RAINY AND NAMAKAN LAKES

RULE CURVES REVIEW

STUDY STRATEGY

Submitted to:
International Joint Commission

Submitted by:
International Rainy and Namakan Lakes Rule Curves Study Board

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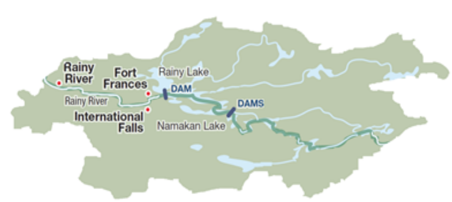

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List of Acronyms

ARIMA	Auto Regressive Integrated Moving Average
ARMA	Auto Regressive Moving Average
EPA	Environmental Protection Agency
CAG	Community Advisory Group (of the IRLWWB)
CREAT	Climate Resilience Evaluation and Awareness Tool
DEM	Digital Elevation Model
DFO	Department of Fisheries and Oceans
DNR	Department of Natural Resources (MN)
GCM	Global Circulation Model
GIS	Geographical Information System
IAG	Industry Advisory Group (of the IRLWWB)
IERM	Integrated Ecological Response Model
IJC	International Joint Commission
IMG	Information Management Group
IRG	Independent Review Group
IRLBC	International Rainy Lake Board of Control
IRLWWB	International Rainy-Lake of the Woods Watershed Board
IRNLRCR	International Rainy and Namakan Lakes Rule Curves Review
IRNLRCSB	International Rainy-Namakan Lakes Rule Curves Study Board
IUGLS	International Upper Great Lakes Study
IWI	International Watersheds Initiative
MN	Minnesota
MNR	Ministry of Natural Resources (ON)
MNRF	Ministry of Natural Resources and Forestry (ON)
NGO	Non-governmental Organizations
NRC	National Research Council
ON	Ontario
PI	Performance Indicator
POS	Plan of Study
RAG	Resources Advisory Group
RC	Rule Curve
RCPAG	Rule Curve Public Advisory Group
SAMS	Stochastic Analysis, Modelling and Simulation
SON	State of Nature
SVP	Shared Vision Planning
SVM	Shared Vision Model
TWG	Technical Working Group
USDA	United States Department of Agriculture

List of Acronyms (cont'd)

WLC	Water Levels Committee (of the IRLWWB)
WOE	Weight of Evidence
YOY	Young of Year

1 INTRODUCTION

Since adopting the *Rainy Lake Convention* in 1938, Canada and the United States have given the International Joint Commission (IJC) the authority to regulate the water levels to avoid emergency levels in Rainy Lake and Namakan Lake, the largest of the many lakes in the Rainy River watershed that is shared by Minnesota and Ontario. The first formal regulations were established by the IJC in 1949 with the adoption of Rule Curves for each lake. These curves prescribed the lake elevation throughout the year that the owners of the dams that control the lake levels were required to target insofar as possible. Over the years, there have been several iterations of these Rule Curves, the most recent being adopted in 2000. When the 2000 Rule Curves were implemented, the IJC stipulated a review of their effectiveness would be undertaken after fifteen years.

In August of 2015, the IJC appointed the International Rainy and Namakan Lakes Rule Curves Study Board (IRNLRCSB, hereafter "the Study Board"), and tasked it with conducting the review of the 2000 Rule Curves. The first requirement of the Study Board was to prepare a Study Strategy that outlines and defines the intended approach for conducting the review. This document is submitted to the IJC in fulfillment of that requirement. The report provides a brief background on the Rainy River basin and the history of Rule Curve-based regulation there, the scope and aims of the Study Board in conducting its review, and a detailed methodology proposed to achieve these aims.

1.1 Basin Description

The Rainy River drainage basin is situated in Ontario and Minnesota, draining 54,900 km^2 (21,200 mi^2) that 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. The basin is also bounded by the English River drainage basin to the north, and the Mississippi River basin to the south (Figure 1).

The basin may be considered as three distinct sub-basins as follows:

1. Namakan Lake sub-basin, which includes the Namakan Chain of Lakes[1], and upstream lakes and rivers, the largest of which are Lac La Croix and Basswood Lake;

2. 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

[1] The Namakan Chain of Lakes refers to the five lakes (Namakan Lake, Lake Kabetogama, Crane Lake, Sand Point Lake, and Little Vermillion Lake) which have water levels influenced by the dam operations at the outlet of Namakan Lake.

3. 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. Rainy River is the boundary between Canada and the United States from Rainy Lake to Lake of the Woods.

At the outlet of Rainy Lake, the drainage area is approximately 38,600 km^2 (14,900 mi^2), of which 58 percent is in Canada and 42 percent is in the United States. The waters that leave the Rainy River basin flow north, via Lake of the Woods and the Winnipeg River, eventually emptying into Hudson Bay.

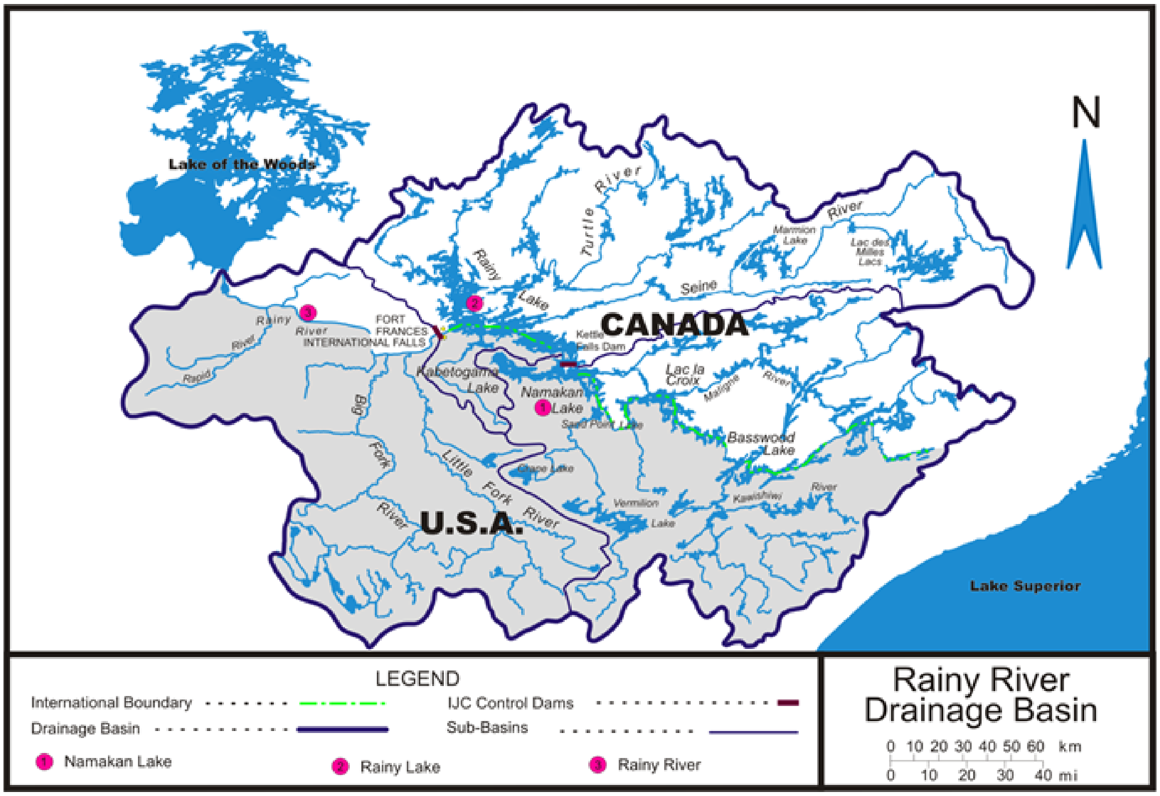


Figure 1. Map of Rainy River Drainage Basin

Under normal inflow conditions, the levels of Rainy Lake and Namakan Lake may be regulated by the dam structures at their principal outlets, and are the only existing control structures in the basin that fall under the authority of the IJC pursuant to the 1938 *Rainy Lake Convention*.

The principal outlet of Namakan Lake includes two dams, built in 1914, located approximately 500 m (1,640 ft) apart on either side of Kettle Island. One dam, at Kettle Falls, spans the Canada-U.S.A. border, while the other, at Squirrel Falls, is entirely within Canada. Flow leaves Namakan Lake through these structures and directly enters Rainy Lake. Each structure 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.

In addition to the flow out from these dams, there are two natural portages which connect to Rainy Lake: Bear Portage, which flows out of Namakan Lake, and Gold Portage which flows out of Kabetogama Lake. The flow through these portages is small relative to the flow out of the dams, and only occurs if the level of these outlet lakes is sufficiently high. Figure 2 provides a map of the Namakan Chain of lakes and illustrates the locations of outflow to Rainy Lake.

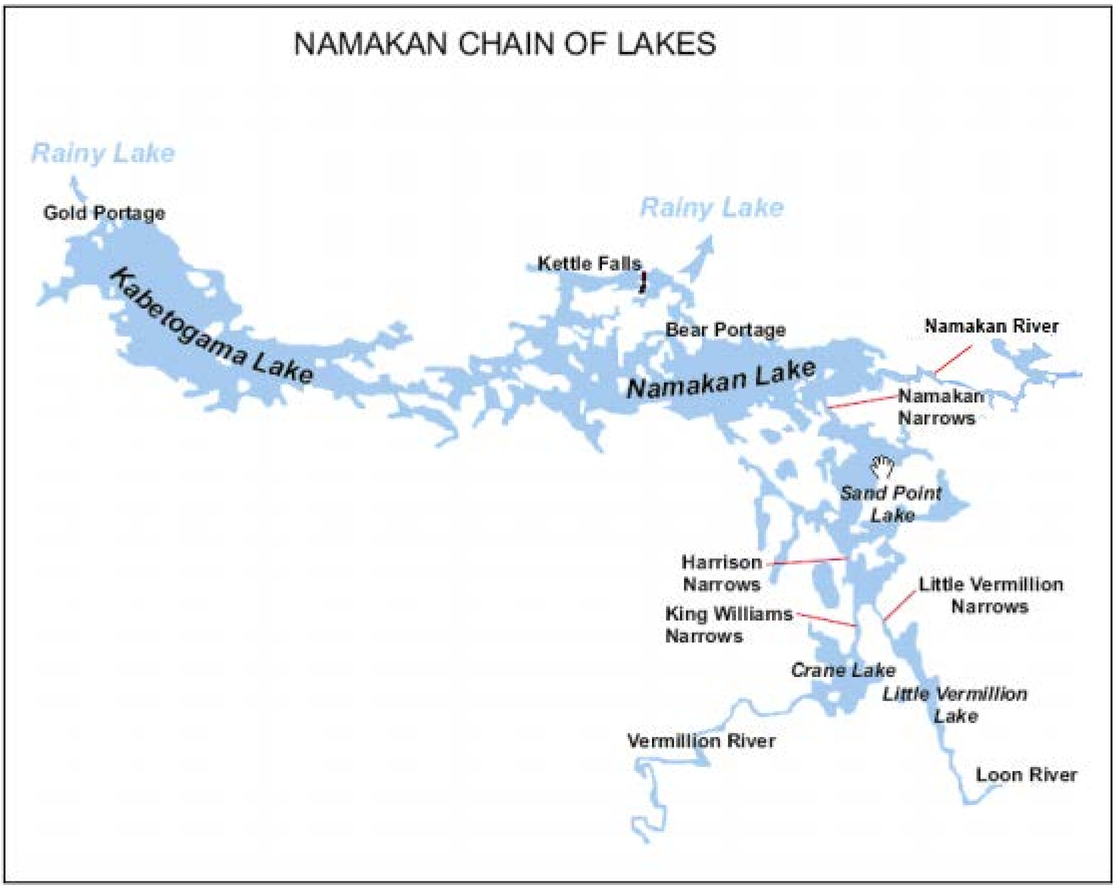
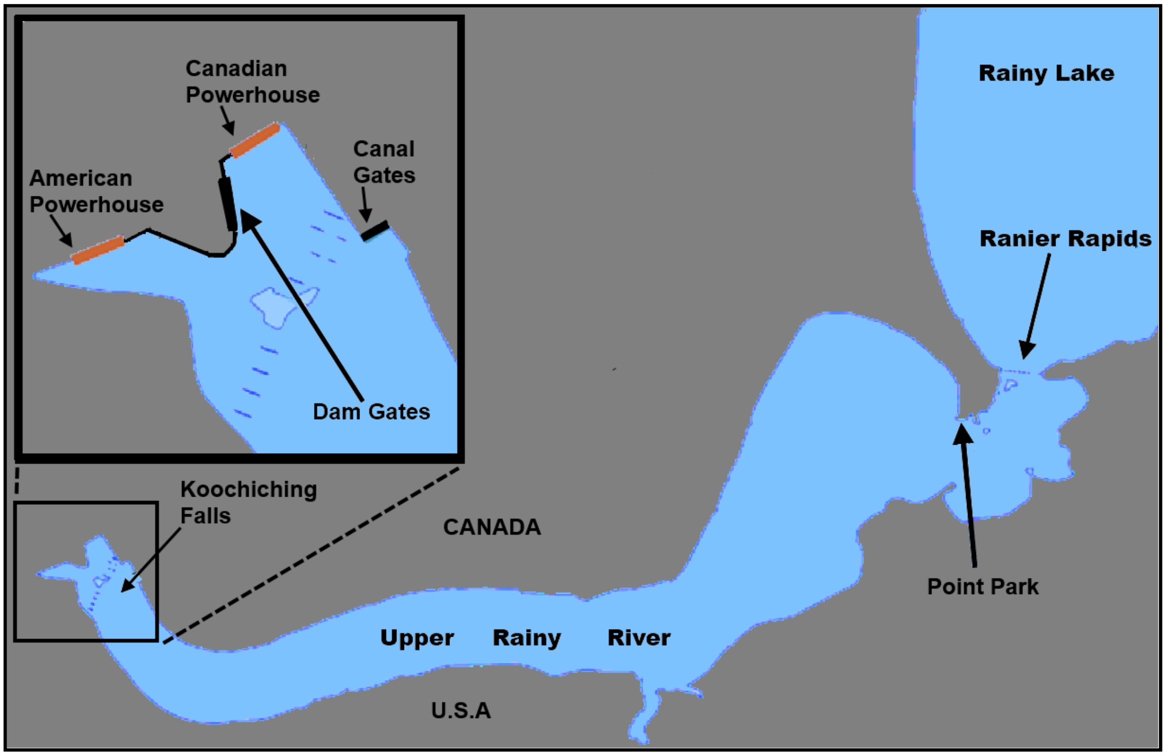


Figure 2. Namakan Chain of Lakes and Outlets to Rainy Lake

The regulation of Rainy Lake levels is accomplished by the international dam at Fort Frances-International Falls (shown in Figure 3). Built in 1910, the dam spans the Rainy River at the former Koochiching Falls, approximately 4 km (2.5 mi) downstream from the natural outlet of Rainy Lake between Ranier, Minnesota and Point Park in Fort Frances, Ontario. Water is conveyed past the dam into the lower Rainy River through the hydroelectric turbines in the two powerhouses (Boise Paper in International Falls, and H2O Power LP in Fort Frances), or through sluice gates on the Canadian side of the dam. There are fifteen sluice gates in total, 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 purposes but was never employed in that manner. Under extremely high water levels, the center of the dam has a spillway to allow the passage of additional flow.

Figure 3. The International Dam at Fort Frances-International Falls

The natural outlet of Rainy Lake, at Ranier Rapids (see Figure 4), is the principal hydraulic feature that limits the maximum rate of flow out of the lake under normal lake level conditions. In basic terms, 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 will vary with the lake level.



Under normal flow conditions, the maximum outflow from Rainy Lake is limited by channel features at the outlet of the lake and along the Rainy River, including Ranier Rapids (and the railway bridge that spans it), the channel constriction at Point Park and the site of the former Koochiching Falls.

Figure 4. Outlet of Rainy Lake and the Upper Rainy River including Ranier Rapids

1.2 Rule Curve Regulation History

With the 1938 *Rainy Lake Convention*, the governments of Canada and the United States gave the IJC the authority to determine when emergency conditions exist in the Rainy Lake basin and to adopt control measures with respect to existing dams at Kettle Falls and International Falls as well as existing or future dams in boundary waters of the Rainy Lake watershed in the event that it determines such conditions exist. In 1941, the IJC formed the International Rainy Lake Board of Control (IRLBC) and charged it with developing recommendations on regulation. In 1949, following extensive study and public hearings, the IJC issued the first Order establishing regulation by Rule Curve for Rainy Lake and Namakan Lake, and gave the IRLBC the supervisory authority over their implementation by the dam operators.

The 1949 Rule Curves provided single target levels for each day of the year and were designed to balance the chief concerns of the time: hydropower (Fort Frances and International Falls were relatively young industry towns whose prosperity depended on the mill industry), riparian interests (the area had recently experienced an increase in the number of cottage and resort properties) and conservation (one of the most vocal participants in the previous two decades of debate on regulation being the Quetico-Superior Council).

Over the following 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, in order to address concerns over high water risk.

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 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.

In 1993, concerns over the ecological effects of the Rule Curve regulation and navigation concerns for the Namakan Chain of Lakes, were the main issues highlighted in a report provided to the IJC by the Rainy Lake and Namakan Reservoir Water Level International Steering Committee, an independent group created to bring these issues to the attention of the IJC. The following year, the owner of the Namakan and Rainy dams at the time, 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 Rule Curves in response to these submittals. This review took place from 1996 to 1999, and involved extensive investigation of the proposed changes by the Steering Committee. In 2000, the IJC issued a Supplemental Order, revising the 1970 Rule Curves and incorporating some, though not all, of the changes suggested by the Steering Committee. The most significant of the changes involved a reduction in the overwinter drawdown for Namakan Lake by roughly 1 m (3 ft), as well as earlier refill of Namakan Lake in the spring. For Rainy Lake, the Rule Curve revisions were relatively small. The 1970 and 2000 Rule Curves for both lakes are presented in Figure 5. 1970 and 2000 Rule Curves for Namakan Lake and Rainy Lake.

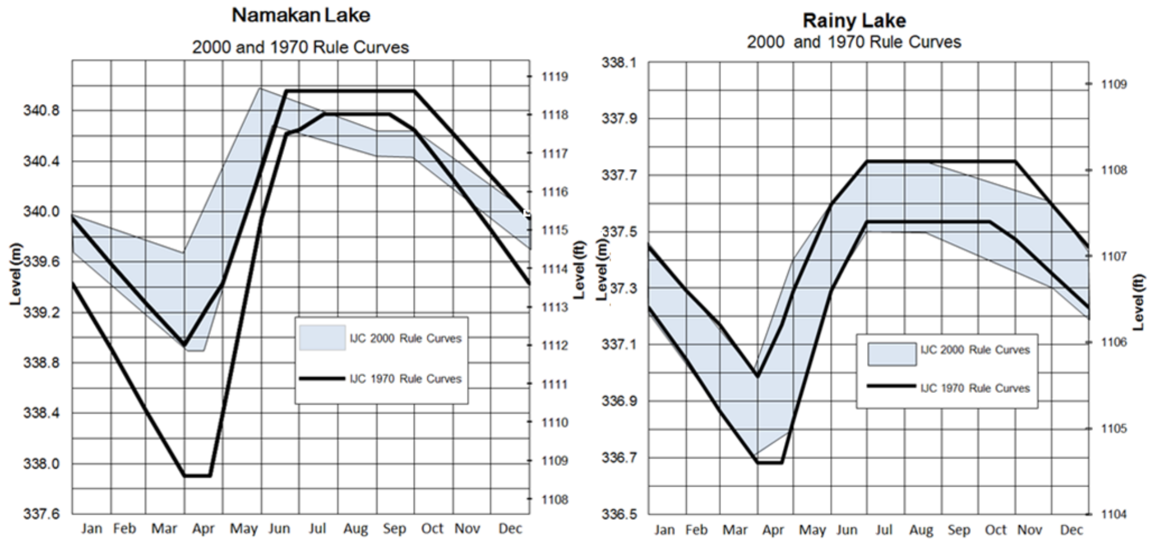


Figure 5. 1970 and 2000 Rule Curves for Namakan Lake and Rainy Lake

The Supplementary Order establishing the 2000 Rule Curves included a requirement that the Order be subject to review fifteen years following its adoption and that the review 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. In anticipation of this review, the IJC established a Plan of Study Workgroup in 2007 to "report on and prioritize the monitoring and analyses required to lead to a scientifically defensible identification of the impacts on the biological and aquatic communities of the adoption of the 2000 Order by 2015 for Rainy and Namakan Lakes and Rainy River" (Kallemeyn *et al.,* 2009). The Plan of Study Workgroup identified a number of gaps in the research that had been conducted in the watershed, the investigation of which was considered necessary for the evaluation of the effect of the 2000 Rule Curves.

Based on the Workgroup's recommendations, the IJC implemented a Plan of Study with investigations deemed necessary to support the review of the 2000 Rule Curves. These included hydrologic model development, hydraulic studies, eco-hydraulic model development, investigations into a variety of ecological factors, as well as effects of water levels on shoreline properties, tourism businesses, and cultural resources. At the time of this report, the majority of these studies had concluded, with several in peer review and two scheduled for completion in 2016 (see Appendix A: List of Studies in Support of Rule Curve Review). Other studies germane to the evaluation of the 2000 Rule Curves, but not included in the Plan of Study, have been conducted either by agencies or through the IJC's International Watersheds Initiative (also listed in Appendix A: List of Studies in Support of Rule Curve Review). 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 IRLBC were assigned to the Water Levels Committee (WLC) of the IRRLWB.

1.3 Review of 2000 Rule Curves

With the creation of the Study Board in August of 2015, the IJC has initiated the formal review of the 2000 Rule Curves. In its Study Board Directive and Terms of Reference, the Study Board is directed 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…".

One of the first activities carried out by the Study Board was to host several information sessions with identified stakeholder groups to describe the review and solicit early feedback on key considerations for investigation (for details, see Appendix B: Key Themes Emerging From Initial Stakeholder Meetings). Based on feedback received at these meetings and the experience of its members in the basin, the Study Board understands that there exists a broad range of interests and concerns in the basin that are affected by the regulation of Rainy Lake and Namakan Lake water levels. These include, but are not limited to, ecological concerns (*e.g*., fish, wild rice, loons, etc.), riparian property interests, hydropower businesses, tourism businesses, and recreational uses.

The Study Board also recognizes that the extreme high water conditions of 2014 (the highest since 1968 for Namakan Lake and since 1950 for Rainy Lake and the highest on record for the Rainy River), as well as other high and low water years since 2000, have raised public interest in the basin in how these lakes are managed. The remainder of this document details the Study Board's plan for evaluating the 2000 Rule Curves as well as possible alternative rule curves and describes how it will do so in a way that is scientifically defensible and also engages those who are interested in or affected by water regulation, so that any recommendations that it develops address and balance their various concerns and preferences.

2 Objectives and Scope

Based upon the IJC's Directive and the Terms of Reference for the Study, the Study Board's overarching goal is to provide the IJC with options and recommendations for regulating levels and flows from the Rainy-Namakan system in order to benefit all interests and the ecosystem as a whole. This is to be done in a manner that conforms to the requirements of the *Rainy Lake Convention* of 1938. The Study Board has established the following key objectives as necessary for achieving this goal:

1. To evaluate the performance of the 2000 Rule Curves in comparison to the 1970 Rule Curves and State of Nature[2] (SON), 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 reflects 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 geographic scope of the Study, including modelling efforts in support of study decisions, 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. The study will 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 Namakan Lake and Rainy River. The Study Board will, however, seek and consider input by downstream interests at Lake of the Woods and the Winnipeg River on any draft recommendations that are made since they may be affected by changes in regulation of Rainy Lake.

During initial stakeholder meetings in September 2015 (see Appendix B: Key Themes Emerging From Initial Stakeholder Meetings for details), a number of suggestions were made to the Study Board on alternatives for regulation of Rainy Lake and Namakan Lake and other areas for investigation. The Study Board has reviewed and considered all of these within the context of the Study Board Directive and Terms of Reference, and has determined that the following suggestions that were raised are either outside the scope of the study, cannot be completed within the time and resource constraints of the study, or are not likely to result in improvements to the regulation of Rainy Lake and Namakan Lake:

1. **Coordination of regulation with other dams in the watershed or the construction of additional dams for flood storage.** The IJC only has authority over control structures in the boundary waters, which to date only include the dams at Namakan Lake and the Upper Rainy River (an uncontrolled concrete weir, the Prairie Portage Dam, is at Basswood Lake, also a boundary water). Other structures in the watershed, therefore, are outside of the scope of the evaluation. It also is beyond the mandate of the IJC to

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[2] 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 paucity of pre-dam data in these areas, it will necessarily be an approximation of actual pre-dam conditions.

pursue or investigate the development of other impoundments that are not within boundary waters.

2. **Development of regulation alternatives that incorporate Rainy Lake outlet modification at Ranier Rapids.** As described in Section 1.1, this natural constriction, as well the abutments on the railway bridge that traverses it, limits the rate of flow out of Rainy Lake. In periods of high inflow to Rainy Lake, this limitation prevents high rates of Rainy Lake outflow if the lake level is not sufficiently high and results in an uncontrolled rise in the level of Rainy Lake. The Study Board received suggestions that enlarging this outlet could improve outflow capacity and should be examined as part of the Study in order to address high water concerns. This, however, is beyond the scope of the Study, which is focused on Rule Curve alternatives and associated regulation.
3. **Adopting a real-time regulation approach where decisions on flow regulation are made by a full-time regulation board, rather than by the dam operators according to rule curves.** This approach, which is used in other jurisdictions such as Lake of the Woods and, to some degree, at the St. Lawrence River, is not within the scope of this study.

Other suggestions heard and listed in Appendix B: Key Themes Emerging From Initial Stakeholder Meetings will be considered as the Study Board establishes which alternatives it will evaluate in comparison to the 1970 Rule Curves, 2000 Rule Curves, and SON flows and water levels.

3 METHODOLOGY

3.1 Overview

In its 2009 report, *The Plan of Study (POS) for the Evaluation of the International Joint Commission (IJC) 2000 Order for Rainy and Namakan Lakes and Rainy River*, the Rule Curve Assessment Workgroup recommended that the evaluation of the 2000 Rule Curves in 2015 employ a Weight of Evidence (WOE) approach. This approach involves an expert panel assessing whether the 2000 Rule Curves resulted in a benefit, a disbenefit, or was neutral with respect to a range of specific outcomes. Results of these individual assessments are brought together in a simple matrix to display the full range of effects of the Rule Curves.

In 2014, as many of the Plan of Study investigations (see Appendix A: List of Studies in Support of Rule Curve Review for a detailed list) were nearing completion, the scientists and stakeholders took stock of the results obtained to date. 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 in a studied subject since 2000 was a result of regulation under the new Rule Curves and not to one or more other influences. For example, there has been an increase in frequency of years with high inflow in the spring since 2000, see Report on High Water Levels in the Rainy River Watershed in 2014 (WLC, 2015). Additionally, the WOE approach was intended only for the analysis of the changes observed due to the implementation of the 2000 Rule Curve 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 flow scenarios.

In order to more thoroughly evaluate the 2000 Rule Curves and potential alternatives to it, the IJC directed the Study Board to undertake a Shared Vision Planning (SVP) approach as a complementary analysis to the WOE approach. This approach, which had proved useful for similar problems in other watersheds, aims to provide a comprehensive, participatory and transparent evaluation process, and allows the evaluation of a range of rule curve alternatives under various water supply scenarios. Details on the background of the SVP approach are provided at the Study Board website, http://ijc.org/en_/RNLRCSB.

The remainder of this section details the Study Board's proposed methodology for conducting the WOE and SVP analyses in support of the study objectives. It describes each approach and the required inputs, followed by an explanation of the planned approach for developing the inputs and analyses.

3.2 Weight of Evidence (WOE) Analysis

The WOE approach is a relatively straightforward assessment, where the results of each study are evaluated to determine whether the subject being studied has improved, worsened, or not been affected since the adoption of the 2000 Rule Curves. WOE comparisons will generally be limited to the data collected (such as fish populations) and it might not be possible to draw conclusions about related factors (such as spawning success). Looking at the collective results from all studies gives an overall view of the changes since 2000.

The Study Board will consider the results of all studies and complete a preliminary matrix classifying each. An example of such a matrix is provided in **Table 1**, which shows a first view of how the study results will be tallied. These will be compared to expectations for the new rule curves to determine if the new rule curves performed as expected. Feedback on these initial classifications will be solicited from the authors of the WOE studies as well as from the Rule Curve Public Advisory Group and the Resource Advisory Group (see Appendix C: Roles and Responsibilities for details on these groups) before finalizing the results of the WOE analysis.

Table 1. Example of Weight of Evidence Matrix

	Namakan Reservoir			Rainy Lake			Rainy River		
Weight of Evidence Study Issue	Better	Neutral	Worse	Better	Neutral	Worse	Better	Neutral	Worse
1. Fish									
Northern Pike Population									
Walleye Population									
Lake Sturgeon Population									
Walleye Spawning									
Whitefish Population									
Mercury Availability									
2. Wildlife									
Beaver Population									
Common Loon Reproductive Success									
3. Economic Impacts									
Power Production									
Flooding and Ice Damage									
Resort Industry									
4. Cultural Resources									
Condition of Resources									
5. Vegetation									
Cattail Invasion									
Wetland Monitoring									
6. Invertebrates									
Invertebrate Community									
Mussels									
7. Water Quality									
Trophic State									
Municipal & Fish Hatchery Water Use									

In this example of a Weight of Evidence Matrix, specific studies are grouped by category and rating choices are provided if applicable (black boxes indicate no study in this location). For each applicable location, study results are reviewed and a judgement is made as to the effect of the 2000 Rule Curves on the study subject (e.g., better, worse, or neutral). The actual Weight of Evidence Matrix for this study may differ from this example, depending on the results of the supporting studies.

The WOE approach is based on what was observed since the adoption of the 2000 Rule Curves. The strength of this approach is that it provides evidence based on collected data; the major weakness is that the results could have been influenced by changing factors other than just the implementation of the 2000 Rule Curves. For instance, basin water supplies are known to have differed between the pre- and post-2000 periods, which can also influence many areas of concern in the study area. In completing the matrix, the Study Board will need to judge whether observed effects from individual studies, if any, can be attributed to management under the 2000 Rule Curves; if this cannot be confidently asserted, the matrix will need to reflect this as the aim of the analysis is specifically to assess the effects of the 2000 Rule Curves, and not whether or not there was an observed change in the study issue not driven by the change in rule curves.

3.3 Shared Vision Planning and Modelling Analysis

A Shared Vision Planning (SVP) and modelling analysis will be conducted in order to expand the study beyond the challenges of the WOE evaluation approach. The SVP approach is designed to evaluate different rule curve options by comparing key evaluation metrics from modelled rule curve simulations under various water supply scenarios. The SVP approach is not limited, therefore, by historic data, and allows evaluation of any chosen rule curve alternative and any water supply scenario.

The main products of the SVP approach will be the development of two computer model tools. The first is a two-dimensional eco-hydraulic numerical model called the Integrated Ecological Response Model (IERM) and the second tool is a Shared Vision Model (SVM).

The IERM (Morin *et al*., 2015) is able to model the spatially distributed physical variables of the system (*e.g*., water levels and waves for Namakan Lake and Rainy Lake, flows in the Rainy River, currents, water level, depth, etc.) over time (quarter-monthly time step) and the response of a number of ecological variables to these hydraulic conditions to build habitat models. Simulations can be performed over a period of years under various rule curve alternatives and water supplies. The IERM also contains more simple models linking only water level to different ecosystem resources.

The IERM is integrated in the sense that the habitat models for plants and wetlands that are directly influenced by temporal changes in the physics of the system are reflected in the faunal model. The IERM developed for the Rainy-Namakan system is based on a computation grid covering Rainy Lake and the Namakan Chain of Lakes with a 20-m resolution (Figure 6) and the Rainy River with a 10-m resolution.

These grids were developed from a Digital Elevation Model (DEM) (Figure 7 and Figure 8) to which were coupled hydrological and biological information. This process integrated several habitat models considering key faunal and floral species that are sensitive to water level management. The habitat models used quarter-monthly time steps to analyse four long-term water level series representing measured levels, as well as simulated levels based on natural conditions (absence of water-level management) and two sets of rule curves (2000 and 1970). Each water level time series ranges from 1950 to 2012, and simulated series were generated through hydrologic response models using recorded inflows over the entire period.

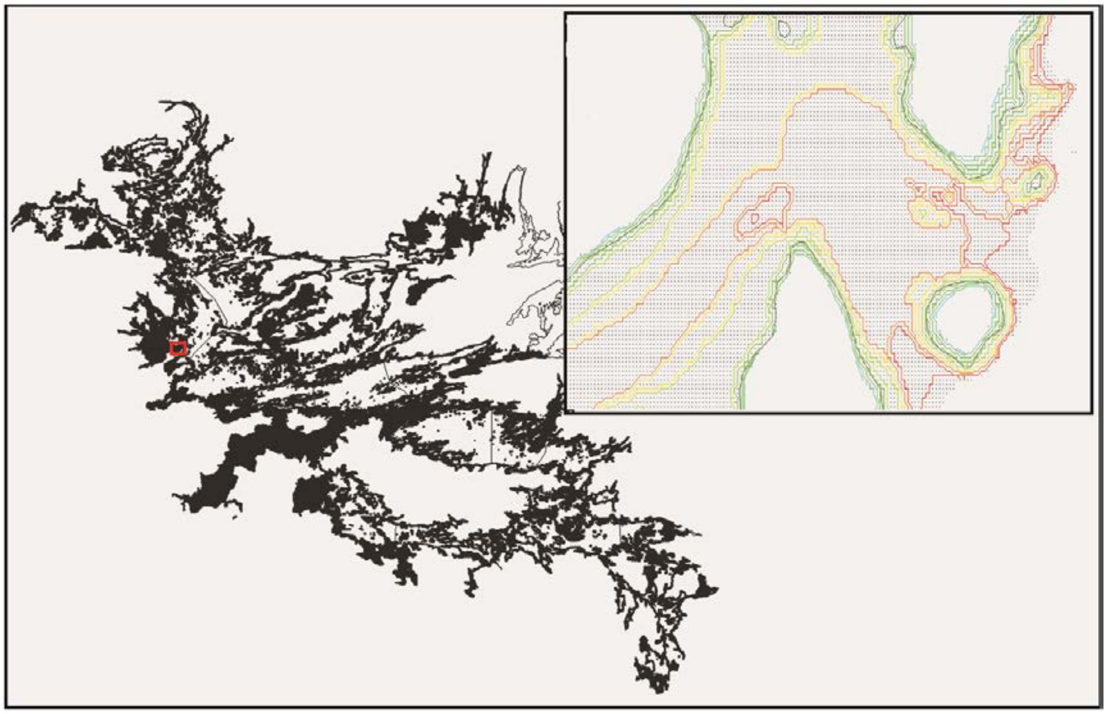

Figure 6. Extent of the IERM2D grid of the Rainy-Namakan system. Black areas represent the distribution of all 1,641,483 nodes. The zoomed box in the top-right corner shows a small section of the grid (20-m regular grid).

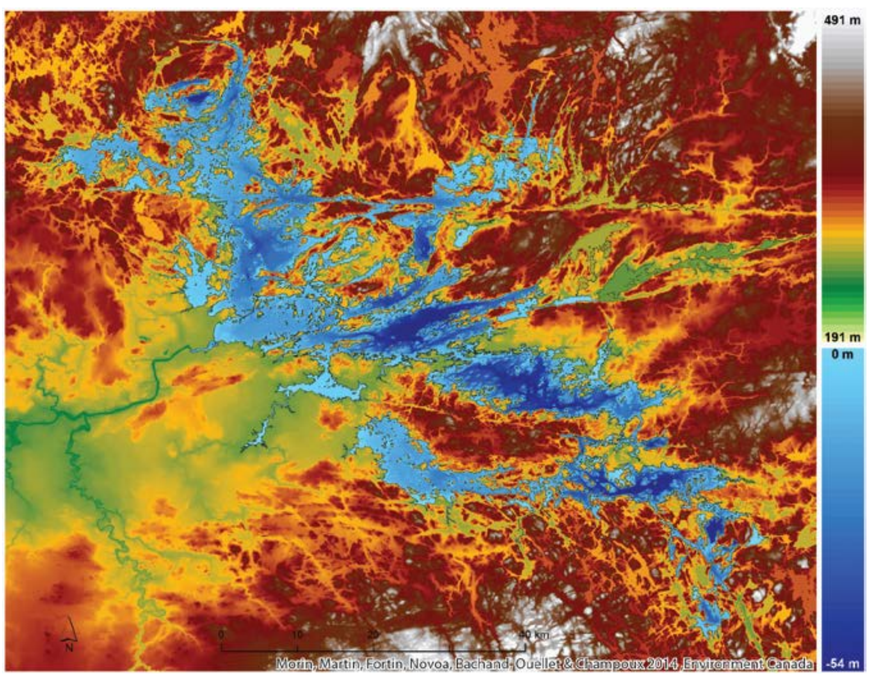

Figure 7. Digital Elevation Model of Watershed. 10-m regular grid showing a seamless topographical sequence (from topographic and bathymetric information based on 8 different datasets)

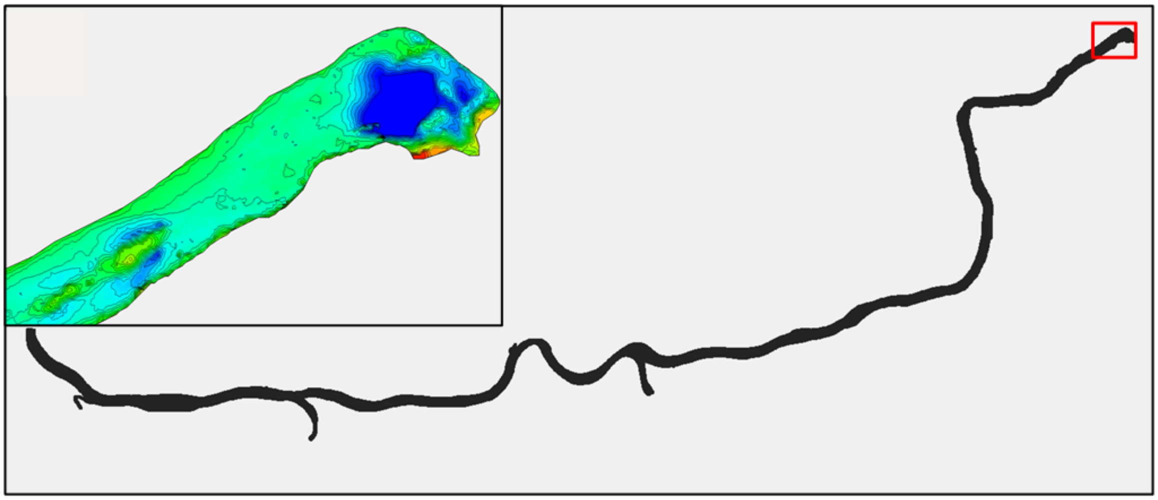

Figure 8. Extent of the IERM2D grid of the Rainy River system. Black areas represent the distribution of all 105,439 nodes. The zoomed box in the top-right corner shows a small section of the grid (10-m regular grid).

For the lakes, several one-dimensional models were produced to evaluate the effect of water level variations on wild rice, common loon, muskrat, and walleye. Based on literature reviews, expert knowledge and available data, the periods during which each species is most sensitive to water level variations and the type of variations that would be detrimental to these species were identified. Spatially explicit two-dimensional models were developed for the lakes to quantify areas of suitable habitat for different taxa: wild rice, cattails, submerged and emergent plants, wet meadows, and shrubby swamps, as well as northern pike and walleye spawning grounds. These models are based on logistic regressions comparing environmental variables (water depth, wave energy, flooding cycles, etc.) in the presence and in the absence of each taxon to predict the probability of occurrence of each taxon at each grid node. The models were also limited by various relevant processes (drying, drowning, vegetation succession, etc.) to predict suitable habitat for each modelled species or group.

For the Rainy River, two-dimensional spawning habitat models were developed for sturgeon and walleye. Physical variables for the river are mainly linked with hydrodynamic models (256 simulations representing various possible conditions) such as currents, shear stress, bottom slope in direction of currents, depth, Froude and Reynolds numbers.

The IERM 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.

The second tool is the Shared Vision Model (SVM), which is primarily designed to interpret results from the IERM, to integrate results from other sources, and to 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 (*e.g.,* 2000 Rule Curves) and water supply set (e.g., drier climate scenario). Water level and flow simulation results will be automatically interpreted against a set of pre-defined evaluation metrics based on results from previously conducted studies (see Appendix A: List of Studies in Support of Rule Curve Review) and modelled ecological outcomes produced by the IERM (see Evaluation Metrics, below, for more details). These evaluation metrics, which represent a quantitative, science-based understanding of the study and model subjects, will form the basis for comparison of different rule curve alternatives under the SVP approach.

The SVM will be designed to be easy to use and understand; this will help develop greater trust in the model and will also allow more people to review and understand the SVM results. The development of the SVM will be an iterative, transparent and interactive process to ensure that the final results are broadly accepted and understood. A schematic of the SVP approach is presented in Figure 9.

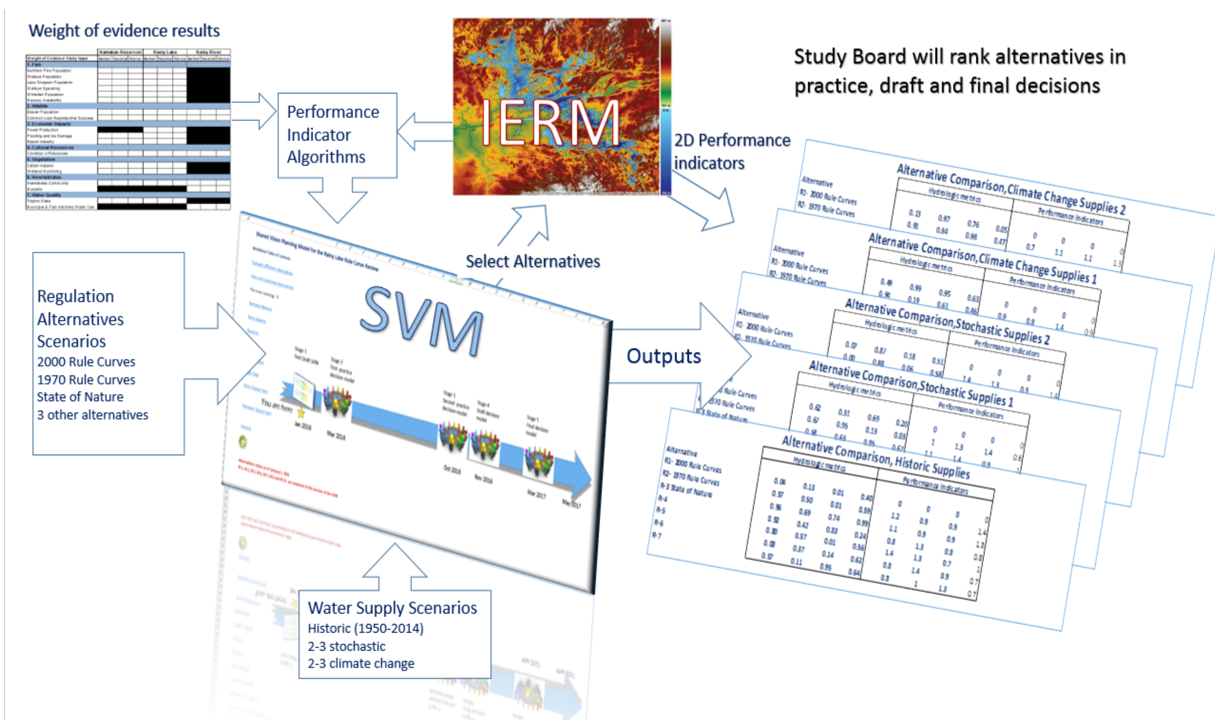

Figure 9. Schematic of Shared Vision Planning Process

The SVM will house water supply datasets, alternative rule curves, and the mathematics necessary to calculate levels and flows for any combination of these. The SVM will directly and immediately evaluate any selected alternative and water supply, producing both hydrologic metrics and performance indicators (see page 29). In some cases, promising alternatives will be run through the IERM for more detailed evaluations that consider how the levels and flow interact with the surrounding topography and ecosystems.

The SVP approach will also be used to establish what water conditions would be like in a State of Nature and to evaluate up to three alternatives to the 1970 and 2000 Rule Curves. In order to account for known variability in basin hydrology, as well as for possible future changes due to climate shifts, all regulation alternatives will be assessed for their relative robustness under a range of possible hydrologic conditions.

Section 3.6 explains how the models will be integrated, while Sections 3.4 and 3.5 describe the essential inputs for the SVM and how these will be developed over the course of the study.

3.4 Shared Vision Model Required Inputs

The essential inputs required for the Shared Vision Model, illustrated in Figure 9, include the regulation alternatives to be considered, water supply scenarios and the evaluation metrics.

Regulation Alternatives and State of Nature

The SVM will be used to evaluate the performance of the 1970 Rule Curves, the 2000 Rule Curves, operation in a SON, and up to three additional alternatives, as required in the Study Board's Terms of Reference. These additional alternatives will be modifications of the 2000 Rule Curves that reflect specific suggestions or areas of concern raised by stakeholders and resource agencies. Some suggestions have already been received by the Study Board at the initial meetings with stakeholder groups and resource agencies held in September, 2015 (see Appendix B: Key Themes Emerging From Initial Stakeholder Meetings for details). Alternatives will be coded in the SVM in consultation with experts in both the operation of the system and the impacts the alternatives are meant to address. The coding of the regulation alternatives into the SVM will reflect the operational constraints of the management system, including imperfect inflow forecasts and lag times for executing flow changes at the dams.

The SON alternative is intended to represent a natural flow regime to which the results of rule curve alternatives can be compared. For this study, SON scenarios will represent water levels and outflows from both Namakan Lake and Rainy Lake in the absence of control structures from their outlets. Details of how the State of Nature will be modelled will be developed during the study.

The SVM will incorporate SON flows from Namakan Reservoir and Rainy Lake. These will be computed using rating curves[3] for each of the lake outlets where dams currently exist. These rating curves will be developed from past studies into the natural release characteristics of the pre-dam outlets. In the case of Namakan Lake, the rating curve is based on work conducted for the original Rainy Lake Reference in the 1930s. For Rainy Lake, more recent data are available

[3] Rating curves are graphs which relate water level to flow in a stream, or at the outlet of a lake. For a given water level, the graph provides the associated flow.

from a two-dimensional hydrodynamic study of the hydraulics of the upper Rainy River above the dam conducted for the IJC by the National Research Council of Canada (NRCC, 2010; 2011). Actual pre-dam measurements are not known to exist for either Namakan Lake or Rainy Lake, so the SON rating curves will necessarily be best estimates based primarily on past studies. The results of the SON model runs will be representative of more natural conditions, but will not be relied upon as detailed and accurate representations of pre-dam conditions. As with all of the other time series of flows in this study, SON flows will be simulated on a quarter-monthly average time step.

Water Supplies

A water supply sequence is a quantification of the amount of water that enters a system over a period of time. The observed historical water supply to the basin since the development of the rule curves is but one sample from an infinite population of possible sequences that could occur in the future or might have occurred in the past. Nature could have produced an alternative flow sequence quite different than the historical sequences observed to date yet having the statistical parameters consistent with the historic data. However, future water supplies are unpredictable, and may depart statistically from those of the past due to changes in climate. Accordingly, the rule curve alternatives will be evaluated for their performance under a range of possible scenarios including: historical conditions, simulated current conditions and possible future climate conditions.

The water supplies that will be used in the SVP process will include the following:

A. Historic Water Supply Sequence

The actual flows are recorded from 1950 to 2014. This flow sequence will allow the comparison of the historic regulation outcomes (actual levels and flows under the various rule curve regimes in place over this period) to specific outcomes from various rule curve alternatives.

B. Stochastic Supply Sequences

Stochastic simulation of hydrological variables is routinely used by hydrologists to assist in evaluating alternative designs and operation rules, particularly where the historical record is relatively short or the risk of impacts is relatively high. The performance of a given regulation plan can be estimated by simulating the behaviour of a water resources system using sequences of inputs that are long enough to contain a large number of potential hydrological scenarios that could occur in the future, including rare and potentially catastrophic events. Stochastic hydrology techniques provide the backdrop for testing the alternative plans, not only for wetter than normal sequences, but for dry sequences as well.

The Study Board will develop a stochastic model based on the historical supply record (1950 – 2014) of the contemporary water supplies. This computational scheme will include the use of an

Auto Regressive Moving Average (ARMA) or an Auto Regressive Integrated Moving Average (ARIMA) Model at the annual or seasonal level and a temporal annual, seasonal, monthly or quarter-monthly disaggregation scheme. If other more practical and statistically acceptable methods are available, these could be used as well. For this analysis, a computer program, Stochastic Analysis, Modelling and Simulation (SAMS), Version 2007, developed at the Colorado State University and employed in two major IJC studies, will be used (Sveinsson *et al*., 2007). The stochastic techniques in SAMS will preserve the essential statistical properties of the historical flow sequences, including features like trends, shifts, outliers, etc. From among a high number of 65-year long water supply series produced, two water supply sequences will be carefully chosen for use in the SVP process and selected to ensure they represent extreme events.

C. Climate Change Supply Sequence

Stochastic flow sequences are generated to conform to the statistical properties of the historical flow record. Because the hydrology of the next few decades is unknown, the Study Board will consider various plausible hydrology test data, including inflows considered more likely under climate change. The Study Board and TWG will develop alternative water supply sets for climate change by leveraging available research on climate change in the basin. In designing and selecting these datasets, the Study Board will focus on water supply conditions that could be most problematic, especially if there is a potential to make a recommendation that would help address potential problems.

Methods for considering future water supply conditions in regulation decisions have evolved over decades. In the late 1950s, the first regulation plans for Lake Ontario were tested using only the supplies recorded from 1860 to 1954. In the 1960s, the U.S. Water Resources Council published bulletins outlining the use of statistical methods and preferred distributions to estimate the probability of different river flows (and hence, flood stages), allowing consideration of floods larger than any recorded. ARMA and ARIMA models allowed the generation of long datasets that were statistically consistent with historic supplies but produced the rare extreme wet and dry supplies that could be expected over a very long period of time. These new datasets could be used in reservoir simulation models to look at impacts in a serial time series. In the 1990s, hydrologists developed procedures for developing hydrologic datasets for use in planning that reflected quasi-periodic climate variations such as those apparent in tree ring records and core samples associated with the long term rise and fall of closed basin lakes. In the mid-1990s, hydrologists began to experiment with ways to integrate global climate change induced by man's increased carbon emissions for the first time. Unlike the stochastic analysis, the challenge with climate change was to credibly characterize a future under climate conditions that had never been recorded. Several methods of downscaling[4] the global circulation model (GCM) outputs such as change in annual average temperature and precipitation over large areas of the

[4] Downscaling is a process for generating local climate data from Global Circulation Models.

world to basin specific hydrologic time series were developed. In the Lake Ontario-St. Lawrence River Study, downscaling was used to create four alternative net basin supply time series representing four possible future conditions associated with different runs of two GCMs. But towards the end of that study, in the mid-2000s, planners criticized these downscaling methods despite the fact that they employed ingenious and reasonable methods to speculate about something that had never happened before;

- the resultant time series were too particular to provide a good test for alternative approaches;
- the final results could not be validated and interim results, such as predictions about inflows under the current climate, were not very good; and
- GCMs and downscaling did not predict persistence or produce time series with longer than historic floods and droughts. The length of a drought can be more important than its peak intensity for reservoir systems because the reservoirs are depleted when the additional year of the drought begins.

In 2010, the International Upper Great Lakes Study (IUGLS) Study Board reduced the role of downscaling and used an approach called “decision scaling”. IUGLS’ decision scaling was based on a wide array of climate research and modeling. It derived its name from its perspective, which was to start with how changed climate could impact important outcomes influenced by the decision, then test regulation plans with water supply series that were plausible. This approach will be used in a simplified manner to test how well alternative rule curves for Rainy and Namakan Lakes will perform under a wide array of possible future water supply sequences representing different plausible climate change conditions.

There are many sources of information about climate change to draw from. The potential impacts to regional precipitation and storm intensity from climate change have been estimated (see Figure 10, for example) at a national or larger scale and these generalized statements can inform the development of water supply datasets that represent the influence of climate change.

There are also regional climate studies that the Study Board will review that will be relevant not only to water supply datasets but also plant and animal communities. For example, Heinz Stefan, University of Minnesota, St. Anthony Falls Laboratory and his collaborators have done a significant amount of work on trends in Minnesota mean annual flows, flood flows, high flows, dates of first spring runoff, spring peak runoff, summer low flow, and winter low flows. Richard Kiesling, USGS, Minnesota Water Science Center who co-authored one of the agency studies that will be considered in the WOE approach has also studied the impact of climate change on algal production.

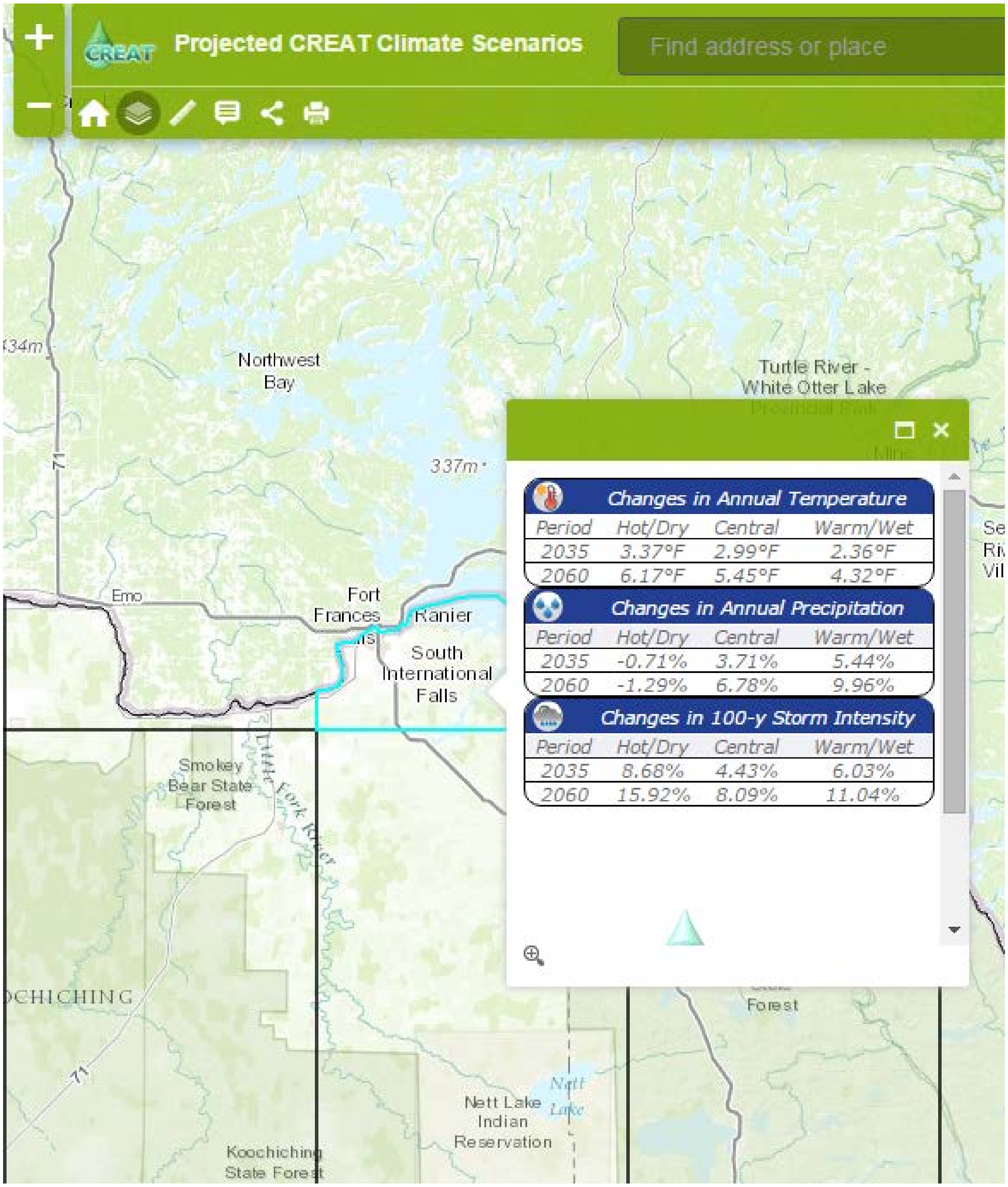

Figure 10. EPA CREAT Website Provides Climate Change Projections by Region

Finally, the Study Board will use general surveys of climate impacts to alert it to issues that should be considered. For example, the IJC's Great Lakes and St. Lawrence River Adaptive Management Committee (http://ijc.org/en_/GLAM) has commissioned three small efforts at part of its "surveillance" of trends that will affect future water management decisions on the Great Lakes. The three efforts are designed to notice research related to economic and environmental trends, including climate change, which would affect the Great Lakes. Some of the findings from this work will be useful even outside the Great Lakes.

The TWG will use simple techniques such as bootstrapping to modify historic and stochastic time-series data to reflect these findings. Alternatives in the SVM will be evaluated using these sequences.

Evaluation Metrics: Hydrologic Metrics and Performance Indicators (PIs)

For a given rule curve alternative and water supply scenario, the SVM and IERM will simulate a time series of water levels (Namakan Lake, Rainy Lake, Rainy River) and outflows (Namakan Lake, Rainy Lake) and Rainy River flows and levels. The next step is to methodically evaluate how these hydrologic outcomes, as water levels and flows, correspond quantitatively to other derived outcomes of importance, such as frequency of high water events, loon nesting success, fish spawning success, flooding damages, etc. In this way, each of these derived outcomes can be quantified and 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 each other since they will all use the same evaluation metrics. These metrics fall into two general categories - Hydrologic Metrics and Performance Indicators (PIs).

Hydrologic Metrics are straightforward statistics on measureable 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 hydrologic metrics will be developed by the Study Board based on past studies and discussions with stakeholders in the study region. The SVM will be programmed to measure the performance of all rule curve alternatives and SON according to these metrics.

PIs are used to quantify other non-hydrologic outcomes that are a function of water level and flow model results. For example, a PI for wild rice could be a percentage of years that wild rice would be expected to grow successfully over a specified time period. A key aspect of PIs is that they are quantitatively related to hydrologic outcomes, and therefore are amenable to modelling. The mathematical relationships that tie water levels and performance together are PI functions. For example, a PI function for flood damages might be structured to return zero damage for water elevations below a certain level, and then incremental damages of ten thousand dollars per inch above that level. If the baseline plan produced $50,000 in flood damage, and an alternative could reduce the peak level by two inches, the flooding damages for the alternative would be $30,000 for that event, creating a net benefit of $20,000. Not all PIs will be measured in dollars, so for now the results of the PI calculations are referred to as scores or results. Figure 11 illustrates a hypothetical sample of PI scores for individual model runs, each pairing a specific rule curve alternative with a specific hydrologic sequence, but all being measured and compared using the same set of PIs. In this example, the PIs are reported as ratios of the alternative score to the baseline score. The 2000 Rule Curves are to serve as the baseline for comparison of PIs from other alternatives.

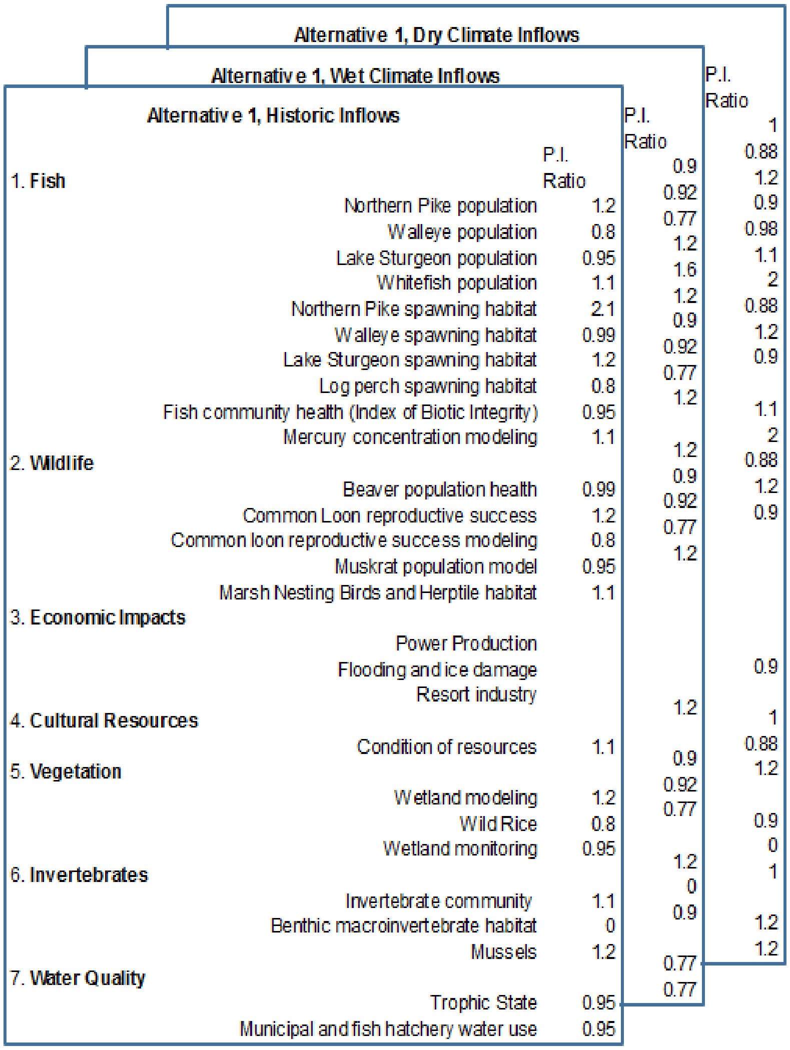

Figure 11. Example of Performance Indicator Outputs for SVM Simulations

The Study Board and TWG will examine the results of all supporting studies for possible PIs that are amenable to being integrated into the SVM or the IERM, including those used in the WOE analysis. These include studies from the IJC's Plan of Study and International Watersheds Initiative, as well as other studies published independently by agencies active in the watershed (see Appendix A: List of Studies in Support of Rule Curve Review for a complete list). As of December 2015, most of the Plan of Study studies have undergone peer review and been accepted by the IJC or are undergoing peer review. The balance of studies is expected to be completed in early 2016. As the studies become available, the Study Board and TWG will review them with the intent of producing a set of PIs supported by this research.

In cases where there are no existing studies to support the development of needed PIs, the Study Board will attempt to develop the required information. Hydropower, for example, is an interest for which no investigation was conducted as part of the Plan of Study. The Study Board will seek to work with the hydropower companies to develop appropriate PI functions.

In some cases where results from the Plan of Study related to ecological subjects cannot be used to develop simple PIs directly in the SVM, the IERM will be used to model responses to simulated water level changes, and these modelled results will be used to develop PIs. Some of the ecological PIs modelled in the IERM may not be suitable for inclusion in the relatively simple SVM. In those cases, the TWG will attempt to develop a simplified PI in the SVM that can be used to screen results, with the IERM used to verify results for alternatives that screen well. For other indicators, it may be that simplifying the indicator for inclusion in the SVM makes the results too unreliable even for screening. In that case, the IERM will be used after the SVM evaluations to add the results from the more complex indicators, and the IERM results will be copied into the SVM to be used in alternative comparisons. This combined model approach is referred to as the Joined SVM.

Table 2 summarizes the studies which will be reviewed for potential PI development based on data collected in the supporting studies or on modelled data from the IERM. The TWG is examining the possibility of adding a small number of additional modelled ecological PIs not listed here in order to have a more robust analysis.

Table 2. Possible Performance Indicators from WOE Studies and IERM Models (black boxes indicate no study available)

Indicator	Namakan Reservoir	Rainy Lake	Rainy River
1. **Fish**			
Northern Pike population	Yellow	Yellow	Black
Walleye population	Yellow	Yellow	Black
Lake Sturgeon population	Yellow	Yellow	Black
Walleye spawning	Yellow	Yellow	Black
Whitefish population	Yellow	Yellow	Black
Northern Pike spawning success model	Red	Red	Black
Walleye spawning success model	Red	Red	Red
Lake Sturgeon spawning habitat	Black	Black	Red
Log perch spawning habitat	Black	Black	Red
Fish community health (Index of Biotic Integrity)	Black	Black	Yellow
Mercury availablity	Red	Red	Black
2. **Wildlife**			
Beaver population	Yellow	Yellow	Black
Common Loon reproductive success	Yellow	Yellow	Black
Common loon reproductive success modeling	Red	Red	Black
Muskrat winter survival model	Red	Red	Black
3. **Economic Impacts**			
Power Production	Black	Red	Black
Flooding and ice damage	Red	Red	Black
Resort industry	Yellow	Yellow	Black
4. **Cultural Resources**			
Condition of resources	Yellow	Yellow	Yellow
5. Vegetation			
Wetland modeling	Red	Red	Black
Submerged plant model	Red	Red	Black
Cattail invasion	Yellow	Yellow	Black
Cattail modelling	Red	Red	Black
Wild rice germination and growth model	Red	Red	Black
Wetland monitoring	Yellow	Yellow	Black
6. **Invertebrates**			
Invertebrate community	Yellow	Yellow	Black
Mussels	Black	Black	Yellow
7. **Water Quality**			
Trophic State	Yellow	Yellow	Black
Municipal and fish hatchery water use	Black	Black	Yellow
	Yellow	Potential PIs from Weight of Evidence	
	Red	PIs from Model-based Studies	

Water Level and Flow Modelling

Together, the SVM and IERM will be used to simulate lake levels and outflows from Namakan Lake and Rainy Lake, as well as Rainy River levels under the specific regulation alternative and water supply set that apply to a specific model run. As part of the Plan of Study, a model of lake levels and outflows from Rainy Lake and Namakan Lake was developed (Thompson, 2014). This Excel-based model simulates outflow decisions from Namakan Lake and Rainy Lake and computes the resulting water levels for the lakes on a quarter-monthly time step for the historic inflows from 1950-2014 under both 1970 and 2000 Rule Curve operating rules. This model will be incorporated into the SVM to provide the required hydrological data.

The IERM will include the Rainy River in an integrated simulation of the impacts of water levels throughout the system in order to extend the evaluation of PIs to the river. A two-dimensional hydrodynamic model of the Rainy River downstream of the international dam that has been developed as part of the Plan of Study and will be used to simulate the levels with the flows generated by the individual model simulations.

3.5 SVP Development and Analysis

Sections 3.3 and 3.4 provided the basic explanation of the SVM and IERM tools and the essential components that the Study Board must assemble for their use. This section describes the general approach the Study Board and TWG will take to complete this development and carry out the analysis. Conceptually, the SVP process is comprised of six stages as depicted in Figure 12. Practically, individual stages are expected to overlap, as data requirements and inputs for the model are developed. A timeline for the development of core activities is provided in Figure 13. SVP is an iterative process, so the activities featured in different stages will occur to a lesser extent in other stages. For example, most plan formulation will occur in the Compilation and Preparation stages, but it will continue at some level until near the end of the study.

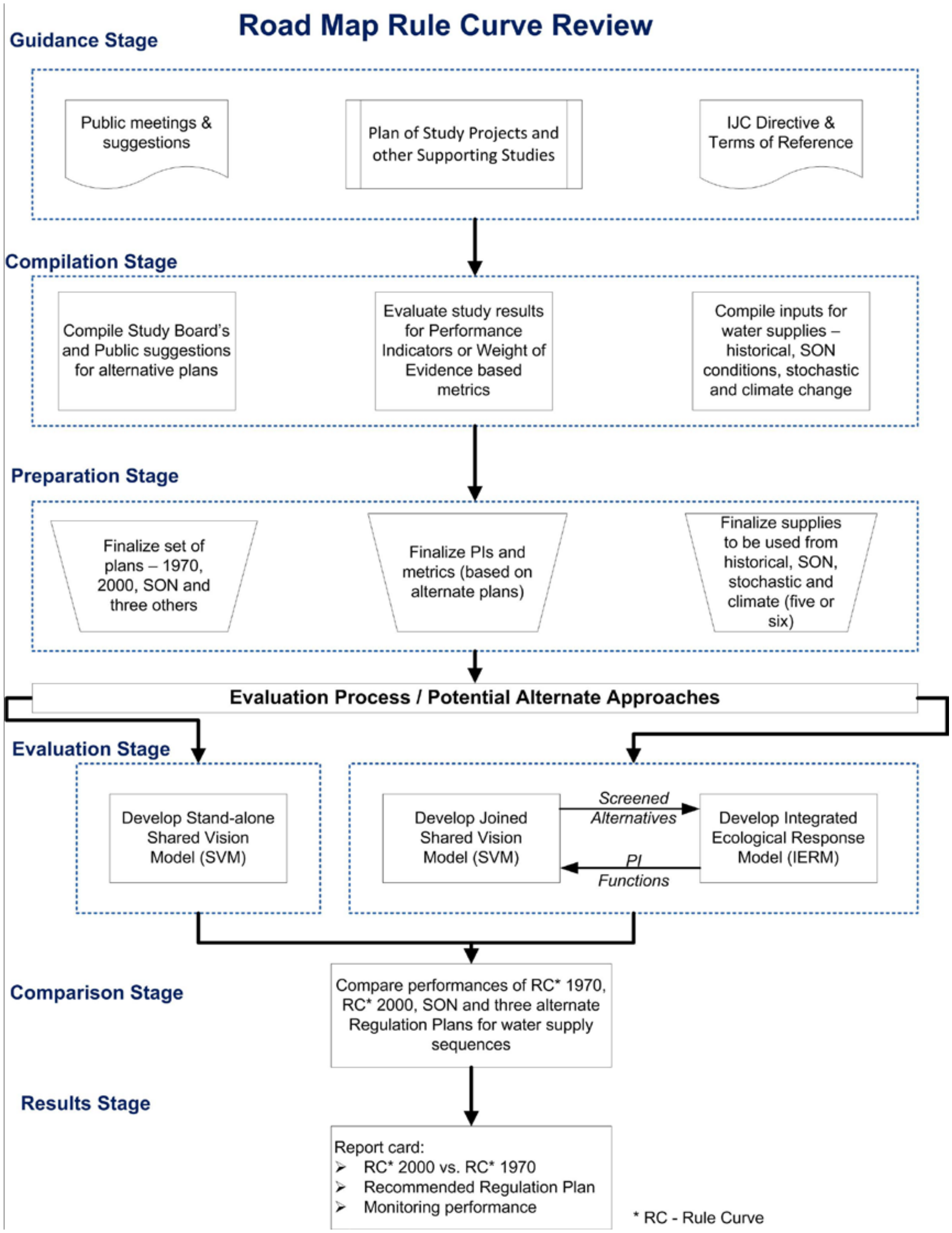

Figure 12. Shared Vision Planning Stages

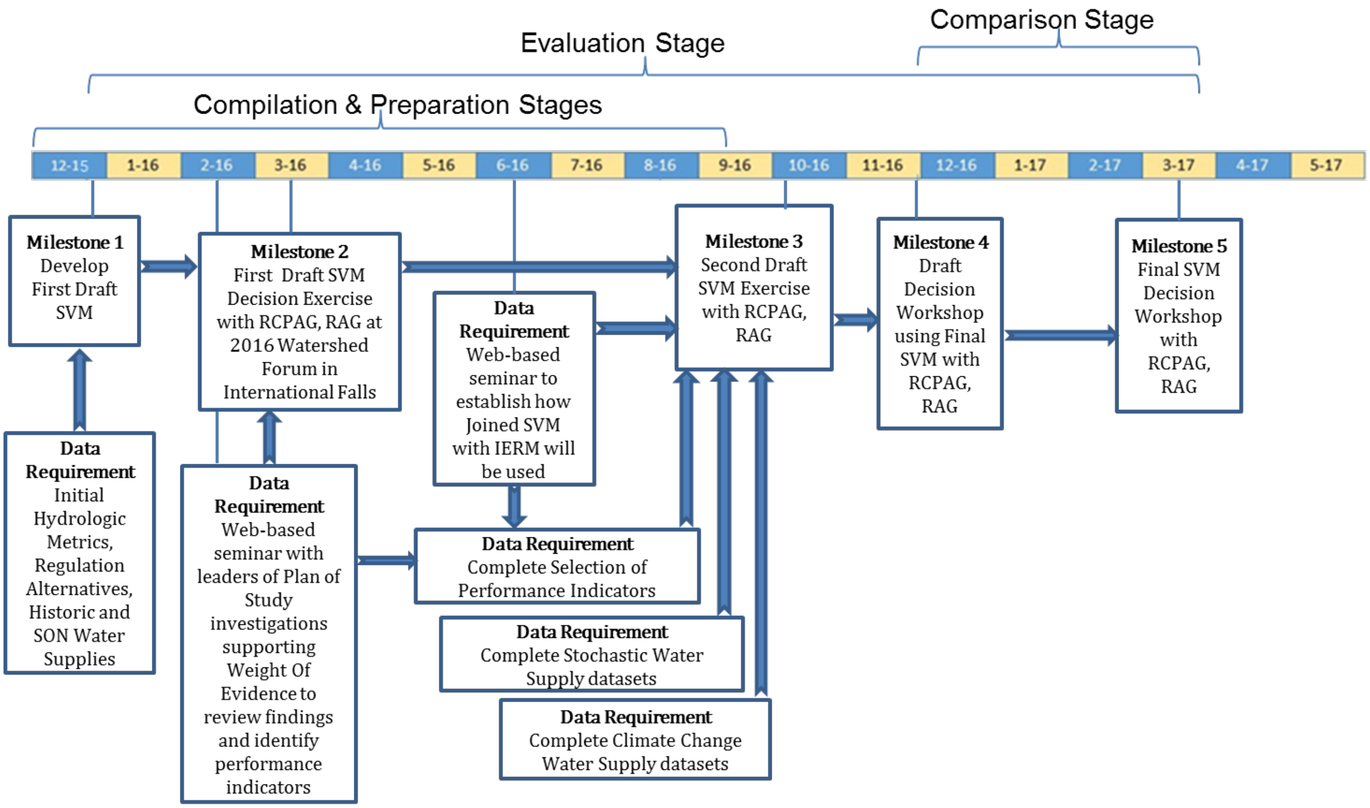

Figure 13. Core Activities in Shared Vision Modelling for Rule Curve Review

Guidance Stage

The initial stage involved collecting the information that is the foundation of the study, including the Directive and Terms of Reference, early feedback on the 2000 Rule Curves from stakeholder groups and resource agencies and reports from supporting studies. With the exception of a small number of reports that are due to be completed in the coming months, this stage is complete.

Compilation Stage

The aim of this stage is for the Study Board to process and understand the materials collected in the Guidance Stage in addition to seeking the other requisite data and inputs necessary to prepare for the assessment. This includes the review of input to support development of the three alternative rule curves, early identification of potential PIs and Hydrologic Metrics, and the acquisition or development of water supply information (stochastic, climate change, SON). This stage is active as of the writing of this report and is expected to continue into mid-2016.

Preparation Stage

With the resources and initial analysis collected in the Compilation Stage, the Study Board will make decisions on the data sets required for the SVM and the TWG will program the First Draft SVM using these. The First Draft SVM will simulate lake levels and flows according to the 1970 and 2000 Rule Curves, but will also include a SON time series and may include new Rule Curve alternatives. Hydrologic metrics proposed to date will be included in this version, but it is unlikely there will be any PIs modelled as the compilation of PIs is not expected to be complete by this time. The hydrologic metrics and model displays will be informed by communication with Study Board members, scientists, RCPAG and RAG members and other interested parties.

Evaluation Stage

The Evaluation Stage is expected to be the longest and is where the RCPAG, RAG and the general public will be most involved. There are five milestones planned in this phase, each representing a further development of, or analysis with, the SVM and IERM. Also shown in Figure 13 are the key data requirements and where these are expected to be included in the SVM.

As the SVM is developed, and more data requirements are assembled and added, the Study Board will undertake decision exercises with the RCPAG and RAG. These exercises allow for the review of the model inputs and performance, and will generate feedback for improving these before the next milestone. The exercises will also serve to teach the participants how to use the SVM and will give them experience and practice in the process for reviewing model results and developing conclusions that will serve the process in the subsequent exercises and decision workshops. The Study Board will hold the first Decision Exercise in a workshop at the International Rainy-Lake of the Woods Watershed Forum in March, 2016. The details of the modifications will be developed in early 2016, but they are expected to include:

- More detailed modelling of one or two alternatives;
- The inclusion of preliminary alternatives to the historical water supply data;
- Specific displays useful in illustrating trade-offs required by most promising alternative; and
- Simple comparisons between alternatives designed to support ranking by the Study Board.

This model will be archived for future reference and made publically available. Feedback from the first practice decision will be used to inform plan formulation and evaluation and the design of future SVM versions.

After more of the required inputs are added to the SVM, a second Decision Exercise workshop will be held in the fall of 2016. This version will reflect on lessons learned from the first Decision Exercise, and will also include most of the PI algorithms and most of the water supply datasets required for the full SVM study. The version of the model used in the second practice decision will also be archived and made publically available.

Comparison Stage and Results Stage

The last stages of the study involve the development of the final SVM model exercises and the synthesis and evaluation of final results. These will form the basis of recommendations to the IJC by the Study Board.

Once all required datasets have been developed and included in the SVM, a Draft Decision Workshop will be held, likely in November 2016. This will follow the same model as the Decision Exercises, and build upon their results as well as improvements from TWG experimentation between workshops. The purpose of this Draft Decision Workshop is to support the development of a Study Board consensus on draft study recommendations. All the modelling and decision making practices to this point will have been designed to provide maximum input from experts and stakeholders, but the Study Board's draft positions based on this version will be widely circulated for review and the SVM will be modified per the Study Board's direction to accommodate ideas raised during that review. The results of the Draft Decision Workshop will provide the basis for the Draft Report from the Study Board to the IJC in early 2017, including draft recommendations for changes to the rule curves, if any.

Following public and IJC responses to the draft report, a final Decision Workshop will be held to address comments on the Draft Decision Report and will provide the refinements needed for the Study Board's final report. The final version of the SVM is expected to be a modest refinement of the final draft model that captures additional ideas generated during review of the draft decisions and model (during final Decision Workshop), features the two or three most promising of all of the alternatives and decision support information that the Study Board can use to explain and document the final ranking of plans and selection of the recommended alternative for IJC consideration.

3.6 Using Weight of Evidence, Shared Vision and IERM Models Together

The distinct nature of each source of information is the most important predictor of how each will be used by the Study Board. Only the WOE studies provide real observations of the system, but the observations are over a particular and limited set of circumstances. The SVM uses evidence-based algorithms in a large Microsoft Excel spreadsheet to estimate the performance of alternative rule curves over much more varied circumstances. The IERM will also be used to estimate outcomes from the rule curves using both hydrologic and topographic modelling for which Microsoft Excel is not advisable (*e.g.*, two-dimensional computations). The Study Board expects that the IERM will both support and supplement the SVM. Some of the IERM results are expected to be translated into algorithms that can be coded as SVM PIs, but there will be other PIs that can be estimated only by the IERM.

The SVM will be the primary tool for evaluating alternative rule curves and regulation plans because it is fast and relatively easy to use and understand. If there are PIs that can be estimated only in the IERM, then the two models will be used together. It may be that the SVM will be used to screen alternatives and the IERM will be run to evaluate alternatives that survive a screening process. This process will evolve as the PIs are finalized as part of this study.

Because the WOE studies document actual results, both the SVM and IERM will be compared to the study results. The "hybrid" analysis will apply the SVM and IERM to the 2000-2014 period (and to the extent possible with data gathered from 1970-2000) with actual levels and flows to determine if the PI results predicted by the models are consistent with the observed facts. Differences will be analyzed and models calibrated if feasible.

The exact way the Study Board considers these three sources of information can only be known as the details are developed over the course of the study, but the following approach can reasonably be expected:

- As the Study Board and TWG go through the WOE studies, the Study Board will work to develop a consensus around the degree to which the evidence shows the 2000 Rule Curves delivered their intended consequences over the fourteen-year sample period.
- Performance Indicators will be incorporated into the models, either based on the WOE studies or compared to them for calibration and validation.
- The SVM will be used to accumulate a body of knowledge about how alternative rule curves and climate conditions affect things people care about like flooding, boating/tourism, and the environment.
- The IERM will be run by the TWG to evaluate rule curves that produced promising results in the SVM.
- As the Study Board, outside experts and stakeholders develop a deeper understanding of the tradeoffs from different rule curves, the plan evaluation and ranking process will evolve to address specific issues raised by the new, shared understanding.
- The SVP process is designed to minimize disagreements about facts (not differences in values or self-interest). When the Study Board makes its final recommendations, it will support those recommendations using the WOE, SVM, and IERM. Because stakeholders and outside experts will have been present as the Study Board processed the information, there should be widespread understanding of the recommendations.

3.7 Peaking and Ponding and Minimum Flow Requirements

Peaking and ponding refers to the practice of varying outflow from a hydroelectric reservoir in order to maximize generation at times of higher market value for electricity. Peaking refers to the hour-to-hour flow changes made by a dam operator over the course of a single day. Ponding refers to day-to-day changes made over the course of a week. In general, when electricity demand is lowest, such as during the night and on weekends, outflows are reduced in order to increase storage for future power production.

The IJC Order that defines the 2000 Rule Curves does not include requirements for peaking or ponding and these operations do not generally affect the overall daily or weekly flow and so do not interfere with lake level regulation. Currently, there are informal practices and arrangements in place to avoid fluctuations of flow in Rainy River due to peaking or ponding operations during critical spawning periods. Boise Paper does not currently conduct peaking activities, and H2O Power LP has voluntarily worked with the IJC's WLC and government resource agencies to limit peaking during critical spawning periods. The Study Board, however, received comments from stakeholders that the rules governing peaking and ponding practices should be formalized under any revised regulations for Rainy Lake (See Appendix B: Key Themes Emerging From Initial Stakeholder Meetings). Furthermore, the Study Board was asked that a minimum outflow requirement for Namakan Lake and Rainy Lake, both year-round and seasonal, be established as they are not well defined under the 2000 Order.

The Study Board will provide a recommendation regarding peaking and ponding activities and minimum outflow requirements based on a review of the history of peaking and ponding practices within the basin, investigations into the literature surrounding best practices, SVM and IERM modelling to the extent advisable and through discussions with resource experts and stakeholders.

4 Study Management and Communication

4.1 Governance

Governance of the Study will involve participation and collaboration at several levels, as outlined in Figure 14.

The Study Board's primary role is the evaluation of options for regulating the levels and flows in the Rainy-Namakan system. While the Study Board is solely responsible for developing recommendations for the IJC at the conclusion of the review, it will rely on the advice and input of the groups identified in Figure 14 to ensure the final report reflects the views presented throughout the process.

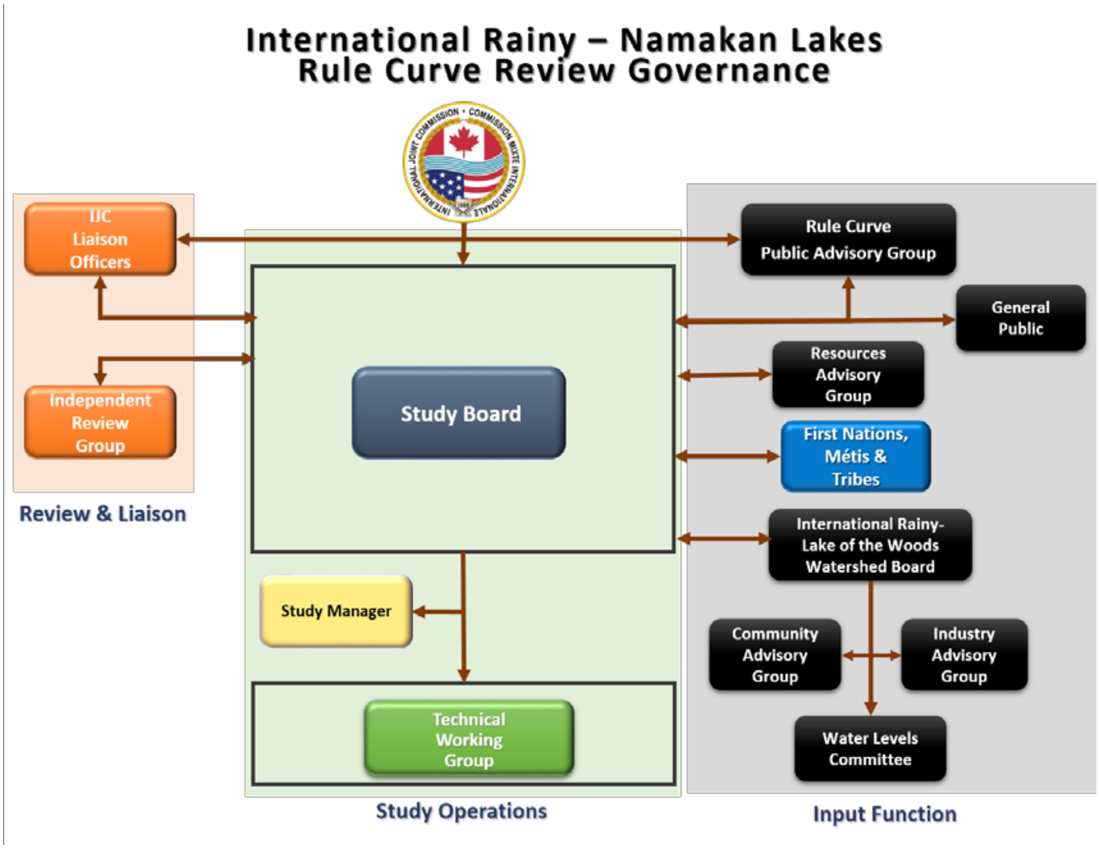

Figure 14. Rule Curve Governance Organizational Chart

The Study Board has worked, and will continue to work, with the IJC to identify key individuals in the study area that are interested in serving on the Rule Curve Public Advisory Group (RCPAG). It is the intention to have members appointed by the IJC who live or operate within the geographic area of the study and represent the following groups:

- First Nations, Métis and Tribes;
- Lake/property owners' associations;
- Navigation interests;
- Local governments and agencies;
- Environmental organizations;
- Tourism and recreation interests;
- Hydro Power companies or organizations; and
- Other interested groups identified by the Study Board that would have a vested interest in the Rainy and Namakan Lake Rule Curve Evaluation.

The Study Board will provide support to the RCPAG and its two co-chairs, via the Study Manager, to organize meetings they may host, post meeting summaries on the Study Board website and distribute documents prepared by the RCPAG co-chairs. The Study Board anticipates meeting with the RCPAG via teleconference when deliverables are being produced and will meet in person with the RCPAG in summer 2016 and at the watershed forums in March 2016 and 2017.

The Study Board has decided to form a Resources Advisory Group (RAG), consisting of members of key resource agencies in the study area who will be consulted throughout the study. The RAG will be asked to comment on all deliverables produced by the Study Board and will be consulted on an as-needed basis by the Study Board when resource expertise is specifically required. Meetings will be held via teleconference and in-person at key points in the study, such as in March 2016, summer 2016 and March 2017 when the Study Board is in the study area meeting with the public and agencies and conducting workshops.

The Study Board has initiated discussion with all of the First Nation communities, Tribes, Métis Nation of Ontario, Grand Council Treaty 3, 1854 Treaty Authority and the Pwi-Di-Goo-Zing Ne-Yaa-Zhing Advisory Services, all within the study area. Contact will be ongoing throughout the study, with invitations to meet and information provided to all indigenous organizations and communities in the study area at each phase of the project. The Study Board has sent a summary of the initial stakeholder meetings to each group and community and has also followed up with additional letters of invite to meet with the Chiefs and Councils and other key individuals.

4.2 Communication and Outreach

Effective communication of the study process and findings is a critical component of this project. As noted in the *Directive for Communication and Public Outreach Activities for the Rainy-Namakan Lake Rule Curves Study* from the IJC, the key objectives of the study's public participation process are 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.

With the assistance of IJC Communications staff, the Study Board will fulfill the objectives stated above and will engage key groups to ensure that the final findings and recommendations are truly a result of extensive engagement, debate and practical, inclusive decision-making. Key groups include:

- Governments at all levels;
- Native Americans/Aboriginal Peoples, including but not limited to First Nations, Métis and Native American Tribes;
- Upstream/downstream riparian interests;
- Commercial navigation;
- Environment;
- General public;
- Hydroelectric power;
- Domestic water supply and sanitation; and
- Recreational boating.

The Study Board has developed a comprehensive contact list that includes representatives from each of these groups and, as it meets more individuals at meetings and through online correspondence, this list is expected to grow.

The Study Board recognizes the importance of clear communication throughout this process in order to ensure that terminology is understandable and consistent and that discussions around evaluation methodologies and results are clear to both the Study Board and the public. To facilitate public outreach and consultation, the Study Board will make information related to the study as widely available as possible, using the Study Board's website as its main venue for posting materials, but also utilizing other approaches as well to disseminate data, reports, summaries, etc. The Study Board will offer the following key communication tools:

- Constantly update the Study Board website to ensure all documents (pursuant to the Commissions' Rule of Procedure), meeting summaries and notices of activities are posted and easy to find;
- Ensure the website is set up to be an easy tool for the posting of comments from the public back to the Study Board;
- Utilize a variety of methods for announcing meetings, given the vast geography and rural nature of the study area (*e.g*., Facebook boosts, postal drops, GIS targeted mailings, flyers, radio, dock to dock visits by students, inserts in utility bills);
- Connect with local partners to enquire about distributing announcements to their memberships or posting meetings on their local websites; and
- Host webinars to brief media, in conjunction with any public meetings or comment period.

The Study Board, together with the IJC Communications staff, have developed a Communication and Outreach Schedule for the duration of the Study that promotes regular internal Study Board communication and takes advantage of existing networking opportunities in the study area for reaching out to stakeholders. Ongoing, regular meetings of the Study Board itself to provide members with opportunities for model demonstrations and in-depth analyses of results will occur throughout the process. As well, meetings with the RCPAG, RAG and the public will occur at key points in the project for input and review of deliverables. The Study Board will ensure that in-person meetings are held at different locations within the study geography to encourage public consultation. All meetings will be announced in advance through the media and our growing list of stakeholder contacts for this study. Section 5 details key milestones and dates for the submission of deliverables and public meetings.

4.3 Information Management

The Study Board recognizes that the five years of research under the "*Plan of Study for the Evaluation of the IJC 2000 Order for Rainy and Namakan Lakes and Rainy River (2009)*" as a pre-cursor to this Rule Curve Review and analysis would generate a number of reports and large quantities of purchased, acquired and leveraged data and information, models and associated documentation.

This collection represents a significant investment and legacy of the study. As a result, the Study Board will pursue the following principle with regard to information management - *"The Rainy-Namakan Lakes Rule Curves Study Board encourages unrestricted access to data. Data collected by the Rainy –Namakan Lakes Rule Curves Study will be made available online once it has been approved for distribution by the Study Board and IJC. Most of the data collected by the study will be available to the general public by the completion of the review, scheduled for mid-2017. However, there may be licensed or proprietary information that may not be made available publicly."*

The Study Board, with the technical assistance of the IJC, will address the information management needs of the study. Options and recommendations for the archiving and dissemination of the study's data assets will be developed. The Study Board will also develop an Information Management and Dissemination process to provide external parties with access to the study's data and information to help meet water level analysis and management objectives.

The Study Board will also develop a web-based dynamic decision-mapping system to ensure the transparency of the Study Board's decisions similar to the one developed for the International Upper Great Lakes Study (http://www.iugls.org/Decision_tree_tool).

4.4 Independent Review Group

As was the case during the Rule Curve Plan of Study, the IJC aims to ensure that the Rule Curve Review is conducted with both internal and external technical scrutiny in a transparent process. The RCPAG, with its broad membership of stakeholders, will be involved in key aspects of study oversight and direction, as will the RAG, the IJC, the Study Board and the TWG.

The IJC, however, is interested in another, more targeted and timely Independent Review Group (IRG) that is separate from the Study Board and its advisory groups and has additional expertise on key issue(s) identified by the Study Board, which may not receive the appropriate technical review that is warranted for the subject matter, otherwise. In addition, there may be issues that are raised by the RCPAG which require a degree of "scientific refereeing", particularly when there is a substantive scientific debate on unresolved issues. An example of this is the interpretation of climate change and water supply scenarios and their application to real-time and operational water management. Overall, though, the IRG function is structured in such a manner that the IJC itself will manage the IRG process, and the IRG will report directly to the IJC.

Based on the experiences gained in the recently concluded IUGLS, the IRG process is to be engaged not only to provide a scientific scrutiny of the adopted approach but also to provide an advisory function at the key stage of scoping the evaluation methodology for the Rule Curve Review. It is proposed to have the following key features embedded in the IRG process:

- The overarching charge shall be to evaluate the appropriateness and sufficiency of the studies and models used to inform decisions related to the rule curve changes. Recommendations from the IRG process shall be limited to those deriving from this overarching charge and shall not address other esoteric elements.
- The rule curve impact assessment science, as represented in the review/analysis and any model documentation provided shall be assessed by the IRG in terms of the degree to which:
    - the models and reports are sufficient and appropriate to evaluate the rule curve review options and impacts of changes in water levels and flows;
    - the studies reflect reasonable scientific methods, assumptions and supported findings; and,
    - the models sufficiently and appropriately integrate and display the key information needed for a comprehensive evaluation and understanding of the sector being evaluated.

5 SCHEDULE AND DELIVERABLES

The schedule of activities and deliverable milestones are illustrated in **Table 3**. These include key engagement and decision-making milestones, as well as the proposed schedule for the release of draft reports and products.

Table 3. Key Milestone/Deliverable Schedule

Date	Key Milestone/Deliverable	Comment
2015		
Early December	Draft Evaluation Methodology	Submit to IJC/IRG for Peer Review

2016		
Mid February	Public Comment Period on Draft Evaluation Methodology	Post on Study Board website, distribute to contacts, IRLWWB, CAG, IAG, RCPAG, RAG
Mid-March	Practice Decision Workshop #1 and Public Meetings; public comments due	Comparison of results from 1970 and 2000 Rule Curves using hydrologic statistics and historic water supplies
Mid-April	Progress Report to Commissioners	Semi-annual Meeting of IJC
June/July	Public Meetings – locations to be determined after consultation with RCPAG	Study Board to break up into teams; host meetings over several days
June/July	Meeting with RCPAG and RAG	In-person
August	Progress Report/feedback during IRLWWB annual basin meetings	Updates to IRLWWB
September	Consolidation Report of previous Rule Curve Studies	Submit to IJC and TWG
October	Practice Decision Workshop #2	Utilization of PIs and alternative water supplies
October	Progress Report to Commissioners	Semi-annual Meeting of IJC
Early November	Draft Decision Workshop	Basis for recommendations in Draft Report
2017		
Early January	First Draft Report	Submit to IJC/IRG for Peer Review
Mid January	Public Webinar and Press Conference	
Mid February	Public Comment period for First Draft Report	Post on Study Board website, distribute to contacts, IRLWWB, CAG, IAG, RCPAG, RAG
Mid-March	Final Decision Workshop and Public Meetings on Draft Report	Address comments on the draft decision; will provide the refinements needed for the Study Board's final report

3rd week March	Public comments due	
End March	Second Draft Report	Submit to IJC/IRG
Mid-April	Final Draft Report	Submit to IJC/IRG
3rd week of April	Appearance before Commissioners	Semi-annual Meeting of IJC
Mid May	IRG comments due	IRG submits comments to IJC on final report
End of May	Final Report & Press Conference	Study Board submits to IJC

Once the final report is submitted to the IJC at the end of May 2017, the Commission will take it under advisement for decision-making purposes and sharing with the governments.

6 REFERENCES

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U.S. Army Corps of Engineers. Managing Water for Drought. Institute for Water Resources Report 94-NDS-8. 1994.210 pp. (http://drought.unl.edu/portals/0/docs/ManagingWaterForDrought.pdf)

Water Levels Committee of the International Rainy-Lake of the Woods Watershed Board. Report on High Water levels in the Rainy River Watershed in 2014. 2015. 87pp.

Appendix A: List of Studies in Support of Rule Curve Review

This table summarizes all of the studies that have been identified by the Study Board as potentially supporting the WOE analysis, the SVP, or both. At the time of this report, the evaluation by the Study Board of each individual supporting study has not been completed, so specific linkages between these studies and the WOE and SVP approaches have not been determined.

Proj. Index	Funder	Agency	Title	Links with water level	Use in WOE or SVM
1	IJC	Northland College & Northern Bioscience	Wetland Vegetation Monitoring- Voyageurs National Park	Observations before and after study - not a direct link to hydraulics; water level fluctuations have a shaping influence on vegetation communities - this in turn effects many other ecosystem components	Can be used for WOE comparison. A PI has been developed from other work developed by TWG.
2	IJC	Environment Canada	Rainy and Namakan Hydrologic Response Model	Provides simulated water levels for Namakan and Rainy Lakes from 1950-2014 under both 1970 and 2000 Rule Curves	Supports SVM analysis and Joined SVM-WOE analysis.
3	IJC	MNR	An Investigation of the Effects of the 2000 Rule Curve Change on the Rainy River Hydrologic and Hydraulic Regime	Provides supporting data on Rainy River hydraulics under 2000 Rule Curves	To be evaluated.
4	IJC	USGS, US National Park Service	Assess effects of water level fluctuation on bio-indicators using analytical models	Rising and falling water level during the loon nesting season can prevent successful nesting	Can be used for WOE comparison. TWG has developed a related PI.
5	IJC	US National Park Service	Detailed bathymetric mapping of the littoral zone of selected reservoir locations. Data only.	Allows computation of water depth in littoral zones under various lake levels	Mapping data supports other studies, not SVM or WOE directly.

Proj. Index	Funder	Agency	Title	Links with water level	Use in WOE or SVM
6	IJC	Environment Canada	Habitat mapping for marsh nesting birds and herpetiles in the Rainy Lake area: Using GIS to assess the effects of the 2000 rule curve changes	Observations before and after study - not a direct link to hydraulics	To be evaluated.
7	IJC	University of Minnesota; Minnesota State University - Moorhead	Sustained Changes in Rainy Lake and Namakan Reservoir: Benthic Macroinvertebrate Communities in Relation to the 2000 Rule Curve Changes	Observations before and after study - not a direct link to hydraulics	Can be used for WOE comparison. Not expected to support a PI. Further analysis needed to determine if a PI can be developed.
8	IJC	USDA Forest Service; Minnesota DNR	Water level change effects on northern pike spawning and nursery habitat and reproductive success in Rainy Lake and Namakan Reservoir, Minnesota	Water level during spawning is important so that vegetation is inundated; water level during nursery phase is important so that appropriate vegetation is available	Can be used for WOE comparison. Related PI has been developed by TWG.
9	IJC	DFO; University of Waterloo; University of Waterloo	Rainy River critical spawning and nursery habitat	Outflows from Rainy Lake heavily influence Rainy River levels and flows	Can be used for WOE comparison. A related PI is being developed by TWG.
10	IJC	Bemidji State University	Economic survey of impact of rule curves on tourist resorts on Rainy Lake and Namakan Reservoir	Spring levels dictate access to resort docks; open water season levels affect navigation hazards	Can be used for WOE comparison. Further analysis needed to determine if a PI can be developed.
11	IJC	Environment Canada	Rainy Lake / Namakan Reservoir flooding and ice damage	Flooding can cause damages to infrastructure during any portion of the open water season; water level changes during winter can cause ice damage to infrastructure	Can be used for WOE comparison. Further analysis needed to determine if a PI can be developed.
12	IJC	US National Park Service	Assess effects on cultural resources at a small number of sites on Rainy	Fluctuating water levels can damage cultural resources and landforms housing cultural resources; ice scour can also cause damage	Can be used for WOE comparison. Further analysis needed to determine if a PI can be developed.

Proj. Index	Funder	Agency	Title	Links with water level	Use in WOE or SVM
			Lake and Namakan Reservoir		
13	IJC	Golder, Inc.	Assess effects on cultural resources at benchmark sites on the Rainy River	Fluctuating water levels can damage cultural resources and landforms housing cultural resources	Can be used for WOE comparison.
14	IJC	Minnesota DNR	Relationship of Rainy River Hydrology to distribution and abundance of freshwater mussels	Fluctuating water levels can damage benthic habitats and affect mussels	Can be used for WOE comparison.
15	IJC	DFO	Rainy River fish community health (Index of Biotic Integrity)	Flow and level characteristics can influence fish communities	Can be used for WOE comparison.
16	IJC	University of Minnesota; Minnesota DNR	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	Water level throughout the open water season can be important - in spring, optimal walleye spawning habitat needs to be inundated by specific depths of water; in other seasons, water level dictates how well spawning substrates are cleaned by wave action	Can be used for WOE comparison. A related PI has been developed by TWG.
17	IJC	Kenora Resource Consultants Inc.	Examine municipal water treatment and hatchery data for Rainy River	Flows and levels can affect water quality which can make additional treatment necessary for municipal water treatment or fish hatchery use	Further analysis needed to determine if WOE or PI can be developed.
18	IJC	USGS, Environment Canada - Natural Resources Canada	Revising Water-Surface Elevation Data for Gages in Rainy Lake, the Namakan Reservoir System, and Selected Rivers in Minnesota, United States and Ontario, Canada	Supports possible future hydraulic modelling along Namakan Chain of Lakes	Study not intended to examine any PIs, no direct application in WOE or SVM.

Proj. Index	Funder	Agency	Title	Links with water level	Use in WOE or SVM
19	IJC	Environment Canada	Development of a 2-D habitat model required to support Study No 7 “Rainy River – critical spawning and nursery habitats	Flows and levels affect the amount of spawning habitat available to these species of fish in Rainy River	PIs are developed.
20	IJC	USGS	Collect bathymetric data for selected shallow areas to assist in the development of a digital elevation model for Rainy Lake and Namakan Reservoir	Data supports other models for water level simulation	No directly used in WOE or SVM.
21	IJC	Environment Canada	Modelling the Rainy Lake and Namakan Reservoir ecosystem response to water level regulation.	Walleye eggs are sensitive to water level change	PI is available.
				Northern pike eggs, larvae and YOY are sensitive to water level change	PI is available.
				Wetlands composition and structure are influenced by changes in Water level (Wet meadows and Shrubby swamps)	PI is available.
				Emergent plant composition and structure are influenced by changes in Water level	PI is available.
				Submerged plants occurrence is directly influenced by water levels	PI is available.
				Water level can flood or strand loon nests	PI is available.
				Wild Rice germination and growth are directly influenced by water level fluctuations	PI is available.
				Cattail thrive in a stable water level system during summer	PI is available.
				Muskrat are killed by stranding or flooding their house during winter	PI is available.

Proj. Index	Funder	Agency	Title	Links with water level	Use in WOE or SVM
22	USGS; US National Park Service	USGS; US National Park Service	Trophic state in Voyageurs National Park lakes before and after implementation of a revised water-level management plan	Water level fluctuation can increase nutrient loading to lakes by chemical processes related to drying and rewetting and by erosion	Can be used for WOE comparison.
23	USGS	USGS	Effects of changes in reservoir operations on water quality and trophic-state indicators in Voyageurs National Park, northern Minnesota	Water level fluctuation can increase nutrient loading to lakes by chemical processes related to drying and rewetting and by erosion	Can be used for WOE comparison.
24	USGS; US National Park Service	USGS; US National Park Service	Evaluation of internal loading and water level changes: implications for phosphorus, algal production, and nuisance blooms in Kabetogama Lake, Voyageurs National Park, Minnesota, USA	Water level fluctuation can increase nutrient loading to lakes by chemical processes related to drying and rewetting and by erosion	Can be used for WOE comparison.
25	Science Museum of Minnesota; University of Minnesota; USGS	Science Museum of Minnesota; University of Minnesota; USGS	Determining the historical impact of water-level management on lakes in Voyageurs National Park	Water level fluctuation influences water quality and clarity which in turn affect diatom assemblages	Further analysis needed to determine if can be used for WOE.
26	USGS; US National Park Service	USGS; US National Park Service	Can mercury in fish be reduced by water level management?	Water level fluctuations cause chemical processes in lake bottom sediments that are dried and rewetted that enhance methylation of mercury; fluctuations also	Can be used for WOE comparison. Further analysis needed to determine if a PI can be developed.

Proj. Index	Funder	Agency	Title	Links with water level	Use in WOE or SVM
			Evaluating the effects of water level fluctuation on mercury accumulation in yellow perch (Perca flavescens)	re-connect lakes with surrounding wetlands allowing methylmercury transport to lakes.	
27	North Dakota State University	North Dakota State University	The effects of water-level manipulation on the benthic invertebrates of a managed reservoir.	Drying and rewetting of large areas of shoreline impacts benthic macroinvertebrates which have minimal mobility; water level change in winter leads to ice scour which kills many benthic macroinvertebrates; major secondary link to water level fluctuation through changes in vegetation - diversity of vegetation physical structure is directly correlated with benthic macroinvertebrate diversity	Can be used for WOE comparison.
28	Northland College & Northern Bioscience	Northland College & Northern Bioscience	Wetland vegetation monitoring: Voyageurs National Park	Observations before and after study - not a direct link to hydraulics; water level fluctuations have a shaping influence on vegetation communities - this in turn effects many other ecosystem components	Can be used for WOE comparison. A related PI has been developed by TWG.
29	University of Minnesota; Science Museum of Minnesota; USGS	University of Minnesota; Science Museum of Minnesota; USGS	Impacts of settlement, damming, and hydromanageme nt in two boreal lakes: a comparative paleolimnological study	Water level fluctuation influences water quality and clarity which in turn affect diatom assemblages	Further analysis needed to determine if can be used for WOE.
30	University of Minnesota-Duluth; USGS	University of Minnesota-Duluth; USGS	Relationship between Mercury Accumulation in Young-of-the-Year Yellow Perch and Water-Level Fluctuations	Water level fluctuations cause chemical processes in lake bottom sediments that are dried and rewetted that enhance methylation of mercury; fluctuations also re-connect lakes with surrounding wetlands allowing methylmercury transport to lakes.	Can be used for WOE comparison. Further analysis needed to determine if a PI can be developed.

Proj. Index	Funder	Agency	Title	Links with water level	Use in WOE or SVM
31	US National Park Service; Biodiversity Research Institute	US National Park Service; Biodiversity Research Institute	Effects of water-level management on nesting success of common loons	Rising and falling water (beyond certain thresholds) during loon nesting causes nest failure	Can be used for WOE comparison. A related PI has been developed by TWG.
32	USGS; Minnesota DNR; US National Park Service	USGS; Minnesota DNR; US National Park Service	Does water level fluctuation influence production of Walleye and Yellow Perch young-of-year in large northern lakes?	For walleye, access to high quality spawning habitat is controlled by water level; for yellow perch, secondary effects of water level fluctuation such as changes in vegetation communities and prey abundance may be the most important link	Can be used for WOE comparison. Further analysis needed to determine if a PI can be developed.
33	USGS; Minnesota DNR; US National Park Service	USGS; Minnesota DNR; US National Park Service	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)?	Primarily through water level effects on availability of spawning habitat, but since this study is based on gillnet catches of adult fish, it also incorporates recruitment which is influenced by many other factors including prey abundance and habitat that may be related to water level fluctuations	Can be used for WOE comparison. Further analysis needed to determine if a PI can be developed.
34	US National Park Service	US National Park Service	Work in progress (beavers)	Water level fluctuation may influence condition for beavers	Can be used for WOE comparison. Further analysis needed to determine if a PI can be developed.
35	USGS; US National Park Service; University of Wisconsin - La Crosse	USGS; US National Park Service; University of Wisconsin - La Crosse	Work in progress (mercury methylation)	Water level fluctuations cause chemical processes in lake bottom sediments that are dried and rewetted that enhance methylation of mercury; fluctuations also re-connect lakes with surrounding wetlands allowing methylmercury transport to lakes.	Can be used for WOE comparison. Further analysis needed to determine if a PI can be developed.
36	IJC	Seine River First Nation & Kenora	Seine River temperature variation with	Variation of flow from the dam operation has a direct effect on water temperature during sturgeon spawning	Knowledge will be used to improve dam operation during sturgeon spawning period.

Proj. Index	Funder	Agency	Title	Links with water level	Use in WOE or SVM
		Resource Consultants Inc.	dam operation - effect on sturgeon spawning		
37	IJC	Seine River First Nation & Lakehead University	Cattails and Wild Rice Study - Cattail removal and influence of water fluctuation on wild rice growth and development	Cattails thrive in the wetlands of the area, occupying the wild rice traditional fields	Knowledge produced from this study will improve our knowledge of the relationship between the two species.
38	IJC	MNRF & Northern Bioscience	Multi-year Rainy River Temperature Study	Dam operation during fish spawning at International Falls has a direct impact on water temperature and on fish reproductive success	Help dam operator to improve peaking operation during fish reproduction period.
39	IJC	Environment Canada	Namakan Pinch-Point Hydraulic Study	Small restrictions to flow in the Namakan Chain of Lakes have an impact on water levels at high discharge	Help water managers regulating the Namakan water levels to better understand the hydraulics

Appendix B: Key Themes Emerging From Initial Stakeholder Meetings

The Study Board held five meetings over two days (September 29 and 30, 2015) in International Falls, MN and Fort Frances ON, to discuss the proposed methodology, as provided by the IJC in the Study Board Directive. There was also a webinar hosted by the Study Board on September 25, 2015 for stakeholders unable to attend the in-person meetings. All sessions were attended by local stakeholder organizations (lake and property owners' associations, industry) and government agencies and a total of approximately 40 individuals were in attendance.

The following key suggestions on regulation emerged from these meetings:

1. *The frequency of high water conditions since the adoption of the 2000 Rule Curves has been greater than in the preceding several decades. This includes major high water events, but also more frequent, smaller events, particularly at Rainy Lake, that are still damaging to docks. The Study should attempt to find ways to address the more frequent, smaller flooding events and should, in particular, examine how to manage risk in the early spring before May. This is normally the start of the wettest period of the year.*

   The SVM will include analysis of adaptive rule curves in spring. This approach would include optional rule curve bands shifted higher or lower in the early spring based on watershed conditions such as snowpack, ice-out timing, or spawning locations and timing. In addition, flooding will be one of many PIs for all alternatives that will be studied. The Study Board also will examine statistics of precipitation and inflow events since 2000 to respond to these concerns.

2. *The rigidity of the 2000 Rule Curves, including the requirement that the dam operators target the middle portion of the Rule Curve range, does not allow enough flexibility to adapt to conditions. This is a particular 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. The Study should examine these issues as they increase the risk of emergency conditions due to high water.*

   The Study Board will review the existing decision-making framework for flow changes from Namakan Lake and Rainy Lake and consider possible recommendations.

3. *The move under the 2000 Rule Curves to earlier refill of the Namakan Chain of Lakes in the spring and the smaller drawdown of these lakes over the winter has been welcomed*

by tourist operators in this area for better navigation early in the tourist season as well as improved fish and wildlife health. *The gradual summer drawdown introduced with the 2000 Rule Curves, however, can be problematic for navigation purposes*.

These changes to the Namakan Lake Rule Curves introduced in 2000 will be examined by the Study Board using the SVM in considering different alternatives. This may involve a hybrid alternative, using both the higher early spring elevations from the 2000 Rule Curves that benefit the tourism industry along the Namakan Chain of Lakes but also including the stable summer levels of the 1970 Rule Curves.

4. *When basin conditions allow for control of lake levels, operations targeting the middle portion of the 2000 Rule Curve band result in little variability from year to year in seasonal lake levels. While this presumably satisfies the regulatory aims of the rule curves, the reduced variability likely has broad, negative ecosystem impacts over the year*s. *For example, there is evidence of an increase in the extent of hybrid cattail, and a decrease in wild rice and native grasses in some areas. The standard winter drawdown on both lakes is also thought to prevent the establishment of muskrats along the major lakes, resulting in a loss of the ecosystem services they provide. The Study should examine methods of incorporating greater variability in seasonal lake levels over time in order to more closely resemble a natural flow regime*.

   The study will include modelling of a SON regulation alternative to provide a reference case for natural flows. The Study Board will also consider other management options that may be used to address year-to-year variability.

5. *Under the 2000 Rule Curves, there is no explicit mandate for the co-ordination of outflows from Namakan Lake and Rainy Lake, and each lake is generally operated independently according to its particular rule curve. It has been proposed that improved co-ordination could help to reduce the frequency and duration of high water conditions. The Study should investigate whether practical gains can be accomplished through co-ordinated regulation.*

   The Study Board will examine whether regulation of these lakes could be improved by co-ordinated outflow changes. If feasible, this will be incorporated into the SVM.

6. *Climate change and the potential effects on increased frequency of emergency conditions, whether by high or low water, is a concern. The Study should consider this when examining various regulation options.*

   The study will examine the performance of all proposed regulation alternatives under various climatic scenarios.

7. *In general, there is limited understanding by the public of how the Water Levels Committee and the dam operators make decisions on outflow changes from the dams. There is also no established mechanism for the public or stakeholder groups to provide input to these decisions. The Study Board should examine these issues and make recommendations to the Commission on how to make these decisions more transparent and better understood.*

   The Study Board will examine this issue and consider recommendations for improvements in stakeholder engagement with the WLC. The Study Board may examine approaches for representatives of stakeholder groups to provide input to the WLC on regulation in advance of the spring refill period, when the risk of emergency conditions due to high water is greatest.

8. *The Study should examine other ways besides lake level targets to limit high water events, including coordination with other dams in the basin, building of new dams and increasing outflow capacity from Rainy Lake at Ranier Rapids*.

   These approaches limit high water events are outside study directive scope, cannot be completed within time and resource constraints, or are not likely to result in improvements (see Section 2 for details). However, other possible methods to limit high water events may be investigated as encountered if appropriate.

9. *The Study should consider approaches other than Rule Curves for regulation, including Regulation Plan-based operation. Regulation plans include a set of established rules for target levels and flows in a system, but which allow operational flexibility based on watershed conditions, forecasts or specific interest factors. Under this approach, water release decisions are based on a variety of factors that are defined ahead of time*.

   This will be examined as part of the study.

10. *Minimum outflow criteria for Namakan Lake and Rainy Lake, both year-round and seasonal, should be established in any revised regulations. Minimum flow criteria have been used in past regulations for these lakes, but are not well defined under normal flow conditions under the 2000 Order*.

    This will be examined as part of the study.

11. *Allow for deviations from the Rule Curve target to enhance spawning conditions as necessary.* Dur*ing spawning periods, changing Rainy Lake outflow on the basis of a decision matrix or rubric developed to minimize risk to spawning.*

    The dam operators, H2O Power LP and Boise Paper, currently work with the IRLWWB, the WLC and resource agencies on a voluntary basis during the sturgeon spawning period to reduce the risk of egg dewatering. The Study Board will investigate the possibility of more formal regulatory approaches for addressing this issue.

12. *Formalize rules for peaking and ponding of flows out of Rainy Lake. Currently, there are informal practices and arrangements in place to avoid fluctuations in flows out of the Rainy dam during critical spawning periods due to peaking or ponding operations. These should be evaluated and made formal by inclusion in any revised regulation*.

    This will be examined as part of the study (for more detail, see Section 3.7).

13. *Improve inflow forecasting and basin gauging to prevent emergency conditions due to high water. The Study Board heard concerns from some stakeholders that there are an insufficient number of precipitation and hydrometric (water level and river flow) gauges in the basin for the companies and WLC to understand when high inflows are developing, and that this delays action, resulting in higher water levels. Similarly, inflow forecasting could be improved to aid in limiting or avoiding high water conditions.*

    The Study Board will review the current basin gauging and evaluate whether additional resources would be useful in making more timely regulation decisions.

14. *The water levels on Rainy Lake in 2015, which were stable and in the low end of the rule curve band, were ideal, allowing for increased area of shoreline and beaches and wild rice while providing for more storage in case significant rainfall developed. The summer target level for Rainy Lake should be lowered.*

    The study will examine this in the SVM.

15. *The modified 1970 Rule Curves proposed by the International Rainy-Namakan Steering Committee in the 1990s should be re-examined for potential changes to the 2000 Rule Curves. These modifications called for an earlier rise in spring water levels, stable or declining water levels in June, a slight summer drawdown and, on Namakan Lake, a reduction in the amount of the overwinter drawdown.*

    The study will examine the success of those recommendations from the Steering Committee which were incorporated into the 2000 Rule Curves, as well as reviewing those recommendations that were not adopted for potential analysis with SVM.

APPENDIX C: ROLES AND RESPONSIBILITIES

Study Board

a. The Study Board's primary role is the evaluation of options for regulating the levels and flows in the Rainy-Namakan system. The Study Board is solely responsible for developing recommendations for the IJC at the conclusion of the review, but the final report shall also identify and discuss all views provided to the Board.

b. The Study Board is responsible for distributing information related to the study as widely as practicable, including white papers, data, reports of the Study Board or any of its subgroups, and other materials, as appropriate.

c. The Study Board shall make all public documents available on the Study Board website.

d. Working with the Rule Curve Public Advisory Group, the Study Board will conduct public participation activities at strategic points in the study as defined in the Directive on Communication and Outreach.

e. The Study Board will maintain liaison with the IRLWWB and the WLC throughout the study. The Study Board will share information and findings from the study process with the WLC as they become available.

f. The Study Board will consult regularly with the IJC's staff liaisons and shall invite them to all meetings of the Study Board.

g. The Study Board shall keep the IJC fully informed of its progress and direction, as well as of factors in the watershed that might affect its work. The Study Board shall appear before the IJC at each of its semi-annual meetings, providing written progress reports to the IJC, the IRLWWB, WLC, the Watershed Board's Community Advisory Group (CAG) and Industry Advisory Group (IAG) at least three weeks in advance.

Technical Working Group (TWG)

a. The role of the TWG, which is appointed by the IJC, is to undertake analysis and modelling as directed by the Study Board.

b. The TWG will report to and take direction from the Study Board.

Rule Curve Public Advisory Group (RCPAG)

a. The RCPAG, appointed by the IJC, will receive direction from and directly liaise with the Study Board.

b. The co-chairs of the RCPAG will be appointed by the IJC from among the RCPAG membership and will include one U.S. and one Canadian member.

c. It will review and provide comment on Study Board reports and products as requested.

d. It will advise the Study Board on the responsiveness of the study process to public concerns.

e. It will advise the Study Board on public consultation, involvement and information exchange.

f. It will serve as a conduit for public input to the study process and for public dissemination of study outcomes.

Resources Advisory Group (RAG)

a. The Study Board has elected to create a separate advisory group for agencies in the watershed that are responsible for natural resource management or environmental protection. This group will be relied upon to provide input and feedback on technical matters related to these areas.

b. The RAG will be open to any provincial, state or federal agency wishing to be involved in reviewing analyses or recommendations made by the Study Board for their potential impact, positive or negative, on natural resources or the environment in the watershed.

First Nations, Métis, and American Tribes

a. The Study Board aims to have a strong engagement with indigenous communities that are affected by water level regulation along the Namakan Chain of Lakes, Rainy Lake, and Rainy River in order that any recommendations developed by the Rule Curve Review take into account their advice and opinions.

b. At the time of the writing of this report, the Study Board is in discussions with First Nations, Métis, and Tribes in the watershed that could be affected by changes to the regulation of Rainy Lake or the Namakan Chain of Lakes.

c. The Red Lake Band of Chippewa Indians has indicated its preference for staying informed of the study proceedings, but does not require additional engagement during the process.

d. The Study Board has contacted Grand Council Treaty #3 and the Chiefs of the following individual First Nations and is awaiting direction on their preferences for participation in the study process: Naicatchewenin First Nation; Mitaanjigamiing First Nation; Couchiching First Nation; Nigigoonsiminikaaning First Nation; Seine River First Nation; Rainy River First Nations.

e. The Study Board has contacted the Métis Nation of Ontario and is awaiting direction on its preference for participation in the study process.

f. The Study Board has also contacted Bois Forte Band of Chippewa, 1854 Treaty Authority and Pwi-Di-Goo-Zing Ne-Yaa-Zhing Advisory Services and is awaiting direction on their preferences for participation in the study process.