INTERNATIONAL RAINY LAKE BOARD OF CONTROL
IRLBC

DRAFT FINAL REPORT

REVIEW OF THE IJC ORDER FOR RAINY AND NAMAKAN LAKES

April 28, 1999

Your comments on the Rainy-Namakan rule curve study, as detailed in this Draft Final Report, are welcomed. Watch for announcements for, and plan to attend, the International Joint Commission's Public Hearing, tentatively planned for early July, 1999.

Alternately, send your comments to either of the two Board Members by July 30th:

Col. Kenneth S. Kasprisin
U.S. Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul MN 55105-1638

kenneth.s.kasprisin@usace.army.mil

Mr. Dale R. Kimmett
Environmental Protection Service
Environment Canada
Ottawa ON K1A 0H3

dale.kimmett@ec.gc.ca

EXECUTIVE SUMMARY

The Rainy Lake basin lies within the Canada-United States boundary waters and is therefore subject to the Boundary Waters Treaty of 1909 ratified by the two countries. The basin has long been of interest to the two governments, which issued a Rainy Lake Reference in 1925 requesting the International Joint Commission (IJC) to make recommendations as to the regulation of Rainy Lake and other boundary waters. A Convention in 1940 assigned the IJC the power to determine when emergency conditions existed on Rainy and Namakan lakes and to adopt control measures as necessary. The Commission created the International Rainy Lake Board of Control (IRLBC) in 1941 to examine and report on emergency conditions, and issued its first Order on regulation of the lakes in 1949. In response to extreme inflow conditions, this Order underwent major reviews twice, and was consequently revised by Supplementary Orders issued in 1957 and 1970. The 1970 Order, still in use, specifies an upper and lower rule curve for both Rainy and Namakan lakes, between which the lake levels must be managed under normal conditions. The Order also provides direction on how the lakes are to be managed if the rule curves are violated due to flood or drought events.

Calls for rule curve change have been ongoing virtually since the 1970 Order was implemented, driven by concerns of resort owners over low levels in the Namakan chain of lakes, the creation of Voyageurs National Park in Minnesota which placed a focus on the ecological and environmental values of the water resource, and the concern of natural resource management agencies and others about declining fisheries populations. In 1991 a number of local interests created the Rainy-Namakan Water Level International Steering Committee (SC) as a voluntary group of private citizens and government agencies with a view to recommending changes that would seek a balance among a number of concerns. The work of the International Steering Committee culminated in a *"Final Report and Recommendations"* that was submitted to the IJC in November 1993. A number of local and national groups and individuals expressed support for the SC proposals, but concerns were expressed by some property owners about increased flood risk and by some navigational interests about a shorter boating season. Boise-Cascade, the operator of the control dams, concerned about reduced hydropower production and increased risk of flooding, filed a formal *"Statement in Response of Boise Cascade Corporation and Boise Cascade Canada Limited"* with the IJC in February of 1994.

The International Rainy Lake Board of Control, in presentations to the Commission in 1994, recommended a review of the rule curves and subsequently was asked by the IJC to develop a draft Plan of Study. Following public review and further deliberation the IJC approved a revised Plan of Study dated February 1, 1996. The IRLBC was directed to assess the existing data and information related to the new rule curves proposed by the SC, with the objective of determining what action, if any, the Commission should take regarding the 1970 Supplementary Order. Given the extent of the work already undertaken by the Steering Committee and Boise Cascade Corporation, the Commission sought to restrict the study to an assessment of the proposed rule curves versus those of the existing rule curves rather than a full assessment of all possible regulation alternatives. In addition the Study Plan included the review of two uncontrolled outlets from Namakan Lake and of the minimum outflow requirements for both Rainy and Namakan Lakes. Further, recognizing the several differing water resource management jurisdictions in the basin, the Plan called for the study work conducted by the IRLBC to focus on Rainy and Namakan lakes only, but to provide details of the altered outflow regime to downstream agencies. These agencies, including in particular the Lake of the Woods Control Board with respect to Lake of the Woods and the Winnipeg River, were expected to conduct their own review of the anticipated impacts on the downstream areas and provide feedback which would then be incorporated into the study report by the IRLBC.

Priority was given by the Board to an independent evaluation of the fisheries information and that aspect was completed early in the study. The Plan of Study defined the initial products of the study as being the results of the hydrologic modelling and inflow forecasting efforts, and summaries of all the existing data and information. The Board provided a Status Report dated March 3, 1998 that met that requirement and, because some of the sectoral studies had gone beyond the summary of information stage, was also able to reach a number of preliminary findings as well. The Status Report was circulated to stakeholders, the public and downstream agencies for review and comment, and additional outflow data was provided to the downstream agencies so that they could begin their own assessment. The Board continued with its remaining study components, with filling information gaps, and with encouraging input from others on downstream impacts below Rainy Lake. The IRLBC and the downstream agencies have now completed their work and, based on all available information and feedback, the IRLBC has prepared this draft final report. A summary of the findings in each of the sectoral areas outlined in the Plan of Study are given below. Additional detail is available in the corresponding section of this report, and elaborated in even more detail in the technical reports listed in the bibliography at the end of the report.

Rainy-Namakan Studies

Hydrologic Modelling - Independent hydrologic modelling was conducted to determine the lake levels and outflows likely to result for Rainy and Namakan lakes under different operating rules. The Environment Canada "REGUSE" computer model was used to simulate the regulation of Rainy and Namakan Lakes under four different sets of rule curves: the existing 1970 IJC rule curves, the rule curves proposed by the Steering Committee, alternative C1 (SC curves on Namakan Lake and IJC curves on Rainy Lake), and alternative M1 (a modification of C1 with a wider rising limb in the spring on Namakan Lake, and a blending of the SC and IJC curves on Rainy Lake). The key findings were that the maximum flood level is about 5 cm higher on Namakan Lake and 10 cm higher on Rainy Lake with the SC rule curves than with the IJC curves. The minimum drought level on Namakan Lake is 20 to 100 cm lower with the IJC curves and on Rainy Lake is 7 to 38 cm higher. Based on the number of rule curve violations the SC curves are nominally more viable than the IJC curves on Namakan Lake, but less viable on Rainy Lake. Under the SC curves there is a significant shift in timing of the outflow from both lakes, with less in winter but more in summer, especially June. Average annual energy generation is 6.6% to 7.7% less with the SC curves than with the IJC curves.

In addition, a simple routing model was developed and used to simulate natural lake levels and outflows, the condition before the dams were constructed. The same inflow data set as used for the REGUSE model runs, for years 1958-96, was used. Although there was a wide variation in the timing of natural refill, the earlier refill under the SC curves appears to better fit the natural situation on Namakan Lake while the existing IJC curves appear to better fit the natural situation on Rainy Lake. In both cases the natural variability in spring refill timing was significantly greater than under rule curve regulation.

Inflow Forecasting - The purpose here was to determine the potential to mitigate flood risk through improved inflow forecasting. The Steering Committee had acknowledged that their proposed rule curves would potentially increase flood risk, but felt that the increased risk could be offset through improved forecasting. To test this, a routing model was developed and used to progressively determine the operational potential to reduce high lake levels and outflows for increasing periods of "perfect forecasts". The results indicated that the number of violations of the upper rule curves are only reduced by 0.8% at best with a perfect 7-day forecast and by 1.6% at best with a perfect 28 day forecast. In essence, an inflow forecast cannot be used to significantly reduce flood peaks because of the hydrologic characteristics of the basin and the limited outflow capacity of the dams.

Flood Risk Assessment - This work was conducted to assess the relative change in risk of high water levels on Rainy and Namakan lakes, if any, under the proposed SC rule curves, as well as under alternatives C1 and M1, compared to the existing IJC rule curves. Assessments were made of the relative change in frequency and duration of Rainy and Namakan levels exceeding the established upper IJC emergency condition levels of 337.75 m on Rainy and 340.95 m on Namakan. The relative change in magnitude and frequency of Rainy Lake outflow was also determined to assess the potential for increased downstream flooding on Rainy River. Compared to the existing curves, all of the alternatives generally produce a small increase in flood levels on Rainy and Namakan for all event frequencies, with the SC curves producing the greatest increase and C1 and M1 producing lower and similar increases. For the 100-yr event on Rainy Lake the increase is 14 cm for the SC curves and 9 cm for C1 and M1. For the 100-yr event on Namakan all of the alternatives produce an increase of 10 cm. The discharge-frequency analysis for Rainy Lake outflow shows that all of the alternatives produce slightly higher discharges for the 5-yr through 100-yr events, compared to the existing condition. The SC curves produces the greatest increase, while M1 produces the least. For the 100-yr event the increase is 50 m^3/s for SC, 40 m^3/s for C1 and 30 m^3/s for M1. The duration of flood levels above the upper IJC emergency level on Rainy Lake increased by about 0.9% for SC, 0.4% for C1 and 0.3% for M1. On Namakan Lake the duration of levels exceeding the upper IJC emergency level increased by about 0.4% for SC, C1 and M1. Overall among the alternatives, increases in Rainy-Namakan flood levels and in Rainy River discharges are relatively small, when compared to the existing condition, and do not appear to very significantly increase flood risk.

Fisheries - The fishery, and the associated tourism, form an important economic resource base for the region. The purpose of this study sector was to determine the impact on the fishery of the present mode of operation, and to determine if the changes proposed by the SC might be effective in aiding the fishery. Two independent fisheries experts, one from Canada and one from the United States, were retained by the Board to evaluate all fisheries studies on Rainy and Namakan lakes and relevant fisheries information from other comparable lakes. The experts, in their initial evaluation, concluded that over-exploitation had played a major role in the decline of fish stocks and that water level regulation has contributed to the decline. The importance of follow-up studies to any management actions was also highlighted. They endorsed the proposed SC rule curve changes as being more representative of natural conditions, and supported continuing efforts to reduce and constrain exploitation pressure. After the natural condition (before dams) simulation results became available a supplemental evaluation was carried out, primarily in light of the new findings regarding the timing of the spring rise on the lakes. In their supplemental evaluation the fisheries consultants recommended that an experimental management approach be adopted that would implement the SC curves on Namakan Lake and leave the existing IJC curves in place on Rainy Lake.

Environmental Data Summary - The environmental review was conducted to determine whether the existing or the proposed regulation would best provide the most benefits for the environmental resource ecosystem components. The initial environmental findings concluded that perceived problems with the existing IJC rule curves were valid. The SC curves would trigger positive responses in the aquatic plant and associated wildlife in Namakan Lake, and minor habitat improvements for the aquatic plant community with consequent benefits to wildlife in Rainy Lake. The report also pointed out the benefits of infrequent high and low water extremes in regulated aquatic system management. Based on a re-evaluation of the findings, following the completion of the natural condition simulation, the reviewers concluded that many of the ecosystem resources would benefit from an earlier spring rise as proposed by the SC on both Namakan and Rainy Lakes. However, regarding Rainy Lake, they acknowledged that if the intent was to obtain more natural conditions, then the later rise provided by the IJC rule curves might be more appropriate. Also in the interest of more natural conditions on Rainy, they encouraged a wider summer band with more "run of the river" operation in order to increase inter-annual variability.

Economic/Social/Recreational Factors - This evaluation was to establish current economic, social and recreational values in a number of impact categories and estimate the incremental changes that would result, if alternate rule curves were adopted. Quantitative analysis was performed to the extent possible, but qualitative where necessary, to determine the effects of the proposed changes.

Hydropower is generated by Boise Cascade on the US side, and by Abitibi-Consolidated on the Canadian side, at the outlet of Rainy Lake. The demand for electricity at the company mills exceeds their power generating capability at all times. The value of the power produced is approximately US$5.1 million per annum. When compared to the existing rule curves, all of the alternatives result in a decrease in hydropower energy production, particularly in the winter months when it is most costly to replace. The additional yearly average cost of replacing this power ranges from US$376,000 with the Steering Committee proposal to US$114,000 under Alternative C1.

All of the alternatives evaluated resulted in increased flood damages when compared to the existing condition. The average annual flood damages were estimated at US$15,000 for the existing rule curves, US$23,000 for the Steering Committee proposal, and about US$21,000 for the two alternatives tested. For the flood of record, 1950, flood damages increased by about US$2.4 million under the two alternatives and by about US$2.8 million under the SC proposal when compared to the existing rule curves. Overall, there are small differences in flood damage potential among the alternatives, except for extreme events where the differences are large.

In 1990 the fishery and associated tourism generated approximately US$8.7 million in gross revenues in the Rainy-Namakan basin, with 98% of this contributed by the sports fishery. (For comparison, the equivalent value on Lake of the Woods is US$46.2 million.). The recreation-tourism benefits of the alternatives evaluated could not be quantified, but were assessed qualitatively. The SC curves on Rainy Lake and particularly the SC, C1 and M1 curves on Namakan Lake should provide positive benefits to recreation and tourism due to the early spring refill and associated improvements in the fishery and navigation access. SC, C1 and M1 curves should provide significant positive benefit to Namakan Lake due to their decreased winter drawdown. However, the SC and M1 curves on Rainy Lake and SC, M1 and C1 on Namakan Lake, which feature slowly declining summer levels, may negatively impact recreation and tourism due to potential problems with navigation access in the late summer.

The study looked at the effects of rule curve change on water supply intakes, on the commercial fishery and on shore erosion, but found either no impacts or minimal impacts in these areas.

Native Peoples, tourism businesses, and recreationists use tributaries to the Namakan Chain of Lakes for navigation for personal, business, and recreation purposes. This should improve with any of the alternatives for Namakan Lake, based on expected increases in spring water levels.

While the wild rice harvest on Rainy Lake is small, it has cultural significance to the Native Peoples. Compared to the existing rule curves, the Steering Committee proposal could provide positive benefits, while the two alternatives maintain the status quo.

Downstream Impacts

Changes to the rule curves on Rainy and Namakan lakes changes the timing and magnitude of outflows from Rainy Lake, which in turn changes the levels and flows down the Rainy River and has the potential to change levels and flows on Lake of the Woods and the Winnipeg River. Implementation of the SC rule curves would result in changes throughout the year, but the most significant would occur from spring to early summer. With the earlier rise of Rainy and Namakan levels under SC rule curve operations, there is less outflow in the spring as water is held back to fill the upper lakes, and then more outflow in the early summer, once the upper lakes are filled. As a result, the changes made to benefit a particular interest on the upper lakes can have the opposite effect on the same interest downstream. The earlier refill of Rainy and Namakan lakes to better ensure good spawning conditions there result in less water being available for the same purpose downstream.

Rainy River - If the SC rule curves were adopted in place of the existing IJC curves, river levels would be lower in the late winter to early spring, and higher in the late spring to early summer. The extent of change diminishes as one moves downstream. Just below the Fort Frances - International Falls dam, the mean level would be 0.6 m lower in late March and 0.4 m higher in late June, whereas at Manitou Rapids the equivalent values would be 0.5 m lower and 0.3 m higher, and at the Town of Rainy River the changes would be within +/- 0.1 m. For other months the differences in level would not be as significant. The Ontario Ministry of Natural Resources (OMNR) believes that the SC curves may enhance the spring spawn on the Rainy River as levels tend to be increasing during the spawning period, but notes that this would be dependent on there being adequate spawning area at the lower initial water levels, which could only be determined through field investigation. Others with an interest in the river believe that there is not yet enough information available regarding impacts on the river and have requested that no changes be made to rule curves until further study has been conducted.

Lake of the Woods - The Lake of the Woods Control Board (LWCB) took a keen interest in how a changed outflow regime from Rainy Lake might affect the waters it regulates. Once the modelled Rainy Lake outflows were available, the LWCB conducted its own extensive modelling to determine the impacts on the levels of Lake of the Woods and the levels and flows on the Winnipeg River. These results were detailed in the report *"Lake of the Woods Modelling - Impacts of Rainy-Namakan Rule Curve Change"* dated June 5, 1998. The LWCB then turned over its results to the public and in particular to the various interest groups active on its waters, seeking their comment. Based on its own work and on the feedback received, the LWCB provided the IRLBC with a summary of the anticipated impacts and a statement of its position on the issue. For Lake of the Woods it was determined that the maximum flood level would be about 5 cm higher with the SC rule curves as opposed to the existing IJC curves, and that the amount of time the lake was above the normal operating range would double, although this still occurs relatively infrequently. It was noted that the proposed SC changes would make the regulation objectives for Lake of the Woods and the Winnipeg River more difficult to achieve, and that the current frequency of success in reaching spring spawning target levels on Lake of the Woods could only be maintained by producing wider variations in flow and less achievement of target levels on the Winnipeg River. All input received by the LWCB from the public and interest groups regarding the impacts was negative. In particular, hydropower interests on the Winnipeg River computed generation losses, and OMNR resource managers cited threats to the downstream fishery and shore nesting birds. The LWCB concluded that there are no benefits, and in some years significant disbenefits, for its downstream areas if the SC rule curve proposals were implemented. Nevertheless, the LWCB offered to consider some disbenefits downstream in order to achieve some benefits upstream, provided that there is a net gain for the basin overall. It is not prepared to accept changes that result in unmanageable impacts downstream, or greater disbenefits downstream than those achieved upstream. Given the available information, the LWCB felt that a reasonable compromise between upstream and downstream interests would be the C1 alternative, provided that it was implemented on a trial basis.

Conclusions and Recommendations

The IRLBC has assembled and evaluated a wide array of existing information in all of the areas defined in the Plan of Study. While some data gaps still exist in relation to the possible impacts of changes to the rule curves on fisheries and on the aquatic environment downstream of Rainy Lake, the Board believes enough information is available to derive and justify its recommendations.

Overall, the Board recommends the rule curves shown on Figure 1, which are defined in metric units and are similar to the alternative M1 rule curves for Namakan Lake (same as the SC proposal except for a wider rising limb in the spring) and the existing IJC rule curves for Rainy Lake. These curves as a set will have less impact, both positive and negative, than the SC proposal for both lakes and should provide a better balance for the basin as a whole than either the existing IJC rule curves or the proposed SC rule curves. The recommended curves should balance not only the upstream versus downstream environmental benefits, but also the tradeoff on the upper lakes between fishery and environmental resources versus hydropower and flood risk.

The recommendations of the Board regarding Rainy and Namakan lakes are given below. The justification is provided in the Conclusions and Recommendations section of the report.

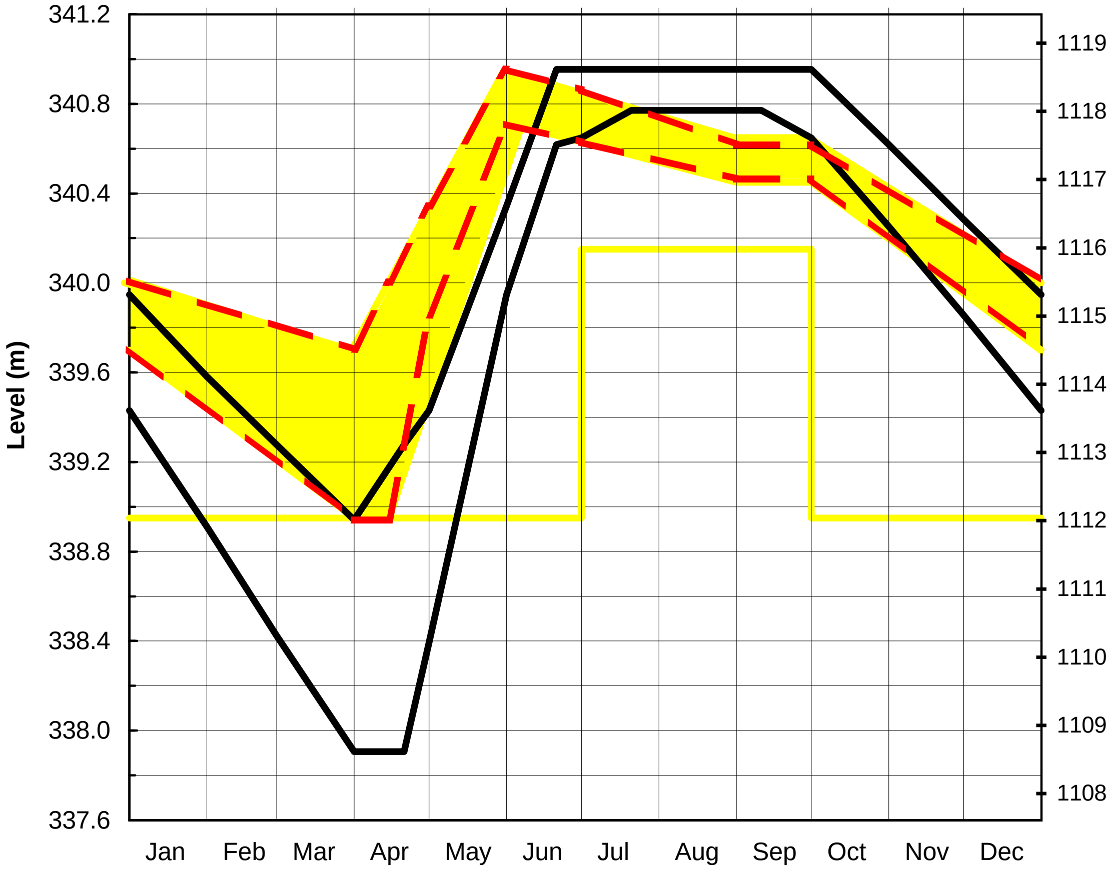
1. *The recommended rule curves shown on Figure 1 should be adopted. These are essentially a minor modification of the proposed International Steering Committee rule curves on Namakan Lake and the existing IJC rule curves on Rainy Lake.*
2. *The minimum outflow criteria for Namakan Lake should be expressed in terms of the total Namakan Chain of Lakes outflow rather than in terms of the Kettle Falls outflow, so that the overflows from Gold and Bear Portage are accounted for.*
3. *The minimum outflow criteria should be revised as follows for both lakes. On Namakan Lake, the outflow should be reduced to 30 m^3/s instantaneous whenever the lake level is below the Lower Rule Curve, and should be further reducible, at the discretion of the IRLBC but no lower than 15 m^3/s, whenever the lake level is below the Emergency Drought Line (EDL) shown on Figure 1. On Rainy Lake, the outflow should be reduced to 100 m^3/s instantaneous whenever the lake level is below the LRC, and should be further reducible, at the discretion of the IRLBC but no lower than 65 m^3/s, whenever the lake level is below the EDL shown on Figure 1. (The current seasonal and diurnal criteria would be eliminated.)*
4. *Any new rule curves adopted should be implemented on a trial basis. The length of the trial could be for a defined period, or linked to certain hydrological extremes occurring during the trial period, but in any case should not be shorter than 10 years so that a range of events can be experienced and adaptations of the biological community can begin to be identified.*
5. *Monitoring programs should be implemented by the resource management agencies in accordance with the recommendations of the fisheries and environmental resources experts to enable the impacts of new rule curves on the biological and aquatic communities to be identified, and to provide an adequate source of information for future reviews.*
6. *The Order should state that, within the rule curve operating bands, regulation operations are to be solely at the discretion of the dam owners in accordance with basin conditions. The flexibility intended to be offered by these bands for responding to current basin conditions and local needs should not be constrained by any additional rules.*

The Board has set aside a three month period (to July 30, 1999) for stakeholder and public review of the draft final report. Comments and feedback will be taken into consideration, along with other information that becomes available, when the Board finalizes this report.

FIGURE 1

Namakan Lake

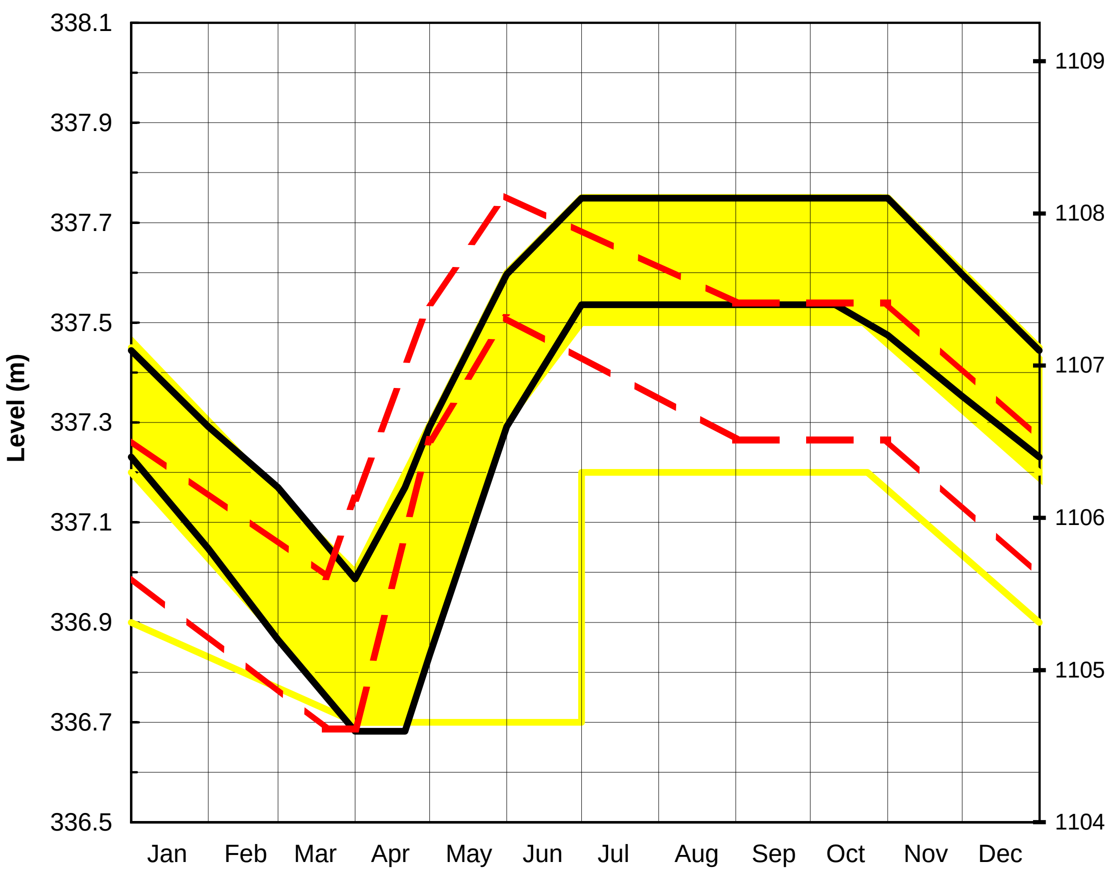
Recommended Rule Curves



Date	LRC	URC	EDL
Jan 01	339.70	340.00	338.95
Apr 01	338.95	339.70	
Apr 15	338.95		
Jun 01		340.95	
Jun 07	340.70		
Jun 30			338.95
Jul 01			340.15
Sep 01	340.45	340.65	
Sep 30			340.15
Oct 01	340.45	340.65	338.95

Rainy Lake

Recommended Rule Curves



Date	LRC	URC	EDL
Jan 01	337.20	337.45	336.90
Apr 01	336.70	337.00	336.70
Apr 21	336.70		
Jun 01	337.30	337.60	
Jun 30			336.70
Jul 01	337.50	337.75	337.20
Sep 30			
Oct 24	337.50		337.20
Nov 01		337.75	

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1. INTRODUCTION

Following its April 1995 semi-annual meeting, the International Joint Commission (IJC) requested that its International Rainy Lake Board of Control (IRLBC) prepare a plan of study to review its 1970 Supplementary Order for the regulation of Rainy Lake and the Namakan Chain of Lakes. This request followed concerns expressed by several organizations within the basin that the current rule curves did not fully reflect certain benefits such as fisheries and navigation that could be better achieved by a change to the rule curves. This concern culminated in a specific proposal for new rule curves, submitted to the Commission by the Rainy Lake and Namakan Reservoir Water Level International Steering Committee (SC) in its "Final Report and Recommendations", dated November, 1993. An opposing viewpoint which supported the retention of the existing 1970 rule curves was submitted to the Commission by Boise Cascade Corporation in a statement dated February 10, 1994. At the IJC semi-annual meetings in the spring and fall of 1994, the Board made presentations to the Commission summarizing the issues and recommended that the Order be reviewed. As a first step the Commission held a public hearing on November 10, 1994 in International Falls, Minnesota to seek public views on the adequacy of its existing order.

The Board then prepared a draft Plan of Study which was released on August 9, 1995 along with an invitation to all interested parties to provide comments on the draft plan by September 30, 1995. On the basis of those responses the draft Plan of Study was modified and a revised Plan of Study prepared dated November 22, 1995. Following the Commission's response to the Board, a final Plan of Study was prepared dated February 1, 1996 and distributed to the public and stakeholders. The Plan was developed based on the recognition that several water resource management jurisdictions exist in the basin area affected. The Board was directly responsible for studies and activities on Rainy and Namakan lakes, for providing the details of the altered outflow regime to downstream agencies, and for taking into account the impacts further downstream in its recommendations. Responsibility for conduct of a review of the anticipated downstream impacts rested largely with the resource management agencies for the Rainy River, and with the Lake of the Woods Control Board (LWCB) with respect to the Lake of the Woods and the Winnipeg River. The IRLBC initiated studies associated with completion of the key study areas which had been detailed in the Plan of Study, and sought the input of other agencies and groups with an interest in the impacts further downstream.

The Plan of Study called for a Status Report to be submitted to the Commission at the point that the results of the hydrologic modelling and inflow forecasting efforts, and the summaries of existing data and information, were completed. In view of the fact that certain of the technical reports commissioned by the Board contained preliminary conclusions and recommendations, it was also possible for the Board to include some preliminary findings in the Status Report. The Status Report was submitted to the IJC on March 3, 1998. The Report was also provided to stakeholders at the Board's annual public meeting held in International Falls, Minnesota on March 10, 1998 and to the downstream agencies. These agencies were also provided with the detailed model results of Rainy Lake outflows for the rule curve options tested so that they could begin their work. Similar data was made available to those Rainy-Namakan groups who had previously conducted their own studies, to allow them to re-assess the impacts from their own perspectives. The Status Report and supporting technical reports were also made accessible to others upon request.

Following the release of the Status Report, the Board continued with technical studies such as the completion of the economic-social-recreational sector evaluation, determination of flood damages and computation of Rainy River levels under the rule curve alternatives being considered. The IRLBC also specifically sought the response of the resource management agencies to the Status Report, and asked that possible impacts on the fisheries and aquatic environment of the Rainy River be evaluated. In addition the Board sought further input from the International Rainy River Water Pollution Board on possible changes to the minimum flow releases from Rainy Lake. The IRLBC, in October of 1998, also followed up on its previous requests to downstream communities for their concerns and views related to the rule curve alternatives evaluated in the Status Report. At the request of the IJC special measures were taken to inform the First Nations in the basin of the findings of the Status Report and to obtain feedback on the rule curve alternatives.

Significant feedback was received by the Board from stakeholder groups and the public on the preliminary findings and factors for consideration contained in the Status Report. The Board also received the results of modelling of the changes to water levels on the Lake of the Woods and the Winnipeg River conducted by the LWCB, plus their analysis of impacts.

This draft final report includes much of the contents of the Status Report, plus a summary of work carried out since the release of the Status Report, a summary of comments received from stakeholders, and the Board's conclusions and recommendations, with supporting rationale. The conclusions and recommendations contained in this report were presented to the Commissioners of the International Joint Commission in Washington, DC on April 13, 1999, and to the public at large at the IRLBC's annual public meeting in Fort Frances, ON on April 28, 1999. The report is being distributed to key stakeholders, and is available upon request to interested members of the public, starting April 28, 1999. Supporting materials and documents will be accessible upon request.

Public comment on the study and the report is welcomed. To facilitate this, the International Joint Commission will hold a Public Hearing in the Rainy-Namakan basin in early July, 1999. In addition, the Commission and the Board will accept written comments until July 30, 1999.

2. BACKGROUND

2.1 Basin Description

Location and Physiographic Characteristics

The Rainy River basin straddles the Minnesota-Ontario boundary and encompasses an area bounded on the east by the Lake Superior drainage system, on the south by the Upper Mississippi River drainage area, and on the west by the Red River basin. The Rainy River runs west and north into Lake of the Woods and eventually discharges to Hudson Bay through the Winnipeg River and Nelson River systems. The portion of the basin above the outlet of Rainy Lake has a total drainage area of 38,600 square kilometres (14,900 square miles), of which 42 percent is in the United States with the remainder being in Canada. Rainy Lake has a surface area of approximately 894 square kilometres (344 square miles) while the Namakan chain of lakes, which discharges into Rainy Lake, is comprised of five lakes (Namakan, Kabetogama, Crane, Sand Point and Little Vermillion) with a combined surface area of 270 square kilometres (104 square miles).

The topography of the Rainy River basin is the result of glacial action. Generally the tributaries to the Rainy River include streams inter-connecting numerous lakes, and flow is in well defined channels without conspicuous floodplains. The eastern headwaters of the basin are about 19 kilometres (12 miles) from Lake Superior at an elevation of 550 metres (1800 feet). The total fall through the chain of boundary lakes from North Lake at the headwaters of the Rainy Lake basin to Rainy Lake is 136 metres (442 feet) in a distance of approximately 260 kilometres (160 miles). The soil cover over the underlying rock formation is so meagre and interspersed with so many boulders and rock outcrops that the basin is generally unsuited for agricultural purposes other than forestry.

The Rainy Lake watershed is in the Superior Upland geological province. The area was subject to violent volcanic activity during an ancient era, and contains heavily wooded igneous rock terrain partially covered by numerous lakes and streams.

<u>Climate</u>

The climate of the Rainy River basin is typified by long, severe winters and short, hot summers. Snow cover usually begins to accumulate in November and is present into April. Lakes typically freeze up in early December and break up near the end of April. Mean annual precipitation is 680 millimetres (27 inches) of which 30 percent falls as snow. Evapotranspiration is 490 millimetres (19 inches), or 72 percent of the mean annual precipitation. December through March are typically the driest months in terms of precipitation, while June, July and August are the wettest. Due to a combination of snowmelt and rainfall the inflow of the streams to the lakes is typically the highest in May and June. However heavy rains at any time during the rainy season can cause significant runoff and consequent flooding.

<u>Hydraulic Works</u>

The outlet of Rainy Lake has been controlled since 1909 by an international dam extending between Fort Frances, Ontario, and International Falls, Minnesota. The dam is located at the site of the former Koochiching Falls. The dam is of stone-masonry construction and is U-shaped, with the apex facing upstream. Ten gate-controlled arched sluiceways are on the Canadian side while the American side is designed as an uncontrolled spillway section. An additional 5 gate-controlled sluiceways discharge into a never-used navigational canal on the Canadian side. Two powerhouses exist at the site, one on each side of the dam, in Canada and the United States respectively.

The outflow from Namakan Lake, located at Kettle Falls, has been controlled by two small dams since 1914. One, entirely located in Canada (at the former Squirrel Falls), is known as the Canadian Dam. The other dam straddles the international boundary and is known as the International Dam. No power is generated at the sites and access is limited to boat or aircraft only. Both structures consist of 5 stop-log controlled sluices. One of the sluices in each structure was constructed as a fishway, but neither has been used as such.

In addition to the structures described above there are two natural overflows from Namakan Lake. These overflows, at Gold Portage and Bear Portage, are significant because they bypass the regulatory dams at Kettle Falls. Gold Portage has become the more significant of the two overflows due to enlargement by local residents in the mid-1950's and by natural erosion.

2.2 Regulation

The Rainy Lake basin lies within the Canada-United States boundary waters and is therefore subject to the Boundary Waters Treaty of 1909 ratified by the two countries. The basin has long been of interest to the two governments, which issued a Rainy Lake Reference in 1925 requesting the IJC to make recommendations as to the regulation of Rainy Lake and other boundary waters. The final report on this reference was submitted by the IJC to governments in May 1934 and was ratified by Canada and the United States in October 1940. The 1940 Convention did not define any specifics for the regulation, but assigned the IJC the power to determine when emergency conditions exist in the Rainy Lake basin and to adopt control measures as necessary. The Commission then created the International Rainy Lake Board of Control in 1941 and directed it to examine and report on the issue of emergency conditions.

The International Rainy Lake Board of Control then initiated studies to fulfil the Commission's obligations, which the Commission integrated into its Order of June 8, 1949. This defined single rule curves for both Rainy and Namakan Lakes, an approach that seemed a good compromise between the desires of the riparian interests for uniform levels year-round and the desires of the power interests for fluctuating levels to obtain outflows when needed for power generation. In issuing its Order, the Commission interpreted its powers as being able to act not only in the event of emergency conditions, defined in terms of absolute levels on the Lakes, but also to preclude the occurrence of such conditions.

Excessive spring runoff during the years 1950 and 1954 caused both Rainy and Namakan Lakes to exceed their respective summer rule curve elevations. Numerous complaints were registered with the Commission from recreational interests regarding the adverse impacts of high water levels. The Commission subsequently issued a directive in April 1956 requesting the Board to prepare a report covering the possibilities of formulating and putting into effect a revised method of regulation. No change was suggested to the Rainy Lake rule curve. However a maximum rule curve was suggested for Namakan Lake in conjunction with the existing rule curve to provide greater flexibility of operation. The Commission adopted the changes and issued a Supplementary Order dated October 1, 1957 which amended the 1949 Order. The Supplementary Order was to be in force until 1962, but was twice extended for five year periods.

Because of high and low water conditions on Rainy and Namakan lakes from 1957 through 1968 the rule curve elevations were violated on many occasions, culminating in the extreme high levels during July 1968. In August 1968 the Commission directed the Board to consider and report on the advisability of further regulatory measures. Experience had demonstrated the difficulties of trying to regulate Rainy and Namakan Lakes to precise elevations on certain dates under all conditions of supply. The Board evaluated the matter and presented its proposals to the Commission in June of 1969. On July 29, 1970 the Commission, after receiving input from the International Rainy River Pollution Advisory Board, issued a Supplementary Order amending the previous Orders. Some of the key provisions of the 1970 Order were: a focus on, insofar as possible, anticipating high and low flows in regulating the lakes so as to prevent the occurrence of emergency conditions, the addition of a rule curve band on Rainy Lake, and the reduction of outflows when low water emergency conditions occur. The rule curves on Namakan Lake were also amended, and elevations defined under which full discharge capacity was to be utilized under high water conditions on both lakes. Since 1970 a number of Supplementary Orders have been issued, primarily to authorise minimum flow deviations during low flow periods.

2.3 Review of the 1970 Order

Calls for change have been ongoing, and increasing, virtually since the Supplementary Order was issued in 1970. For example, resort operators expressed concern about low levels in the Namakan chain of lakes in 1974-75 and have continued to express concern over low spring and early summer levels. The creation of Voyageurs National Park in Minnesota also resulted in a number of studies starting in 1983 of alternate operating regimes to benefit park interests, and the stronger interest in general in protecting the ecological values of the area. A number of local interest groups such as the resort operators on Crane Lake and the Border Lakes Association have called for avoidance of extreme low lake levels and better protection from high water events. Natural resource management agencies in Canada and the United States, concerned with declining fisheries populations, carried out a number of studies and concluded that changes to the rule curves would enhance the spawning success of desirable species.

In 1991, at the conclusion of the fisheries studies, a number of local interests created the International Steering Committee as a voluntary, nine-member group of private citizens, government officials and a Boise Cascade representative. The Steering Committee committed itself to a comprehensive process, involving open dialogue and analysis, frequent and wide-ranging public consultation, and the exploration of a broad scope of concerns regarding the use of the Rainy-Namakan watershed. The Steering Committee began with consideration of the International Joint Commission 1970 Order rule curves with a view to recommending changes that would seek a balance among a number of concerns. The Steering Committee activities were carried out in three steps: to establish guidelines within which alternatives would be considered, to identify several single purpose rule curves to maximise benefits to that group of interests and to then develop a compromise rule curve for both Rainy and Namakan Lakes that considered the needs of all interests. The work of the International Steering Committee culminated in a "Final Report and Recommendations" that was submitted to the International Joint Commission in November 1993.

The Executive Summary of the International Steering Committee (SC) report of November, 1993 noted two primary recommendations. The first was that the IJC should make modest changes in the existing curves. The second was that the IJC should enforce the provision of its 1970 Supplemental Order requiring the dam operators to anticipate inflows and maximize the discharge capabilities of the dams to prevent emergency water levels. The body of the report listed six recommendations overall, as summarized below:

- That specific modifications of the existing (1970) rule curves be made, resulting in earlier spring refill, a decline in levels over the summer/fall period and less winter drawdown on Namakan Lake,

- That improvements be made to hydrologic monitoring and modelling of the drainage basin, to facilitate anticipation of high and low inflow to Rainy Lake and Namakan Reservoir and to improve water management,

- That the IJC conduct a hydrologic analysis of the Steering Committee recommendations,

- That, upon implementation of the recommended rule curve modifications, extensive monitoring and research be conducted by the appropriate agencies to determine if the rule curve modifications are reducing the negative impacts on various interests or users without seriously conflicting with other uses,

- That the Minnesota Department of Natural Resources (MDNR) and the Ontario Ministry of Natural Resources (OMNR) take steps to facilitate approvals for structural changes needed because of the adoption of the proposed rule curves, such as dredging and dock modifications if required to maintain dock access in late summer. However, they recommended against physical alteration of the Loon River at its outlet or at "56 Rapids",

- That the liability of the dam operators for shoreline property damage should not increase as a result of adopting the proposed rule curves, provided that the dams are operated in accordance with IJC and FERC (US Federal Energy Regulatory Commission)

A number of local and national groups and individuals expressed support for the International Steering Committee proposal. Conversely, some local property owners concerned about flooding, and local boaters and sailors fearing a shorter navigation season, expressed concern. Boise Cascade Corporation, the operator of the works, commissioned independent studies of the proposals by Acres International Limited who prepared a *"Report on Analysis of Proposed Changes to Rule Curves of*

Rainy and Namakan Lakes", dated March 1993. The main impacts identified were a decrease of potential hydroelectric energy production of 7 percent, a significant increase in the risk of lake levels exceeding the upper emergency flood level, and a modest decline in exceedance of flood levels in late summer/fall.

A formal *"Statement in Response of Boise Cascade Corporation and Boise Cascade Canada Limited"* was filed with the IJC on February 21, 1994. The Statement indicated that according to the respondent's own analysis, if the changes proposed by the Steering Committee were implemented, there would be a significant increase in the risk of flooding in the spring and early summer, an increase in damage to property as a result of the flooding, a substantial loss of hydroelectric generation and no demonstrated benefits to fish or wildlife. The conclusions of fisheries experts retained by the respondents were that the fishery impacts of the recommended rule curve change were small, not necessarily beneficial, and of high uncertainty. Wildlife experts retained by the respondents concluded that there was no credible scientific evidence that the present water level regime is detrimental to wildlife and aquatic vegetation on Rainy and Namakan Lakes. The Statement then concluded that no change in the 1970 rule curves for Rainy and Namakan Lakes was warranted.

2.4 Plan of Study

The International Rainy Lake Board of Control, in presentations to the Commission in April and September 1994, recommended that a review of the Rainy and Namakan Lakes rule curves be carried out. As a first step the Commission held a public hearing on November 10, 1994 in International Falls, Minnesota to seek public views on the adequacy of the 1970 Order. Subsequently the Commission asked the Board to develop a draft Plan of Study. This draft Plan was released by the Board for public comment on August 9, 1995, with 281 copies distributed to known stakeholders and interested individuals. A total of 17 written responses were received, of which 12 provided comments on the draft plan and the others expressed opinions on the issues or asked questions. Based on the responses received the Board submitted a revised Plan of Study to the Commission on November 22, 1995. Following the Commission's response to the Board, a finalized Plan of Study dated February 1, 1996 was issued.

Specifically, the Commission had asked the Board to prepare a Plan of Study to assess the existing data and information related to the proposed new rule curves, with the objective of determining what action, if any, the Commission should take regarding the 1970 Supplementary Order. Given the extent of work already conducted by the International Steering Committee and Boise Cascade Corporation, the Commission sought to restrict the study to an assessment of the merits of the proposed rule curves versus those of the existing rule curves, rather than a full evaluation of all possible regulation alternatives. Similarly the Board proposed limiting the study to an evaluation, to the extent possible, based on a review and analysis of information already available in numerous specific studies carried out in the basin. However, in certain areas such as the fishery, the information available was not unanimous as to the potential benefits of the proposed new rule curves and new, independent evaluations of existing information were deemed necessary. Further, since the proposed rule curves potentially would increase the risk of flooding, there was a necessity to examine that aspect very carefully. In addition, the Commission agreed that certain other issues such as the impact of the two uncontrolled overflows from Namakan Lake, and the appropriateness of the current minimum outflow requirements from both Rainy and Namakan Lakes should be reviewed at the same time.

The Plan of Study defined a study process, the involvement of the public and other agencies, the organizational structure, resource requirements, a study methodology, and a number of key study areas along with the evaluation process and the tasks to be carried out. The key study areas were defined as hydrologic modelling, inflow forecasting, flood risk assessment, other hydrologic issues, the fishery and other environmental resource factors, and economic/social/recreational factors. A schedule of activities over a two year period was included. The basic structure of the key study areas formed the framework for Newsletters periodically issued by the Board on study progress, and also for the Status Report and this report.

2.5 Status Report

After the Plan of Study was approved, the Board initiated certain activities associated with its completion. Priority was given to an independent review of the existing information on the fishery of Rainy and Namakan Lakes. A statement of work was developed and two specialists, one from the United States and one from Canada, were retained to carry out this task. The approach and summary of the conclusions reached are described in greater detail in the section of the report on Fisheries Review. The remainder of the tasks were then apportioned to government agencies or study coordinators appointed by the Board. Immediate priority was given to the hydrologic modelling and the establishment of a mechanism for stakeholder input to the inflow forecasting. Work was essentially completed in the hydrologic modelling and environmental resource study areas, including fisheries and wildlife, at the time the Status Report of March 3, 1998 was prepared. In addition the modelling for the inflow forecasting was completed, and under review by a stakeholder group set up by the Board for that purpose when the Status report was released.

The Plan of Study indicated that the Status Report would contain the results of the hydrologic modelling and inflow forecasting efforts, and summaries of all of the existing data and information. In view of the fact that certain of the studies completed at that time had gone beyond the summary of information stage and conclusions had been reached, the Board was able to provide a number of preliminary findings in the Status Report.

The Status Report was distributed to the IJC, stakeholders and the public for review and comments. The Board also provided details on the hydrologic modelling to downstream natural resource agencies and to the Lake of the Woods Control Board, so that they could begin their review of impacts on the downstream areas. Rainy-Namakan groups, who had previously conducted their own studies, where given the same details to allow them to re-assess (if necessary) the impacts from their own perspective.

2.6 Draft Final Report

Following release of the Status Report, the Board continued with its activities including completion of the economic/social/recreational factors sectoral studies, and additional computations to define the water level changes in the Rainy River under the various rule curve alternatives. The Board also solicited input from resource management agencies and the Lake of the Woods Control Board on the downstream impacts on the Rainy River and Lake of the Woods. A concerted effort was made to determine the views of municipalities and other groups downstream of Rainy Lake, and First Nations within the basin.

This Draft Final Report is essentially an extension of the Status Report. Sections 1, 2 and 3 are largely drawn from the Status Report, but are updated with the study results obtained since then, and with the addition of public and agency comments on the Status Report. A new separate section of the report, Downstream Impact Studies, provides a summary of the predicted downstream impacts and the comments received from resource agencies, the Lake of the Woods Control Board and municipalities regarding the downstream areas. This additional information obtained by the Board, plus the original studies, provides the basis for the Board's draft conclusions and recommendations.

The Board believes that its draft final report addresses the concerns raised in the Plan of Study and fulfills the Board's obligations as defined. In general the Board feels that the information base, while not complete, provides an adequate basis for its recommendations and conclusions. The information base for the fishery and aquatic environment sectors is more complete for Rainy and Namakan lakes than for the Rainy River. The technical reports which have been prepared under the auspices of the study, as listed at the end of the report, are available upon request.

3. RAINY-NAMAKAN STUDIES

This section of the report describes the various assessments carried out to determine the effect of rule curve change on Rainy and Namakan lakes directly. As described previously, the Plan of Study called for the IRLBC to be responsible for this portion of the study work, while work regarding downstream impacts was left to be conducted by other agencies. Consequently, all work described herein was conducted either by staff of the government agencies supporting the Board, or by independent consultants hired by the Board. Sub-sections 1 through 7 describe the studies themselves, while sub-section 8 addresses comments received by the Board on this work.

3.1 Hydrologic Modelling

This section summarizes the computer-based modelling conducted to determine the lake levels and outflows likely to result for Rainy and Namakan lakes under different operating rules and physical outlet conditions. There are two parts: Part 3.1.1 deals with results of the "REGUSE" model, which compares lake operations under the existing and proposed rule curves, and Part 3.1.2 deals with the timing of the spring refill under natural (not regulated) conditions.

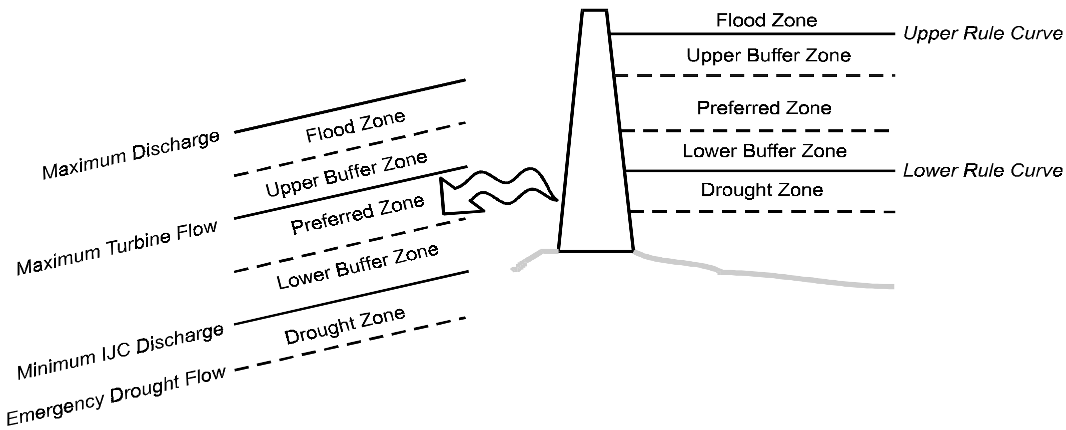
3.1.1 Simulation of Regulated Lake Levels and Outflows

The "REGUSE" computer model, developed by Environment Canada and used previously in other IJC transboundary basin studies, was used to simulate the regulation of Rainy and Namakan lakes. The model determines the levels and outflows that are likely to result from any given mode of reservoir operation, which in turn can be used to compare and assess the benefits and disbenefits associated with the various modes of operation tested. Initially, the model was used to test the existing 1970 International Joint Commission (IJC) rule curves versus those proposed by the Rainy-Namakan Water Level International Steering Committee (SC). Subsequently, the model was used to test several variants of these two sets of rule curves. A description of the initial tests (IJC vs. SC) is given in sub-section 3.1.1.2; a description of the testing of several alternate rule curve sets is given in sub-section 3.1.1.3. In addition, special attention was given to 1950 as the flood of record in the basin; this is addressed in sub-section 3.1.1.4.

3.1.1.1 *Model Operation*

The Rainy-Namakan "REGUSE" model balances the water available in the system between Namakan and Rainy lakes and their respective outflow channels at a given point in time, according to a set of "rules" which have been developed by the modellers. The "rules" are provided to the model by defining level zones for the lakes and flow zones for the outflow channels. The sketch shows the level and flow zones defined for Namakan and Rainy lakes. These zones are co-ordinated to provide the balance between lake level and outflow. The model's zone definitions and operating rules were developed from a combination of:

- the existing IJC rule curves and proposed SC rule curves
- physical constraints
- review of historic operation
- model calibration



Daily net inflows were developed for a 39-year period (1958-1996) from the historical record and used for the various model runs. The model has perfect knowledge of past inflows and can "see" the actual inflow two days in advance. At each solution step the model computes the levels and outflows for the next two days using the daily inflows and the operating criteria. The model then moves forward one day and repeats.

<u>*Namakan Lake*</u>

Namakan Lake operation is defined in the model so that outflow will be between 50 and 300 cubic metres per second (m^3/s) when the solution lake level is within the preferred level zone. Water available in the system is distributed to the other storage and flow zones in a hierarchical manner. In surplus water situations, when the lake level reaches the top of the preferred zone, extra water will begin to be spilled, up to a maximum discharge of 400 m^3/s or the physical maximum determined from the stage-discharge curve, whichever is lower. Once outflow reaches 400 m^3/s, extra water will be stored in the lake (in the upper buffer zone) until it reaches the upper rule curve. At the upper rule curve, outflow will be increased as necessary up to the maximum physically possible. More water will be stored in the lake above the upper rule curve only if the outflow is at the maximum physically possible and this is exceeded by the inflow.

If a low inflow condition is encountered, the outflow will be reduced to 28.3 m^3/s at Kettle Falls (the IJC minimum outflow) to prevent the lake from declining through the lower buffer zone. An exception to this rule can occur when extra water is needed in Rainy Lake to keep it above its lower rule curve and additional releases will not cause Namakan to drop below its lower rule curve. Once the lake level is at the lower rule curve, the Kettle Falls outflow is fixed at the minimum of 28.3 m^3/s. Note that uncontrolled overflow at Gold and Bear Portage may cause total outflow from Namakan to be higher than the IJC minimum which is defined for Kettle Falls alone. Once outflow from Kettle Falls is set to the minimum of 28.3 m^3/s, the lake level will continue to decline if the net inflow is below the <u>total</u> discharge from the lake. For Namakan Lake, there is no special flow definition for the drought zone.

Rainy Lake

The modelling of Rainy Lake is defined so that outflow in the preferred level zone will be between 275 and 400 m^3/s. As for Namakan Lake, the available water is distributed in a hierarchical fashion when there is either too much or too little water for the solution to be in the preferred level and flow zones. For surplus water situations, outflow is increased to as much as 500 m^3/s before the lake level rises into the upper buffer zone. The outflow is then held at the 500 m^3/s cap until the level in the lake rises to the upper rule curve. At that point, additional water is handled by increasing outflow to match inflow and prevent the lake from exceeding the upper rule curve, or it is set to the maximum physically possible (defined by a level versus maximum discharge curve), whichever is lower. Of course, once outflow is at maximum (which increases with lake level), the level will continue to rise if inflow exceeds the outflow.

Under a dry scenario, outflow is reduced to 150 m^3/s before the lake level is allowed into the lower buffer zone. Outflow is not reduced further until the level declines to the lower rule curve, at which point it is set to the IJC minimum of 103 m^3/s in the summer or 93.4 m^3/s for the remainder of the year. If, due to very low inflow, the lake level continues to decline below the lower rule curve and through the drought zone to its lower limit, the outflow is reduced further to 85 m^3/s.

During the winter drawdown period, water availability is typically insufficient to keep the lake in the preferred zone. As a result, it is quite common for the lake to decline along the top of the lower buffer zone. By increasing or decreasing the lower buffer zone, the predominant drawdown trajectory of water levels is easily moved up or down.

3.1.1.2 *Initial Tests Comparing Existing IJC and Proposed SC Rule Curves*

A total of 24 pairs (IJC and SC) of complete model "runs" (a run is a day by day simulation of lake regulation for a specified period with set operating rules) and many partial runs were done to test model performance and select appropriate modelling parameters. A final set of 8 run pairs were then prepared which are believed to provide a representative and unbiased indication of the lake levels and outflows that are likely to result from operations with either the IJC or SC rule curves.

The 8 runs can be broken into 3 groups as follows:

- Base Case and Operating Policy Variants

  Runs F1 through F5 represent a range of operating practices that might be followed by the dam operator <u>within</u> the rule curves. While they are certainly not exhaustive, they are intended to show how much the results might vary depending on whether the operator tends to maintain levels higher or lower within the rule curve bands, and depending on the extent of annual drawdown and refill targeted by the operator, again within the flexibility afforded by the rule curve bands. The Base Case, Run F1, starts to limit power flows from Rainy Lake whenever the level falls below the mid-point within the rule curve band, and thus the level tends to most often track this mid-point, subject to other operational criteria and the magnitude of inflows.

- Sensitivity to Higher/Lower Inflows or to Inflow Data Errors

  In spite of best efforts to assess and correct historic data records for the lakes, a number of uncertainties and suspected errors remain. In particular, there is reason to believe that the Rainy and Namakan outflows, and therefore the computed inflows, might periodically be both overestimated and underestimated. The range for Namakan is likely at least +/- 5%, with a tendency to overestimate. The range for Rainy is at least +/- 10%. In addition, due to climatic change or other factors, it is reported that certain areas of the continent may experience increases or decreases in water supply. Runs F6 and F7 were done with the inflows simply increased and decreased, respectively, by 10%, as a relatively crude means of determining whether the results with the two sets of rule curves, and thus the conclusions drawn from them, might be sensitive to such changes or errors.

- Effect of Reduced Minimum Outflow Requirement

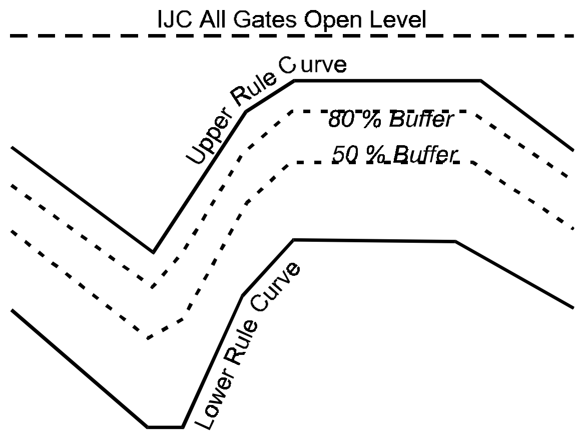
  The current IJC minimum outflow requirement for Rainy Lake was based on mill effluent dilution requirements and aesthetic values which may no longer be relevant due to improved treatment processes. The basis of the minimum flow requirement for Namakan is unknown but may be related to aeration needs for fish stocks, or for the fish sluices which have not been used as such for many years. Run F8 was done to assess what improvements in low lake levels might be achieved during drought periods with either set of rule curves through adoption of reduced minimum outflows. Reduced minimum outflows were selected for modelling purposes as follows. In 1988 and 1998 the IJC issued Supplementary Orders which authorized outflow reductions to as low as 63.7 m^3/s. (This flow value is related to minimum depth requirements for the Township of Emo water intake downstream rather than to any water quality issues.) However, actual outflows in this range have only been reached when the lake level was well below the lower rule curve. It was felt that this would be too low an outflow to be implemented right at the lower rule curve. In both 1988 and 1998, the first step outflow reduction ordered by the IRLBC under the respective Supplementary Orders was to 85 m^3/s; this was the value chosen as the reduced minimum outflow for Rainy Lake for Run F8. The reduced minimum outflow for Namakan was chosen arbitrarily as half of the existing criteria, but in addition was applied to the total Namakan Lake outflow rather than just the Kettle Falls outflow as is now the case. (Other agencies would have to be consulted on the appropriateness of these reduced limits.)

Following is a brief description of the final 8 model runs.

Main Run	**Title**	**Rule Curve Buffer**		**Minimum Outflow**		**Inflow Factor**
		Namakan	**Rainy**	**Namakan**	**Rainy**	
Base Case and Operating Policy Variants						
F1	Base Case - 50% Buffer	50/80	50/80	28.3 KF	103/93.4/85	1.00
F2	30% Buffer	30/80	30/80	28.3 KF	103/93.4/85	1.00
F3	80% Buffer	80/100	80/100	28.3 KF	103/93.4/85	1.00
F4	Maximum Refill	BC1	BC1	28.3 KF	103/93.4/85	1.00
F5	Minimum Refill	BC2	BC2	28.3 KF	103/93.4/85	1.00
Sensitivity to Higher/Lower Inflows or to Inflow Data Errors						
F6	110% Inflow	50/80	50/80	28.3 KF	103/93.4/85	1.10
F7	90% Inflow	50/80	50/80	28.3 KF	103/93.4/85	0.90
Effect of Reduced Minimum Outflow Requirement						
F8	Reduced Minimum Outflow	50/80	50/80	15.0 NL	85	1.00

Two 39-year (1958-1996) runs were done for Runs F1 through F8, one using the IJC 1970 rule curves and one using the SC rule curves.

An entry of "50/80" in the table above means that the buffer zones were a fixed percentage width of the rule curve band. Specifically, as shown by the sketch, the lower buffer zone was the lower 50% of band and the upper buffer zone began at 80% of the rule curve band, occupying the upper 20% of the band. The rule curve buffer BC1 in the table refers to a buffer scheme where the lower and upper buffer zones varied from 0% and 30%, respectively, at the end of winter, to 80% and 100% of the rule curve band in the summer, thereby defining a preference for a maximum drawdown and refill (within the rule curve band) each year. For each lake and rule curve set, BC2 varied from 80/100 at the end of winter to 0/30 in the summer, thereby defining a preference for a minimum drawdown and refill each year.



As shown in the table, the minimum outflow was the same for all runs except Run F8. For Namakan Lake, Runs F1 to F7 used the current IJC minimum outflow constraint of 28.3 m^3/s from Kettle Falls, denoted by “28.3 KF”. Run F8 was used to test a lower minimum discharge of 15 m^3/s total discharge from Namakan Lake (15.0 NL). Rainy Lake minimum discharge was also reduced for Run F8, so that outflow would be reduced to 85 m^3/s when the lake level drops to the lower rule curve. (As noted previously, 103 and 93.4 m^3/s are existing IJC minimums for the summer and the remainder of the year, respectively, while a minimum of 85 m^3/s was chosen as an appropriate reduced minimum outflow for the purpose of Run F8.)

The final column in the table shows the multiplier applied to the inflow hydrology set to test the model sensitivity to hydrologic and hydraulic uncertainties as described earlier.

3.1.1.3 *Subsequent Tests to Assess Alternate Rule Curves*

Based on the initial results, on questions posed by the IJC Commissioners at their October 1997 Semi-Annual Meeting, and on the position taken by the Border Lakes Association, two additional 39-year runs were made. These runs are directly equivalent to the previous base case runs (F1-IJC and F1-SC) except for altered rule curves. Run C1 is simply a combination of the proposed SC curves on Namakan used in conjunction with the existing 1970 IJC curves on Rainy (the Border Lakes Association proposal). Run M1 is a modification of C1. On Namakan, the rule curves are very similar to the SC curves but have a wider (in terms of time) rising limb in the spring. On Rainy, the rule curves used in Run M1 are the same as the IJC curves for the April through June refill period but then provide summer drawdown similar to the SC curves before blending back into the IJC curves over the winter. The altered curves can be seen on the applicable results graphs, such as Graph 10.

It is important to note that no attempt has been made to refine or optimize these altered curves, whereas both the existing IJC rule curves and the proposed SC rule curves are the result of fine-tuning processes. For this reason it was not deemed worthwhile during the main modelling stage of the study to perform a full set of runs equivalent to F1 through F8 of the initial tests, but to compare only the base cases. It was assumed that, based on the assessment of the results and on feedback from the public, revisions and/or refinements to these rule curve alternatives might be proposed, which would lead to further modelling and the opportunity to do a full set of runs on the revised curves at that time. However, no revisions to these alternatives were proposed. Further, it is believed that the conclusions reached from the operating policy variant and sensitivity runs with the IJC and SC rule curves would be little changed with the alternative curves.

3.1.1.4 *1950 Flood Event and Flood Ranking*

The period of historic inflows (1958-1996) used for modelling does not include the largest flood (in terms of water volume) recorded in the basin, which occurred in 1950. The modelling period commenced with 1958 since daily outflow data (and thus inflow data) is generally not available for Namakan Lake prior to 1958, and the nearly 30 years of data since then was deemed to be of sufficient duration for most purposes. However, so that the various rule curves sets could be tested with 1950 inflows, sluice setting records were located for Namakan Lake for 1950 and daily inflow data was generated. One year REGUSE runs equivalent to F1-IJC, F1-SC, C1 and M1 were done for 1950, using the actual December 31, 1949 water level as the starting point for both lakes. In addition, some analysis was done to rank years on the basis of spring inflow volume and to compare peak levels resulting from the different sets of rule curves.

3.1.1.5 *Model Results*

Model results are summarized on a number of tables and graphs in the Appendix, as noted below:

Table 1 - summarizes key level and flow parameters for Namakan Lake for the simulated period 1958-1996 for Runs F1-F8, C1 and M1, plus some parameters for the same period under actual historic regulation and under simulated natural (unregulated) conditions (see section 3.1.2)

Table 2 - as above, but for Rainy Lake and including energy generation data

Graph 1 - compares the simulated base case (Run F1) IJC and SC levels on Rainy and Namakan lakes resulting from 1968 inflows. This year has the largest spring inflow volume in the 1958-1996 period. The IJC and SC rule curves are both shown on the graphs, as are the actual levels for 1968. In spite of the greater winter drawdown on Namakan Lake with the IJC rule curves, the spring flood level peaks at 58 cm above the maximum upper rule curve level and is only 5 cm lower than the peak with the SC curves. On Rainy Lake, the peak with the IJC curves is 31 cm above the maximum upper rule curve level but is 10 cm lower than the peak with the SC curves. Note that the actual peak levels which occurred in 1968 where higher than either of the simulated results.

Graph 2 - same as Graph 1, but for 1996, which was also a high spring inflow year

Graph 3 - same as Graph 1, but for 1977, which was the second year of a drought period until the drought was broken by a fall flood event. On Namakan Lake, operation with the IJC curves with their lower winter drawdown resulted in lower levels for a longer period of time (compared to the SC curves) during the continuing drought for the first half of the year. Then, with their higher late summer levels, the IJC curves resulted in a higher fall flood peak. However, on Rainy Lake, operation with the SC curves resulted in lower levels during the first half of the year. The lake level was drawn lower with the SC curves in the late summer of 1976 and, with the continuing drought, this difference could not be made up until higher inflows returned. Then, however, with the lower level again of the SC curves in the fall of 1977 but this time hit with high inflows, the SC curves resulted in a lower fall flood peak.

Graph 4 - shows the effect on resultant levels, with 1968 inflows, of the various within-rule-curve operating policies tested (Runs F1-F5) for the IJC and SC rule curves. For each set of rule curves, the results are shown as an "envelope" around the base case - for example, for the IJC rule curves, the F1 (base case) level is plotted as a solid line while dot-dash lines above and below it show the extremes in levels produced by any of the operating policy variants (Runs F2-F5). As shown, the various within-rule-curve policies, while resulting in significant level differences elsewhere, had very little impact on the spring flood peak.

Graph 5 - the 4 bar charts on this graph summarize level data for Namakan Lake for all 39 years (1958-1996) for Runs F1-F8. The top two charts compare the number of flood or high water days resulting from operations with the IJC or the SC curves. They show the total number of days for each run that the level exceeded the IJC "all gates open" level and exceeded the maximum upper rule curve level. The IJC curves consistently result in fewer such days than do the SC curves, but the difference is small and the number of exceedance days out of the total run length is small (typically 200 days or less out of over 14000 days, or 1.4%). The results are quite consistent regardless of the within-rule-curve operating policy, and increase when the water supply is increased, as would be expected. The lower two charts show the total number of days the lake level was above or below the IJC and SC rule curves. This assesses the "viability" of the IJC versus the SC curves - how well the dam operators might be expected to stay within the curves with the given inflow hydrology, or how well the curves "fit" the inflow hydrology. As shown, there are typically more violations of the IJC upper rule curve than of the SC upper rule curve, with the differences being significant, while typically the IJC lower rule curve has fewer violations than the SC lower rule curve but the differences are smaller. The number of rule curve violations fluctuates more with the operating policy than did the number of flood days. Rule curve violations occur about 7-11% of time with the SC curves and about 9-12% of time with the IJC curves.

Graph 6 - same as Graph 5, but for Rainy Lake. As with Namakan, the IJC rule curves result in fewer flood or high water events than do the SC rule curves, and the total number of days involved for both is small, but the differences tend to be more pronounced than with Namakan. The SC rule curves result in about double the number of violations of the "all gates open" level compared to the IJC curves, but this occurs only about 1.2% versus 0.6% of time. Similarly, the number of days above the maximum upper rule curve level is 50% greater with the SC curves than with the IJC curves. Regarding the lower two bar charts, it is seen that the lake level is consistently within the operating bands more of the time with the IJC curves than with the SC curves - rule curve violations occur about 12-15% of time with the IJC curves and about 14-20% of time with the SC curves.

Graph 7 - shows the difference in electrical energy generation with the IJC curves versus the SC curves. Overall, the SC curves produce 6.6% to 7.7% less energy annually, with little variation due to the operating policy. However, within the year, the difference varies from about 20% less in March-April to about 3% more in May-June.

Graph 8 - presents annual and monthly outflow-duration curves for Namakan Lake for IJC rule curve operation and for SC rule curve operation, but for the base case only (Runs F1). As an example of usage, refer to the plot for January. With the IJC rule curve operation (solid line), the outflow is about 100 m^3/s or less 50% of time, and is less than about 250 m^3/s 100% of time. The plots show that Namakan outflows are slightly greater with the IJC curves from January through April, that the outflow becomes greater in May with the SC rule curves and is significantly larger in June, but then is only marginally greater with the SC curves in July and is about the same with either set of rule curves from August through to year end.

Graph 9 - same as Graph 8, but for Rainy Lake. The pattern in outflow variation is similar to that described for Namakan, but the differences are larger. The outflow with the IJC rule curves grows steadily larger than that with the SC curves from January through April, but then reverses, and the SC outflows are quite significantly larger than the IJC outflows in June.

Graph 10 - compares, for 1996 inflows, the resultant lake levels with Runs F1-IJC, F1-SC, C1 and M1. The F1-IJC and F1-SC results are the same as shown previously on Graph 2. The IJC and SC rule curves, and the M1 modifications, are shown lightly on the plots. On Namakan, the level with C1 and M1 is virtually the same as with F1-SC, as might be expected. On Rainy, the C1 result is very similar to the F1-IJC result. The M1 line declines from January through March parallel to but somewhat above the F1-SC line, then rises to a peak a little higher than halfway between the F1-IJC peak (lower) and the F1-SC peak (higher). It then declines in the late summer to be above the F1-SC line but closer to it than to the much higher F1-IJC and C1 lines.

Graph 11 - same as Graph 10, but for 1977 inflows. Again, C1 and M1 are very similar to F1-SC on Namakan. On Rainy, C1 is fairly similar to F1-IJC for most of the year, and produces about the same fall flood peak. M1 is fairly close to F1-SC for most of the year, producing a very similar fall peak level but not falling as low in March.

Graph 12 - similar to Graphs 5 and 6, but compares number of flood and high water days, and number of days above or below the rule curves, for Run F1-IJC versus Runs F1-SC, C1 and M1. As shown, for Namakan Lake there is very little difference in results with C1 and M1 from those with F1-SC. For Rainy Lake, while the existing IJC rule curves (F1-IJC) still give the fewest flood and high water days, the C1 or M1 rule curve options produce fewer such days than the pure SC option (F1-SC)

Graph 13 - similar to Graph 7, this shows the difference in annual and bi-monthly energy generation between IJC rule curve operation and operation with the SC rule curves and the other two tested rule curve variants. Whereas the energy loss was 7.4% with the SC rule curves (F1-SC), it is 2% and 5% with the C1 and M1 options.

Graph 14 - similar to Graph 9, but this graph presents the outflow-duration curves for Rainy Lake not only for the two F1 runs but for C1 and M1 as well. As the lines can be difficult to distinguish, it may help to compare this graph with Graph 9. In most cases the results with C1 and M1 lie between those of F1-IJC and F1-SC. In particular, for the month of June where the difference between the two F1 runs was the greatest, the C1 and M1 results lie at about the mid-point.

Graph 15 - compares the simulated levels on Rainy and Namakan lakes resulting from 1950 inflows, the flood of record in the basin. Note that these graphs are to a different scale than the other lake level plots, in order to accommodate the higher peak levels reached. All 4 rule curve sets tested are plotted, plus the historic levels. While the existing IJC rule curves produce the lowest flood peaks of any of the rule curve sets tested, the difference between their peaks is small compared to the overall rise above the upper rule curves. (Note that these were 1-year runs. The rapid change in level and outflow during January for the simulations is due to the transition from the starting water level to levels consistent with the respective operating policy. This is not a factor for single years selected for plotting out of the continuous 39 year runs.)

Table 3 - ranks the years in order of spring inflow in the May through July period, gives the actual peak level that occurred for each year (in the May- July period) and, for those years that where modelled, gives the peaks for each of the 4 rule curve schemes tested. Difference in peak level between the IJC rule curves versus the SC curves and the other two variants are shown in brackets. Note that the upper rule curve maximum level is 340.95 m on Namakan Lake and 337.75 m on Rainy Lake. Peak levels below these values cannot be considered flood events.

3.1.1.6 *Observations*

Some key observations based on the model results follow.

Existing IJC Rule Curves versus Proposed SC Rule Curves

- the maximum flood level in the 1958-1996 period is somewhat higher with the SC curves than with the IJC curves - about 5 cm higher on Namakan and about 10 cm higher on Rainy. During some lesser flood events the difference is larger - for example, about 16 cm on Namakan Lake and about 13 cm on Rainy Lake with 1974 inflows.

- varying the mode of operation within either set of rule curves (Runs F1-F5) has little or no impact on flood levels (same maximum level, nearly the same number of days over either the "all gates open" or "maximum upper rule curve" levels), but does somewhat affect the number of violations of the upper rule curve and, more importantly, significantly affects the number of low level or drought days and the extent of the low levels

- the minimum drought level on Namakan Lake is 20 to 100 cm lower with the IJC curves than with the SC curves, but on Rainy Lake is 7 to 38 cm higher with the IJC curves than with the SC curves. On Namakan, the minimum level is quite consistent for the SC curves regardless of the mode of operation (F1-F5), but varies considerably for the IJC curves.

- based on the number of rule curve violations, the SC curves appear to be nominally more viable than the IJC curves on Namakan Lake, but less viable on Rainy Lake. Given the inflow hydrology represented by the 1958-1996 period and the limited outflow capacity of the dams, it appears that the operators would be able to maintain the lake level within the SC rule curves more often than within the IJC curves on Namakan, but vice versa on Rainy.

- while some of the differences between the IJC and SC level results appear large, these occur quite infrequently. For example, on Rainy Lake, the number of days above the IJC "all gates open" level with the SC curves is about double that with the IJC curves, about 50% higher for the number of days above the upper rule curve maximum level, and about 40% higher for the number of days above the upper rule curve. However, with either set of rule curves, these levels are exceeded for only a relatively small percentage of time - 0.6 % for IJC versus 1.2% for SC for time above the "all gates open" level, and 3.5% for IJC versus 4.9% for SC for time above the upper rule curves. Overall, with either rule curve set, Namakan is out of its band about 10% of time (5% under, 5% over), and Rainy about 15% of time (10% under, 5% over).

- average annual energy generation is 6.6 to 7.7% less with the SC curves than with the IJC curves (based on Runs F1-F5 - the difference is 7.4% for base case Run F1). However, more significant are the larger differences at certain times of the year. For the base case, SC energy generation is 8.8% less in November-December, 14.3% less in January-February and 19.3% less in March-April, much larger differences when replacement energy is more expensive.

- with the earlier refill of the SC rule curves, there is a significant shift in timing of the outflow from both lakes, with less in winter but more in summer, especially June. The differences are larger for Rainy than for Namakan. Rainy Lake outflows are about 140 m^3/s greater 50% of the time for the month of June with the SC rule curves than with the IJC curves.

- regarding Runs F6-F7, having more or less inflow does not appear to change the relative outcomes with the two sets of curves. For example, with more inflow, flood levels increase with either set of curves but the increment is about the same for both.

- regarding Run F8, reducing the Namakan minimum outflow by half is quite successful in reducing the number of extreme low level days and the number of days below the lower rule curve (even better than having an extra 10% water supply [Run F6] or targeting the 80% level within the rule curve band [Run F3]). The reduction tested on Rainy (from 103.3/93.4 m^3/s down to 85 m^3/s) had little impact, but of course this reduction barely offset the reduced inflow from Namakan when both lakes were at minimum outflow, so the net change would often have been 0.

- while it is believed that the differences in lake levels resulting from the two sets of rule curves should be reasonably representative of what might be expected, there is greater uncertainty regarding the absolute levels. The reason for this is evidenced by plots for Rainy Lake such as Graph 1 (1968) or Graph 2 (1996) - the model operating with the IJC rule curves produced significantly lower flood levels than those that occurred in real life. Also, on Table 2, the differences in parameters such as the total number of days above the upper rule curve maximum level is much greater between the historic versus the IJC simulated than it is between the IJC simulated and the SC simulated (for Rainy, 1189 for historic vs 254 for IJC vs 373 for SC). There are inaccuracies in some of the outflow rating relationships, for which there is insufficient data to make corrections. Also, part of the discrepancy in 1968 is due to increased outflow capacity in the model to reflect current structural conditions that changed after 1968. However, a significant difference likely remains. It was not possible to run the model with a shorter forecast, but tests showed that the 2-day forecast did not likely account for much of the improvement. Another factor that may be more significant is that the model also has perfect knowledge of past inflows and can react immediately, whereas in real life responses must be delayed by days before apparent changes in inflow can be confirmed with confidence. In summary, in spite of best modelling efforts, it is quite likely that higher levels will occur in real life with either set of rule curves than are demonstrated by the model.

Alternate Rule Curves

- on Namakan Lake the peak flood level is basically unchanged with either C1 or M1 compared to F1-SC, while the minimum drought level is about 10 cm higher. On Rainy, the peak flood level with C1 and M1 is halfway between the pure IJC and SC results, or 5 cm higher than the F1-IJC peak and 5 cm lower than the F1-SC peak. The minimum drought level with C1 is only 2 cm lower than with F1-IJC but, with M1, is 18 cm lower than with F1-IJC and 17 cm higher than with F1-SC.

- on Namakan, the number of days above the two flood levels (all gates open level and high point on upper rule curve) is about the same with either C1 or M1 as it was with F1-SC. There are a few more violations of the upper rule curve than with F1-SC but still significantly fewer than with F1-IJC. Run C1 has a few more violations of the lower rule curve than does F1-SC but still has fewer than F1-IJC, while run M1 has about 10% fewer than even F1-SC.

- on Rainy, the number of days above the all gates open level with C1 and M1 (about 120) is about half way between that for F1-IJC (84) and that for F1-SC (177). Regarding the number of days above the high point on the upper rule curve, C1 is about half-way between F1-IJC (lower) and F1-SC (higher) whereas M1 is only a little higher than the F1-IJC result. M1 has nearly as many violations of the upper rule curve as does F1-SC (higher than F1-IJC) while C1 is about halfway between F1-IJC and F1-SC. Both C1 and M1 have fewer lower rule curve violations than either F1-IJC or F1-SC, with M1 having fewer than C1.

- whereas F1-SC produced 7.4% less energy annually than F1-IJC, C1 produced 2% less and M1 about 5% less. Over the winter, whereas F1-SC produced 14-19% less, C1 produced 6 % less and M1 9-12% less.

- whereas F1-SC produced Rainy River flows in June about 140 m^3/s higher than F1-IJC 50% of time, the amount is about 70 m^3/s with C1 and M1.

Overall, with C1 or M1, results for Namakan are little changed from F1-SC. On Rainy, as would be expected, most results fall part way between those for F1-IJC and F1-SC, the main exception being that both C1 and M1 produce fewer lower rule curve violations. Compared to the existing (IJC on both lakes) and proposed (SC on both lakes), C1 permits the full proposed change on Namakan at a cost of splitting the difference on flood issues (between F1-IJC and F1-SC), a 2% annual loss in energy over the existing rules, and no summer drawdown environmental benefits on Rainy. Compared to this, M1 adds in the presumed summer drawdown environmental benefits on Rainy with no additional flood issue cost but with an increase in annual energy loss to 5%.

1950 Flood Event and Flood Ranking

- the different sets of rule curves result in differing peak levels even for a large inflow event like 1950. Previously it was thought that the peak level would converge to the same value for a large enough event - in other words, that the rule curve set would be overwhelmed by the inflow volume to the point of not being significant. Nevertheless, while the differences in peak level in 1950 between the various sets of rule curves are significant, still the differences are less than 6% of the amount by which all the peaks exceed the maximum upper rule curve level.

- while the peak levels are generally directly correlated with the May-July inflow volume, the differences between peak levels produced by the different sets of rule curves do not appear to be correlated in this manner (the differences are likely more a function of the specific timing and intensity of the inflow).

- Table 3 again illustrates that higher levels are likely to occur in real life than the simulated peaks given by the model.

3.1.2 Simulation of Natural Lake Levels and Outflows

A model was written to simulate the daily levels and outflows of Rainy and Namakan lakes in a state of nature, as if the dams had never been built. The primary purpose was to assess the natural timing of the spring refill, in order to verify the claim by the Steering Committee (SC) that the lakes would have refilled earlier under natural conditions.

3.1.2.1 *Model Operation*

The model is a simple routing model, working on a daily basis, and using lake elevation-storage curves and natural elevation-discharge curves taken from reports for the Rainy Lake Reference (1929, 1931). No time lag is assumed between the lakes. The same inflow data set as used for the REGUSE runs, for years 1958-96, was used.

3.1.2.2 *Model Results*

Samples of model lake level results are presented for Rainy and Namakan lakes on Graph 16 (covering the period 1970 to 1974) and on Graph 17 (1979-1983). They are plotted with the historic regulated levels and the existing IJC rule curves and the proposed SC rule curves. Graphs for the full 1958-1996 period can be found in the Natural Levels Report listed in the Bibliography.

Initially the intent was to statistically summarize and compare the timing of refill that would have occurred naturally versus that which has actually occurred under regulation and those which are imposed by the existing and by the proposed rule curves. However, due to the great irregularity of the natural water level cycle (little or no refill, several refill peaks of differing magnitude, refill peaks late in season, etc.), it is virtually impossible to define an objective algorithm (to compute the date and magnitude of refill) that would not be subject to bias. However, by simply viewing the graphs for the full 1958-1996 period, certain observations, albeit subjective, appear to be clear.

3.1.2.3 *Observations*

Observations drawn from the graphs are:

- on Namakan Lake:
  - the actual historic refill under regulation has typically occurred about the same time as the natural refill would have occurred - in some years it has been earlier and in some years it has been later but there is no regular pattern of it being either earlier or later - in fact, they are virtually superimposed for a number of years.
  - although there is wide variation in the timing of the natural refill, and in fact the time span of the natural refill period is wider than both the IJC and SC rule curve bands put together, the earlier refill of the SC band appears to be a better fit to the natural refill in a number of years.
  - the above two observations are not contradictory because, under historic regulation, the water level was often permitted to rise in advance of the IJC band if the inflow was "early".
- on Rainy Lake:
  - the actual historic refill under regulation has typically occurred earlier than it would have occurred naturally.
  - although there is wide variation in the timing of the natural refill, the timing of the IJC rule curve band refill appears to better fit the natural timing than does the SC rule curve band. The SC rule curve band refill is typically earlier than the natural refill, and even the IJC band may be on the early side.

- on both lakes:
  - both the IJC and the SC rule curves provide a much narrower time slot for refill than would be experienced naturally.
  - both in refill timing and in overall lake level range and year-to-year variability, the IJC and SC rule curves are much more similar to each other than either is to the state of nature.

Regarding timing, and based on the above observations, it would appear that:
- the earlier refill proposed by the SC for Namakan Lake is more natural. However, it would be questionable whether past regulation has been actually detrimental with respect to timing (relative to natural) since it has often duplicated the natural timing.
- the earlier refill proposed by the SC for Rainy Lake is less natural rather than more natural as claimed, and is therefore not something that the fish stocks would have typically experienced under natural conditions.

3.2 Inflow Forecasting

This section summarizes the work done to evaluate inflow forecasting for Rainy and Namakan lakes. While the Steering Committee acknowledged that their proposed rule curves potentially increased the risk of flooding, they suggested that any increased flood risk could be offset by improved reservoir inflow forecasting. In response, a two-stage work plan was developed - first, to assess whether or not improved inflow forecasting could realistically mitigate flood risk in a meaningful way and, if this appeared to be the case, second, to attempt to develop and implement the required methodology.

3.2.1 Assessing Forecast Viability

Due to the significant storage volume of the reservoirs, their limited outflow capacity relative to peak inflow volumes, the long travel times of runoff in the basin, and the undesirable impacts on the downstream regime of large and frequent outflow changes, it was deemed unlikely that an inflow forecast of only several days would have any measurable benefit on reservoir operations. However, it was unknown how far into the future inflows would have to be known in order to be able to improve operations. To determine this, a hydrologic routing computer model was developed to simulate reservoir operation with various periods of perfect foreknowledge of inflows. Perfect foreknowledge periods of 3, 7, 14, 21 and 28 days were selected for testing. The perfect foreknowledge of inflow events, or perfect forecast, is readily available for model simulation runs using historic inflow data. The modeller simply controls the amount of historic inflow data that the model can "see" at any one time, and that therefore affects the model's decision making process. It must be remembered, however, that the result represents the maximum benefit that could possibly be achieved for any forecast period, since any actual forecast methodology can only at best approach the perfect forecast, but never achieve it. Thus the benefits with an actual forecast will be less than those achieved with the perfect forecast for any given forecast period and, further, can reasonably be expected to be less and less as the forecast period becomes longer. This is because our ability to forecast becomes less and less accurate the farther into the future we try to predict. Thus, if model results show that the length of forecast required to achieve a meaningful improvement in reservoir operations is clearly beyond current capabilities, or if no significant improvement in operations is achieved, then there would be no point in trying to actually develop inflow forecasting methodology as part of this study.

3.2.2 Model Operation

The model used the same historic daily inflow data for the 1958-1996 period as used in the "REGUSE" modelling, using the historic total inflow to Namakan and the historic local inflow plus modelled Namakan outflow as input to Rainy. It was assumed that each forecast would be of inflow volume over the forecast period, represented by an average inflow over that period. However, of the forecast periods being tested, each forecast also included and used the information from any shorter duration forecasts, thereby at least partially accounting for the distribution of inflows within any given forecast period. For example, the 7-day forecast also included a 3-day forecast made at the same time, and the solution considered not only the appropriate actions to meet target levels 7 days in the future, but also 3 days in the future. Whenever there was a conflict, the shortest period was given priority. For example, in reacting to a large inflow over the next 7 days, the lake level would be drawn down to create storage space for it, but not to the point of violating the lower rule curve 3 days in the future. The model used a 3-day time step and attempted to track the middle of the rule curve band (either IJC or SC) on each lake. It deviated from this track only if inflows were greater than the outflow capacity, if the inflows were less than the specified minimum outflow allowable, or if, in response to the forecast, it needed to draw down the level to provide additional flood storage or raise up the level to provide drought reserves. However, violations of the rule curves were permitted only if the inflow exceeded the outflow capacity or was less than the minimum outflow; no violations were permitted in responding to the forecast. For comparison purposes, a base case or no forecast case was run using the average inflow over the past 3 days as the "forecast", upon which the outflow over the next 3 days was based, and then computing the actual level 3 days hence using the actual inflow.

3.2.3 Model Results

A summary of results is presented as follows:

Table 4 - documents the number and percent of time of rule curve violations, plus the maximum and median deviations, for both IJC and SC rule curves on both lakes for all of the forecast periods tested.

Table 5 - documents the peak flood levels reached in the 6 highest level flood years, (in the 1958-1996 sequence) with the various forecast periods and both sets of rule curves.

Graph 18 - shows, for 1968 inflows, the resultant levels on Rainy and Namakan lakes for all the forecast periods and the no-forecast case, operating with the IJC rule curves.

Additional graphs, for both IJC and SC rule curve operation, can be found in the Inflow Forecasting Component Report listed in the Bibliography.

Table 4 shows that, with either set of rule curves and for either lake, the percent of time that the upper and lower rule curves are violated diminishes as the forecast grows longer. However, the amount of improvement is rather modest. For example, on Rainy Lake with the SC rule curves, compared to the base case (no forecast), the number of violations of the upper rule curve are only reduced 0.65% (3.84% - 3.19%) with a perfect 7-day forecast, and only 1.6% (3.84% - 2.24%) if a perfect 28-day forecast could be achieved. Further, there is little or no improvement in the maximum deviation above and below the rule curve bands, and where there is a change it is about the same with either set of rule curves. As well, it is noted that there is little change in median deviation from the bands; in fact, some increase with the longer forecasts. This is simply due to the smaller deviations being eliminated with the longer forecasts, while the larger deviations remain, this resulting in a larger median.

Table 5 shows that, as the forecast lengthens, the peak level reached during the 6 largest flood years does tend to reduce but, again, by a rather modest amount in most cases. Compared to the base case, the reduction is typically 2 cm or less (maximum is 6 cm) for a 7-day perfect forecast and typically 5 cm or less (maximum is 15 cm) for a 28-day perfect forecast. The improvement is about the same for both the IJC and SC rule curves.

The Rainy Lake plot on Graph 18 can be used to illustrate model operation. First, note that the lines are plotted in the order shown in the legend and so, if two lines plot in the same place, only the lower of the two in the legend will appear on the graph as the upper one will be hidden beneath it. On the level plot, during the spring refill rising limb, it can be seen that the solutions for all the forecast periods are tracking up the middle of the band until at least mid-May. At this point the 28-day forecast solution starts to draw toward the lower rule curve, in response to having seen the large inflow coming in June and therefore trying to create storage space for it. At later dates the 21-day and 14-day solutions take similar actions, having not seen the looming flood inflow as early. All three reach the lower rule curve and so cannot do anything further to deal with the upcoming flood. Then, when the flood inflow arrives, the inflow rate is quickly greater than the dam's outflow capacity. Although the outflow is increased to maximum possible, the level rises through the rule curve band and well above it. The 7-day and 3-day forecast solutions only detect the large inflow slightly before it hits. They have achieved very little drawdown before the inflow overwhelms the outflow capacity. The base case, with no forewarning, is the first to rise above the rule curve and also produces the highest peak. However, this is less than 1 cm above the 7-day forecast peak, and only 2 cm above the 28-day forecast peak. In October, some of the solution lines again deviate from the mid-band tracking position, in response to detecting higher fall inflows. However, in this case, none of the solutions go outside the rule curve band. In fact, the shorter forecast solutions appear to be better than the longer ones in that they continue to track the mid-band target without unnecessary deviations. This is due to the simplistic nature of the model. The fall inflow does not exceed the dam's outflow capacity and so deviating from the target level is not actually necessary, but a more complex model would be needed to detect and account for this. This is not a problem in assessing the results since only unavoidable violations from the rule curve bands are counted.

3.2.4 Overall Observations

Inflow forecasting appears to be of little help in mitigating flood risk on these lakes. Given the limited outflow capacity of the dams, especially at lower lake levels, much of the incoming flood volume has to be handled by reservoir storage rather than by discharge. A forecast well in advance of the flood event is needed in order to provide the time needed to create the required storage, but then the rule curves themselves become an impediment since the rule curve bands are too narrow to permit sufficient storage space to be created to accommodate the flood volume. Thus, while it was initially believed that significant improvements in operations would eventually be seen with longer and longer inflow forecasts, this proved not to be the case.

3.2.5 Conclusions

With either the IJC or the SC rule curves, it appears that inflow forecasting could lead to only very modest improvements in reservoir operations, as measured by the number and magnitude of rule curve band violations. With either set of curves, a perfect 7-day inflow forecast would reduce the amount of time the upper and lower rule curves are violated by no more than 0.8% and 0.4% respectively, and would give virtually no change in magnitude of violations. Given that an actual

7-day forecast would likely achieve only a fraction of the perfect forecast benefits, and these are already low, inflow forecast development work is not warranted as part of this rule curve review. Further, given that the modest benefits are about the same for either set of rule curves, the inclusion of forecast benefits would not change the overall ranking of performance of the two sets of rule curves.

3.3 Flood Risk Assessment

This section summarizes the work conducted to assess the relative change in flood risk, if any, under the proposed SC rule curves, as well as under alternatives C1 and M1, compared to the existing IJC rule curves. The assessment was commenced by the St. Paul District of the US Army Corps of Engineers in November 1997 and defined the elevation-frequency and elevation-duration curves for Rainy and Namakan lakes, and the discharge-frequency curves for Rainy Lake outflow. These curves are based on correlations to longer-term records using graphical techniques as well as the REGUSE hydrologic modelling run results discussed in Section 3.1.1. That section also addresses annual and monthly flow-duration curves for Rainy Lake outflows.

Comparisons were made between Alternatives F1-IJC (existing condition), F1-SC, C1 and M1 to assess the relative change in the frequency and duration of Rainy and Namakan lake levels exceeding the established upper IJC emergency condition levels of 337.75 m on Rainy and 340.95 m on Namakan. The relative change in the frequency and magnitude of Rainy Lake outflow was determined and compared among the rule curve sets to assess the potential for increased downstream flooding on the Rainy River. Namakan Lake outflow was not analyzed as any changes in the discharge-frequency characteristics there are accounted for in the changes determined for Rainy Lake outflow.

3.3.1 Elevation/Discharge Frequencies

Annual peak frequency curves were developed for Rainy and Namakan lake elevations and Rainy Lake discharge using a daily time interval. The results of the REGUSE hydrologic model runs were utilized in the analysis using the continuous time period simulated in the model (1958-1996), but with historic extension of the time period using the 1950 flood event model run. Because Rainy and Namakan lake elevations and the discharge from Rainy Lake are affected by regulation, the peak values were analyzed graphically rather than analytically.

The 1950 event was known to have produced the highest peak discharge and elevation for the period of record for both Rainy Lake and Namakan Lake. It was assumed that this event was the highest since 1907 based on available flow and elevation data. When compared to the trend of the rest of the data, the 1950 event may have a return period longer than assumed. However, research to confirm its true frequency of occurrence is beyond the scope of this study.

The annual peak frequencies were computed using median plotting positions from the Flood Frequency Analysis (FFA) computer program of the Hydrologic Engineering Center (HEC) of the US Army Corps of Engineers. Peak annual elevations for both lakes for the highest twenty modelled years were correlated to the highest twenty years of ranked May-July inflow volumes (Table 3) from the longer record (1907-1996) and assigned appropriate plotting positions. This process allowed extension of the shorter modelled period (1958-1996), for which daily elevation values were available, to the longer period of record (1907-1996). This was necessary because only monthly elevation values were available for much of the period, prior to the 1950's. Lake elevations were correlated to the ranked inflow volumes, because the frequency of the inflow volumes is independent of lake regulation effects. Table 6 shows the elevation-frequency comparisons for Rainy and

Namakan Lakes. Peak annual daily discharge from Rainy Lake for the modelled period (1958-1996) was correlated to 91 years of peak outflow record and assigned the appropriate plotting positions. Table 7 shows the discharge-frequency comparisons for Rainy Lake outflow.

3.3.2 Elevation Duration

Elevation-duration curves were developed for Rainy and Namakan lakes. The REGUSE hydrologic model runs were utilized in the analysis using the continuous time period simulated in the model (1958-1996). Plots of lake elevation versus percent of time at or below a given elevation were computed. Graph 19 shows the elevation–duration relationships for Rainy and Namakan lakes.

3.3.3 Results and Observations

Examination of the results of the elevation-frequency analysis shown in Table 6 for Rainy and Namakan lakes shows that all of the alternatives produce a small increase in flood levels for the 5-yr through the 100-yr events, compared to the existing condition, with two minor exceptions. For the 5-yr event on Rainy the increase is 2 cm for F1-SC, but C1 and M1 show a decrease of 1 cm. For the 100-yr event on Rainy the increase is 14 cm for F1-SC and 9 cm for C1 and M1. On Namakan all of the alternatives produce about the same increase at each frequency. For the 5-yr event on Namakan the increase is 1 cm and for the 100-yr event the increase is 10 cm.

The results of the discharge-frequency analysis (Table 7) for Rainy Lake outflow shows that all of the alternatives produce slightly higher discharges on the Rainy River for the 5-yr through 100-yr events, compared to the existing condition. F1-SC produced the greatest increase, while M1 produced the least increase and was closest to the existing condition. C1 fell between the two in terms of overall increase. For the 5-yr event the increase is 40 m^3/s for F1-SC, 25 m^3/s for C1 and 10 m^3/s for M1. For the 100-yr event the increase is 50 m^3/s for F1-SC, 40 m^3/s for C1 and 30 m^3/s for M1.

Elevation-duration comparisons of the rule curve sets for Rainy Lake, shown on Graph 19, reveal no significant increase in duration of flood levels above elevation 337.75 m (existing IJC flood condition level) for alternatives F1-SC, C1 and M1 over the existing condition (F1-IJC). The duration of flood levels above the upper IJC emergency condition level on Rainy Lake was increased by about 0.9% for F1-SC, 0.4% for C1 and 0.3% for M1. On Namakan Lake the duration of flood levels exceeding the upper IJC emergency condition level was increased by about 0.4% for F1-SC, C1 and M1.

Overall, increases in flood levels on Rainy and Namakan lakes and in Rainy River discharge, among alternatives F1-SC, C1 and M1 when compared to the existing rule curves, are relatively small and do not appear to be very significant.

3.4 <u>Other Hydrologic Issues</u>

The Plan of Study called for a number of other hydrologic issues to be evaluated. These were the question of whether rule curves are the best approach for regulating Rainy and Namakan lakes, the minimum outflow criteria for the lakes, impacts of Bear and Gold Portage overflows on low Namakan Lake levels, and the balancing of water between lakes (between Rainy and Namakan or between these lakes and those further downstream). The Board's views on these issues, based on the hydrologic modelling work, can be expressed at this point but the development of recommendations on several of these issues is very much dependent on public and agency input which is addressed in subsequent sections of the report.

3.4.1 Lake Management Alternatives

To address the question of whether rule curves are the best approach for regulating Rainy and Namakan lakes, it is important to consider the classic options available for water resource management. Out of the full spectrum of regulation management options, rule curves lie close to one end of the spectrum and a fully mandated control board, with authority over the full range of levels and outflows, lies at the other end. Provided that water management objectives can reasonably be met, the rule curve approach is attractive since it is simple, low cost, and consistent so that everyone knows what to expect. Rule curves are typically developed as a result of a study, such as the original IJC study for Rainy and Namakan lakes, that attempts to consider and balance the interests of all stakeholders. However, rule curves are rigid. They are a compromise, based on views at the time of their development, for not only all the interests but also for the full range of inflows to be expected. They can provide a reasonable strategy for all years but probably not the optimum for any single year. In contrast, a fully mandated control board has the flexibility to respond to changing conditions, such as wet and dry years, and can react more fully to inflow forecasts (if reliable forecasts are possible and available). It can accommodate changing priorities, perhaps giving one interest a higher priority under certain circumstances. An example would be giving fish spawning a higher priority in the current year if the past several years have had poor success due to, say, low inflows.

Of specific relevance to Rainy-Namakan, a fully mandated board could address the suggestions by the environmental interests that water levels should rise above normal highs and decline below normal lows every few years in order to improve habitat. This sort of flexibility comes at a cost, however. A board requires a management structure, full time staff and appropriate technical tools, all of which are expensive. It requires a process for the active involvement of stakeholders on an on-going basis, and must initially develop and then evolve criteria for balancing the various interests on both a long and short term basis. Also, where the potential for good inflow forecasts of sufficient duration is limited, even a board may have to resort to using guidelines very similar to rule curves. Finally, compared with rule curve operations, there is no guarantee that the public is going to be any more satisfied with a board's attempts to best balance interests and inflows, or even be convinced of the board's impartiality. Between the extremes of rule curves and a control board, one might consider alternatives with level and flow guidelines as opposed to rules, coupled with a policy defining limited flexibility under certain circumstances. However, trying to anticipate such circumstances and define limited operational flexibility for each case in advance can be very complex, and still requires an objective body to operate the system.

The Board is presently of the view that rule curves can continue to adequately meet water management objectives on these lakes. This is based in part on the degree of compromise already achieved among the interests, in part on the technical work such as the modelled system response to inflows and in part on a review of attempts at inflow forecasting for the basin which indicate limited potential for reliable forecasts of sufficient duration. In addition, it is unlikely that governments would be prepared to make the resources available for a more pro-active form of management in this continuing era of fiscal restraint. Certainly the preference is to adopt the simplest approach which is satisfactory.

3.4.2 Minimum Outflow Criteria

Experience with five significant drought events in the Rainy-Namakan basin since 1977 has provided the IRLBC with considerable experience in managing these situations. The IRLBC believes that, with this experience, and the precedents that have been set through the granting of Supplementary

Orders by the IJC, the process of managing these events can be simplified and improved for all concerned.

The Board's concept is to define a two-step minimum outflow rule. The first minimum outflow would come into effect at the lower rule curve, as is currently the case. A second, lower minimum outflow would come into force at a new, predefined lower drought level. When the second minimum outflow condition is in effect, the actual releases from the dams would be determined by the Board at their discretion, with the defined minimum setting the lower bound. The Board has become fully familiar with the issues and the interests in the basin, and would implement outflows below the first minimum only after appropriate consultation with basin resource managers and other concerned parties.

This two step approach would have two main advantages over the current drought management procedures. First, and most importantly, basin resource managers and other users of the water resource would know what to expect in a drought situation as the rules would be defined in advance. However, they would still have the assurance that they would be consulted before lower flows are implemented. Secondly, the amount of administrative overhead and delay would be reduced in responding to drought situations. Supplementary Orders would be requested by the IRLBC, and issued by the IJC, only in very special circumstances.

The Board believes that the concept presented here will improve basin management. The actual definition of the minimum outflows and the trigger levels for the second minimum flow, however, is dependent on input from resource managers and other interests which is presented in Section 3.8.

3.4.3 Impacts of Bear and Gold Portage Overflows on Low Namakan Lake Levels

The two natural overflows from Namakan Lake at Bear Portage and Gold Portage are significant because they provide flow paths to Rainy Lake that bypass the regulatory dams at Kettle Falls. The capacity of the two overflows at the lower limit of summer levels can be approximately 60% of the specified minimum flow at Kettle Falls, making the actual outflow up to 1.6 times the minimum specified in the Order. The control over levels in Namakan Lake is diminished in proportion to the capacity of these overflows.

Historically, overflow at Bear Portage was probably more significant than at Gold Portage. A timber and stone crib was constructed in the early years to inhibit outflows at Bear Portage and the 1949 IJC Order specified that this was not to be altered or maintained. Gold Portage overflow was stable until the mid-1950's at which time it was enlarged, probably by local residents. Since that time it has enlarged further by erosion, by the removal of a logging road that acted as a partial dam and possibly by further tampering. Between 1958 and 1981, Gold Portage overflows increased over tenfold. Outflow capacity increased further, but at a decreasing rate, through the 1980's. No appreciable change in the rating has occurred since 1991. Flow commences at Gold Portage when the water elevation of Namakan Lake reaches 339.29 m and Bear Portage at an elevation of 340.39 m. At a Namakan elevation of 340.77 m (summer lower rule curve level), Gold Portage outflow is 16.2 m^3/s, compared to a Bear Portage flow of 1.3 m^3/s. During flood events overflow at the portages provides additional capacity for removing water from Namakan Lake. Any reduction in their capacity would reduce outflows, and thus raise Namakan Levels, since the capacity to release water at Kettle Falls is limited by the control structures.

The Board believes that the most pragmatic means of dealing with the overflows is to include the amount of the overflows in the minimum outflow specified in the Order. This essentially moves the "monitoring point" from Kettle Falls to the combined outflow points of Namakan Lake. This approach will require the continued periodic monitoring of the outflow at Bear and Gold Portage to ensure that the elevation-outflow relationship remains current and is not continuing to increase too quickly. This approach is reflected in Recommendation 2 of the report.

3.4.4 Balancing of Water Between Lakes

Water resource management on a basin scale, rather than in jurisdictional units or on a local scale, is an ideal pursued by water resource managers everywhere. Under this ideal, the IRLBC would have liked to propose that Rainy and Namakan Lakes be managed inter-dependently, and perhaps the water resource situation of the Rainy River and regions further downstream could be considered as well in setting outflows from these upper lakes.

In practice, however, there is not much opportunity or flexibility for this kind of interaction in the Rainy-Namakan basin. As noted in Section 3.4.1, the Board recommends retaining the rule curve approach for regulating these lakes. Real-time consideration of downstream areas such as Lake of the Woods or the Winnipeg River, or more than a simple treatment of Rainy River regulation, is far too complex to incorporate along with rule curves, and can only practically be addressed on the basis of average conditions when the rule curves are developed. Regarding an effort to balance between Namakan and Rainy Lakes, experience has shown that the lakes tend to be stressed by low or high inflow conditions at the same time. The interests on each lake have led to the definition of narrow, specific operating criteria. Any storage volume that Namakan can spare in flood or drought years is small and doesn't help Rainy Lake significantly.

In the comments from downstream interests, which are presented in Section 4, there is an emphasis on the need to consider the basin overall and to strive for a "global" optimum. It is the Board's intent to consider the overall basin in defining the recommended rule curves, but the Board proposes that more elaborate balancing schemes not be incorporated.

3.5 Fisheries Review

3.5.1 Initial Fisheries Evaluation

The Board gave priority to an independent review of the existing information on the fisheries of Rainy and Namakan Lakes. A Statement of Work was developed, which highlighted the questions related to the fisheries resources in the Plan of Study, and asked for opinions on questions such as (i) what impacts does the present mode of regulation have on the fishery?, (ii) would the changes being proposed be effective in aiding the fishery? and (iii) are all of the proposed changes required to effect a benefit? The Statement of work also asked for a detailed review of the fisheries literature in the basin and relevant external information, and to document areas of insufficient or inclusive information.

A search for experts was initiated and fisheries agencies, fisheries research managers and the International Joint Commission were approached to obtain the names of candidates. The Board reviewed the credentials of each person proposed, and retained two experts under contract, one from Canada and the other from the United States, to undertake the work. The Canadian, Gordon Koshinsky, is a retired fisheries research manager, previously employed as a special projects consultant with the Canadian Federal Department of Fisheries and Oceans in Winnipeg, Manitoba. The American, James Kitchell, is a Professor of Zoology, and Director of the Center of Limnology at the University of Wisconsin. Both experts were highly recommended by colleagues in the fisheries field, were knowledgeable of the fisheries in the basin, and were independent of studies carried out by agencies or bodies with a direct interest in the regulation of the Rainy Lake system.

The experts were retained in early February, 1996 and asked to produce independent interim assessment reports for the Board by April 1, 1996. The consultants did so. One of the interim reports presented a detailed review of the scientific literature and findings, and the other interim report presented an overview of the fisheries issues in the Rainy Lake basin. A final combined consensus report was prepared and submitted to the Board in August, 1996. The major findings and conclusions of that report, reproduced from the executive summary, are given in the paragraphs which follow. The full final report is listed in the Bibliography.

Excerpt from Executive Summary - Final Fisheries Report

Two general sets of information were evaluated: long-term monitoring results on fisheries and fish populations of Rainy Lake and the Namakan Lakes and short-term, site-specific studies within these lake systems. Commercial fishing records and standard fisheries assessment data sets were collected by the Minnesota Department of Natural Resources and the Ontario Ministry of Natural Resources. These long-term data sets served as the basis for a series of statistical analyses intended to evaluate the relationship between water level fluctuations and fisheries yields or the catches made in test netting programs conducted by the two agencies. A shorter-term group of comparative studies and surveys were sponsored through the US National Park Service. Those offered evidence of water level effects on some of the key fish species as well as other components of the biota.

Fish populations in Rainy Lake and the Namakan Reservoir systems have generally declined since the dams were built and the fisheries developed. Commercial fishing on these lakes has been largely eliminated by both Minnesota and Ontario, yet catch rates in the recreational fisheries continue to decline or remain at low levels. Poor recruitment of juvenile fishes is associated with the ecological consequences of current water level management practices. The SC recommendations offer new rule curves designed to simulate seasonal changes in the unregulated hydrograph and, thereby, mitigate negative ecological effects through earlier spring filling of the reservoirs, late summer drawdown to improve spawning habitat and a reduced amplitude of water level changes in the Namakan system.

We endorse the proposed changes in rule curves as recommended by the International Steering Committee in its 1993 report. We believe that current water level regulation practices and fishery exploitation act in concert to exacerbate the inherent variability in fish populations, leading to uncertainty about the relative importance of causes of decline in those populations. Nevertheless, remedial actions can help rehabilitate the currently depressed fish populations and should include water level regulatory practices that seek to simulate those representative of previous, natural conditions known to sustain fish populations. In addition, we support continuing efforts to reduce and constrain exploitation pressure.

Our five major findings and conclusions are:

1. **Further analysis of the existing data sets will not offer significant improvement in understanding of effects of water regulation on fisheries.** The long-term data were derived from general monitoring efforts that were not designed to directly evaluate the effect of water level fluctuations on fish spawning success.

2. **Overexploitation has played a major role in the decline of fish stocks.** Records of commercial catches are confounded by changes in effort and gear. Those for recreational catches are intermittent and incomplete. Nevertheless, these fish populations exhibit well-known symptoms of overexploitation. Newly-implemented fishery regulations are an appropriate step toward diminishing exploitation effects and increase the likelihood that fisheries yields will begin to improve.

3. **Water level regulation has contributed to the decline of fish stocks.** Drawdown of water levels during the winter produces low water levels during the spring. In addition, the dams sustain high water levels during summer and early autumn. These practices have reduced the likelihood of successful spawning and recruitment by several important fish species. Although regulated water levels will remain, rule curves designed to more closely simulate the previous, natural hydrologic regime are likely to improve the changes for rehabilitation of desirable fish stocks.

4. **Fisheries managers should develop and implement a more aggressive program to evaluate the importance of invasion by the exotic smelt (Osmerus mordax).** In many ecologically similar lakes, smelt have had adverse effects on walleye, yellow perch, whitefish and cisco populations.

5. **Management actions such as those embodied in new rule curves and more restrictive fishery regulations require follow-up studies.** These actions offer an excellent chance for learning through the management process. Careful and effective documentation of the consequent results is more than an opportunity, it is also an obligation. Key areas for further work are:
a) Repeat and expand previous surveys of macrophytes and benthic invertebrates,
b) Evaluate changes in, and associated with, fish spawning habitats,
c) Sustain or expand fisheries assessment efforts, and
d) Evaluate the role of exotics (e.g., rainbow smelt).

We emphasize that variable recruitment is an inherent property of the life history for fish species that dominate these fisheries. Thus, managers must accept uncertainty as a fundamental reality. Rehabilitation of high-value, sustainable fisheries can be enhanced by management actions, but must be viewed as part of the ecosystem management process rather than as an equilibrium condition or an end point.

3.5.2 Supplemental Fisheries Evaluation

Following completion of the simulation of natural lake levels and outflows, undertaken as part of the Hydrologic Modelling component of the Study and described in Section 3.1.2 of this report, the fisheries experts were approached to determine if the results of the modelling impacted on their earlier findings. The experts agreed to carry out a supplemental evaluation which was completed in January, 1998 and is referenced in the Bibliography of Technical Reports. The Summary of that evaluation is reproduced in the following section.

Summary

The fish and related biota of the Rainy-Namakan system are the products of a long and complex evolutionary history. Human activity has recently impacted on these fisheries, both directly and by actions that have been mediated through the environment. The latter actions have included substantive changes to the hydrological regime. The general conclusion that was expounded earlier is re-iterated, that measures tending toward restoration of natural conditions will be to the general benefit of the indigenous fishery resources. This conclusion has been adopted in the present instance as the basis for a specific working hypothesis.

The recent modelling exercise with respect to natural (unregulated) lake levels has confirmed that both lakes have been markedly altered as habitat for fish. Changes have been wrought in lake levels per se, in the timing of lake-level maxima and minima, and in the amount of variability pertaining to both lake levels and the timing of hydrological events. The greatest changes in absolute terms have been manifested in reduced lake-level variability.

It is now obvious that neither of the two options for hydrological management that are under active consideration for this system comes particularly close to approximating the natural unregulated condition, certainly not from the perspective of the fisheries. The regulatory regime as proposed by the International Steering Committee (1993), however, does represent a worthwhile improvement in that direction, more notably for Namakan Lake, and most particularly in respect to the timing of spring refill and the promotion of summer drawdown. Ongoing exploitation of the fisheries and the recent invasion of the system by rainbow smelt are confounding variables that are common to, but presumably not functionally identical in, both of the major lakes.

The contention is repeated that significantly better understanding and prediction of the effects of alternative hydrological regimes on these fisheries are not to be expected from further more detailed analysis of the existing data sets. This is not to suggest that the existing data are without utility for constructing response models pertaining to alteration of the hydrological regime, and is certainly not meant to imply that more/other process research would not be useful. It is merely to emphasize once again that the existing data were not derived for the particular purpose of understanding the relative benefits or dis-benefits of different water regimes on the fish and the fisheries. The data that do exist have already been exploited to or beyond their inherent limitations for that purpose.

Based on the above observations it is recommended that an experimental management approach be adopted for rehabilitating the fisheries of the Rainy-Namakan system. It is contended that such an approach could be pursued advantageously and expeditiously by implementing the recommendations of the Steering Committee in respect to the hydrological management of Namakan Lake, while maintaining operations as per the current regime for Rainy Lake. Such a procedure, if it were appropriately designed and implemented, and accompanied by adequate response monitoring, over time should markedly diminish the uncertainty that so hampers and confounds present efforts to understand the controlling factors in these fisheries. Specifically, it should provide a clear indication if a return to a more natural hydrological regime is the key to rehabilitation. If a positive result were achieved, the approach might be expanded or at least maintained. If no appreciable positive effect were observed, it could then reasonably be concluded that solutions would need to be sought in other avenues, most likely in more rigorous controls on fishery exploitation.

3.6 Environmental Data Summary

The review of existing environmental data and information was undertaken by the St. Paul District of the US Army Corps of Engineers and published in a draft report entitled *"Review of the Potential Effects on Selected Ecological and Cultural Resources of Proposed Changes in Water Level Regulations for Rainy and Namakan Lakes"* dated January, 1997. The report is included in the Bibliography. The main thrust of that review was how regulation of the reservoirs (specifically the IJC rule curves versus the proposed Steering Committee rule curves) can be improved to enhance/restore the ecological conditions in the lake system.

3.6.1 Initial Environmental Findings and Conclusions

The major findings and conclusions, contained in the Executive Summary of the above noted report, are reproduced below:

"*Is the information adequate for making decisions on the proposed rule curve changes?*"

There is adequate information available to make a decision to support the proposed rule curve changes. The information indicates the present water level regulation plan constrains certain natural resources within the Rainy Lake-Namakan Reservoir system.

"*Are the concerns/perceived problems valid for the existing rule curves?*"

The concerns and perceived problems with the existing rule curve are valid. Available information shows the hydrologic regime under the present water level regulation plan is negatively impacting Voyageurs National Park (VNP) natural resources.

"*What further changes to the ecosystem components can be expected under the present mode of regulation?*"

The VNP studies reviewed were short-term and lacked the temporal quality to allow trend analyses to be completed. The present water level regulation plan has been in effect for 25 years. Many components of the lake ecosystems have not shown declines under the regulated hydrologic regime. Other components of the lake ecosystems have shown decline over the last 25 years. The VNP studies reviewed did not include long-term forecasts of future ecological conditions under the present water level regulation regime.

"*Would the proposed rule curve changes contribute, and by what magnitude, to meeting the objectives established for the proposed resolution to address the concerns/perceived problems?*"

The proposed rule curve changes would contribute to the objectives established addressing the perceived problems in a number of ways. Initial physical changes (i.e., decreased shoreline erosion and nutrient input) resulting from reducing the large seasonal water level fluctuations in Namakan Reservoir, would trigger positive responses in the aquatic plant and associated wildlife communities. The Rainy Reservoir water levels would fluctuate more than present under the proposed rule curve change. The new rule curve would provide minor habitat improvements for the aquatic plant community through an earlier spring rise and declining summer water levels. Wildlife would benefit from the increased extent, diversity, and abundance of aquatic plants.

"*Would other causal factors mask any effects of the proposed rule changes?*"

The operation of the Rainy and Namakan chain of lakes as impoundments for hydropower generation and flood control affects the quality of the environment, regardless of the water level regulation plan followed. They are impoundments with higher water levels than prior to their operation and natural water level conditions are not possible. But it is possible to regulate the reservoirs in a manner that more closely matches the unregulated, natural hydrologic regime. Inter-annual variability in water levels is not being addressed by the proposal, yet is an important consideration to optimize the aquatic plant community. The natural brown-stained water present in this system will continue to limit the photic zone and depth of aquatic plant colonization. Human disturbances to wildlife will also continue to occur in the Rainy system.

"*Are all of the proposed changes required to achieve environmental resource benefits?*"

All the proposed changes to the reservoir water level regulation plans would be required to realize predicted benefits to the full array of ecosystem components. The most important increment to change in the current rule curve is reducing winter drawdown on the Namakan reservoir system because of its broad impacts on the lake ecosystem. However other seasonal changes proposed by the SC may be more important to some species than modifying the winter drawdown on the Namakan reservoir.

"*Are there alternative changes to the proposed rule curves that would further enhance environmental resources?*"

Infrequent occurring events, both high and low water, are characteristics of unregulated hydrologic regimes and are key factors in regulated aquatic system management. Sustained low water conditions for a period will lower overall productivity of the area during a drought, but benefits such as future increased plant productivity outweighs the short-term losses. High water events often temporarily upset terrestrial habitat conditions, but the temporary disturbances to these areas have been shown to be critical to its perpetuation. We suggest that the IJC ruling occasionally allow operation outside the proposed water level regulation band. It has been shown in a number of studies the key to optimum habitat management is infrequent extreme events.

"*Recommendations for Additional or Future Studies*"

No additional studies should be necessary to make a decision concerning a rule curve change. Both the studies performed within VNP and supporting studies performed world-wide provide sufficient data and interpretations to warrant a rule curve change. If the decision is made to change the water level rule curves, additional studies and surveys should be conducted prior to and during the change to monitor effects of the altered hydrologic regime. Primary producers and species low in the food chain should be targeted for monitoring because they respond more rapidly to habitat changes than do species higher in the food chain.

3.6.2 Re-evaluation of the Initial Environmental Findings

Following completion of the simulation of natural lake levels and outflows, as described in Section 3.1.2, the authors undertook a re-evaluation of their conclusions and prepared a memorandum for record, dated 17 December 1997, which is largely reproduced below:

General

We observed two trends in our review of the revised hydrologic modelling results that could influence conclusions reached in our initial evaluation:

- The SC and IJC rule curves require an earlier spring rise than the simulated conditions on Rainy Lake.
- The simulated natural inter-annual variability, especially in summer, is significantly stifled under both the SC and IJC curves.

Other components of the proposed rule curve change, including an earlier spring rise and reduced winter drawdown on Namakan, seem to be supported by the simulation of natural conditions. Therefore, the conclusions we reached during the preliminary evaluation would not be altered by the revised hydrologic modelling for these components of the proposed rule curve changes.

Namakan Lake

We believe there are both positive and negative impacts to the proposed SC rule curve. Compared to the simulated natural curve, the SC rule curve provides a closer match to spring water level increases. The SC rule curve also more closely follows the rate of natural water level declines after the spring high water peak. One of the main environmental concerns of the IJC rule curve was the enormous winter drawdown band width. The new rule curve does narrow the band width during the winter drawdown, while obtaining higher water levels during this period. As a result of the proposed winter water level operation, many of the unnatural habitat alterations occurring during this period would be dampened.

There are also serious environmental concerns with the proposed SC rule curve. The narrow operating band (other than during winter) does not allow enough room for "catastrophic" water events. The bottom of the SC band could be lowered by 1 foot to allow for higher management capabilities, such as summer drawdowns. Whereas in natural conditions water levels declined between 0.5 and 3 feet in summer, this plan only allows for less than 0.5 feet. For the new plan to benefit this area, a higher degree of management options needs to be available. The water level declines after the spring peak only allow 0.5 foot drawdowns. The estimated natural drawdown from the spring high looks to average approximately 2 feet. There will be very little area within the littoral area that would be benefited by only a 0.5 foot water level decline. The benefits we claimed in our report assumed the drawdown would be more considerable than a 0.25 foot change during the growing season. Using Kabetogama Lake as an example and assume it has 75 miles of shoreline. During a 0.25 foot summer drawdown, probably 2 feet of shoreline would be exposed in this period. Using this number, it is estimated exposed shoreline would be 18 acres. The point of this example is, the further the water level declines during the growing season, the more the littoral zone habitat would be affected. Supporting documentation shows a well developed littoral area forms the base of the food web and the system is driven by base habitat conditions. We believe a greater band width during this period would allow more management control to optimize overall habitat conditions on the Namakan system. The key to proper management of these lakes lies in optimizing water level control during the summer months. The habitat would be vastly improved by allowing more dramatic water level changes during this period.

Rainy Lake

Again, there are both positive and negative impacts of the proposed SC rule curve from an environmental perspective. The proposed curve appears to provide room for a drawdown during the vegetative growing season, or from the period from late May through October. The IJC rule curve provided very little room for water level declines during this period. The new curve only has peak water levels for a short period of time which more simulates what occurs naturally. After peak water levels occur, the rule curve calls for water level declines from June through March. The new plan comes closer to the simulated natural curve than the IJC rule curve, which maintains peak water levels throughout the growing season.

The peak water levels proposed by the Steering Committee appear to occur earlier than what the modellers predicted in simulations of natural conditions. Many of the simulated natural peak water levels would occur in June or July, rather than the proposed late May peaks. Many of the benefits predicted for an earlier spring rise on Rainy, as recommended by the SC, would probably still occur. For example, loon and other shore and marsh birds and turtle nesting in Voyageurs National Park begins in late May to early June. An earlier spring rise would reduce nest flooding. Another example, walleye and northern pike spawning begins and is completed between water temperatures of 2 to 10 C., or earlier. Payne (1991) measured May temperatures in Rainy Lake in the range of 5 to 10 C over several years of monitoring, indicating that under normal conditions spawning and egg incubation occurs in April and May. The earlier spring rise proposed by the SC would more closely align with the needs of some of the selected target organisms than either the IJC or simulated natural hydrographs. However, if the intent is to simulate more natural hydrographic conditions then it would appear the peak spring levels could be a couple of weeks later on Rainy Lake, similar to the existing IJC rule curve. However, it would also appear higher inter-annual variability, especially during the summer, would better simulate natural hydrographs and be beneficial to both the Namakan and Rainy Lake ecosystems. We would strongly encourage a wider band in the summer, with more of a "run of the river" mode of operation on both Namakan and Rainy Lakes. This would increase inter-annual variability, allowing lower levels during drought cycles and high water levels during wet cycles.

Summary

- The SC and IJC rule curves require an earlier spring rise than the simulated natural conditions on Rainy Lake.
- We believe that many of the ecosystem resources would benefit from an earlier rise on Rainy as proposed by the SC. However, if the intent is to simulate more natural conditions then a later rise, similar to the existing IJC curves, may be more appropriate. This may be especially true if an attempt is made to further align the proposed rule curve changes with the simulated natural hydrographs, as recommended below.
- The simulated natural inter-annual variability, especially during the summer, is significantly stifled under both the SC and IJC curves.
- We would strongly encourage a wider band in the summer (increase band width by 1 foot), with more of a "run of the river" mode of operation on both Namakan and Rainy Lakes. This would increase inter-annual variability, allowing lower levels during drought cycles and higher water levels during wet cycles.

3.7 Economic/Social/Recreational Factors

The evaluation of the existing economic, social and recreational data was undertaken by the St. Paul District of the US Army Corps of Engineers and the initial stages of this work was published in a draft report entitled *"Rainy and Namakan Lakes Proposed Rule Curve Changes - Phase A - Economics: Evaluation of Existing Data"*, October 1996. Additional background socio-economic data was then compiled by the Corps of Engineers in order to understand the broader economic and social characteristics of the region, and their possible sensitivity to issues involving potential changes to the rule curves for Rainy and Namakan Lakes. Statistics were gathered on population, housing, family data, education, poverty, unemployment rate, income, labour force, and employment for both the United States and Canadian portions of the basin. Subsequent to the release of the Status Report, further work was undertaken to broaden the economic analysis; to determine for nine impact categories the incremental changes that would result from any of the rule curve alternatives. The results are contained in the report *"Evaluation of the Economic, Social, and Recreational Impacts of Proposed Changes to the Rule Curves Defining the Operation of Rainy and Namakan Lakes"*, March 1999, prepared by the Corps of Engineers and listed in the bibliography.

The results of this analysis have shown that the effects of the proposed changes in the existing rule curves at Namakan and Rainy Lakes will vary widely depending on the alternative and resource category being considered. There are significant negative effects in some categories, and beneficial effects in others. To the extent possible, quantitative analysis was performed to estimate the effects, however, this was not possible in all categories being considered. The overall effects in each of the resource categories are summarized below.

3.7.1 Socioeconomic Profile

The area surrounding Rainy and Namakan Lakes is well established as a destination for a wide range of outdoor recreation pursuits. In order to better understand the broader economic and social characteristics of the region, and their possible sensitivity to issues involved with potential changes to levels and flows on Rainy and Namakan Lakes and adjoining waters, these characteristics are summarized in the sections that follow. The socioeconomic profile information is provided for the surrounding area in the United States, followed by the surrounding area in Canada.

3.7.1.1 *Rainy Lake and Surrounding Area in the United States*

Socioeconomic information was obtained for the city of International Falls, Minnesota and the surrounding Koochiching County. These areas were selected because they represent the major population and economic center adjacent to the lakes in the US. International Falls is the major center for government services in the region and plays a pivotal role in the trading area that contributes significantly to the local economy. It is also a major point of entry into the US, on the border of the Province of Ontario and the State of Minnesota. Koochiching County extends from near the town of Rainy River on the west, to Voyageurs National Park on the east..

In 1990 the population of International Falls was 8,325 and the population of the surrounding Koochiching County was 16,292. The population trends in the area show a population increase since 1980 of about 48% in International Falls, and a population decrease of about 7.8% in Koochiching County. The 1993 unemployment rate was 5.3% for International Falls, and 10.9% for Koochiching County. There were 6,506 workers in the Koochiching County labor force in 1993, and this is projected to decline by 15.5% by the year 2020. The major employer in the county is the pulp and paper mill owned by Boise Cascade Corporation, with about 1,200 employees, followed by the International Falls School District and United Health Care, with about 300 employees each.

3.7.1.2 *Rainy River District and Surrounding Area in Canada*

Information was gathered for the Town of Fort Frances, Ontario, and the surrounding area, which is known as the Rainy River District. These areas were selected because they represent the major population and economic centre adjacent to the lakes in Canada. They were also selected because they were the primary areas for which socioeconomic data was available in the region.

Fort Frances is the major centre for government services in the region and plays a pivotal role in the trading area that contributes significantly to the local economy. It is also a major point of entry into Canada, on the border of the Province of Ontario and the State of Minnesota. The Rainy River District is a large region that extends from the town of Rainy River on the west, to the eastern edge of Quetico Provincial Park on the east, and from Nestor Falls on the north, to the border between Canada and the US on the south.

The 1990 population of Fort Frances was 8,891, and for the Rainy River District it was 22,997. The population of Fort Frances has been relatively stable, fluctuating around 9,000 people from 1976 to 1990. The unemployment rate is 10.1% in Fort Frances, which is slightly higher than the unemployment rate of 9.9% in the Rainy River District. The total labor force in Fort Frances was 4,570 in 1991. The major employer in Fort Frances is the pulp and paper mill owned by Abitibi-Consolidated, Inc., which has about 900 employees. The next largest employer is the Rainy River Board of Education, with about 450 employees.

Together, the towns of Fort Frances and International Falls provide a broad spectrum of facilities, services, and activities that enhance the potential for economic development in the region.

3.7.2 Hydropower

The hydropower projects that would be affected by the alternatives evaluated in this report are located at the site of the International Dam at the outlet of Rainy Lake on the US/Canadian Border between Fort Frances, Ontario, and International Falls, Minnesota. The Canadian powerplant, owned and operated by Abitibi-Consolidated Incorporated, has a total generating capacity of 12.8 MW, with a historical average annual generation of 59,800 MWh. The US powerplant, owned and operated by Boise Cascade Corporation under FERC license #5223, has a total generating capacity of 11.3 MW, with a historical average annual generation of 67,200 MWh. The value of power produced by both plants is US$5.1 million per annum.

The power generated by these powerplants is used to supplement the power needs of the two pulp and paper mills. Because the demand for power from both of these plants exceeds their power generating capability at all times, all of the energy that can be generated is of value in reducing their reliance on outside sources of power. On an annual average basis, these hydropower projects supply about 10% of the total power required to run the plants.

The hydropower economic analysis was accomplished using data generated by the REGUSE model runs for the period 1958-1996. This data, combined with pricing information to determine the cost of replacement energy purchased from local utilities, was used to determine the total power cost associated with the lost generation for the various alternatives.

When compared to the existing rule curves, all of the alternatives result in a decrease in hydropower energy production, particularly in the winter months when it is most costly to replace. The average annual energy produced by both plants under the existing rule curves (Alternative F1-IJC) is about 121,700 MWh. The average annual decrease in energy produced by the plant is 2,400 MWh under

Alternative C1, 5,900 MWh under Alternative M1 and 9,000 MWh under Alternative F1-SC. The additional yearly average cost of replacing this power is US$114,000 under Alternative C1, US$261,000 under Alternative M1 and US$376,000 under Alternative F1-SC. These costs could vary significantly in individual years depending on water conditions and future power replacement costs.

3.7.3 Flood Damages

The flood damage analysis employed a conventional approach to assessing damages based on developing elevation-damage relationships and determining flood damages based on historical flood levels. Two primary types of data were used in performing this analysis. The first was estimates of annual flooding, which were based on simulated water levels obtained from simulations conducted by Environment Canada using the "REGUSE" computer model for the years 1958-1996 and 1950. The second type of data was elevation-damage relationships that were used to determine the damages associated with different levels of flooding.

Annual damages were calculated for each of the years 1958-1996, and separately for the flood of record experienced in 1950. Average annual damages were calculated for the 1958-1996 period for the four rule curve alternatives evaluated using a simple arithmetic average of the annual values. The 1950 event was not included in the average because it is not representative of the period modelled, but is representative of a much longer time period. The 1950 event produced almost 19 times as much damage as the total damages produced by all the floods in the 1958-1996 period. Examination of the 1950 event is useful to provide insight into the potential for increased flood damages under the various alternatives for an extreme event.

Elevation-damage data was obtained from a previous assessment of flood damage potential on the Rainy/Namakan Lake System, which was completed in July 1993 by Acres International Limited under contract to Boise Cascade Corporation. At the request of the Corps of Engineers, Acres International, Inc. provided additional information about the nature of the flood damage estimates to supplement what was used in their previous analysis. This new information provides an insight into the types of damage that occur at any given elevation, and demonstrates the relative importance of each damage category in comparison to the whole for any level of flooding. Damage categories considered in the analysis include: docks, shops/ sheds/ pumps, offices/showrooms, commercial lodges/cabins/parking lots, and private cottages/residences. Additionally, the zero-damage elevation for each damage category is identified. Interviews conducted by the Corps of Engineers with local officials suggest that the zero damage points identified by the ACRES study are consistent with the personal experiences of lakeshore residents.

All of the alternatives evaluated resulted in increased flood damages when compared to the existing condition (F1-IJC). Flood damages occur for all of the alternatives in about 20% of the years in the 1958-96 period of record analyzed. The average annual flood damages for the 1958-96 simulation period are US$15,066 for the existing condition (F1-IJC), US$21,260 for Alternative C1, US$21,324 for Alternative M1 and US$23,450 for the rule curves proposed by the International Steering Committee (F1-SC). The damages estimated for the 1950 event under Alternative F1-IJC were US$11 million, US$13.8 million under Alternative F1-SC and US$13.5 million under Alternative C1.

3.7.4 Recreation-Tourism

Tourism based on the fishery generates a substantial economic benefit to the region surrounding Rainy and Namakan Lakes. It is estimated that tourism based on Rainy Lake is responsible for approximately 250 full or part-time jobs at 24 tourist establishments on the Minnesota side of the lake, and another 58 jobs and 22 tourist operations on the Ontario side of the lake. The fishery generated approximately $5.7 million (US$ 1990) per annum in gross revenues in the local area surrounding Rainy Lake, distributed US$1.15 million in Ontario, and US$4.55 million in Minnesota.

For Namakan Lake, it is estimated that approximately 113 full or part-time jobs are generated by tourist anglers. Additionally, there are 47 tourist establishments on the Minnesota side of the lake, and 2 tourist establishments on the Ontario side of the lake that rely on the Namakan Lake fishery. The fishery generated approximately $3 million (US$1990) in gross revenues to the local area. Most of this revenue is contributed by tourists who fish on Namakan Lake. Less than 1% of the total revenues are produced by the commercial fishery. In comparison to the combined Rainy-Namakan fishery which generated an estimated US$8.7 million in economic activity in 1990, the fishery in nearby Lake of the Woods generated an estimated Cdn$54.3 million (US$46.2 million) in economic activity in 1990.

There are a number of recent studies estimating recreational use in the area, prepared by the National Park Service and agencies within Minnesota and Ontario. The National Park Service reports annual visitation for Voyageurs National Park (VNP), which includes most of the Rainy-Namakan Chain of Lakes. The number of recreation visits rose from 164,000 in 1983 to a high of 245,000 in 1990, and remained around 240,000 to 245,000 through 1994. The number of fishing visits averaged around 130,000 annually during the first half of the 1990's, and the number of persons on houseboats averaged 27,000 annually. Most of the visits occurred between May and September.

The Minnesota Department of Natural Resources has conducted creel surveys on these lakes regularly since 1983. The 1994 (summer season) survey recorded 67,000 angler trips on Lake Kabetogama, 22,000 angler trips on Namakan Lake, and 34,000 angler trips on Rainy Lake. This amounts to 123,000 total angler trips, and equates to approximately 500,000 angler hours. Most of the anglers on Lake Kabetogama and Namakan Lake were non-local Minnesota residents, whereas most anglers on Rainy Lake (Minnesota waters) were local Minnesota residents. A 1985 MDNR regional survey of the Edge-of the-Wilderness Area (including VNP and the Boundary Waters Canoe Area) estimated regional fishing hours at 21 million; the Rainy-Namakan chain therefore accounts for roughly 2.4 percent of regional fishing activity.

Although the fishery information presented is the most recent information available, it is thought to be a conservative estimate of the revenues, since this data is somewhat dated, and tourism has continued to increase in the area. Postulation of potential future impacts resulting from adoption of any rule curve alternative is highly subjective, and dependent upon forecasting future trends and reliance on an information base by sectoral components that is not available. For these reasons, impacts of changes in the rule curves on recreation and tourism were not quantified. The International Steering Committee had estimated annual benefits of $800,000 to the fishery/tourism sector if the SC curves were implemented because of the earlier spring rise and an increased number of sports fishermen that would utilize the tourist facilities available. This number cannot be confirmed based on the information available, but is felt to represent the upper possible limit of possible economic benefits. However, an attempt was made to give a qualitative assessment of the potential changes that might result from the adoption of these proposed alternatives compared to the existing condition.

The effects in this resource category are mixed depending on the time of the year. Higher spring water levels that may result from many of the alternatives would be beneficial to the fishery, according to fisheries experts. Higher levels would also allow navigation and access to boat docks closer to the start of the fishing season opening, which would have a positive effect on tourism.

Examples of alternatives that would result in higher spring water levels include F1-SC at Rainy and Namakan Lakes, as well as C1 and M1 at Namakan Lake. Reduction of the winter drawdown on Namakan Lake under most of the alternatives provides positive benefits to the fishery and would indirectly benefit tourism. During the summer months, many of the alternatives result in slowly declining lake levels, which might have a negative effect on tourism due to potential problems with navigation and access to some areas. Examples of alternatives that result in slowly declining lake levels include F1-SC and M1 at both Rainy and Namakan Lakes, and C1 at Namakan Lake.

3.7.5 Recreation-Navigation

Both Rainy and Namakan Lakes are used extensively for navigation, primarily for recreational use such as boating and fishing. Namakan Lake is also used on a limited basis as a transportation route for personal, business, and recreational use, particularly by Native Americans. Historically, the lakes have also been used for the booming of logs and navigation of large tugboats through shallow channels and bays. However, this practice ceased in the mid-1970s, and is no longer a relevant factor.

On Rainy Lake, the elevation on which all navigation charts are based is 337.4 m. On Namakan Lake, information obtained from the Lac La Croix First Nation, area residents, and tourist operators on Sand Point and Crane Lakes suggests that the rule curve should not go below 340.5 m during the navigation season from about May through September.

The effects in this resource category are similar to those in tourism and can only be defined qualitatively. Higher spring water levels that result under many of the alternatives would be beneficial for navigation early in the season. However, lower summer levels that occur in many of the alternatives would potentially have a negative effect on navigation by limiting access to the shallower areas of both lakes, particularly by sailboat.

Regarding early spring water levels, F1-SC is the only alternative that provides average May water levels greater than 337.4 m on Rainy Lake. Average May water levels under Alternatives F1-IJC, C1, and M1 are slightly below 337.4 m on Rainy Lake. None of the alternatives provide average May water levels up to the desired level of 340.5 m on Namakan Lake. However, all of the alternatives except F1-IJC are relatively close to the desired level.

Regarding late summer water levels, all of the alternatives provided water levels greater than 337.4 m. on Rainy lake and 340.5 m on Namakan lake, except for Alternative F1-SC on Rainy Lake, which provided average September water levels just slightly below 337.4 m. Alternatives F1-IJC and C1 provided the highest average September Rainy Lake levels, while Alternative F1-IJC provided the highest average September Namakan Lake levels.

3.7.6 Water Supply

Water is withdrawn from Rainy and Namakan lakes for both commercial and private water supply uses. Permits are required for larger users (those withdrawing over about 3.8 million litres per year), while smaller users are not required to have a permit. The holders of these permits for larger water supply withdrawals include the City of International Falls, Minnesota and Boise Cascade Corporation in the US and the Town of Fort Frances, Ontario and Abitibi-Consolidated Incorporated in Canada. No commercial water users have been identified on Namakan Lake. Water is also withdrawn from both lakes for domestic water supply by an unknown number of lakeshore households and small year-round and seasonal resorts. There are only two year-round resorts on Rainy Lake that have an average annual withdrawal large enough to require a permit.

Water intakes on both lakes would primarily be effected only in conditions of extreme drawdown. Since none of the alternatives evaluated result in this type of drawdown, there would not be an effect. However, slightly lower lake levels do result from many of the alternatives during the summer months when the majority of the water supply withdrawals are made. Lower lake levels would reduce the head on the pumps of all of these users, which would reduce the efficiency of the pumps and increase the cost of electricity required to pump the water. The magnitude of these changes is expected to be fairly small.

3.7.7 Commercial Fishing

In 1996, there were four commercial fishing operations on six commercial fishing lots in the Ontario part of Rainy Lake. Whitefish, northern pike, walleye, and recently black crappie are the main species in the commercial fishery since the 1920s. All are under quota management since 1984. Unlimited quotas are available for course fish, including suckers, lake herring (cisco), bullhead, burbot, and mooneye.

The commercial harvest of walleye was reduced by 97% from 1986 to 1996 through government buy-outs and trades for individual species quotas. Lake whitefish comprise the majority of the harvest, representing 53% of the total commercial catch in 1996, and 43% of the catch since 1990. The annual commercial catch of all fish species, including course fish, has averaged 49,700 kg per year for this same period.

Commercial sport fish harvest on the Minnesota side of Rainy Lake was gradually reduced by gear restrictions and then reduced significantly with a legislative buy-out in 1985. There remains one commercial fishing operation that uses gill nets to harvest an average of about 17,000 kg per year of whitefish south of Brule Narrows.

The commercial fishery was valued at US$92,650 in Ontario, and US$17,000 in Minnesota. Commercial fish production from Rainy Lake was 17,440 kg in 1989, and was valued at about US$17,260. The 1989 Ontario commercial harvest from Rainy Lake had an estimated dockside value of US$92,990, based on a total quota of 54,500 kg of walleye, northern pike, crappie, whitefish, and sturgeon. This value has declined since 1989 with reduced levels of harvest. Whitefish accounted for all commercial fishing gross revenues in Minnesota. Less than 2% of the total Rainy Lake fisheries revenues are produced by the commercial fishery.

Commercial fishing on Namakan Lake began in 1916-17. However, with the growth of the tourist trade, commercial fishing for walleye and northern pike was eliminated on Minnesota waters in 1946. Currently, there are two licensed commercial operators on Namakan Lake, one in Minnesota and one in Ontario. About 1% of fisheries revenues are produced by the commercial fishery. Whitefish account for 33% of the gross revenues from commercial fishing, followed by walleye (25%). It has been estimated that the commercial fishery generates approximately four jobs.

In the future, commercial fishing in the US and Canada on both lakes will probably stay the same or decline, particularly for species such as walleye. This is because fisheries agencies such as the Ontario Ministry of Natural Resources have been actively purchasing fishing quotas and/or licenses since 1986 on a “willing seller” basis. The management intent in Ontario on Rainy Lake is to reduce the commercial walleye quota to zero, while maintaining a commercial fishing industry that is based primarily on whitefish, northern pike, and crappie. No changes are anticipated, with regard to commercial fishing, on the Minnesota side. It is expected that domestic consumption by aboriginal people will increase, as their population increases.

Any potential improvement in the fishery on the lakes could have a positive effect on the commercial fishing industry. However, because of the quotas that have been imposed by regulatory agencies on the harvest of several species, it is uncertain whether an improvement in the fishery would translate directly to an improvement in the commercial fishing industry. Positive impacts to navigation, such as raising the spring water levels with many of the alternatives, would also probably have a positive effect on commercial fishing. Conversely, negative changes such as lower summer lake levels that result from several alternatives may have a negative impact to commercial fishing as well. Overall, impacts to commercial fishing that would result from implementation of any of the rule curve alternatives are small.

3.7.8 Erosion

Erosion and damage to shoreline development is known to occur throughout the area, especially under conditions of high water in conjunction with strong winds. Erosion is especially problematic on the south shore of Sand Bay on Rainy Lake. However, discussions with representatives of local Soil and Water Conservation Districts in Koochiching and St. Louis Counties indicated that there were not a lot of requests from homeowners around Rainy Lake for assistance on erosion control projects. This finding is confirmed by the fact that shoreline erosion was reported as a significant concern by only a small number of respondents to a damage survey done by the International Steering Committee. Many residents have built breakwaters or have riprapped the shoreline to reduce damages.

Another consideration in this resource category is the fact that archaeological surveys conducted along these lakes have shown that there are numerous prehistoric and historic Indian cultural sites located along the shorelines. Information provided in the International Steering Committee Report indicates that about 75 percent of the sites have been partially or totally destroyed by the rise in lake levels resulting from the construction of the dams. No major problems with erosion were identified with any of the alternatives evaluated.

3.7.9 Native American Transportation

The effects of the regulation of Namakan Lake at Kettle Falls and Squirrel Falls extend upstream to the Loon Portage on the Loon River, a tributary to Namakan Reservoir. People of the Lac La Croix First Nation, tourism businesses, and recreation interests use the Loon River for navigation between Crane and Sand Point lakes and isolated parts of the upper watershed on Loon Lake and Lac La Croix. The people of the Lac La Croix First Nation travel this route for personal, business, and recreational reasons. They have indicated to the International Steering Committee that restriction of boat access via the Loon River affects their livelihood, their safety with regard to medical emergencies, and their cost of living. The movement of anglers upstream to the Lac La Croix tourism resorts from Crane Lake is also important to their livelihood. This is because a majority of the men in the Lac La Croix First Nation are employed as fishing guides at these resorts.

Springtime navigation by boat and motor up the Loon River is difficult until Namakan Lake reaches elevation 340.5 metres above sea level, as measured at the Kettle Falls Dam. Under the existing rule curve, this water level is not attained until the second or third week of June. The navigation problems are most critical at Loon Narrows, where there are extensive mud flats, and at an area known as "56 Rapids", which is another mile and a half (2km) upstream. Passage is difficult at "56 Rapids" until the water level reaches elevation 340.5 metres, after which the rapids can be run, unless river flow is low due to drought conditions.

Water-based transportation by Native Americans / First Nations is expected to be improved under Alternatives F1-SC, C1 and M1. This improvement is based on expected increases in spring water levels, allowing easier access to and from tributary lakes and rivers in the upper reaches of the basin.

3.7.10 Wild Rice

Wild rice is an important renewable resource which grows in the shallow portions (water depth of less than 1.2 metres) of freshwater lakes and slow moving rivers. In addition to its commercial value, the harvest of wild rice has been an important part of the cultural and social activity of Aboriginal Peoples in Ontario as well as Native Americans in Minnesota.

The bays and inlets of Rainy Lake serve as one of the major wild rice growing areas within the region. The total available crop of wild rice varies widely from year to year, depending upon fluctuations in water levels and the weather. Wild rice is a high value crop, and the product is a specialty item for which premium prices are paid. With the expanding popularity of wild rice, competition between buyers has increased and all available harvest has typically been purchased.

As part of the development of the proposed SC rule curves, a single purpose optimization curve for wild rice was developed. All of the rule curve alternatives evaluated in this report, including the existing IJC rule curves, produce water levels that are as much as two feet higher through the late spring and summer months than the optimized single purpose wild rice curve presented in the Steering Committee's report. Alternative F1-SC may be most advantageous of all the alternatives for Rainy Lake, since it produces the earliest spring rise followed by slowly declining levels beginning in June at the time when the floating leaf stage is most active. Under Alternatives F1-IJC, C1 and M1 Rainy lake levels continue to rise through the end of June, increasing the potential for uprooting the young plants during the floating leaf stage.

Overall, compared to the existing condition (F1-IJC), it appears that Alternative F1-SC provides positive benefits to wild rice, while Alternatives C1 and M1 maintain the status quo.

3.8 <u>Comments Received and Board Response</u>

This section summarizes the comments received from agencies, associations, companies and the public at large in response to the study work on Rainy and Namakan lakes. Board responses to some of the comments are also provided, but generally only to provide clarification where appropriate or to explain the Board's position regarding comments it cannot support. Comments received and Board responses regarding the downstream areas are addressed under Section 4.

This section is broken into two parts. The first addresses comments from a small group invited to work with the Board regarding the inflow forecasting issue. The second addresses more general comments on the contents of the Status Report and the Board's preliminary findings.

3.8.1 Inflow Forecasting

In March 1996, an initial meeting was held in the basin with potential members of an inflow forecasting working group. Participants included the dam operators, provincial and state natural resource agencies and the Steering Committee, among others. The Board's proposed two-stage review concept, as laid out in the Plan of Study, was discussed in detail. Although there were several reservations with the approach, the basic concept was agreed to. The next step in the process was for the Board to develop a detailed work plan, including specifications for the proposed "perfect forecast" modelling, and distribute it to the participants for review. It was then hoped that, following agreement on the work plan, the various groups would take on part of the work to be completed. Boise Cascade offered the services of their hydrologic consultant.

Unfortunately, work on this component was delayed due to a higher priority being assigned to the "REGUSE" modelling. Then, difficulties were encountered in conceptualizing algorithms for the "perfect forecast" model, and the required model was essentially developed during efforts to prove the concept. Thus, having gotten that far and with little time remaining before the Status Report was due, Board staff carried on with conducting the first phase of the study, leaving working group involvement to the second, more work-intensive phase, if such work were deemed warranted. The results of the first phase review were released to the potential working group members and other interested parties in a report *"Rainy Namakan Study / Inflow Forecasting Component"* on October 30, 1997. This work is described in Section 3.2.

3.8.1.1 *Comments Received*

Comments received by the IRLBC in response to this report are summarized below:

Boise Cascade Corporation and Abitibi-Consolidated Inc. (November 26, 1997)
- the IRLBC approach to assess the merits of inflow forecasting was reasonable and results were similar to those obtained by the Companies' hydrologic consultants, Acres International Limited. Acres' model SIMUL8 could have been modified quite easily to carry out the forecasting feasibility assessment, but there was value in having had this review carried out independently of previous work.
- it is important to acknowledge that weather radar at present covers only a small percentage of the basin.
- it would have been of value to show that, even with drawdown below the rule curve band, the benefit in reduced flood levels would not be significantly better than results already show.
- the Companies agree with, but believe there would be value in explaining, the rationale for considering a 7-day forecast as maximum feasible; they suggested describing the state of the art in forecasting precipitation and snowmelt.

Border Lakes Association (December 6, 1997)
- reiterated their previously stated position that the IJC rule curves for Namakan should be modified while Rainy Lakes' IJC curves should not be.
- acknowledged that they understood that better forecasting would not have a significant impact on flooding occurrences for Rainy Lake. They noted that the potential water inflow is much greater that the outflow capacity and that the only outflow for Rainy Lake is the natural narrow restriction at Rainier MN.

Rainy/Namakan Water Level International Steering Committee (December 12, 1997)
- expressed disappointment in the process which generated the report and in what was evaluated. They understood that they would be given the opportunity to review and comment on a detailed work plan prior to the actual commencement of a forecasting study.
- are there benefits to forecasting that the IRLBC missed?
- more information and increased awareness of watershed conditions helps water level management.
- does the existing monitoring network adequately represent basin flows and hydrology?
- is forecasting beneficial for non-extreme events?
- are there storage and inflow conditions where forecasting can reduce high and low water events?
- would the use of forecasting help reduce fall high water conditions and some early summer low water conditions?

- are there limits in outflow capacity that can be improved with re-engineering?
- if it is assumed that violations to the lower rule curve are allowed when the intent is to increase storage capacity for a predicted high water event, would forecasting be helpful?
- difficulty in interpreting some of the results and felt that it would be helpful to report the number of times water levels exceed the "all gates open" level versus the number of violations of the upper rule curve.
- using average inflows over the forecast period in the model assumes a normal distribution and hides trends within the daily inflow data; giving priority to the shortest forecast period appears unreasonable.
- explicit presentations of model uncertainty were not provided and would aid in decision making.
- even if forecasting with current technology may not reduce flood peaks, improved forecasting and water management skills would still provide significant benefits.

Minnesota Department of Natural Resources (MDNR) (December 16, 1997)
- share the Steering Committee's disappointment that it and the state and provincial resource agencies were not provided a greater opportunity to be involved in the study.
- the assumption to minimize violations of rule curves immediately dooms the premise of improved flow forecasting to failure, especially when the methodology targets the mid-point of the range for all years and all hydrologic/climatic conditions.
- the study process used by the IRLBC seems overly complex, not easily understood and is not the common perception of how improved flow forecasting would work.
- 1996 provides a good example of how forecasting might be used to improve regulation. As a better test of the benefits of flow forecasting, this phase of the study should analyze whether opening the gates to the greatest extent possible on Rainy and/or Namakan Lakes on April 1, or April 8, or April 15 in anticipation of high spring runoff, would have lowered the lakes sufficiently to provide any meaningful additional storage.
- would an alternative scenario to target the low end of the rule curve band instead of the mid-point during heavy snowfall winters provide any benefit?
- there is a large gap between even the existing flood forecasting capabilities for the Red River basin and what the IRLBC is suggesting is good enough for the Rainy River basin.
- the IRLBC should be pro-active in proposing modifications to the management of the system which will achieve this objective (improved fishery) while protecting other interests as well.

3.8.1.2 *Board Response*

A meeting was held in International Falls on March 10, 1998 to review the methodology used in the inflow forecasting work, to address the comments received, and to seek and address additional comments.

Board staff explained in detail the methodology for the "perfect forecasting" component and explained the circumstances that led to the Board completing this phase on its own. Also, in response to many of the comments and questions received, the IRLBC explained that, under the mandate of the present study, the review of forecasting was to proceed only to the extent of determining if and how inflow forecasting capability might affect the rule curve decision. Unfortunately, it was not possible to carry out a general hydrologic/hydraulic review of the basin or to attempt to develop forecasting for the basin outside of this objective.

Table 8 was presented to document the number and percent of time of violations of the "all gates open" level as well as of the summer upper rule curve maximum level, plus their respective maximum and median deviations, for both IJC and SC rule curves on both lakes for all of the forecast periods tested. This table can be compared to Table 4, presented under Section 3.2 of the report.

In response to comments regarding the forecast benefit being rendered less effective by constraining operations within the rule curves, further model runs were made without the levels being constrained. This means that, with a future forecast of high inflow, the lake level could be drawn down below the lower rule curve to provide storage in anticipation of the additional inflow. Table 9 shows the effect of not constraining operation within the rule curve band while trying to release water for a forecast flood condition. The table, which can be compared directly to Table 8, shows that there is only a small improvement in the number of high water violations. From the "Maximum Deviation" columns, it can be seen that there is no improvement in the maximum flood level reached for perfect forecasts up to 14 days. The maximum improvement at 28 days is 4 cm for Namakan Lake and 9 cm for Rainy Lake. Graph 20 shows Namakan and Rainy Lake levels for the IJC case for 1968. This graph can be directly compared to Graph 18 (Section 3.2), the former showing the results for the case where the model solution is constrained by the rule curves. Note for the Rainy Lake graph that the 28-day forecast line begins to deviate from the base case at about mid-May, as it did in the constrained case. However, the level continues to decline below the lower rule curve to make storage room for the higher inflow that can be "seen" coming. However, when the flood inflow arrives, the inflow rate is quickly greater than the dam's outflow capacity. Although the outflow is the maximum possible, the level rises through the rule curve band and well above it. With a 28-day forecast, the level reaches a peak of 337.98 m, 9 cm below the base case and only 3 cm below the level reached in the simulation shown in Graph 18 where the model solution was constrained by the rule curves. Overall, because of the lower peak outflow capacities at lower lake levels, and the limited total outflow capacity, relaxing operation to allow the creation of flood storage below the rule curve band does not provide significant benefit.

Regarding comments on the use of snowpack to forecast spring floods, the IRLBC noted that studies carried out in the past have shown that it is not a good predictor of lake refill in the Rainy-Namakan basin. Snowmelt water volume was accounted for by using actual total inflow volumes in the analysis. This means that snowmelt was used in the "perfect forecasts" and there is no evidence that snowpack is a significant variable in predicting runoff longer than the 28-day forecast period used in the model.

The Board staff noted that they definitely agreed with others that improved forecasting methodologies and improved data collection would be beneficial in managing the water resources of the Rainy-Namakan basin. However, the inflow forecasting studies carried out have shown that improved forecasting would offer only modest improvements at best in reducing flood or drought risks and that these benefits would apply to any of the rule curves being considered. Therefore, forecasting is not a factor in an operating rule curve decision for Rainy and Namakan Lakes. It was also noted that the IRLBC cannot act in a pro-active manner toward any particular interest, including the fishery, in order to carry out an impartial rule curve review as mandated by the IJC.

3.8.2 Status Report

3.8.2.1 *Comments Received*

Comments received by the IRLBC in response to the Status Report are summarized below:

Tom Worth, Rainy Lake Sportfishing Club, International Falls, MN (April 28, 1998)

- vigorously object to conclusion to remove Rainy Lake from consideration for improved water levels regulation.

- Rainy Lake has been under improved water level regulation for about 10 years, during which time the fishery has improved. Eliminating improved levels now would be a step backwards.
- inconsistent to hire fisheries experts who advise that improved water levels management will benefit the whole environment and then choose not follow that advice.
- concerned that Board is ignoring the club's work over the past 10 years aimed at improving water levels and their public opinion surveys that show 84% of public support improved water level management.
- concerned that Board referenced Border Lakes Association in status Report, but made no mention of the Sportfishing Club's work. Would like to see report redone using more balance.

Barbara J. West, Voyageurs National Park, International Falls, MN (May 5, 1998)
- concerned over length of review process and had hoped for a quicker resolution by the IJC. Believe it is time for a decision as expeditiously as possible. Agree that further analysis or data collection is unlikely to resolve conflicts over use of the water resources of the Rainy basin.
- disappointed by the suggestion to give further consideration to the restoration of the 1970 rule curves for Rainy Lake and believe this to be a significant step backwards. Concerned over use of fishery experts recommendations to justify this action as it implies the rule curve revision is being done solely for the benefit of the fishery. Goal is to achieve broad improvements in the entire ecosystem -- fish, wildlife and habitat.
- agree with environmental experts that periodic operation outside of any proposed rule curve (natural variability) is in keeping with the National Park Service's mandate to protect, perpetuate and restore natural aquatic environments, but recognize that the public support for periodic high or low extremes of operation does not exist at this time.

Paul J. Radomski and Dr. William R. Darby, Rainy Lake and Namakan Reservoir Water Level International Steering committee, Brainerd, MN & Fort Frances, ON (May 5, 1998)
- pointed out that FERC requirement of Article 403 to achieve maximum allowable lake levels on Rainy Lake from ice-out until 15 days thereafter, which is similar to the SC recommendation for spring water levels is believed to have yielded benefits to the environment. Failing to adopt the SC curve for Rainy lake and returning to the IJC curve in light of these benefits would create a harmful condition. It would be unfair and unethical to refuse a recommended change that could achieve substantial benefits to the environment.
- pleased IRLBC undertook such a thorough hydrologic analysis.
- conclusions of Status Report provide additional perspectives on benefits of SC curves of reduced extent of fall flooding, lower winter but higher spring discharges into the Rainy River than under the IJC curves, benefitting navigation and fish spawning. Drought conditions would likely be less severe on Namakan with the SC curves.
- economic analysis in status Report is weak. Additional work to be completed should look at broad economic issues and address recreation in greater detail.
- disagree with fisheries experts recommendation to use an experimental approach adopting the SC curves on Namakan Lake, but delaying any change on Rainy Lake so that it might be used as a control. Steering Committee proposes an adaptive management approach, implementing the SC curves on both lakes, conducting post-treatment studies and comparing to pre-treatment data already reported. Several other experimental approaches were discussed and the Steering committee is interested in hearing from the fish experts.
- noted that the Environmental findings in the Board's Status Report support the SC proposal.
- stressed that further consideration to maintaining the use of the 1970 rule curves for Rainy Lake is a major and harmful step backward and expressed concern over their view that the Board's fish experts' recommendations were being used to justify the continued use of the 1970 IJC rule curves on Rainy Lake. The Steering Committee stressed their efforts sought a balance among numerous concerns and broad improvements in the entire ecosystem.

Paul B. Stegmeir, St. Paul, MN (No Date; envelope dated May 9, 1998)
- outlined need to optimize environmental and fisheries benefits. Supports the Steering Committee proposal and urged the Board to recommend its timely adoption to the IJC.

Ronald W. Esau, Citizen's Council on Voyageurs National Park, International Falls, MN (May 12, 1998)
- concerned over delays in the study to the IJC Order for Rainy and Namakan lakes and believe it imperative that efforts to move forward be placed on a priority status, due to continued problems relating to regional tourism and environmental impacts.
- fully support Steering Committee's proposal and encourage its adoption by the IRLBC and the IJC.

Ron Shimizu and Jodi Traub, International Rainy River Water Pollution Board (May 12, 1998)
- reduction in Rainy Lake minimum flow would result in more restrictive receiving water based effluent criteria specified in permits for point-source discharges in Minnesota.
- agree that any change to the existing rule curves must be accompanied by an appropriate fisheries and monitoring program for the Rainy River as well as Rainy and Namakan Lakes, raising the issue of who will be responsible for the work and how will it be resourced.

J. D. McQuarrie, Fort Frances, ON (May 12, 1998)
- the minimum flow requirement for Namakan Lake was established primarily to prevent the buildup of algae at the dams during the summer.
- tinkering with the rule curves will do little to improve fishing on the lakes. Fishing will not improve so long as commercial and sport over-fishing is allowed on both sides of the Border.

Richard Baxendale, Abitibi-Consolidated Inc. and Boise Cascade Corporation, Seattle WA, (May 14, 1998)
- extensive detailed comments on the Hydrologic Modelling, Inflow Forecasting, Fisheries Review and Environmental Data Summary components of the Status Report were provided by the companies in addition to general comments concerning the overall study and report findings.
- general comments provide by the Companies are as follows:
  - the present regulation has done a good job of balancing interests in the affected lakes by keeping flood risks at acceptable levels. The proposed SC changes will increase flood risk and will not have a salutary effect with respect to fish and wildlife as claimed in Steering Committee's IJC filing.
  - Steering Committee's claims of improved regional economy through implementation of its proposal are unsupported by any credible analysis. The Companies play a central role in the regional economy and the proposed SC changes will negatively affect their competitiveness by reducing hydro production, necessitating purchase of additional electricity.
  - Status Report provides the factual basis for leaving the present IJC rule curves in place on Rainy Lake and the Companies support this recommendation and urge its adoption.
  - the Companies cannot support the recommendation to adopt the Steering Committee's rule curves for Namakan Lake, as no scientific case has been made that its adoption will benefit the lake's fish and wildlife. In the Company's view, strict harvest controls are the answer. Additionally, the earlier spring rise under the SC proposal for Namakan Lake will significantly narrow the present IJC band and impose an unnatural constraint on lake level variation.
- comments on IRLBC's preliminary Status Report findings as follows:
  - agree that enough information exists for the Board to make recommendations to the IJC on rule curve changes with the exception of downstream effects analysis and definitive fisheries analysis.

- disagree that proposed SC rule curves would enhance fisheries and environmental benefits, but do agree proposed SC rule curves increase potential for spring flooding and reduced hydropower production.
- agree that improved forecasting and management practices are unlikely to offset potential increased flooding if SC proposal adopted.
- agree SC curves are nominally more viable (as defined in Status Report) than IJC rule curves on Namakan Lake and less viable on Rainy Lake as measured by the number of rule curve violations.
- disagree that there is merit to use of SC curves on Namakan Lake, but agree with the retention of IJC curves on Rainy Lake.
- agree that the natural level and outflow modelling indicates SC curves come closer to simulating the timing of the natural spring refill on Namakan Lake and that IJC curves come closer to simulating the timing of the natural refill on Rainy Lake.
- agree (or more accurately, are prepared to accept) that adjustments to the minimum outflow requirements of Namakan and Rainy Lakes would decrease the number of lake level excursions outside of either the existing or proposed SC rule curves during low flow periods.
- agree that any modifications to the existing rule curves, if recommended, must be accompanied by an appropriate fisheries and environmental monitoring program, to confirm whether change, if implemented, achieves any results and can be separated from other management decisions, such as restrictions on fishery regulations. To do otherwise will mean that the additional cost to the Companies of foregone hydro production and replacement power purchases will be for naught.

Don Johnson, Border Lakes Association, International Falls, MN (No date; envelope dated May 18, 1998)

- Border Lakes Association directors unanimously support Alternative C1, based upon their own studies, conducted by hydrology and fisheries experts, and the modelling work done by the IRLBC.
- believe the C1 Alternative offers a reasonable compromise for all parties involved in the water level issues of Rainy and Namakan Lakes, providing higher spring water levels for Namakan Lake, minimizing flood risk for Rainy Lake, reducing loss of energy generation at the International Falls dam and more closely matching the natural water fluctuations of both lakes.

W. Collin Hewitt and Jack Bartlett, Rendezvous Yacht Club, Fort Frances, ON and International Falls, MN (June 3, 1998)

- concerned about ability to continue to safely navigate and have access to docking on Rainy Lake.
- concerned navigation for both sailboats and powered craft has ranked extremely low in information provided to the public by the Rainy/Namakan Water Level International Steering Committee.
- adjustments to the Namakan rule curves are necessary to improve fishery.
- no substantial adjustments to Rainy rule curves are needed. This will maintain existing navigation and dock access.
- support Alternative C1. Encouraged that alternatives to the SC curves are being considered that appear more favourable to navigation and dock access on Rainy Lake.

James G. Chandler, International Joint Commission, Washington, DC (June 4, 1998) and Murray Clamen, International Joint Commission, Ottawa ON (June 5, 1998)

- Commission pleased with efforts to date and believes Board has collected considerable information and developed useful models for assessing the proposed changes to the rule curves.
- It would be useful for the Board to determine what the appropriate minimum flows for Rainy Lake might be now in light of improvements in mill effluent quality in recent years and the fact

that the current minimum flow requirements may be outdated and not required. It would be desirable to investigate the basis for the current Namakan minimum flow requirements.
- will the final report explain the rationale for either attempting or abandoning any attempt to refine or optimize Alternatives C1 and M1?
- does the Board plan to provide more detailed suggestions on how the Commission might allow for infrequent excursions outside the rule curves in extreme events, if desired, as a means of enabling increased variability in lake levels, suggested in the Status Report as a positive benefit to enhance environmental resources? How would potential impacts from this suggestion be handled?
- the Status Report suggests that any rule curve change should be monitored to assess the effects of the change on the environment. Does the Board plan to provide further detail on what studies might be required and will the Board identify appropriate agencies and costs required to perform the monitoring?
- the Status Report notes natural summer Namakan levels decline by 0.3 to 3 feet and suggests lowering the bottom of the SC band by one foot, as the proposed summer drawdown of the lake would provide limited environmental benefit. Does the Board plan to evaluate this suggestion? The Commission would anticipate the final report would evaluate the change in environmental benefits from any summer drawdown proposed.
- how does the Board plan to weave together the different segments of work in the Status Report to reach a supportable conclusion in the final report.
- input from Native Americans/First Nations in the basin is essential and thus far their input has been minimal. Every effort should be made to consult with them.

M. L. Willick, Ontario Ministry of Natural Resources, Thunder Bay, ON (December 1, 1998)
- in general, favour proposals that better achieve ecological sustainability and are appreciative of competing basin interests, but concerned whether the overall benefits to the entire water system outweigh the risks and disadvantages.
- it is clear that positive effects will result from the proposed changes to Rainy and Namakan Lakes, but concerned that altered inflow patterns to Lake of the Woods will affect Lake of the Woods regulation and discharge to the Winnipeg River exerting undue pressure on other water bodies such as Lac Seul and the English River.

James V. Jansen, Kabetogama Lake Association, Ray, MN (February 17, 1999)
- concerns over low water in recent years, particularly fall 1998, prospects for low again in spring 1999. Low spring water levels have significant adverse effects on tourism, Voyageurs National park visitation and the related economic base.
- represents 30 businesses that are directly affected by lake levels. Many resort operators are hurting financially from recent low water years and one more could be financially devastating. Believe that implementation of proposed SC rule curves would help alleviate low water conditions.
- expressed concern that over five years have passed since SC proposal was submitted in 1993 and no action has taken place. Request the IJC to move as quickly as possible to implement a decision favouring the SC proposal by the April meeting of the IJC.

Katy Ebel, Ash River Trail Commercial Club, Orr, MN (February 27, 1999)
- same comments as Jansen letter above.

Bill Darby, Ontario Ministry of Natural Resources, Fort Frances, ON (February 23, 1999)
- supports SC curve which appears to be most suitable alternative for Namakan, providing significant environmental benefits through an earlier, more natural refill, less severe winter drawdown, and modest summer drawdown.

- regarding minimum Namakan outflow, it may be acceptable to reduce outflow to 15 m^3/s during the period July through September, but not other months of the year which are critical fish spawning periods. Request an opportunity for further discussion and field evaluation if the Board decides to reduce outflows during the July through September period.
- prefer a curve on Rainy Lake that better simulates natural conditions than does the existing IJC curve. Both M1 and SC curves are better than IJC curve in this regard, but wish to withhold stating a preference between the two. Specific comments for Rainy Lake are provided below:
  - based upon simulation of natural lake levels the Board showed that the earlier refill under the SC curve was less natural than the ascending limb of M1. The M1 curve seems to have an advantage over the SC curve in this regard. However, it should be noted that the Steering Committee's report (Figure G-1) used average pre-dam water levels from the Corps of Engineers suggesting an earlier refill of Rainy Lake than does the Board's model output. Which is right?
  - the M1 curve has an advantage over the SC curve with regard to flood risk.
  - both M1 and SC include a summer drawdown which is more natural and preferred in comparison to other curves.
  - improvements to the ecosystem are likely with both the M1 and C1 curves.
  - average annual loss of hydropower production is reduced to 5% with M1 curve compared to 7.4% for the SC curve.
- prefer that the minimum flow Order for drought or low flow conditions not be changed and for the Board to continue using the issuance of Supplementary Orders, when needed. Feel the present process has featured effective communication between the Board and OMNR and allows for discussion and adjustment for unforeseen factors.
- agree improved water quality on Rainy River has lessened the need for diurnal fluctuations in Rainy Lake outflow. Pulsing or peaking strategies on the river for managing hydropower production have a negative effect on the downstream fisheries, especially during the spawn. Recommend removing the diurnal flow requirements gradually with monitoring of dissolved oxygen levels.
- dissolved oxygen in Rainy River should be monitored in case of reductions to outflows from Rainy Lake.

Lee Herseth, Tomahawk Resort, Ray, MN (March 10, 1999)
- concerned over the extremely low water levels in May for over 30 years in the Namakan Chain of Lakes and associated negative impacts to fishing related resort and tourism business, creating hardship for business owners.
- supports the Steering Committee proposal and urges IJC to implement the proposal and stop the government foot dragging, as the study has been in process for over five years and it is now time to finish it.

Mayor Glenn Witherspoon, Office of the Mayor, Fort Frances, ON (March 12, 1999)
- Mayor's Office contacted Ontario Ministry of Natural Resources and Town of fort Frances Public Works and both agree any changes would be minor in nature for Fort Frances.
- Rainy River would probably be more impacted.
- request to keep Town informed of all changes as they occur.

Dave Gibson, Department of Fisheries and Oceans, Burlington, ON (March 22, 1999)
- support the concept of bringing rule curves closer to that of the natural hydrograph and recognize that none of the proposed curves fully return the water level regime back to natural conditions; however, the SC and M1 Curves are closer to the natural hydrograph and in general should benefit fish habitat in the long term.

- cited compliance with Sections 35 and 22(3) of the Fisheries Act in Canada in that changes in water level ratings must not result in harmful disruption or destruction of fish habitat and must provide at all times such a quantity of water that will, in the opinion of the Minister, be sufficient for the safety of fish and fish spawning.
- of the information received, there is little that links water levels with Rainy and Namakan lake reservoir basin profiles, lacustrine wetlands and fish access to tributary stream or spawning grounds. This information should be provided for review, prior to any decision to alter the curves, and should look both upstream and downstream of the Fort Frances dam and at times of the year sensitive to fish.
- noted no assessment of the viability of using fish passage structures for Walleye, Pike or Sturgeon with any of the proposed alternatives. Further noted that two existing fish passages in the system are not being used and asked if there are any short or long-term plans for these structures. Offered DFO expertise to determine if fish passage structures could be used with the new curves.

Teresa Jaksa, Koochiching County Board of Commissioners, International Falls, MN (March 24, 1999)

- resolution forwarding and supporting comments, information from Jennifer Mercer, Rainy River Watershed Program Coordinator and Paul Radomski, Steering Committee Co-Chair, regarding impacts to Rainy River from any changes to the Rainy and Namakan rule curves.
- support the proposed Steering Committee changes to the rule curves for Rainy and Namakan Lakes and endorse the study and public consultation process followed by the Steering Committee.
- recommend extensive monitoring and research upon implementation of the proposed rule curves to verify if modifications are reducing negative impacts on interests and users without conflicting with other uses or resources.

3.8.2.2 *Board Response*

Many of the comments in the previous section either do not require a response or are dealt with elsewhere in the normal flow of the report. This section addresses those comments that do require a response or a clarification of the Board's studies.

Several commenters reacted quite strongly to the preliminary finding in the Status Report that there would be merit in considering the use of the Steering Committee rule curves on Namakan Lake, while maintaining the existing IJC curves on Rainy Lake. They stated that keeping the existing rule curves on Rainy Lake would be a step backwards, claiming that Rainy Lake has been under "improved" water level regulation for about 10 years due to first the FERC Article 403 requirement and then the Wellstone amendment.

In response, it is important to note that Rainy Lake has been operated under the same IJC rule curves since the summer of 1970. If there has been improvement, it has occurred under the existing IJC rule curves. Further, efforts by others to restrict operations within the existing rule curves have not altered regulation significantly. Review of Rainy Lake water levels by the Board has shown that average April and May levels during the spawning season changed very little during the years when the "FERC rules" or the Wellstone amendment were in effect, compared to the earlier years under the IJC 1970 rule curves alone. Therefore it is difficult to credit these measures with improvements in the fish population.

An article in the November-December issue of MDNR's *Minnesota Volunteer* reported on the rebound in the walleye fishery on Rainy Lake. This recovery in the fish population, which has led to a tripling of catch rates, was credited to three factors: the experimental slot limit, the end of commercial fishing and favorable spawning conditions that have naturally produced several strong year classes. Recruitment through 1991, which had a strong year class, was attributed at least in part to recovery of the walleye brood stock following reduced harvest. Strong year classes also occurred in 1994 and 1995. In 1994, Rainy Lake level did not reach the SC lower rule curve level until late May. In 1995, Rainy Lake's level was near the mid-IJC band throughout the spawning season.

Commenters also disagreed with the proposal by the Board's fishery consultants to use an experimental approach (change on Namakan, no change on Rainy) and felt that this focus on the fisheries consultant's recommendation would deprive Rainy Lake of the broader environmental benefits being sought, for habitat and other wildlife, not just fish. The Board's fishery and environmental experts did conclude that a water level regime more closely following the natural hydrologic regime is most desirable. They stated that the most important change to the current rule curves would be reducing the winter drawdown on Namakan Lake because of its broad impacts on the ecosystem, and also noted the role of over-exploitation of the fishery in the decline of fish stocks. These findings were supportive of the SC proposal. However, they also noted that spring refill timing for Namakan Lake under the SC proposal was reasonably close to the natural regime, whereas spring refill timing for Rainy Lake was closer to the natural regime under the 1970 IJC rule curves. This led logically to the suggestion of adopting the SC curves on Namakan while retaining the IJC curves on Rainy. The suggestion of an experimental management approach recognized that restoration of a more natural level and flow regime should be beneficial to the fishery and that while neither the existing or proposed SC curves came particularly close to approximating the natural regime, especially with regard to reduced lake level variability, the SC curves represented a worthwhile step in that direction, most notably for Namakan Lake. However, it also recognized that over-exploitation of the resource, and invasion by exotic smelt, are confounding variables to assessing the effects of any regulation changes. The fisheries experts believe that this experimental management approach should be adopted for rehabilitating the fisheries of the Rainy-Namakan system. This approach should diminish the uncertainty confounding present efforts to understand the controlling factors in the fisheries of both lakes. If positive results were obtained, consideration could be given to expanding the approach. If no appreciable positive effect were observed, it could reasonably be concluded that other solutions would need to be sought, most likely through more rigorous controls on fishery exploitation. Additionally, of course, anticipated benefits on the upper lakes must be weighed against anticipated disbenefits downstream. This is the subject of the next major section of the report, but it generally shows that the more the regulation of Rainy Lake is changed from the current situation, the greater the disbenefits are likely to be downstream.

Regarding the timing of the spring refill on Rainy Lake, the Steering Committee noted that they had based their proposal for an earlier refill in part on graphs of simulated natural levels produced by the US Army Corps of Engineers a number of years ago. They believed that these graphs showed an earlier refill than does the Board's modelling of natural levels under this study. In response, the Board can only reply that it has made the same comparisons and finds the refill timings to be generally in agreement between the two simulation efforts.

Regarding the proposals for periodic excursions above and below the rule curves for environmental benefits, and the questions on how this might be managed, it is the Board's view that this is not a viable option under rule curve operations. The Board has addressed the issue of water level management by rule curve versus other management approaches in Section 3.4.1. While not denying the benefits of periodic highs and lows, the Board is unaware of any safe means of allowing for such excursions under the rule curve concept. A more active management structure would be required. Having concluded previously that rule curve operation is still the most reasonable compromise for water level management of the Rainy-Namakan system, the Board sees the loss of this capability as part of that compromise. Thus the Board does not intend to address this objective further. However, it is noted that there will still definitely be periodic and significant excursions above and below the rule curves. Rather than pre-planned, these will be driven by nature, through the occasional more extreme flood and drought events. The Board also agrees with the comment from Voyageurs National Park that there would be little or no public support for an enforced regime of highs and lows, in spite of the environmental benefit. The deliberate attainment of such extremes would have negative impacts to flood control, navigation, tourism and recreation, and could result in significant financial costs.

Related to the above, it was noted in the Status Report that natural summer Namakan levels would decline by 0.3 to 3 feet. The environmental consultants suggested that lowering the bottom of the SC band by one foot would increase the environmental benefit. Consequently, a commenter felt that this should be evaluated. However, while lowering the bottom of the summer band might well be positive for environmental factors, it would be detrimental to navigation, tourism and recreation. The Board does not plan to evaluate this suggestion further.

The comments and questions regarding the proposed monitoring programs, to assess the benefits and disbenefits of change on the fishery and the environment, strike a chord with the Board. The current study has certainly been hampered by the lack of sufficient data to draw concrete conclusions and linkages regarding causes and effects. As a result, the Board's fishery and environmental consultants have ended up having to base their findings as much on general understandings of what "should" be better as on solid fact. The Board sees proper monitoring programs as essential for both determining the impacts of any rule curve changes made as a result of this review, and for creating the database needed to evaluate future proposals for change (which should certainly be anticipated). However, the Board itself does not have either the resources or the expertise to design and implement the needed programs. The Board's fishery consultants have provided some guidance in this regard, but the Board believes that the involvement of, and leadership by, the main resource managers for the area (OMNR and MDNR) is of key importance. Thus the comments by these agencies about lack of resources for such programs is very disturbing. The Board believes that the IJC must play an active role in ensuring that an appropriate mechanism is put in place for the required monitoring as part of any action that it ultimately decides upon.

Closely related to the above issue was the comment that no scientific case has been made that adoption of the SC proposal would benefit Rainy-Namakan fish and wildlife; rather, that strict harvest controls are the answer. The Board certainly agrees that there are many confounding variables, including over-exploitation of the fishery, which have made rigorous objective assessments of the effects of any proposed rule curve changes very difficult. However, it is the Board's view that there is enough scientific evidence, from these lakes and others, to support the position that regulation regimes that more closely follow the natural regime produce benefits to fish, wildlife and the environment. Over-exploitation of the fishery is certainly significant and control of this problem will certainly also contribute to the improvement of the fishery.

One of the comments expressed the view that the Status Report contained little to link water levels with Rainy and Namakan lake reservoir basin profiles, lacustrine wetlands and fish access to tributary stream or spawning grounds. The Board agrees but refers the reader to the background reports listed in the Bibliography, where these matters have been reviewed by the Board's consultants. Similarly, a comment was made regarding the viability of the existing (but unused) fish passages with the alternative rule curves. This had not been addressed previously but, when the comment was passed on to the Board's environmental consultants, the fish passages were not felt to be a significant factor in this study.

Finally, the IJC had asked that the Board make special efforts to obtain input from Native Americans / First Nations. The Board's mailing listed was checked to ensure that all potentially affected peoples were being kept informed, and meetings were held collectively with First Nations to explain the study and seek input.

4. DOWNSTREAM IMPACT STUDIES

This section of the report addresses the impacts of Rainy-Namakan rule curve change on the water bodies downstream of Rainy Lake. Whereas the Board was directly responsible for the studies on Rainy and Namakan lakes (its normal area of jurisdiction), the Board relied on others to conduct the studies and reviews needed to assess the downstream impacts. In particular, regarding impacts on the Rainy River, the Board relied on the Ontario Ministry of Natural Resources (OMNR) and the Minnesota Department of Natural Resources (MDNR) as the key resource managers for the river. Input was also sought from the International Rainy River Water Pollution Board (IRRWPB) and from First Nations and municipalities along the river. Regarding Lake of the Woods and the Winnipeg River, the IRLBC relied primarily on the Lake of the Woods Control Board (LWCB), as it is mandated by international treaty and Canadian legislation to regulate those waters. The LWCB in turn consulted with interest groups, other agencies and the public in completing its review. This information is presented herein because, as outlined in the Plan of Study, the IRLBC's conclusions and recommendations to the IJC regarding the Rainy-Namakan rule curves, while focussing on Rainy and Namakan lakes, are to consider the broader area, not just those lakes in isolation.

4.1 Rainy River

The process of soliciting input to the study for the Rainy River area commenced in early 1996 with letters to the OMNR, MDNR, IRRWPB, Rainy River First Nation and local municipalities, advising them of the study and inviting them to a meeting in March. At this meeting the study process was outlined, the likely nature of impacts on the river of Rainy-Namakan rule curve change was described, and attendees were asked for initial concerns and an indication of how they wished to be involved in the study. The next major point of contact came when the Status Report of March, 1998, was provided to the downstream interests. This report contained the modelling results and, in particular, the simulated Rainy Lake outflows into the Rainy River for each rule curve option. It was anticipated that the interests contacted could use this information as a basis for their own assessment and comment. However, while some could work with this data, it became apparent later in the year that others could not, and several groups eventually asked for additional information from the Board in terms of changes in river level (rather than just flow) under the different rule curve options. Thus the Board undertook additional work to determine river levels at several sites along the river, based on the modelled outflows for the rule curve options. The results of this work were made available as an Addendum to the Status Report in early December, 1998, and are summarized in the following sections. Subsequent sections then detail the comments received and the Board's response to them.

4.1.1 Simulation of Rainy River Levels

4.1.1.1 *Rainy River Level Sites*

Unlike the basically horizontal water level of a lake, the water level of a river declines with a varying slope as one moves downstream. The water level slope or rate of decline is dependent on factors such as the volume of flow and the channel geometry. Thus, while a single modelled water level applies to a whole lake shoreline, modelling a river's water surface profile is challenging and requires a significant amount of channel data. Such data is not available for the Rainy River. However, water levels have been recorded at three sites along the river, and it is possible to establish a relationship between river flow and level at these sites. These sites are at the dam tailwater (downstream side of dam) at Fort Frances - International Falls, at Manitou Rapids, and at the Town of Rainy River. The relationships between level and flow were used in conjunction with the modelled Rainy Lake outflows to estimate levels at these sites under the various regulation schemes, but these levels are only applicable close to these sites. In addition, climate provides a further constraint on reliable modelling of river levels in that ice effects cause the river flow versus level relationship to be highly variable. Levels were therefore generated for the open water period of the year only.

4.1.1.2 *River Level Results*

Rainy River level model results at the three sites are summarized on a table and on a number of graphs in the Appendix, as noted below. More graphs and detail on the level versus flow relationships are given in the Status Report Addendum, referenced in the Bibliography. All results are based on 39 years of simulation (1958-1996). All levels used are three-day means centred on the reporting date.

Table 10 - provides a statistical summary of river levels at the three sites, for spring and summer month-end dates, resulting from the four modelled Rainy-Namakan regulation schemes.

Fort Frances Tailwater

Graph 21 - compares the Fort Frances tailwater percentile levels, obtained with regulation on Rainy-Namakan in accordance with the existing 1970 IJC rule curves, with those obtained when regulation is by the proposed SC rule curves. The percentile levels are plotted every quarter month for the nominal open water season (April through November). For example, at the end of June, the 75^{th} %ile level with IJC rule curve operation is 329.99 m, meaning that 75% of time the river surface at the end of June would be at or below this level with IJC operation, and would be above this level 25% of time. In contrast, the 75^{th} %ile level at the end of June with SC operation is 330.41 m, or about 0.4 m (1.3 ft) higher than for the IJC operation case. Table 1 presents some of this same data in tabular form, for specific dates only, but also provides mean levels and results for the C1 and M1 regulation schemes as well. In general, the river levels at the Fort Frances tailrace can be seen to be lower with SC operation than with IJC operation from April through early to late May, but then higher with SC operation than with IJC operation through to September or early October. Because of this switchover, the river level tends to rise more with SC operation than with IJC operation. For example, the median level (the level that is not reached 50% of time and is reached or exceeded 50% of time) rises about 1.15 m (3.8 ft) from the first of May to its high point at the end of the first week in June with SC operation, whereas it rises only slightly and varies over about a 0.25 m (0.8 ft) range with IJC operation. Results with C1 and M1 regulation generally fall between those of IJC and SC, as can be seen for certain dates on Table 1.

Graph 22 - provides Fort Frances tailwater level-duration plots under the four regulation schemes for each of the open water months. It is important to note, though, that these plots are not based on the set of 39 average monthly levels for each regulation scheme for each of these months. Instead, they are based on combining the 4 sets of 39 levels (one at each of the 1/4-month points) that fall in each month for each regulation scheme. To help explain these plots, the plot for June will be used as an example. This plot actually covers the period from the end of the first quarter of June (roughly the end of the first week) through to the end of the fourth quarter of June, since these are the timings of the data points used. Over this period, and with all regulation schemes, the level is never below about 327.1 m (the level is at or below 327.1 m 0% of time), and is never above about 332.7 m (the level is at or below 332.7 m 100% of time). Similarly, with IJC regulation, the level is at or below about 329.1 m 50% of time during this period and, with SC regulation, is at or below about 329.7 m 50% of time during this period. Overall, these plots show that the largest differences in Fort Frances tailwater levels due to the differing regulation schemes occur in April and in June, with smaller differences occurring in July, August and September, and only minor differences in the other open water months. (This is not to say that you may not still get significant differences between regulation schemes in some other months for individual years, but that on average over many years the biggest differences will be found in those months noted.) Also, as with the previous graph and table, the largest differences are between the levels resulting from IJC and SC operation, while the levels resulting from C1 and M1 operation generally lie between those of IJC and SC. As per the above example, these plots may be used to determine, for each month and for each regulation scheme, how often (what percent of time) river levels should be expected to be at or below certain target levels.

Graph 23 - the upper and lower plots compare, for 1968 and 1974 respectively, the Fort Frances tailwater levels for the open water months for the four Rainy-Namakan regulation schemes that were modelled. Again, the data is plotted on a 1/4-month basis. As noted previously, there is a tendency for SC levels to be lower than IJC levels for April and perhaps into May, but then to be higher through September. Often the differences in levels do not appear to be significant. However, note that the grid scale on the plots is 0.5 m (1.6 ft) and that, in areas where the plot lines are rising or falling steeply, the vertical difference between respective curves is greater than it appears at first glance.

Manitou Rapids

Graphs 24-25 - same as Graphs 21-22, but for the Manitou Rapids site

Town of Rainy River

Graphs 26-27 - same as Graphs 21-22, but for the Town of Rainy River site

4.1.2 Comments Received

Cecil A. Wilson, Corporation of the Township of Chapple, Barwick, ON (March 9, 1998)

- concerned over large annual fluctuations in Rainy River levels of as much as 18 feet, making stable use of the river impossible and causing damage to the shoreline, thereby endangering wildlife inhabiting the shoreline area.
- request the IRLBC to implement a study of the river system to address the problem and come up with a solution.

Marilyn Fesnak, Ontario Ministry of the Environment, Thunder Bay, ON (March 12, 1998)

- primary concern to ensure any reduction in the current minimum outflow requirement for Rainy lake does not adversely affect water resources of the Rainy River. During the low flow years of 1987 and 1988, water quality impairment was not a factor, but receding levels did threaten to expose the Township of Emo's water supply intake.

- OMOE opinion that Emo intake would be impacted in any substantial reduction in Rainy River flows. Any proposed rule curve change should take into account the need for the Emo intake to remain submerged at all times. Previous correspondence on the matter indicates at least 3 inches of water should remain above the intake to avoid operational problems.

Ron Shimizu and Jodi Traub, International Rainy River Water Pollution Board (May 12, 1998)
- water quality impairment during low flow periods in recent years has not been a limiting factor as in the past. Of more concern now is the impact of low flows in maintaining adequate water depth over the Township of Emo, Ontario water supply intake. A minimum depth of three inches should be maintained to avoid operational problems. The issue of low flow reduction and protection of the Emo intake should be a component of the IRLBC study.
- reduction in Rainy Lake minimum flow would result in more restrictive receiving water based effluent criteria specified in permits for point-source discharges in Minnesota.
- concern that the downstream implications to fisheries resource has not been adequately addressed. Under the scenario of adopting SC curves, Rainy outflow would on average be 140 m^3/s higher 50% of the time in June, as indicated in the Status Report.
- recommend contracting the services of the fisheries experts used for the Status Report to determine what effects, if any, the proposed rule curves would have on the Rainy River fishery. The experts could also assess if whatever is proposed as most beneficial for Rainy and Namakan lakes is also beneficial for the river.
- additional studies should be conducted prior to and during any rule curve changes to monitor the effects of the altered hydrologic regime on the Rainy River. This work should be conducted by more resource based agencies such as MDNR and OMNR. Budgetary constraints will likely require external funding for this purpose.
- agree that the downstream impacts must be evaluated and would like to see a schedule for achieving this end.
- agree that any change to the existing rule curves must be accompanied by an appropriate fisheries and monitoring program for the Rainy River as well as Rainy and Namakan Lakes, raising the issue of who will be responsible for the work and how will it be resourced.

Scott Lockhart, Ontario Ministry of Natural Resources, Kenora ON (July 20, 1998)
(see relevant comments on Rainy River in letter sent to the Lake of the Woods Control Board and listed in Section 4.2.2)

M. L. Willick, Ontario Ministry of Natural Resources, Thunder Bay, ON (December 1, 1998)
- in general, favor proposals that better achieve ecological sustainability and are appreciative of competing basin interests, but concerned whether the overall benefits to the entire water system outweigh the risks and disadvantages.
- it is clear that positive effects will result from the proposed changes to Rainy and Namakan Lakes, but concerned that altered inflow patterns to Lake of the Woods will affect Lake of the Woods regulation and discharge to the Winnipeg River exerting undue pressure on other water bodies such as Lac Seul and the English River.
- questions concerning mitigation of altered Rainy Lake discharge patterns and the ability of the Lake of the Woods Control Board to meet its regulation objectives on Lake of the Woods without impacting other water bodies must be addressed and impacts quantified.
- recommend additional model runs for Alternatives SC, C1, and M1 to address the following:
  - compare the risk of doing nothing on Rainy and Namakan lakes to the risk of adopting the proposed SC curves with the analysis covering the entire downstream water system.
  - isolated mitigation for Rainy River and Lake of the Woods to determine the maximum mitigation possible for these two water bodies, given the environmental, socio-economic and engineering constraints.

  - determination and mitigation of impacts downstream of Lake of the Woods to the Winnipeg River and Lac Seul. What flow management changes will be required for these water bodies, due to changes upstream flow patterns.
- need to determine if all competing interests are appropriately considered in the model (e.g. habitat for Piping Plover, endangered species). A workshop may be required to formulate criteria for the model runs.
- the Status Report has not addressed flood risks and ice jam risks of the Rainy River.

Thomas W. Balcom, Minnesota Department of Natural Resources, St. Paul, MN (February 8, 1999)
- concerned that Rainy River flow under the existing IJC rule curves has reduced natural minimum flows, altered the timing of low flow occurrence and increased the frequency of low flows to the detriment of the river fishery, especially during spawning periods, by exposing spawning beds or providing water that was too shallow.
- concerned over reduced variability of river flows and marked diurnal river fluctuations, or peaking on a daily basis and over weekends. Reduced variability and peaking strategies are well documented in harming fish and aquatic resources.
- it is desirable for Rainy Lake outflow to be more similar to the natural pattern. The existing regulated flow has altered the yearly hydrograph with summer flows less than the natural condition and this is harmful to fish and wildlife in the Rainy River.
- alternative M1 produces Rainy River flow more similar to the natural pattern than either the existing IJC rule curves or the SC curves. Rankings in order of least to most deviation from natural are M1, SC, C1 and IJC.
- concerns over negative impacts to Walleye and Northern spawn period in April and May and sturgeon spawn in Late May and early June from decreasing flows during these periods.
- based upon MDNR analysis, recommend the following:
  - stable or rising water levels during April 15 through June 15 period to protect spawning and nursery habitats.
  - no diurnal peaking permitted.
  - development and use of more appropriate ramping rates.
  - rule curves which produce a more natural hydrograph for Rainy River (Alternative M1 or SC proposed rule curves).
  - minimum flows to protect fish habitat, such as a minimum of 10,000 cfs at Manitou Rapids through late April and early May.
  - existing diurnal flow requirements appear unnecessary now that the paper mills dump less pollution in the river (more uniform flow distribution would be possible); however, dissolved oxygen monitoring during drought conditions may warrant emergency diurnal flow requirements.
  - an investigation of critical habitats within the Rainy River and associated flow impacts.
  - notice to the public whenever flow will have negative impacts such as ice damage, flooding and recreational boating.
- impacts of rule curve changes on Rainy River flood potential should receive consideration. Concerned over the slightly higher than expected peak elevations on the river using the SC curves. Other alternatives such as M1 do not seem to differ much from the existing IJC curves.

Bill Darby, Ontario Ministry of Natural Resources, Fort Frances, ON (February 23, 1999)
- steady or increasing river levels in the spring from late April through early June is better for fish spawning. This suggests the SC curve has an advantage over the IJC and M1 curves for fish spawning in Rainy River, based upon Graphs 1 & 7 of Addendum 1.
- cannot comment at this time on the effects on spawning of lower river levels at Fort Frances and Manitou Rapids in late April and Early May as suggested by Graph 1 of Addendum 1. Much depends upon availability of suitable substrate at these depths and a field investigation would be

required. It may not be a problem if suitable substrate exists, especially in light of steady or increasing river levels.
- higher river levels associated with the SC curve from June through August should be good for effluent dilution, dissolved oxygen, fish nursery and growth and for navigation. Winter levels may be slightly lower than with the IJC curve, but this could not be examined due to lack of data. Any impacts to overwintering fish from the SC curve should be offset by the increasing river levels through the spawning period. Impacts of level changes should be related to the natural condition.
- river levels at the Town of Rainy River are affected by Lake of the Woods levels, Rainy River flows and ice jams. Consideration should be given to the timing of water level increases in the river and the potential for increasing flood risk from ice jams (more important in the context of flood risk to the town than level differences between the SC and IJC curves at other times of the year.
- increasing water levels on Lake of the Woods in June may negatively impact nesting success of Piping Plover, an endangered species, since they tend to nest on sand beaches at elevations 4 inches to 3 feet above the lake level.
- the problem of rising water levels on Lake of the Woods in June exists with all four curves being evaluated (IJC, SC, C1 and M1). Regular monitoring and mitigation of the flood risk to the Town of Rainy River through management of Lake of the Woods levels is required, as well as mitigation of Lake of the Woods levels for the Piping Plover.
- prefer that the minimum flow Order for drought or low flow conditions not be changed and for the Board to continue using the issuance of Supplementary Orders, when needed. Feel the present process has featured effective communication between the Board and OMNR and allows for discussion and adjustment for unforeseen factors.
- agree improved water quality on Rainy River has lessened the need for diurnal fluctuations in Rainy Lake outflow. Pulsing or peaking strategies on the river for managing hydropower production have a negative effect on the downstream fisheries, especially during the spawn. Recommend removing the diurnal flow requirements gradually with monitoring of dissolved oxygen levels.
- dissolved oxygen in Rainy River should be monitored in case of reductions to outflows from Rainy Lake.
- strongly encourage the Board to examine the possibilities for mitigation of downstream effects before making a recommendation to the IJC.

Chief Jim Leonard II, Rainy River First Nations, Emo, ON (March 9, 1999)
- hydrologic modelling of the Rainy River to show water level effects of the proposed Rainy-Namakan rule curve changes was completed very late in the study but the impact of the water level changes has never been studied.
- if the present rule curves are altered, certain questions remain to be answered:
  - how will fish habitat be altered?
  - how will benthic productivity will be lost?
  - how will water velocities be changed and how will this affect spawning activity of important game species such as Walleye and Lake Sturgeon?
  - will the loss of fish habitat increase predator/prey interactions; thereby making it harder for young of year fish to survive?
  - how will the previous 4 points affect recruitment of fish in Rainy River?
  - how will the reduction in the dilution of effluent from the pulp and paper mills affect the concentration of contaminants in the fish and water of Rainy River?
  - will there be higher flood and ice jam risks?
  - will there be more shoreline erosion?
- changing the rule curves my result in harmful effects on the river fishery and may affect erosion, flooding, ice jams, water quality, fish contamination and, consequently, social, economic and

recreational factors. Feel that the rule curves can not be changed until the impacts of these changes on Rainy River are studied.

Reeve Lloyd J. Hodges, Township of Dawson, Rainy River, ON (March 10, 1999)
- same comments as Chief Leonard letter of March 9, 1999.

Robert Sutherland, Lake of the Woods County, Baudette, MN (March 10, 1999)
- same comments as Chief Leonard letter of March 9, 1999.

Anna H.M. Boily, The Corporation of the Township of Morley, Stratten, ON (March 11, 1999)
- same comments as Chief Leonard letter of March 9, 1999.

Laurie A. Witherspoon, Township of La Vallee, Devlin, ON (March 12, 1999)
- same comments as Chief Leonard letter of March 9, 1999.

Dave Gibson, Department of Fisheries and Oceans, Burlington, ON (March 22, 1999)
- cited compliance with Sections 35 and 22(3) of the Fisheries Act in Canada in that changes in water level ratings must not result in harmful disruption or destruction of fish habitat and must provide at all times such a quantity of water that will, in the opinion of the Minister, be sufficient for the safety of fish and fish spawning.
- of the information received, there is little that links water levels with Rainy and Namakan lake reservoir basin profiles, lacustrine wetlands and fish access to tributary stream or spawning grounds. This information should be provided for review, prior to any decision to alter the curves, and should look both upstream and downstream of the Fort Frances dam and at times of the year sensitive to fish.
- share the concerns of the Rainy River First Nations and Township of Chapple that reduced flows at certain times of the year with some of the alternatives proposed may alter or harm fish habitat. The issue of minimum downstream flows and water levels at times of the year sensitive to fish does not seem to be adequately addressed.

Teresa Jaksa, Koochiching County Board of Commissioners, International Falls, MN (March 24, 1999)
- resolution forwarding and supporting comments, information from Jennifer Mercer, Rainy River Watershed Program Coordinator and Paul Radomski, Steering Committee Co-Chair, regarding impacts to Rainy River from any changes to the Rainy and Namakan rule curves.
- support the proposed Steering Committee changes to the rule curves for Rainy and Namakan Lakes and endorse the study and public consultation process followed by the Steering Committee.
- downstream impacts on Rainy River from changes in lake outflow are becoming better understood, particularly for the river fishery and the timing and magnitude of flows and their impacts to fish spawning success and habitat of important sport fish species like Walleye and Lake Sturgeon.
- concerned that Rainy River flow under the existing IJC rule curves has reduced natural minimum flows, altered the timing of low flow occurrence and increased the frequency of low flows to the detriment of the river fishery, especially during spawning periods by exposing spawning beds or providing water that was too shallow.
- Rainy River Watershed Program and Steering Committee feel certain questions remain unanswered:
  - How will fish habitat be altered?
  - How will benthic productivity change?
  - How will water velocities be changed and how will this affect spawning activity of important game species such as Walleye and Lake Sturgeon?

- How will changes affect recruitment of fish in Rainy River?
  - How will winter reductions in flows affect the concentration of pulp and paper by-product contaminants in the fish and water of Rainy River?
  - Will there be more shoreline erosion?
  - How similar are the Rainy Lake discharges with the proposed rule curves to simulated natural Rainy River flows?
- recommend extensive monitoring and research upon implementation of the proposed rule curves to verify if modifications are reducing negative impacts on interests and users without conflicting with other uses or resources.
- would like to see Rainy Lake discharges that mimic the natural flow to benefit fish and wildlife, navigation, recreation and tourism.

Keith Patterson, Water Manager for the Town of Emo, ON (personal communication with Denis A. Davis - March 25, 1999)

- summary of discussion as follows:
  - main concern is minimum flows in the Rainy River and the difficulties they create in meeting the town's water supply needs. The town wishes to continue to be able to use the river for its supply.
  - improvements to the town's delivery system, including installation of extra low level intake and larger pump were made during the low flow conditions of 1998.
  - low flows and associated variable water chemistry made water treatment more difficult, requiring more frequent changes to the treatment process to deliver high quality water.

Ron Shimizu, International Rainy River Water Pollution Board (April 6, 1999)

- remedial water quality measures carried out since the 1970's have played an important role in improving habitat conditions, allowing a return of the fishery to a river once devastated by pollution. It is important to maximize the fishery and all its spin-off benefits by selecting a flow regime that will allow for maximum spawning and hatching success.
- dissolved oxygen levels in the Rainy River were not a problem during the low flows of 1998, but the effect of decreased mill effluent due to shutdown of the Canadian mill during a labour dispute at the time is difficult to assess.
- under normal operations, the choice of rule curves will not likely make a significant difference in water quality conditions. Water quality is more likely to become an issue when operating at the low end of the rule curve bands or under extremely low flow conditions, such as those experienced when under a Supplementary Order.
- there is no need to continue a diurnal discharge regime; the less fluctuation there is during spawning periods, the less chance there is for any disruption and exposure of spawning beds.

4.1.3 Board Response

A prevalent theme throughout the comments on Rainy River impacts is that more studies and evaluation are required. The Board certainly agrees that some additional work could be desirable. Resource management agencies, such as the OMNR and MDNR, are encouraged to conduct such studies as their budgets permit. However, the Board itself has neither the mandate nor the budget to conduct studies on downstream impacts. As defined in the Plan of Study, the Board was dependent on others with the appropriate mandate and expertise to provide the necessary information for the downstream areas. Further, the Board believes that there is currently sufficient information to support recommendations that would result in relatively minor changes to the Rainy River flow regime. It is only if major impacts on the river flows and levels were being anticipated that the Board might agree that more information is needed before making any change even on a trial basis. Nevertheless, the Board strongly believes that impact studies and monitoring programs should be on-going during a trial period with any new rule curves. The provincial and state natural resource agencies should take the lead in these studies, which hopefully can be integrated into their on-going resource management programs.

The Board agrees that protection of the Township of Emo water supply must continue to be given high priority during low flow periods. The installation by the Township of a lower level intake in late 1998 is certainly a help in this regard, in that this constraint to low flows is no longer quite as restrictive as it has been. Nevertheless, the same consultative process as has been followed in the past should continue whenever contemplating reducing Rainy Lake outflows below the standard minimum outflow defined at the lower rule curve. In the same way, downstream fisheries and water quality concerns, and any other issues that may develop in the future, must be fully taken into account whenever reductions in Rainy Lake outflow below the standard minimum are considered. As addressed in Section 3.4.2, the Board believes that defining a second minimum outflow, and predefining the lake level at which that reduced outflow would be considered, will benefit all users by providing advance knowledge of operating procedures. Significant experience has been gained over the past three decades in dealing with drought conditions. Supplementary Orders will still provide a valuable mechanism for dealing with special or more extreme circumstances.

The proposal to set a minimum flow for late April - early May of 280 m^3/s (10,000 cfs) for the Rainy River at Manitou Rapids would have dramatic implications for the regulation of Rainy Lake during low inflow years. Historically, Manitou Rapids flows have been well in excess of this flow in most years (during late April - early May). Modelling results indicate that flows at Manitou Rapids down to lower quartile will be in excess of 280 m^3/s for all rule curve options except SC (245 m^3/s). However, at lower decile the Manitou Rapids flows have been about 200 m^3/s historically and modelled results range from 195 m^3/s for the IJC rule curves down to 166 m^3/s for the SC curves. Under such lower decile inflow conditions, there is barely sufficient inflow to Rainy Lake to maintain a constant lake level at the current IJC minimum outflow. This inflow is well short of that needed to have the lake level rise within the rule curves. If Rainy Lake outflow was increased sufficiently to maintain 280 m^3/s at Manitou Rapids, the lake level would decline quite quickly.

The desire by several parties to have Rainy River flows more similar to the “natural pattern” is acknowledged. However, the comment that the current pattern of regulation on the river has actually been harmful would seem to be disputable, especially given the statements at the same time that insufficient data exists. It is clear that none of the rule curve options will give a completely natural pattern. Further, it is clear from the modelling work that while none of the options gives the variability in spring flows typical of nature, the IJC curves better represent the average spring timing than do the proposed curves. Similarly, the modelling shows that the minimum river flows under regulation are higher than the minimum would have been in a state of nature, not lower as commented.

Regarding the lack of investigation of flood risk and ice jam risk on the Rainy River, Tables 7 and 10 in the Appendix shed some light on the former. While the timing of peak discharge from Rainy Lake may well change under the various rule curve options, the peak discharge itself, and thus the river levels, do not change significantly. The biggest change comes in the lower reach of the river that is affected not only by the river discharge but also by the level of Lake of the Woods. Table 10 provides a good indication of the difference in level of the river at the Town of Rainy River for the various rule curve options, and the modelling results provided by the Lake of the Woods Control Board are also useful, as addressed in the next section of this report. As to ice jams, any investigation is very complex due to the wide variety of compounding factors and the typically sparse data available for analysis. While no such study has been undertaken here, the particular combination of factors needed for an ice jam are not believed to be any more likely with any one of the rule curve options than with the others. It must be remembered that ice jams, such as occurred on the Rainy River in the spring of 1997, are quite rare. Special conditions such as these will continue to be dealt with by the Board and the IJC on a case by case basis.

The potential for mitigation of higher flood levels at the Town of Rainy River, and of higher levels affecting piping plover nests on Lake of the Woods, by varying the regulation policy for Lake of the Woods is acknowledged. In fact, the mitigation of downstream impacts caused by rule curve change was the major focus of the review conducted by the Lake of the Woods Control Board, as addressed in Section 4.2. Unfortunately, the work of the LWCB showed that these downstream impacts could not be mitigated overall but only moved around. The attempted mitigation of adverse impacts on Lake of the Woods resulted in more negative impacts on the Winnipeg River.

The Board believes that the dam operators should have operating flexibility when lake levels are within the defined rule curves. This could include power plant peaking operations when hydraulic/hydrologic conditions permit. However, the Board certainly recognizes the additional stress that daily or weekly peaking may put on spawning fish. The Board strongly urges cooperation between the dam operators and provincial resource agencies to work together to establish flow criteria beneficial to both parties on a time-of-year basis. This type of cooperation has been shown to work very well in other jurisdictions and areas.

Finally, regarding the issuing of public notices or advisories, the Board notes that in recent years the Companies, as dam operators, have endeavoured to provide timely public notice of outflow changes that may have adverse impacts downstream. The Board strongly urges this practice to continue, and to be modified or expanded as the need arises.

4.2 Lake of the Woods / Winnipeg River

The Lake of the Woods Control Board commenced its study of impacts on Lake of the Woods and the Winnipeg River once the modelled outflow records from Rainy Lake were available from the IRLBC for the four rule curve sets under evaluation. The Board provided a preliminary response to the IRLBC's Status Report by letter dated May 15, 1998. This letter also outlined the process the LWCB intended to follow in completing its work and seeking public input. Excerpts from the letter follow:

....The impact on Lake of the Woods of a change in rule curves on Rainy and Namakan lakes is an altered pattern of inflow, in both timing and magnitude. At issue is whether or not this Board can meet, and with what difficulty and frequency, its regulation objectives on Lake of the Woods with such an altered pattern of inflow. Further, in that water is either drawn from or stored in both Lake of the Woods and Lac Seul in order to address downstream river level and flow targets, changes in regulation needed to manage an altered inflow regime to Lake of the Woods may require a re-balancing of the system overall, thus impacting on these other water bodies as well.

The Board has initiated its modelling work to determine the impact on Lake of the Woods. The preliminary results to date indicate a progressive impact from the rule curve alternatives defined in the Status Report. With the IJC curves as the base case, the impact on Lake of the Woods increases as the curves are modified first to C1, then M1, and finally to SC. While there are impacts throughout the year, the most significant occur from spring to early summer. As the rule curves are altered, there is progressively less inflow during the spring, as waters are held back to fill the upper lakes, and then more water in the early summer, once the upper lakes are filled. The result is that Lake of the Woods receives less inflow during the spring when it is important to raise the level to meet fish spawning targets, and then more water during the June - early July period, when inflows are already typically at their highest, and it is important to limit the rate of rise for the benefit of wild rice and also important to limit the maximum level to prevent high water damage.

Based on the results to date, it is clear that any of the proposed changes would make the regulation objectives for Lake of the Woods and the Winnipeg River more difficult to achieve, with the least impact resulting from option C1 and greatest resulting from option SC. However, we have not yet been able to quantify, and in fact may not be able to quantify, at what point (if any) this impact unacceptably jeopardizes the achievement of Lake of the Woods objectives. We note, however, that the rule curve changes being proposed primarily to improve the Rainy and Namakan fisheries may prove detrimental to the fishery on Lake of the Woods. It will be more difficult to meet fishery target levels in the spring without exceeding high water targets by the summer. The Status Report credits the fishery on Rainy and Namakan for area expenditures totalling $10.2 million, whereas the Lake of the Woods fishery reportedly generates $54.3 million (ref. pg 34).

....Regarding process, once this Board has completed its initial assessment, it intends to turn over its results to the various Interest Groups it recognizes on Lake of the Woods and the Winnipeg River, for their review and comment. Once the Board has completed both its technical review and its consultation with its Interest Groups, it will provide you with its position and reasons for it. Of course, any further options and alternatives that may yet arise out of the Rainy-Namakan study will also have to be assessed by both this Board and its Interest Groups.

When the LWCB completed its technical work, it issued a report *"Lake of the Woods Modelling / Impacts of Rainy-Namakan Rule Curve Change"* dated June 5, 1998. Excerpts from this report appear in the following section. Tables and figures referred to are in the Appendix.

4.2.1 Excerpts From LWCB Modelling Report

4.2.1.1 *Lake of the Woods Simulation Model*

The "ARSP" computer model (Acres Reservoir Simulation Program), acquired several years ago by the Board from Acres International Ltd. and configured for the Winnipeg River basin, was set up to model only Lake of the Woods. Given an operating policy and the physical lake and outlet conditions, the model determines the lake levels and outflows resulting from provided inflows. The model balances the inflowing water between lake storage and outflow at a given point in time, according to the given operating policy. The operating policy is defined in the model by a series of level zones for the lake and flow zones for the river, each with an associated "penalty". Through a model calibration process, which considers the regulatory legislation, the physical constraints of the system and the objectives of the various interests, the zones and their penalties are adjusted and co-ordinated to achieve the desired operation.

The four Rainy Lake outflow scenarios from the Rainy-Namakan study consisted of daily flows for a 39 year period, based on historic inflow data for 1958 through 1996. As it was decided to use a quarter-monthly "time-step" in the model, these daily outflows were converted to quarter-monthly outflows. Then quarter-monthly local net inflows were computed for Lake of the Woods for the same historic period, to account for the local basin runoff not originating in Rainy Lake and also to account for local losses such as evaporation. These local net inflows were added within the model to the Rainy Lake outflows to produce the total net inflow to Lake of the Woods.

....In addition to the basic balance between lake level and outflow, a couple of other special rules are applied in the model. A small penalty is applied to prevent spill in excess of Abitibi-Consolidated's hydroelectric generating capacity. A penalty is also applied to any outflow change greater than 100 m^3/s in any given quarter-month period. Finally, during the spring, constraints are applied, through additional penalties, to reflect the regulating decisions which are made to protect the walleye spawning in the river. The model tries to prevent the outflow from declining more than 5% during the first 3 weeks of the spawn, and from declining more than 10% during the last 2 weeks (a 5-week spawn period is defined). The model also tries to prevent outflow increases greater than 20% in each of the 5 quarter-month periods.

Work could continue almost indefinitely in trying to adjust and fine tune the operating policy in the model. ....In particular, the current balance in the model tends to have a somewhat bigger impact on outflows than on levels when inflows are greater in any given period, but this is at least in part explained by the fact that, due to the large surface area of the lake, it takes a large volume of water to increase the lake level only a small amount. Overall, it is felt that the model in its present state at least addresses current objectives sufficiently well so as to not bias the outcomes with the four inflow scenarios being evaluated.

4.2.1.2 *Model Results*

Model results are summarized on a table and a number of graphs, as noted below:

Table 11 - summarizes key level and flow parameters for Lake of the Woods for the simulated period 1958-1996 for Runs F1-IJC, F1-SC, C1 and M1. These use Rainy Lake outflows from “base” case runs of the same name in the Rainy-Namakan study. The IJC run uses the existing IJC rule curves on Rainy and Namakan lakes. The SC run uses the rule curves proposed for Rainy and Namakan lakes by a local Steering Committee. Compared to the IJC curves, the SC curves rise earlier in the spring and provide for some summer drawdown on both lakes, and reduce the extent of winter drawdown on Namakan. Run C1 combines the existing IJC curves on Rainy with the proposed SC curves on Namakan. Run M1 uses a modified form of the C1 curves, with the most significant change being the provision of limited summer drawdown on Rainy.

Graph 28 - compares the percentile levels and outflows for Lake of the Woods for the F1-IJC and F1-SC 39 year runs. For example, the blue lines in the middle of the range on both graphs show the 50 %ile results for the IJC (solid) and the SC (dashed) curves respectively. The green pair above these are the 75 %ile results, the green pair below are the 25 %ile results, and so on. It is best to compare the IJC and SC results by looking at a single pair at a time. For example, looking at the blue pair in the level plot, it can be seen that the 50 %ile or median lake level (half the years have a higher level than this, and half the years have a lower level) in mid-May with the SC curves is about 3 or 4 cm lower than with the IJC curves. Then, in July, the maximum 50 %ile level is about 5 cm higher with the SC curves than with the IJC curves. Similarly, on the flow plot, the median outflow in June is up to 100 m^3/s lower with the SC curves than with the IJC curves (about 350 versus about 450 m^3/s), but in July the median outflow is up to 200 m^3/s higher with the SC curves than with the IJC curves (700 versus 500 m^3/s). The overall tendency shown by this graph is for slightly lower lake levels and lower outflows from January through May with the SC curves versus the IJC curves, followed by higher lake levels and higher outflows in the summer with the SC curves versus the IJC curves.

Graph 29 - compares the median levels and outflows for all four inflow scenarios (F1-IJC, F1-SC, C1 and M1). These results are the same as the median lines (the blue lines) on Graphs 1, 2 and 3. The lines are plotted in the order as shown in the legend, F1-IJC first and F1-SC last. Thus, where two lines have the same value, only the colour of the one last plotted will show. By comparing these results, it can be seen that the difference is generally greatest between IJC and SC, with the C1 and M1 results lying somewhere in-between, but often (but not always) with the C1 result lying closer to the IJC result and the M1 result lying closer to the SC result. The same pattern is generally true at the other percentile levels as well, as can be seen by referring back to the first three graphs.....

Graph 30 - compares the lake levels and outflows for Lake of the Woods for simulated 1978 inflow hydrology. ....One area of interest for this year is the summer level, which is about 10 cm higher with SC operation than with IJC operation, and about 6 cm higher with either C1 or M1 operation. Note the difference in outflows as well, both in July and especially in April, where greater cutbacks are required with the other curves (compared to IJC) in order to meet the fish spawn target level. This then results in up to an extra 150 m^3/s outflow increase (compared to IJC outflow) during the incubation period in the river.

Graph 31 - similar to previous graph, but for simulated 1991 inflow hydrology. Note the higher summer levels with SC, C1 and M1 curves compared to IJC, and also the higher summer outflows. Note the lower outflows in the spring in order to keep the lake rising.

Graph 32 - similar to previous graph, but for simulated 1996 inflow hydrology. This is a year of high spring inflow of recent memory. Note the progressive greater cutback in outflow (50 to 75 m^3/s) in April, before the high inflow commenced, in order to meet the fish spawn target level. Note the higher levels in the summer with the other rule curves compared to the IJC curves (up to an extra 8 cm over elevation 1061 ft), and the second spike of outflow to the river in July (an extra 250 m^3/s over an already high flow) with all but the IJC curves.

Graph 33 - compares the monthly outflow-duration curves on Lake of the Woods for the four inflow scenarios. This graph shows that the outflow is typically greater with the IJC curves than with the SC curves from January through May. The outflow with the C1 and M1 curves is typically between that of the IJC and SC values, but may be close to the IJC values (for example, with higher outflow amounts in May). In terms of power generation, the most significant of these months is probably February, where the IJC outflows appear to be 70 m^3/s or more greater than the SC flows about 80% of time. This would presumably benefit the downstream utilities most of this time but would benefit Abitibi-Consolidated only about 30% of time since the outflows are greater than their plant capacity for the remainder. For June through October, when the power utilities requirement for flow is not great and river residents wish to avoid high water, outflows from IJC rule curve operation tend to be lower than with the other rule curves, with the biggest difference coming in July. IJC outflows are about 150 m^3/s lower than SC outflows about 50% of time in July, and 50-70 m^3/s lower about 75% of time. However, these percents of time are cut in half or more if one only considers periods where the river flow is above the threshold value of 700 m^3/s, the point at which Minaki levels begin to rise. For November there is little difference in the outflows resulting from the different rule curves and, by December, outflows are starting to again be larger with the IJC rule curves than with the other curves, although the differences are still typically very small.

4.2.1.3 *Observations*

As can be seen from the IRLBC's Status Report, changing the rule curves on Rainy and Namakan lakes causes a change in the timing and magnitude of outflows from Rainy Lake. While the total outflow over a year remains the same, its release is redistributed within that time frame. One of the most significant changes with the SC curves is that, compared to the IJC curves, Rainy and Namakan lakes are refilled earlier in the spring. As a result, more water is held back in the late winter and early spring, compared to the present practice, in order to fill the lakes and then, in early summer, more water is released since the lakes are already full when the typically higher June and early July inflows arrive. Another change is summer drawdown, which results in more water being released over the summer and early fall but then less over the winter. With the C1 and M1 alternatives, the effect on Rainy outflows is similar but less pronounced.

With this shift in timing of inflows to Lake of the Woods, one of the anticipated effects was that there would be less water available to refill the lake to the spring spawn target level, and then more water coming in during June when inflows are already typically high and it is desirous to avoid both overly high lake levels and high downstream river levels due to high outflow. Less water for winter power generation was also anticipated. The modelling exercise has basically confirmed these anticipated impacts. However, with the operating policy adopted, there appears to be little change in the frequency of success in reaching the spring spawn target level on the lake. The consequence of the relatively high priority placed on this criteria is that there is typically a greater reduction in Lake of the Woods outflows in March and April, and then both higher outflows and higher lake levels in the early summer since more water is coming in after the fish spawn target level has been reached. This of course will have some impacts on other users of the resource, and also results in a greater flow (and thus level) range on the river during its fish spawn and incubation period. While it does not appear that a significant increase in unacceptable conditions is likely, there may well be an increase in frequency of “less desirable” conditions. In terms of the Board being able to best address its usual operating criteria, it is clear that the status quo (existing IJC curves) is the best case scenario. The Board’s task becomes more difficult and the likely degree of success in meeting regulation objectives deteriorates as one moves from the IJC curves to the C1 alternative, then to the M1 alternative, and finally to the SC proposal.

Changes in operating policy could of course affect the relative balance of the interests in dealing with altered inflows from Rainy Lake. For example, it would be possible to reduce the lake level and outflow increases in the summer by having the lake level lower in the spring. This, however, would result in the spring fish spawn target level being met less often on the lake. Also, the modelling exercise has considered impacts only on Lake of the Woods and its outflow. Since water is either drawn from or stored in both Lake of the Woods and Lac Seul in order to address downstream river level and flow targets, changes in operating policy to deal with the altered inflow regime could impact on these other areas and water bodies as well.

Finally, it is noted that the impact on Lake of the Woods of any decrease in the current IJC specified minimum outflow from Rainy Lake has not yet been tested. Also, as the IRLBC has not yet recommended the adoption of any of the four rule curve sets examined, and other alternatives may yet be developed, further modelling of a final proposal may be required.

A few summary facts drawn from the table and graphs follow:

- given the operating policy used, there is little change in the frequency of success in meeting the spring fish spawn target level on the lake with any of the inflow scenarios.

- there is little change in the maximum discharge for the simulated 1958-1996 period with any of the inflow scenarios. Compared with IJC curve results, the maximum flood level is about 5 cm higher with the SC curves, and 3-4 cm higher with the C1 and M1 curves.

- with the SC curves, the number of periods with the lake level over 323.47 m (1061.25 ft) is double that with the IJC curves, and the number of periods over 323.39 M (1061 ft) is nearly 70% greater. However, these events occur very infrequently; less than 2% of time.

- the number of periods with outflow greater than 1100 m^3/s increases by 60% with the SC curves as opposed to the IJC curves, and the number of periods with outflows over 900 and 700 m^3/s increase as well but, as with extreme lake levels, these occur only a small percentage of time. The number of periods with spill at the Abitibi-Consolidated powerplants (over 420 m^3/s) actually decreases slightly with the SC or alternate rule curves.

- the mean January-February outflow is 30 m^3/s less with the SC curves than with the IJC curves, and the median outflow is about 40 m^3/s less, rising to about 70 m^3/s less for about 80% of time in February. Thus the SC curves consistently deliver less water than the IJC curves for power generation in the coldest months. While this is a disadvantage for the downstream powerplants that have higher capacities, it does not affect the Abitibi-Consolidated Kenora plants since the flows in this period are often over their capacity.

- the mean spring refill is 7 cm greater with the SC curves than with the IJC curves, and about 4 cm greater with C1 or M1 versus IJC.

- the mean lake level in July is 5 cm higher with the SC curves than with the IJC curves, and about 3 cm higher with C1 or M1 versus IJC, while the mean July outflow is about 80 m^3/s higher with the SC curves than with the IJC curves, and about 30 m^3/s higher with C1 or M1.

4.2.2 Comments Received

Once the LWCB had completed its modelling, it presented the results to the various interest groups and natural resource agencies it works with, to solicit their comment. A news release summarizing the anticipated impacts was also issued to solicit comments from the public at large. Given below is a summary of the written comments received by the LWCB:

Vincent Proteau, Pine Tree Campground & Trailer Park, Prawda MB (July 17, 1998)
- on the Boggy / Birch River systems and is very concerned with on-going flooding and chlorine contamination, which he attributes to the Shoal Lake Aqueduct. He believes the proposed changes would make their drainage problems worse.

Scott Lockhart, Ontario Ministry of Natural Resources, Kenora ON (July 20, 1998)
- Rainy River
  - less flow during early spring could negatively impact available walleye, sturgeon and sucker spawning habitat.
  - increased summer/fall flow could alleviate dissolved oxygen depression in backwater areas.
- Lake of the Woods
  - the slightly lower anticipated levels from mid-April to late May would have minimal effect on walleye spawning but might negatively impact northern pike.
  - slightly higher levels in June-July would favour centrarchids, especially rock bass and black crappie.
  - rising levels in June may negatively impact nesting piping plovers, loons, grebes, etc and also wild rice. In particular, the proposed changes may completely destroy piping plover nesting sites/habitat.
- Winnipeg River
  - lower outflows during April-June may impact the amount of available walleye spawning habitat, and the eggs will not survive if flows drop after spawning. Declining flows in April may negatively impact pike spawning.
  - increased outflows in June will flood nesting loons and other waterfowl.
  - the potential for more outflow fluctuations will compound the above problems and lead to increased property owner complaints.

Overall, supports the existing IJC rules on Rainy-Namakan and notes that the federal Department of Fisheries and Oceans may be interested in reviewing the impacts to fisheries habitat, as protected under the Fisheries Act.

Frederick Jost, Morden MB (July 22, 1998)
- a property owner on Lake of the Woods who believes that less inflow in the spring would reduce fish habitat for spawning while higher summer levels would reduce lake recreational activities, such as outings to beaches. Rainy and Namakan would benefit at the expense of Lake of the Woods.

Fred Zroback, Kenora ON (July 27, 1998)
- concerned that the proposed changes would negatively affect loons on Lake of the Woods.

Paul Radomski, Minnesota Department of Natural Resources, Brainerd MN (US Co-Chair of Rainy Namakan Steering Committee) (July 28, 1998)
- posed a list of questions on the LW modelling report, which were answered.
- expressed the hope that the LWCB not excessively limit potential improvements for Rainy-Namakan, especially for reasons such as institutional bias against change.

Hart Oldenburg, Winnipeg MB (rec'd August 4, 1998)
- with property on the lake near Sioux Narrows, he feels that adopting the proposal would be tampering with the unknown, and that lowering spring levels while adding to the summer peak would be foolhardy at best.

Richard Myers, Warroad MN (August 5, 1998)
- with property near the Northwest Angle, he opposes any temporary or permanent rise in water levels above present levels. He is concerned with loss of vegetation protecting his harbour, and irreparable damage to shoreline and docks.

Catherine Milner, Winnipeg MB (a Director of the LWDPOA) (August 9, 1998)
- with property on Sand Lake near Minaki on the Winnipeg River, she is opposed to the proposal. She feels all the benefits would accrue to Rainy-Namakan residents and all the disbenefits to the Lake of the Woods - Winnipeg River disbenefits. She is concerned with the potential for more frequent and larger flow variations, and especially more frequent higher levels, stating that the damage to wildlife and private property and summer enjoyment would be catastrophic.

Marjorie Hare, Ontario Hydro, Toronto ON (August 28, 1998)
- the SC proposal would reduce mean annual generation at Whitedog by 5000 MWh, and up to 26000 MWh in some years. Generation would tend to be less from mid-February to mid-June, and greater from mid-June to mid-October, with an overall net loss. The largest losses occur in years with above normal local June-July runoff.
- the M1 and C1 alternatives result in less loss of generation than SC, with C1 being slightly preferable.
- re-balancing by the Board may result in additional losses in generation on the English system.
- potential generation losses would reach ½ to 3/4 million dollars in years with higher June-July inflows.

David Kerr, Abitibi-Consolidated, Kenora ON (September 17, 1998)
- proposed rule curve changes will be detrimental to the operation of the Kenora and Norman generating stations and to the overall cost structure of the Kenora mill operation.
- outflow reductions during April and May when outflow is often low, in an effort to rebuild the lake level, will result in a further shutdown of generating units. Higher flows during the summer and autumn will also lead to reduced generation due to higher tailwater levels and flows exceeding plant capacity.
- Abitibi-Consolidated is opposed to the proposed Rainy and Namakan rule curve changes.

Katherine Unertl, City of Warroad, Warroad MN (September 29, 1998)
- concerned about possible negative impacts on Lake of the Woods levels of the proposed rule curves, with an adverse impact on the growing Warroad area tourism industry. Specifically:
  - concern over lower spring levels with a negative impact on fish spawning, as well as hindering boat access to Lake of the Woods and Warroad harbour when the fishing season opens in May; spring levels are already perceived as being very low.
  - concern over the increased potential of flooding caused by higher water levels during the summer.

Jack McKenzie, Lake of the Woods District Property Owners Association, Winnipeg MB (September 30, 1998)
- the LWDPOA is not in favour of the proposed Rainy-Namakan changes.
- changes to Lake of the Woods inflows that could see the lake exceed 1060 ft (323.09 m) more often than in past years would likely increase erosion along the south shore and would be of deep concern to their membership. The lake is considered to be high any time the lake level exceeds 1060 ft.
- concern that Winnipeg River flows and levels would experience greater fluctuations and that high flows might occur more often.
- concern that larger May-June inflows, leading to higher levels, would adversely impact nesting shorebirds such as loons and the piping plover, and would potentially destroy natural beaches which are under water once the lake level exceeds 1060 ft.
- concern about impacts on the fish population of reduced inflow during the spring spawn.

Joan Murash, Whiteshell District Association, Seven Sisters MB (October 2, 1998)
- the Association objects to the proposed rule curve changes. Association members already experience problems with high water. The proposals would exacerbate these problems and make it more difficult for the Board to adequately address downstream concerns.
- there is also concern over the impact on Manitoba fish and habitat, primarily on river sturgeon and walleye spawning.

John Barr, Ontario Ministry of the Environment, Kenora ON (October 2, 1998)
- OMOE supports position of OMNR, as outlined above (Scott Lockhart, July 20, 1998).
- attached copies of International Rainy River Water Pollution Board and OMOE letters to IRLBC (April 23, 1996, March 12, 1998 and May 12, 1998). Main concerns relate to adverse impacts on water resource uses of the Rainy River.

Ardythe McMaster, Rossendale MB (October 15, 1998)
- with property on the Winnipeg River, she is concerned about more frequent high levels and even more water level variability than currently exists. Her property is dramatically affected by high water.
- as the Board knows, she has been a public advocate for the common loon for many years and is concerned that loons on the river would be more negatively impacted during nesting under the proposed operating changes, due to greater water level fluctuations. She notes that fish spawn dates and water level requirements are similar to the nesting needs of the loons.

C.E. (Ted) Brimblecombe, Longbow Lake ON (October 17, 1998)
- objects very strongly to unilateral action which appears to benefit Rainy Lake without balanced input from Lake of the Woods. Finds this action to be intolerable in that it appears to adversely affect Lake of the Woods fish spawn and the Winnipeg River wild rice crop.
- believes that the present system should remain unchanged.

David Cormie, Manitoba Hydro (and on behalf of Winnipeg Hydro), Winnipeg MB (November 4, 1998)
- all proposals result in a net loss of generation. Even worse, this net loss consists of a large winter loss partially made up by a summer gain. The Manitoba system already typically has energy surpluses in the summer and deficits in the winter, and counts on utilizing reservoir storage to effect a transfer of generation from summer to winter, when power demands are the greatest. These proposals reduce this transfer and diminish winter generation capability. This ultimately leads to the need for new power facilities. Of the three alternatives, SC reduces winter generation the most, and C1 the least.

- there is a similar concern with peaking capability. Units will be shut down with greater frequency during peak demand periods due to lack of water, mainly in the February to April period. Again, the SC alternative has the greatest impact, the C1 alternative the least. With the SC alternative, an average of 70 MW of peaking capacity, out of a total 560 MW, would be lost in the worst year.
- the SC proposal would reduce mean annual generation on the Winnipeg River by 8770 MWh, and by up to 126,000 MWh in some years. The combined effect of reduced energy generation, reduced seasonal energy transfer and reduced peaking capability is estimated for the SC alternative at $477,000 average annual cost, with a maximum annual cost of almost $3.5 million, and for the C1 alternative at $286,000 average annual cost and $1.6 million maximum annual cost.
- adverse impacts are also anticipated for other users of the waters under the Board's jurisdiction, including Ontario power interests, shorefront property owners (affected by increased frequency of high and low water), and fish and waterfowl (less desirable levels during spawning and nesting periods). This will result in more pressure on the Board by conflicting interests to mitigate impacts, leading to a more difficult management role for the Board.
- MH recommends that the LWCB oppose any rule curve change. The downstream areas incur only disbenefits from any of the proposed rule curves. The changes will reduce the effectiveness of MH's existing generating facilities, will contribute to the need to construct new ones, will result in increased power costs to their customers, will adversely impact the other LWCB interest groups and create additional tensions among them, and will make regulating the waters under the LWCB's jurisdiction more difficult.
- MH would rank the existing rule curves and the three alternatives as follows, from most preferred to least preferred: IJC, C1, M1 and SC.

G. Johnson, Winnipeg MB (November 6, 1998)
- a Clearwater Bay (Lake of the Woods) cottager, also representing L. Perron, J. Jarema, B. Marcelle, C Reimer, J. Stanier, A. Rutherford & F. Nuttall.
- they are opposed to the proposed Rainy-Namakan changes because of the potential for reduced spring inflow to Lake of the Woods. In many years there is insufficient water depth to navigate into the marina for gas and the proposed changes would aggravate this situation.
- They would like to see Lake of the Woods water level at 1060 ft by early May.

Wendy Reid, Birch Island Resort, Minaki ON (December 11, 1998)
- concerned that the proposals would result in adverse impacts on bird nests (loons, etc.) and damage to shorelines on Lake of the Woods and the Winnipeg River, but particularly in the south end of Lake of the Woods.
- concerned that the impacts of the proposed changes (more frequent river level fluctuations, more high water events) could be financially devastating to some property owners who depend on their waterfront to do business. (Note: Birch Island Resort, on Gun Lake near Minaki, is dramatically affected by high Winnipeg River water levels. In high water years, the resort has had to significantly curtail its operations, with a large loss of revenue in addition to increased costs to modify docking, etc.)
- notes that the proposals are supposedly to benefit the fishery on Rainy Lake, and would likely harm the fishery on the Winnipeg River, while at the same time a writer for the Minnesota Department of Natural Resources is reporting in the November-December 1998 issue of the "Minnesota Volunteer" that walleye fishing on Rainy Lake currently "is booming". She questions why change is necessary if this is the case.

In addition to the above comments received by the LWCB, the IRLBC also received several letters of comment relating to Lake of the Woods and the Winnipeg River:

Simon Peet, Ontario Ministry of Natural Resources, Sioux Lookout, ON (March 24, 1998)

- concerned that IRLBC Status Report findings do not consider implications of suggested changes on the rest of the drainage basin area managed by the Lake of the Woods Control Board (LWCB), in particular the potential effects that changes to Rainy Lake will have on Lac Seul water levels and flows.
- request that before IRLBC's findings are approved and implemented the LWCB examine the potential effects of these changes on Lac Seul and provide this information to OMNR so they can fully understand and agree to any changes to the system that may affect Lac Seul.

Joan Eaton, Lake of the Woods Control Board, Ottawa, ON (May 15, 1998)
(For these comments, see Report Section 4.2)

M. L. Willick, Ontario Ministry of Natural Resources, Thunder Bay, ON (December 1, 1998)
(For these comments, see Section 4.1.2)

Wendy Reid, Birch Island Resort, Minaki ON (December 11, 1998)
(Essentially the same letter as sent to the LWCB and reported above)

Rick Bowering, Lake of the Woods Control Board, Ottawa, ON (March 10, 1999)
(For these comments, see Report Section 4.2.3)

4.2.3 Position of the Lake of the Woods Control Board

Based on the studies it undertook and on the public and agency comments it received, the LWCB provided the Study Board with its position on the rule curve issue by letter dated March 10, 1999. Excerpts from this letter follow:

....In summary, our modelling shows that any of the proposed changes would make the regulation objectives for Lake of the Woods and the Winnipeg River more difficult to achieve, with the least impact resulting from option C1 and the greatest resulting from option SC.

Once the likely impacts in terms of levels and flows on the downstream areas were known, we turned to our Interest Groups and the public at large for their input. ....In response we received a number of written submissions..... We also received verbal input, some by telephone and much in person at our annual public open house, held in Kenora on September 30, 1998. In summary, all of the input received has been negative to the proposed Rainy-Namakan rule curve changes. In particular, there are significant concerns expressed by the natural resource managers for the downstream areas regarding negative impacts on the fishery and waterfowl, and significant losses in energy generation are predicted by the power utilities. Resort operators on the Winnipeg River, who already must contend with large variations in water level during their short operating season, fear greater costs and lost business due to the predicted increase in river level fluctuations and extremes.

Overall, it is clear that there are no benefits, and significant disbenefits in some years, for the downstream areas if the proposed rule curve changes were to be implemented. Continuing with the existing IJC rule curves on Rainy-Namakan is the best option for Lake of the Woods and the Winnipeg River, while an adoption of the C1 alternative, then the M1 alternative, and finally the SC proposal, would lead to progressively more severe negative impacts by all indications. Nevertheless, as a water management Board ourselves with a full mandate for day-to-day operations, we understand the pressures the IJC is under to address certain water control issues on Rainy-Namakan. We cannot argue against the concept of an appropriate balance of water management policy for the basin overall. We are therefore prepared to consider some disbenefits downstream in order to achieve some benefits upstream, provided that the steps taken lead to an apparent net gain for the system overall. We are not prepared to accept changes that would lead to a net loss overall (greater disbenefits downstream than the benefits achieved upstream) or changes that would result in unmanageable impacts downstream for the interests and the users that we must consider. Unfortunately, in our business, it is impossible to determine the benefits and disbenefits absolutely and quantitatively in advance. There are uncertainties involved.

Given the information currently available, a compromise that we believe would be reasonable for both upstream and downstream interests, and one that we would be willing to accept, would be the adoption of the C1 alternative on a trial basis. From our perspective, we believe we can manage the impacts of this alternative with reasonable success. As for Rainy and Namakan, this would allow all the changes being sought for Namakan and would give Rainy the benefit of earlier flows from Namakan. However, the changes proposed for Rainy itself would result in less success in meeting our objectives downstream, with the earlier spring refill being especially harmful. This could pit the Rainy fishery directly against the Lake of the Woods and Winnipeg River fisheries, and has been shown by your own studies to be less natural in terms of timing than the current rules. Also, since the earlier refill is primarily to benefit the Rainy fishery, we draw your attention to the enclosed article from the November-December 1998 Minnesota Volunteer, which indicates that the Rainy fishery is recovering very well in response to more responsible fishery management practices, while still under the current water management rules. As to the duration of the trial period, we believe a trial in the order of 10 years would be reasonable, in order to collect data to assess the impacts of the change and in order to have a chance of experiencing a reasonable range of inflows to the system. Of course, we would call for an earlier review if impacts on Lake of the Woods and the Winnipeg River appear to be more severe than anticipated.

5. CONCLUSIONS AND RECOMMENDATIONS

The Board has assembled and evaluated a wide array of existing information in all of the sectoral areas defined in the Plan of Study. Where necessary new information was generated or requested, with attention focussed on the downstream impacts and the economic/social recreational factors since the preparation of the Status Report in March 1998. While some data gaps still exist in relation to the possible impacts of changes to the rule curves on fisheries and the aquatic environment on the Rainy River, the Board believes enough information is available to justify its recommendations.

Management of the water resources in the basin requires a careful balancing of the interests of a myriad of resource sectors and users. Conflicts exist between management of the lakes for fisheries and hydropower purposes, between the development of habitat for fish spawning and the desire for stable water levels by the boating and cottage users, and between managing for ecological benefits and flooding. Similarly there is a need to balance the interests of the upstream and downstream users, not only between Namakan and Rainy lakes but also between these lakes and the Rainy River / Lake of the Woods / Winnipeg River. The Board has attempted to take a basin-wide approach that will satisfy, to some degree, the needs of the majority of users and maximize a net gain for the system overall.

In making its recommendations the Board found it necessary to achieve a balance between what were quantifiable economic disbenefits in the hydropower and flood damage areas with possible fisheries/tourism, ecological, environmental and recreational benefits and disbenefits that could not be quantified to the same degree. In a similar way it was not possible to weigh quantitatively the possible fisheries and related benefits on Rainy and Namakan lakes against possible losses on Lake of the Woods and the Winnipeg River. The Board has based its decisions on what it feels is the probable outcome of the recommendations and has attempted to make its tradeoffs based on the information generated under the study, experience and intuition rather than strictly the defined economics. A trial period of implementation is recommended as the recommendations of the Board reflect a number of uncertainties as to the benefits and disbenefits.

In addition to recommending new rule curves, the Board has made a number of recommendations to improve the Order from a management perspective in terms of minimum flows, operations within the rule curve bands, and inclusion of the overflows at Bear and Gold Portages in the setting of minimum outflows from Namakan Lake. The recommendations are an integrated whole and should not be considered in a piecemeal manner.

The recommendations follow.

1. **The recommended rule curves shown on Figure 1 should be adopted. These are essentially a minor modification of the proposed International Steering Committee rule curves on Namakan Lake and the existing IJC rule curves on Rainy Lake.**

Rationale

This proposal more closely approximates the natural runoff timing than the present IJC rule curves, and provides an appropriate balance between enhancing the ecological benefits on the Namakan Chain of Lakes and Rainy Lake and the anticipated ecological disbenefits on Lake of the Woods. The impacts on the Rainy River are not expected to be major, with perhaps minor improvements to the ecology and some increased flooding. It also significantly reduces the high lake levels and hydropower disbenefits associated with the Steering Committee proposal.

Pro

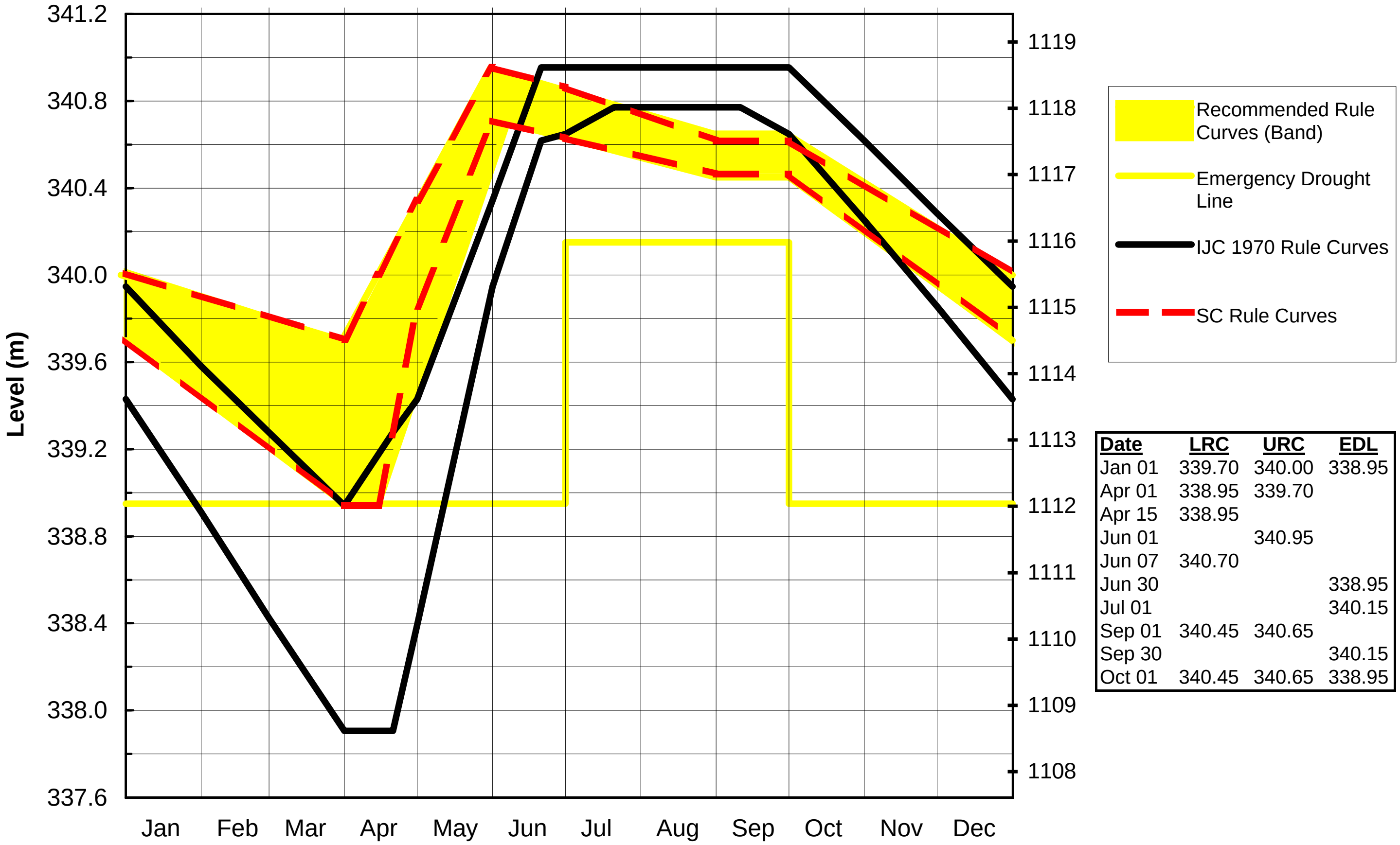
- potential improvement to fish spawning on the Namakan Chain of Lakes through a combination of earlier access to spawning beds and improved fish habitat related to summer and fall drawdown.
- potential improvement in the aquatic plant and associated wildlife communities in the Namakan Chain of Lakes through reduction in large seasonal water level fluctuations.
- improved early spring navigation and access to docks on Namakan Lake.
- provides virtually the same results on Namakan Lake as the Steering Committee proposal, but allows a wider period of spring refill closer to conditions under nature, and provides flexibility for a later refill in years of anticipated heavy runoff. To move the rising rule curve band as far forward as proposed by the Steering Committee would be in direct conflict with the studies prior to the 1970 rule curve change, which recommended moving the curves back to their present position because of flooding experienced when they had been moved forward by the 1957 Order.
- essentially supported by the Board's fisheries experts and groups such as the Border Lakes Association.
- the number of low flow violations on Namakan Lake would decrease.
- the environmental resources associated with Voyageurs National Park would probably be enhanced.
- the impacts on the limited wild rice harvest on Rainy Lake would not change.
- flood damages and hydropower disbenefits would be reduced compared to SC rule curves.

Con

- the maximum flood level on Namakan Lake will increase about 4 cm, and there would a small increase in flood damages during medium to high flow events.
- average annual energy generation at Fort Frances - International Falls is reduced by 2%, and winter generation by 6%.
- late summer and fall navigation on the Namakan Chain of Lakes, and access to docks, would be more difficult.

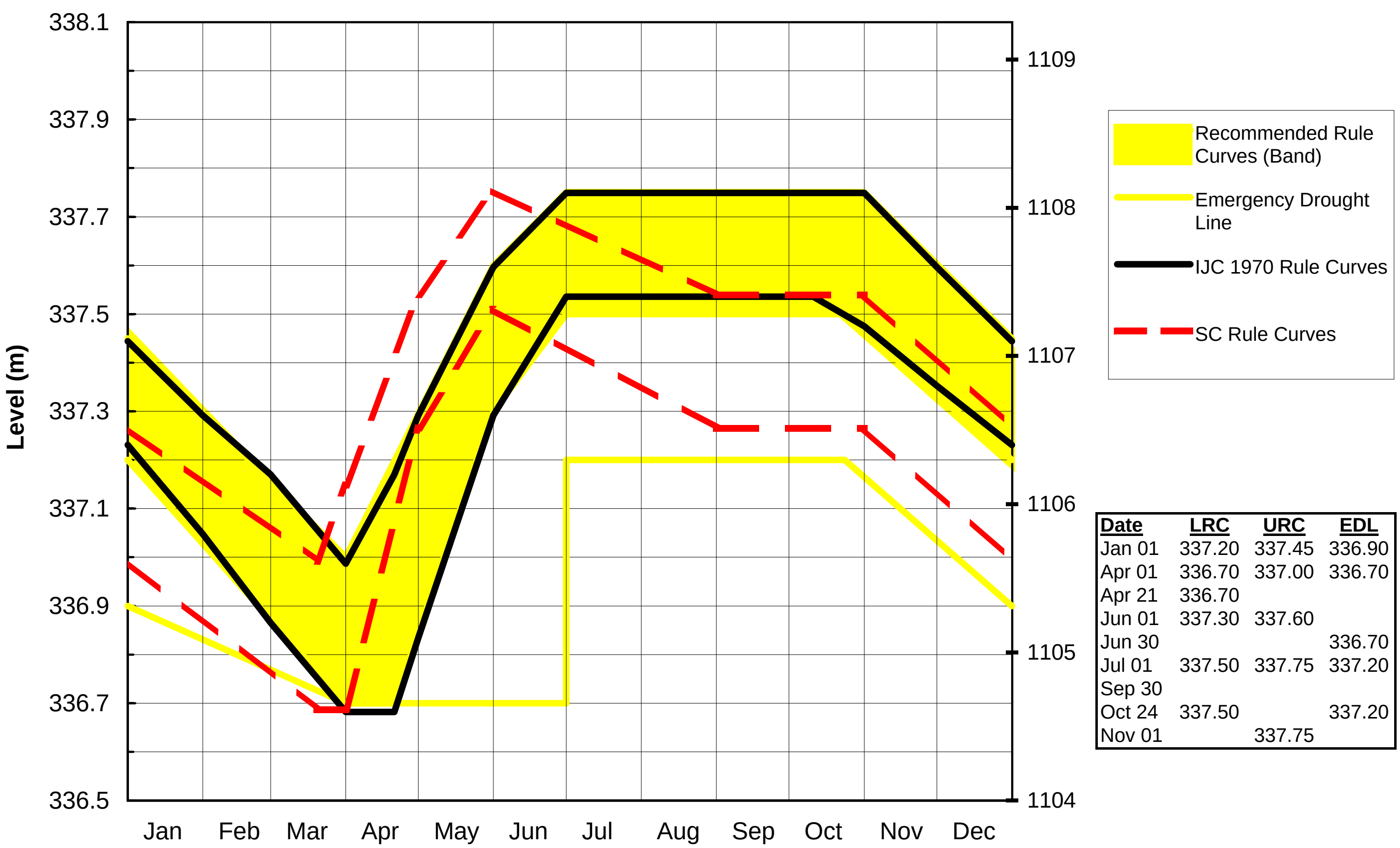
FIGURE 1

Namakan Lake
Recommended Rule Curves



Date	LRC	URC	EDL
Jan 01	339.70	340.00	338.95
Apr 01	338.95	339.70	
Apr 15	338.95		
Jun 01		340.95	
Jun 07	340.70		
Jun 30			338.95
Jul 01			340.15
Sep 01	340.45	340.65	
Sep 30			340.15
Oct 01	340.45	340.65	338.95

Rainy Lake
Recommended Rule Curves



Date	LRC	URC	EDL
Jan 01	337.20	337.45	336.90
Apr 01	336.70	337.00	336.70
Apr 21	336.70		
Jun 01	337.30	337.60	
Jun 30			336.70
Jul 01	337.50	337.75	337.20
Sep 30			
Oct 24	337.50		337.20
Nov 01		337.75	

- Rainy River flows in June would increase by about 70 cubic metres per second. However, this is about half the increase of the proposed International Steering Committee rule curves if applied to both lakes.
- the presumed ecological benefits (identified by the Steering Committee) of an earlier refill and summer drawdown on Rainy Lake would not be achieved.
- the frequency of less desirable spring spawning conditions on Lake of the Woods would increase, and the maximum flood level would be 3-4 cm higher.
- increased fluctuation in the levels of the Winnipeg River would occur as a consequence of meeting operating objectives on Lake of the Woods.
- there would be hydropower losses on the Winnipeg River, with an average annual cost in the neighbourhood of US$160,000 and a maximum annual cost of about US$1 million.
- this alternative (and all the other options tested) do not incorporate the concept of inter-annual variability to more closely duplicate the extremes of nature (flood and drought) as recommended by the Environmental Data technical report prepared by the US Army Corps of Engineers.

2. **The minimum outflow criteria for Namakan Lake should be expressed in terms of the total Namakan Chain of Lakes outflow rather than in terms of the Kettle Falls outflow, so that the overflows from Gold and Bear Portage are accounted for.**

Rationale
The overflows are not accounted for in the current Order. This, in conjunction with the minimum outflow specified at Kettle Falls, can make it difficult to maintain the level of Namakan Lake under low flow conditions.

Pro
- the proposed change would reflect the increased discharge capacity of Gold Portage, caused by erosion, since the original Order was developed.
- future changes in the outflow capacity of either Gold Portage or Bear Portage would automatically be accounted for.
- the level of Namakan Lake would be maintained somewhat higher under drought conditions.

Con
- Gold and Bear Portage flows, presently unaccounted for, contribute to maintaining Rainy Lake levels under drought conditions. Although the impact will be small due to the relative larger size of Rainy Lake versus Namakan Lake, somewhat lower levels could result on Rainy Lake.
- if Gold Portage continues to enlarge, eventually there could be less minimum flow than desirable under drought conditions at Kettle Falls. However, if Gold Portage did continue to enlarge to such a point, action involving the IJC would be required since overall control over Namakan Lake would be greatly diminished.

3. **The minimum outflow criteria should be revised as follows for both lakes. On Namakan Lake, the outflow should be reduced to 30 m^3/s instantaneous whenever the lake level is below the Lower Rule Curve, and should be further reducible, at the discretion of the IRLBC but no lower than 15 m^3/s, whenever the lake level is below the Emergency Drought Line (EDL) shown on Figure 1. On Rainy Lake, the outflow should be reduced to 100 m^3/s instantaneous whenever the lake level is below the LRC, and should be further reducible, at the discretion of the IRLBC but no lower than 65 m^3/s, whenever the lake level is below the EDL shown on Figure 1. (The current seasonal and diurnal criteria would be eliminated.)**

Rationale
This approach would provide minimum outflows very close to the existing whenever the lower rule curves are reached, but would eliminate the seasonal and diurnal fluctuations currently experienced on the Rainy River, which apparently are no longer deemed to be useful and are even believed to be harmful by the Minnesota Department of Natural Resources. Further, it would pre-authorize the Board to go to lower discharges under more extreme drought conditions in a manner similar to that followed numerous times in the past, but without requiring the IJC to first issue a temporary Order. The Board would still follow the same consultative process with the resource agencies and others before implementing further reductions, but would have more flexibility to address changing conditions and user needs under such extreme conditions. However, the Board's discretionary powers are still limited to flow ranges which are understood to be acceptable for all interests, and for which there is a precedent. IJC involvement would still be required if even more extreme measures were contemplated.

Pro
- there would be greater certainty as to how the minimum outflow rate would be managed under drought conditions.
- water level fluctuations in the Rainy River would be reduced and habitat for spawning of walleye and sturgeon improved.

Con
- reduced frequency of direct IJC involvement under moderate drought conditions.

4. Any new rule curves adopted should be implemented on a trial basis. The length of the trial could be for a defined period, or linked to certain hydrological extremes occurring during the trial period, but in any case should not be shorter than 10 years so that a range of events can be experienced and adaptations of the biological community can begin to be identified.

Rationale
There are a number of uncertainties regarding the benefits of the proposed changes on Namakan-Rainy Lakes and possible impacts on downstream areas, as well as the optimum balance between interests on any of the individual water bodies. A trial period would provide a direct mechanism for reversal or revision of the rule curves proposed without having to start the entire review process over again. Any new Order should have a ten year life span to allow an opportunity for the IJC to initiate additional studies, or decide on the nature of any review to be conducted in the second or subsequent Order periods.

Pro
- a trial period provides an opportunity to actually experience and identify the benefits and problems associated with a new regulatory regime in a timely manner. A significant body of hydrological and fisheries baseline data exists and it is expected that potential detrimental impacts would begin to manifest themselves within a five year period. The positive and more subtle changes to the biological community as a consequence of the proposed rule curve changes may take longer to identify; hence the 10 year suggested trial period.
- a trial implementation of new rule curves rather than a "final" implementation may somewhat relieve the concerns of any individuals or groups opposed to the recommendations, since it offers timely recourse if the results are different than anticipated.

Con
- uncertainty and debate over the most appropriate rule curves might be extended.

5. **Monitoring programs should be implemented by the resource management agencies in accordance with the recommendations of the fisheries and environmental resources experts to enable the impacts of new rule curves on the biological and aquatic communities to be identified, and to provide an adequate source of information for future reviews.**

Rationale

There is still some uncertainty that the proposed changes will result in the desired benefits to the fisheries and aquatic environment, and the associated socio-economic interests, that have been predicted. On the other hand the potential adverse effects on hydropower generation and flooding are reasonably well quantified. It is therefore appropriate that the resource management agencies be tasked with identifying the changes to the fisheries and aquatic resources in Rainy and Namakan Lakes, and the Rainy River, based on adequate and well funded monitoring programs. Consideration should be given to the establishment of an IJC Monitoring Committee, on which the resource agencies are represented, to define the necessary monitoring programs. This work can also be tied to ongoing IJC reviews of monitoring requirements for Boundary Waters management purposes.

Pro

- defining and implementing the necessary and critical monitoring programs will ensure that the factual base needed to quantify benefits and disbenefits to the fisheries and aquatic resources are in place, rather than continuing to remain in doubt.

Con

- representatives of the resource management agencies have expressed concern that an adequate monitoring program cannot be designed and implemented within present resource limitations.

6. **The Order should state that, within the rule curve operating bands, regulation operations are to be solely at the discretion of the dam owners in accordance with basin conditions. The flexibility intended to be offered by these bands for responding to current basin conditions and local needs should not be constrained by any additional rules.**

Rationale

The existing Order has essentially been altered by additional restrictions imposed by the United States Federal Energy Regulatory Commission (FERC) on the United States outlet facilities. This has reduced the flexibility intended in the original Order to permit the Companies to modify operations in response to basin conditions or inflow forecasts. It has also resulted in the two Companies regulating their works at cross purposes during the spring refill period. Defining the intent of operational flexibility within the IJC rule curves would eliminate the possibility of limiting rules being imposed by others. It would permit the companies to address, within the curves, their own needs and the needs of others in response to specific basin conditions.

Pro

- the responsibility and clear authority of the IJC over water management in the Rainy- Namakan basin would be restored.
- overlapping or conflicting water management objectives would be eliminated.
- the Canadian and United States operations would not be at cross purposes due to conflicting regulations.
- operating objectives that meet a wider range of user needs could be implemented.

Con

- other agencies would not be able to impose their water management criteria on these lakes.

6. PROVISION OF COMMENTS

The conclusions and recommendations of this Draft Final Report were presented to the Commissioners of the International Joint Commission in Washington, DC on April 13, 1999, and to the public at large at the IRLBC's annual public meeting in Fort Frances, ON on April 28, 1999. The report is being distributed to key stakeholders, and is available upon request to interested members of the public, starting April 28, 1999. Supporting materials and documents will be accessible upon request.

Public comment on the study and the report is welcomed. To facilitate this, the International Joint Commission will hold a Public Hearing in the Rainy-Namakan basin in early July, 1999. In addition, the Commission and the Board will accept written comments until July 30, 1999. Comments to the Board may be sent to either of the two Members:

Col. Kenneth S. Kasprisin
US Army Corps of Engineers
St. Paul District
190 Fifth Street East
St. Paul MN 55105-1638

kenneth.s.kasprisin@usace.army.mil

Mr. Dale R. Kimmett
Environmental Protection Service
Environment Canada
Ottawa ON K1A 0H3

dale.kimmett@ec.gc.ca

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APPENDIX

This appendix contains the tables and graphs referenced in Sections 3 and 4. They appear in the order referenced in the text.

A. Hydrologic Modelling

A.1 Simulation of Regulated Lake Levels and Outflows

A.2 Simulation of Natural Lake Levels and Outflows

B. Inflow Forecasting

C. Flood Risk Assessment

D. Response to Inflow Forecasting Comments

E. Rainy River - Simulation of River Levels

F. Lake of the Woods / Winnipeg River - LWCB Model Results

TABLE 1 - NAMAKAN LAKE REGUSE RESULTS - 39 YEAR RUNS (1958-96)

SCENARIO RUNS	**Natural (Simulated)**	**Historic (Regulated)**	**BASE CASE** Run F1 Base Case - 50 % Buffer IJC	SC	**OPERATING POLICY VARIANTS** Run F2 30 % Buffer IJC	SC	Run F3 80 % Buffer IJC	SC	Run F4 Maximum Refill IJC	SC	Run F5 Minimum Refill IJC	SC
Maximum Lake Level/Year	341.38/1968	341.69/1968	341.53/1968	341.58/1968	341.53/1968	341.58/1968	341.53/1968	341.58/1968	341.53/1968	341.58/1968	341.53/1968	341.57/1968
Minimum Lake Level/Year	337.03/1977	338.09/1972	338.40/1977	338.94/1977	338.19/1977	338.94/1977	338.71/1977	338.94/1977	337.89/1977	338.92/1977	338.71/1977	338.92/1977
Mean Lake Level	339.04	339.99	339.97	340.19	339.89	340.13	340.11	340.28	339.82	340.09	340.00	340.19
#Days > All Gates Open Level/Ann Max	58/32	129/57	106/41	139/48	105/41	139/48	107/41	140/48	105/41	138/48	107/41	136/46
#Days > URC Max. Level/Ann Max	112/42	531/79	207/50	260/60	202/50	260/60	219/50	262/60	204/50	260/60	206/50	257/58
#Days > URC/Ann Max	NA	NA	674/81	482/88	655/81	469/88	876/84	527/88	628/81	459/88	860/82	481/87
#Days Jul-Sep < SC Sep LRC/Ann Max	3459/92	110/76	241/92	127/48	261/92	196/55	214/92	81/49	284/92	212/92	214/92	311/50
#Days < LRC/Ann Max	NA	NA	709/188	680/164	827/203	906/167	505/170	493/152	902/221	1091/204	786/170	913/176
#Days < LRC Min. Level/Ann Max	227/162	0/0	0/0	0/0	0/0	0/0	0/0	0/0	8/6	0/0	0/0	0/0
Outflow - Namakan Total - Mean	162.0	162.1	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0	162.0
- Max	670.7	704.3	663.5	674.0	663.5	674.0	664.1	674.0	663.5	674.0	662.7	672.9
- Min	20.3	0.0	28.3	28.3	28.3	28.3	28.3	28.3	28.3	28.3	28.3	28.3
#Days Outflow < 28.3	215	729	0	0	0	0	0	0	0	0	0	0
Mean Outflow - Jan	98.8	123.2	126.3	104.6	129.5	107.8	121.9	100.2	135.5	113.2	116.9	97.8
- Apr	113.6	112.1	126.1	113.2	125.5	111.3	126.8	118.6	121.5	107.2	123.6	129.1
- Jun	330.1	280.1	262.8	320.6	260.6	318.9	266.8	322.4	251.6	317.2	274.6	320.4
- Aug	179.1	144.7	143.8	154.9	144.3	155.1	143.7	155.9	142.4	155.2	145.9	155.2
Winter Drawdown - Mean	0.7	1.7	1.8	0.9	1.9	1.0	1.6	0.7	2.2	1.2	1.5	0.7
- Max	1.7	2.5	2.3	1.7	2.5	1.7	2.0	1.6	2.8	1.8	2.0	1.7
- Min	0.1	0.9	1.6	0.8	1.7	0.9	1.3	0.7	2.0	1.0	1.3	0.6
Annual Refill - Mean	1.7	2.4	2.4	1.6	2.6	1.8	2.2	1.4	2.9	2.0	2.1	1.4
- Max	3.3	3.0	3.1	2.3	3.3	2.4	2.7	2.0	3.6	2.6	2.8	2.0
- Min	0.2	1.9	1.5	1.3	1.5	1.4	1.4	1.2	1.6	1.5	1.4	1.1
Mean Lake Level - Jun	339.94	340.62	340.56	340.83	340.52	340.81	340.64	340.86	340.48	340.83	340.54	340.79
- Jul	339.67	340.83	340.81	340.75	340.78	340.73	340.87	340.79	340.80	340.77	340.77	340.68
- Aug	339.23	340.83	340.82	340.61	340.78	340.59	340.88	340.65	340.82	340.64	340.76	340.54
- Sep	338.95	340.80	340.80	340.55	340.76	340.52	340.86	340.59	340.81	340.58	340.72	340.48
#Days >URC/<LRC(1209 days) - Jan	NA	NA	0/ 2	0/ 46	0/ 2	0/ 46	0/ 2	0/ 46	0/ 2	0/ 46	0/ 2	0/ 46
#Days >URC/<LRC(1102 days) - Feb	NA	NA	0/ 0	0/ 28	0/ 0	0/ 28	0/ 0	0/ 28	0/ 0	0/ 28	0/ 0	0/ 28
#Days >URC/<LRC(1209 days) - Mar	NA	NA	0/ 0	0/ 11	0/ 0	0/ 13	0/ 0	0/ 1	0/ 0	0/ 1	0/ 0	0/ 17
#Days >URC/<LRC(1170 days) - Apr	NA	NA	42/ 0	12/ 36	41/ 2	9/ 86	93/ 0	36/ 15	26/ 65	2/ 288	105/ 0	23/ 32
#Days >URC/<LRC(1209 days) - May	NA	NA	309/ 115	106/ 157	296/ 165	97/ 208	447/ 60	120/ 110	283/ 272	87/ 263	441/ 60	104/ 153
#Days >URC/<LRC(1170 days) - Jun	NA	NA	175/ 147	171/ 98	174/ 156	171/ 114	183/ 134	177/ 80	173/ 178	177/ 124	172/ 136	165/ 100
#Days >URC/<LRC(1209 days) - Jul	NA	NA	41/ 128	52/ 41	41/ 128	52/ 77	41/ 124	52/ 32	41/ 133	52/ 82	39/ 124	52/ 40
#Days >URC/<LRC(1209 days) - Aug	NA	NA	6/ 98	20/ 31	6/ 101	19/ 31	8/ 79	21/ 31	6/ 104	20/ 62	6/ 125	17/ 58
#Days >URC/<LRC(1170 days) - Sep	NA	NA	29/ 118	46/ 82	25/ 170	46/ 137	32/ 63	46/ 40	27/ 72	46/ 72	26/ 236	45/ 258
#Days >URC/<LRC(1209 days) - Oct	NA	NA	31/ 85	34/ 89	31/ 84	34/ 105	31/ 40	34/ 49	31/ 49	34/ 64	31/ 92	34/ 120
#Days >URC/<LRC(1170 days) - Nov	NA	NA	31/ 16	30/ 30	31/ 19	30/ 30	31/ 3	30/ 30	31/ 27	30/ 30	30/ 11	30/ 30
#Days >URC/<LRC(1208 days) - Dec	NA	NA	10/ 0	11/ 31	10/ 0	11/ 31	10/ 0	11/ 31	10/ 0	11/ 31	10/ 0	11/ 31

NOTES:

1) Total number of days simulated = 14244

2) #Days Jul-Sep < SC Sep LRC/Ann Max = number of days between July1 and Sept 30 when the level is below that defined by the SC lower rule curve in Sept.

3) Winter drawdown is the difference between the highest level after Nov 15 and the lowest level before Mar 31;

4) Annual Refill is the rise between the lowest level after Feb 1 and the highest level before Jul 31

5) UNITS are metres for levels, cubic metres per second for flows and Gwh for energy

TABLE 1 - NAMAKAN LAKE REGUSE RESULTS - 39 YEAR RUNS (1958-96)

SCENARIO RUNS	Natural	Historic	BASE CASE		SENSITIVITY TO HIGHER/LOWER INFLOWS OR TO INFLOW DATA ERRORS				EFFECT OF REDUCED MIN OUTFLOW REQ'MT	
	(Simulated)	(Regulated)	Run F1		Run F6		Run F7		Run F8	
			Base Case - 50 % Buffer		110 % Inflow		90 % Inflow		Reduced Min Outflow	
			IJC	SC	IJC	SC	IJC	SC	IJC	SC
Maximum Lake Level/Year	341.38/1968	341.69/1968	341.53/1968	341.58/1968	341.80/1968	341.85/1968	341.27/1968	341.30/1968	341.53/1968	341.58/1968
Minimum Lake Level/Year	337.03/1977	338.09/1972	338.40/1977	338.94/1977	338.41/1977	338.94/1977	338.39/1977	338.92/1977	338.42/1977	339.08/1977
Mean Lake Level	339.04	339.99	339.97	340.19	340	340.21	339.93	340.17	339.98	340.20
#Days > All Gates Open Level/Ann Max	58/32	129/57	106/41	139/48	243/52	301/58	30/25	30/30	106/41	139/48
#Days > URC Max. Level/Ann Max	112/42	531/79	207/50	260/60	391/60	470/66	84/39	115/45	208/50	260/60
#Days > URC/Ann Max	NA	NA	674/81	482/88	1021/101	789/101	376/57	272/70	677/82	485/88
#Days Jul-Sep < SC Sep LRC/Ann Max	3459/92	110/76	241/92	127/48	215/92	83/42	280/92	231/67	135/84	9/3
#Days < LRC/Ann Max	NA	NA	709/188	680/164	563/173	557/137	857/204	923/199	477/156	307/79
#Days < LRC Min. Level/Ann Max	227/162	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0	0/0
Outflow - Namakan Total - Mean	162.0	162.1	162.0	162.0	178.2	178.2	145.8	145.8	162.0	162.0
- Max	670.7	704.3	663.5	674.0	724.3	734.5	606.8	613.2	663.5	674.0
- Min	20.3	0.0	28.3	28.3	28.3	28.3	28.3	28.3	15.0	15.0
#Days Outflow < 28.3	215	608	0	0	0	0	0	0	592	684
Mean Outflow - Jan	98.8	123.2	126.3	104.6	135.0	113.5	116.8	95.7	126.4	104.3
- Apr	113.6	112.1	126.1	113.2	138.4	127.7	112.4	99.7	125.7	113.5
- Jun	330.1	280.1	262.8	320.6	301.8	353.2	226.5	288.0	261.8	321.0
- Aug	179.1	144.7	143.8	154.9	159.5	170.3	128.9	140.0	144.2	155.0
Winter Drawdown - Mean	0.7	1.7	1.8	0.9	1.8	0.9	1.8	0.9	1.8	0.9
- Max	1.7	2.5	2.3	1.7	2.5	1.8	2.0	1.5	2.3	1.4
- Min	0.1	0.9	0.5	0.4	1.6	0.8	1.6	0.8	1.6	0.8
Annual Refill - Mean	1.7	2.4	2.4	1.6	2.5	1.7	2.4	1.6	2.5	1.6
- Max	3.3	3.0	3.1	2.3	3.3	2.5	2.8	2.0	3.1	2.3
- Min	0.2	1.9	1.5	1.3	1.6	1.4	1.3	1.2	1.8	1.4
Mean Lake Level - Jun	339.94	340.62	340.56	340.83	340.64	340.88	340.50	340.79	340.59	340.85
- Jul	339.67	340.83	340.81	340.75	340.85	340.78	340.77	340.72	340.85	340.76
- Aug	339.23	340.83	340.82	340.61	340.84	340.62	340.79	340.60	340.85	340.61
- Sep	338.95	340.8	340.8	340.55	340.82	340.56	340.77	340.53	340.84	340.56
#Days >URC/<LRC(1209 days) - Jan	NA	NA	0/ 2	0/ 46	0/ 2	0/ 44	0/ 2	0/ 47		
#Days >URC/<LRC(1102 days) - Feb	NA	NA	0/ 0	0/ 28	0/ 0	0/ 22	0/ 0	0/ 28	0/ 2	0/ 12
#Days >URC/<LRC(1209 days) - Mar	NA	NA	0/ 0	0/ 11	0/ 0	0/ 0	0/ 0	0/ 24	0/ 0	0/ 0
#Days >URC/<LRC(1170 days) - Apr	NA	NA	42/ 0	12/ 36	64/ 0	25/ 33	26/ 0	3/ 55	0/ 0	0/ 0
#Days >URC/<LRC(1209 days) - May	NA	NA	309/ 115	106/ 157	464/ 90	221/ 147	191/ 130	41/ 184	42/ 0	12/ 31
#Days >URC/<LRC(1170 days) - Jun	NA	NA	175/ 147	171/ 98	261/ 137	263/ 82	76/ 160	95/ 118	311/ 86	105/ 149
#Days >URC/<LRC(1209 days) - Jul	NA	NA	41/ 128	52/ 41	63/ 118	91/ 19	29/ 143	34/ 93	175/ 136	172/ 75
#Days >URC/<LRC(1209 days) - Aug	NA	NA	6/ 98	20/ 31	16/ 68	25/ 31	0/ 104	7/ 63	41/ 112	53/ 6
#Days >URC/<LRC(1170 days) - Sep	NA	NA	29/ 118	46/ 82	45/ 93	47/ 51	12/ 178	34/ 129	6/ 62	21/ 25
#Days >URC/<LRC(1209 days) - Oct	NA	NA	31/ 85	34/ 89	32/ 55	40/ 67	31/ 99	31/ 121	30/ 62	46/ 6
#Days >URC/<LRC(1170 days) - Nov	NA	NA	31/ 16	30/ 30	45/ 0	47/ 30	11/ 41	27/ 30	31/ 17	34/ 3
#Days >URC/<LRC(1208 days) - Dec	NA	NA	10/ 0	11/ 31	31/ 0	30/ 31	0/ 0	0/ 31	31/ 0	31/ 0

TABLE 1 - NAMAKAN LAKE REGUSE RESULTS - 39 YEAR RUNS (1958-96)

SCENARIO RUNS		**Natural (Simulated)**	**Historic (Regulated)**	**IJC & SC RULE CURVES** Run F1 IJC	Run F1 SC		**RULE CURVE VARIANTS** Run C1 Combined Curves RL/IJC & NL/SC	Run M1 Modified Curves RL/IJCa & NL/SCa
Maximum Lake Level/Year		341.38/1968	341.69/1968	341.53/1968	341.58/1968		341.58/1968	341.57/1968
Minimum Lake Level/Year		337.03/1977	338.09/1972	338.40/1977	338.94/1977		339.04/1977	339.06/1977
Mean Lake Level		339.04	339.99	339.97	340.19		340.19	340.18
#Days > All Gates Open Level/Ann Max		58/32	129/57	106/41	139/48		138/48	138/48
#Days > URC Max. Level/Ann Max		112/42	531/79	207/50	260/60		258/59	257/59
#Days > URC/Ann Max		NA	NA	674/81	482/88		491/87	484/88
#Days Jul-Sep < SC Sep LRC/Ann Max		3459/92	110/76	241/92	127/48		163/50	132/57
#Days < LRC/Ann Max		NA	NA	709/188	680/164		690/164	619/154
#Days < LRC Min. Level/Ann Max		227/162	0/0	0/0	0/0		0/0	0/0
Outflow - Namakan Total	- Mean	162.0	162.1	162.0	162.0		162.0	162.0
	- Max	670.7	704.3	663.5	674.0		673.8	673.7
	- Min	20.3	0.0	28.3	28.3		28.3	28.3
#Days Outflow < 28.3		215	608	0	0		0	0
Mean Outflow	- Jan	98.8	123.2	126.3	104.6		104.3	104.4
	- Apr	113.6	112.1	126.1	113.2		108.4	116.1
	- Jun	330.1	280.1	262.8	320.6		321.4	316.0
	- Aug	179.1	144.7	143.8	154.9		154.8	154.9
Winter Drawdown	- Mean	0.7	1.7	1.8	0.9		0.9	0.9
	- Max	1.7	2.5	2.3	1.7		1.7	1.6
	- Min	0.1	0.9	0.5	0.4		0.8	0.8
Annual Refill	- Mean	1.7	2.4	2.4	1.6		1.6	1.6
	- Max	3.3	3.0	3.1	2.3		2.2	2.3
	- Min	0.2	1.9	1.5	1.3		1.3	1.2
Mean Lake Level	- Jun	339.94	340.62	340.56	340.83		340.83	340.82
	- Jul	339.67	340.83	340.81	340.75		340.74	340.74
	- Aug	339.23	340.8	340.8	340.6		340.6	340.6
	- Sep	338.95	340.8	340.8	340.55		340.55	340.55
#Days >URC/<LRC(1209 days) - Jan		NA	NA	0/ 2	0/ 46		0/ 46	0/ 46
#Days >URC/<LRC(1102 days) - Feb		NA	NA	0/ 0	0/ 28		0/ 28	0/ 28
#Days >URC/<LRC(1209 days) - Mar		NA	NA	0/ 0	0/ 11		0/ 16	0/ 11
#Days >URC/<LRC(1170 days) - Apr		NA	NA	42/ 0	12/ 36		20/ 25	20/ 8
#Days >URC/<LRC(1209 days) - May		NA	NA	309/ 115	106/ 157		109/ 134	102/ 87
#Days >URC/<LRC(1170 days) - Jun		NA	NA	175/ 147	171/ 98		172/ 91	171/ 113
#Days >URC/<LRC(1209 days) - Jul		NA	NA	41/ 128	52/ 41		52/ 40	52/ 61
#Days >URC/<LRC(1209 days) - Aug		NA	NA	6/ 98	20/ 31		18/ 31	18/ 31
#Days >URC/<LRC(1170 days) - Sep		NA	NA	29/ 118	46/ 82		45/ 121	46/ 84
#Days >URC/<LRC(1209 days) - Oct		NA	NA	31/ 85	34/ 89		34/ 97	34/ 89
#Days >URC/<LRC(1170 days) - Nov		NA	NA	31/ 16	30/ 30		30/ 30	30/ 30
#Days >URC/<LRC(1208 days) - Dec		NA	NA	10/ 0	11/ 31		11/ 31	11/ 31

TABLE 2 - RAINY LAKE REGUSE RESULTS - 39 YEAR RUNS (1958-96)

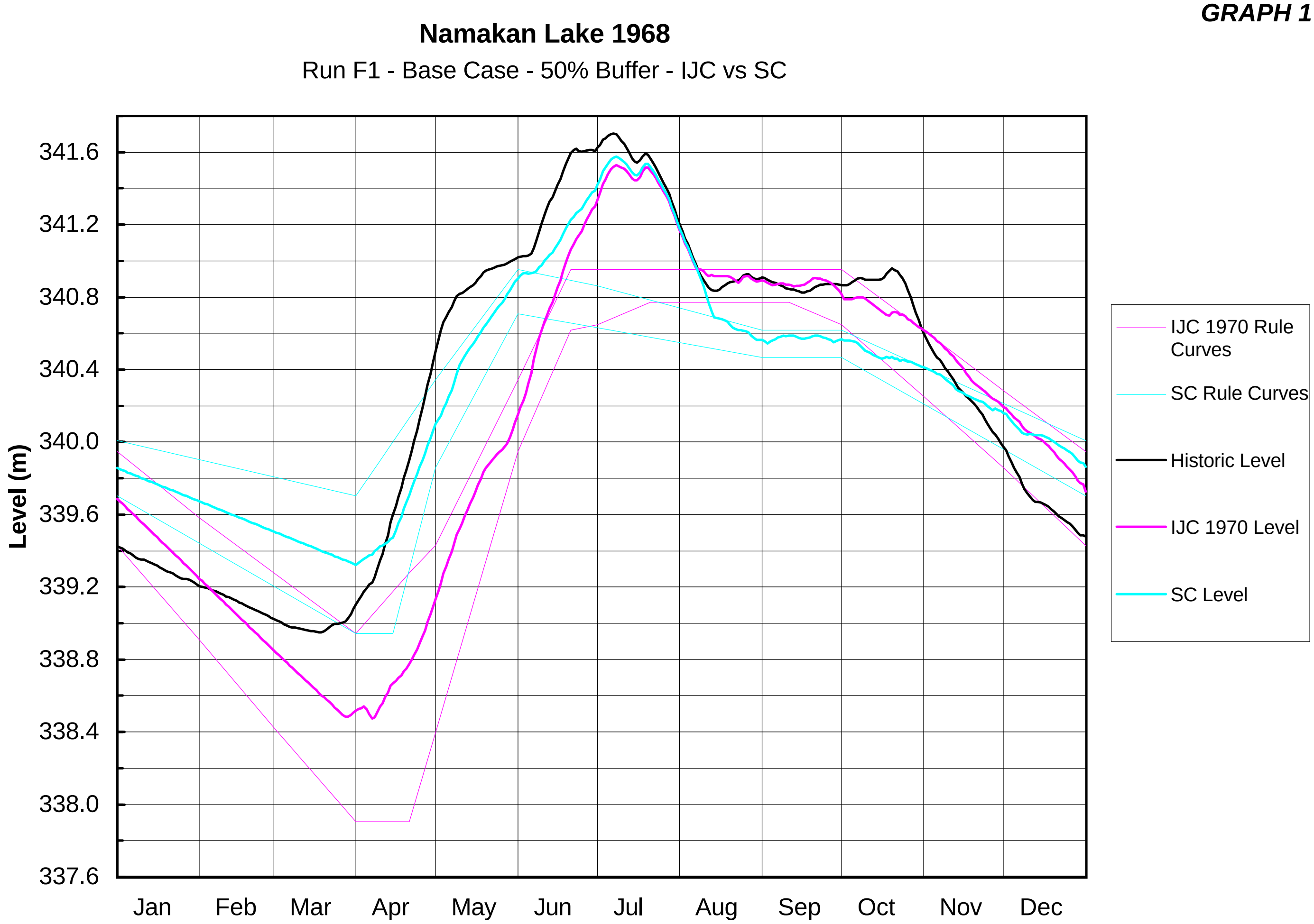
SENARIO RUNS	Natural (Simulated)	Historic (Regulated)	BASE CASE Run F1 Base Case - 50 % Buffer IJC	SC	OPERATING POLICY VARIANTS Run F2 30 % Buffer IJC	SC	Run F3 80 % Buffer IJC	SC	Run F4 Maximum Refill IJC	SC	Run F5 Minimum Refill IJC	SC
Maximum Lake Level/Year	338.79/1966	338.35/1968	338.06/1968	338.16/1996	338.06/1968	338.16/1996	338.07/1968	338.16/1996	338.06/1968	338.15/1996	338.05/1968	338.16/1996
Minimium Lake Level/Year	334.25/1977	336.45/1970	336.71/1987	336.36/1977	336.63/1987	336.32/1977	336.69/1977	336.41/1977	336.50/1987	336.43/1977	336.69/1977	336.31/1977
Mean Lake Level	336.24	337.36	337.37	337.28	337.34	337.24	337.43	337.33	337.34	337.27	337.35	337.25
#Days > All Gates Open Level/Ann Max	543/78	271/62	84/31	177/50	81/31	177/50	92/32	184/50	81/30	180/50	88/29	167/44
#Days > URC Max. Level/Ann Max	716/89	1189/123	254/55	373/64	249/54	373/64	280/58	386/64	260/52	373/64	245/51	364/62
#Days > URC/Ann Max	NA	NA	500/69	696/71	480/69	688/71	590/76	758/89	461/63	680/76	536/72	662/72
#Days Jul-Oct < SC Sep LRC/Ann Max	3704/123	460/123	323/123	573/108	338/123	687/109	283/113	407/107	357/123	509/114	296/113	934/105
#Days < LRC/Ann Max	NA	NA	1358/192	1664/242	1595/198	1987/241	1145/204	1284/240	1529/219	2106/240	1634/211	1941/241
#Days < LRC Min. Level/Ann Max	10226/366	272/75	0/0	132/128	35/23	136/134	0/0	122/119	180/109	158/118	0/0	144/140
Outflow - Mean	300.4	297.8	300.9	301.0	300.9	301.0	300.8	300.9	301.0	301.0	300.9	301.1
- Max	844.5	301.0	1032.2	1058.8	1031.7	1058.3	1034.4	1059.2	1030.6	1057.6	1028.7	1058.8
- Min	45.4	1040.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0
#Days Outflow > 410.00	3393	14.3	2594	2988	2475	2878	2696	2961	2443	2789	3065	3390
#Days Outflow > 350.00	4740	3470	4051	4291	4056	4415	3984	4215	3823	4121	4340	4519
#Days Outflow<103.0 May-Oct	17	651	459	190	487	242	372	104	507	272	407	147
#Days Outflow< 93.4 Nov-Apr	283	224	69	173	111	220	54	120	150	237	75	238
#Days Outflow < 85.00	227	586	0	0	0	0	0	0	0	0	0	0
Mean Outflow - Jan	225.0	259.1	259.3	224.7	264.7	233.2	249.9	218.2	281.8	249.1	238.0	210.0
- Apr	193.5	222.2	244.3	169.5	246.1	162.2	240.6	180.1	237.9	142.2	246.5	207.0
- Jun	439.7	473.4	446.5	560.9	441.0	557.3	456.8	564.6	423.8	548.2	462.8	560.0
- Aug	410.7	274.5	264.5	305.1	266.2	307.9	264.2	301.3	257.6	296.5	270.8	316.8
Winter Drawdown - Mean	0.8	0.7	0.7	0.5	0.7	0.6	0.7	0.5	0.9	0.7	0.6	0.4
- Max	1.9	1.2	0.9	0.8	0.9	0.8	0.8	0.7	1.0	0.9	0.8	0.7
- Min	0.0	0.2	0.4	0.4	0.4	0.4	0.4	0.3	0.4	0.5	0.4	0.3
Annual Refill - Mean	1.8	1.0	0.9	0.9	0.9	1.0	0.8	0.9	1.0	1.0	0.8	0.8
- Max	3.8	1.6	1.2	1.4	1.3	1.4	1.1	1.4	1.4	1.5	1.1	1.4
- Min	0.2	0.4	0.1	0.3	0.1	0.3	0.1	0.3	0.1	0.3	0.1	0.4
Mean Lake Level - Jun	336.93	337.59	337.55	337.64	337.52	337.63	337.59	337.67	337.52	337.63	337.53	337.61
- Jul	337.07	337.63	337.62	337.56	337.60	337.55	337.66	337.60	337.62	337.58	337.58	337.51
- Aug	336.80	337.58	337.60	337.46	337.57	337.42	337.66	337.52	337.62	337.50	337.54	337.37
- Sep	336.47	337.56	337.60	337.38	337.57	337.35	337.65	337.45	337.63	337.44	337.54	337.29
#Days >URC/<LRC(1209 days) - Jan	NA	NA	0/ 31	1/ 33	0/ 31	1/ 31	0/ 31	1/ 31	0/ 31	1/ 31	0/ 31	1/ 31
#Days >URC/<LRC(1102 days) - Feb	NA	NA	0/ 24	0/ 28	0/ 19	0/ 28	0/ 28	0/ 28	0/ 5	0/ 28	0/ 28	0/ 30
#Days >URC/<LRC(1209 days) - Mar	NA	NA	0/ 0	0/ 31	0/ 0	0/ 33	0/ 8	0/ 33	0/ 1	0/ 33	0/ 15	0/ 33
#Days >URC/<LRC(1170 days) - Apr	NA	NA	20/ 5	11/ 347	15/ 9	9/ 498	54/ 7	32/ 218	5/ 55	4/ 793	41/ 7	15/ 216
#Days >URC/<LRC(1209 days) - May	NA	NA	146/ 178	146/ 319	134/ 273	139/ 354	179/ 118	166/ 260	121/ 311	120/ 396	173/ 119	147/ 265
#Days >URC/<LRC(1170 days) - Jun	NA	NA	203/ 225	261/ 162	201/ 230	258/ 170	212/ 191	271/ 151	197/ 233	268/ 191	198/ 203	246/ 153
#Days >URC/<LRC(1209 days) - Jul	NA	NA	59/ 175	119/ 138	58/ 186	119/ 140	61/ 161	123/ 120	60/ 203	124/ 145	59/ 173	116/ 128
#Days >URC/<LRC(1209 days) - Aug	NA	NA	8/ 155	20/ 74	7/ 204	20/ 84	9/ 122	21/ 67	9/ 164	21/ 95	7/ 284	19/ 151
#Days >URC/<LRC(1170 days) - Sep	NA	NA	20/ 236	35/ 141	19/ 288	35/ 205	20/ 178	35/ 78	20/ 210	35/ 80	19/ 376	22/ 379
#Days >URC/<LRC(1209 days) - Oct	NA	NA	19/ 225	48/ 267	19/ 244	52/ 307	22/ 204	55/ 179	20/ 193	53/ 204	17/ 295	43/ 396
#Days >URC/<LRC(1170 days) - Nov	NA	NA	21/ 73	39/ 93	23/ 80	39/ 106	29/ 65	39/ 87	25/ 92	39/ 79	18/ 72	39/ 128
#Days >URC/<LRC(1208 days) - Dec	NA	NA	4/ 31	16/ 31	4/ 31	16/ 31	4/ 32	15/ 32	4/ 31	15/ 31	4/ 31	14/ 31
Annual Energy Generation (% diff)	NA	NA	121.7	112.7(-7.4)	121.7	112.4(-7.7)	122.4	114.0(-6.9)	122.1	114.0(-6.6)	117.9	109.9(-6.8)
Energy Generation (% diff) - Jan-Feb	NA	NA	10.7	9.2(-14.3)	10.8	9.2(-15.)	10.6	9.3(-13.)	11.0	9.7(-11.3)	9.9	8.8(-11.6)
- Mar-Apr	NA	NA	9.0	7.3(-19.3)	9.0	7.2(-20.)	9.0	7.3(-18.7)	8.8	7.1(-19.4)	8.6	7.5(-12.5)
- May-Jun	NA	NA	8.8	9.0(2.5)	8.7	9.0(3.2)	8.9	9.0(1.3)	8.5	8.7(1.9)	8.9	9.2(3.8)
- Jul-Aug	NA	NA	11.2	11.3(0.5)	11.2	11.3(0.5)	11.4	11.5(1.)	11.2	11.3(1.5)	10.9	10.8(-0.4)
- Sep-Oct	NA	NA	9.9	9.4(-5.3)	9.9	9.3(-6.2)	10.0	9.6(-3.9)	10.0	9.6(-4.2)	9.8	8.9(-9.2)
- Nov-Dec	NA	NA	11.2	10.2(-8.8)	11.2	10.2(-8.5)	11.3	10.3(-8.7)	11.5	10.5(-8.8)	10.9	9.7(-10.7)

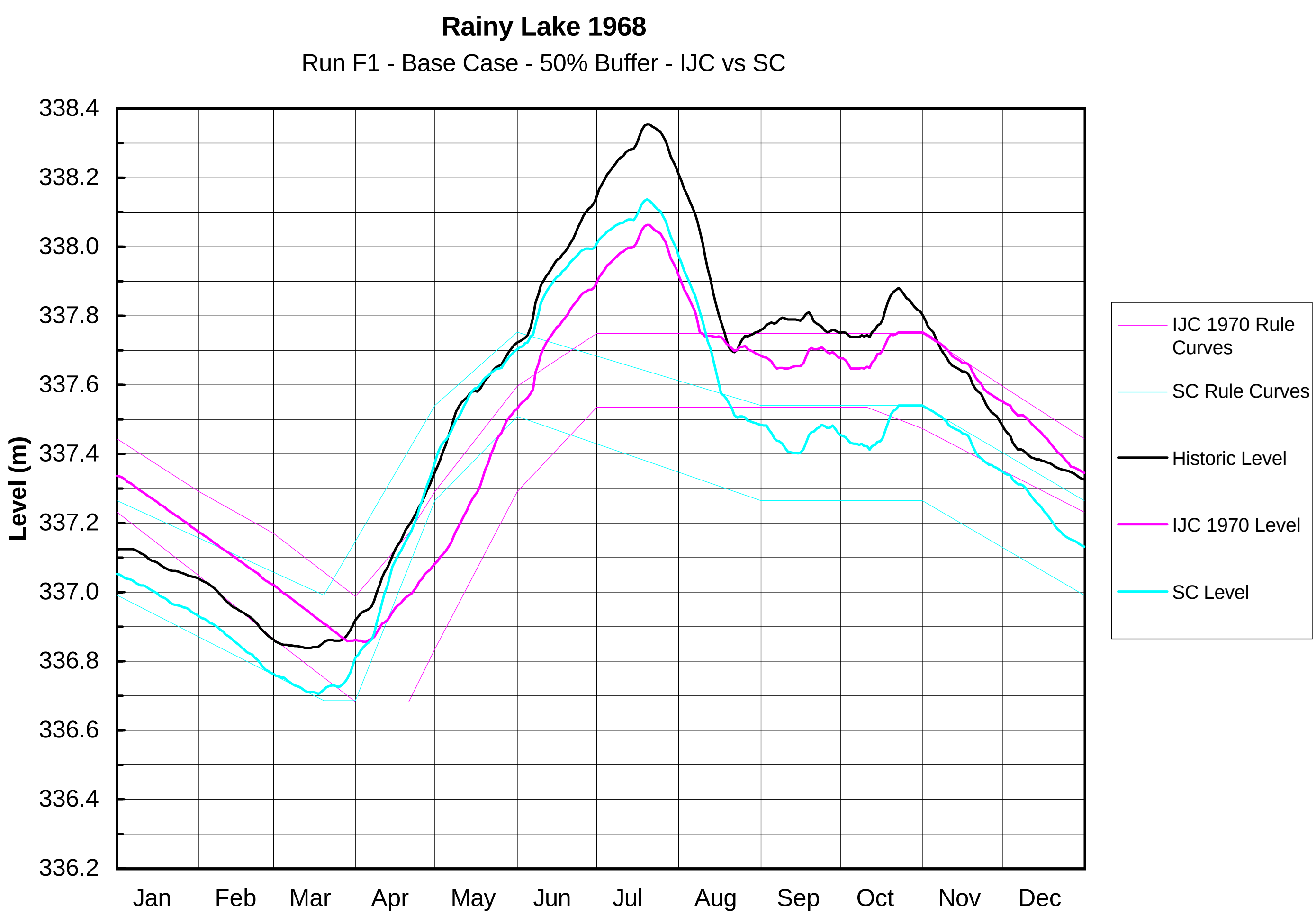
TABLE 2 - RAINY LAKE REGUSE RESULTS - 39 YEAR RUNS (1958-96)

SENARIO RUNS		Natural (Simulated)	Historic (Regulated)	BASE CASE Run F1 Base Case - 50 % Buffer		SENSITIVITY TO HIGHER/LOWER INFLOWS OR TO INFLOW DATA ERRORS Run F6 110 % Inflow		Run F7 90 % Inflow		EFFECT OF REDUCED MIN OUTFLOW REQ'MT Run F8 Reduced Min Outflow	
				IJC	SC	IJC	SC	IJC	SC	IJC	SC
Maximum Lake Level/Year		338.79/1966	338.35/1968	338.06/1968	338.16/1996	338.28/1968	338.37/1996	337.87/1968	338.00/1996	338.06/1968	338.16/1996
Minimium Lake Level/Year		334.25/1977	336.45/1970	336.71/1987	336.36/1977	336.74/1977	336.48/1977	336.63/1987	336.26/1977	336.63/1987	336.52/1977
Mean Lake Level		336.24	337.36	337.37	337.28	337	337	337	337	337	337
#Days > All Gates Open Level/Ann Max		543/78	271/62	84/31	177/50	229/52	343/64	0/0	49/17	84/31	177/50
#Days > URC Max. Level/Ann Max		716/89	1189/123	254/55	373/64	495/66	604/73	90/29	207/54	254/55	374/64
#Days > URC/Ann Max		NA	NA	500/69	696/71	793/79	1054/102	261/54	381/62	500/69	700/71
#Days Jul-Oct < SC Sep LRC/Ann Max		3704/123	460/123	323/123	573/108	242/111	436/96	360/123	756/121	320/123	453/92
#Days < LRC/Ann Max		NA	NA	1358/192	1664/242	1123/173	1300/208	1695/212	2113/253	1181/181	1462/211
#Days < LRC Min. Level/Ann Max		10226/366	272/75	0/0	132/128	0/0	92/87	30/27	153/150	21/19	85/82
Outflow	- Mean	300.4	297.8	300.9	301.0	331.0	331.1	270.8	270.9	300.9	301.0
	- Max	844.5	301.0	1032.2	1058.8	1093.0	1118.5	961.2	1011.8	1032.2	1058.8
	- Min	45.4	1040.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0	85.0
#Days Outflow > 410.00		3393	14.3	2594	2988	3199	3470	2063	2437	2603	2990
#Days Outflow > 350.00		4740	3470	4051	4291	4710	4895	3255	3709	4054	4308
#Days Outflow<103.0 May-Oct		17	651	459	190	360	99	516	328	998	714
#Days Outflow< 93.4 Nov-Apr		283	224	69	173	50	120	98	261	329	916
#Days Outflow < 85.00		227	586	0	0	0	0	0	0	0	0
Mean Outflow	- Jan	225.0	259.1	259.3	224.7	275.2	243.0	241.4	210.6	259.4	224.0
	- Apr	193.5	222.2	244.3	169.5	270.2	195.3	220.5	147.5	243.8	167.4
	- Jun	439.7	473.4	446.5	560.9	509.0	616.0	379.9	503.0	445.9	561.9
	- Aug	410.7	274.5	264.5	305.1	286.6	328.1	237.9	274.3	263.9	306.3
Winter Drawdown	- Mean	0.8	0.7	0.7	0.5	0.7	0.5	0.7	0.5	0.7	0.5
	- Max	1.9	1.2	0.9	0.8	0.9	0.9	0.8	0.7	0.9	0.8
	- Min	0.0	0.2	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Annual Refill	- Mean	1.8	1.0	0.9	0.9	0.9	1.0	0.8	0.9	0.8	0.9
	- Max	3.8	1.6	1.2	1.4	1.4	1.6	1.0	1.2	1.2	1.4
	- Min	0.2	0.4	0.1	0.3	0.1	0.4	0.1	0.2	0.1	0.4
Mean Lake Level	- Jun	336.93	337.59	337.55	337.64	337.60	337.70	337.50	337.59	337.54	337.65
	- Jul	337.07	337.63	337.62	337.56	337.65	337.61	337.59	337.52	337.61	337.57
	- Aug	336.80	337.58	337.60	337.46	337.62	337.47	337.57	337.43	337.60	337.46
	- Sep	336.47	337.56	337.60	337.38	337.62	337.40	337.58	337.37	337.60	337.39
#Days >URC/<LRC(1209 days) - Jan		NA	NA	0/ 31	1/ 33	0/ 31	1/ 31	0/ 33	1/ 32	0/ 22	1/ 31
#Days >URC/<LRC(1102 days) - Feb		NA	NA	0/ 24	0/ 28	0/ 12	0/ 28	0/ 28	0/ 28	0/ 0	0/ 28
#Days >URC/<LRC(1209 days) - Mar		NA	NA	0/ 0	0/ 31	0/ 0	0/ 31	0/ 8	0/ 33	0/ 0	0/ 31
#Days >URC/<LRC(1170 days) - Apr		NA	NA	20/ 5	11/ 347	35/ 3	25/ 252	8/ 10	3/ 490	20/ 7	11/ 328
#Days >URC/<LRC(1209 days) - May		NA	NA	146/ 178	146/ 319	211/ 153	211/ 255	72/ 243	81/ 397	146/ 177	148/ 308
#Days >URC/<LRC(1170 days) - Jun		NA	NA	203/ 225	261/ 162	270/ 197	362/ 148	117/ 233	164/ 185	203/ 215	262/ 157
#Days >URC/<LRC(1209 days) - Jul		NA	NA	59/ 175	119/ 138	129/ 156	194/ 96	35/ 205	60/ 146	58/ 164	120/ 120
#Days >URC/<LRC(1209 days) - Aug		NA	NA	8/ 155	20/ 74	19/ 117	40/ 33	0/ 198	7/ 99	8/ 157	20/ 42
#Days >URC/<LRC(1170 days) - Sep		NA	NA	20/ 236	35/ 141	30/ 189	48/ 120	15/ 303	19/ 184	20/ 207	35/ 138
#Days >URC/<LRC(1209 days) - Oct		NA	NA	19/ 225	48/ 267	47/ 190	75/ 204	6/ 275	19/ 341	20/ 160	49/ 192
#Days >URC/<LRC(1170 days) - Nov		NA	NA	21/ 73	39/ 93	35/ 43	63/ 71	8/ 123	24/ 144	21/ 41	39/ 55
#Days >URC/<LRC(1208 days) - Dec		NA	NA	4/ 31	16/ 31	17/ 32	35/ 31	0/ 36	3/ 34	4/ 31	15/ 32
Annual Energy Generation (% diff)		NA	NA	121.7	112.7(-7.4)	123.8	114.6(-7.5)	118.7	110.(-7.3)	121.6	112.6(-7.4)
Energy Generation (% diff)	- Jan-Feb	NA	NA	10.7	9.2(-14.3)	11.0	9.55(-13.5)	10.4	8.79(-15.1)	10.8	9.2(-14.5)
	- Mar-Apr	NA	NA	9.0	7.3(-19.3)	9.3	7.66(-17.3)	8.7	6.87(-21.2)	9.0	7.23(-19.9)
	- May-Jun	NA	NA	8.8	9.0(2.5)	8.6	8.77(1.6)	8.9	9.14(3.1)	8.7	8.99(3.0)
	- Jul-Aug	NA	NA	11.2	11.3(0.5)	11.3	11.26(-0.2)	11.0	11.19(1.6)	11.2	11.27(0.8)
	- Sep-Oct	NA	NA	9.9	9.4(-5.3)	10.2	9.66(-5.6)	9.6	9.08(-4.8)	9.9	9.33(-5.3)
	- Nov-Dec	NA	NA	11.2	10.2(-8.8)	11.4	10.38(-9.3)	10.9	9.93(-8.5)	11.3	10.27(-8.8)

TABLE 2 - RAINY LAKE REGUSE RESULTS - 39 YEAR RUNS (1958-96)

SENARIO RUNS	Natural (Simulated)	Historic (Regulated)	IJC & SC RULE CURVES Run F1 IJC	Run F1 SC	RULE CURVE VARIANTS Run C1 Combined Curves RL/IJC & NL/SC	Run M1 Modified Curves RL/IJCa & NL/SCa
Maximum Lake Level/Year	338.79/1966	338.35/1968	338.06/1968	338.16/1996	338.11/1968	338.11/1968
Minimium Lake Level/Year	334.25/1977	336.45/1970	336.71/1987	336.36/1977	336.69/1977	336.53/1977
Mean Lake Level	336.24	337.36	337.37	337.28	337.38	337.29
#Days > All Gates Open Level/Ann Max	543/78	271/62	84/31	177/50	121/42	120/41
#Days > URC Max. Level/Ann Max	716/89	1189/123	254/55	373/64	317/60	270/60
#Days > URC/Ann Max	NA	NA	500/69	696/71	599/71	682/71
#Days Jul-Oct < SC Sep LRC/Ann Max	3704/123	460/123	323/123	573/108	212/105	346/109
#Days < LRC/Ann Max	NA	NA	1358/192	1664/242	1298/222	1219/247
#Days < LRC Min. Level/Ann Max	10226/366	272/75	0/0	132/128	0/0	109/105
Outflow - Mean	300.4	297.8	300.9	301.0	300.9	301.0
- Max	844.5	301.0	1032.2	1058.8	1044.8	1044.3
- Min	45.4	1040.0	85.0	85.0	85.0	85.0
#Days Outflow > 410.00	3393	14.3	2594	2988	2764	2825
#Days Outflow > 350.00	4740	3470	4051	4291	4049	4189
#Days Outflow<103.0 May-Oct	17	651	459	190	335	318
#Days Outflow< 93.4 Nov-Apr	283	224	69	173	82	82
#Days Outflow < 85.00	227	586	0	0	0	0
Mean Outflow - Jan	225.0	259.1	259.3	224.7	237.5	225.3
- Apr	193.5	222.2	244.3	169.5	230.4	230.1
- Jun	439.7	473.4	446.5	560.9	500.2	494.6
- Aug	410.7	274.5	264.5	305.1	277.9	298.5
Winter Drawdown - Mean	0.8	0.7	0.7	0.5	0.7	0.6
- Max	1.9	1.2	0.9	0.8	0.9	0.8
- Min	0.0	0.2	0.4	0.4	0.4	0.4
Annual Refill - Mean	1.8	1.0	0.9	0.9	0.9	0.9
- Max	3.8	1.6	1.2	1.4	1.3	1.4
- Min	0.2	0.4	0.1	0.3	0.2	0.2
Mean Lake Level - Jun	336.93	337.59	337.55	337.64	337.58	337.57
- Jul	337.07	337.63	337.62	337.56	337.64	337.61
- Aug	336.80	337.58	337.60	337.46	337.62	337.53
- Sep	336.47	337.56	337.60	337.38	337.61	337.45
#Days >URC/<LRC(1209 days) - Jan	NA	NA	0/ 31	1/ 33	0/ 31	1/ 31
#Days >URC/<LRC(1102 days) - Feb	NA	NA	0/ 24	0/ 28	0/ 28	0/ 28
#Days >URC/<LRC(1209 days) - Mar	NA	NA	0/ 0	0/ 31	0/ 28	0/ 31
#Days >URC/<LRC(1170 days) - Apr	NA	NA	20/ 5	11/ 347	30/ 9	30/ 32
#Days >URC/<LRC(1209 days) - May	NA	NA	146/ 178	146/ 319	189/ 185	182/ 177
#Days >URC/<LRC(1170 days) - Jun	NA	NA	203/ 225	261/ 162	229/ 178	227/ 185
#Days >URC/<LRC(1209 days) - Jul	NA	NA	59/ 175	119/ 138	81/ 154	89/ 150
#Days >URC/<LRC(1209 days) - Aug	NA	NA	8/ 155	20/ 74	9/ 116	15/ 97
#Days >URC/<LRC(1170 days) - Sep	NA	NA	20/ 236	35/ 141	21/ 216	35/ 127
#Days >URC/<LRC(1209 days) - Oct	NA	NA	19/ 225	48/ 267	16/ 252	54/ 234
#Days >URC/<LRC(1170 days) - Nov	NA	NA	21/ 73	39/ 93	21/ 69	38/ 95
#Days >URC/<LRC(1208 days) - Dec	NA	NA	4/ 31	16/ 31	3/ 32	11/ 32
Annual Energy Generation (% diff)	NA	NA	121.7	112.7(-7.4)	119.3(-2.0)	115.8(-4.9)
Energy Generation (% diff) - Jan-Feb	NA	NA	10.7	9.2(-14.3)	10.1(-5.9)	9.4(-12.3)
- Mar-Apr	NA	NA	9.0	7.3(-19.3)	8.5(-5.6)	8.2(-8.9)
- May-Jun	NA	NA	8.8	9.0(2.5)	8.8(0.2)	8.8(0.5)
- Jul-Aug	NA	NA	11.2	11.3(0.5)	11.4(2.2)	11.5(2.3)
- Sep-Oct	NA	NA	9.9	9.4(-5.3)	9.8(-0.8)	9.7(-2.6)
- Nov-Dec	NA	NA	11.2	10.2(-8.8)	10.9(-2.4)	10.3(-7.8)


Namakan Lake 1968
Run F1 - Base Case - 50% Buffer - IJC vs SC
Level (m)
341.6
341.2
340.8
340.4
340.0
339.6
339.2
338.8
338.4
338.0
337.6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
IJC 1970 Rule Curves
SC Rule Curves
Historic Level
IJC 1970 Level
SC Level


Rainy Lake 1968
Run F1 - Base Case - 50% Buffer - IJC vs SC
Level (m)
338.4
338.2
338.0
337.8
337.6
337.4
337.2
337.0
336.8
336.6
336.4
336.2
Jan
Feb
Mar
Apr
May
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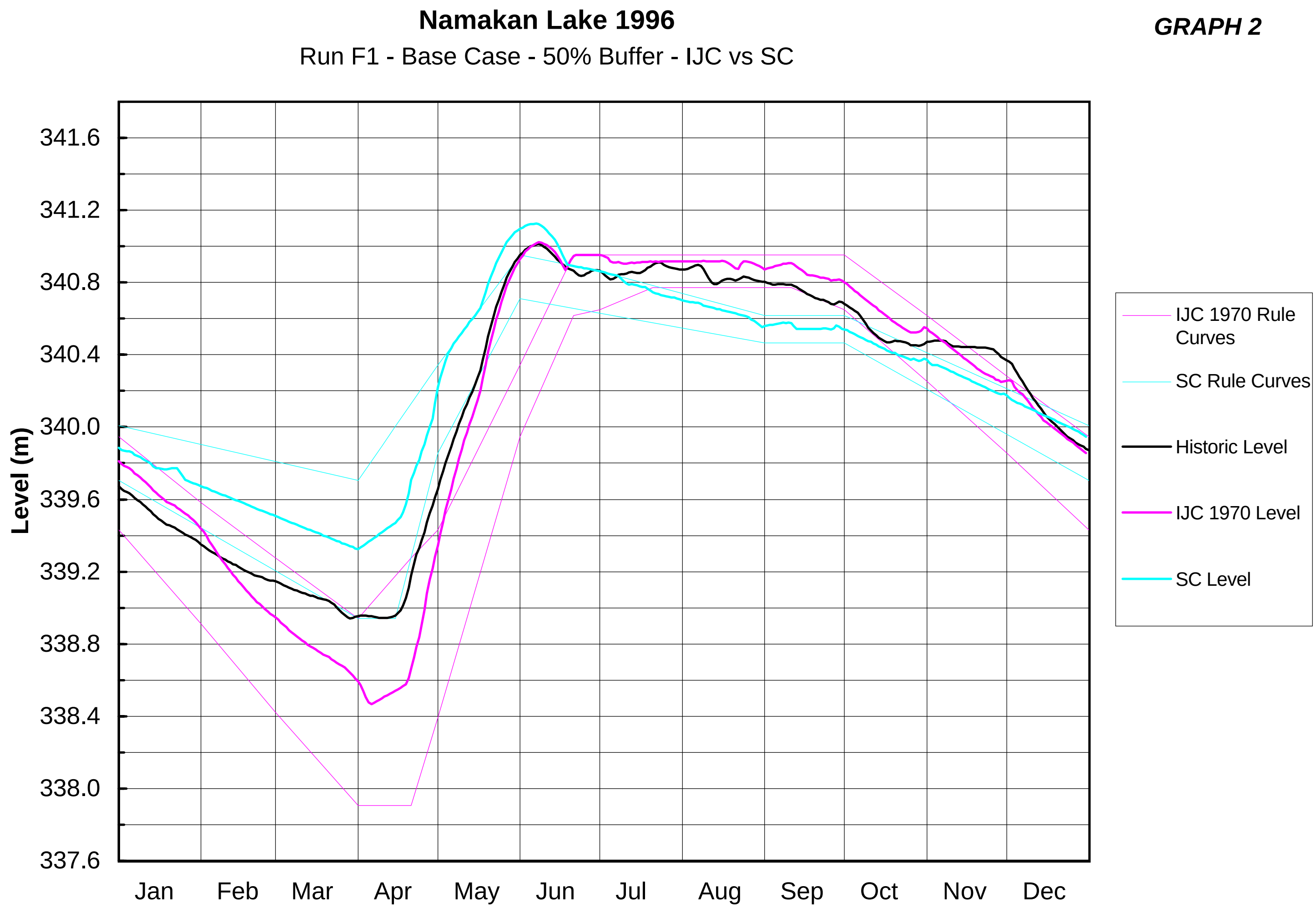
Oct
Nov
Dec
IJC 1970 Rule Curves
SC Rule Curves
Historic Level
IJC 1970 Level
SC Level


Namakan Lake 1996
Run F1 - Base Case - 50% Buffer - IJC vs SC
Level (m)
341.6
341.2
340.8
340.4
340.0
339.6
339.2
338.8
338.4
338.0
337.6
Jan
Feb
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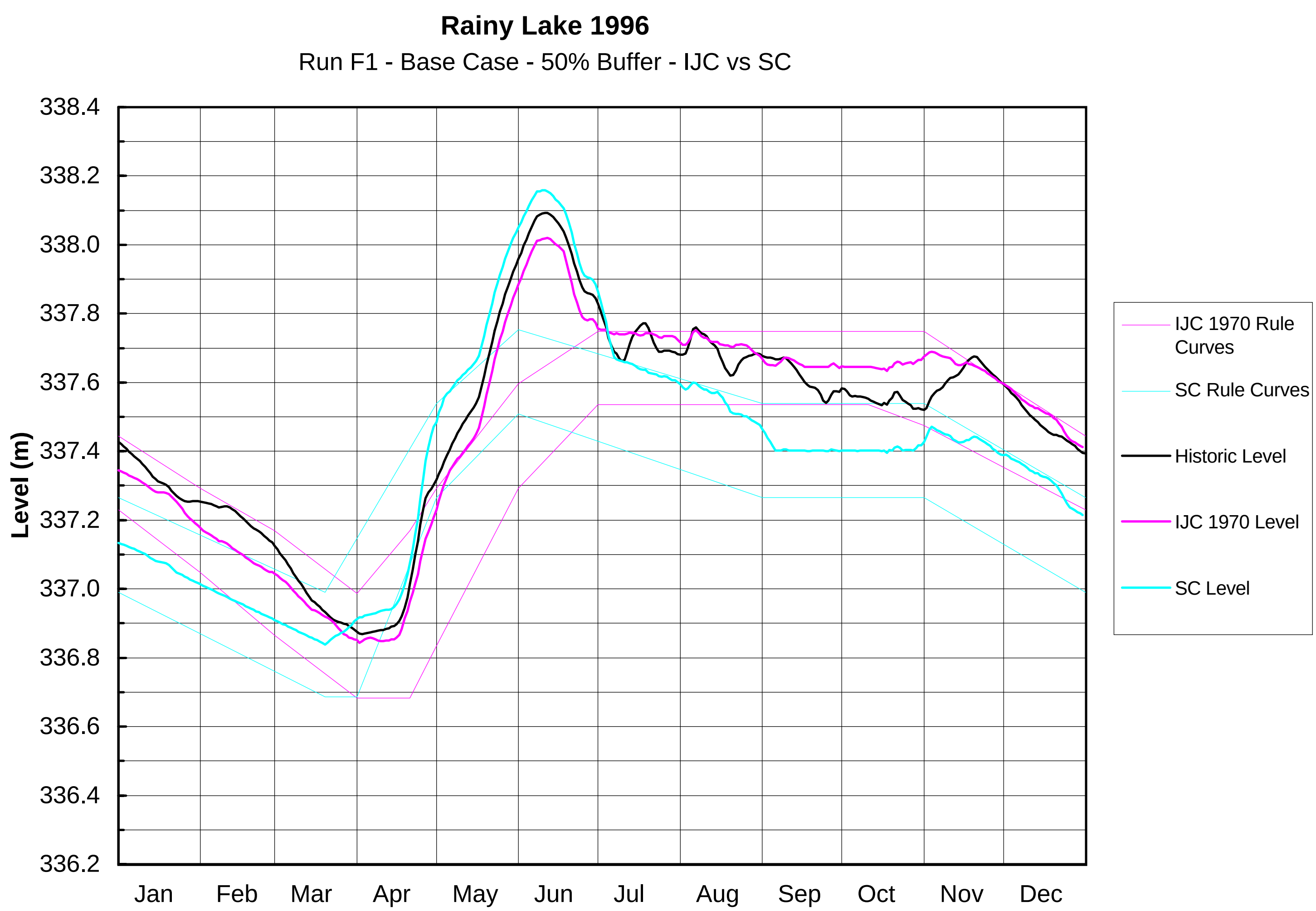
Dec
IJC 1970 Rule Curves
SC Rule Curves
Historic Level
IJC 1970 Level
SC Level


Rainy Lake 1996
Run F1 - Base Case - 50% Buffer - IJC vs SC
Level (m)
338.4
338.2
338.0
337.8
337.6
337.4
337.2
337.0
336.8
336.6
336.4
336.2
Jan
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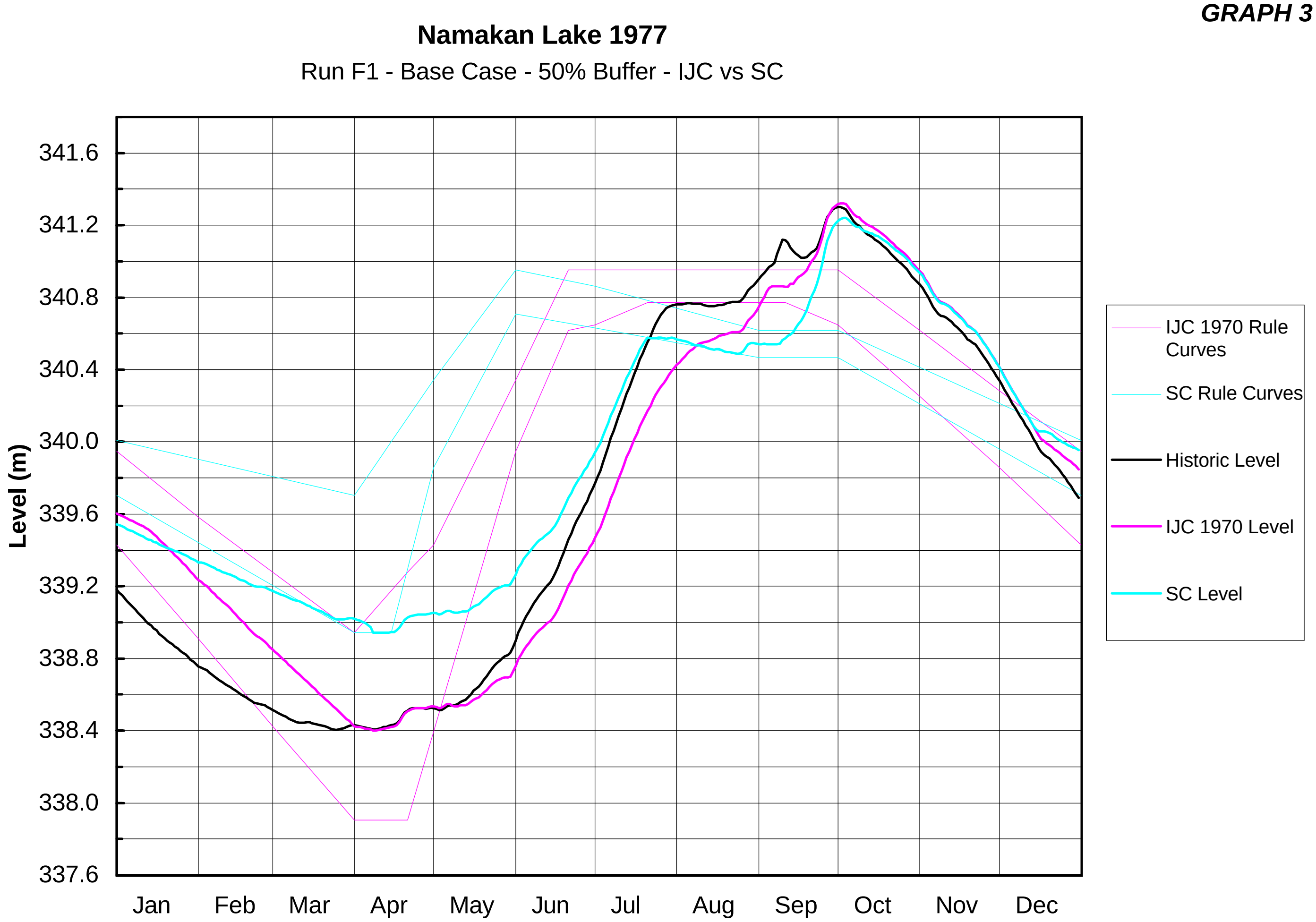
Oct
Nov
Dec
IJC 1970 Rule Curves
SC Rule Curves
Historic Level
IJC 1970 Level
SC Level

GRAPH 3



Namakan Lake 1977
Run F1 - Base Case - 50% Buffer - IJC vs SC
Level (m)
341.6
341.2
340.8
340.4
340.0
339.6
339.2
338.8
338.4
338.0
337.6
Jan
Feb
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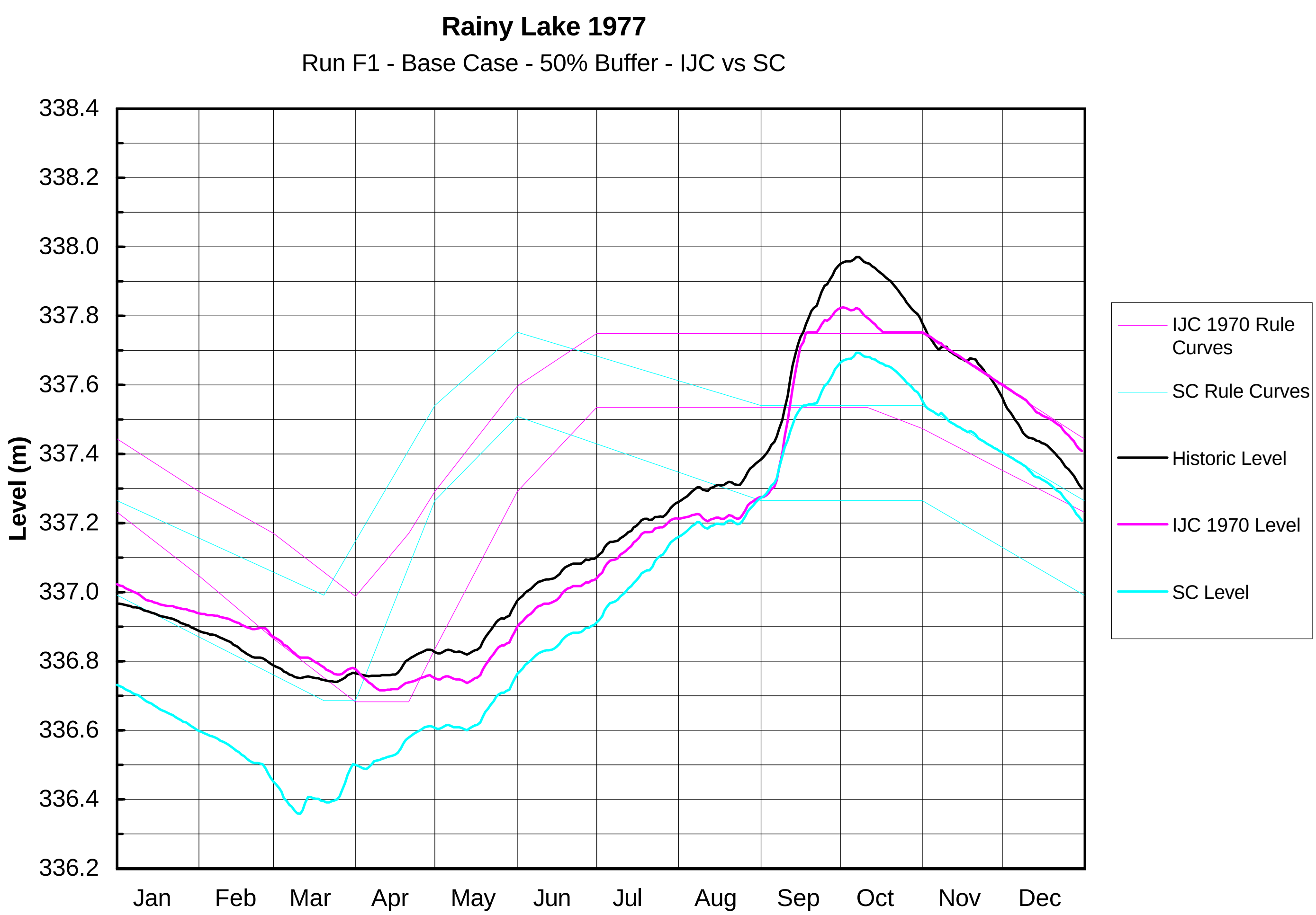
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
IJC 1970 Rule Curves
SC Rule Curves
Historic Level
IJC 1970 Level
SC Level



Rainy Lake 1977
Run F1 - Base Case - 50% Buffer - IJC vs SC
Level (m)
338.4
338.2
338.0
337.8
337.6
337.4
337.2
337.0
336.8
336.6
336.4
336.2
Jan
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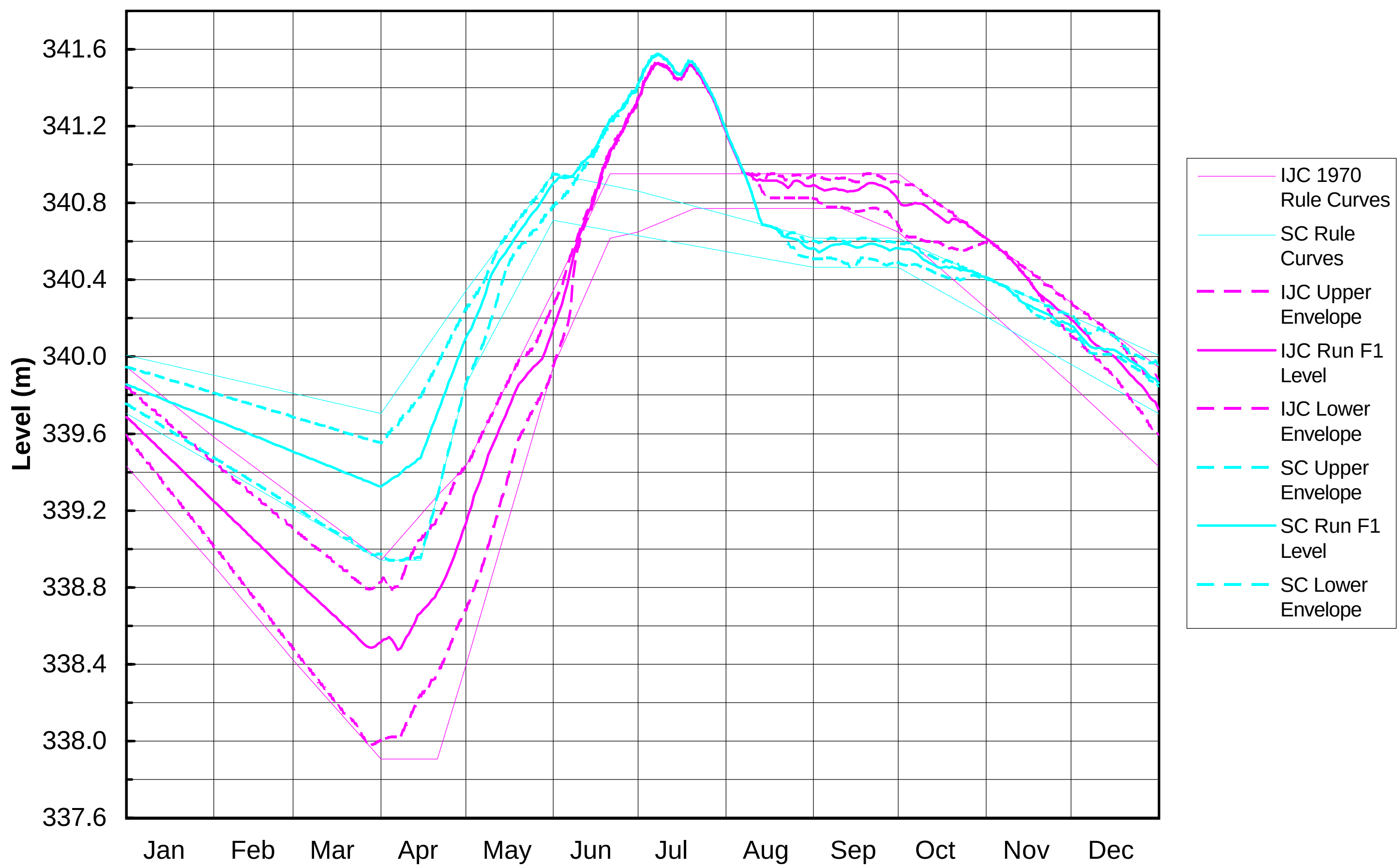
Nov
Dec
IJC 1970 Rule Curves
SC Rule Curves
Historic Level
IJC 1970 Level
SC Level

GRAPH 4

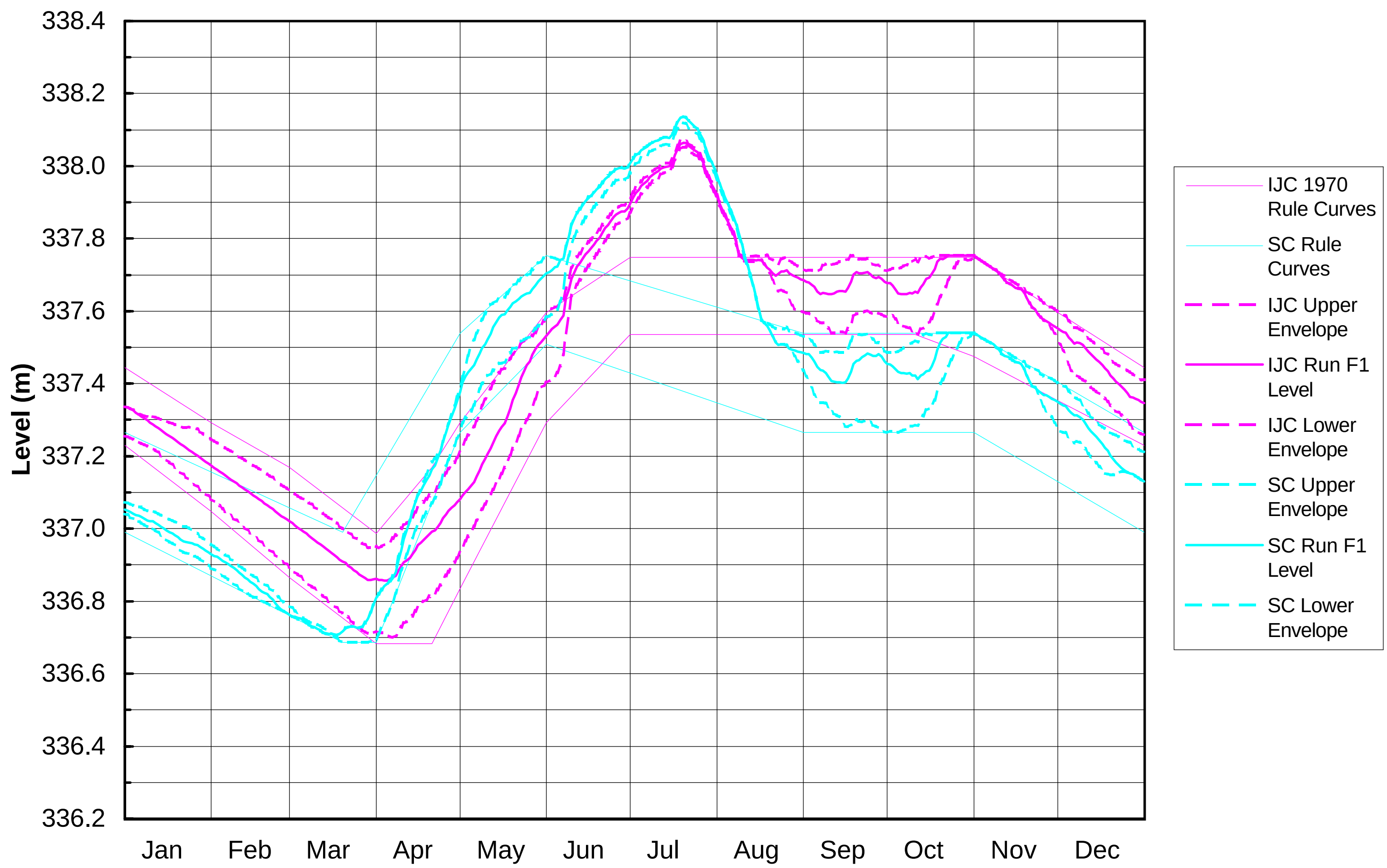
Namakan Lake 1968

Runs F1-F5 - Operating Policy Variants - IJC vs SC



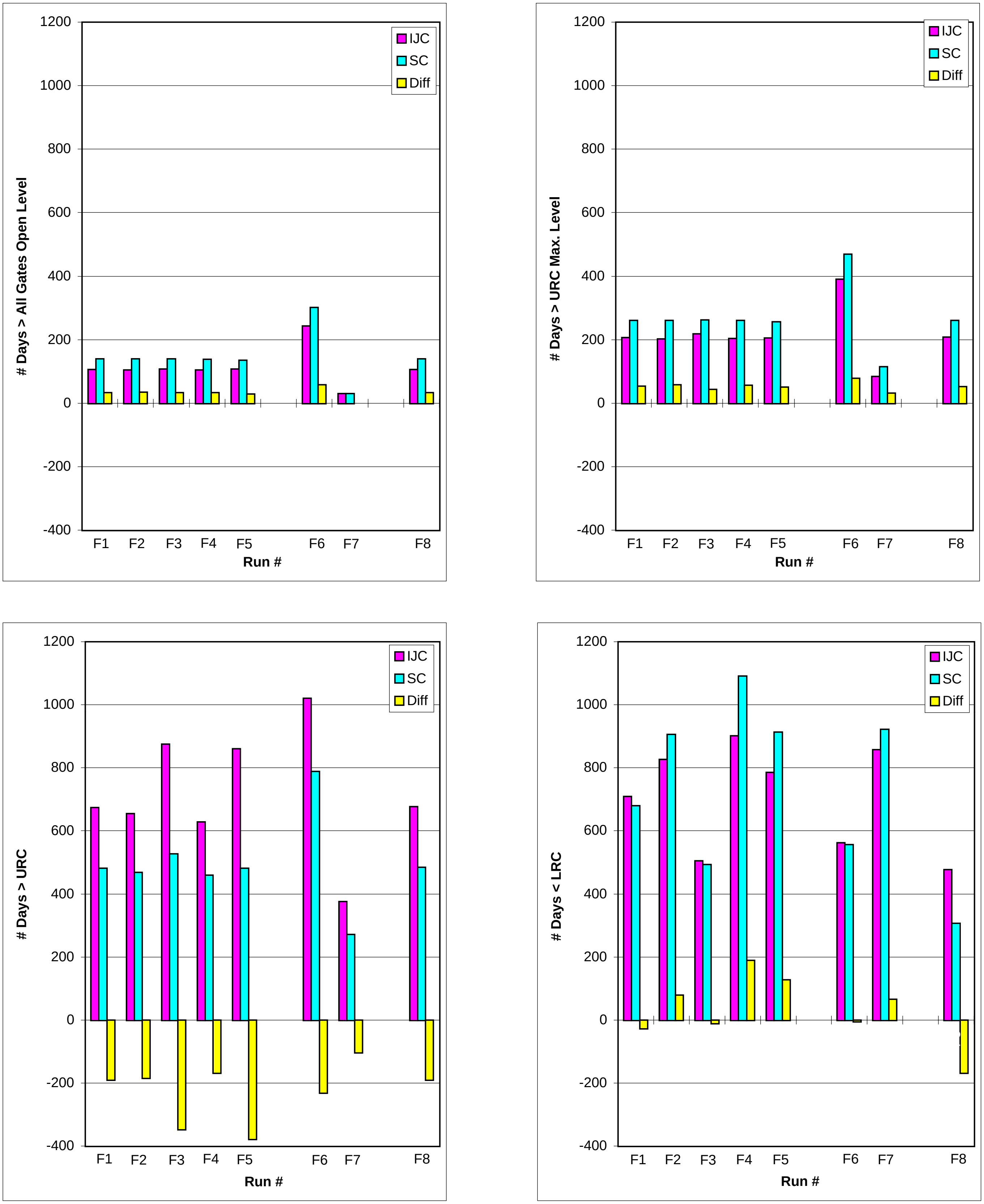
Rainy Lake 1968

Runs F1-F5 - Operating Policy Variants - IJC vs SC

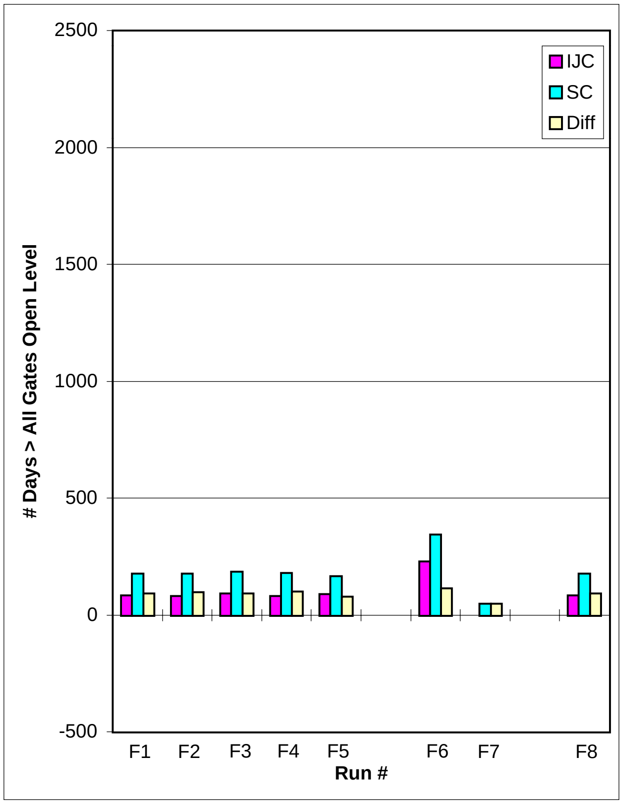


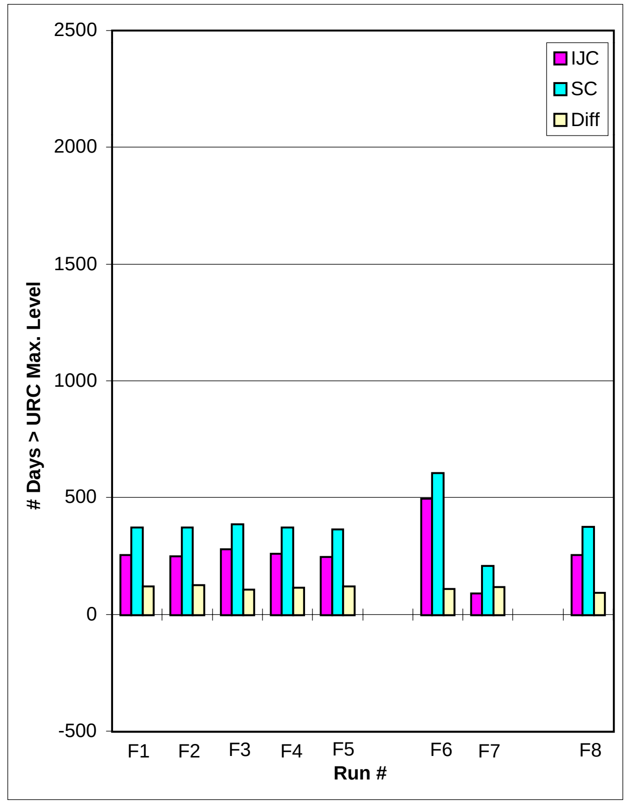
Namakan Lake

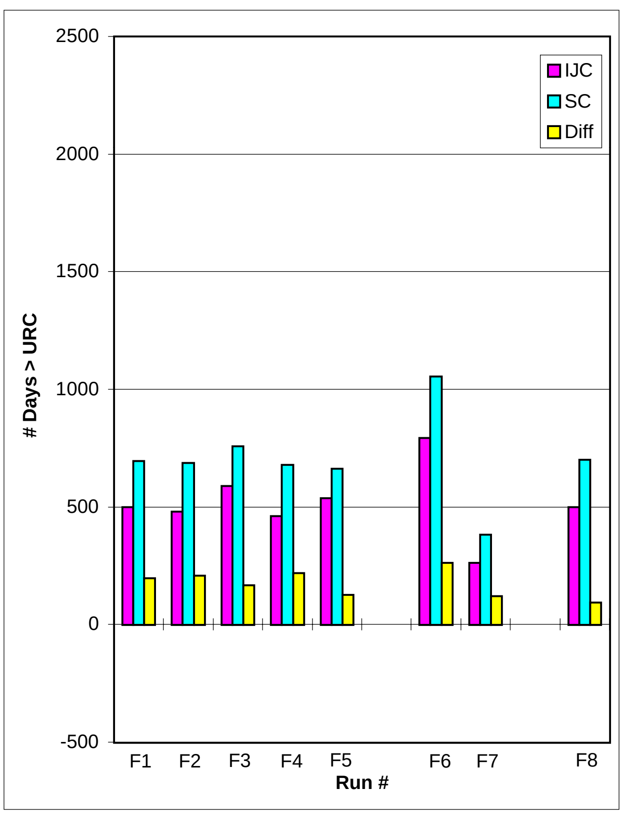
Runs F1-F8 - Level Parameter Comparison

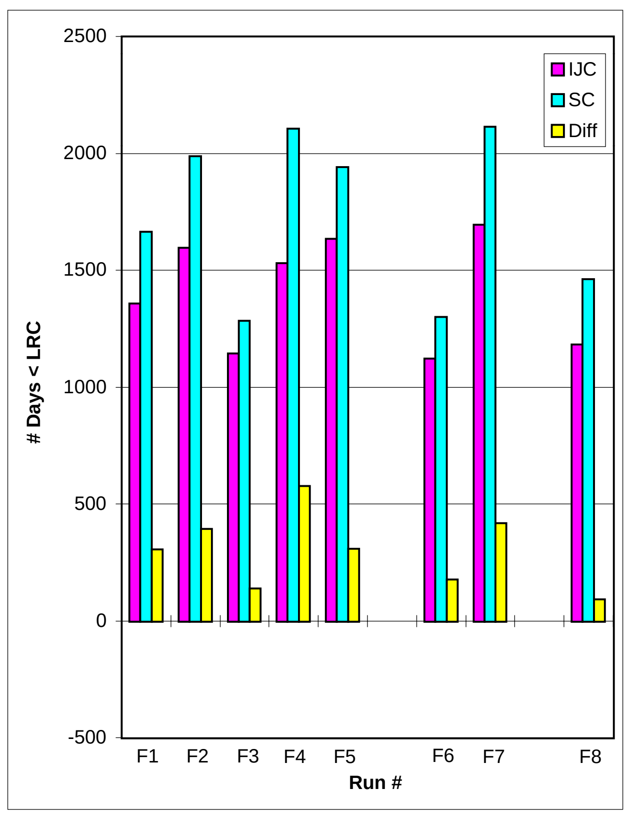


Rainy Lake
Runs F1-F8 - Level Parameter Comparison

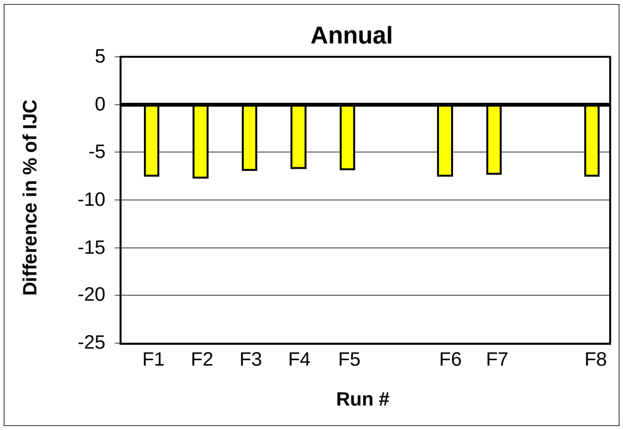






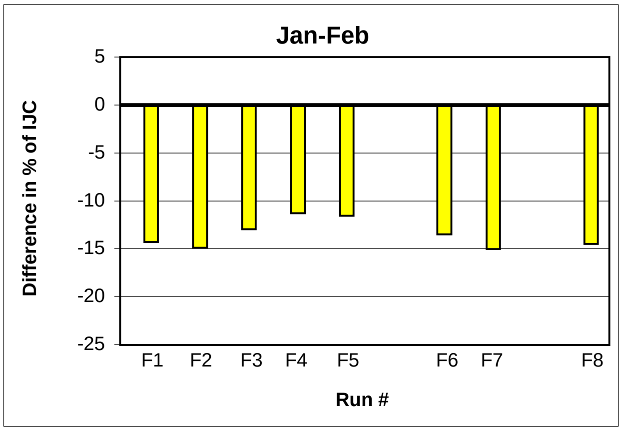


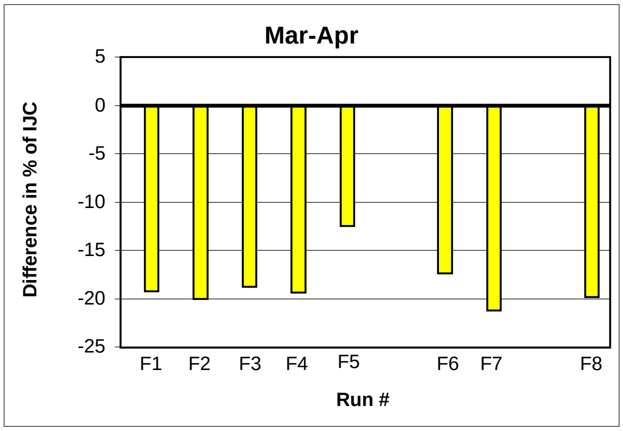
Rainy Lake
Runs F1-F8 - Energy Generation Comparison

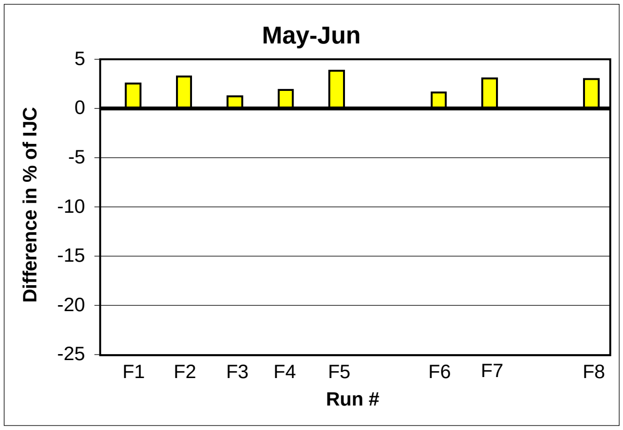


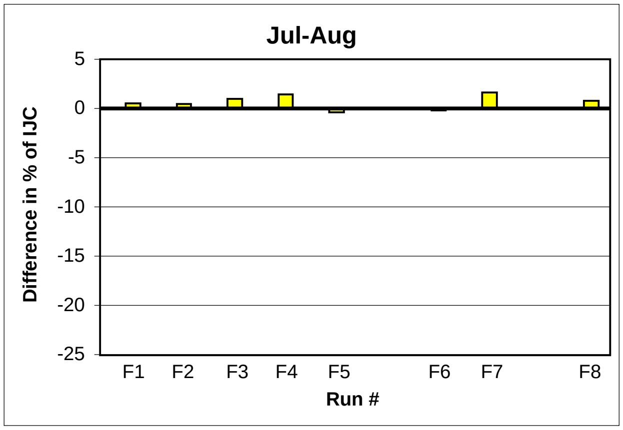
Difference in Energy Generation in % Between IJC and SC

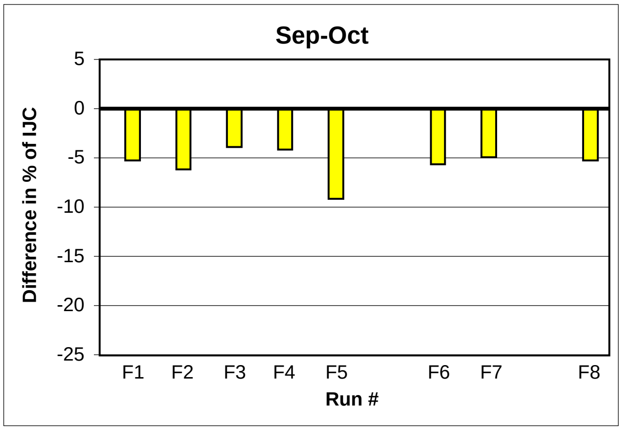
Difference in % of IJC = (SC - IJC) x 100 / IJC

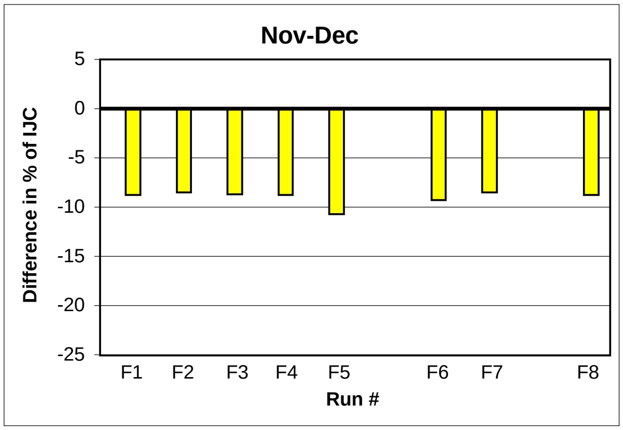






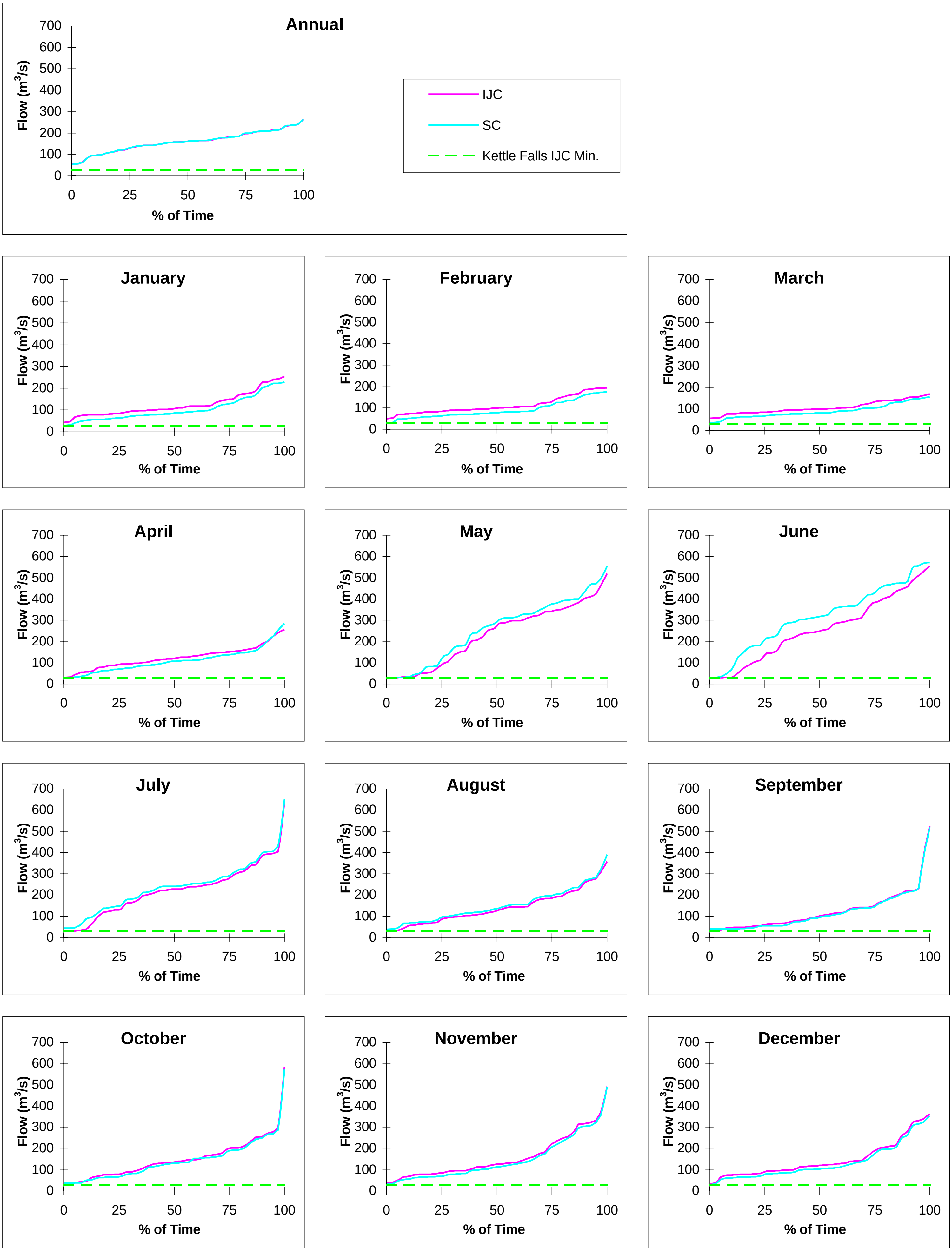






Namakan Lake Run F1 - Base Case - 50% Buffer *GRAPH 8*

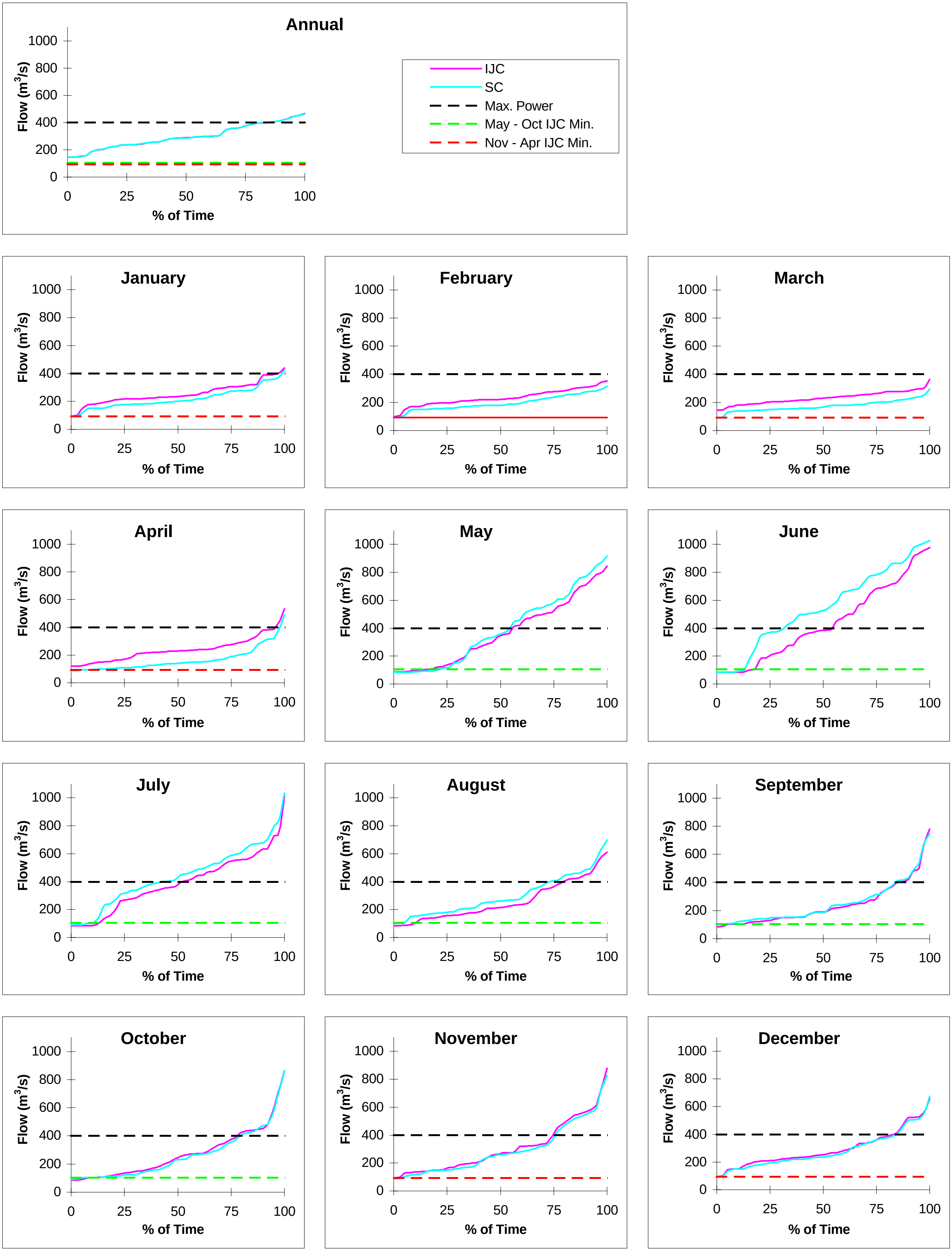
Outflow Duration Curves

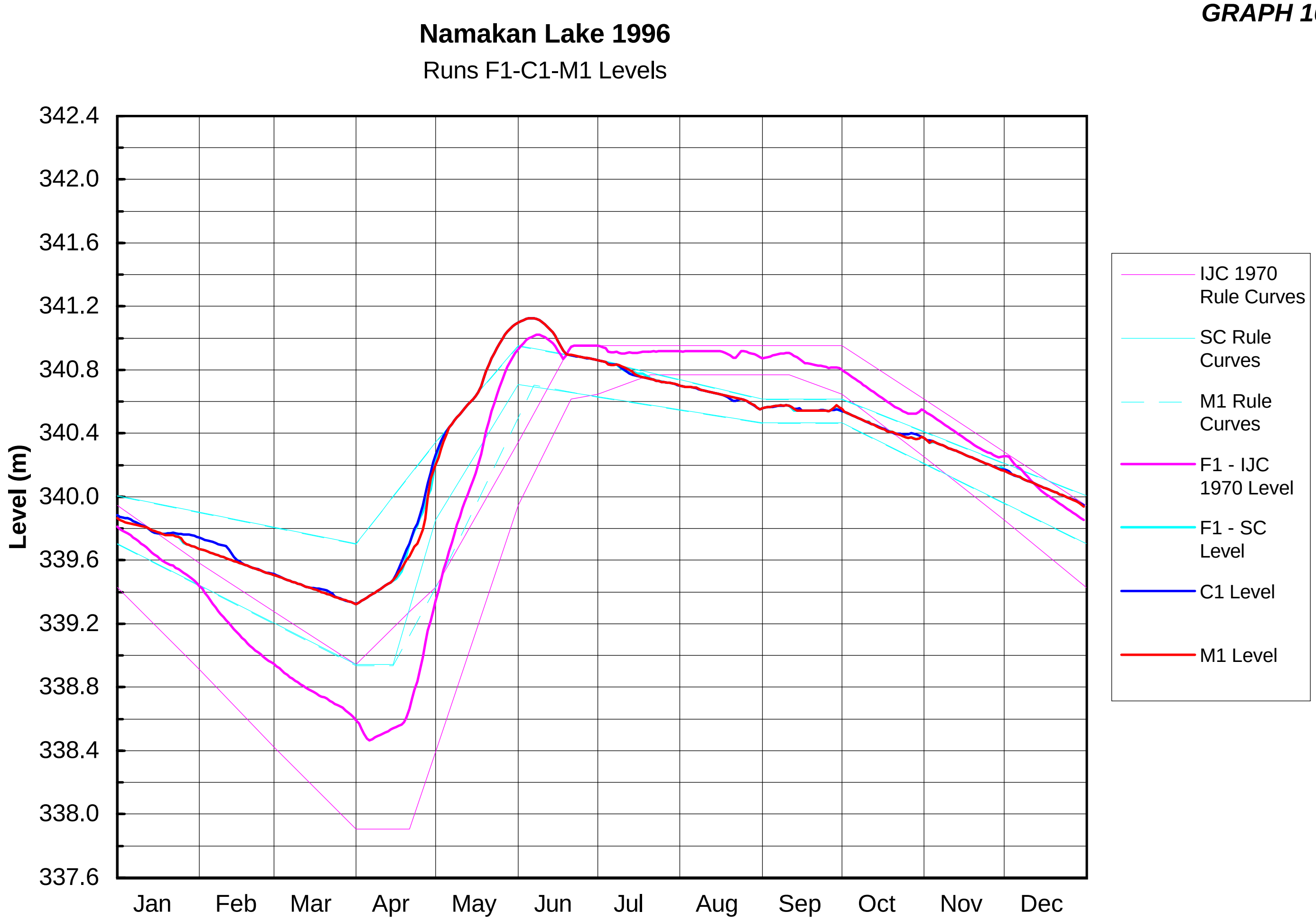


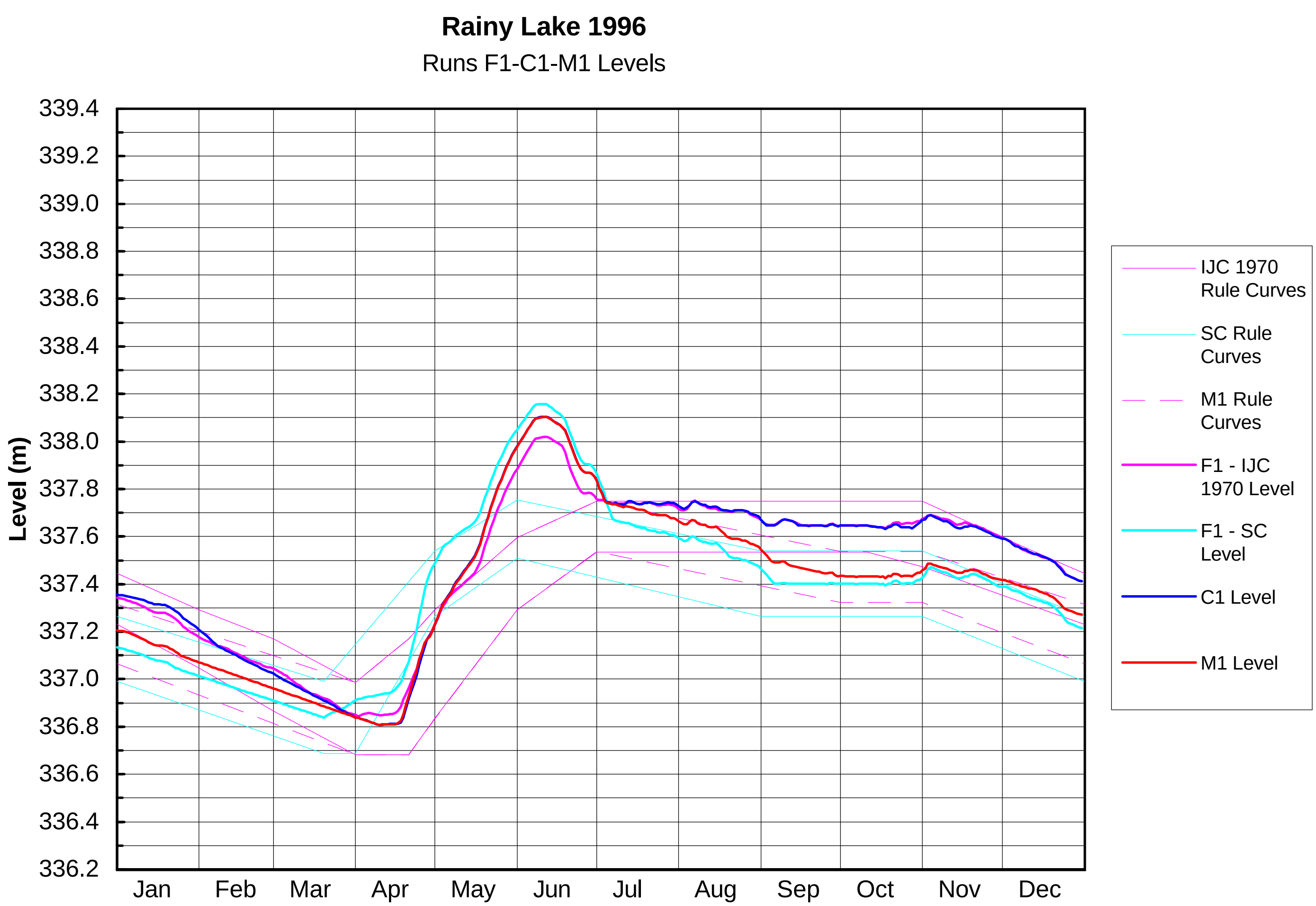
Rainy Lake Run F1 - Base Case - 50% Buffer

GRAPH 9

Outflow Duration Curves




Namakan Lake 1996
Runs F1-C1-M1 Levels
Level (m)
342.4
342.0
341.6
341.2
340.8
340.4
340.0
339.6
339.2
338.8
338.4
338.0
337.6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
IJC 1970 Rule Curves
SC Rule Curves
M1 Rule Curves
F1 - IJC 1970 Level
F1 - SC Level
C1 Level
M1 Level


Rainy Lake 1996
Runs F1-C1-M1 Levels
Level (m)
339.4
339.2
339.0
338.8
338.6
338.4
338.2
338.0
337.8
337.6
337.4
337.2
337.0
336.8
336.6
336.4
336.2
Jan
Feb
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Jul
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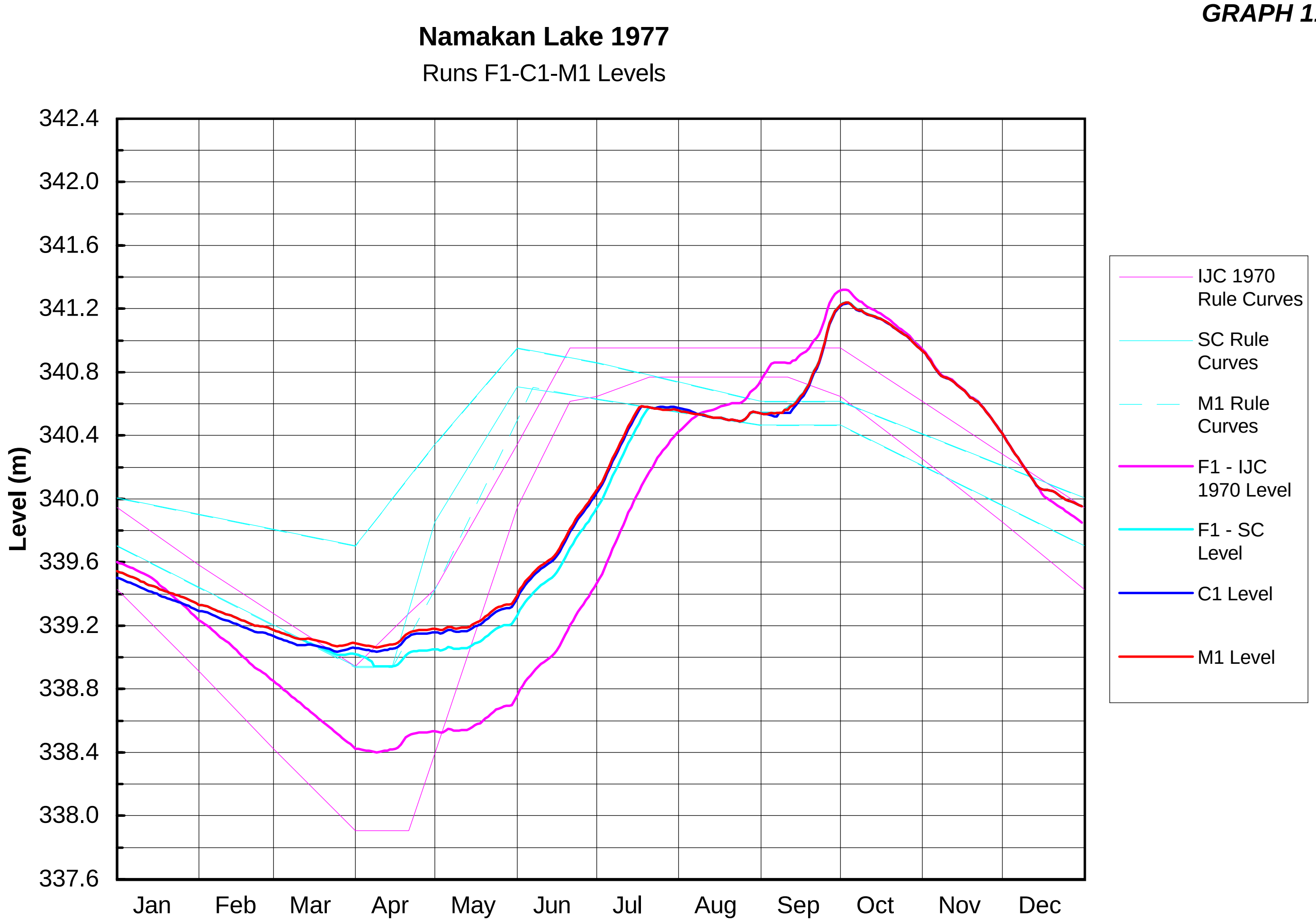
Oct
Nov
Dec
IJC 1970 Rule Curves
SC Rule Curves
M1 Rule Curves
F1 - IJC 1970 Level
F1 - SC Level
C1 Level
M1 Level



Namakan Lake 1977
Runs F1-C1-M1 Levels
Level (m)
342.4
342.0
341.6
341.2
340.8
340.4
340.0
339.6
339.2
338.8
338.4
338.0
337.6
Jan
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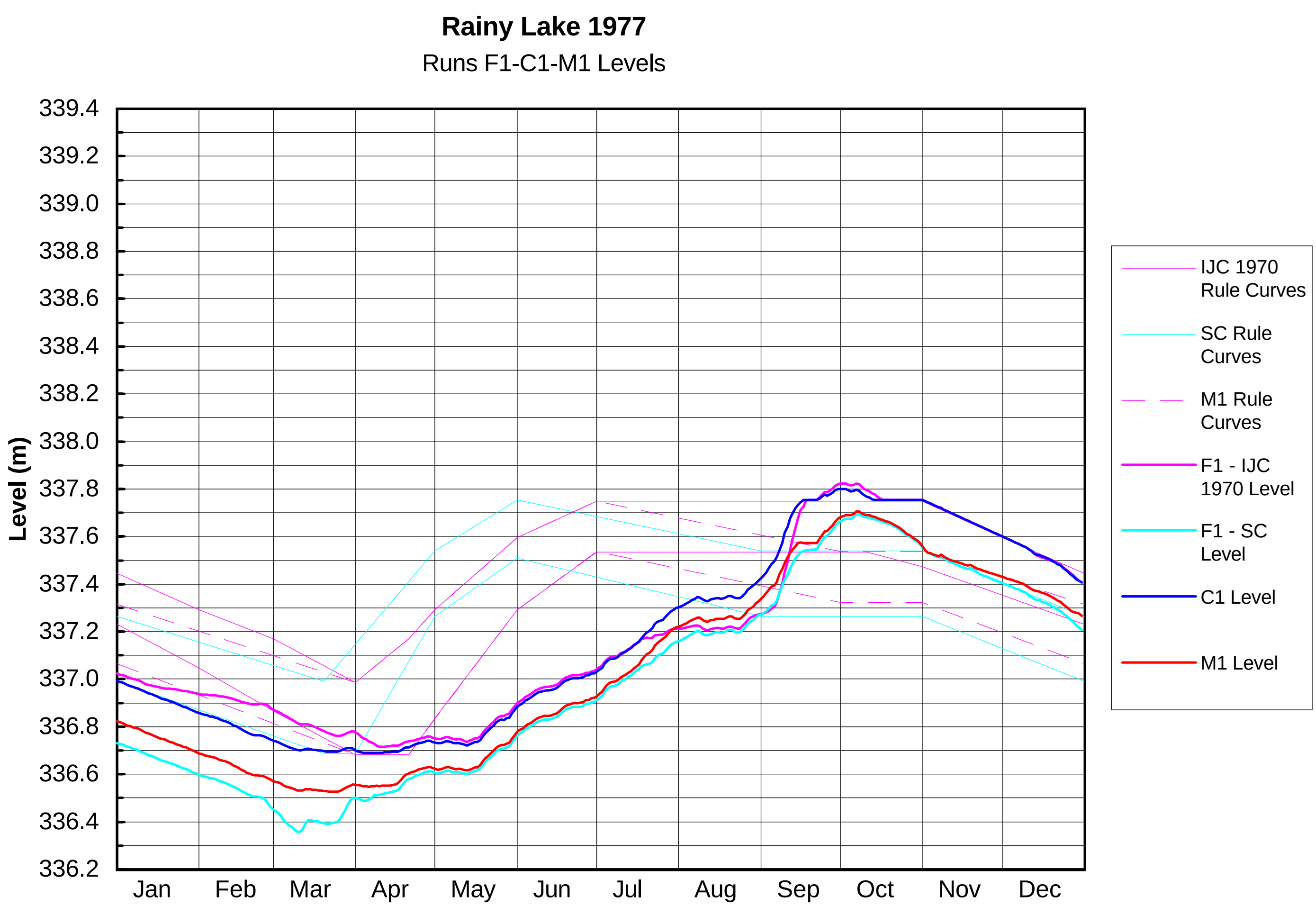
Oct
Nov
Dec
IJC 1970 Rule Curves
SC Rule Curves
M1 Rule Curves
F1 - IJC 1970 Level
F1 - SC Level
C1 Level
M1 Level



Rainy Lake 1977
Runs F1-C1-M1 Levels
Level (m)
339.4
339.2
339.0
338.8
338.6
338.4
338.2
338.0
337.8
337.6
337.4
337.2
337.0
336.8
336.6
336.4
336.2
Jan
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Mar
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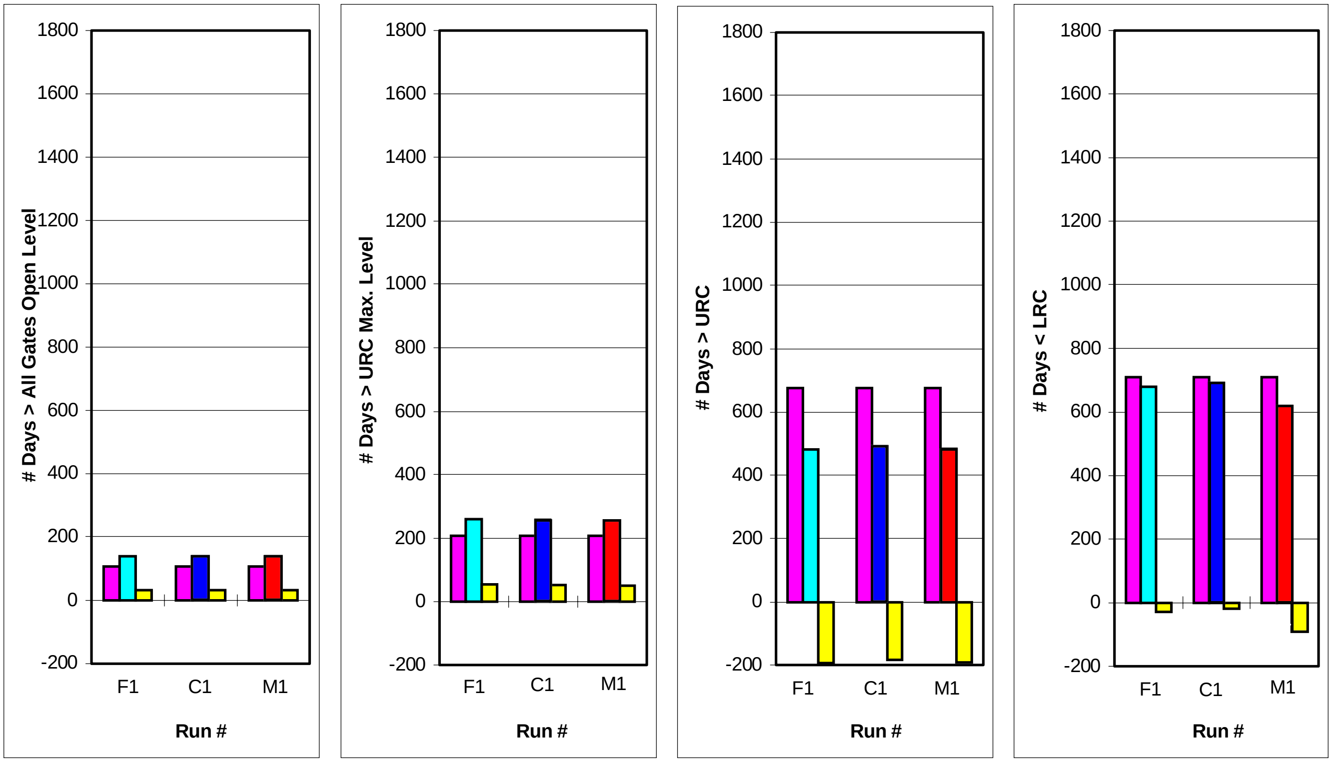
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
IJC 1970 Rule Curves
SC Rule Curves
M1 Rule Curves
F1 - IJC 1970 Level
F1 - SC Level
C1 Level
M1 Level

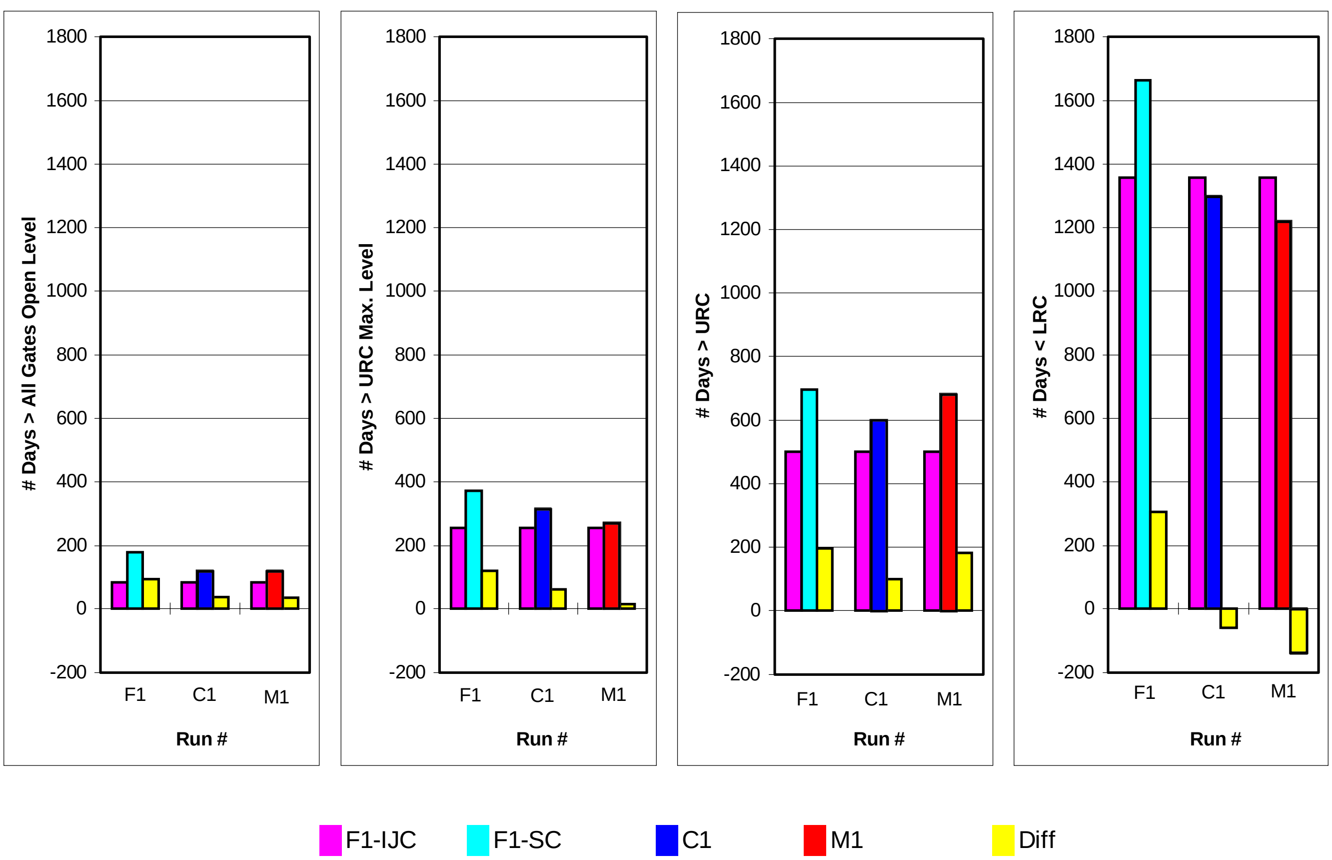
Namakan Lake

Runs F1-C1-M1 - Level Parameter Comparison

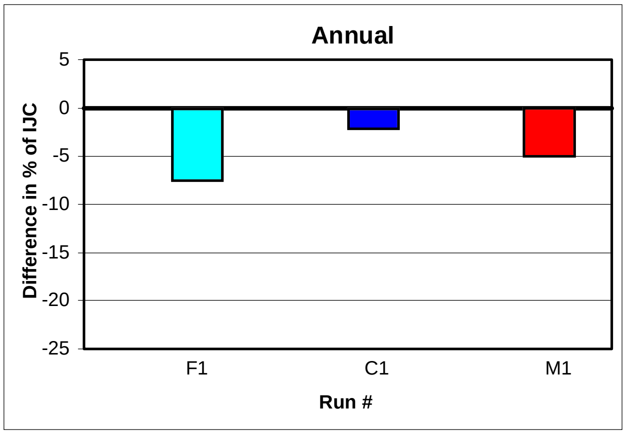


Rainy Lake

Runs F1-C1-M1 - Level Parameter Comparison



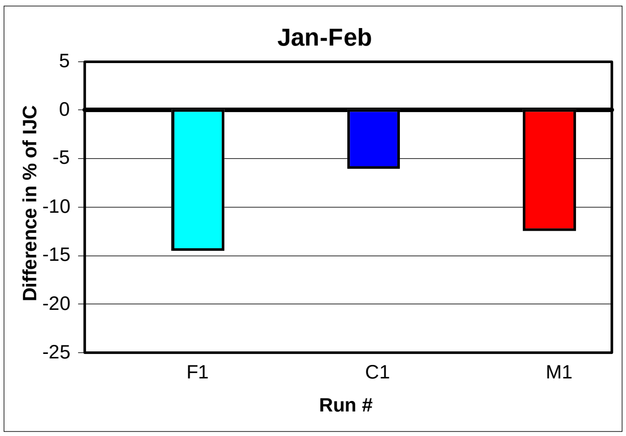
Rainy Lake
Runs F1-C1-M1 - Energy Generation Comparison

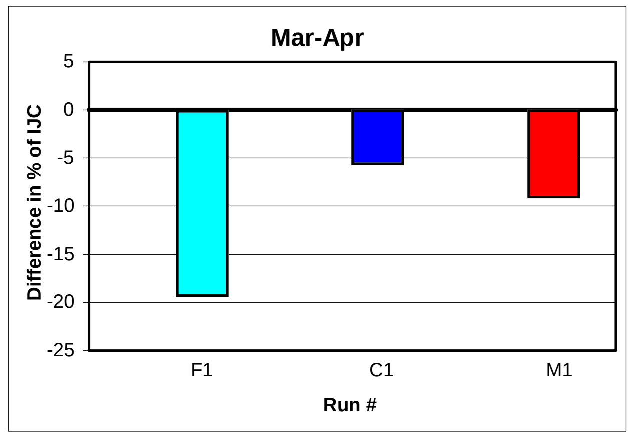


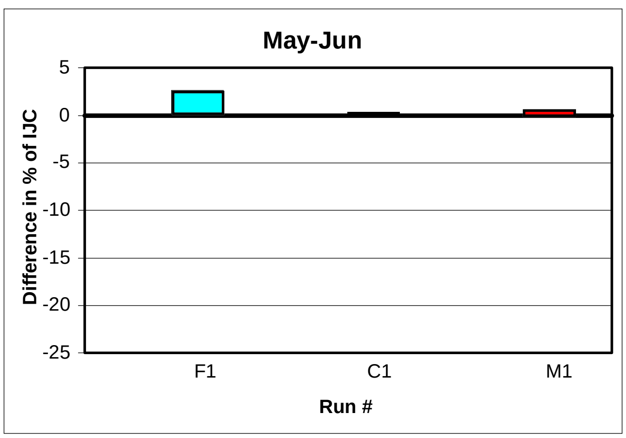
Difference in Energy Generation in %

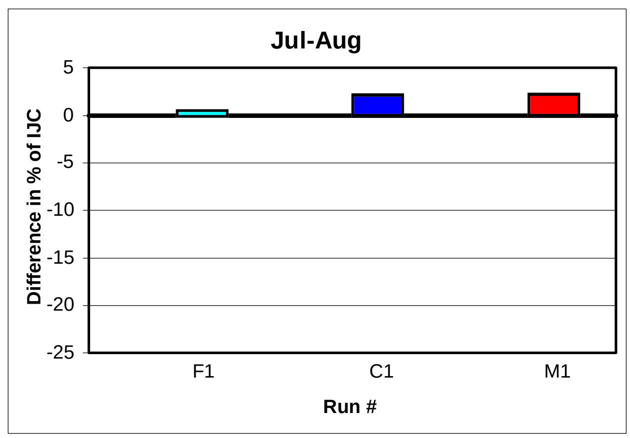
- Run F1-IJC vs Run F1-SC
- Run F1-IJC vs Run C1
- Run F1-IJC vs Run M1

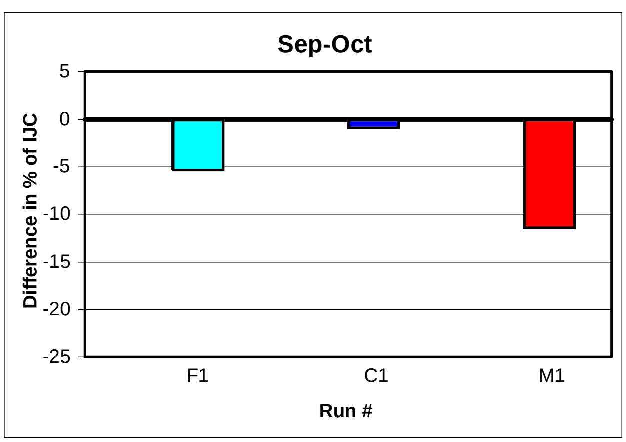
Difference in % of F1-IJC = $\frac{(\text{other - IJC}) \times 100}{\text{IJC}}$

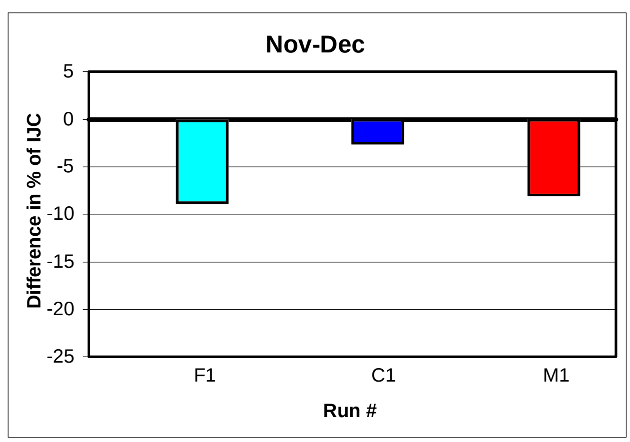








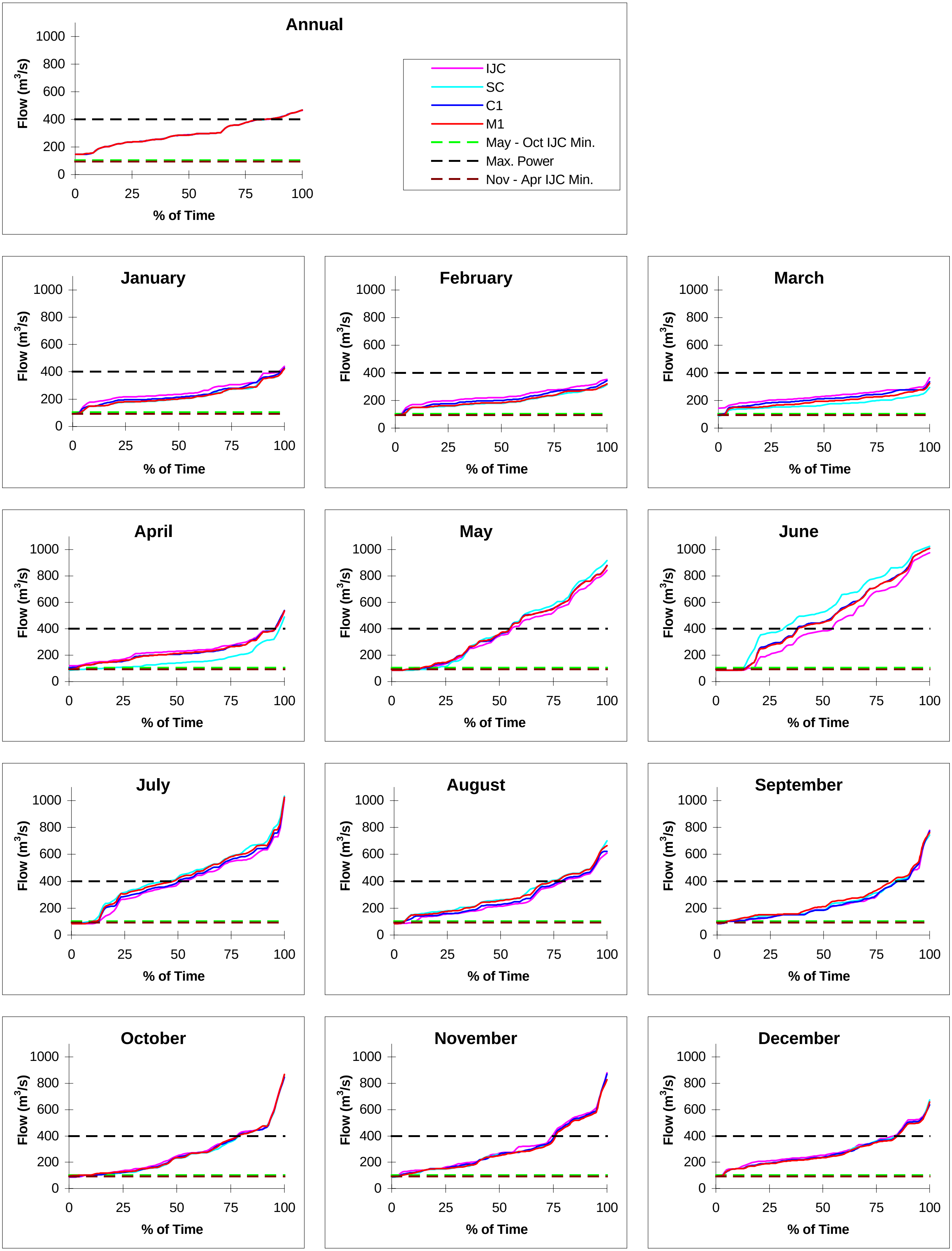


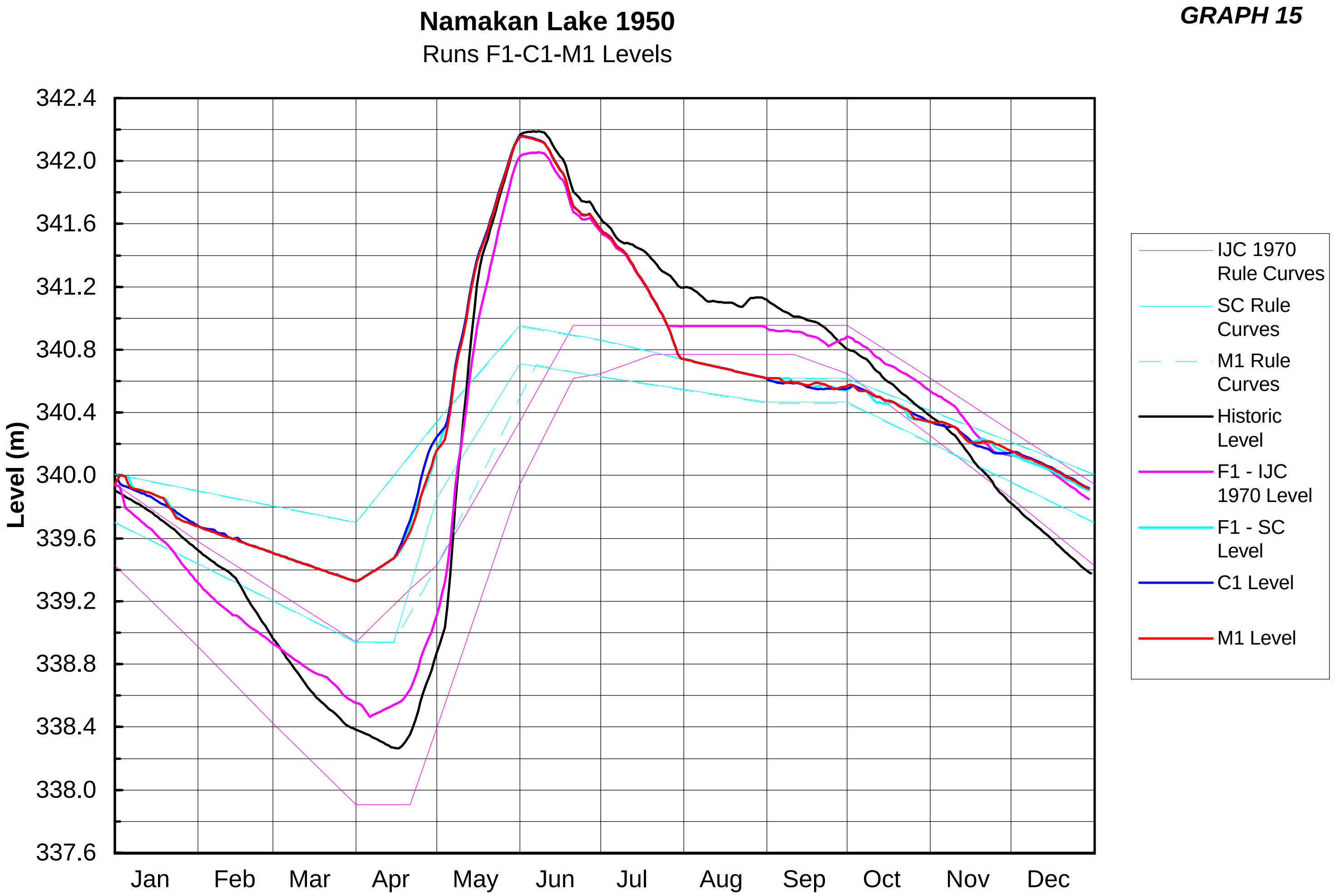


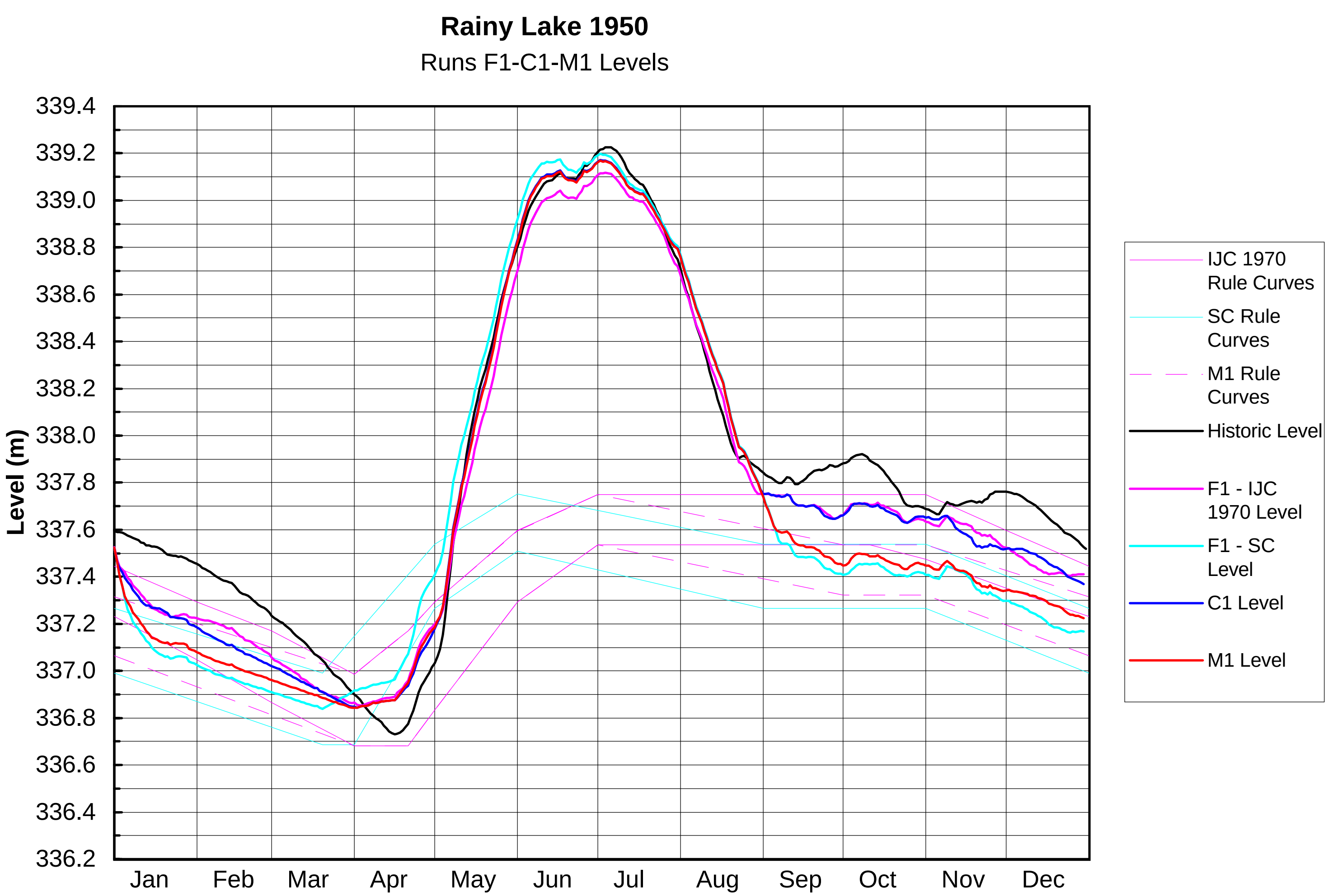
Rainy Lake

Runs F1-C1-M1 - Outflow Duration Curves

GRAPH 14




Namakan Lake 1950
Runs F1-C1-M1 Levels
Level (m)
342.4
342.0
341.6
341.2
340.8
340.4
340.0
339.6
339.2
338.8
338.4
338.0
337.6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
IJC 1970 Rule Curves
SC Rule Curves
M1 Rule Curves
Historic Level
F1 - IJC 1970 Level
F1 - SC Level
C1 Level
M1 Level


Rainy Lake 1950
Runs F1-C1-M1 Levels
Level (m)
339.4
339.2
339.0
338.8
338.6
338.4
338.2
338.0
337.8
337.6
337.4
337.2
337.0
336.8
336.6
336.4
336.2
Jan
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Mar
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May
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Jul
Aug
Sep
Oct
Nov
Dec
IJC 1970 Rule Curves
SC Rule Curves
M1 Rule Curves
Historic Level
F1 - IJC 1970 Level
F1 - SC Level
C1 Level
M1 Level

Ranked Spring Level Peaks and Differences

Namakan Lake

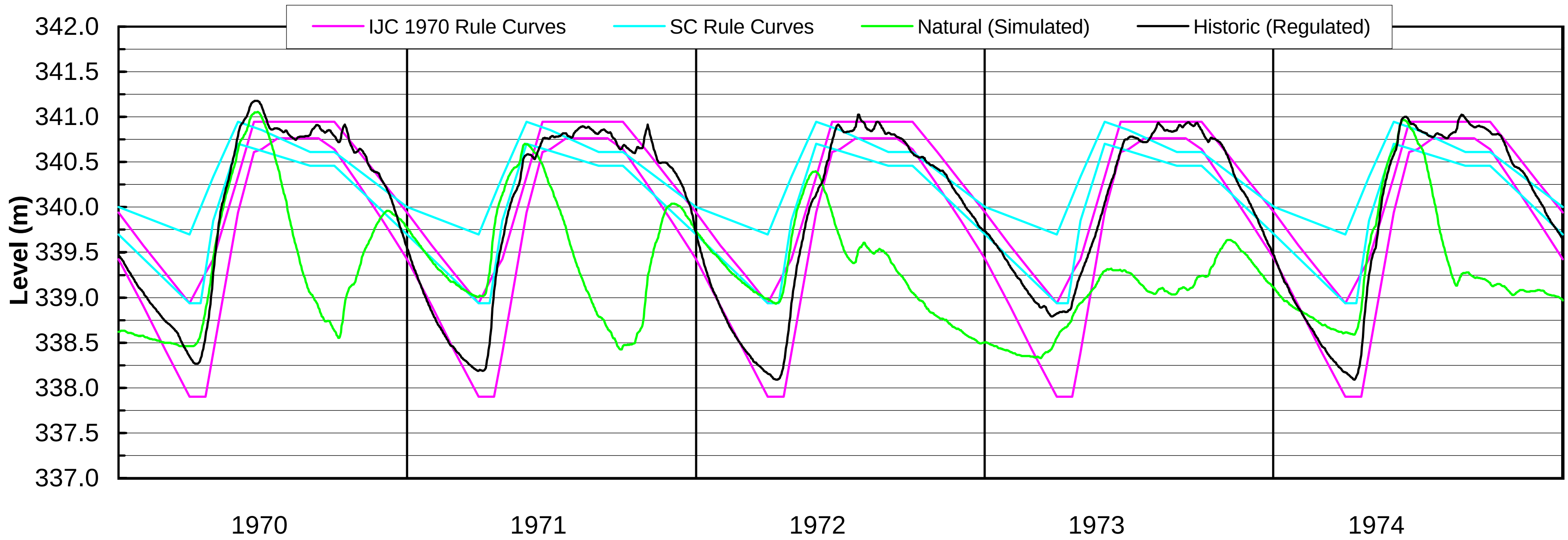
May-July Inflow Rank	Year	Historic	F1-IJC	F1-SC		C1		M1	
1	1950	342.20	342.05	342.16	(0.11)	342.16	(0.11)	342.15	(0.10)
2	1927	341.97	-	-		-		-	
3	1968	341.69	341.53	341.58	(0.05)	341.58	(0.05)	341.57	(0.04)
4	1916	342.25	-	-		-		-	
5	1938	341.84	-	-		-		-	
6	1970	341.18	341.13	341.22	(0.09)	341.22	(0.09)	341.22	(0.09)
7	1966	341.32	341.35	341.39	(0.04)	341.39	(0.04)	341.39	(0.04)
8	1944	341.47	-	-		-		-	
9	1943	341.44	-	-		-		-	
10	1954	341.39	-	-		-		-	
11	1974	341.00	341.00	341.16	(0.16)	341.16	(0.16)	341.16	(0.16)
12	1996	341.01	341.02	341.13	(0.11)	341.13	(0.11)	341.13	(0.11)
13	1969	341.00	341.02	341.06	(0.04)	341.06	(0.04)	341.06	(0.04)
14	1934	341.34	-	-		-		-	
15	1979	340.91	340.95	340.95	(0.00)	340.95	(0.00)	340.95	(0.00)
16	1964	341.21	340.95	341.07	(0.12)	341.07	(0.12)	341.07	(0.12)
17	1962	341.09	340.95	340.95	(0.00)	340.95	(0.00)	340.95	(0.00)
18	1985	341.02	340.98	340.95	(-0.03)	340.95	(-0.03)	340.95	(-0.03)
19	1965	341.05	340.95	340.99	(0.04)	340.99	(0.04)	340.99	(0.04)
20	1971	340.82	340.92	340.95	(0.03)	340.95	(0.03)	340.95	(0.03)
21	1920	341.49	-	-		-		-	
22	1951	340.98	-	-		-		-	
23	1994	340.94	340.95	340.90	(-0.05)	340.88	(-0.07)	340.85	(-0.10)
24	1990	340.89	340.95	340.94	(-0.01)	340.94	(-0.01)	340.94	(-0.01)
25	1978	340.91	340.95	340.95	(0.00)	340.94	(-0.01)	340.94	(-0.01)

Rainy Lake

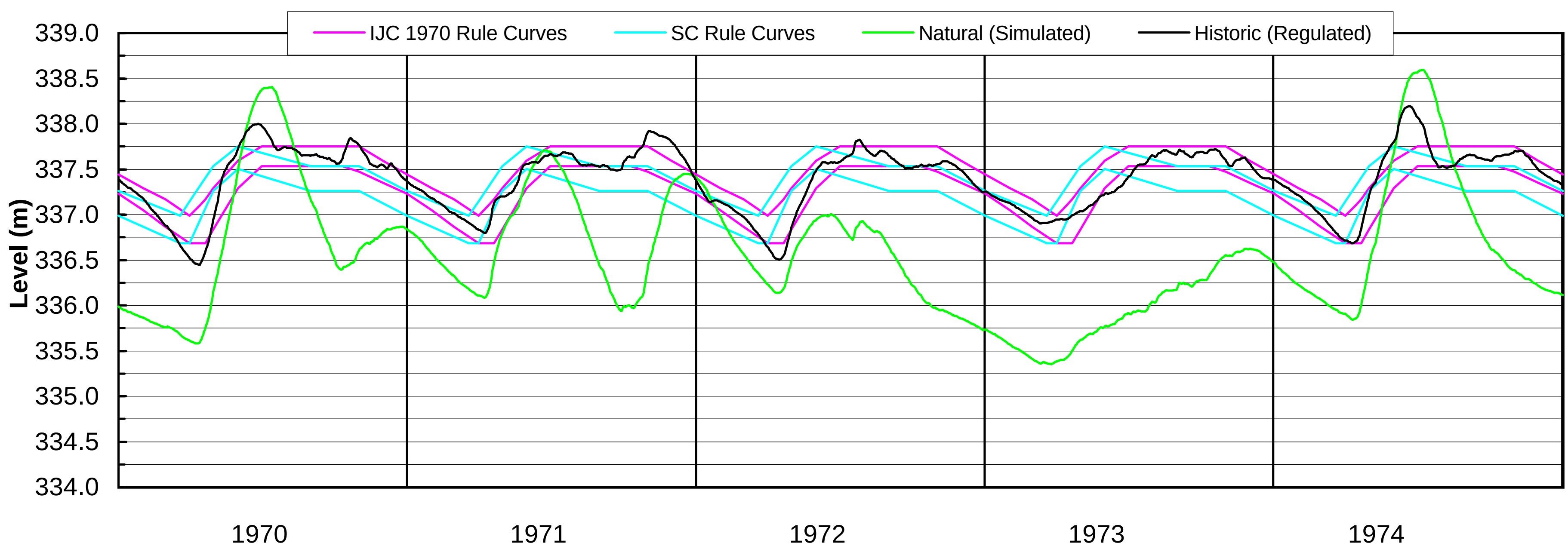
May-July Inflow Rank	Year	Historic	F1-IJC	F1-SC		C1		M1	
1	1950	339.23	339.12	339.20	(0.08)	339.17	(0.05)	339.17	(0.05)
2	1927	338.44	-	-		-		-	
3	1954	338.18	-	-		-		-	
4	1968	338.35	338.06	338.16	(0.10)	338.11	(0.05)	338.11	(0.05)
5	1996	338.09	338.02	338.16	(0.14)	338.10	(0.08)	338.10	(0.08)
6	1916	339.09	-	-		-		-	
7	1985	338.02	337.86	337.87	(0.01)	337.88	(0.02)	337.88	(0.02)
8	1938	338.26	-	-		-		-	
9	1974	338.20	337.98	338.11	(0.13)	338.06	(0.08)	338.06	(0.08)
10	1970	338.00	337.82	337.96	(0.14)	337.90	(0.08)	337.90	(0.08)
11	1943	338.05	-	-		-		-	
12	1966	338.15	337.96	338.03	(0.07)	338.01	(0.05)	338.01	(0.05)
13	1964	338.08	337.79	337.94	(0.15)	337.89	(0.10)	337.89	(0.10)
14	1962	337.83	337.75	337.85	(0.10)	337.76	(0.01)	337.75	(0.00)
15	1944	337.90	-	-		-		-	
16	1947	337.94	-	-		-		-	
17	1969	337.83	337.75	337.82	(0.07)	337.75	(0.00)	337.73	(-0.02)
18	1979	337.70	337.74	337.75	(0.01)	337.74	(0.00)	337.74	(0.00)
19	1951	337.82	-	-		-		-	
20	1965	337.80	337.75	337.76	(0.01)	337.74	(-0.01)	337.74	(-0.01)
21	1990	337.73	337.75	337.75	(0.00)	337.75	(0.00)	337.75	(0.00)
22	1978	337.79	337.75	337.75	(0.00)	337.75	(0.00)	337.75	(0.00)
23	1989	337.78	337.75	337.74	(-0.01)	337.75	(0.00)	337.75	(0.00)
24	1956	337.85	-	-		-		-	
25	1937	337.86	-	-		-		-	

Note: Numbers in brackets are differences from the F1-IJC levels
Maximum upper rule curve level on Namakan lake is 340.95 m and on Rainy Lake is 337.75 m.

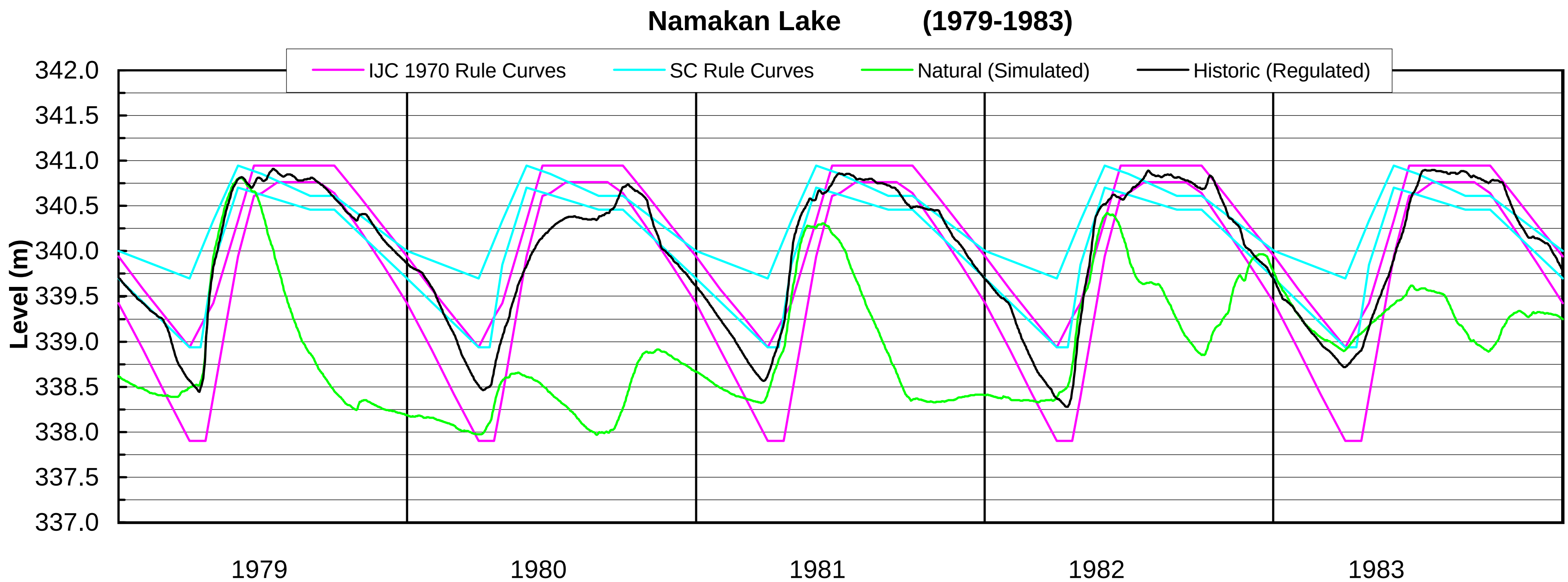
Namakan Lake (1970-1974)

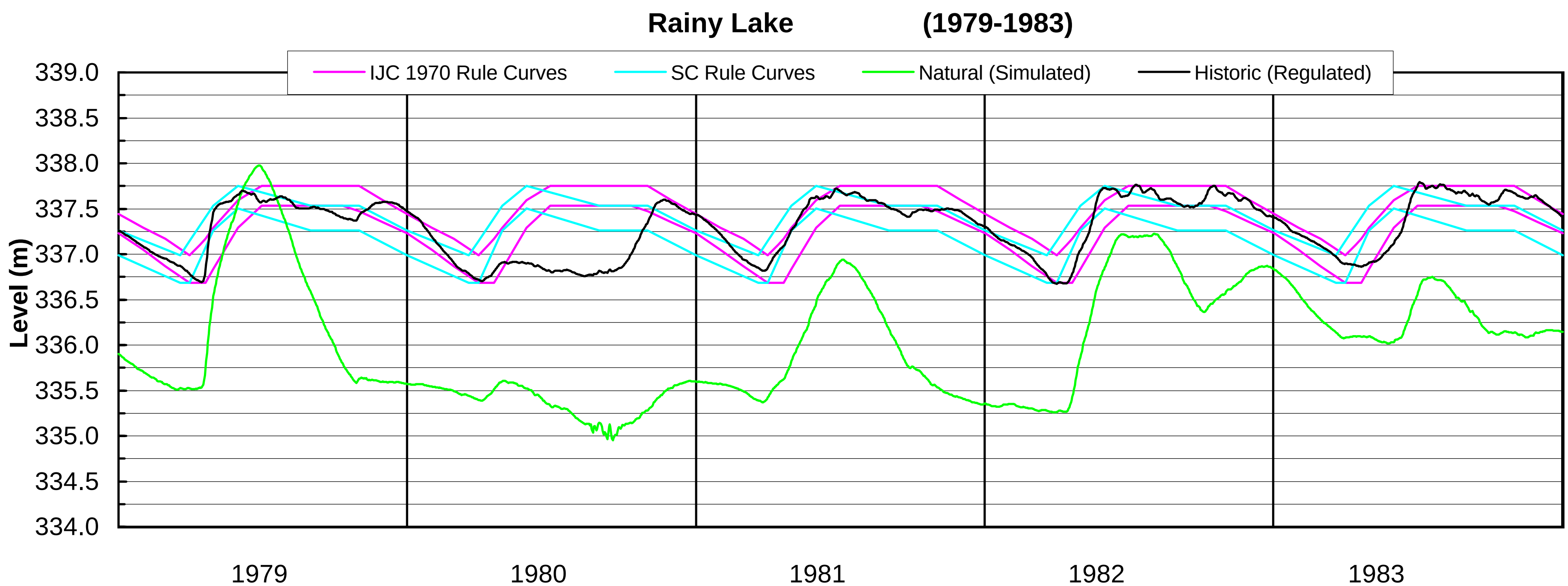


Rainy Lake (1970-1974)



GRAPH 16


Namakan Lake (1979-1983)
IJC 1970 Rule Curves
SC Rule Curves
Natural (Simulated)
Historic (Regulated)
Level (m)
342.0
341.5
341.0
340.5
340.0
339.5
339.0
338.5
338.0
337.5
337.0
1979
1980
1981
1982
1983


Rainy Lake (1979-1983)
IJC 1970 Rule Curves
SC Rule Curves
Natural (Simulated)
Historic (Regulated)
Level (m)
339.0
338.5
338.0
337.5
337.0
336.5
336.0
335.5
335.0
334.5
334.0
1979
1980
1981
1982
1983

GRAPH 17

Perfect Inflow Forecast
Rule Curve Deviations

IJC 1970 Rule Curves

Namakan Lake

# of Days of Perfect Inflow Foreknowledge	Total # of 3-Day Time Steps	# of Time Steps > URC	% of Time Steps > URC	Maximum Deviation (m)	Median Deviation (m)	# of Time Steps < LRC	% of Time Steps < LRC	Maximum Deviation (m)	Median Deviation (m)
3-Day Back-Cast	4740	229	4.83	1.18	0.23	171	3.61	1.40	0.59
3	4740	207	4.37	1.18	0.26	168	3.54	1.39	0.57
7	4740	206	4.35	1.18	0.26	168	3.54	1.39	0.57
14	4740	204	4.30	1.18	0.26	168	3.54	1.39	0.57
21	4740	200	4.22	1.18	0.25	167	3.52	1.39	0.57
28	4740	195	4.11	1.18	0.25	160	3.38	1.38	0.52

Rainy Lake

# of Days of Perfect Inflow Foreknowledge	Total # of 3-Day Time Steps	# of Time Steps > URC	% of Time Steps > URC	Maximum Deviation (m)	Median Deviation (m)	# of Time Steps < LRC	% of Time Steps < LRC	Maximum Deviation (m)	Median Deviation (m)
3-Day Back-Cast	4740	133	2.81	0.37	0.08	376	7.93	1.00	0.30
3	4740	102	2.15	0.36	0.10	367	7.74	1.00	0.30
7	4740	94	1.98	0.36	0.12	367	7.74	1.00	0.30
14	4740	76	1.60	0.36	0.15	366	7.72	1.00	0.30
21	4740	68	1.43	0.34	0.14	351	7.41	1.00	0.29
28	4740	66	1.39	0.32	0.13	323	6.81	0.94	0.28

SC Rule Curves

Namakan Lake

# of Days of Perfect Inflow Foreknowledge	Total # of 3-Day Time Steps	# of Time Steps > URC	% of Time Steps > URC	Maximum Deviation (m)	Median Deviation (m)	# of Time Steps < LRC	% of Time Steps < LRC	Maximum Deviation (m)	Median Deviation (m)
3-Day Back-Cast	4740	156	3.29	0.76	0.20	83	1.75	1.06	0.29
3	4740	128	2.70	0.75	0.21	73	1.54	1.06	0.32
7	4740	124	2.62	0.75	0.21	73	1.54	1.06	0.32
14	4740	119	2.51	0.74	0.23	73	1.54	1.06	0.32
21	4740	116	2.45	0.74	0.25	69	1.46	1.06	0.28
28	4740	116	2.45	0.74	0.24	61	1.29	1.02	0.22

Rainy Lake

# of Days of Perfect Inflow Foreknowledge	Total # of 3-Day Time Steps	# of Time Steps > URC	% of Time Steps > URC	Maximum Deviation (m)	Median Deviation (m)	# of Time Steps < LRC	% of Time Steps < LRC	Maximum Deviation (m)	Median Deviation (m)
3-Day Back-Cast	4740	182	3.84	0.50	0.13	380	8.02	0.95	0.32
3	4740	160	3.38	0.49	0.11	364	7.68	0.94	0.31
7	4740	151	3.19	0.49	0.11	364	7.68	0.94	0.31
14	4740	118	2.49	0.46	0.13	354	7.47	0.92	0.30
21	4740	107	2.26	0.46	0.13	335	7.07	0.90	0.29
28	4740	106	2.24	0.46	0.13	311	6.56	0.87	0.26

Perfect Inflow Forecast
Peak Level (m) for 6 Highest Level Years

IJC 1970 Rule Curves

Namakan Lake

# of Days of Perfect Inflow Foreknowledge	1968	1966	1977	1970	1996	1969
3-Day Back-Cast	341.547	341.379	341.357	341.157	341.064	341.043
3	341.540 (-0.007)	341.379 (0.000)	341.327 (-0.030)	341.157 (0.000)	341.060 (-0.004)	341.041 (-0.002)
7	341.540 (-0.007)	341.379 (0.000)	341.321 (-0.036)	341.157 (0.000)	341.060 (-0.004)	341.041 (-0.002)
14	341.529 (-0.018)	341.379 (0.000)	341.308 (-0.049)	341.157 (0.000)	341.060 (-0.004)	341.040 (-0.003)
21	341.525 (-0.022)	341.379 (0.000)	341.308 (-0.049)	341.157 (0.000)	341.052 (-0.012)	341.039 (-0.004)
28	341.524 (-0.023)	341.379 (0.000)	341.308 (-0.049)	341.154 (-0.003)	341.048 (-0.016)	341.038 (-0.005)

Rainy Lake

# of Days of Perfect Inflow Foreknowledge	1968	1996	1966	1974	1970	1985
3-Day Back-Cast	338.070	338.012	337.969	337.961	337.792	337.797
3	338.050 (-0.020)	338.005 (-0.007)	337.969 (0.000)	337.951 (-0.010)	337.787 (-0.005)	337.761 (-0.036)
7	338.049 (-0.021)	338.005 (-0.007)	337.969 (0.000)	337.951 (-0.010)	337.787 (-0.005)	337.761 (-0.036)
14	338.025 (-0.045)	338.003 (-0.009)	337.969 (0.000)	337.951 (-0.010)	337.787 (-0.005)	337.731 (-0.066)
21	338.015 (-0.055)	337.995 (-0.017)	337.964 (-0.005)	337.944 (-0.017)	337.783 (-0.009)	337.681 (-0.116)
28	338.012 (-0.058)	337.972 (-0.040)	337.961 (-0.008)	337.933 (-0.028)	337.774 (-0.018)	337.646 (-0.151)

SC Rule Curves

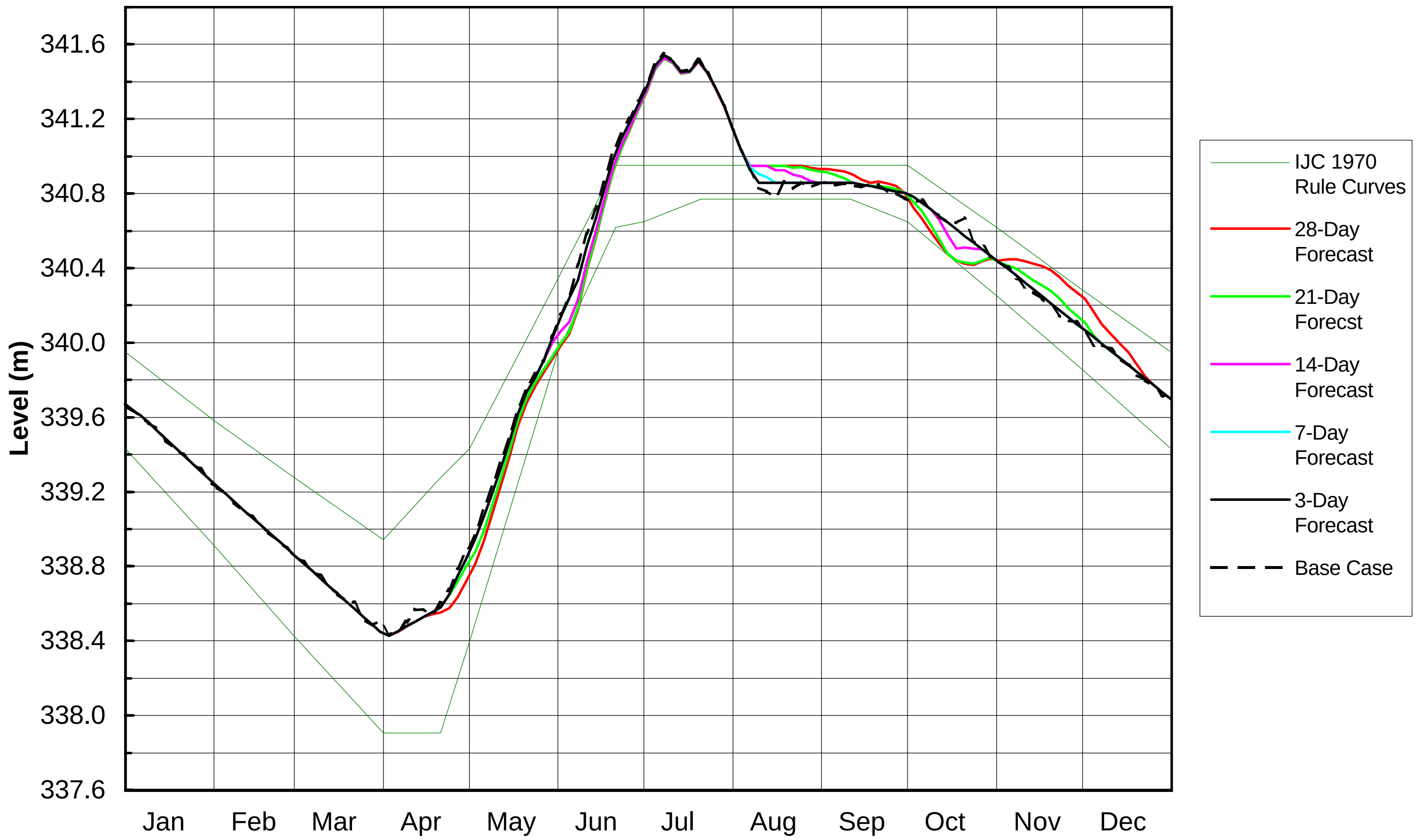
Namakan Lake

# of Days of Perfect Inflow Foreknowledge	1968	1966	1977	1970	1996	1974
3-Day Back-Cast	341.592	341.400	341.290	341.216	341.112	341.117
3	341.585 (-0.007)	341.397 (-0.003)	341.263 (-0.027)	341.209 (-0.007)	341.110 (-0.002)	341.115 (-0.002)
7	341.585 (-0.007)	341.397 (-0.003)	341.248 (-0.042)	341.209 (-0.007)	341.110 (-0.002)	341.115 (-0.002)
14	341.577 (-0.015)	341.397 (-0.003)	341.248 (-0.042)	341.197 (-0.019)	341.103 (-0.009)	341.098 (-0.019)
21	341.577 (-0.015)	341.393 (-0.007)	341.248 (-0.042)	341.191 (-0.025)	341.092 (-0.020)	341.086 (-0.031)
28	341.577 (-0.015)	341.390 (-0.010)	341.248 (-0.042)	341.191 (-0.025)	341.092 (-0.020)	341.086 (-0.031)

Rainy Lake

# of Days of Perfect Inflow Foreknowledge	1968	1996	1974	1966	1970	1964
3-Day Back-Cast	338.143	338.133	338.102	338.026	337.911	337.915
3	338.126 (-0.017)	338.129 (-0.004)	338.082 (-0.020)	338.016 (-0.010)	337.903 (-0.008)	337.884 (-0.031)
7	338.123 (-0.020)	338.129 (-0.004)	338.082 (-0.020)	338.016 (-0.010)	337.903 (-0.008)	337.859 (-0.056)
14	338.095 (-0.048)	338.107 (-0.026)	338.063 (-0.039)	338.014 (-0.012)	337.892 (-0.019)	337.820 (-0.095)
21	338.095 (-0.048)	338.078 (-0.055)	338.038 (-0.064)	337.996 (-0.030)	337.855 (-0.056)	337.805 (-0.110)
28	338.095 (-0.048)	338.078 (-0.055)	338.038 (-0.064)	337.989 (-0.037)	337.852 (-0.059)	337.806 (-0.109)

Namakan Lake 1968
Perfect Forecast Routing
IJC 1970 Rule Curves



Rainy Lake 1968
Perfect Forecast Routing
IJC 1970 Rule Curves

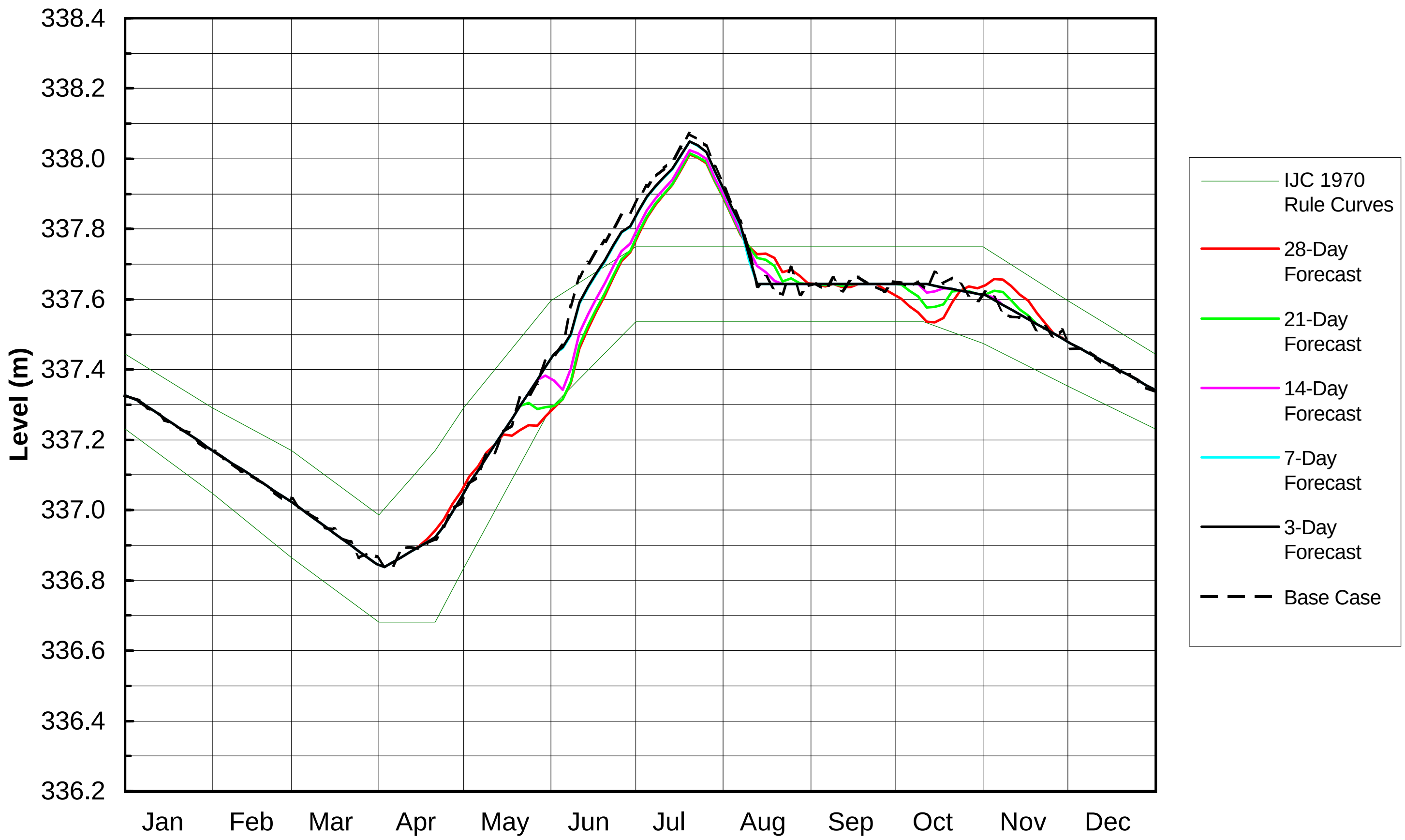


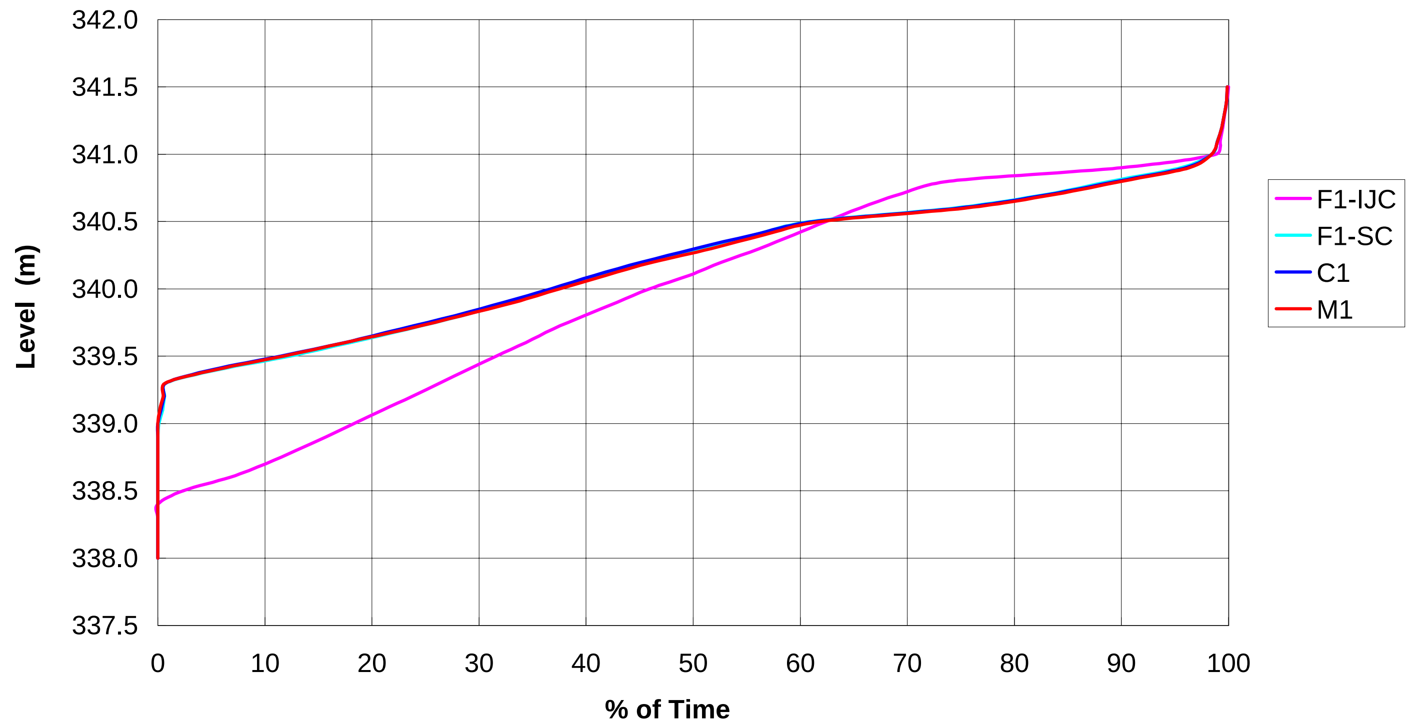
Table 6 - Peak Annual Elevation-Frequency, Rainy and Namakan Lake Levels

	Lake Level Percent Chance Exceedance (Elevation in Meters)			
Namakan Lake Alternatives	**20% (5-yr)**	**10% (10-yr)**	**2% (50-yr)**	**1% (100-yr)**
F1 –IJC	340.95	341.10	341.63	341.92
F1-SC	340.96	341.18	341.77	342.02
C1	340.96	341.18	341.77	342.02
M1	340.96	341.18	341.77	342.02
Rainy Lake Alternatives				
F1-IJC	337.77	337.86	338.50	338.91
F1-SC	337.79	338.00	338.69	339.05
C1	337.76	337.94	338.61	339.00
M1	337.76	337.94	338.61	339.00

Table 7 – Peak Annual Discharge-Frequency, Rainy Lake Outflow

	Rainy Lake Outflow (m^3/s) Percent Chance Exceedance			
Alternatives	**20% (5-yr)**	**10% (10-yr)**	**2% (50-yr)**	**1% (100-yr)**
F1-IJC	925	1040	1270	1330
F1-SC	965	1070	1300	1380
C1	950	1060	1300	1370
M1	935	1040	1270	1360

Namakan Lake
Annual Elevation-Duration Curves
Alternatives F1-IJC, F1-SC, C1 and M1



Rainy Lake
Annual Elevation-Duration Curves
Alternatives F1-IJC, F1-SC, C1 and M1

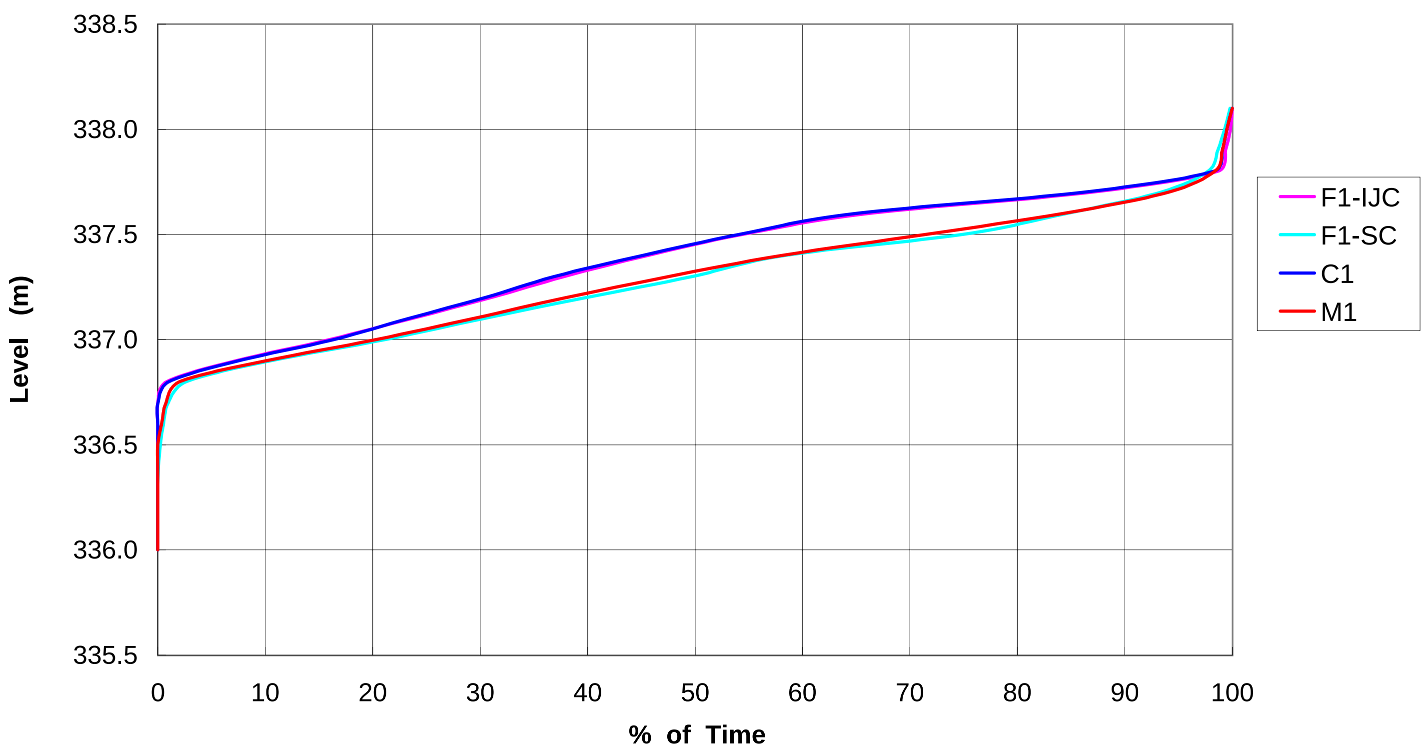


Table 8
Perfect Inflow Forecast
AGO & URC Max Deviations
Constrained by LRC

IJC 1970 Rule Curves

Namakan Lake

# of Days of Perfect Inflow Foreknowledge	Total # of 3-Day Time Steps	# of Time Steps > AGO Level	% of Time Steps > AGO Level	Maximum Deviation (m)	Median Deviation (m)	# of Time Steps > UR Max Level	% of Time Steps > UR Max Level	Maximum Deviation (m)	Median Deviation (m)
3-Day Back-Cast	4740	37	0.78	0.45	0.2	74	1.56	0.6	0.15
3	4740	35	0.74	0.44	0.19	65	1.37	0.59	0.18
7	4740	35	0.74	0.44	0.19	64	1.35	0.59	0.18
14	4740	35	0.74	0.43	0.19	62	1.31	0.58	0.19
21	4740	35	0.74	0.42	0.19	62	1.31	0.57	0.19
28	4740	35	0.74	0.42	0.19	62	1.31	0.57	0.18

Rainy Lake

# of Days of Perfect Inflow Foreknowledge	Total # of 3-Day Time Steps	# of Time Steps > AGO Level	% of Time Steps > AGO Level	Maximum Deviation (m)	Median Deviation (m)	# of Time Steps > UR Max Level	% of Time Steps > UR Max Level	Maximum Deviation (m)	Median Deviation (m)
3-Day Back-Cast	4740	27	0.57	0.17	0.06	75	1.58	0.32	0.1
3	4740	25	0.53	0.15	0.06	59	1.24	0.3	0.12
7	4740	25	0.53	0.15	0.06	58	1.22	0.3	0.12
14	4740	23	0.49	0.12	0.05	50	1.05	0.27	0.15
21	4740	22	0.46	0.12	0.05	47	0.99	0.27	0.15
28	4740	19	0.4	0.11	0.05	46	0.97	0.26	0.14

SC Rule Curves

Namakan Lake

# of Days of Perfect Inflow Foreknowledge	Total # of 3-Day Time Steps	# of Time Steps > AGO Level	% of Time Steps > AGO Level	Maximum Deviation (m)	Median Deviation (m)	# of Time Steps > UR Max Level	% of Time Steps > UR Max Level	Maximum Deviation (m)	Median Deviation (m)
3-Day Back-Cast	4740	46	0.97	0.49	0.16	80	1.69	0.64	0.17
3	4740	43	0.91	0.48	0.15	72	1.52	0.63	0.19
7	4740	43	0.91	0.48	0.15	70	1.48	0.63	0.2
14	4740	39	0.82	0.48	0.17	67	1.41	0.63	0.2
21	4740	39	0.82	0.48	0.16	67	1.41	0.63	0.19
28	4740	39	0.82	0.48	0.15	67	1.41	0.63	0.19

Rainy Lake

# of Days of Perfect Inflow Foreknowledge	Total # of 3-Day Time Steps	# of Time Steps > AGO Level	% of Time Steps > AGO Level	Maximum Deviation (m)	Median Deviation (m)	# of Time Steps > UR Max Level	% of Time Steps > UR Max Level	Maximum Deviation (m)	Median Deviation (m)
3-Day Back-Cast	4740	46	0.97	0.24	0.12	111	2.34	0.39	0.14
3	4740	41	0.86	0.23	0.12	97	2.05	0.38	0.14
7	4740	41	0.86	0.23	0.12	94	1.98	0.38	0.14
14	4740	36	0.76	0.21	0.1	77	1.62	0.36	0.14
21	4740	34	0.72	0.2	0.09	69	1.46	0.35	0.15
28	4740	33	0.7	0.2	0.09	68	1.43	0.35	0.15

Note: AGO is All Gate Open.
UR Max is Upper Rule Curve Maximum.

Table 9
Perfect Inflow Forecast
AGO & URC Max Deviations
Not Constrained by LRC

IJC 1970 Rule Curves

Namakan Lake

# of Days of Perfect Inflow Foreknowledge	Total # of 3-Day Time Steps	# of Time Steps > AGO Level	% of Time Steps > AGO Level	Maximum Deviation (m)	Median Deviation (m)	# of Time Steps > UR Max Level	% of Time Steps > UR Max Level	Maximum Deviation (m)	Median Deviation (m)
3-Day Back-Cast	4740	37	0.78	0.45	0.2	74	1.56	0.6	0.15
3	4740	35	0.74	0.44	0.19	65	1.37	0.59	0.18
7	4740	35	0.74	0.44	0.19	64	1.35	0.59	0.18
14	4740	34	0.72	0.43	0.16	60	1.27	0.58	0.18
21	4740	30	0.63	0.42	0.19	58	1.22	0.57	0.16
28	4740	27	0.57	0.42	0.23	57	1.2	0.57	0.13

Rainy Lake

# of Days of Perfect Inflow Foreknowledge	Total # of 3-Day Time Steps	# of Time Steps > AGO Level	% of Time Steps > AGO Level	Maximum Deviation (m)	Median Deviation (m)	# of Time Steps > UR Max Level	% of Time Steps > UR Max Level	Maximum Deviation (m)	Median Deviation (m)
3-Day Back-Cast	4740	27	0.57	0.17	0.06	75	1.58	0.32	0.1
3	4740	25	0.53	0.15	0.06	59	1.24	0.3	0.12
7	4740	25	0.53	0.15	0.06	58	1.22	0.3	0.12
14	4740	23	0.49	0.12	0.06	51	1.08	0.27	0.15
21	4740	22	0.46	0.1	0.05	49	1.03	0.25	0.14
28	4740	18	0.38	0.08	0.05	47	0.99	0.23	0.14

SC Rule Curves

Namakan Lake

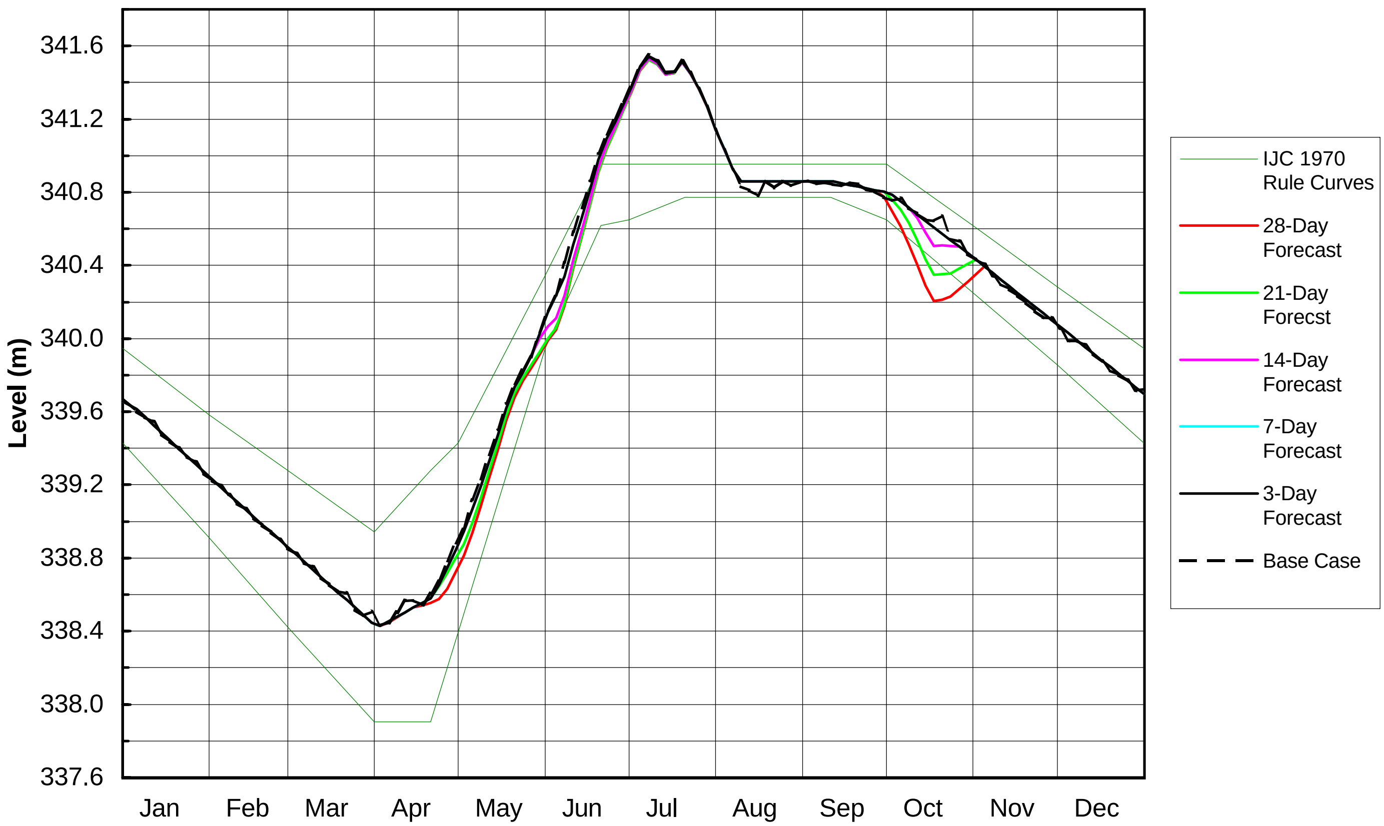
# of Days of Perfect Inflow Foreknowledge	Total # of 3-Day Time Steps	# of Time Steps > AGO Level	% of Time Steps > AGO Level	Maximum Deviation (m)	Median Deviation (m)	# of Time Steps > UR Max Level	% of Time Steps > UR Max Level	Maximum Deviation (m)	Median Deviation (m)
3-Day Back-Cast	4740	46	0.97	0.49	0.16	80	1.69	0.64	0.17
3	4740	43	0.91	0.48	0.15	72	1.52	0.63	0.19
7	4740	42	0.89	0.48	0.14	70	1.48	0.63	0.19
14	4740	34	0.72	0.47	0.19	67	1.41	0.62	0.16
21	4740	30	0.63	0.45	0.21	62	1.31	0.6	0.13
28	4740	28	0.59	0.44	0.23	60	1.27	0.59	0.13

Rainy Lake

# of Days of Perfect Inflow Foreknowledge	Total # of 3-Day Time Steps	# of Time Steps > AGO Level	% of Time Steps > AGO Level	Maximum Deviation (m)	Median Deviation (m)	# of Time Steps > UR Max Level	% of Time Steps > UR Max Level	Maximum Deviation (m)	Median Deviation (m)
3-Day Back-Cast	4740	46	0.97	0.24	0.12	111	2.34	0.39	0.14
3	4740	41	0.86	0.23	0.12	97	2.05	0.38	0.14
7	4740	41	0.86	0.23	0.12	93	1.96	0.38	0.14
14	4740	36	0.76	0.21	0.1	72	1.52	0.36	0.16
21	4740	30	0.63	0.15	0.08	59	1.24	0.3	0.16
28	4740	24	0.51	0.11	0.06	54	1.14	0.26	0.14

Note: AGO is All Gate Open.
UR Max is Upper Rule Curve Maximum.

Namakan Lake 1968
Unconstrained Perfect Forecast Routing
IJC 1970 Rule Curves



Rainy Lake 1968
Unconstrained Perfect Forecast Routing
IJC 1970 Rule Curves

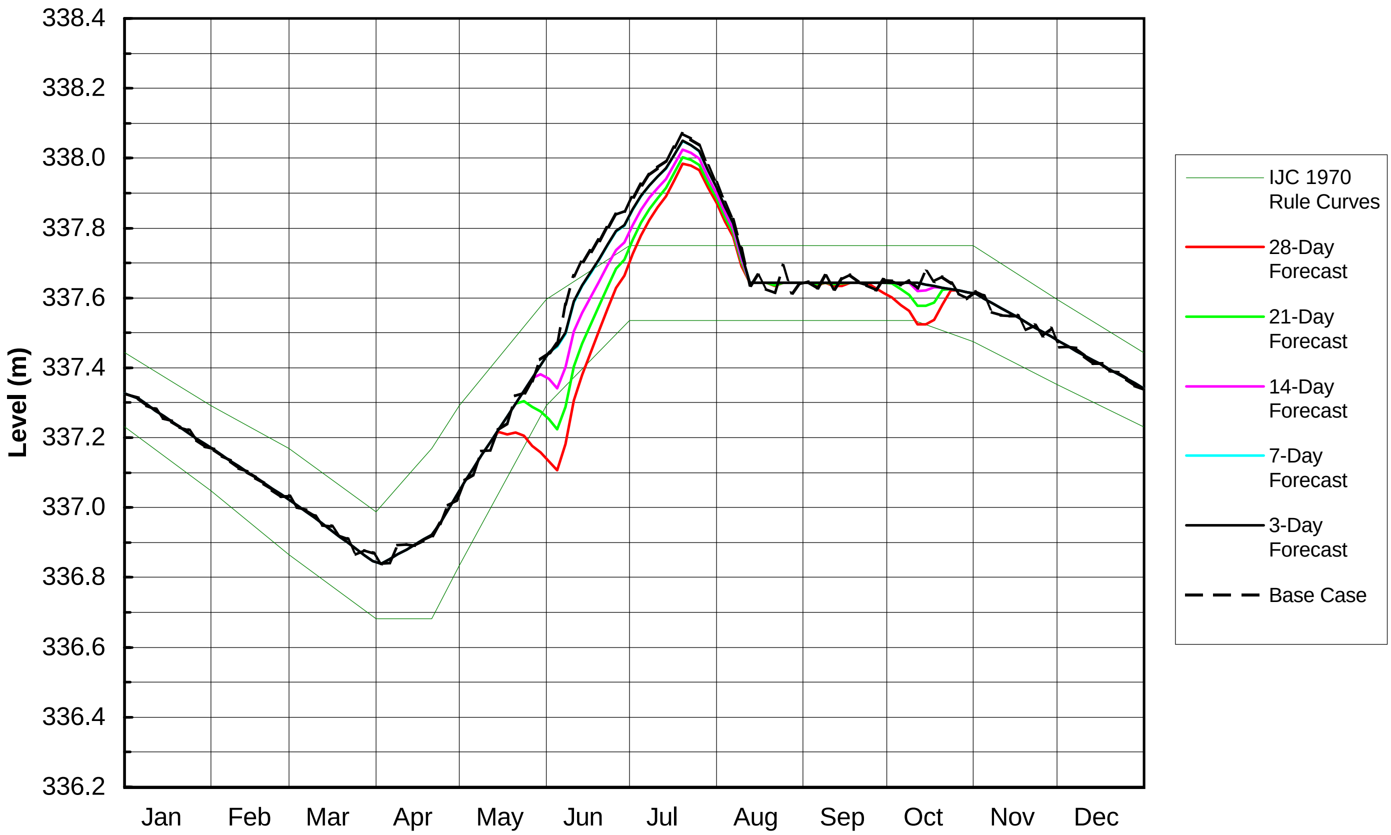
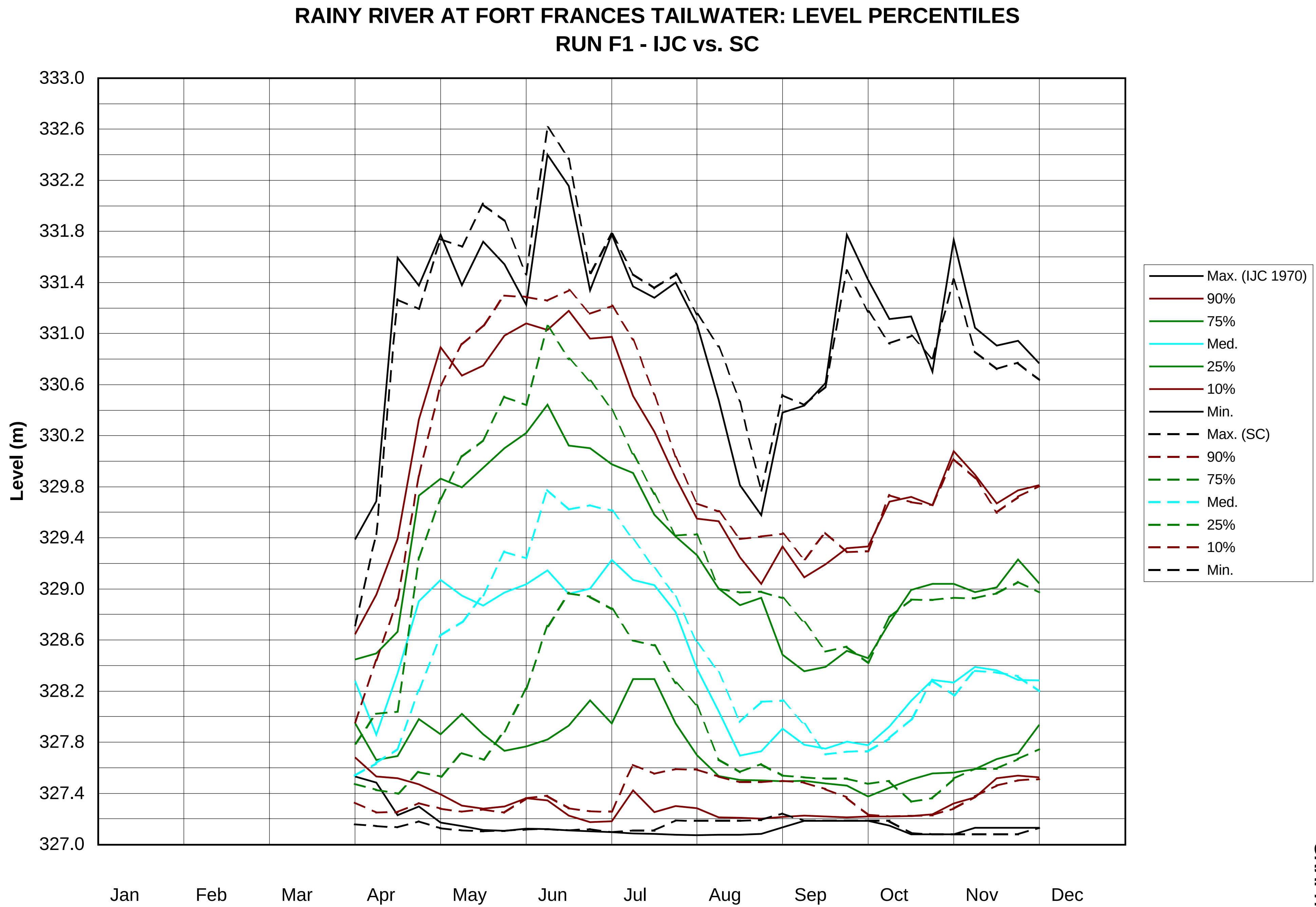


TABLE 10 - RAINY RIVER LEVEL RESULTS - 39 YEAR RUNS (1958-96)

SCENARIO RUNS		FORT FRANCES TAILWATER				MANITOU RAPIDS				TOWN OF RAINY RIVER			
		F1-IJC	F1-SC	C1	M1	F1-IJC	F1-SC	C1	M1	F1-IJC	F1-SC	C1	M1
Mar 31	Mean Level	328.25	327.63	328.18	328.05	325.54	325.03	325.48	325.38	322.41	322.39	322.41	322.40
	Max Level/Year	329.39/1966	328.71/1966	329.35/1966	329.11/1966	326.57/1966	326.00/1966	326.54/1966	326.32/1966	322.57/1966	322.51/1966	322.56/1966	322.55/1966
	75 %ile Level	328.46	327.79	328.39	328.26	325.74	325.16	325.69	325.56	322.43	322.40	322.43	322.42
	50 %ile Level	328.28	327.54	328.20	328.04	325.53	324.94	325.51	325.37	322.41	322.39	322.41	322.39
	25 %ile Level	327.95	327.47	327.87	327.78	325.31	324.84	325.26	325.18	322.39	322.36	322.38	322.37
	Min Level/Year	327.53/1977	327.16/1988	327.50/1977	327.18/1977	324.82/1977	324.41/1977	324.78/1977	324.41/1977	322.34/1977	322.32/1964	322.32/1977	322.32/1977
Apr 30	Mean Level	329.08	328.84	329.06	329.09	326.62	326.42	326.59	326.62	322.77	322.73	322.77	322.77
	Max Level/Year	331.78/1975	331.74/1975	331.92/1975	331.89/1975	329.52/1975	329.50/1975	329.61/1975	329.60/1975	323.93/1975	323.98/1979	323.96/1975	323.96/1975
	75 %ile Level	329.87	329.78	329.88	329.92	327.40	327.30	327.41	327.43	322.93	322.88	322.93	322.93
	50 %ile Level	329.08	328.64	329.06	329.06	326.43	326.27	326.37	326.38	322.64	322.56	322.63	322.63
	25 %ile Level	328.01	327.56	327.89	328.06	325.61	325.27	325.52	325.64	322.45	322.41	322.43	322.44
	Min Level/Year	327.17/1977	327.13/1977	327.16/1977	327.16/1977	324.49/1977	324.43/1977	324.48/1977	324.47/1977	322.32/1987	322.32/1958	322.32/1987	322.32/1987
										35946.00	35946.00	35946.00	35946.00
May 31	Mean Level	329.09	329.31	329.18	329.16	326.37	326.55	326.45	326.43	322.89	322.93	322.91	322.91
	Max Level/Year	331.23/1966	331.46/1962	331.33/1996	331.33/1996	328.51/1962	328.70/1962	328.58/1962	328.56/1962	323.85/1962	323.97/1962	323.89/1962	323.88/1966
	75 %ile Level	330.26	330.49	330.42	330.34	327.45	327.61	327.48	327.48	323.15	323.21	323.18	323.16
	50 %ile Level	329.05	329.25	329.11	329.07	326.24	326.46	326.32	326.30	322.76	322.83	322.79	322.79
	25 %ile Level	327.91	328.31	328.02	327.98	325.62	325.79	325.68	325.65	322.54	322.53	322.54	322.54
	Min Level/Year	327.12/1980	327.12/1980	327.12/1980	327.13/1977	324.39/1958	324.39/1958	324.39/1958	324.39/1958	322.30/1958	322.27/1958	322.29/1958	322.30/1958
Jun 30	Mean Level	329.16	329.53	329.26	329.26	326.38	326.70	326.47	326.47	323.02	323.11	323.06	323.06
	Max Level/Year	331.78/1985	331.78/1985	331.80/1985	331.80/1985	329.37/1985	329.37/1985	329.38/1985	329.38/1985	324.23/1985	324.30/1985	324.29/1985	324.29/1985
	75 %ile Level	329.99	330.41	330.09	330.07	327.27	327.54	327.28	327.26	323.24	323.35	323.29	323.29
	50 %ile Level	329.39	329.62	329.39	329.39	326.50	326.86	326.57	326.58	322.97	323.04	323.00	323.00
	25 %ile Level	328.18	328.93	328.35	328.35	325.55	326.06	325.68	325.70	322.68	322.78	322.74	322.74
	Min Level/Year	327.09/1980	327.09/1980	327.09/1980	327.09/1980	324.35/1958	324.41/1980	324.35/1958	324.35/1958	322.33/1958	322.31/1958	322.32/1958	322.33/1958
Jul 31	Mean Level	328.53	328.71	328.57	328.66	325.78	325.94	325.83	325.90	322.90	322.95	322.92	322.94
	Max Level/Year	331.07/1968	331.15/1968	331.12/1968	331.12/1968	327.92/1968	328.00/1993	327.95/1968	328.03/1993	323.63/1968	323.69/1968	323.67/1968	323.68/1968
	75 %ile Level	329.29	329.44	329.37	329.44	326.41	326.57	326.44	326.53	323.08	323.11	323.10	323.12
	50 %ile Level	328.41	328.60	328.47	328.59	325.63	325.84	325.69	325.87	322.93	322.93	322.93	322.95
	25 %ile Level	327.77	328.12	327.84	328.03	325.17	325.40	325.16	325.32	322.75	322.83	322.80	322.81
	Min Level/Year	327.07/1988	327.18/1988	327.08/1980	327.08/1980	324.32/1988	324.47/1988	324.37/1980	324.37/1980	322.36/1980	322.36/1980	322.36/1980	322.36/1980
		USCGS(1912) Datum				GSC(1929) Datum				GSC(1979) Datum			

TABLE 10

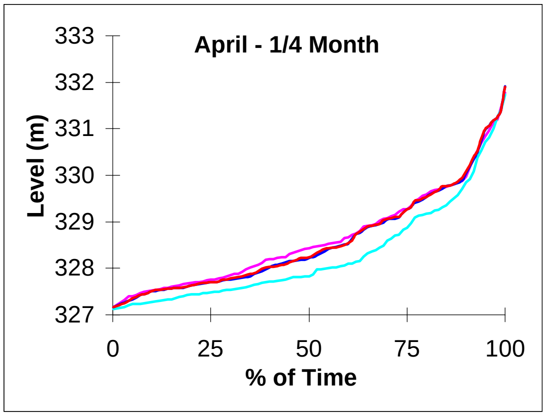


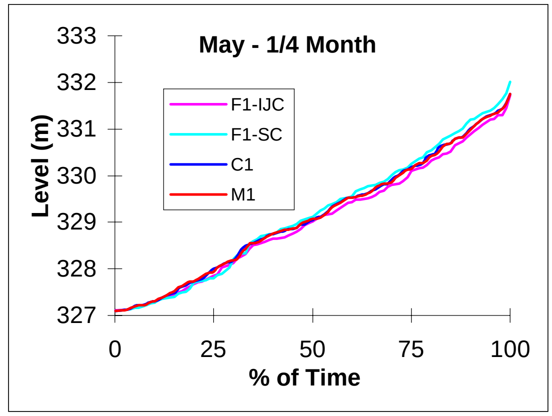
USCGS(1912) Datum

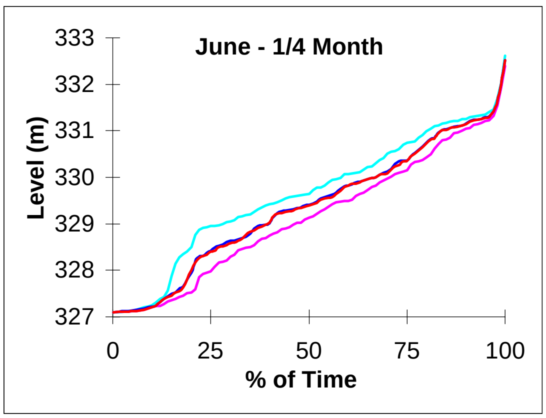
GRAPH 21

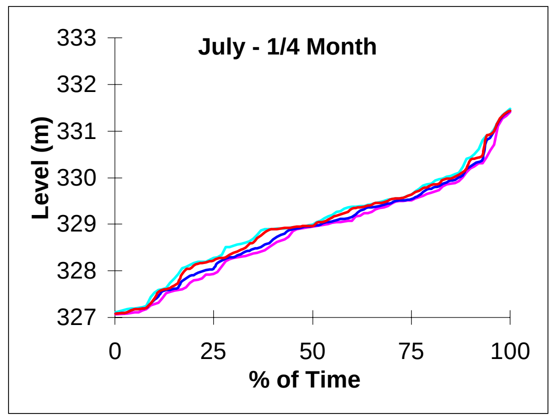
Rainy River at Fort Frances Tailwater

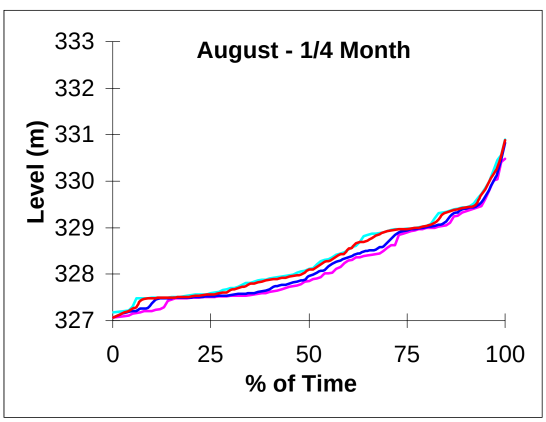
IJC-SC-C1-M1 - Level Duration Curves

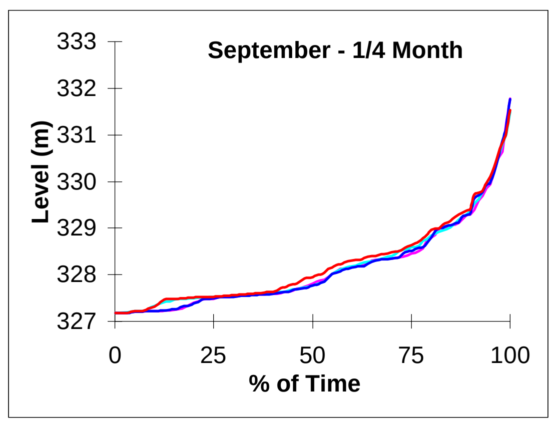


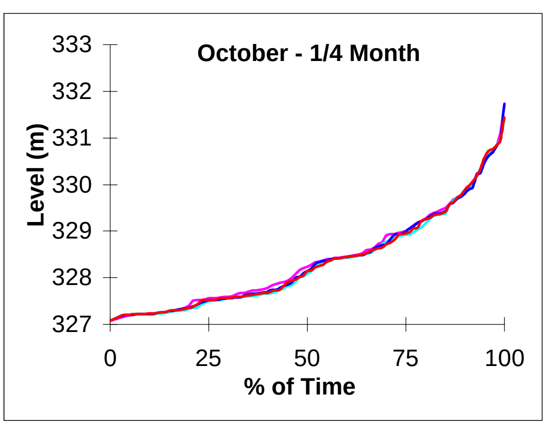


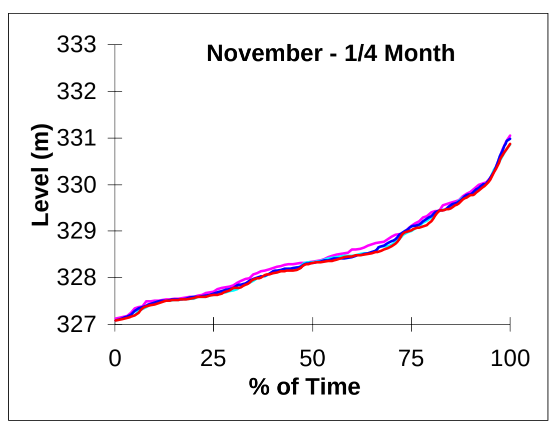






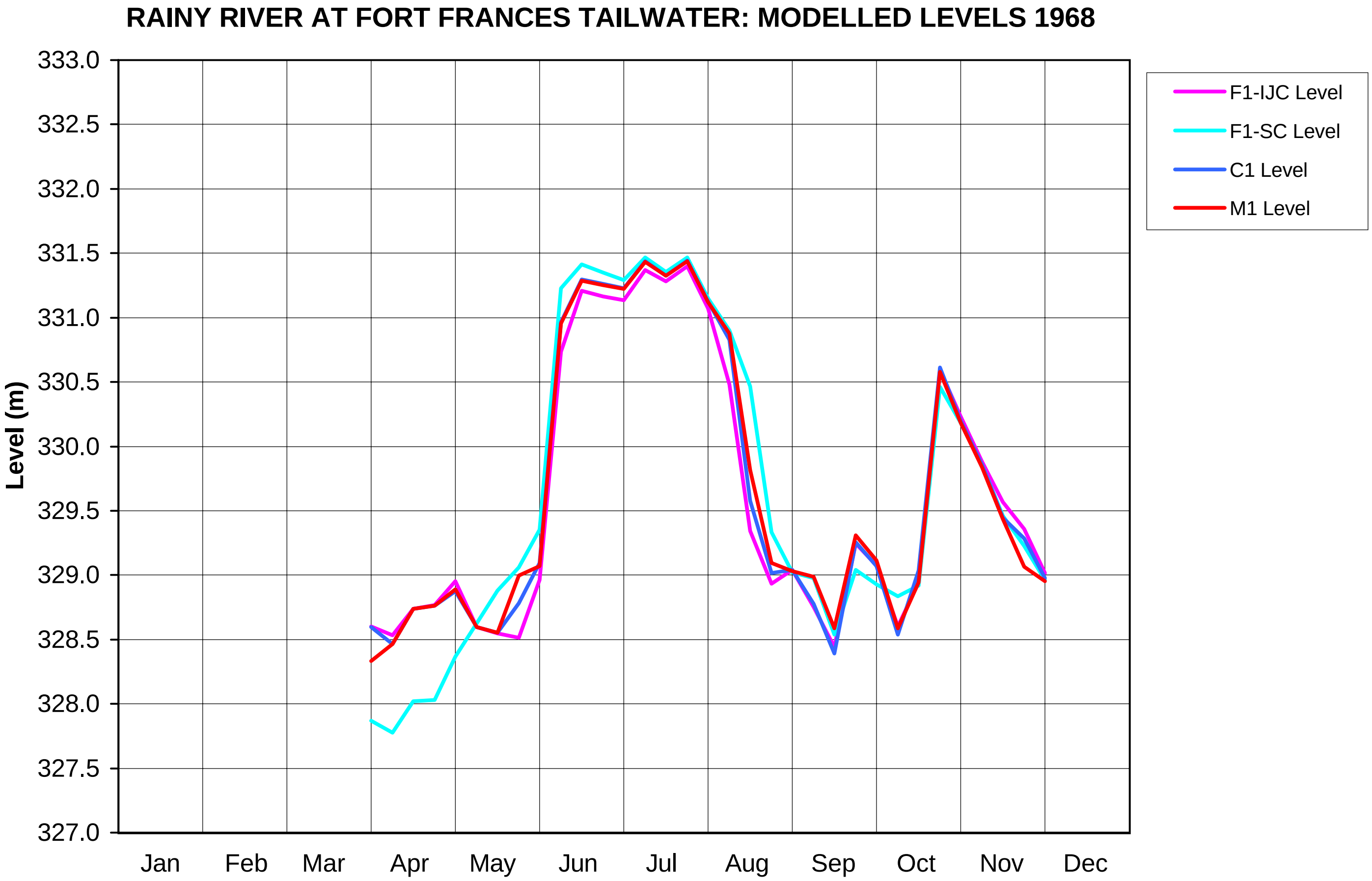


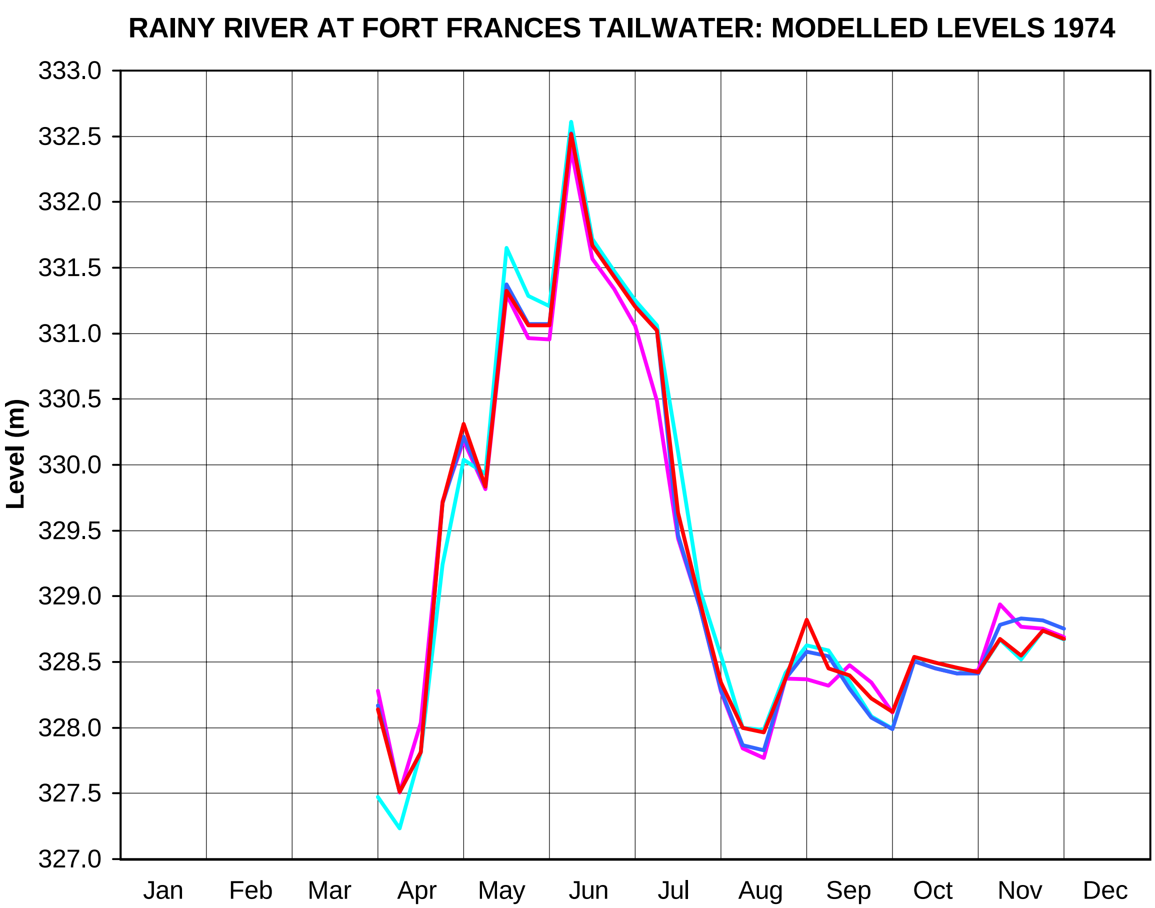




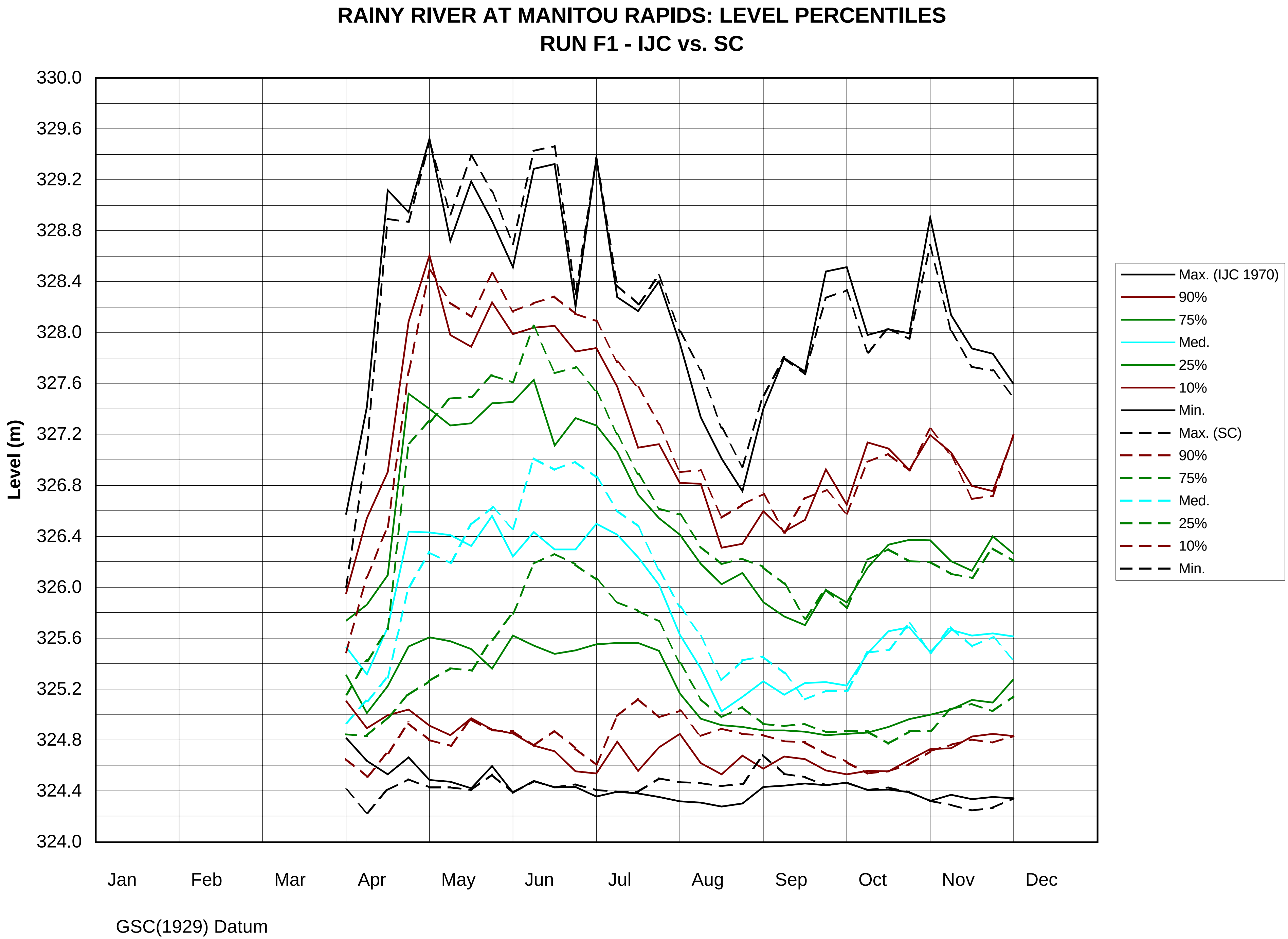
USCGS(1912) Datum

GRAPH 23





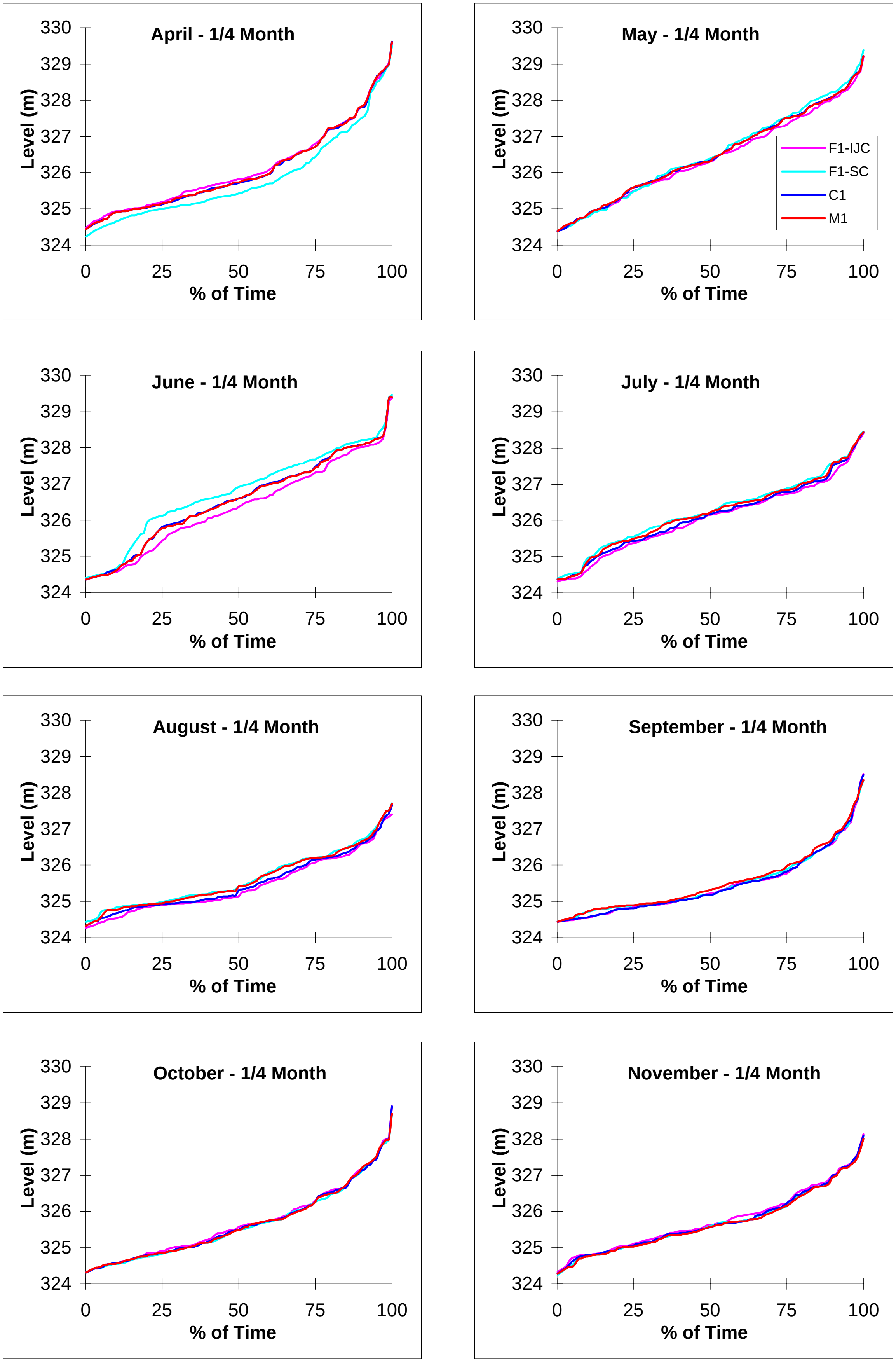
USCGS(1912) Datum


RAINY RIVER AT MANITOU RAPIDS: LEVEL PERCENTILES
RUN F1 - IJC vs. SC
Level (m)
330.0
329.6
329.2
328.8
328.4
328.0
327.6
327.2
326.8
326.4
326.0
325.6
325.2
324.8
324.4
324.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Max. (IJC 1970)
90%
75%
Med.
25%
10%
Min.
Max. (SC)
90%
75%
Med.
25%
10%
Min.
GSC(1929) Datum

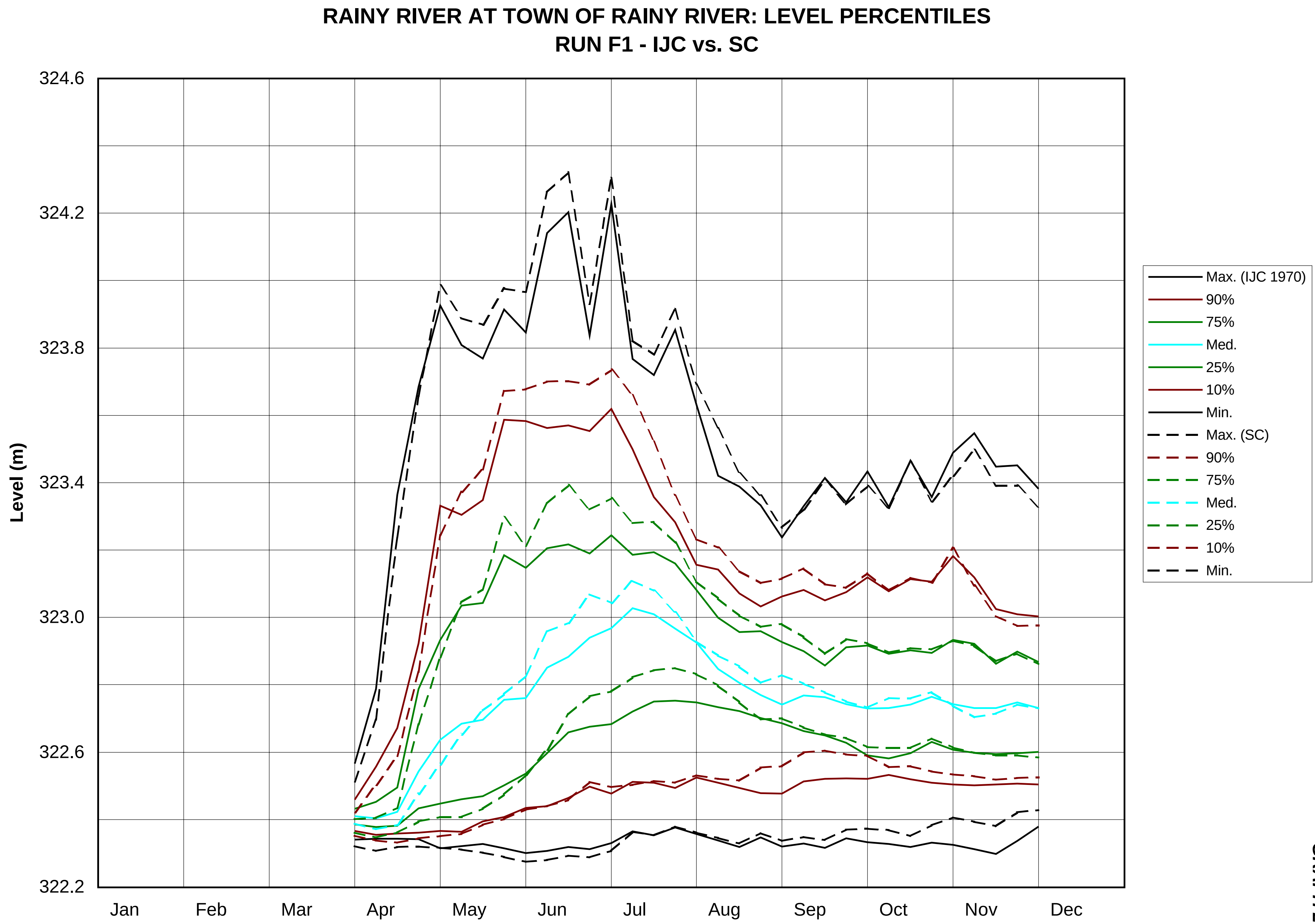
GRAPH 24

Rainy River at Manitou Rapids

IJC-SC-C1-M1 - Level Duration Curves



GSC(1929) Datum

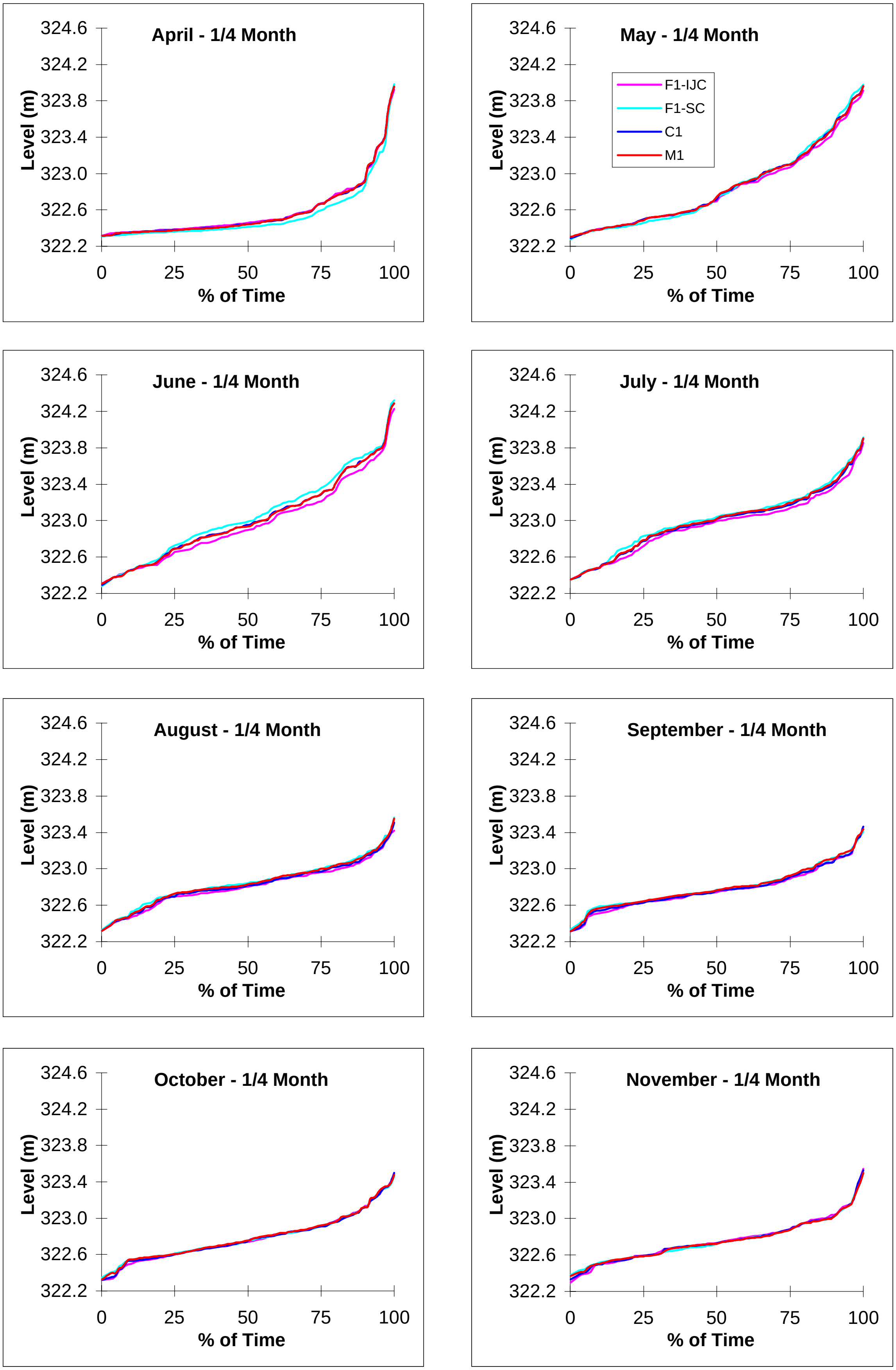


GSC(1979) Datum

GRAPH 26

Rainy River at Town of Rainy River

IJC-SC-C1-M1 - Level Duration Curves



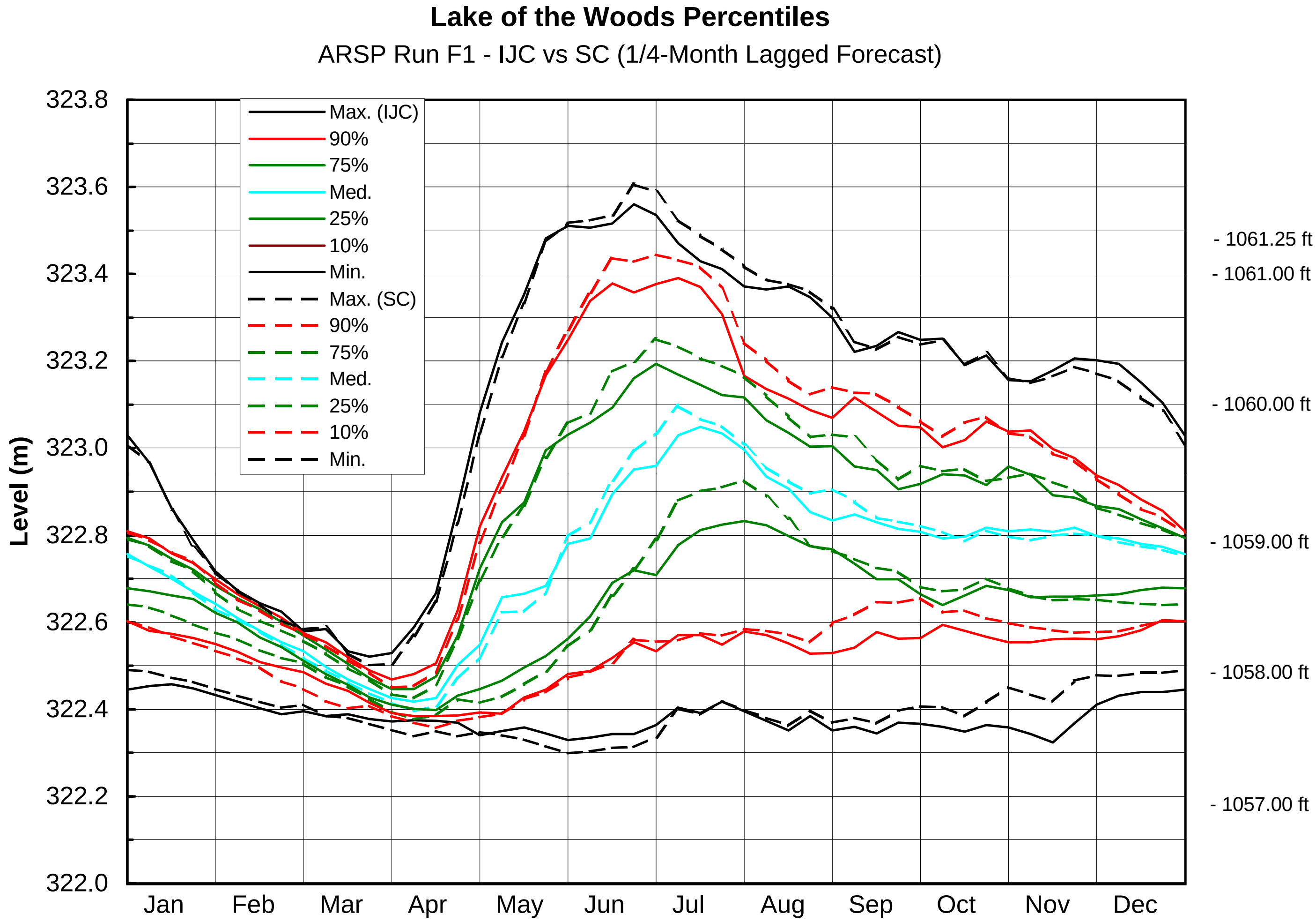
GSC(1979) Datum

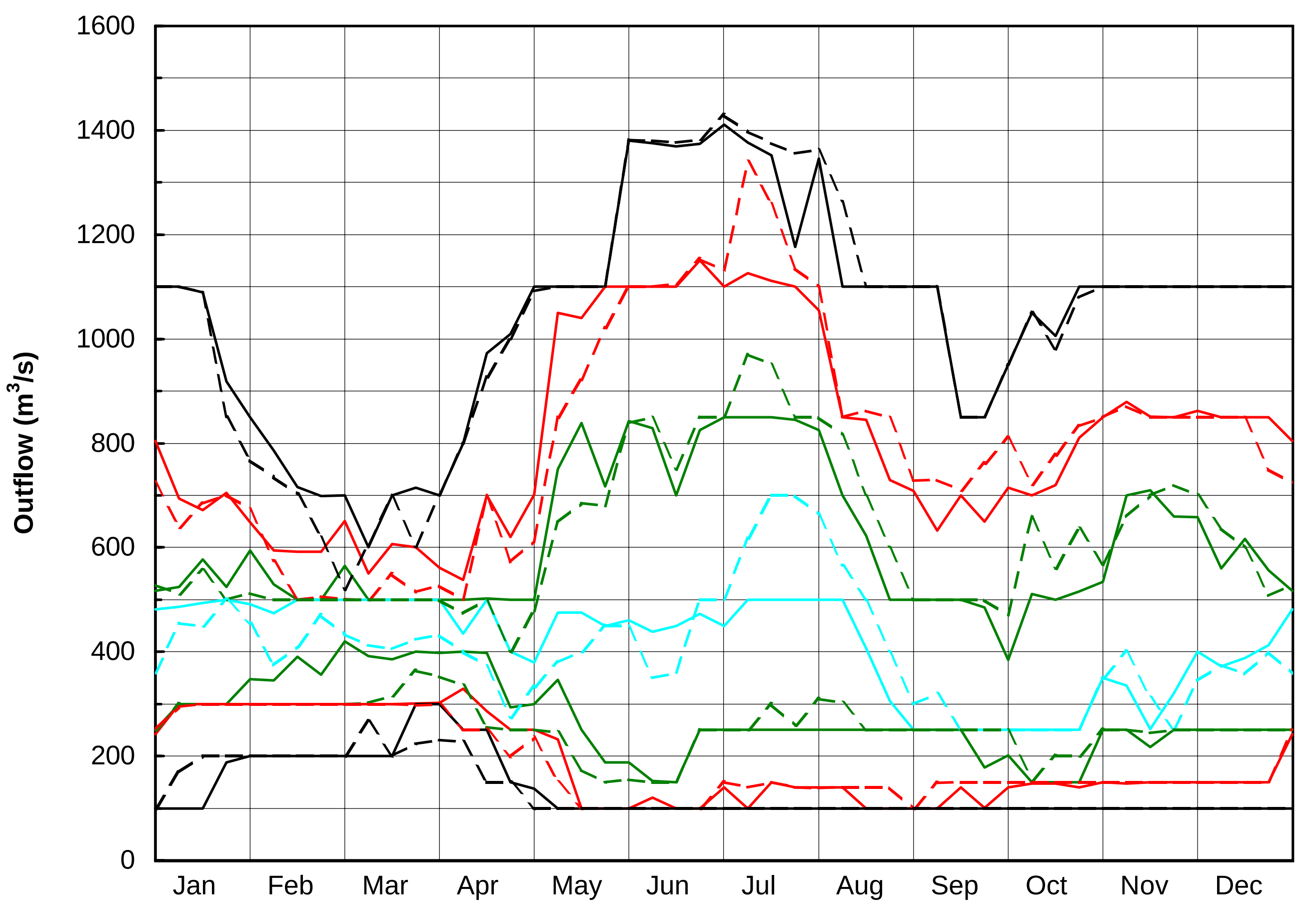
LAKE OF THE WOODS MODELLING - SUMMARY OF RESULTS FROM 39 YEAR RUNS (1958-1996) - 1/4-Month Lagged Forecast

SCENARIO RUNS	F1-IJC (Existing IJC Rule Curves)	F1-SC (Proposed Strg Committee Rule Crvs)	C1 (IJC Crvs on Rainy, SC on Namakan)	M1 (Modified C1)
Maximum Lake Level / Year	323.560 / 1970	323.606 / 1970	323.594 / 1970	323.598 / 1970
Minimum Lake Level / Year	322.324 / 1958	322.299 / 1958	322.316 / 1958	322.332 / 1958
Mean Lake Level	322.739	322.747	322.743	322.746
#Periods Lake Level > 323.47 (1061.25)	8	16	14	13
#Periods Lake Level > 323.39 (1061.00)	21	35	31	31
#Periods Lake Level > 323.24 (1060.50)	70	81	72	74
#Periods Lake Level > 323.09 (1060.00)	165	201	183	186
#Periods Lake Level > 322.94 (1059.50)	384	419	397	417
Maximum Discharge / Year	1411 / 1970	1429 / 1970	1424 / 1970	1425 / 1970
#Periods Discharge > 1100 m^3/s	23	37	31	31
#Periods Discharge > 900 m^3/s	135	142	136	139
#Periods Discharge > 700 m^3/s	290	314	303	297
#Periods Discharge > 420 m^3/s	950	892	924	913
#Periods Discharge < 420 m^3/s	922	979	948	959
#Periods Discharge < 300 m^3/s	599	619	610	598
#Periods Discharge < 150 m^3/s	137	116	123	112
Mean / Max / Min Lake Level - May	322.742 / 323.397 / 322.350	322.727 / 323.384 / 322.322	322.744 / 323.410 / 322.337	322.746 / 323.409 / 322.353
Mean / Max / Min Lake Level - June	322.913 / 323.506 / 322.346	322.944 / 323.527 / 322.316	322.934 / 323.529 / 322.333	322.933 / 323.529 / 322.349
Mean / Max / Min Lake Level - July	322.973 / 323.353 / 322.402	323.024 / 323.424 / 322.402	323.002 / 323.405 / 322.402	323.005 / 323.412 / 322.403
Mean / Max / Min Lake Level - August	322.876 / 323.342 / 322.365	322.912 / 323.353 / 322.378	322.891 / 323.345 / 322.366	322.903 / 323.358 / 322.366
Mean / Max / Min Lake Level - September	322.816 / 323.219 / 322.362	322.849 / 323.210 / 322.388	322.825 / 323.206 / 322.363	322.842 / 323.219 / 322.364
Mean / Max / Min Outflow - January-February	468 / 840 / 173	438 / 787 / 196	449 / 808 / 179	437 / 781 / 188
Mean / Max / Min Outflow - April	451 / 970 / 211	391 / 936 / 194	431 / 954 / 200	420 / 948 / 192
Mean / Max / Min Outflow - May	530 / 1170 / 100	482 / 1170 / 100	523 / 1196 / 100	524 / 1192 / 100
Mean / Max / Min Outflow - June	520 / 1374 / 100	547 / 1381 / 100	535 / 1382 / 100	534 / 1382 / 100
Mean / Max / Min Outflow - July	573 / 1218 / 100	651 / 1283 / 100	609 / 1243 / 100	606 / 1248 / 100
Mean / Max / Min Outflow - August	431 / 1065 / 100	483 / 1090 / 100	462 / 1097 / 100	475 / 1100 / 100
Mean / Max / Min Winter Drawdown	0.379 / 0.736 / 0.085	0.389 / 0.739 / 0.136	0.385 / 0.739 / 0.108	0.388 / 0.725 / 0.122
Mean / Max / Min Annual Refill	0.643 / 1.179 / 0.121	0.711 / 1.246 / 0.107	0.679 / 1.228 / 0.126	0.683 / 1.226 / 0.124
#Years Summer Level < 322.78 (1059.00)	23	22	23	24
#Years Summer Level < 322.63 (1058.50)	10	10	10	10
#Years Summer Level < 322.48 (1058.00)	4	4	4	4
#Years Summer Level < 322.33 (1057.50)	0	1	0	0
#Years End April Level < 322.48 (1058.00)	12	15	13	13

NOTES:
1) Total number of quarter monthly periods simulated = 1872
2) Mean / Max / Min - are obtained from 39 averages computed for each year
3) Winter drawdown is the difference between the highest level after Nov 15 and the lowest level before Mar 31
4) Annual Refill is the rise between the lowest level after Feb 1 and the highest level before Jul 31
5) Units are metres for levels and cubic metres per second for flows

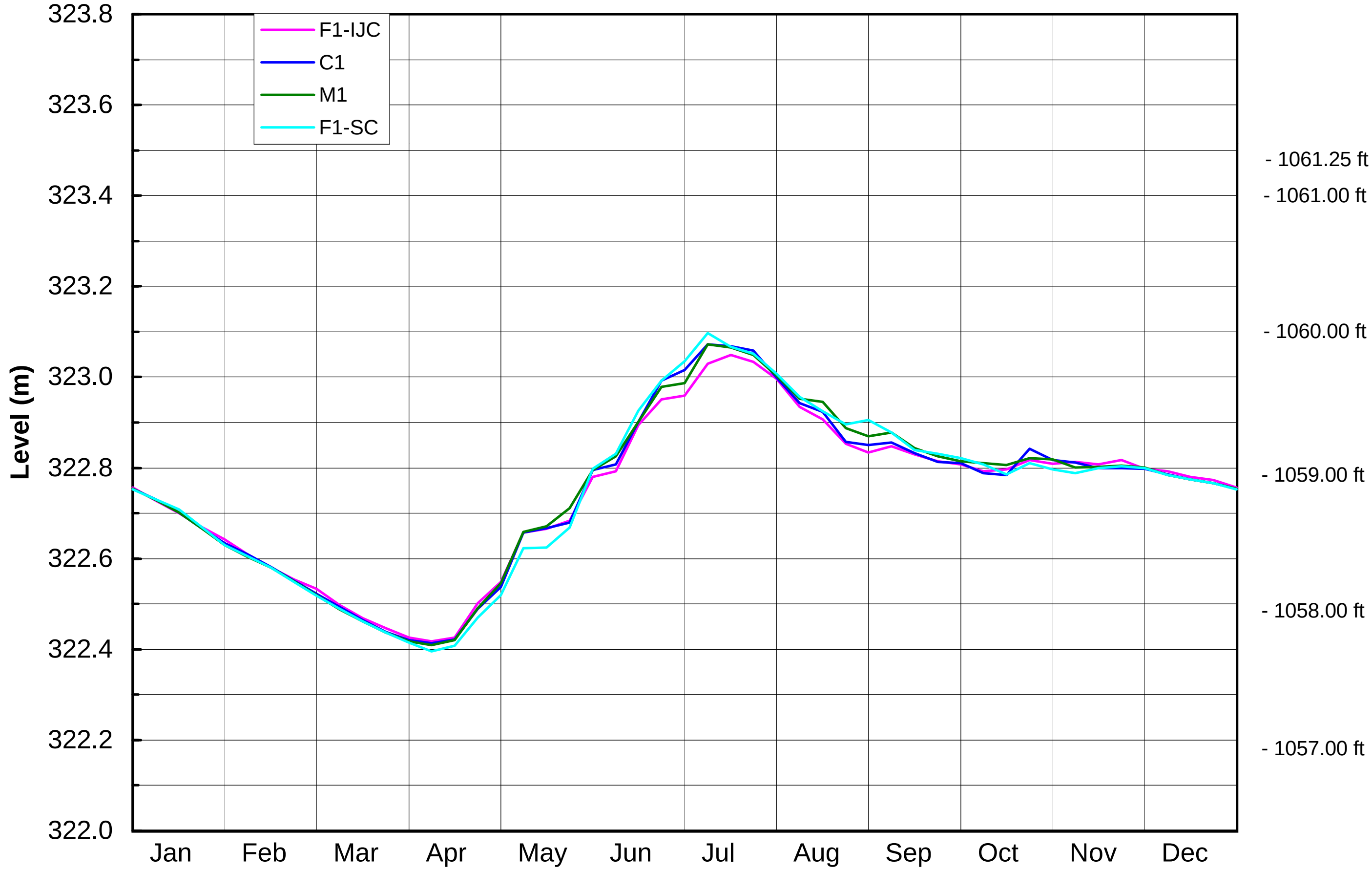
TABLE 11

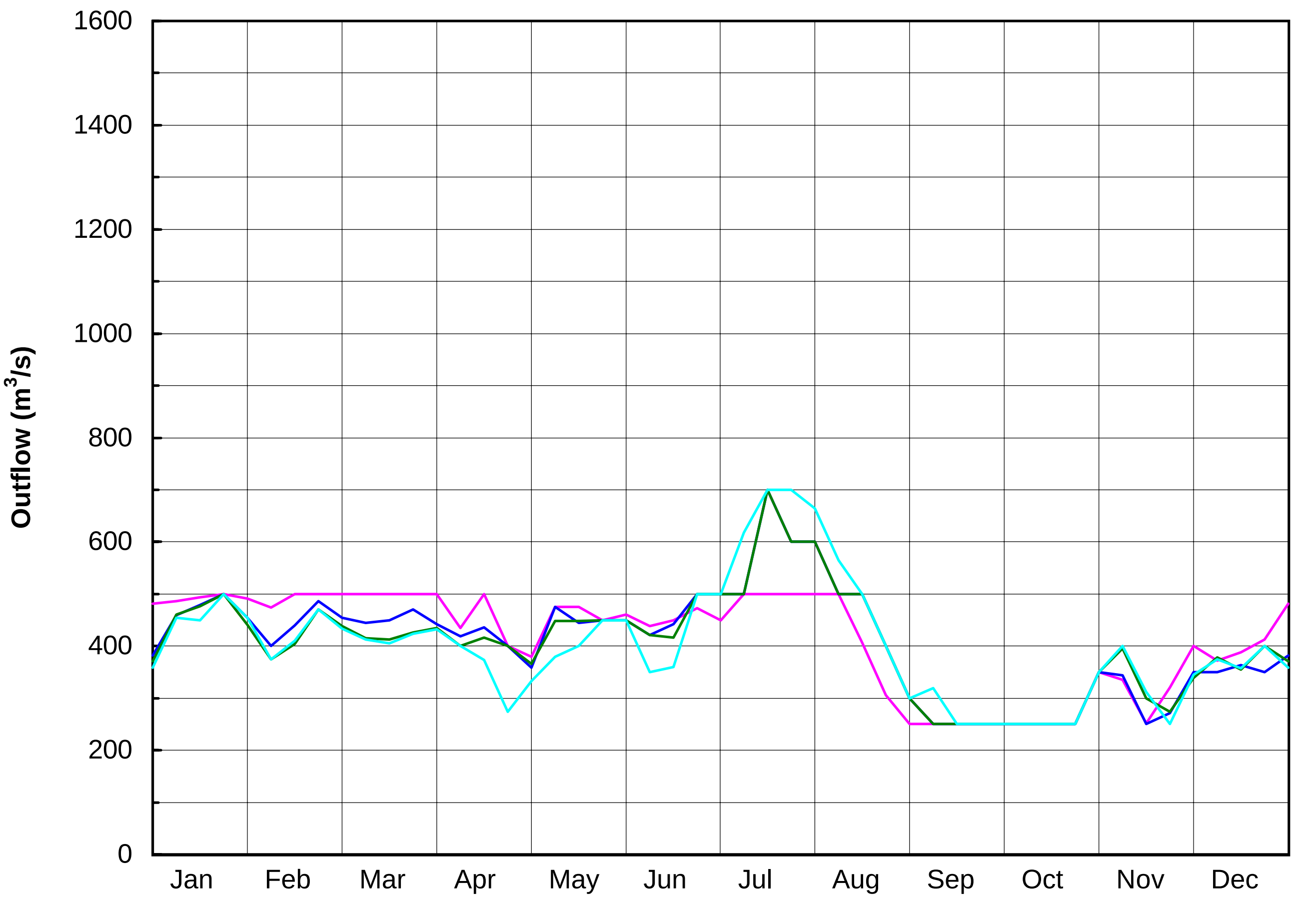

Lake of the Woods Percentiles
ARSP Run F1 - IJC vs SC (1/4-Month Lagged Forecast)
Level (m)
323.8
323.6
323.4
323.2
323.0
322.8
322.6
322.4
322.2
322.0
Max. (IJC)
90%
75%
Med.
25%
10%
Min.
Max. (SC)
90%
75%
Med.
25%
10%
Min.
- 1061.25 ft
- 1061.00 ft
- 1060.00 ft
- 1059.00 ft
- 1058.00 ft
- 1057.00 ft
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec


Outflow (m^3/s)
1600
1400
1200
1000
800
600
400
200
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Lake of the Woods 50th Percentile Comparison

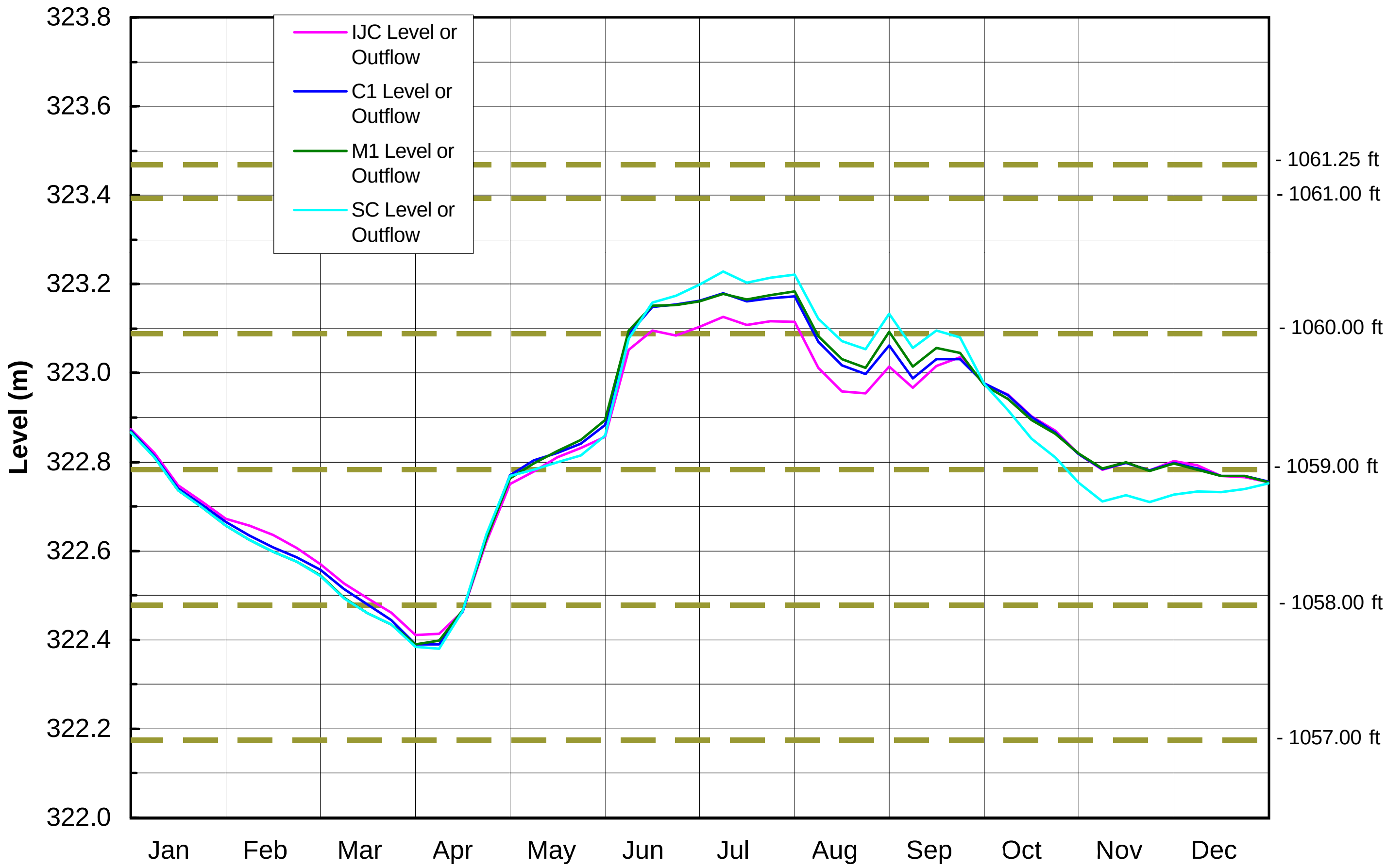
ARSP Run F1-(IJC & SC)-C1-M1 (1/4-Month Lagged Forecast)

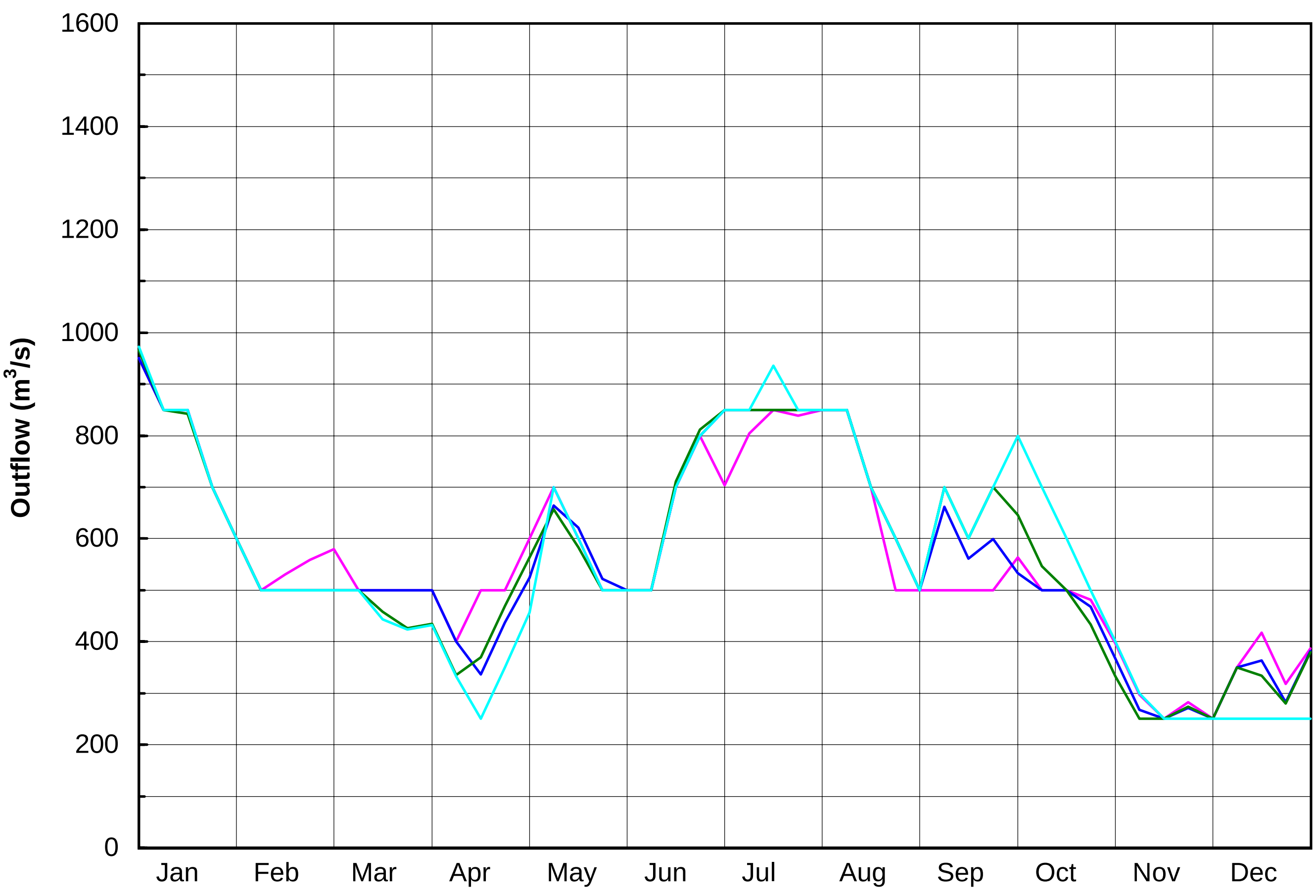




Lake of the Woods 1978

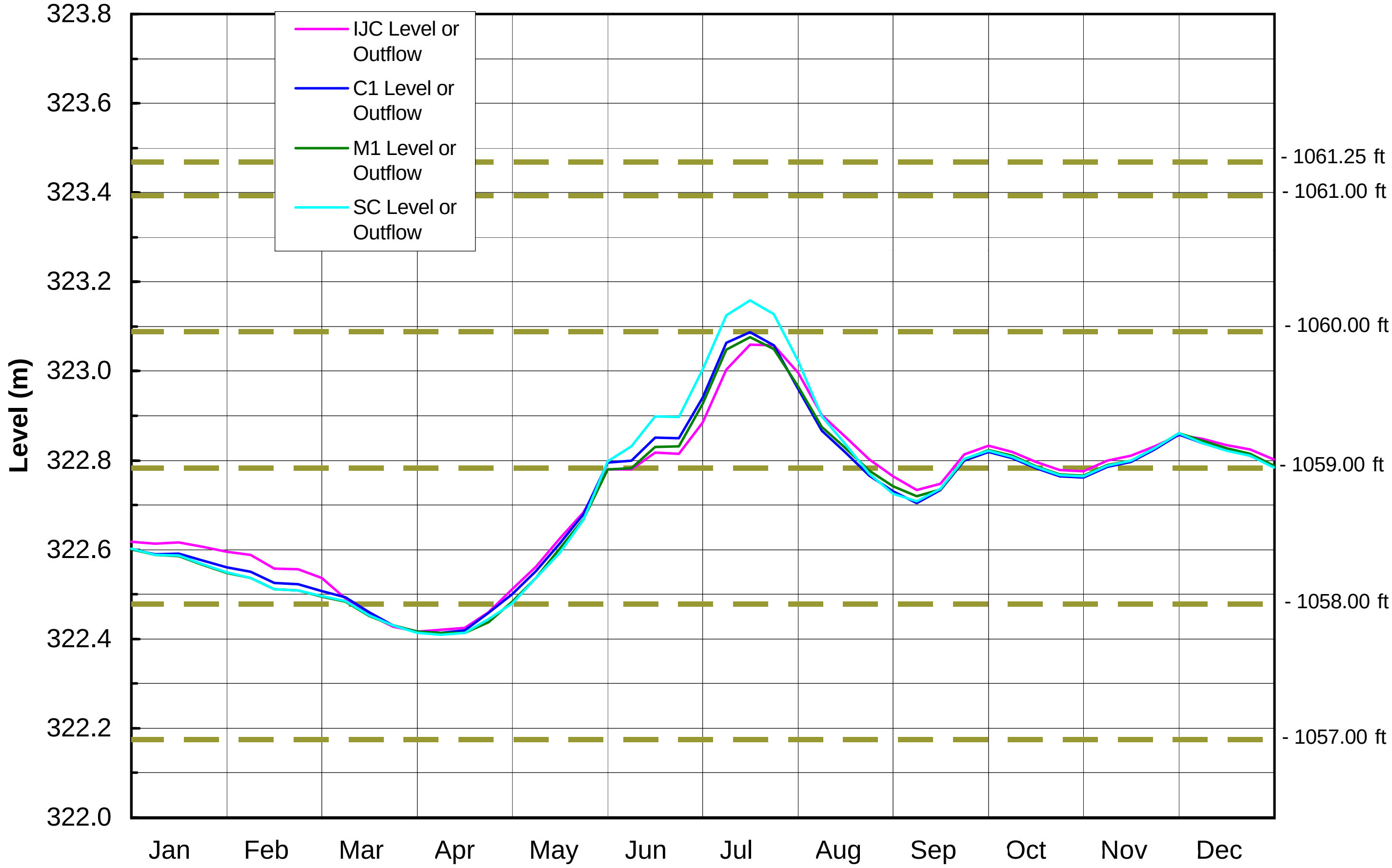
ARSP Runs F1(IJC & SC)-C1-M1 (1/4-Month Lagged Forecast)

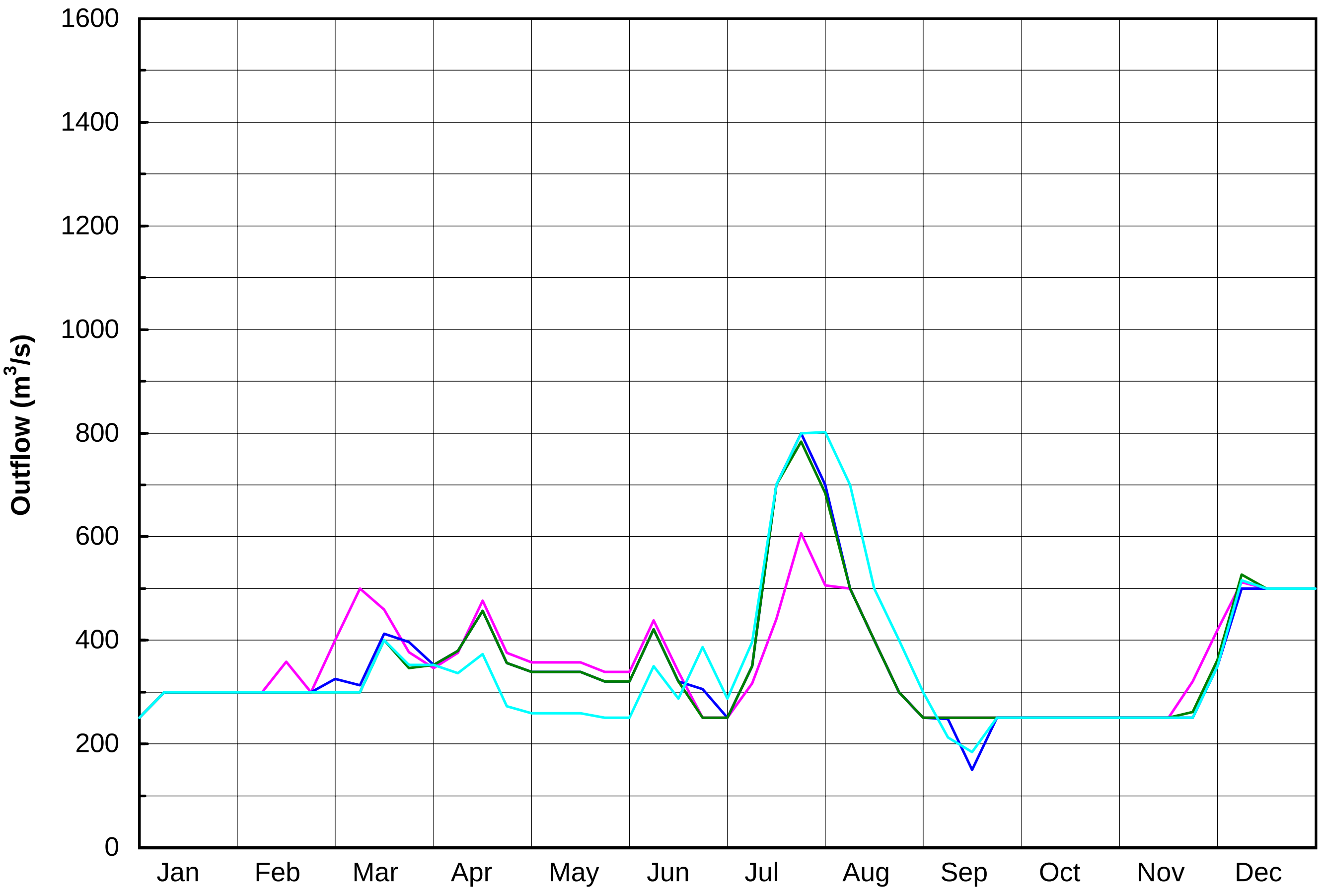




Lake of the Woods 1991

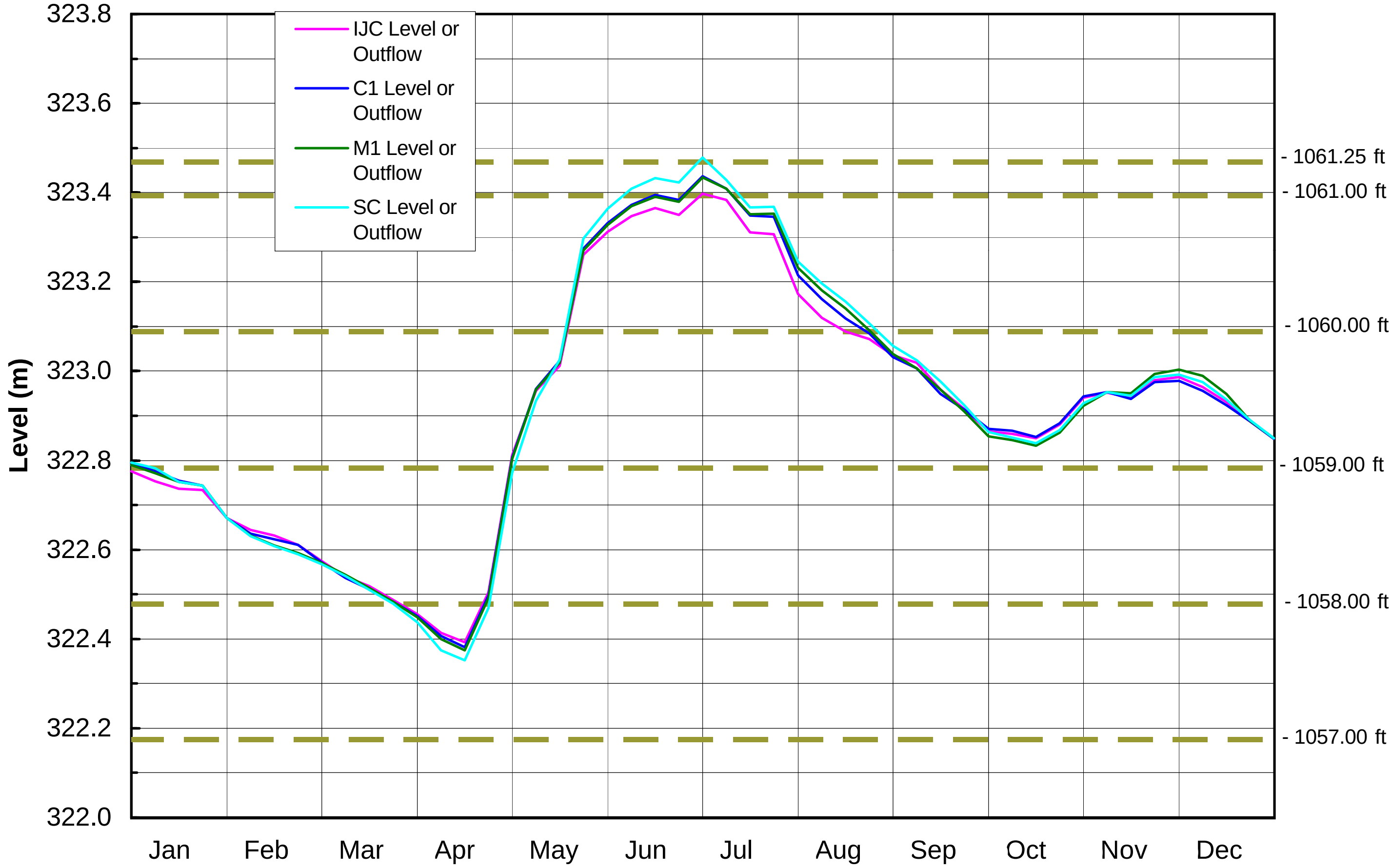
ARSP Runs F1(IJC & SC)-C1-M1 (1/4-Month Lagged Forecast)

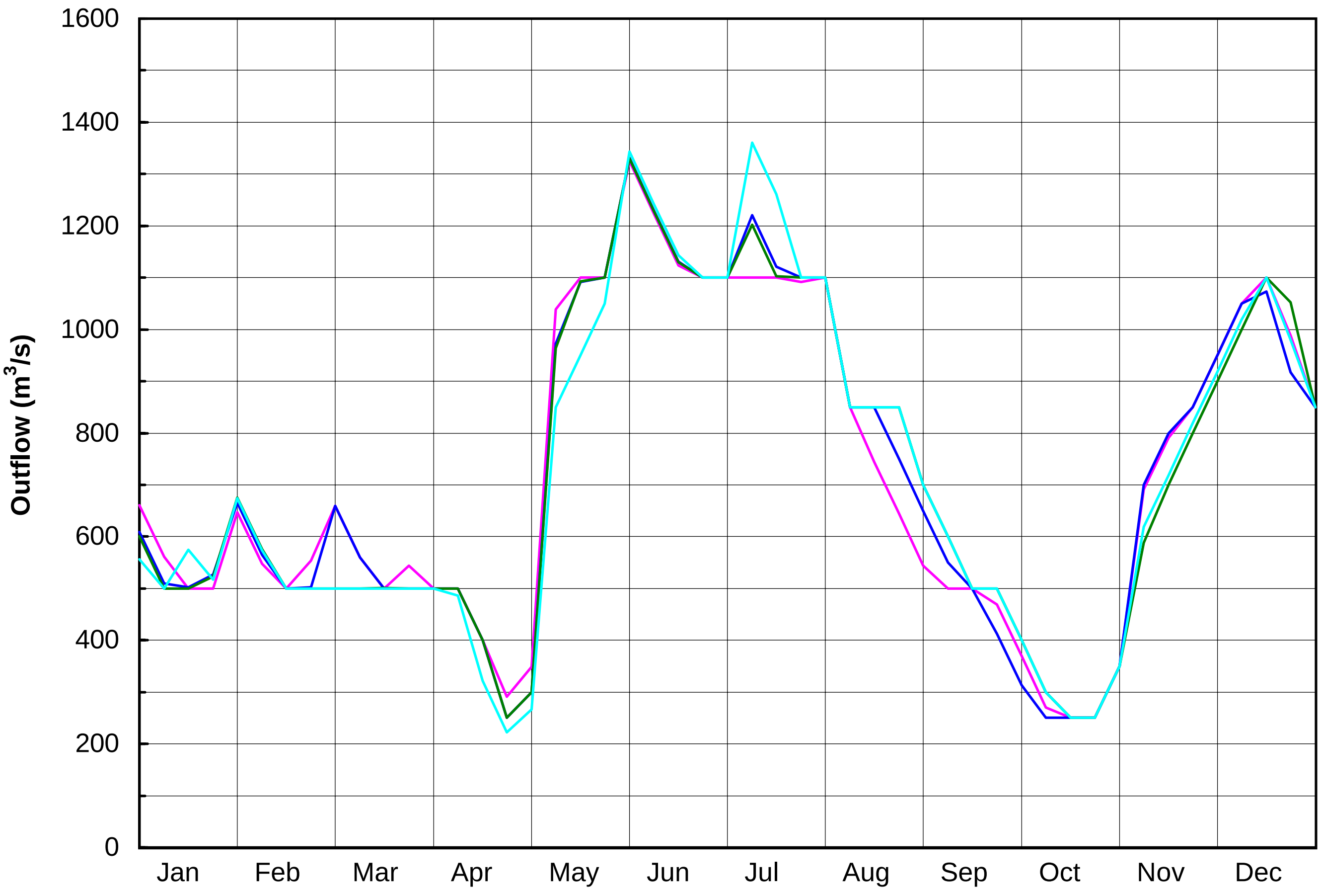




Lake of the Woods 1996

ARSP Runs F1(IJC & SC)-C1-M1 (1/4-Month Lagged Forecast)





Lake of the Woods

Runs F1(IJC & SC)-C1-M1 - Flow Duration Curves (1/4-Month Lagged Forecast)