relative to the level in the previous year in 14 NE Minnesota lakes. The same results were observed for Sand Point Lake where the data were available from the early 1990s to 2003. The studies provided a possible explanation how the changes from year to year might account for observed variations in Hg levels in YoY yellow perch. Explanation involved flooding of littoral sediments that underwent drying and then were flooded in the subsequent year.

Study 26, which used a ten-year data set from Rainy Lake and the Namakan Chain of Lakes, did not find a strong relationship between water level rise and fish mercury concentrations. Year to year variation in maximum water levels was, however, positively associated with fish mercury content.

However, neither study specifically examined the pre- and post-2000 Rule Curve period for changes in mercury so no attribution to 2000 Rule Curve can be made.

The PI model (see Annex 5) was used to assess whether the different water time level series would produce different yellow perch mercury concentrations. Natural water level fluctuations were associated with the highest mercury concentrations in Kabetogama Lake, and when taking the Namakan Chain of Lakes as a whole whereas in Rainy, Namakan, and Sand Point Lakes, the highest mercury concentrations were predicted for either of the regulated rule curves. The model also showed that the regulated regimes appeared to stabilize mercury concentrations and thus make it more easily predictable from year to year.

## **17. Beaver Population**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

### **Study or Studies Referenced:**

*Study 34*

Effects of Water Level Management on American Beaver Abundance, Behavior, and Lodge Characteristics (US National Park Service Technical Report Series DRAFT)

### **Description of Research:**

The objectives of the study were to assess the effects of the implementation of the 2000 Rule Curves on beaver abundance, behavior, and lodge characteristics in Rainy Lake and the Namakan Chain of Lakes by assessing: 1. Density of beaver lodges before and after 2000; 2. Differences in lodge turnover rates between Rainy Lake and the Namakan Chain of Lakes under the 2000 Rule Curves; 3. Frequency of winter drawdown – induced behaviors before and after 2000; and 4. Lodge characteristics before and after 2000.

### **Summary of results:**

The author made use of data previously collected on these lakes whenever possible in this study. He found that mean annual lodge density did not differ before and after 2000 and that there were not differences in lodge turnover rates between Rainy and Namakan under the 2000 Rule Curves. Improvements in winter drawdown-induced behaviors were detected in the Namakan Chain of Lakes after the 2000 Rule Curves were implemented. The author also concluded that the data suggest beavers have more favorable winter water level conditions at lodge sites under the 2000 Rule Curves on the Namakan Chain of Lakes than they did prior to 2000.

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## **18. Habitat for Birds and Herptiles**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

### **Study or Studies Referenced:**

*Study 6*

Habitat mapping for marsh nesting birds and herptiles in the Rainy Lake and Namakan Reservoir area

### **Description of Research:**

This project was designed to test whether there was more or less habitat available for marsh nesting birds and herptiles in the Rainy Lake and the Namakan Chain of Lakes area after implementation of the 2000 Rule Curves. The study design was to use a before and after snapshot approach using aerial photographs taken before (1995 and 1997) and after (2008) implementation of the 2000 Rule Curves. The authors mapped vegetation types that could be influenced by hydrological regulation in Rainy and Namakan Lakes, including emergent, meadow and rooted and floating submersed communities.

**Summary of results:**

Although the analysis showed that there was less marsh habitat of all of these types for marsh nesting birds and herptiles in the 2008 photographs, confounding influences including considerable water level differences when the pre and post 2000 photographs were taken and differences in image resolution made it impossible to conclude that there was truly less habitat available for marsh nesting birds and herptiles after the 2000 Rule Curves were implemented. For this reason, the authors concluded that the study was inconclusive in determining the effect of the 2000 Rule Curves on Rainy Lake and the Namakan Chain of Lakes area marsh nesting bird and herptile habitat.

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**19. Common Loon Reproductive Success**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:***Study 4*

Assess Effects of Water Level Fluctuation on Bio-indicators Using Analytical Models (Final Report to IJC)

*Study 21*

Modeling the Rainy Lake and Namakan Reservoir Ecosystem Response to Water Level Regulation (Final Report to IJC)

*Study 31*

Effects of water-level management on nesting success of common loons (Journal of Wildlife Management 2013)

**Description of Research:**

Common Loon nesting success is influenced by rising and falling water levels. These birds are also only able to deal with small decreases in water level while nesting; when large decreases in water level occur during nesting, they are no longer able to climb from the water to the nest, causing stranding of eggs and nest failure. All three studies examined the relationship between Common Loon nesting success and water level fluctuation, including an assessment of the effects of the 2000 Rule Curves. Studies 4 and 21 developed models to relate water level management to the nesting success of these birds. The reduction in the overall range of Namakan Lake target levels with the 2000 Rule Curves was hypothesized to improve nesting success, while the limited alteration of the Rule Curve for Rainy Lake was not expected to have an effect.

**Summary of results:**

Model results from studies 4 and 21 concluded that the 2000 Rule Curves produced an improvement in Common Loon reproductive success over the 1970 Rule Curves on Namakan Lake but had no effect for those on Rainy Lake. A before-after comparison (#31) found that productivity (chicks hatched/territorial pair) increased significantly on the Namakan Chain of Lakes but not on Rainy Lake after implementation of the 2000 Rule Curves.

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## **20. Muskrat Lodge Winter Viability**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

### **Study or Studies Referenced:**

*Study 21*

Modeling the Rainy Lake and Namakan Reservoir Ecosystem Response to Water Level Regulation (Final Report to IJC)

### **Description of Research:**

Muskrats are mostly vulnerable to water level variations during winter, when they rely on their lodge for shelter and access to food is limited by ice. The study describes the development of a 1-dimensional computer model to evaluate the susceptibility of Muskrats to over-winter mortality due to reservoir drawdown, as practiced on the Namakan Chain of Lakes and Rainy Lake under both the 1970 and 2000 Rule Curves.

### **Summary of results:**

The 1-D model suggests that the low Muskrat abundance in the system is linked to the important water level decreases during winter, which limit Muskrat lodge viability. The 2000 Rule Curve resulted in minor improvement in conditions for Muskrats in Rainy Lake, but not in the Namakan Chain of Lakes. Natural water levels would be more favorable to Muskrats than any regulated water level series because they would generally result in smaller water level decreases during winter.

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## **21. Power Production**

**Water Body:** Rainy Lake

### **Study or Studies Referenced:**

No study number or title (proprietary information)

### **Description of Research:**

The WOE analysis on hydropower was based on a report commissioned by H2O Power LP to assess the impacts to hydroelectric generation at both the Canadian and American powerhouses attributable to change in regulation from the 1970 to the 2000 Rule Curves. The key highlights of the report were shared with the IJC for the purposes of the Rule Curve evaluation, but the detailed report was not made available due to concerns that sensitive data would be made available to competitors.

### **Summary of results:**

The key highlights of the report indicated that hydropower production, as projected in the 1999 International Rainy Lake Board of Control report, was negatively impacted by the implementation of the 2000 Rules Curves.

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## **22. Flooding**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:**

*Study 11*

Rainy Lake / Namakan Reservoir flooding and ice damage

**Description of Research:**

The study compared the relative flood and ice impacts associated with the 1970 and 2000 rule curves used for managing the water levels of Rainy Lake and the Namakan Chain of Lakes. Flood damages were calculated for lived-in and non-lived-in buildings, docks, and boathouses on an annual basis based on water level inundation using a Flood Tool developed for this project, informed by extensive property owner surveys. Potential ice impacts were considered using separate water level metrics. Results were compared for the 1950 to 2014 period based on simulated 1970 and 2000 Rule Curves water levels.

**Summary of results:**

Economic damages increased 2.7 percent for all damage categories collectively under the 2000 Rule Curves as compared to under the 1970 Rule Curves.

The author concluded that there was a change for the worse (more economic damage caused by flooding) under the 2000 Rule Curves versus the 1970 Rule Curves and that this slight increase in impacts under the 2000 rule curves was consistent with predictions of the 1999 International Rainy Lake Board of Control report. The net changes of the 2000 Rule Curve results as a percentage of the 1970 Rule Curve results tended to be greater for the Namakan Chain of Lakes but that the average annual impacts were about four times greater on Rainy Lake due to the greater number of structures that could potentially be affected on Rainy Lake.

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## **23. Ice Damage**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:**

*Study 11*

Rainy Lake / Namakan Reservoir flooding and ice damage

**Description of Research:**

The study compared the relative ice impacts associated with the 1970 and 2000 rule curves used for managing the water levels of Rainy Lake and the Namakan Chain of Lakes. Potential ice impacts were considered using separate water level metrics from the flood component of the study. Results were compared for the 1950 to 2014 period based on simulated 1970 and 2000 rule curve water levels.

**Summary of results:**

Compared to the analysis of flood damage reported in the same study, the author noted

that the effect of the rule curve change on ice damages was less conclusive, and that further work should be considered to improve that component of the analysis before there can be high confidence in model results. There was insufficient information to quantify a change in ice damage caused by a shift in Rule Curves, but the study report notes concern that damage could increase if levels were higher when the ice forms and if the water levels dropped more over the ice cover period. Based on those water level metrics, the report noted little difference in the 1970 and 2000 Rule Curves on Rainy Lake.

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## **24. Resort Industry**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

### **Study or Studies Referenced:**

*Study 10*

Economic survey of impact of rule curves on tourist resorts on Rainy Lake and Namakan Reservoir

### **Description of Research:**

This study was designed to assess the economic impact on resorts on Rainy Lake and the Namakan Chain of Lakes due to changes in the suitability of water levels for navigation and recreation as a result of the change in rule curves in 2000. The author used multiple lines of evidence including regional economic data (routinely summarized and distributed separately from this study) and survey responses from both resort owners and long term customers to assess this impact. The 2000 Rule Curves were expected to have a positive economic effect on resorts on Namakan.

### **Summary of results:**

This study produced qualitative relationships between water level conditions and economic conditions for resorts. The author concluded that benefits were observed as predicted for Namakan, especially due to the higher spring water levels and that negative impacts observed on Rainy Lake were primarily due to high water levels that were outside of the 2000 Rule Curves and more related to precipitation-driven inflows than to the rule curves.

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## **4 ARCHEO- LOGICAL RESOURCES**

## **25. Condition of Resources (Lakes)**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

### **Study or Studies Referenced:**

*Study 12*

Assess effects on cultural resources at a small number of sites on Rainy Lake and Namakan Reservoir.

(Note: this study is confidential due to concerns over publicizing the location of cultural resources. Although the full report was made available to the Study Board for review, a redacted version has been made available on the Study Board website.)

**Description of Research:**

The study assessed the effects of water level management on archeological sites in Voyageurs National Park (Rainy Lake and the Namakan Chain of Lakes), compared the theoretical effects of the 1970 and 2000 rule curves, and developed quantitative metrics for the evaluation of these and other rule curve scenarios for impacts to archeological resources. Patterns related to the formation and preservation of archeological sites, including vegetation differences, beach formation and erosion, served as the basis for evaluation of the two management regimes. Hydrological response models were associated with archeological site formation processes to identify critical variables for continued preservation of archeological resources.

**Summary of results:**

The study found that the 2000 Rule Curves potentially erode a total of 17 recorded archeological sites, as opposed to 29 sites affected by the 1970 Rule Curves, seven more archeological sites are submerged (protected) under the 2000 Rule Curves than under the 1970 Rule Curves, and that operations under the 1970 Rule Curves have a greater potential to cause erosion in both lakes than under the 2000 Rule Curves due to greater water level stasis time under the latter.

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**26. Condition of Resources (Rainy River)**

**Water Body:** Rainy River

**Study or Studies Referenced:**

*Study 13*

Assess effects on cultural resources at benchmark sites on the Rainy River

(Note: this study is confidential due to concerns over publicizing the location of cultural resources. Although the full report was made available to the Study Board for review, it has not been made available to the public.)

**Description of Research:**

The study assessed the vulnerability of identified archeological sites along Rainy River (from the Fort Frances / International Falls dam to Manitou Rapids) to erosion from Rainy River flows under three conditions (pre-dam, 1970 Rule Curves and 2000 Rule Curves).

**Summary of results:**

The authors conclude that cultural resources on the Rainy River are not being directly impacted by the 2000 Rule Curves and that they did not detect a measurable difference in potential impacts to cultural resources on this stretch of the Rainy River under modelled pre-dam, 1970 Rule Curves or 2000 Rule Curves conditions.

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## 27. Cattail Invasion

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:**

*Study 21*

Modeling the Rainy Lake and Namakan Reservoir Ecosystem Response to Water Level Regulation (Final Report to IJC)

**Description of Research:**

The objective of this study was to quantify the effects of water level regulations on key species and habitat types of this ecosystem. The authors used a combination of 1-D relationships between habitat suitability and water level variations and more complex 2-D habitat modelling to evaluate the impact of different water level management plans on these biological indicators.

The authors used an IERM-based on a computation grid covering the entire Rainy-Namakan system with a 20 m resolution to make their assessment of rule curve effects.

**Summary of results:**

Both 1-D and 2-D models were used to assess conditions for cattails in Rainy Lake and the Namakan Chain of Lakes. The 1-D model provided estimates of the suitability of water level variations for cattails, and the 2-D model provided estimates of the availability of suitable habitat for cattail. Both models suggest that all regulated water level series promote establishment and persistence of cattails in the system while the natural water level series would provide more benefit to the ecosystem by not allowing as much cattail, especially not monotypic stands of cattail which are detrimental to the ecosystem and to Wild Rice in particular. These models showed that the 2000 Rule Curves provided an increase in suitable water levels for cattails in the Namakan Chain of Lakes as compared to conditions under the 1970 Rule Curves. These models also showed there would be less cattail habitat available in Namakan under the 2000 Rule Curves than under the 1970 Rule Curves.

Overall, the 2000 Rule Curves provide slightly less area of habitat suitable to cattails than the 1970 Rule Curves, but they provide adequate conditions for very high survival of cattails and development of monotypic stands of cattail. The presence of monotypic stands of cattail reduces plant diversity as cattails out-compete native plants, such as Wild Rice, for habitat. Furthermore, monotypic stands have the potential to produce large floating mats that can present navigational hazards to boaters on the lakes.

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## 28. Wetland Vegetation

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:**

*Study 1*

Wetland Vegetation Monitoring – Voyageurs National Park (US NPS Natural Resources Technical Report)

### *Study 28*

Changes in Wetland Vegetation Associated with Lake Level Management, Voyageurs National Park (Final Report to IJC)

#### **Description of Research:**

Investigators predicted change that would occur in four elevational bands of the littoral zone of the Namakan Chain of Lakes (substantial change predicted) and Rainy Lake (minimal change predicted) after implementation of the 2000 Rule Curves. To test these hypothesized changes, wetland vegetation was monitored on and near Rainy, Kabetogama, Namakan, and Sand Point Lakes in 2004-2006 (there was also sampling done in 2001-2002 through a separate study).

#### **Summary of results:**

The analysis provided qualitative but not quantitative evidence of a functional relationship between water levels and wetland vegetation. The authors concluded that there was a post-2000 Rule Curves improvement in the wetland vegetation in Namakan Chain of Lakes. Many of the predicted changes were evident in Namakan in 2002-2006, indicating that recovery was occurring. Some, but not all, metrics showed unpredicted changes in Rainy Lake, Namakan and Lac la Croix, and these changes were not all in the same direction – for example, cover of aquatic vegetation increased in Rainy Lake and decreased in Lac la Croix. This suggests that a regional influence other than lake level management was likely responsible for some, but not all, of the change measured in the Namakan Chain of Lakes.

The authors note that a portion of the decrease in annual fluctuation in Namakan began to occur in approximately 1987 when the dam operators started targeting the middle of the rule curves and that the predicted changes in Namakan vegetation likely began at that time. Because the authors proposed mechanisms for change in wetland vegetation related to this decrease in annual fluctuation and made science-based predictions of what changes would occur in wetland vegetation communities of Namakan after 2000 because of these mechanisms, a logical argument can be made that the observed changes (which match predicted changes for Namakan fairly well) are due to the change in rule curve.

For Rainy Lake, significant changes were not hypothesized due to the small differences for Rainy Lake in the 1970 and 2000 Rule Curves. However, the data did not provide a sufficiently clear outcome for the Study Board to make a conclusive statement on whether vegetation had an overall improvement, worsening or was neutral following the adoption of the 2000 Rule Curves.

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## **29. Emergent Vegetation - Wet meadow**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

#### **Study or Studies Referenced:**

##### *Study 21*

Modeling the Rainy Lake and Namakan Reservoir Ecosystem Response to Water Level Regulation (Final Report to IJC)

**Description of Research:**

The objective of this study was to quantify the effects of water level regulations on key species and habitat types of this ecosystem. The authors used a combination of 1-D relationships between habitat suitability and water level variations and more complex 2-D habitat modelling to evaluate the impact of different water level management plans on these biological indicators.

The authors used an IERM based on a computation grid covering the entire Rainy-Namakan system with a 20 m resolution to make their assessment of rule curve effects.

**Summary of results:**

Emergent vegetation was modelled (2-D) for Rainy Lake and the Namakan Chain of Lakes. Models showed that there was slightly less emergent plant habitat under the 2000 Rule Curves as compared to under the 1970 Rule Curves in Namakan and no difference in emergent plant habitat between the two rule curve scenarios for Rainy Lake.

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**30. Submerged Plants**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:***Study 21*

Modeling the Rainy Lake and Namakan Reservoir Ecosystem Response to Water Level Regulation (Final Report to IJC)

*Study 28*

Changes in Wetland Vegetation Associated with Lake Level Management, Voyageurs National Park (Final Report to IJC)

**Description of Research:**

Study 21 used the IERM to create a 2-D model of submerged vegetation for Namakan Reservoir and Rainy Lake and compare condition prior to and after the implementation of the 2000 Rules Curves.

Study 28 included the collection and analysis of monitoring data for submerged vegetation from Rainy Lake, Namakan Lake, and Lac la Croix.

**Summary of results:**

The model showed a decrease in suitable habitat for high density submerged vegetation in the post-2000 time period compared to in the pre-2000 time period; no change was evident for low density submerged vegetation. However, because the amount of habitat for all water level series varied synchronously through time and because the modelled results based on the 1970 Rule Curves and 2000 Rule Curves predict similar amounts of submerged plant habitat, the authors conclude that the changes in submerged plant habitat in Rainy Lake and the Namakan Chain of Lakes are unrelated to the change from the 1970 to 2000 rule curves and that the variation in submerged plant habitat is likely primarily driven by climatic conditions.

However, Study 28 showed that significant changes to the submerged aquatic



vegetation community were observed on Namakan Reservoir. The authors emphasized the importance of maintaining the reduced fluctuation on Namakan (the fluctuation currently dictated by the 2000 Rule Curves) in order to allow the persistence of the improved submerged vegetation community.

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### **31. Wild Rice**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:**

*Study 21*

Modeling the Rainy Lake and Namakan Reservoir Ecosystem Response to Water Level Regulation (Final Report to IJC)

**Description of Research:**

The objective of this study was to quantify the effects of water level regulations on key species and habitat types of this ecosystem. The authors used a combination of 1-D relationships between habitat suitability and water level variations and more complex 2-D habitat modelling to evaluate the impact of different water level management plans on these biological indicators.

The authors used an IERM-based on a computation grid covering the entire Rainy-Namakan system with a 20 m resolution to make their assessment of rule curve effects.

**Summary of results:**

Models (1-D and 2-D) were used to assess Wild Rice survival and abundance in Rainy Lake and the Namakan Chain of Lakes. Based on the water level variable alone, the 1-D models predicted an increase in Wild Rice survival in the Namakan Chain of Lakes and very little change in Wild Rice survival for Rainy Lake under the 2000 Rule Curves compared to under the 1970 Rule Curves. After further assessment, the authors wrote that the increase in Wild Rice survival predicted by the 1-D model under the 2000 Rule Curve for Namakan Lake would not be realized because monotypic stands of cattail also thrive on the artificially stable water levels and prevent wild rice from growing in many areas of Namakan. The 2-D models predict that the amount of Wild Rice habitat would be similar on Rainy Lake for the 1970 Rule Curves and the 2000 Rule Curves and that the amount of Wild Rice habitat in the Namakan Chain of Lakes would increase under the 2000 Rule Curves as compared to under the 1970 Rule Curves. Because of competition with cattails under the three regulated water level series, the authors conclude that the more variable water levels of the natural water level series are more beneficial to Wild Rice production in the Namakan Chain of Lakes than are any of the regulated water level series.

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### 32. Invertebrate Community

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:**

*Study 7*

Sustained Changes in Rainy Lake and Namakan Reservoir: Benthic Macroinvertebrate Communities in Relation to the 2000 Rule Curve Changes (Final Report to IJC)

*Study 27a*

The effects of water-level manipulation on the benthic invertebrates of a managed reservoir (US NPS Natural Resources Technical Report; and Freshwater Biology 2010)

Study27b Impacts from Water-Level Regulation on Benthic Macroinvertebrate Community Structure in Namakan Reservoir and Rainy Lake

**Description of Research:**

Study 7 determined if the previously-documented changes related to the change in rule curves (qualitative functional relationship) were sustained over longer time scales and if they now included changes in deeper areas of the littoral zone of Namakan.

Study 27 investigated how the changed magnitude and timing of water release under the 2000 Rule Curves affected benthic invertebrate communities in the Namakan Chain of Lakes using Rainy Lake as a control lake. They justified the use of Rainy Lake as a control in this case based on the fact that the small changes from the 1970 to 2000 rule curves for Rainy Lake were very unlikely to affect benthic invertebrates at the depths studied (McEwen and Butler, 2008 and 2010). The authors assessed whether the benthic macroinvertebrate community of the Namakan Chain of Lakes had begun to recover from negative impacts attributed to the 1970 Rule Curves by Kraft (1988), specifically that the winter drawdown of the 1970 Rule Curves on Namakan Lake negatively impacted many species of benthic macroinvertebrates in the Namakan Chain of Lakes through desiccation, freezing, and other factors.

**Summary of results:**

The results indicate a shift toward a healthier benthic macroinvertebrate community in Namakan Chain of Lakes after implementation of the 2000 Rule Curves and are consistent with predictions of the effects of the 2000 Rule Curve on Namakan Lake benthic macroinvertebrates.

The authors concluded that the post-2000 positive changes in the benthic macroinvertebrate community of Namakan first detected by McEwen and Butler (2008 and 2010) have been sustained in 1-2 m depths of the littoral zones and have expanded to include benthic macroinvertebrate communities found in deeper areas of the littoral zone (3-5 m depths) of the Namakan Chain of Lakes.

Invertebrate communities of Namakan changed differently than those of Rainy Lake just as the rule curve changes were far greater on Namakan than on Rainy Lake.

### **33. Mussels**

**Water Body:** Rainy River

**Study or Studies Referenced:**

*Study 1*

Relationship of Rainy River Hydrology to distribution and abundance of freshwater mussels

**Description of Research:**

The objective of the study was to assess whether mussel assemblages in the Rainy River were affected by the 2000 Rule Curve change. The authors assessed mussel assemblages in three 1-km reaches of the Rainy River that could be affected differently by the rule curve changes:

1. within the dam-regulated zone (Reach 2),
2. the nearly unaffected zone (Reach 7), and
3. the zone impounded by Lake of the Woods (Reach 9).

The zones were defined by hydrological models (Luce and Metcalfe, 2014) that indicate changes in hydrology along the course of the river. The mussel assessment was based on data from this study and from a qualitative mussel assessment completed in 2007. There were no data available from before implementation of the 2000 Rule Curves.

**Summary of results:**

The authors did not conclude that there was a change for better or worse for Rainy River mussels under the 2000 Rule Curves as compared to under the 1970 Rule Curves. The authors made use of data from the 2007 qualitative study of Rainy River mussels and noted the lack of pre-2000 mussel data for Rainy River. They propose qualitative relationships between level and flow conditions and success of mussels. They reference results of Luce and Metcalfe (2014) that show the flow regime at the International Falls Dam has an altered flow pattern in both the pre- and post- 2000 rule-curve periods. They note that flows at this dam were outside the range of variability of the natural river for the pre-2000 Rule Curve period but not for the post-2000 Rule Curve period (Luce and Metcalfe 2014) and write that although a measurable effect is not yet evident, over time, mussels in upstream reaches may respond positively to flows that remain within the range of natural variability.

### **34. Trophic State**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:**

*Study 22*

Trophic state in Voyageurs National Park lakes before and after implementation of a revised water-level management plan (Journal of the American Water Resources Association 2015)

*Study 23*

Effects of changes in reservoir operations on water quality and trophic-state indicators in Voyageurs National Park, northern Minnesota (USGS Scientific Investigations Report)

**Description of Research:**

Secchi depth, chlorophyll-a, and total phosphorus data were compared between pre-2000 Rule Curves (1977-1999) and post-2000 Rule Curves (2000 – 2011) periods for Rainy, Kabetogama, Namakan, and Sand Point Lakes. The authors made use of literature from within and outside of the region and made extensive use of data from previous studies carried out on Rainy Lake and the Namakan Chain of Lakes.

**Summary of results:**

Positive changes (decreases) were detected in the post-2000 Rule Curves dataset for chlorophyll-a (and for trophic state based on chlorophyll-a values) for the two most eutrophic water bodies in this study, Lake Kabetogama and Black Bay of Rainy Lake. These two water bodies suffer from cyanobacterial blooms (harmful blooms of blue-green algae) each summer, so a decrease in the trophic state of these lakes is a beneficial change.

A previous modeling study (Kepner and Stottlemeyer 1988) provides evidence of a relationship between a more natural hydrological regime for the Namakan Chain of Lakes and decreased phosphorus concentrations (the lower annual fluctuation for Namakan under the 2000 Rule Curves is closer to its natural fluctuation compared to its annual fluctuation under the 1970 Rule Curves).

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**35. Lake Water Phosphorous Concentrations**

**Water Body:** Namakan Chain of Lakes, Rainy Lake

**Study or Studies Referenced:**

*Study 22*

Trophic state in Voyageurs National Park lakes before and after implementation of a revised water-level management plan (Journal of the American Water Resources Association 2015)

*Study 23*

Effects of changes in reservoir operations on water quality and trophic-state indicators in Voyageurs National Park, northern Minnesota (USGS Scientific Investigations Report)

*Study 24*

Evaluation of internal loading and water level changes: implications for phosphorus, algal production, and nuisance blooms in Kabetogama Lake, Voyageurs National Park, Minnesota, USA (USGS Scientific Investigations Report; Lake and Reservoir Management 2013)

**Description of Research:**

The authors tested whether chlorophyll-a and total phosphorus decreased in Lake Kabetogama after implementation of the 2000 Rule Curves. They also investigated the potential for internal nutrient loading in Lake Kabetogama to help with interpretation

of the results of these tests. Finally, they assessed whether the cyanobacterial blooms (harmful blooms of blue-green algae) that occur each summer and fall on Lake Kabetogama are producing a liver toxin, microcystin. The authors made use of literature from within and outside of the region and made extensive use of data from previous studies carried out on Lake Kabetogama.

**Summary of results:**

Although total phosphorus was predicted to decrease in Lake Kabetogama after implementation of the 2000 Rule Curves, no decrease in total phosphorus was detected. Multiple lines of evidence point to internal loading of phosphorus as a possible explanation for this result in Lake Kabetogama.

Annual internal loading of phosphorus is a potential explanation for the lack of a decrease in total phosphorus concentrations in Lake Kabetogama after implementation of the 2000 Rule Curves. Although annual water level fluctuation decreased after 2000 in Lake Kabetogama, internal phosphorus loading may have been significant enough to prevent the authors from detecting any decrease in total phosphorus loading to the lake that may have occurred in conjunction with the smaller amount of shoreline dried and rewetted each year under the 2000 Rule Curves compared to under the 1970 Rule Curves.

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**36. Municipal & Fish Hatchery Use**

**Water Body:** Rainy River

**Study or Studies Referenced:**

*Study 17*

Examine municipal water treatment and hatchery data for Rainy River (Final Report to IJC)

**Description of Research:**

The objective of this study was to assess whether municipal water treatment and fish hatchery operations on Rainy River have been affected by the 2000 Rule Curves for Rainy Lake and Namakan Lake. The authors met with the managers of the Rainy River and Emo water treatment plants and of the Rainy River First Nation lake sturgeon hatchery to acquire information as to what water quality or quantity issues these facilities encounter. The author used available data to assess whether these issues were affected by the 2000 Rule Curves.

**Summary of results:**

The author found no evidence of an effect of the 2000 Rule Curves on the municipal water treatment plants and the fish hatchery on the Rainy River, but he suggested that additional modelling could be pursued to further investigate whether there is a difference in turbidity in the Rainy River at the intakes for the water treatment plants under different water management scenarios. That modelling could include methods to separate the effects of non-water level regulation related hydrology from the effects of water level management.

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## A N N E X 7

### ALTERNATIVE RULE CURVES

**Annex 7** presents detailed information on the 2000 Rule Curves (Alternative A) and the four alternative rule curves under consideration by the Study Board. The four alternatives are:

- **Alternative B:** Conditional spring flood reduction for Rainy Lake;
- **Alternative C:** Within-year ecosystem improvements;
- **Alternative D:** Hybrid 1970-2000 Rule Curve for Namakan for improved late summer navigation, reduced Rainy Lake flooding; and
- **Alternative E:** Increased Inter-annual Variability for Ecosystem Benefit.

The tables under each of the alternatives list the lower and upper levels, in metres above sea level (*i.e.*, the rule curve band) for each quarter-month period, for each lake.

#### ALTERNATIVE A 2000 Rule Curves

##### Namakan Lake

Date	Lower RC (m)	Date	Upper RC (m)
01-Jan	339.70	01-Jan	340.00
01-Apr	338.95	01-Apr	339.70
15-Apr	338.95	01-Jun	340.95
07-Jun	340.70	01-Sep	340.65
01-Sep	340.45	01-Oct	340.65
01-Oct	340.45	31-Dec	340.00
31-Dec	339.70		

##### Rainy Lake

Date	Lower RC (m)	Date	Upper RC (m)
01-Jan	337.20	01-Jan	337.45
01-Apr	336.70	01-Apr	337.00
01-May	336.80	01-May	337.40
01-Jun	337.30	01-Jun	337.60
01-Jul	337.50	01-Jul	337.75
15-Aug	337.50	15-Aug	337.75
01-Dec	337.30	01-Dec	337.60
31-Dec	337.20	31-Dec	337.45



## ALTERNATIVE B

### Conditional spring flood reduction for Rainy Lake

#### Overview

Implementation of the 2000 Rule Curves resulted in slightly higher peak water levels during flood periods on Rainy Lake, largely due to loss in storage room in the Namakan Chain of Lakes that was available under the 1970 Rule Curves. This was a recognized trade-off in the adoption of the 2000 Rule Curves. Alternative B aims to reduce peak flood levels on Rainy Lake without changes to the Namakan Lake Rule Curve, thereby retaining all the benefits of the 2000 Rule Curves for the Namakan Chain of Lakes confirmed by the WOE analysis.

The existing 2000 Rule Curves are retained for Namakan and Rainy Lakes. In years when risk of spring flooding is considered to be high, the rule curve for Rainy Lake is altered so that the refill of the lake begins at the end of April and the target range from May through early July is lower. The lake returns to the 2000 Rule Curve band in early July.

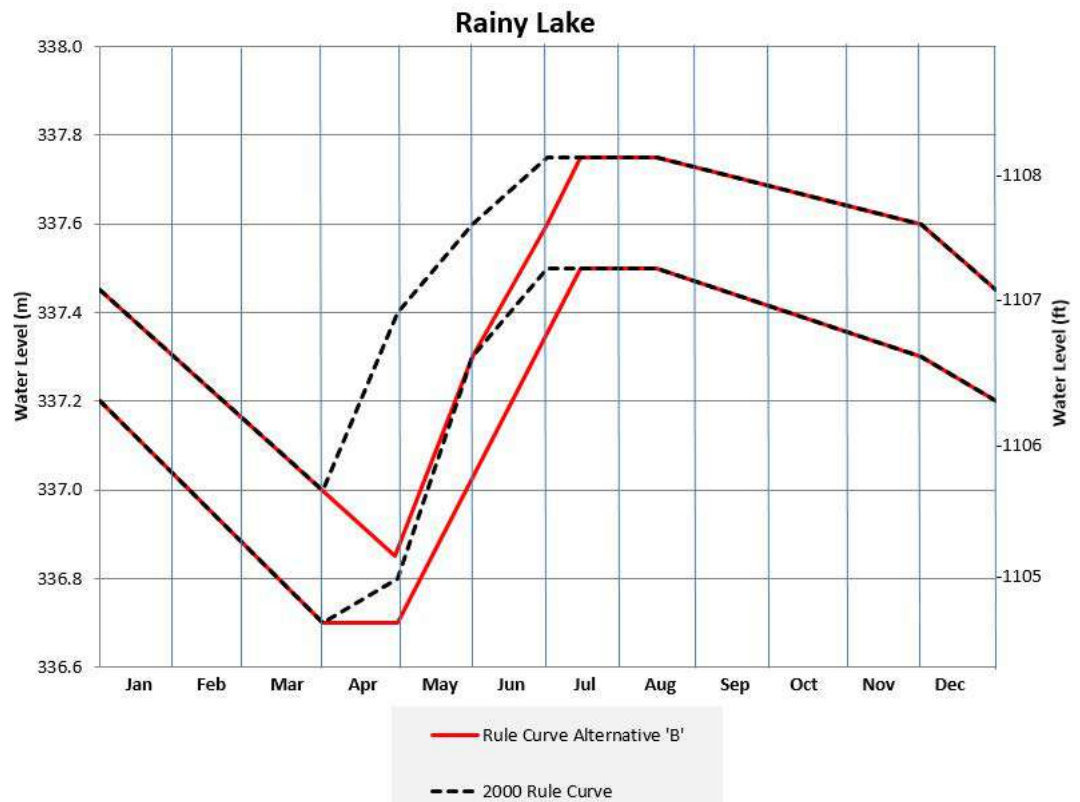
This alternative is expected to reduce flood damages on Rainy Lake without major impacts to other interests.

#### Namakan Lake

No changes to the Namakan Lake 2000 Rule Curve.

#### Rainy Lake

Date	Lower RC (m)	Date	Upper RC (m)
01-Jan	337.20	01-Jan	337.45
01-Apr	336.70	30-Apr	336.85
01-May	336.70	01-Jun	337.30
15-Jul	337.50	01-Jul	337.60
15-Aug	337.50	15-Jul	337.75
01-Dec	337.30	15-Aug	337.75
31-Dec	337.20	01-Dec	337.60
		31-Dec	337.45



**Figure A7-1 Rule Curve Alternative B and the 2000 Rule Curve for Rainy Lake**

**Alternative B** maintains the 2000 Rule Curve targets on Namakan Lake, and on Rainy Lake in most years. However, in years where spring flood risk is deemed to be heightened, the target range is shifted to delay refill and maintain additional storage room from April to mid-July.

## ALTERNATIVE C

### Improving within-year ecological outcomes

#### Overview

This alternative aims to retain the benefits of the 2000 Rules Curves and reduce the potential for flooding on Rainy Lake (as demonstrated by **Alternative B**), while enhancing some ecological conditions for fish and fur-bearers.

This alternative includes modifications to both the Namakan Lake and Rainy Lake Rule Curves that result in a reduced over-winter drawdown from late November to late March. In years when flood conditions are projected, the lower target range for Rainy Lake is included in **Alternative B** is followed from April to mid-July.

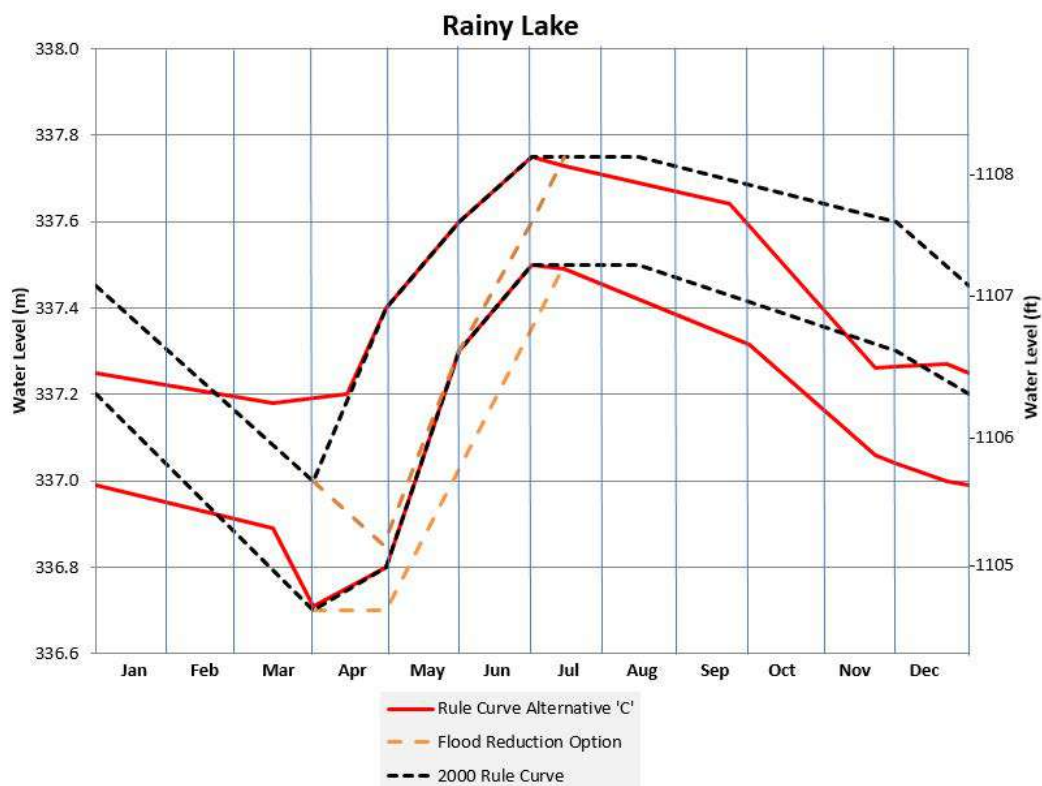
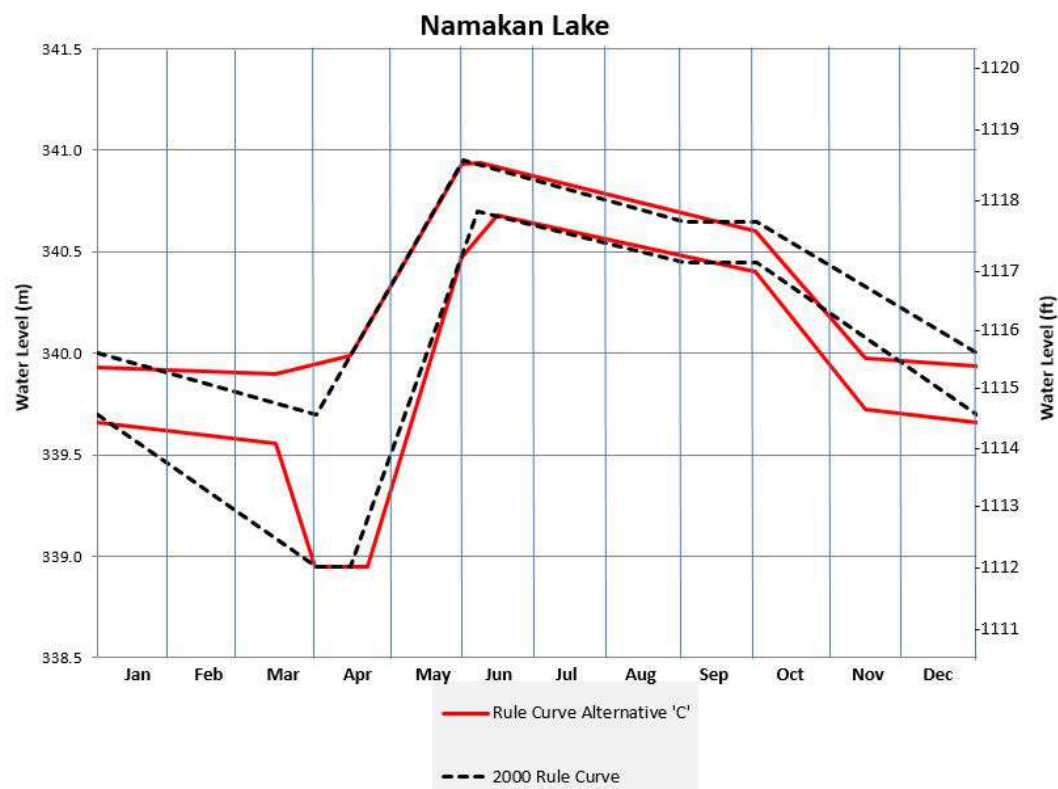
This rule curve is designed to benefit Muskrat survival by ensuring their lodges are built at water levels that allow for continued access to aquatic vegetation over the winter. As described in Section 2.2, Muskrats play a vital role in the control of Hybrid Cattail expansion and create channels through cattail beds that benefit many fish species.

#### Namakan Lake

Date	Lower RC (m)	Date	Upper RC (m)
01-Jan	339.70	01-Jan	340.00
01-Apr	338.95	01-Apr	339.70
15-Apr	338.95	01-Jun	340.95
07-Jun	340.70	01-Sep	340.65
01-Sep	340.45	01-Oct	340.65
01-Oct	340.45	31-Dec	340.00
31-Dec	339.70		

#### Rainy Lake

Date	Lower RC (m)	Date	Upper RC (m)
01-Jan	336.99	01-Jan	337.25
15-Mar	336.89	15-Mar	337.18
01-Apr	336.71	15-Apr	337.20
01-May	336.80	01-May	337.40
01-Jun	337.30	01-Jun	337.60
01-Jul	337.50	01-Jul	337.75
15-Jul	337.49	15-Jul	337.73
30-Sep	337.31	22-Sep	337.64
22-Nov	337.06	22-Nov	337.26
30-Nov	337.04	30-Nov	337.26
22-Dec	337.00	22-Dec	337.27
31-Dec	336.99	31-Dec	337.25



**Figure A7-2 Rule Curve Alternative C and the 2000 Rule Curves**

**Alternative C** is designed to maximize ecological benefit in several areas each year while meeting constraints of high and low levels for flood protection and navigation.

## ALTERNATIVE D

### Hybrid 1970-2000 Rule Curves for Namakan Lake

#### Overview

This alternative provides stable level targets on Namakan Lake from June 1 to October 1, similar to the 1970 Rule Curve (i.e., eliminates gradual summer drawdown), but retains the 2000 Rule Curves for the remainder of the year. No modifications are made to the 2000 Rule Curves for Rainy Lake.

This alternative was expected to provide the following benefits:

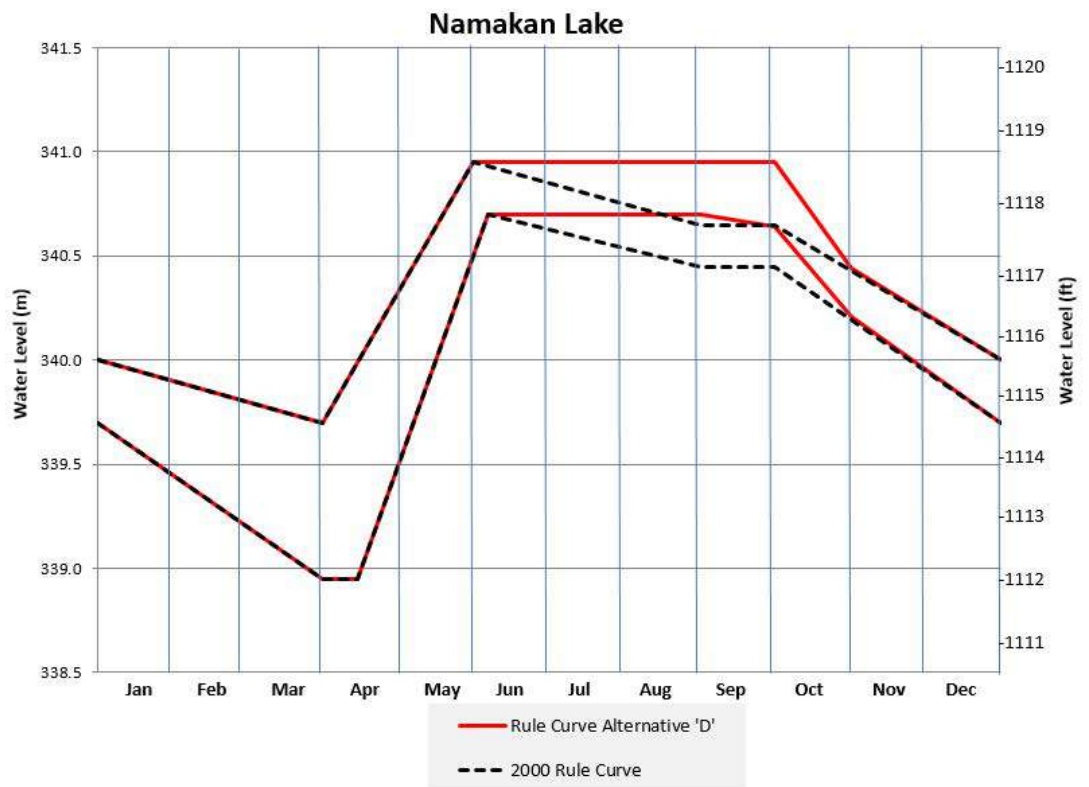
- provide Rainy Lake with additional flood protection in late spring and early summer by reducing discharge from Namakan Lake while Rainy Lake is still refilling; and
- improve navigation over the summer period on Namakan Lake by maintaining a higher lake level throughout the boating season.

#### Namakan Lake

Date	Lower RC (m)	Date	Upper RC (m)
01-Jan	339.70	01-Jan	340.00
01-Apr	338.95	01-Apr	339.70
15-Apr	338.95	01-Jun	340.95
07-Jun	340.70	01-Sep	340.65
01-Sep	340.45	01-Oct	340.65
01-Oct	340.45	31-Dec	340.00
31-Dec	339.70		

#### Rainy Lake

No changes to the Rainy Lake 2000 Rule Curve.



**Figure A7-3 Alternative Rule Curve D and the 2000 Rule Curve for Namakan Lake**

**Alternative D** holds the target range on Namakan Lake flat from the start of June to the end of September with the aim of reducing flooding downstream on Rainy Lake (by holding water upstream) and improving navigation conditions in late summer and early fall on the Namakan Chain of Lakes.



## ALTERNATIVE E

### Increased inter-annual variability

#### Overview

This alternative is designed to enhance ecological conditions by increasing the variability in seasonal water levels over the years.

This alternative consists of three sets of rule curves for each lake. The SVM is forced to target a low, normal or high using an ENSO-based projection of basin conditions. All three sets of curves for each lake contain features that aim to improve ecological interests, such as the reduced over-winter drawdown to encourage Muskrat survival, and the rapid refill in early spring to benefit Walleye spawning.

#### Namakan Lake

Alternative E-1			
Date	LRC-F	Date	URC-F
01-Jan	339.68	01-Jan	340.09
22-Mar	339.53	22-Mar	339.97
01-Apr	339.69	15-Apr	340.61
15-Apr	339.86	22-Apr	340.74
22-Apr	340.06	15-Jun	340.51
15-Jun	340.29	30-Sep	340.30
30-Sep	340.16	15-Nov	340.08
15-Nov	339.78	31-Dec	340.00
31-Dec	339.68		

Alternative E-2			
Date	LRC-F	Date	URC-F
01-Jan	339.78	01-Jan	340.09
22-Mar	339.63	22-Mar	340.07
01-Apr	339.84	15-Apr	340.86
15-Apr	340.11	22-Apr	341.01
22-Apr	340.36	15-Jun	340.81
15-Jun	340.59	30-Sep	340.30
30-Sep	340.20	15-Nov	340.13
15-Nov	339.88	31-Dec	340.09
31-Dec	339.78		

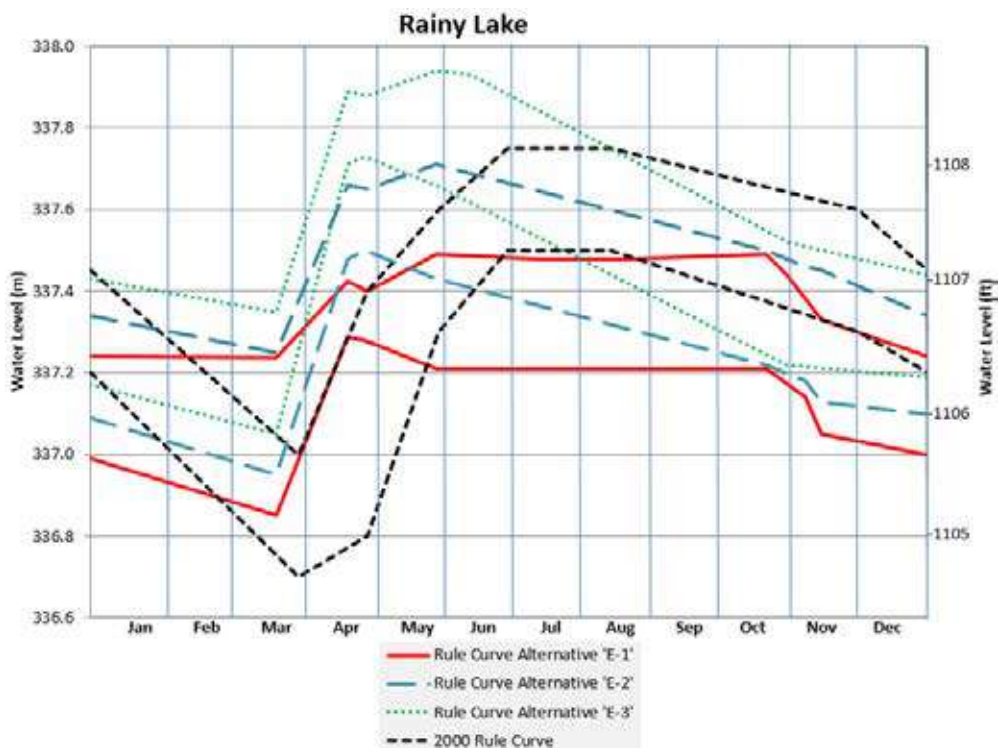
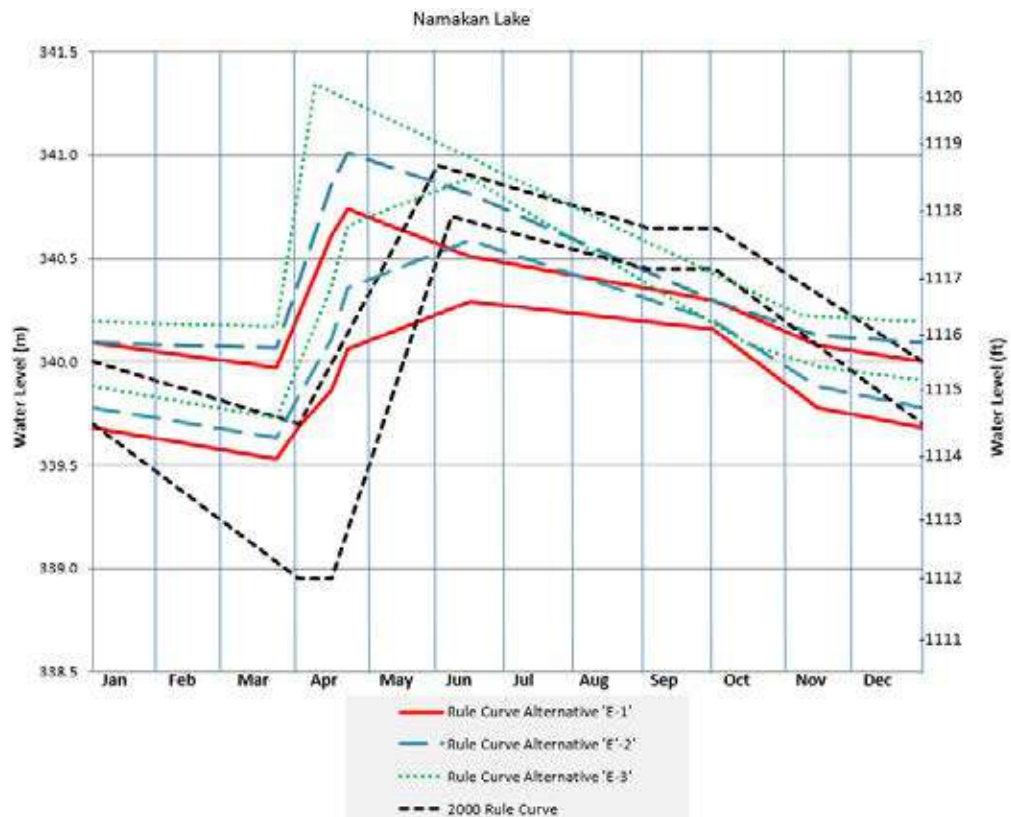
Alternative E-3			
Date	LRC-F	Date	URC-F
01-Jan	339.88	01-Jan	340.19
22-Mar	339.73	22-Mar	340.17
15-Apr	340.36	08-Apr	341.34
22-Apr	340.66	08-Nov	340.23
15-Jun	340.89	31-Dec	340.20
15-Oct	340.08		
15-Nov	339.98		
31-Dec	339.91		

## Rainy Lake

Alternative E-1			
Date	Lower RC (m)	Date	Upper RC (m)
01-Jan	336.99	01-Jan	337.24
22-Mar	336.85	22-Mar	337.24
22-Apr	337.29	22-Apr	337.43
30-Apr	337.28	01-May	337.40
31-May	337.21	31-May	337.49
22-Oct	337.21	15-Jul	337.48
08-Nov	337.14	22-Aug	337.48
15-Nov	337.05	22-Oct	337.49
31-Dec	337.00	31-Oct	337.44
		15-Nov	337.33
		31-Dec	337.24

Alternative E-2			
Date	Lower RC (m)	Date	Upper RC (m)
01-Jan	337.09	01-Jan	337.34
22-Mar	336.95	22-Mar	337.25
22-Apr	337.48	22-Apr	337.66
30-Apr	337.50	01-May	337.65
31-May	337.43	31-May	337.71
22-Oct	337.22	22-Oct	337.50
08-Nov	337.18	08-Nov	337.46
15-Nov	337.13	15-Nov	337.45
31-Dec	337.10	31-Dec	337.34

Alternative E-3			
Date	Lower RC (m)	Date	Upper RC (m)
01-Jan	337.17	01-Jan	337.43
22-Mar	337.05	22-Mar	337.35
22-Apr	337.71	22-Apr	337.89
30-Apr	337.73	01-May	337.88
31-May	337.66	31-May	337.94
31-Oct	337.22	15-Jun	337.93
31-Dec	337.19	31-Oct	337.52
		31-Dec	337.44



**Figure A7-4 Rule Curve Alternative E and the 2000 Rule Curves**

**Alternative E** is designed to increase inter-annual variability in water levels for ecological benefits. Under this approach, there are three sets of curves, and each year a different set is selected.

## SAMPLE OPERATIONAL GUIDELINES

Under the 2000 Rule Curves, the dam operators are required to target the middle portion of the Rule Curve bands on Rainy Lake and the Namakan Chain of Lakes. The Water Levels Committee of the International Rainy-Lake of the Woods Watershed Board has the authority to direct the operators to target elsewhere within these bands. Since 2000, such deviations have typically been made to adjust to anticipated risks of dry or wet conditions, and occasionally to address specific ecological concerns.

The present Rule Curves review has been supported by a wide range of studies that have advanced the understanding of how water levels affect various interests. This knowledge could support more frequent use of the Water Levels Committee's authority to target outside the middle portion of the Rule Curve band to benefit specific interests as the opportunity arises.

Operational Guidelines, that describe how particular management goals would benefit from specific management approaches, may provide a useful resource to the Water Levels Committee to support improved outcomes as the opportunity arises. Operational Guidelines may be enhanced by describing the practical challenges in managing flows at the dams. Making the Operational Guidelines publicly available would allow stakeholders to better understand when target deviations might reasonably be applied, and how they might benefit regulation outcomes. They would also help inform the public of the practical issues related to dam management that must be considered in regulation.

The Study Board has compiled the following list of sample Operational Guidelines, based on information collected as part of the Rule Curves review. The Study Board views these as a resource for potential use by the Water Levels Committee in developing a comprehensive set of guidelines that evolve over time with new research and experience.

### **1. Year-round Considerations**

- a. In general practice, it is prudent to target the middle portion of the Rule Curve bands (25–75 percent) under normal inflow conditions as this provides a buffer in case inflow conditions rise or decline sharply. In some seasons, other targets within the Rule Curve bands may be more suitable depending on the risk of Emergency Conditions, as described below.
- b. The general public has an interest in how outflows from the dams at Namakan and Rainy Lakes are managed. The dam operators and Water Levels Committee should provide information on changes to outflows that is timely and relevant. This includes status of dam sluices/gates, maintenance and planned outflow changes when available.
- c. Compared to Rainy Lake, water level changes on Rainy River are more rapid and have a greater range. Large, quick fluctuations may contribute to shoreline erosion, harm ecological interests, cause issues with docks (damage, limit accessibility) and may limit

recreational activities on the river. Large flow changes during spawning periods can also be detrimental to fish eggs and larvae in the river. Changes in the rate of outflow from Rainy Lake, regulated by the dam at Fort Frances-International Falls, contribute to these fluctuations, as do local natural inflows from tributaries to the river (e.g. Little Fork and Big Fork rivers). The relative contribution of each varies.

Provided that emergency conditions due to low or high water are not anticipated, consideration should be given to limiting outflow increases or decreases from Rainy Lake to no more than 150 m<sup>3</sup>/s in a 24-hour period for the purposes of managing the lake level. When larger changes in outflow are required for purposes such as dam maintenance, notification should be provided to the public.

## **2. Winter Considerations**

- a. The winter period for the purposes of this document is from lake freeze-up to the start of freshet, normally from mid-November to April.
- b. During the winter period, there is little risk of developing Emergency Conditions due to high or low water.
- c. During the winter period, flow changes that involve log operations at the Namakan Lake dams or gate operations at the Rainy Lake dam can be difficult to execute due to ice and the challenges of working in an extremely cold environment.
- d. Large fluctuations in Rainy Lake outflow, up or down, following freeze-up of Rainy River can cause problems during the winter period, including ice-damming, break-up of ice cover used for recreational purposes and erosion and damage to shoreline infrastructure due to ice movement.
- e. For the reasons outlined in 2a-d above, it is preferable to allow for the levels of the Namakan Chain of Lakes and Rainy Lake to fluctuate within the full range of the Rule Curve bands during the winter as gradual changes in inflow to the lakes develop. This requires less frequent changes in outflow than would be needed to maintain lake levels within the middle 25-75 percent of the Rule Curve bands. Targets in the late winter may need to be adjusted to reflect spring risks in advance.
- f. Rainy Lake and the Namakan Chain of Lakes support several fall and winter spawning fish species, including Lake Whitefish, Cisco and Burbot. Lake Whitefish typically spawn between late October to mid-November and hatching occurs in March to April. Cisco usually spawn a week or two after the Lake Whitefish, also in shallow water (1 -3 m). Lake Whitefish spawning and egg incubation is generally unaffected by water level variation of less than 50 cm above or below the water level at the time of egg deposition. Egg survival declines as water level variation, whether higher or lower, exceeds 50 cm. At 125 cm variation, the probability of egg survival drops to 50 percent, at 200 cm, the probability of survival is zero. Decisions on over-winter drawdown within the Rule Curves for these lakes should consider the effects on Lake Whitefish and Cisco eggs.
- g. Muskrats begin to build lodges during fall, up until lake freeze-up. Lake level changes over the winter following lodge establishment are normally tolerated by Muskrats up to 15 cm, but become increasingly problematic for survival as water level changes increase

past this. Water level increases of more than 30 cm or decreases of more than 60 cm are likely to prevent Muskrat survival over the winter.

### **3. Spring Considerations**

- a. The spring period for the purposes of this document is from the onset of freshet (typically start of April) to the end of June.
- b. The spring period has the highest frequency of Emergency Conditions due to high water. Most high-water events follow above-normal rainfall when the basin conditions are wet and are driven by inflow to the lakes exceeding the limits of outflow imposed by the natural outlet features of the lakes.
- c. Early in March of each year, the Water Levels Committee should review basin conditions and forecasts for the spring period and adjust the lake level targets for the spring accordingly. Based on historic data, Emergency Conditions due to high water are most common following winters with a La Niña climate pattern from December through February, with high snowpack in early March and colder-than-normal winters.
- d. During the spring period, to reduce the risk of Emergency Conditions due to high water, it is prudent to target the lower portion of the Rule Curve band on Rainy Lake and the Namakan Chain of Lakes if inflow to the lakes is, or is forecast to be, above the normal range (25th to 75th percentile based on Water Levels Committee inflow statistics).
- e. During the spring period, to reduce the risk of Emergency Conditions due to lower water, it is prudent to target the upper portion of the Rule Curve band on Rainy Lake and the Namakan Chain of Lakes if inflow to the lakes is, or is forecast to be, below the normal range.
- f. Sudden, large increases in Rainy River flow early in the spring period can create ice-damming and related flooding. Break-up of river ice cover due to high flows can also create problems for recreational interests along the river, such as ice fishing, and contribute to shoreline erosion. Rising spring flows may also be due to natural increases in flow from tributaries to the Rainy River, due to large increases in Rainy Lake outflow, or a combination of these. Increasing Rainy Lake outflow gradually during the spring period, in balance with conditions on Rainy Lake, reduces the risk of the ice-related issues.
- g. Walleye in Rainy Lake and the Namakan Chain of Lakes spawn soon after lake ice-out, peaking when the water temperature is near 8 °C. Water level fluctuations are related to the survival of walleye eggs, which usually hatch after about three weeks. Eggs are not considered vulnerable if fluctuation in water level is between a 10 cm decline and a 50 cm rise during this period. Declines below 10 cm decrease the probability of egg survival with nearly all eggs being lost at a 1.0 m drop. Rising water levels beyond 50 cm also decrease survival probability, with complete loss likely at 2.5 meters.

Walleye reproduction in the Rainy River is favored by moderate and stable river discharge during the spawning and egg incubation period which usually occurs between April and early June. Walleye generally spawn on clean gravel substrates in shallow waters (0.10 to 1.5 m) with water velocities between 0.1 to 1.4 m/sec. To help provide suitable spawning conditions, the dam operators voluntarily suspend daily peaking operations during the spawning period in coordination with the state and provincial resource agencies.



- h. Northern Pike spawn in the spring shortly after ice-out, generally in shallow areas with vegetation. Higher water levels increase the available spawning and nursery areas by submerging a larger area of suitable habitat, and support recruitment. Declining water levels after spawning risk desiccation of eggs, while rapidly rising levels can also be damaging to larvae. Very good water level conditions (high water level soon after ice-out remaining stable for five to six quarter-months) occurring every three to five years should be sufficient to sustain the Northern Pike population.
- i. The Common Loon builds nests close to water, generally within 0.5 m of the water's edge and between 7 and 10 cm above the water surface. Eggs are laid roughly six to seven weeks after ice-out, with incubation for approximately 30 days, followed by a nesting period of a few days. The nests are vulnerable to rising water levels, whether due to natural fluctuation or reservoir regulation. Loons can adapt their nests to slow and moderate water level increases, but not to rapid or large increases. Water level declines beyond 30 cm also decrease nesting success due to the poor walking ability of the loons: it increases distance to the water and increases vulnerability to predators. Reducing water level variability during the incubation and nesting period could improve loon productivity across a large area. Loons may attempt to re-nest if the first nest fails, which can result in eggs being incubated well into August. To limit the negative effects of water level increases during the reproductive season, the peak lake water level should occur generally before the nest initiation period, roughly six to seven weeks following ice-out. During the nesting period, it is ideal to limit water level changes to increases of no more than 20 cm and decreases of no greater than 40 cm.
- j. In the Rainy River, Lake Sturgeon typically spawn once water temperatures have reached 12 °C for two consecutive days. Spawning takes place preferentially in areas of high flow velocity at various locations between Lake of the Woods and the tailrace of the Fort Frances-International Falls dam. Once spawning has occurred, the eggs are susceptible to exposure to air due to declining river levels, therefore stable or rising water levels are preferred. The Water Levels Committee is engaged with resource agencies, Rainy River First Nations, the dam operators and community organizations to monitor water level temperatures and spawning activity each spring with the intent of avoiding, where feasible, Rainy Lake outflow decreases that would result in egg dewatering. This arrangement is known as the Sturgeon Protocol.
- k. Wild Rice germinates from late April to early May, generally following ice-out. The submerged leaf phase of early growth lasts until late May or early June, when the leaves reach the water surface. Rapid water level rise during this period can diminish light penetration. If the plant is unable to grow to the surface, it is lost. The plant is vulnerable as well during the floating leaf stage (mid-June), as a water level rise of only a few inches can be sufficient to uproot the plant. Conversely, a water level drop can kill the plant during this period, as it has insufficient structural strength to remain standing out of the water.

Wild Rice on Rainy Lake tends to do best in years with spring water levels in the lower portion of the 2000 Rule Curves. Water level increases of up to 0.5 m after germination can generally be tolerated, but plant survival drops sharply with additional water level rise. If conditions allow for the emergence of a promising crop, consideration could be given to adjust lake level targets within the Rule Curve range to allow for stable levels through late spring into summer.

#### **4. Summer Considerations**

- a. The summer period for the purposes of this document is from the start of July to the end of August.
- b. Emergency Conditions due to high water occur less frequently during the summer period than during the spring period. However, above normal inflows during the summer period increase the risk. As in the spring period, it is prudent to target the lower portion of the Rule Curve bands on Rainy Lake and the Namakan Chain of Lakes if inflow to the lake is, or is forecast to be, above the normal range.
- c. Low inflows are more common during the summer period than during the spring period. To reduce the risk of Emergency Conditions due to lower water, it is prudent to target the upper portion of the Rule Curve bands on Rainy Lake and the Namakan Chain of Lakes if inflow to the lake is, or is forecast to be, below the normal range.
- d. The summer period is the primary tourist season in the region. Recreational uses of the Namakan Chain of Lakes, Rainy Lake, and Rainy River are affected by water levels. Both extremely high and extremely low water levels can be problematic for recreational users, affecting access to boats from docks and creating navigational hazards. Levels within the Rule Curve ranges for both lakes are generally satisfactory for most users.
- e. The lower end of the Rule Curve ranges for Rainy Lake and the Namakan Chain of Lakes allow for a larger area of beaches than at higher water levels.
- f. Based on information from the Rendezvous Yacht Club, Rainy Lake elevations below 337.27 m (1106.5 ft) limit launch access for keel-boats with draughts of 5 ft or greater.
- g. In years where Wild Rice is performing well by early summer, stable or gradually declining levels are beneficial through the summer period.
- h. Hydroelectric rates are normally the highest in the summer. Higher Rainy Lake levels within the Rule Curve band typically allow for greater hydroelectric power generation.
- i. Stable water levels during the summer present the highest risk of erosion to archeologically-important shoreline sites. Gradually changing water levels over this period affords less time at a given elevation for waves to cause erosion.
- j. Gradually declining water levels for Rainy Lake and the Namakan Chain of Lakes increase the likelihood of shoreline substrate washing through wave action. This improves the spawning habitat for walleye and other species the following year. The summer drawdown may also expand the area of aquatic vegetation that Northern Pike can use for spawning the following spring.

#### **5. Fall Considerations**

- a. The fall period for the purposes of this document is from the beginning of September to lake freeze-up, typically in November or early December.
- b. Fall water levels within the Rule Curve ranges for Rainy Lake and the Namakan Chain of Lakes are generally acceptable for recreational interests.

- c. In years with promising wild rice crops, stable or gradually declining levels in the early fall period until harvest are preferred.
- d. Lake Whitefish and Cisco typically spawn in the fall at relatively shallow depths. Thus, winter drawdown may result in dewatering of the spawning areas and desiccation of their eggs.
- e. Muskrats build houses in the late fall in advance of lake freeze-up. The closer late fall water levels are to end-of-winter target levels, the lower the risk to Muskrat survival.