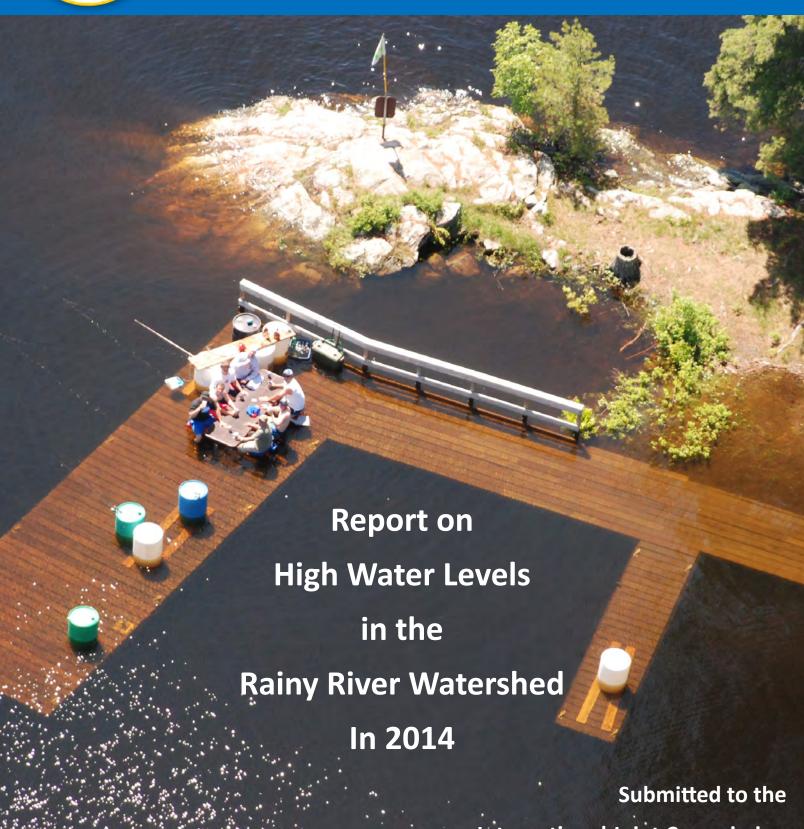


Water Levels Committee of the International Rainy-Lake of the Woods Watershed Board



Submitted to the International Joint Commission April, 2015



Executive Summary

In June and July of 2014, the Namakan Chain of Lakes and Rainy Lake reached levels higher than experienced in several decades. Flows out of the dams at the outlets of these lakes are under the authority of the International Joint Commission (IJC). The IJC-appointed International Rainy-Lake of the Woods Watershed Board (IRLWWB) has a committee, known as the Water Levels Committee (WLC), which is responsible for monitoring the operation of the dams for compliance with the IJC's regulatory regime (known as Rule Curves). This report provides a review of the conditions that led to high water and answers a number of questions put forward by the IJC with respect to the high water event and management of water quantity in the Rainy River watershed.

The following points highlight the most significant details of the high water event:

- As a very substantial snowpack melted across the watershed in April, tributary flows rose above normal.
 The snowpack was nearly completely gone by early May, and inflow to most tributaries to the Namakan
 Chain of Lakes and Rainy Lake had nearly stabilized by mid-May. Significant rainfall in mid-May kept flows
 in the watershed above normal, but not exceptionally high. Record-high rainfall in the month of June
 brought inflow to extremely high levels across the watershed throughout June and into July.
- The extremely high inflow in June exceeded the capacity of the outlets to pass water, resulting in an uncontrolled rise in the water levels of Rainy Lake and the Namakan Chain of Lakes.
- H2O Power LP and Boise Paper are the companies that own dams at the outlets of Rainy Lake and Namakan Lake and operate them under the direction of the IJC. The companies increased flow out of both lakes quickly in late April and early May. Namakan Lake was fully opened by May 16 to maximize outflow, while greater than 95% of the outflow capacity was released from Rainy Lake from May 20 until all gates at the dam were opened on June 6.
- The Namakan Lake dams remained fully opened from May 16 until July 20. Namakan Lake peaked at the third highest level since IJC regulation began in 1949. The lake remained above the Emergency Conditions level for forty-four days.
- The Rainy Lake dam remained fully opened from June 6 to August 8. Rainy Lake peaked at the second highest level since IJC regulation began in 1949 and remained above the Emergency Conditions level for seventy-two days.
- The level of the Rainy River, driven by extremely high local flows and maximum flow from the Rainy Lake dam, reached a new record stage in June, exceeding the previous record by nearly 30 cm (1 ft).
- Damage from high water was extensive across the watershed, including shoreline erosion and tree loss,
 dock and boathouse damage, and damage to buildings and other infrastructure. In addition, there were
 reports of reduced business at tourist outfitters and the considerable costs of time and resources devoted
 to the construction, maintenance and removal of flood defences. States of Emergency were declared in
 locations in both countries.

The highlights of the findings of the WLC's review of the high water event are as follows:

• Fundamentally, high water occurred because the supply of water resulting from the June rainfall was far in excess of maximum outflow from the fully opened dams at Namakan and Rainy Lakes for several weeks.

- The WLC directed the companies to target the lower end of the Rule Curve ranges for these lakes in early
 April in order to create additional storage room for the melting of the substantial snow pack. This action did
 not influence the peak levels in the summer, as the companies returned to targeting the middle of the Rule
 Curve bands once the freshet was underway.
- Targeting much lower lake levels in mid-May for both lakes would have resulted in a very small reduction in the peak level at Rainy Lake, and almost no benefit at Namakan Lake. However, the extreme June rainfall was not forecast in early May and flows had been stabilizing by that point. As such there was no clear indication that lower targets were necessary. By mid-May, with outflow from the lakes at or near maximum, there were no additional steps that could have been taken to avoid the high water to come in June and July.
- The flow changes made at the outlets of the lakes by the dam owners were timely, prudent, and in compliance with the IJC's regulations.
- Computer simulation modelling indicates that a 25 % reduction in the amount of precipitation between April and June would likely have allowed the levels of Namakan Lake and Rainy Lake to be maintained below Emergency Conditions levels.
- Simulations were completed to investigate the effect that operating under the current Rule Curves (established in 2000) had in comparison to operating under the previous Rule Curves (from 1970). The 2000 Rule Curves have a higher end-of-winter level at Namakan Lake and earlier refill of Namakan Lake in the spring. The simulation results indicate that following the 1970 Rule Curve in 2014 would have resulted in a slightly lower peak on Rainy Lake and would have had virtually no effect on the peak at Namakan Lake. This was anticipated when the review of the 1970 Rule Curves took place in the 1990s, and was considered an acceptable outcome when balanced against the benefits the Rule Curve changes were thought likely to provide.
- The WLC is not aware of any changes to the landscape or structures at the outlets of these lakes since the original IJC order that could have reduced the outflow capacity at the Fort Frances/International Falls dam or the outlets of Namakan Lake.
- The peak levels reached in the Namakan Chain of Lakes and at Rainy Lake were much lower than in the record year of 1950. The lakes in 2014 also remained in Emergency Conditions for a much shorter period than in 1950. There is no regulation of the dams at the outlets of these lakes that will prevent a return to the levels experienced in 1950, or higher, if sufficiently extreme inflow develops in the future. The IJC, through the IRLWWB and WLC, should work with local governments, First Nations, and other community organizations to ensure that it is widely understood that the watershed is vulnerable to high water events and that regulations on shoreline building reflect this fact.
- The forthcoming review of the 2000 Rule Curves should give weight to avoiding conditions that would increase the likelihood of Emergency Conditions due to high water.
- The WLC recommends that the IJC review the role and responsibilities of the WLC during Emergency Conditions, and that it also consider the development of a protocol for communications during emergency events between the IJC, the IRLWWB, WLC, and local First Nations, tribes, and governments.

Contents

	Introduction	6
1.	Hydrology Review: Winter-Summer 2014	8
2.	Water Level Regulation Operations Winter-Summer 2014	.19
3.	High Water Impacts	.28
4.	Assessment of Actions	.33
5.	Role of the 2000 Rule Curves	.48
6.	Review of Watershed / Outlet Changes	.52
7.	Answers to Frequently Asked Questions	.53
8.	Floodplain Management	.58
9.	Summary and Recommendations	.59
Арр	endix A—Map of the Rainy River Watershed	.62
Арр	endix B— References	.64
Арр	endix C— List of Acronyms	.65
Арр	endix D—Glossary of Technical Terms	.66
Арр	endix E— Water Quantity Management in the Rainy River Basin	.68
Арр	endix F— Hydraulics of Outflow from Namakan Lake and Rainy Lake	.70
Арр	endix G— 2014 Water Level and Flow Graphs	.77

Introduction

During the spring and summer of 2014, lakes and rivers across the Rainy River watershed rose to very high levels. In some cases, peak water levels were highest on record. In most others, they were the highest experienced in several decades. These high water levels damaged shorelines and shoreline infrastructure and caused hardship for many people and communities across the watershed. In addition to the costs of damaged infrastructure, considerable time, effort and expense were dedicated by communities and individual property owners who worked to minimize the damaging effects of rising waters and to restore and repair property in the wake of the high water event.

The flow of water out of Namakan Lake and Rainy Lake has been partly controlled since the early twentieth century by dams. These dams, which are owned and operated by private companies (currently H2O Power LP in Canada and Boise Paper in the USA, hereafter referred to as the Companies), are under the authority of the International Joint Commission (IJC) since these lakes are boundary waters shared by the two countries. The 1938 Rainy Lake Convention between the United States and Canada gave the IJC the authority to determine when Emergency Conditions, whether by low or high water, exist in the Rainy Lake watershed and empowered the IJC to adopt such measures of control that it might deem proper with respect to these dams.

Since 1949 the IJC has directed the owners of the dams, through formal orders, to maintain the levels of Namakan Lake and Rainy Lake within specific ranges through the year. These ranges, defined by what are known as the Rule Curves, have been modified several times since, with the latest Rule Curves established in 2000. In 2013, the IJC established the International Rainy-Lake of the Woods Watershed Board (IRLWWB), to monitor and report on the ecological health of the boundary waters aquatic ecosystem. A committee of the IRLWWB, known as the Water Levels Committee (WLC), is delegated the responsibility of monitoring compliance by the Companies with the Rule Curves, and at times directing outflow from the lakes.

On November 19, 2014 the IJC directed the co-chairs of the WLC to report on the 2014 high water event in the Rainy River watershed. The IJC noted the following key areas for inclusion in the report:

- A description of the hydrologic conditions, as the situation developed in the spring and summer of 2014;
- An assessment of the actions and decisions taken by the power companies (H20 Power and Boise Paper), the Water Levels Committee, the Board, and the Commission, in response to these conditions and their impacts;
- The effects of the Rainy and Namakan 2000 Rule Curves, including actions taken to target other than the middle of the band;
- The potential effects of the 1970 Rule Curves, had they been in place;
- The physical changes to the landscape and structures made since the original IJC order that could have reduced (or changed) the outflow capacity at the Fort Frances/International Falls dam and the Namakan outlet;

- Any other information the Committee and Board considers relevant; and
- Any Board recommendations for further action or follow-up by the Board or the Commission.

This report addresses these topics in several sections, as follows:

1. Hydrology Review: Winter-Summer 2014

Details the winter, spring and summer hydrology in the watershed that contributed to high water.

2. Water Level Regulation Operations Winter-Summer 2014

Details the chronology of rising water levels in the watershed and reports on the actions taken by the WLC, the IJC and the Companies leading up to and during high water conditions.

3. High Water Impacts

Provides an overview of the impacts of the high water event around the watershed.

4. Assessment of Actions

Examines the actions of the Companies, the WLC, the IRLWWB, and the IJC. Details the communication efforts made before, during, and after the higher water event.

5. Role of 2000 Rule Curves

Assesses the role of the 2000 Rule Curves in the high water event. Compares the outcomes of following the 2000 Rule Curves versus the 1970 Rule Curves.

6. Review of Watershed/ Outlet Changes

Addresses the IJC's directive to describe landscape or outlet changes that could affect the outflow capacity of Rainy Lake and Namakan Lake.

7. Answers to Frequently Asked Questions

Provides responses to questions received by the Water Levels Committee during and after the high water event.

8. Floodplain Management

Discusses the importance of understanding the recurring nature of high water in this basin and of managing shoreline property to minimize risk.

9. Conclusions and Recommendations

Summarizes the main findings of the WLC regarding the high water of 2014. Recommends actions to be taken by the IJC and members of the pubic based on lessons learned from 2014, and provides suggestions for the forthcoming review of the Rule Curves.

Appendices are included to provide relevant background that is not specific to the aims of the above sections. Included are references, a glossary of technical terms, an overview of the Rainy River watershed, the roles of various Boards within the watershed, a review of the hydraulics of the outlets of Namakan Lake and Rainy Lake, graphs of precipitation, water levels and flows in 2014, and a map of the Rainy River basin.

1. Hydrology Review: Winter-Summer 2014

The hydrological and meteorological conditions that contributed to high water conditions in the Rainy River watershed in 2014 are summarized in this section and provide important context for the review of dam operations from Namakan Lake and Rainy Lake in Section 2. All precipitation, water level and flow data used herein was obtained from the database of the Secretariat of the Lake of the Woods Control Board which collects the data from various American and Canadian government agencies. At the time of preparation of this report, this data was provisional and subject to revision. Refer to Appendix A for a map of the Rainy River basin, and to Appendix G for graphs of water levels, flows, and precipitation.

1.1 Watershed Conditions Fall 2013 through Winter 2014

Following above-normal flow conditions during the summer of 2013, inflow to both Namakan Lake and Rainy Lake declined into the low-normal range (25th to 50th percentile) by October, 2013 (refer to Appendix D for an explanation of statistical terms used in this report). Flows remained in the normal range, with relatively constant inflow to both lakes, until the end of March, 2014.

Although inflow was stable and normal, the winter was unusual in two respects: the amount of accumulated snow and the persistent, unusually cold temperatures. The basin-wide average temperature for the January 1 -March 31 period was the coldest in 100 years of record. This resulted in little melting of the snowpack before April. Basin-wide snowfall during this period was 95th percentile and ranked fourth out of 105 years of record (snowfall was slightly less than in 2009).

For most years over the past several decades, the U.S. Army Corps of Engineers (USACE) St. Paul District has carried out early March snow surveys in the watershed. These surveys involve measuring snow depth and determining the equivalent amount of water in the snow column. Ranks of snow water equivalent measurements are provided in Table 1, and include four stations that were highest on record in 2014. Figure 1.1 provides a map of these locations, as well as data provided by Ontario Power Generation for March 1 snowwater equivalent at Ontario locations.

Table 1.1. March 1, 2014 Snow Survey Data in the Lake of the Woods Watershed Source: USACE, St. Paul District

Snow Survey	Snow Water E	Rank	Years of	
Location	Millimeters	Inches	Ralik	Record
Isabella, MN	157	6.2	14	52
Tower, MN	165	6.5	1	18
Ely (Winton), MN	137	5.4	13	76
Cook, MN	140	5.5	5	53
Ash Lake, MN	145	5.7	6	53
Ray, MN	125	4.9	1	21
Little Fork, MN	133	5.2	1	21
Birchdale, MN	157	6.2	1	21
Baudette, MN	83	3.2	30	53
Williams, MN	87	3.4	7	21



Figure 1.1. March 1, 2014 Snow Water Equivalent Measurements (USACE, OPG)

Estimates of snow on the ground by the Minnesota Climatology Working Group were consistent with these measurements at the beginning of March, with much of the Minnesota portion of the watershed ranking near record-high (Figure 1.2).

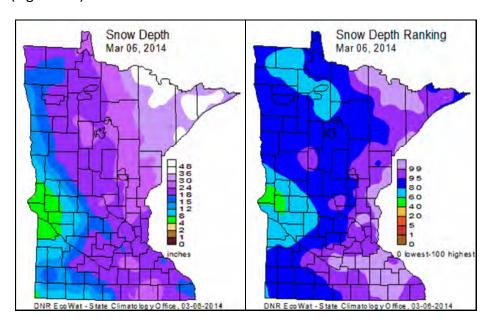


Figure 1.2. Snow Depth and Rank in Minnesota, March 6, 2014 Source: DNR Eco Wat—MN State Climatology Office

The snowpack depth declined in mid-March across most of the basin due to several days where temperatures exceeded the freezing point. Some snowfall in late March and early April brought additional accumulation so that the snowpack entering the spring freshet was 80th to 95th percentile; still significant but not as deep as at the start of March.

Due to the very cold temperatures throughout most of the winter, soil frost was deep and the lakes had exceptionally thick ice cover by the start of freshet. The combination of very deep snow and frozen ground

were indicators of a potentially significant spring melt, although the low-normal base flows in the basin pointed to capacity in the watershed to absorb some of these flows once temperatures warmed.

1.2 Spring Freshet

Consistent daytime high temperatures above the freezing mark in early April initiated the spring freshet. The snowpack depth and water content declined steadily throughout the basin during the month, with snow completely melting in a gradual progression from southeast to the northwest. Precipitation throughout this period was near seasonal norms, mostly rainfall with some late season snow. Inflow to Namakan Lake, Rainy Lake and their tributaries rose steadily in response, climbing to the upper-normal range (75th percentile) by the end of April. By the first week of May, all observation stations in the watershed were reporting no snow on the ground, and snow-water equivalent estimates by Environment Canada's Climate Processes Section indicated that no snow remained in the watershed. Figures 1.3 and 1.4 illustrate estimates of snow-water equivalent at half-month intervals in April and May, respectively. They demonstrate the progress of snow-melt from southwest to northeast during this time.

Flows in most of the tributaries in the basin were no longer climbing following a week of normal rainfall at the beginning of May. The exceptions were in the upper parts of the basin where flows were still responding to the late snowmelt. In the second week of May, nearly twice the normal precipitation fell across the watershed. This caused flows for all major tributaries and for inflows to the major lakes to begin rising. By the second half of May, however, flows had stabilized for most areas of the basin, including inflows to Rainy Lake and Namakan Lake. With the exception of Basswood Lake and Vermilion River, where inflows peaked above the 90th percentile, flows in the third week of May were in decline after reaching highs in the 75th to 90th percentile range. Soil conditions remained wet, however, as the combination of May rainfall and cool temperatures following the late snowmelt afforded little opportunity for drying.

The combination of exceptionally thick ice and cool spring temperatures led to very late ice-out for lakes in the watershed. According to the Minnesota State Climatology Office, the ice out date for Rainy Lake was May 20, two days shy of the record-late ice out set in 1950. Ice out for Kabetogema Lake was on May 14, four days before the latest date on record.

1.3 Three Heavy Rainfall Periods, late May through mid-June

A week of significant rainfall that began on May 30 quickly changed the trend of slowing flows. On a basin-average basis, 93 mm (3.66 in) of rainfall fell over this period, with locally higher amounts exceeding 125 mm (4.9 in) reported in some locations of Minnesota (e.g. Hibbing, Vermilion). This was the highest basin rainfall on record for this seven-day period, more than double the normal rainfall for the start of June, and it resulted in flows in all tributaries and inflows to the major lakes moving well above the respective 90th percentiles. Flows across the basin peaked quickly following this rainfall, and were once again in decline by the end of the first week of June. This decline was short-lived, however, as a second period of heavy rainfall delivered an additional 95mm (3.74 in) of rainfall on a basin-average basis from June 10 to 15. Figure 1.5 shows the distribution of rainfall during these two time periods. Once again, river flows and lake inflows climbed swiftly, with the largest flows of the summer occurring near the middle of June in most areas. Table 1.2 summarizes

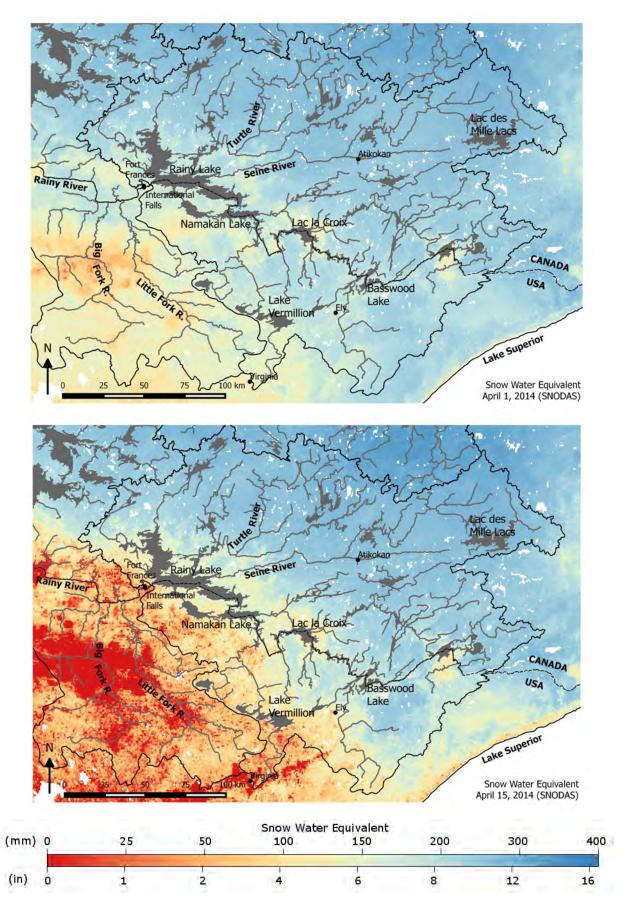


Figure 1.3. Estimated Snow Water Equivalent April 1 and 15, 2014

Data: SNODAS by National Operational Hydrologic Remote Sensing Center

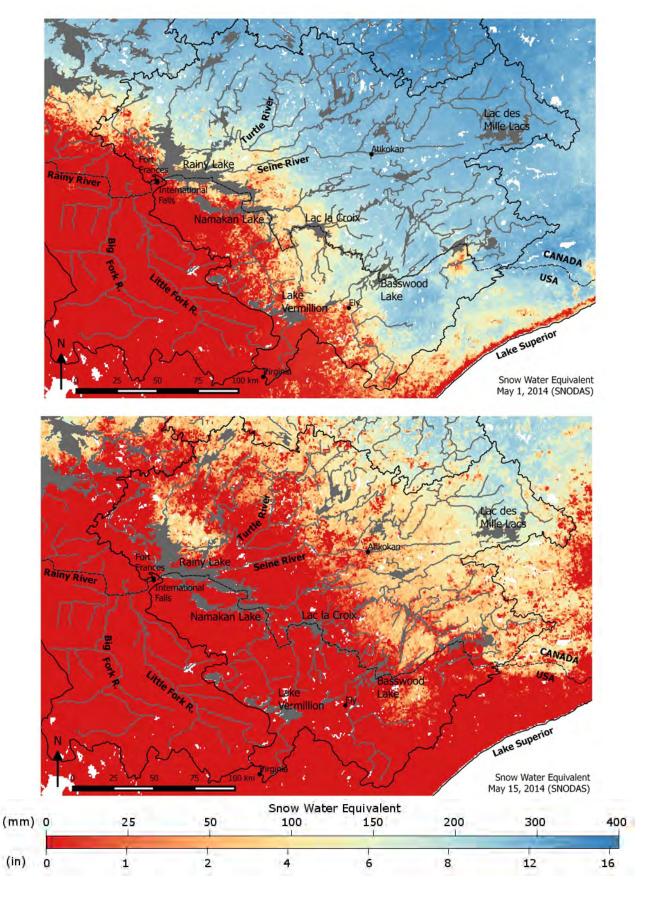


Figure 1.4. Estimated Snow Water Equivalent May 1 and 15, 2014

Data: SNODAS by National Operational Hydrologic Remote Sensing Center

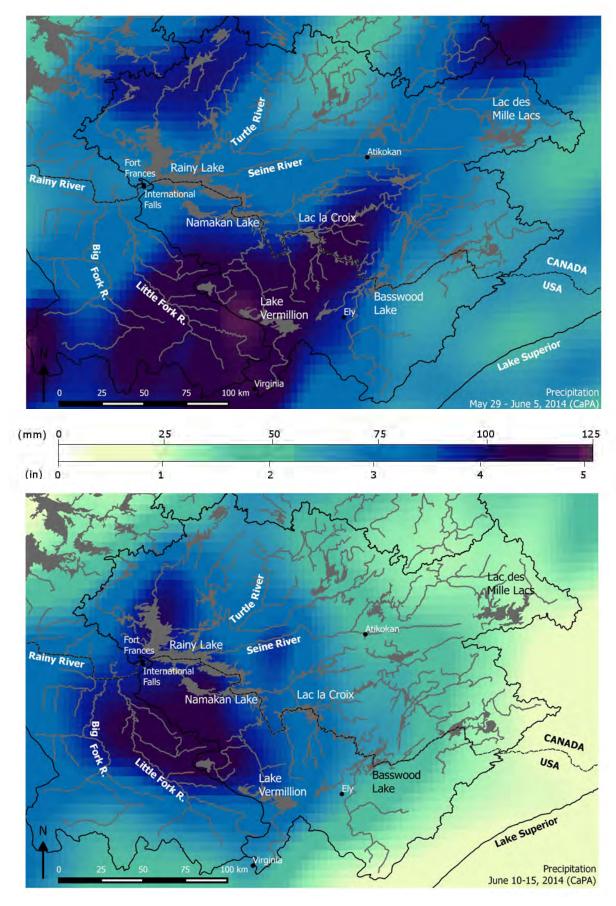


Figure 1.5. Total Precipitation May 29-June 5 and June 10-15 Data: EC's Canadian Precipitation Analysis (CaPA)

the statistics of peak flows in the basin. Nearly all tributary flows and lake inflows were greater than 95th percentile, though some set new records for this time of year or for the entire period of record.

Table 1.2. June 2014 Flow Statistics

River or Lake Location	Peak Date	Inflow & No for Peak	Inflow & Normal flow for Peak date Inflow & N		Flow/ Lake Iormal Flow ak Date ers / Second)	Statistic at Peak Date
		Peak	Normal	Peak	Normal	
Vermilion River	June 4	3446	1024	98	29	New Maximum for time of year
Atikokan River	June 3	683	177	19	5	New Maximum of record
Raft Lake*	June 13	5796	1801	164	51	New Maximum for time of year
Seine River*	June 5	6845	2154	194	61	New Maximum of record
Turtle River	June 18	7633	1978	216	56	95th percentile
Namakan Lake	June 7	29000	11760	821	333	Greater than 95th percentile
Rainy Lake	June 18	61296	17375	1736	492	New Maximum for time of year
Little Fork River	June 17	13914	1130	394	32	New Maximum for time of year
Big Fork River	June 16	10524	989	298	28	New Maximum for time of year
Rainy River at Manitou Rapids	June 17	75962	17375	2151	492	New Maximum of record

^{*}Outflow from dam

Averaged across the Rainy-Namakan watershed, the total rainfall that fell between May 28 and June 15 was 192 mm (7.6 in). This is the highest rainfall total for this period in 100 years, higher even than the same period in 2002 which saw the record '49th Parallel' storm with 175 mm (6.9 in) of rainfall. This average does not tell the full story of the rainfall during this period, however. The heaviest rainfall was concentrated in two areas: to the south of Namakan Lake where observed rainfall at Vermilion River was 225 mm (8.8 in), and in the watershed of the Big Fork and Little Fork rivers to the south of Rainy River, where 261 mm (10.25 in) was recorded at Big Fork.

The combination of very high outflow from the Rainy Lake dam and the extremely high flows emerging from the Big Fork and Little Fork rivers led to a dramatic rise in the flow rate of the Rainy River. At Manitou Rapids, where records have been kept by the USGS since 1928, the river flow reached a new record on June 17, exceeding the previous record set in 1950 by 6 %. By comparison to more recent high water years, the 2014 Rainy River peak flow exceeded the peaks from 2001 and 2002 by 26 % and 20 %, respectively.

From June 16 to 22, the third significant rainfall of June delivered an average of 32 mm (1.25 in) of precipitation across the basin. Locally, however, some locations had much larger totals, including Big Fork where 77 mm (3.0 in) was recorded. Although this rainfall added to the already saturated conditions in the watershed, it was not enough to sustain flows at the extremely high rates observed earlier in the month. Flows had, at last, begun to decline for the season.

Figure 1.6 presents cumulative precipitation through June at fourteen observation stations across the water-shed, compared to normal basin-average precipitation for this time of year.

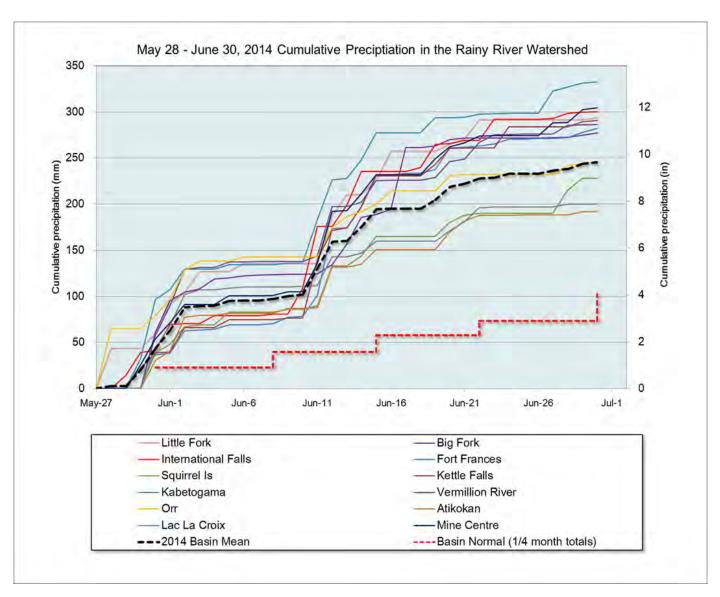


Figure 1.6. Cumulative 2014 Precipitation at Rain Gauge Locations and Basin Normal Data: EC, NOAA, USGS, LWCB

1.4 High, Declining flows Late June through August

The last week of June was the driest of the summer for the Rainy-Namakan watershed, with totals of roughly half the normal precipitation for that week. July precipitation was near normal with the exception of the third week, when nearly double the normal amount of rain fell. For most areas of the watershed, however, the decline from the exceptionally high peak flows of June continued despite the rainfall. One exception was a sharp increase in the flow of the Turtle River, the largest unregulated tributary to Rainy Lake. Increased flow from here was sufficient to halt the steady decline of Rainy Lake for nearly a week.

In general, flows across the basin remained high but steadily declining through July and early August before returning to seasonal normals. By this time, most areas of the watershed had experienced flows above seasonal normals for three months.

Summary of Precipitation and Hydrology

In summary, the substantial snowpack and early spring rainfall resulted in above-normal, but below 90th percentile inflow in May. The principal factor in the development of the period of exceptionally high flows in the late spring and summer of 2014 was several consecutive weeks of frequent, widespread rainfall in June. Tables 1.3 and 1.4 provide a summary of inflow statistics for early spring (April to May) and late spring to early summer (June to July) that indicate the shift towards higher flows late in the season.

Tables 1.3 and 1.4. Average Inflow Statistics By Lake for April to May and June to July Data: LWCB
April to May

Lac La Croix (since 1908)				Namakan Lake (since 1905)				Rainy Lake (since 1912)			
Rank	Year	m ³ /s	ft ³ /s	Rank	Year	m³/s	ft ³ /s	Rank	Year	m ³ /s	ft ³ /s
1	1938	550	19408	1	1950	538	19016	1	1950	874	30865
2	1950	479	16914	2	1966	508	17945	2	2001	867	30618
3	2001	479	16877	3	2001	505	17822	3	1996	865	30547
4	1954	471	16647	4	1969	455	16085	4	1927	860	30371
5	1969	462	16325	5	2009	439	15493	5	2009	789	27863
6	1966	452	15956	6	1954	421	14861	6	1938	789	27863
7	1927	449	15855	7	1971	407	14359	7	1916	760	26839
8	2009	448	15838	8	1948	405	14289	8	1996	708	25003
9	1945	446	15739	9	1996	398	14064	9	1954	697	24614
10	1951	441	15558	10	1979	389	13737	10	1985	694	24508
21	2014	226	7981	18	2014	341	12042	24	2014	547	19317

June to July

Lac La Croix (since 1908)				Namakan Lake (since 1905)			Rainy Lake (since 1912)				
Rank	Year	m³/s	ft ³ /s	Rank	Year	m ³ /s	ft ³ /s	Rank	Year	m³/s	ft ³ /s
1	1950	473	16704	1	1950	627	22142	1	1950	1326	46827
2	1968	445	15715	2	2014	586	20694	2	2014	1190	42024
3	2014	353	12466	3	1968	581	20518	3	1968	1026	36233
4	1970	346	12219	4	1943	535	18893	4	1927	924	32631
5	1943	339	11972	5	1944	520	18364	5	2002	905	31960
6	1944	334	11795	6	2008	475	16774	6	2008	898	31713
7	2008	307	10842	7	1970	469	16563	7	1943	894	31571
8	1947	299	10559	8	1964	418	14762	8	1944	820	28958
9	1994	285	10065	9	1947	411	14514	9	1964	811	28640
10	1974	284	10029	10	1974	406	14338	10	1970	780	27545

Total rainfall for the Rainy-Namakan watershed from May 1 through July 31 was the highest in 100 years, with an average of 426 mm (16.7 in) of rainfall. The greatest accumulation of rainfall during this period was to the south of Namakan Lake, Rainy Lake, and Rainy River, where estimates by Environment Canada reached as high as 550 mm (21.6 in). The highest local rainfall totals for the month of June alone were near 300 mm (11.8 in), occurring southeast of International Falls – Fort Frances. Figure 1.7 shows the distribution of total rainfall over June in contrast to the average June rainfall from 2002 to 2013.

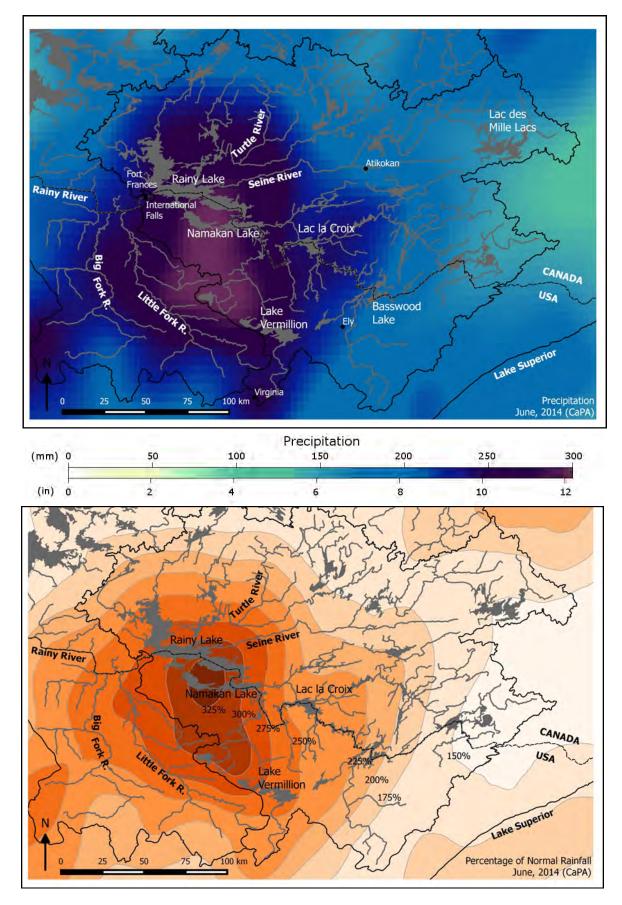


Figure 1.7. Total June 2014 Precipitation and Comparison to 2002 to 2013 Average Total June Precipitation Data: EC's Canadian Precipitation Analysis (CaPA)

At International Falls, where the longest available rainfall record in the watershed exists, total precipitation from May 1- July 31 was reported as 480 mm (18.9 in), the highest since recordkeeping began in 1895, 18% higher than the previous record set in 1962, and nearly double the historical average for this period of 254 mm (10.0 in) (data source: Midwestern Regional Climate Center).

Driven by this extraordinary rainfall, the maximum outflow capacities of Rainy Lake and Namakan Lake were exceeded by the rates of inflow for several consecutive weeks. When water enters a lake faster than it exits, the level of the lake inevitably climbs higher. A summary of the dam operations at Rainy Lake and Namakan Lake that occurred in response to the developing high water conditions is the focus of Section 2.

2. Water Level Regulation Operations Winter-Summer 2014

While the record precipitation in late spring described in Section 1 provided the input that led to high water conditions, it is important to account for and to understand the role of the dam operations at Rainy Lake and Namakan Reservoir before, during, and following the high water conditions. This section reviews the dam operations at Rainy Lake and Namakan Lake during the winter, spring, and summer of 2014, and details the actions and decisions taken by the Companies, the WLC, the IRLWWB, and the IJC, in response to these conditions. Appendix G provides graphs of rainfall, water levels and flows that are described in this section.

2.1 Winter 2014

As detailed in Section 1, the snowpack across the watershed at the beginning of March was very deep with significant water content. On March 5, H2O Power LP contacted the WLC to discuss the regulation plan for the spring in light of the snow survey data issued by the USACE. The WLC reviewed conditions and, considering the low-normal base flows, the substantial snowpack, and the deep frost conditions that had developed, directed the dam owners as follows:

"Beginning after March 7, 2014, adjust outflow as necessary to target the bottom 25% of the respective Rule Curve bands on Rainy Lake and Namakan Lake by the first week of April, 2014. In doing so, attempt to limit outflow increases to no more than 50 m 3 /s per week from Rainy Lake and 25 m 3 /s per week from Namakan Lake."

Throughout the late fall and winter, the Rule Curves require a lowering of the levels of both lakes to create storage room for the spring freshet. By early March, the levels of both lakes had been following close to the mid-point of the respective Rule Curves and had dropped gradually through the winter. Beginning on March 7 for Namakan Lake and March 8 for Rainy Lake, the Companies made modest flow increases to comply with the WLC's directive. As inflow in early March was consistently in the low-normal range, only small flow increases were required to achieve the level targets. By the first week of April, the level of Rainy Lake had declined to 15% of the Rule Curve band, 5.4 cm (2.1 in) above the lower Rule Curve. At Namakan Lake, the April 7 level was 17.6 cm (6.9 in) above the lower Rule Curve, or 20 % of the band. In comparison to mid-Rule Curve, beginning freshet at the lower level provided 12.6 cm (5.0 in) of additional storage depth on Rainy Lake. This would accommodate 39 m³/s of additional inflow for thirty days, roughly 15% of the normal mid-April inflow to Rainy Lake. For Namakan Lake, the additional storage gained was 26 cm (10.2 in), equivalent to 23.5 m³/s (830 ft³/s) of additional inflow for thirty days, or 17% of the normal mid-April inflow.

The WLC notified the IRLWWB and the IJC of the directive. On April 2, the IRLWWB issued a media release, made available to the public on its website. It explained the action that had been taken by the WLC during March, summarized basin conditions at the time, and advised of the potential for quickly rising inflows.

2.2 Spring Freshet, April-May

Flows across the watershed began rising around the second week of April once daytime temperatures were well above freezing. Inflow to both Rainy Lake and Namakan Lake rose through April, but the rates of increase were slowing by the end of the month. In some tributaries, such as Vermilion River and Atikokan River, flows were actually falling, while in others further upstream (e.g. Lac La Croix, Basswood Lake) they continued to rise due to the later snowmelt in the uppermost parts of the watershed. Below Rainy Lake, the Big Fork and Little Fork rivers had peaked and declined to normal flow for early May, the snowmelt having oc-

curred earliest in this area. American and Canadian meteorological agencies reported precipitation outlooks for the month of May in the watershed ranging from normal (Environment Canada) to an equal chance of below-normal, normal, and above-normal (National Weather Service).

At Namakan Lake, 67 of the total 104 stop-logs for the two dams were in place for most of the month of April as the lake refilled along the lower half of the Rule Curve band (details of the outlet structures of both lakes are provided in Appendix F). In order to keep pace with the rising rate of inflow, the Companies conducted three log operations in the last week of April, reducing the total logs-in count to 52. As of May 1, Namakan Lake level was at 50% of the Rule Curve band, and on May 2 the Companies reduced the number of logs in the dams to 22 in order to further increase outflow in response to rising inflow.

Namakan Lake inflow and outflow were both 75th percentile at the end of the first week of May, while the lake level was at 55% of the Rule Curve band. The heavy precipitation in the second week of May caused the rate of inflow rise to climb faster, reaching a plateau slightly below 90th percentile by mid-month. The Companies removed all remaining logs from the Namakan Lake dams by May 16 to maximize the outflow. The dams were fully opened with the level of Namakan Lake 49 cm (19.3 in) below the IJC All Gates Open level.

Even with the removal of the remaining logs, the inflow to Namakan Lake exceeded the outflow by 8%, or 39 m³/s (1377.6 ft³/s). From May 20 to May 30, inflow to Namakan Lake was stable, while outflow increased steadily with the rising lake level. As the difference between the inflow and outflow grew smaller, the rate of lake level rise slowed. On June 1, the highest point in the Rule Curve for the year, the levels of Namakan Lake and Crane Lake rose above the upper Rule Curve by 3 cm (1.2 in).

At Rainy Lake, all of the five canal gates and ten dam gates at the dam were closed throughout the winter and during April, as all of required flow to maintain the lake within the Rule Curve range was accomplished with the turbines in the Boise Paper and H2O Power powerhouses. In April, the Companies increased outflow through the turbines as inflow to Rainy Lake picked up. This allowed the lake to rise within the lower half of the Rule Curve through most of April, reaching 52% of the Rule Curve band by the start of May.

H2O Power opened the first two gates of the season at the Rainy Lake canal on April 30. The remainder of the five canal gates were opened by May 7 as the Companies aimed to keep Rainy Lake within the mid-band of the Rule Curve. With the above-normal rain-



April 16, 2014. Brule Narrows on Rainy Lake, from northwest to southeast along the boundary across the big lake toward Kettle Falls. This is one of the first areas to open up in the spring. 2014 was a very late ice-out year, in part due to the very thick ice following the cold winter. Photo: Lee Grim

fall during the second week of May, H2O Power commenced opening dam gates on May 13. On May 14, the forecast by the Province of Ontario was for dry conditions in northwest Ontario for the following week, some rain for the last week of May, and very dry conditions in June. Despite the favourable forecast, rising inflow

led H2O Power to continue opening additional dam gates so that seven of the ten dam gates and all five of the canal gates were open by May 20.

The rising level of Rainy Lake in late May pushed water through the outlet at Ranier Rapids at an increasing rate. H2O Power opened dam gates to match the increasing flows without unnecessarily lowering the water level above the dam (for a description of the hydraulic limitations on outflow from Rainy Lake, see Appendix F). Between May 20 and May 30, outflow from the dam was between 96% and 98 % of the theoretical maximum for the level of the lake. On May 30, with 13 of 15 gates open at the dam (98% of theoretical maximum outflow), inflow was 14% greater than the outflow. Under these conditions, the level of Rainy Lake rose above the upper Rule Curve for the first time in the year.



The water level at Second Bridge, International Falls, just above the upper Rainy River shows the effect of maximizing flow from the dam before the level of Rainy Lake is above normal.

Photo: Tom Worth

2.3 High Water in the Namakan Chain of Lakes, June 1-July 9

The slowing of the rise in Namakan Lake level at the end of May was halted with the start of the three-week period of heavy rainfall detailed in Section 1. The first major rainfall event began at the end of May, pushing inflow to the lake in the first week of June to what would be the highest rate of the year, 821 m³/s (8990 ft³/s). This exceeded the rate of outflow from the fully opened dam by 24%, 160 m³/s (650 ft³/s). As a result, the level of Namakan Lake rose by 46 cm (18 in) from May 31 to June 7. Above Namakan Lake, more intense local rainfall and hydraulic constrictions limiting the rate of flow between the Namakan Chain of Lakes resulted in Crane lake rising by 55 cm (21.7 in) during this same seven-day period.

The June 12-15 rainfall once again raised the rate of inflow to Namakan Lake, though not quite as sharply as at the start of the month. From the start of June to this point, outflow from the fully opened dams had increased by 25% due to the rising lake level. The lake level continued to rise until June 18, when outflow from the dams finally matched the inflow to the lake. The peak elevations for the Namakan chain of lakes were 341.55 m (1120.6 ft) at Namakan Lake and Kabetogema Lake, and 341.68 m (1121.0 ft) at Crane Lake, the highest recorded levels since 1968.

The third major rainfall period of the month, June 19 to 22, was not sufficient to raise the inflow rate again at Namakan Lake. Though declining, inflow to Namakan Lake remained well above 90th percentile until the first week of August. The fully opened dams continued to pass outflow in excess of inflow during the rest of June and the first half of July, though the difference was never greater than 11% of the inflow. This small edge, however, was sufficient to allow for a steady decline in the levels of the Namakan Chain of Lakes over this period.

Namakan Lake level fell below the IJC All Gates Open level on July 9. The level at Crane Lake, however, was still 10 cm (4 in) above this level. Outflow from the fully opened dams was just 7 % greater than the rate of inflow at this point, a difference of 52 m³/s (1836 ft³/s).

On July 18, the WLC directed the Companies to target the upper Rule Curve for Namakan Lake so as to pro-

vide some reduction of flow into Rainy Lake which remained well above the IJC All Gates Open level. At that time, inflow to Namakan Lake was above 95th percentile, just 12% less than the outflow rate. The first log operation to reduce flows from Namakan Lake was conducted by the Companies on July 20 with the addition of 11 logs. Logs were added every few days until August 7 to stabilize the level of Namakan Lake and target the upper Rule Curve. Namakan Lake returned to the Rule Curve range on July 21, while the level of Crane Lake reached this level on July 25. Inflow continued to decline for the remainder of the summer, returning to normal seasonal flows in the second half of August, and allowing Namakan Lake to remain within the Rule Curve band.

2.4 High Water at Rainy Lake, June 6 – August 8

On June 1, thirteen of the fifteen spill gates at the Rainy Lake dam were open, passing 98% of the maximum theoretical flow for the lake level on that day. The level of the lake was 8 cm (3.1 in) above the upper Rule Curve, and 22 cm (8.7 in) below the IJC All Gates Open level.

The May 30 to June 2 rainfall, which was heaviest to the south of Rainy Lake, caused a rapid rise in the inflow rate to Rainy Lake. The lake rose swiftly in response, filling by 30 cm (12 in) from May 31 to June 7. Meanwhile, flows into the Rainy River were extremely high due to the combined flows from the Big Fork and Little Fork rivers and outflow from the Rainy Lake dam. Under very high flow conditions such as this, the Rainy River level experiences a backwater effect from the Little Fork River up to the dam. The tailwater level at the dam rose as a result of this backwater effect. At the same time, the level of water in the headpond area in front of the dam was very low on the Canadian side due to the thirteen open spill gates. The combination of low



June 17, 2014. Squirrel Falls Dam, Namakan Lake, releasing maximum flow one day after the peak. Photo: Lee Grim

headpond level and high tailwater level resulted in a very short fall of water through the dam, or hydraulic head. In general, the larger the hydraulic head, the greater the flow through the turbines. By June 4, the hydraulic head on the Canadian side of the dam limited turbine flow to 10% of its capacity. Meanwhile, the Boise Paper powerhouse was admitting water due to the rising river level below the dam, and sandbagging had begun to protect the turbines.

As Rainy Lake rose nearer to the IJC All Gates Open level, the WLC became concerned that opening the last two gates would further lower the headpond level and raise the tailwater level, reducing the overall hydraulic head to a point where the turbines would have to be taken offline or risk being damaged. This raised the possibility that opening the last two remaining dam gates would actually result in an overall *loss* of flow capacity. Following a review of the situation in the early hours of June 6, the WLC formally requested that the IJC suspend the IJC All Gates Open condition of the 2001 Consolidated Order so as to delay the opening of the last two gates. The IJC scheduled an emergency meeting for that day to review the request. However, later in the morning it was confirmed that the tailwater level had begun declining. Based on this trend and the short-

term meteorological forecasts which suggested that the tailwater would continue to decline, the WLC withdrew its request to the IJC. At noon on June 6, the last two dam gates at the Rainy Lake dam were opened, the same day that the lake crossed the IJC All Gates Open level.

There followed a respite from June 6-9, during which inflow to Rainy Lake declined slightly, though still greater than the outflow from the fully opened dam. The rainfall during the period of June 10 to 15 sent inflow much higher, however. On June 16, the rate of inflow reached its highest point of the season, more than triple the normal mid-June inflow and 66% greater than the outflow from the fully opened dam. Below Rainy Lake, the Rainy River again rose rapidly. It crested on June 16, 28 cm (11 in) higher than the previous record stage for Manitou Rapids set in 1950, and the highest in 85 years of record. The tremendous influx of water from the Fork Rivers once again caused a backwater effect, raising the level of the Rainy River below the dam.



The Water Survey of Canada water level gauge at the Town of Rainy River at the record crest, June 16, 2014.

Photos: Craig Paul, Water Survey of Canada.

The rising level of the Rainy River led the Town of Rainy River, Ontario to declare a State of Emergency on June 14. Round-the-clock sandbagging efforts had already been underway there to protect the town. The WLC became concerned that the flood prevention efforts might not be sufficient to protect the town from the rising river. Town of Rainy River officials were in regular contact with the WLC and inquired what might be done to alleviate the situation, but did not make a formal request to have flows from Rainy Lake reduced. The WLC convened an emergency call on the evening of June 14 to review the latest data and evaluate the situation. Due to the extraordinary rate of rise in Rainy River flows, the high, rising level of Rainy Lake, and the time it would take for any flow adjustment at the Rainy Lake dam to reach the town, the WLC determined that no net benefit could be gained from a flow reduction out of Rainy Lake. A media release to that effect was

issued on June 15 by the IRLWWB. The peak elevation of the Rainy River was reached the following day and the extensive sandbagging efforts made at the Town of Rainy River were sufficient to protect most of the town from inundation.

On June 16, H2O Power notified the WLC that the mill basement had been flooded and all of the bearing cooling water pumps for its turbines were under water due to the rising level of the Rainy River below the dam. It advised that it had taken the precautionary measure of shutting down all eight turbines at 6:13 a.m. to prevent damage to these units. The reduction in outflow was computed to be 6.1 % of the total Rainy Lake outflow. Seven of these turbines were restored to service by 4:11 p.m. that day.

The WLC was also advised on June 16 that the Boise Paper powerhouse was flooding and that its turbines were in danger of being inundated by the rising tailwater level. The WLC convened a call on June 17 with the Companies to examine the situation and determined that, if a temporary reduction in Rainy Lake outflow



June 2009 and June 17, 2014. Hannam Park along the shore of Rainy River at the Town of Rainy River.

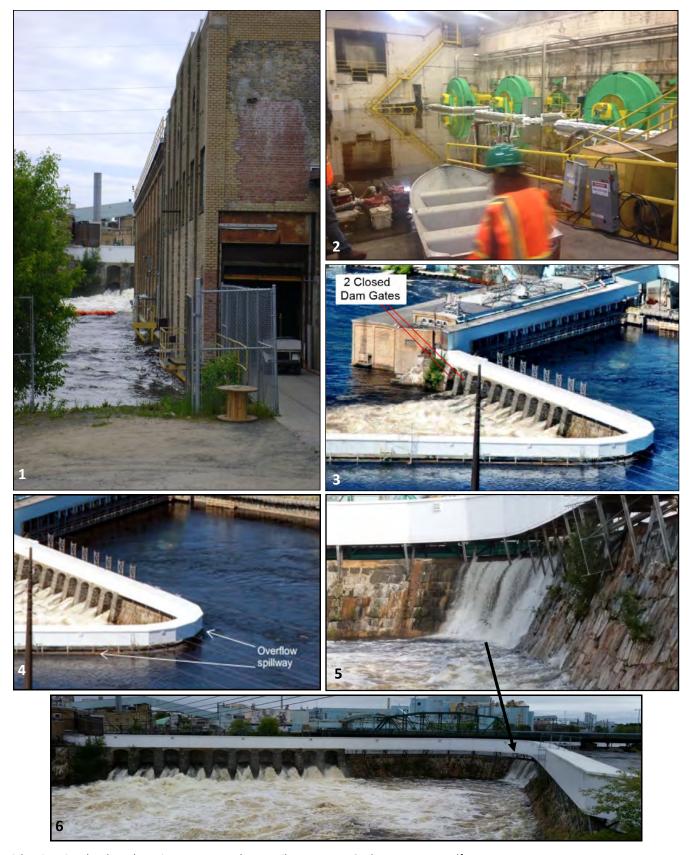
Photos: Google Maps; Matt DeWolfe

would suffice to prevent loss of the turbines due to flooding, this action should be taken as not acting would risk losing the flow capacity of these turbines, perhaps for weeks. The WLC requested and was granted permission from the IJC to conduct a two hour reduction in outflow on June 17 in order to collect data on the effect of the flow reduction on the tailwater level. This data was considered necessary to inform any future reduction in flows should the tailwater level be likely to overtop the sandbagged berms protecting the turbines. The test was carried out on the afternoon of June 17 and consisted of closing two dam gates for two hours, during which time detailed measurements of the tailwater level were recorded by the Companies. A media release describing this temporary test and the rationale for it was issued by the IRLWWB on June 17.

Following the test, the WLC reviewed the data and was satisfied that it had sufficient information on which to base any further flow reductions if the tailwater continued to rise. On June 19, with additional rainfall in the short-term forecast, the WLC requested that the IJC extend it the authority to direct H2O Power to close gates at the dam in the event that the tailwater elevation were to rise above 333.15 m (1093.0 ft). The IJC approved this emergency authority that same day. The authority was not exercised, however, as the tailwater level continued to recede despite the additional rainfall in the third week of June. Had the river level continued to climb, however, it likely would have been necessary to reduce outflow as necessary to protect the turbines. The flow through the Boise Paper turbines in June was approximately 17% of the total flow out of Rainy Lake. Had the turbines been lost to flooding, the resulting reduction in outflow would have resulted in Rainy Lake peaking higher than it did.

On June 22, the level of the upper Rainy River above the dam reached the spillway crest in the center of the dam and the additional spill capacity of the dam over this crest came into use. This emergency spillway had last passed flow in 1950. Responding to reports of public concern over dam safety as a result of this overflow, the IRLWWB issued a media release on June 22 to acknowledge the spillway use and to explain that it is designed for the safe passage of flow under just such conditions.

Inflow to Rainy Lake reached the highest rate of the year on June 16, after which it fell steadily through mid-July. At this peak, 40% of the inflow to Rainy Lake was from Namakan Lake outflow, the remainder being from other tributaries. Although in decline, inflow for the remainder of June was still exceptionally high and the lake level continued to rise. With rising water levels, however, the outflow capacity of the dam also in-



- 1. High Rainy River levels at the Boise Paper powerhouse tailwater, June 18. Photo: Matt DeWolfe
- 2.. Water in the turbine room, Boise Paper powerhouse, June 18. Photo: Matt DeWolfe.
- 3. June 17, 2014. Dam gates closed for two hours at the Rainy Lake dam to test the effect on tailwater levels. Photo: Lee Grim
- 4., 5., 6.: Water flows over the spillway crest at the center of the Rainy Lake dam for the first time since 1950. 4: Lee Grim, 5-6: Boise Paper

creased. The declining inflow and rising outflow came into balance on July 1, resulting in a peak Rainy Lake elevation for 2014 of 338.74 m (1111.35 ft). This was 84 cm (33 in) above the IJC All Gates Open level and marked the highest level since it reached 339.23 m (1112.96 ft) in 1950.

On July 4, the IRWWLB issued a media release to provide an update on the declining water levels in Namakan Lake and Rainy Lake as well as to address the apparent disparity between the levels of these two lakes. The WLC had received a number of inquiries from residents around Rainy Lake asking why outflow was not being reduced from Namakan Lake since it had peaked ahead of Rainy Lake and had declined earlier (discussed in Section 4).

In July, basin precipitation was near normal with the exception of the third week when approximately double the normal rainfall was received across the Rainy-Namakan watershed. For several days following this rainfall, the level of Rainy Lake rose slightly, but this was the only interruption in an otherwise constant decline from the July 1 peak level. On August 8, Rainy Lake fell below the IJC All Gates Open level, finally returning to the Rule Curve band on August 12.

High Water Levels in Context

In many locations in the Rainy River watershed, the peak water levels reached in 2014 were unprecedented in the record or greater than experienced in more than a generation. Compared to the record peaks since the IJC began regulation with Rule Curves in 1949, 2014 ranked second highest for Rainy Lake and third highest for Namakan Lake. In comparison with the record peaks for these lakes in 1950, Rainy Lake in 2014 was 49 cm (19.3 in) lower at its peak, while Namakan was 65 cm (26 in) lower. In the first half of the twentieth century, before the IJC began Rule Curve-based regulation, Rainy Lake exceeded the 2014 peak level once, in 1916, and Namakan Lake twice (1916, 1927).

A summary of the high water rankings since 1949 is given in Tables 2.1 and 2.2. This includes the number of days above the respective Emergency Levels defined by the IJC, 340.95 m (1118.6 ft) for Namakan Lake, and 337.75 (1108.1) ft for Rainy Lake. While 2014 was the highest year in memory for many property interests around these lakes, it was not close to what history has shown possible in this watershed.

Tables 2.1 and 2.2. Top 5 Peak Lake Levels for Namakan Lake and Rainy Lake Since 1949

N	Namakan Lake Peak (since 1949)										
Peak Rank	Peak Year	Level (m)	Level (ft)	# Days Above Emergency Level							
1	1950	342.20	1122.7	131							
2	1968	341.71	1121.1	83							
3	2014	341.55	1120.6	44							
4	2001	341.49	1120.4	38							
5	1966	341.32	1119.8	66							

Rainy Lake (since 1912)										
Peak Rank	Peak Year	Level (m)	Level (ft)	# Days Above Emergency Level						
1	1950	339.23	1113.0	176						
2	2014	338.74	1111.4	72						
3	2002	338.57	1110.8	48						
4	1968	338.36	1110.1	132						
5	2001	338.24	1109.7	65						

The scope of high water in 2014 should also be considered in the context of the broader geographical area surrounding the watershed. Across nearly all regions of the Winnipeg River basin, a quarter of which is made up by the Rainy-Namakan watershed, exceptionally high water levels were observed in June and July. In addition to Rainy River, record flood peaks were observed in tributaries near Sioux Lookout, Ontario and along the Winnipeg River at the Whiteshell, Manitoba, while near-record levels were observed along the English

River in Ontario. At Lake of the Woods and the Winnipeg River in Ontario, water levels were the highest since 1950. Further downstream, at the outlet of the Winnipeg River, Lake Winnipeg elevations reached a summer peak which was the 3rd highest on record post regulation (1976) and was above post regulation maximum levels in September and October. Outflow from Lake Winnipeg, regulated by the powerhouse and spillway at Jenpeg Generating Station, was maintained at the maximum possible rate for twenty weeks during the open water season. As a result of this operation, communities downstream of Lake Winnipeg experienced extremely high water level conditions as well.

In Minnesota, June was the wettest month in the modern record on a state-wide basis, with total precipitation in June exceeding 200 mm/ 8.0 in, and numerous individual stations reporting new June rainfall records. Flooding was widespread, ranging from farm fields to homes, closing roads and causing mudslides. States of Emergency due to high water were declared in 35 Minnesota counties, including Koochiching and Lake of the Woods Counties.

3. High Water Impacts

High water threatened or caused damage to a wide area of the watershed in 2014. This section provides an overview of the extent of the damages and the efforts to protect against rising water levels. A more comprehensive study was undertaken in 2014 by Environment Canada. This project, which was organized by the IJC ahead of 2014 to support the upcoming review of the 2000 Rule Curves, was initially aimed at developing a relationship between high Namakan Lake and Rainy Lake levels and damage costs. Following the exceptionally high water levels of the summer, the project scope was modified to document the extent of damages that occurred in 2014. The findings of that study, which is ongoing at the time of the writing of this report, are to be issued separately.

The high water levels on Rainy Lake, Namakan Lakes and other lakes upstream were damaging to structures and shorelines. Strong, sustained winds generated waves and wind setup, a process where the wind pushes the lake surface higher along the downwind shoreline while lowering it on the opposite one. The resulting locally higher lake levels and breaking waves pushed against vulnerable shorelines, infrastructure and protective works. In addition, seepage of groundwater from high lake levels entered basements and crawlspaces of homes and businesses.

Besides shoreline damage, there were safety concerns on the water. Reports of floating debris such as broken docks and downed trees, were widespread, including some reports of large floating bog-mats damaging shoreline structures or blocking channels.

As the water levels rose, significant expense and effort was devoted to protecting shoreline property and infrastructure. Volunteers in many communities responded to the call for assistance in sandbagging efforts, as did organizations such as the Red Cross and National Guard in Minnesota and the Ministry of Natural Resources and Forestry in Ontario. The rising water levels, however, caused damage despite these efforts, though without the extensive protective measures that were put in place in most areas, the damage would undoubtedly have been much more severe.

Ten communities in the Ontario portion the Rainy River watershed declared States of Emergency as a result of high water, among them the First Nations of Couchiching, Mitaanjigamiing, Seine River, and Nigigoonsiminikaaning, the towns of Fort Frances and Rainy River, and the townships of La Vallee and Emo. The Ontario Ministry of Natural Resources and Forestry (OMNRF) distributed over 150,000 sandbags to six First Nations, the town of Fort Frances and two rural fire departments. Dozens of shovels were also provided by OMNRF to First Nation communities. OMRNF Fire Crews, and most of the Fort Frances fire crews were active during the rising water period, assisting with protection efforts in many of these areas and in unincorporated areas where the impact of high water was particularly significant. \$2.47 million in disaster relief funding was made available through the Ontario Disaster Relief Program to help four municipalities rebuild critical infrastructure.

General descriptions of high water impacts, either directly shared to the WLC or reported in the media, were as follows, and may not be exhaustive (for map of locations, see Appendix A):

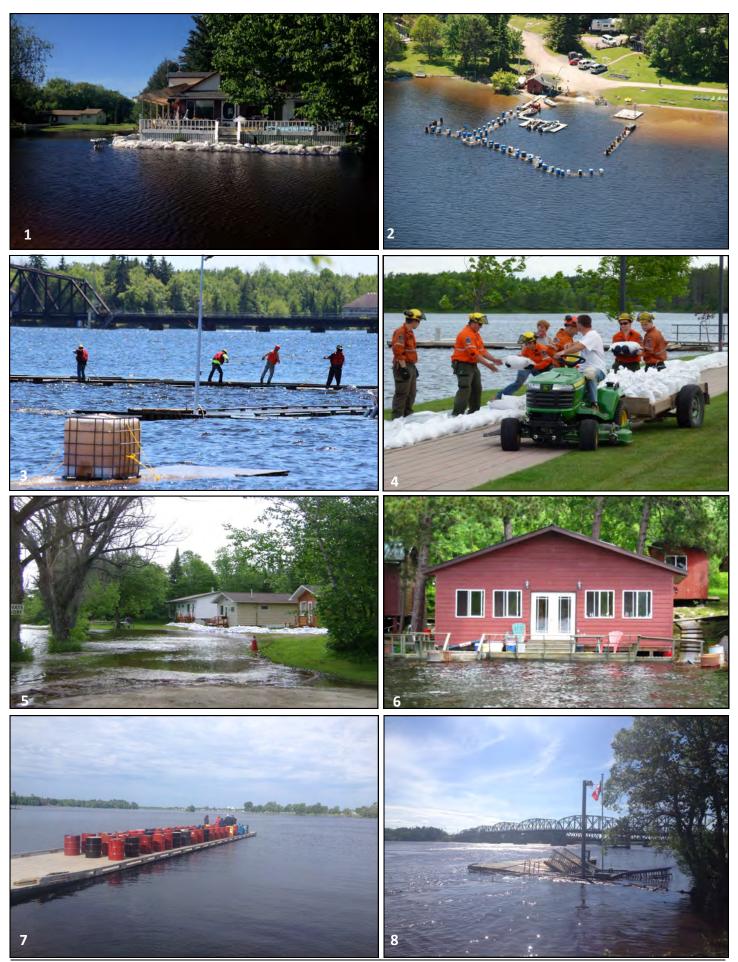
• Around Rainy Lake in Ontario, reported damage consisted mainly of shoreline erosion and damaged or lost shoreline structures. There were also reports of structural damage buildings, flooded basements, and, in the longer term, extensive areas of dying trees along the shoreline.

- Couchiching First Nation: Erosion was a significant issue, with reports of over 5 meters / 16 ft of eroded shoreline. As the water rose, the shoreline at the cemetery began to be undermined, but was kept from more significant damage through emergency stabilization and erosion prevention. Fifteen to twenty homes at Couchiching First Nation were damaged or threatened by the rising in water in June and July, while homes were reported to have water in crawl spaces and basements from groundwater seepage. Over 34,000 sand bags were deployed to keep up with rising water levels. In addition, rock walls were installed to build up the shorelines to protect against further erosion. An additional 1-1.5 km of such protection works are slated to be completed in 2015.
- Mitaanjigamiing First Nation: Rising water levels threatened its only access road as well as its water treatment plant.
- Town of Rainy River: earthwork and round-the-clock sandbagging were carried out in advance of the Rainy River crest. Damage occurred to municipal infrastructure, including loss of the government dock, as well as at private residences with many basements being flooded.
- Township of Emo: Rainy River's unprecedented rise led to significant damage to the water treatment plant, which is at a lower elevation than most town buildings.
- Township of La Vallee: Highway 11 was washed out during the heavy rainfall in early June.
- Fort Frances: Over 50,000 sandbags were deployed to protect the shoreline along Rainy Lake and the upper Rainy River. A rock wall was built along the Rainy Lake shorefront near Point Park in an attempt to halt rapid erosion. Due to the saturated ground conditions, the town contended with numerous sink holes, water main and sewer main breaks as well as erosion under roads. The town's water treatment plant, which is shared with Couchiching First Nation, was put into bypass mode once the sanitary sewer collection system reached maximum operating capacity.
- In Minnesota, the majority of reported damage was to cribs, docks, retaining walls and water entering basements and crawlspaces. Damages at individual properties in some cases were in the tens of thousands of dollars, while some tourism businesses lost earnings in addition to suffering infrastructure damage.
- Extensive sandbagging efforts, more than 300,000 deployed in Koochiching County, prevented more widespread damage as did the use of pumps to limit infiltration to structures. County officials registered over 2,500 volunteers, with an estimated 19,250 combined hours in preparing sandbags. This does not include work in other support roles such as equipment operators, truck drivers, barge operators, Red Cross/Salvation Army, County and City staff, Emergency Responders staff and National Guard. As of early August, the estimated damage to public infrastructure was over \$1 million, including the county, International Falls, MN Department of Natural Resources, and the Sanitary Sewer District.
- H2O Power advised the WLC that the low head conditions at the Fort Frances dam through the summer significantly reduced its electrical generation, with 77.99% lost generation in June, 61.10% in July, and 27.49% in August.

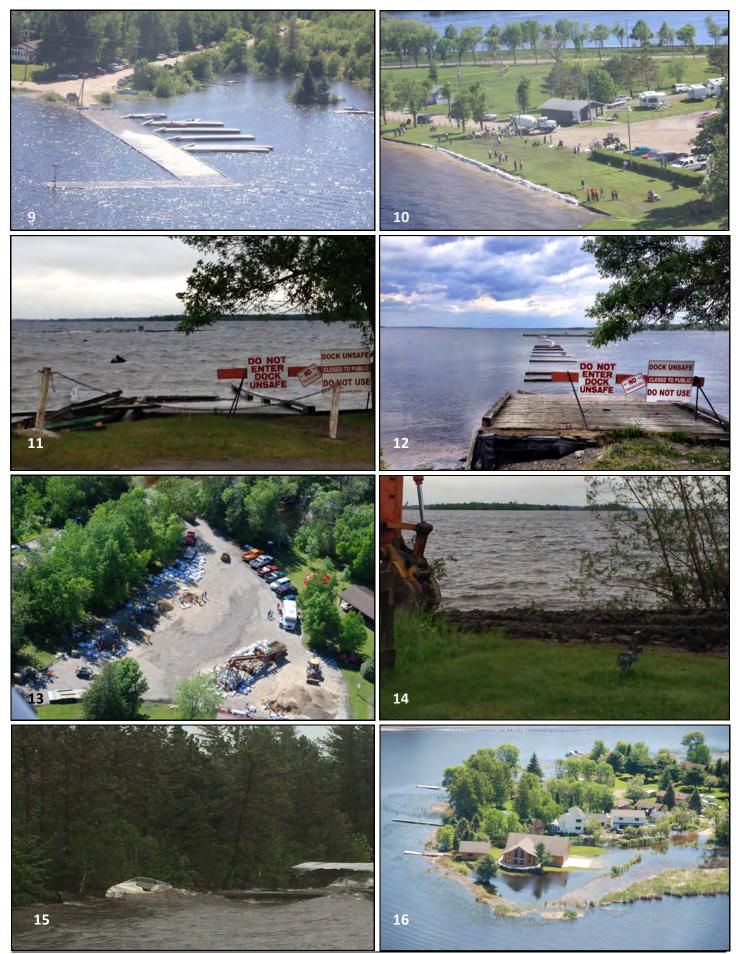
In addition to direct damage to property and the costs of mitigation efforts, considerable time, effort and resources were required clean up and rebuild after the high water receded.

Photographs 1-16 on the following pages illustrate some of the impacts of high water and efforts to mitigate against them.

- 1. Home in the Town of Rainy River. Photo: Matt DeWolfe
- 2. Submerged docks, like these on Kabetogema Lake, were common throughout the watershed. Photo: Lee Grim
- 3. and 4. Crews work to secure docks and sandbag the town waterfront in Fort Frances. Photos: Fort Frances Times
- 5. Rainy Lake inches closer to homes in Ranier. Photo: Alexandra Lavictoire
- 6. Before the peak of Rainy Lake, this camp in the Northwest Arm came very close to flooding of cabins. Photo: Tom Pearson
- 7. IJC Commissioner Rich Moy and WLC members saw many docks weighed with barrels in June, though this one, in Rainier, was the most extensive. Photo: Matt DeWolfe
- 8. The government dock at the Town of Rainy River. Photo: Matt DeWolfe
- 9. Five Mile dock near Fort Frances was closed due to high water. Photo: Chief Sara Mainville
- 10. Volunteers and town crews work to protect the eroding shoreline along Point Park, Fort Frances.
 - Photo: Chief Sara Mainville
- 11. and 12. A dock near Point Park in June (Photo 11) and August (Photo 12). Photo 11: Chief Sara Mainville.
 - Photo 12: Matt DeWolfe
- 13. Organized sandbagging efforts in Rainier. Photo: Lee Grim
- 14. Rainy Lake encroaches on the cemetery at Couchiching First Nation. Photo: Chief Sara Mainville
- 15. A boat is tossed against the shore during a period of strong winds in Sandy Bay, Rainy Lake. Photo: Tom Worth
- 16. Water nears homes at the mouth of Ash River, above Kabetogema Lake on June 17. Photo: Lee Grim



Report on High Water Levels in the Rainy River Watershed in 2014



Report on High Water Levels in the Rainy River Watershed in 2014

Page 32

4. Assessment of Actions

The chronology of dam operations at Namakan Lake and Rainy Lake, as well as the decisions taken by the WLC, the IRLWWB, and the IJC before, during, and after the flood peaks were reviewed in detail in Section 2. This section provides an assessment of these decisions, and relies on the results of computer simulations that model various alternative approaches to dam operations in the spring of 2014. Following this, an overview of the communications efforts made by the WLC, IRLLWB and IJC to inform and respond to the public during the event is provided.

A key technical element discussed in this section, and touched on earlier in the report, is the relationship between lake level and the maximum outflow from the dams. This concept is critical to understanding the results of the scenarios presented below. It is not possible for the Companies to set any outflow they choose from the dams at Namakan Lake or Rainy Lake. In both cases, the maximum possible outflow is limited by the lake level. In general, the higher the lake level, the higher the maximum flow. When the lakes are relatively low, such as early in the spring after they have been drawn down for the winter, the maximum outflow is relatively small. As the lakes refill in the spring, the maximum possible outflow increases with the rising lake level. Further details on this relationship and other constraints on releasing flows from these lakes are covered in Appendix F.

4.1 End of Winter

Historically, the principal factors contributing to high summer water levels in these lakes have been the timing and magnitude of spring rainfall. While snowpack is clearly a factor in providing wetter conditions heading into freshet, it is not a reliable predictor of high water conditions. There have been recent years, for example, where a significant snowpack has given way to a dry spring and low lake levels (e.g. 2006) and, conversely, years where a limited snowpack preceded a high water year (e.g. 2002, 2008). With this context in mind, the WLC directed the Companies to target the lower 25% range of the respective Rule Curves for the start of April. In setting this target, it was the intent of the WLC to augment the room for storage that is already provided by the over-winter drawdown required by the Rule Curves. This action was not intended to provide additional storage to absorb the entire freshet or above-normal late spring rainfall. The levels of both lakes at the start of the nominal freshet period (early April) were the lowest since the adoption of the 2000 Rule Curves.

Computer-based model simulations of the 2014 flows and levels for Namakan Lake and Rainy Lake were completed by the Lake of the Woods Secretariat to investigate whether alternative regulation actions would have resulted in different peak lake levels. The simulation was completed using a simple spreadsheet-based model that has been used in the evaluation of past high water events, and which was independently reviewed at the request of the IJC by the US Army Corps of Engineers Hydrologic Engineering Center following the 2001 and 2002 high water events. The model incorporates data on inflows to the basin and, based on user inputs, determines the optimal outflow from Namakan Lake and Rainy Lake for achieving the level and flow objectives required by the IJC Rule Curves or alternative objectives. Outputs include outflow and lake level for each lake on a daily basis. The scenarios evaluated were as follows (results are summarized in Figures 4.1 and 4.2 and Table 4.1).

S1 – Baseline – A simulation of the actual operations in 2014, the model targets the lower 25% of the Rule Curve bands of both lakes at the start of April, then the middle portion of the bands for the rest of spring.

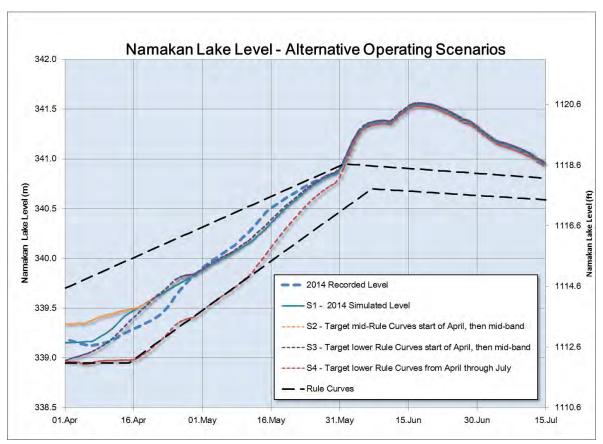


Figure 4.1. Results of Simulations S1-S4, Alternative Operating Scenarios for Namakan Lake

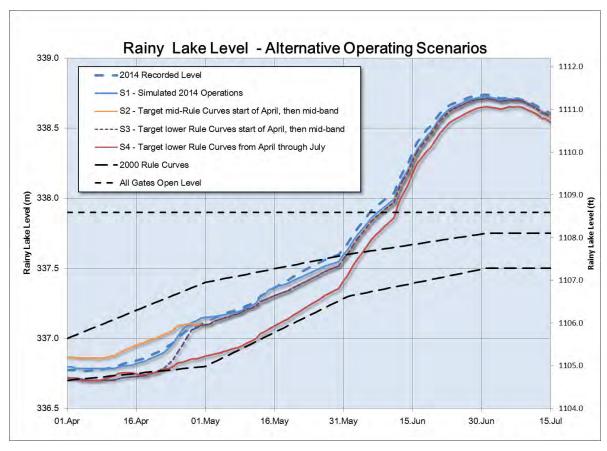


Figure 4.2. Results of Simulations S1-S4, Alternative Operating Scenarios for Rainy Lake

Table 4.1 Summary of Scenarios S1-S4 and Comparison with 2014 Historical Data

Scenario	Description	Rainy Peak	Namakan Peak
S1	Simulation of actual high 2014 opera- tions. Target 25% of Rule Curve bands at start of April, then mid- band	338.73 m 1111.32 ft	341.55 m 1120.57 ft
S2	Target mid-band of Rule Curves throughout	338.72 m 1111.29 ft	341.56 m 1120.60 ft
S3	Target lower Rule Curve at start of April then mid-band for spring	338.72 m 1111.29 ft	341.55 m 1120.57 ft
S4	Target lower Rule Curve throughout	338.66 m 1111.10 ft	341.53 m 1120.50 ft
2014 Actual	Actual 2014 peak lake levels	338.74 m 1111.35 ft	341.55 m 1120.57 ft

- **S2** Model targets mid-Rule Curve band on both lakes from the start of April through July.
- **S3** Model targets lower Rule Curve of each lake at the start of April, then mid-band for the rest of the spring.
- **S4** Model targets lower Rule Curve of each lake from April to July.

The S1-S4 simulation results indicate that targeting the lower 25% of the Rule Curve bands for both lakes at the end of winter was neither sufficient nor necessary to provide protection against higher peak water levels in early summer. Whatever the starting point in early April, from the Lower Rule Curve (0% of the band) to the middle of the Rule Curve band (50%), the lake levels in early summer are nearly identical. The early spring storage provided in all three scenarios, S1-S3, is sufficient to absorb the freshet flows into early May while dam operations are capable of maintaining the lakes at the middle of the Rule Curve bands. Under each scenario, therefore, the storage is the same heading into the heavy inflow period beginning in late May. The dams are quickly opened, and the same lake level pattern results as maximum outflow is exceeded by the extremely high inflow. Only in the S4 scenario, where the lakes are held at the Lower Rule Curves throughout the spring, is any benefit observed. The benefits, however, are very small for both lakes.

4.2 Early Spring

At the beginning of May, both lakes were tracking closely near the center of the respective Rule Curve bands. Flows were in the upper-normal range in the basin, with some freshet flows still developing in the upper reaches of the watershed. The WLC was monitoring conditions closely, but did not direct the Companies to target lower in the Rule Curve range. At this point, there was no indication of the high rainfall period that was to begin later in the month. With the above-normal rainfall in the second quarter of the month, the Companies had the Namakan Lake dams fully opened by mid-May and were operating the Rainy Lake dam gates to pass greater than 90% of the maximum theoretical flow. This being the case, the WLC did not deem it necessary to direct the Companies to target lower in the Rule Curve ranges at this time. Had the WLC done so, only a small additional flow out of Rainy Lake could be achieved, and the reduction in peak lake levels would have

been smaller than that in the S4 scenario described above.

4.3 Late Spring

Figures 4.3 and 4.4 and Tables 4.2 and 4.3 detail the log operations at the Namakan Lake dams and the gate operations at the Rainy Lake dam during the spring and summer of 2014. These are provided with the context of the developing inflow pattern. For Namakan Lake, only 30 of the available 125 logs were in the dam sluices by May 2. These were all removed by the Companies by May 16 following rainfall in the second quarter of the month. With the dams fully opened, the outflow from Namakan Lake was maximized from this date until the first logs were returned to the dams in late July.

At Rainy Lake, the Companies had opened sufficient gates by mid-May to ensure that outflow from the Rainy Lake dam was close to the theoretical maximum flow. At this time, the level of Rainy Lake was within the Rule Curve band, inflow was above normal and rising slowly, and the forecasts for the remainder of the month and June did not indicate significant precipitation. From May 20 until June 6 (when the last two dam gates were opened), daily outflow was within 94-99% of the theoretical maximum based on the lake level. Once all fifteen gates were opened, the dams gates passed the maximum possible flow. The total flow from the dam however, was slightly below the theoretical maximum for much of June and July. This is attributable to sub-optimal flows through the turbines. The combination of high Rainy River levels below the dam and low levels directly above the dam, particularly on the Canadian side where all fifteen gates are located, resulted in limited hydraulic head to engage the turbines through the high flow period.

The WLC, monitoring conditions closely as inflows rose in May and in regular communication with the Companies, the IRLWWB, and the IJC, was satisfied that the dam operations were prudent, timely, and in compliance with the IJC Order. Without the knowledge that a period of extremely high rainfall would begin at the end of May, the WLC considered the nearly maximum flow out of Rainy Lake as the appropriate response. The additional storage room that could have been gained by passing a full 100% of theoretical flow in mid-May from Rainy Lake would have been quickly lost in the heavy inflow period. This is because the slightly lower lake level from the fully opened dam at the start of June would have had a slightly lower maximum outflow. With lower outflow, the lake level would rise slightly faster and the peak elevation would not have been reduced. The WLC is satisfied that all appropriate steps were taken in the lead-up to fully opening both dams.

Once the dams were fully opened at both lakes, there was no further action that could be taken to increase the rate of outflow from either lake. In short, once the dams are fully opened there is nothing more that can be done to control the rate of flow into the lakes and the resulting lake level rise. The focus of the WLC at that point was on communications, providing the latest information on lake levels and forecasts to the public, state and provincial agencies, and community officials. This is covered in detail in sub-section 4.8.

4.4 Post-Peak – Summer 2014

Beginning on June 18, the maximum outflow rate from the dams at Namakan Lake was slightly more than the rate of inflow to the lake. This allowed the lake level to begin a three-week period of slow decline, reaching the IJC All Gates Open Level on July 9. Meanwhile, the level of Rainy Lake over this period had continued to climb, peaking on July 1 but not beginning a steady decline until a week later. During this period, the WLC received a number of inquiries from property interests at Rainy Lake asking why outflow from Namakan Lake was not being reduced to balance the severity of high water between the two lakes.

Table 4.2 Summary of Dam Operations at Namakan Lake Spring 2014

Date	Inflow		Outflow		# Logs in
Date	m³/s	percentile	m ³ /s	percentile	(Max 125)
April 6	75	15th	98	39 %	67
April 25	210	35th	118	37 %	64
April 26	233	45th	145	45 %	59
April 29	288	60th	185	53 %	52
May 2	320	50th	231	63 %	30
May 12	410	75th	328	78 %	22
May 15	474	85th	395	88 %	7
May 16	498	85th	459	100 %	0—Fully Open
July 20	460	> 95th	472	93 %	11

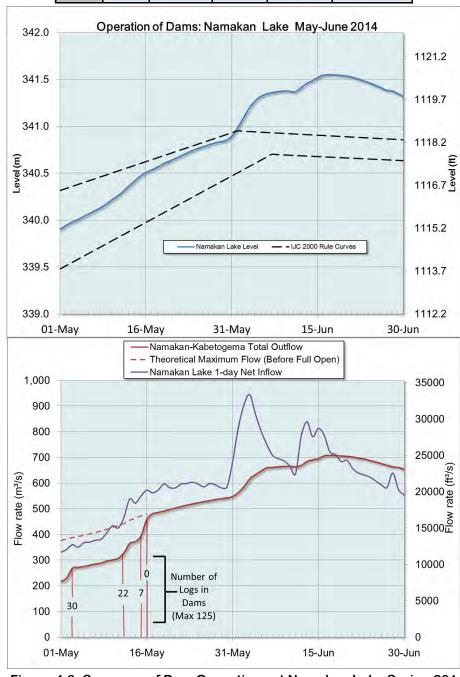


Figure 4.3. Summary of Dam Operations at Namakan Lake Spring 2014

Table 4.3 Summary of Dam Operations at Rainy Lake Spring 2014

Date	Inflow		Outflow		# Gates Open	
	m³/s	percentile	m ³ /s	% of Max	Canal	Dam
May 1	503	65th	437	68 %	2	0
May 5	571	75th	486	72 %	4	0
May 7	607	76th	540	79 %	All 5	0
May 13	708	83rd	572	79 %	All 5	1
May 15	765	84th	624	85 %	All 5	3
May 16	796	85th	683	92 %	All 5	5
May 20	884	86th	741	96 %	All 5	7
May 30	969	82nd	821	98 %	All 5	8
June 6	1323	97th	927	95 %	All 5	All 10

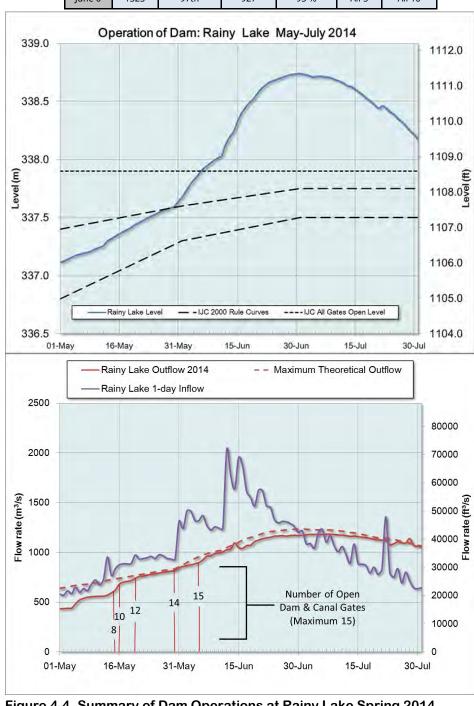


Figure 4.4. Summary of Dam Operations at Rainy Lake Spring 2014

The WLC examined this situation carefully, and provided a basic rationale for its decision not to direct reduced outflows from Namakan Lake in an information release on July 4. A more detailed explanation follows.

On July 1, outflow from Namakan Lake was approximately 18 % greater than inflow, a difference of about 100 m³/s (3500 ft³/s). This difference had allowed the gradual decline in the level of Namakan Lake from the peak. Since holding Namakan Lake above the IJC Emergency Level was not an option, the only action available was to reduce Namakan Lake outflow by a small amount so that the decline would not be halted. As the lake level fell, however, so too did the outflow capacity from the dam. By July 7, outflow was just 9% greater than the inflow, which had remained nearly constant since the start of the month. Any reduction in outflow would necessarily be limited to between 25 to 50 m³/s (880 to 1,760 ft³/s), to prevent Namakan Lake from rising again.

A reduction of 25 m³/s (883 ft³/s) from the maximum outflow over the first week of July would have limited the rate of decline on Namakan Lake to 5.7 cm (2.25 in) per week, postponing the fall of the lake below the IJC All Gates Open level. Because Rainy Lake has nearly four times the surface area of Namakan Lake, this reduction in outflow from Namakan would only have resulted in 1.5 cm (0.60 in) of additional drawdown in the Rainy Lake level over this week. At the time, the forecast was favourable, but any significant rainfall in the near term could have again resulted in Namakan Lake inflow rising and, with outflow so close to maximum capacity, there would have been no way to prevent a return to high water levels at Namakan Lake. Because additional outflow was not possible, the only tool that was available to protect Namakan Lake from a return to high levels if more significant rainfall had developed in July was additional storage in the lake. In the opinion of the WLC, the very minor benefit to Rainy Lake was outweighed by the tenuous nature of the decline that was underway on Namakan Lake. For these reasons, the WLC, continuing to monitor conditions closely, waited until July 20 before directing the companies to target the Upper Rule Curve on Namakan Lake and begin reducing outflow.

With the benefit of computer modelling and historic data for the period, the effect of reducing outflow from Namakan Lake in early July to hasten the decline in Rainy Lake level was evaluated. This scenario assumes that Namakan Lake daily outflow rate was 50 m³/s (1765 ft³/s) lower than that reported for the month of July. Results of the scenario are presented in Figures 4.5 and 4.6.

Under this scenario, the level of Rainy Lake begins to decline from the peak slightly faster, while the level of Namakan Lake declines much more slowly in early July, and actually climbs late in the month until the outflow reduction is ended on August 1. Once this reduction is ended, the outflow from Namakan Lake is increased sharply so as to target a return to the Rule Curve band in early August. This results in an *increase* in inflow to Rainy Lake. The overall result is that the decline of Namakan Lake to the IJC All Gates Open level is delayed by 23 days, while the decline to the Rule Curve band is delayed by 18 days. The level of Rainy Lake, meanwhile, reaches the IJC All Gates Open level 1 day *later* due to the increased Namakan Lake outflow in early August, and returns to the Rule Curve band two days later than in the scenario with no reduction in Namakan Lake outflows. The scenario could be modified to continue to have lower flows out of Namakan Lake into August and therefore not increase inflow to Rainy Lake. However, this would result in a continued rise in Namakan Lake level above Emergency Conditions, which is not an action that the WLC would have directed or recommended.

These results indicate that even a modest reduction in outflow from Namakan Lake in July would have significantly delayed the return to normal lake levels on Namakan Lake while providing a minor benefit to Rainy

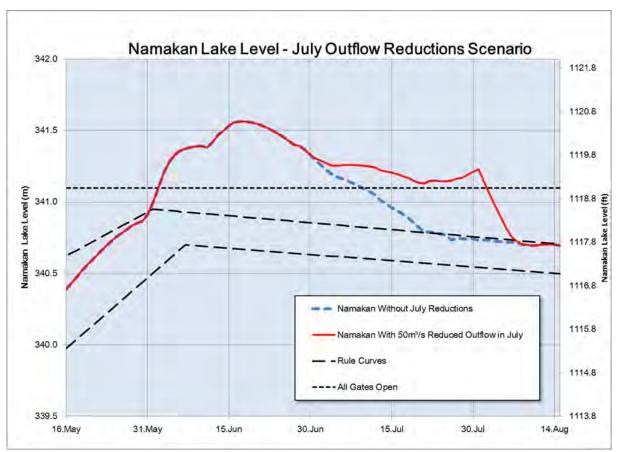


Figure 4.5. Namakan Lake level— July Outflow Reduction Scenario

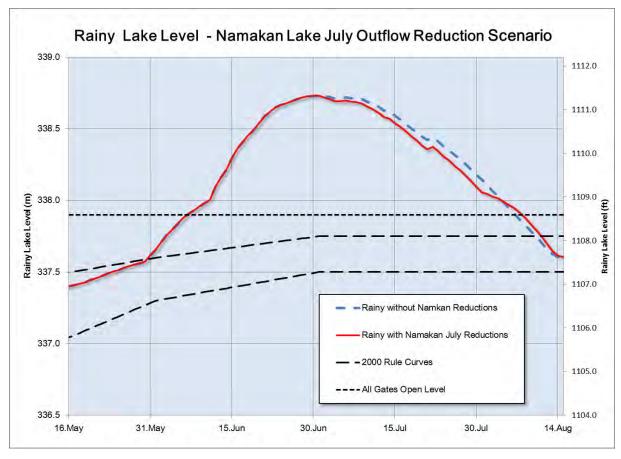


Figure 4.6. Rainy Lake level—July Outflow Reduction Scenario

Lake in mid-July and little or no benefit later in the month. This scenario only considers the inflows that resulted from the actual rainfall patterns of July, 2014, which could not be known in advance. Had July rainfall been significantly higher, a decision to hold water back on Namakan Lake would likely have resulted in a much longer period of sustained high water conditions there.

After reviewing the data and various simulation scenarios, the WLC is of the opinion that its decision to maintain maximum outflow from Namakan Lake in early July was appropriate. In prolonged periods of widespread, extremely high inflow, it is important to pass water through the system as quickly as possible. This allows for the quickest recovery of total storage capacity in the reservoirs so that there may be some protection should heavy precipitation return. The balance of conditions across the watershed is important to consider, but short of significant risk to human safety or critical infrastructure (e.g. hospital, water treatment facilities), ensuring the fastest possible release of flows under conditions such as experienced during June 2014 is the preferred approach of the WLC, and is consistent with the IJC Order.

4.5 Extreme Drawdown Simulation

The results of simulation scenarios S1-S4 suggest that there was no realistic, practical regulation option under the Rule Curves that could have avoided Emergency Conditions at Namakan Lake and Rainy Lake in the summer of 2014. The rate of water flowing into the lakes in a short period of time was simply far greater than the maximum flow rate out of the lakes. This would have been the case under any scenario of dam operation on either lake. The results of an additional simulation scenario, S5, further support this conclusion. This scenario examines what would have happened if both lakes had been drawn down to very low levels as of May 15, shortly before the start of the heavy rainfall period that produced the extreme inflows from late May through July. This is not intended as a potential regulation option to consider, as drawing the lakes down to these levels would be devastating to most interests. Instead, it is included here to demonstrate that even taking the most extreme steps to prepare for the high June inflow would not have prevented the development of Emergency Conditions at these lakes.

In this scenario, both Namakan Lake and Rainy Lake are drawn down nearly to the lowest level that still allows for outflow from the dams. For Namakan Lake, the level is 337.21 m (1106.3 ft), 1.74 m (5.71 ft) below the IJC Drought Line of 338.95 m (1112.04 ft), and 59 cm (23 in) lower than the minimum recorded level since IJC regulation began in 1949. For Rainy Lake, the scenario starting elevation on May 15 is 335.40 m (1100.39 ft), 1.7 m (5.6 ft) below the IJC Drought Line, and over 1 m (3 ft) lower than the minimum recorded level since IJC regulation began in 1949. Under this scenario, maximum outflows from the dams at both lakes are maintained from the start (May 15) until the lake levels peak.

Figures 4.7 and 4.8 illustrate the results of this simulation. The resulting peak on Namakan Lake is 341.41 m (1120.11 ft), 31 cm (12.2 in) above the IJC All Gates Open level and 14 cm (5.5 in) below the actual 2014 peak. For Rainy Lake, the peak elevation is 338.15 m (1109.42 ft), 25 cm (10 in) above the IJC All Gates Open level. In both cases, the extremely low starting lake elevations result in a very small outflow capacity from the lakes. The sudden rise in inflow in June far exceeds the maximum outflow capacity for several weeks, the lakes fill rapidly, and eventually exceed the respective IJC All Gates Open levels.

Two additional points related to scenario S5 are important to note. First, even with perfect foreknowledge in the winter that extreme rainfall would develop in June, the low May 15 levels in the S5 scenario would not have been attainable. By releasing maximum outflow from both lakes on January 1 and maintaining this through the entire winter and spring, the lakes would not have fallen to the May 15 minimum level consid-

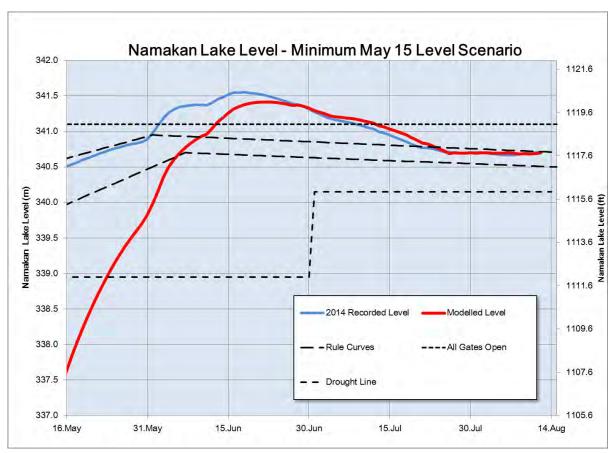


Figure 4.7. Namakan Lake Simulation S5—Minimum May 15 Level

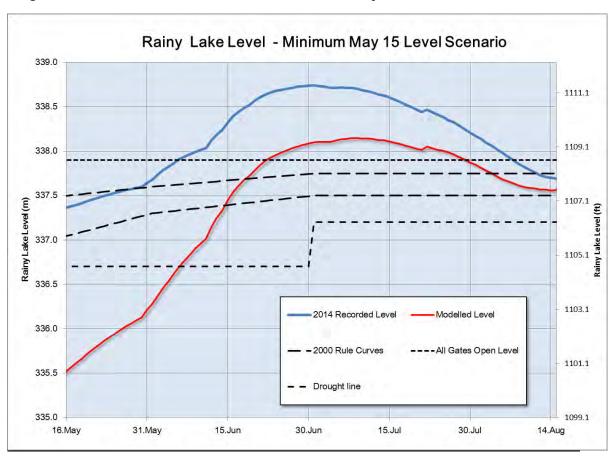


Figure 4.8. Rainy Lake Simulation S5—Minimum May 15 Level

ered in the S5 scenario. Second, there are no reliable long-term precipitation forecasts, so there is no fore-knowledge of spring rain patterns in the winter. That being the case, consider a scenario where extremely low spring levels are targeted on the remote chance that extremely high inflows would develop. Should spring rainfall turn out to be normal or below normal in such a scenario, the lakes may take many weeks to return to the Rule Curve range. Worse, if drought conditions were to develop, the control of lake levels could be lost in the opposite sense. The results would be very harmful for many of the interests that the IJC seeks to balance through Rule Curve-based regulation. Hedging against a rare, but exceptional, high inflow spring every year by dramatically drawing down the lakes is not a reasonable operation policy, and in any case will not guarantee the lakes will remain below emergency high water levels.

4.6 Alternative Precipitation Scenarios

If emergency high water conditions were unavoidable 2014 due to the scale of the late spring precipitation, the question arises: How much rain *could* have fallen without the lakes reaching emergency levels? To evaluate this question, several scenarios were simulated. For these scenarios, a watershed hydrologic model (WATFLOOD) was used to simulate inflow patterns. Based on inputs that reflect the watershed's physical characteristics and meteorological conditions, the model provides estimates of inflow to the major lakes in the watershed. This model was used operationally during the 2014 high water event to assist with forecasts of lake level change. For the purposes of this report, the historic rainfall data used by the model was reduced from April 1-July 1 to simulate the inflow patterns that would have occurred in several scenarios, as follows:

- **S6.** Precipitation reduced to 50% of actual from April 1-July 1.
- **S7.** Precipitation reduced to 65% of actual from April 1-July 1.
- **S8.** Precipitation reduced to 75% of actual from April 1-July 1.
- **S9.** Precipitation reduced to 90% of actual from April 1-July 1.
- **\$10.** Precipitation reduced to 95% of actual from April 1-July1.

The inflow results from these WATFLOOD scenarios were then used to simulate the lake regulation assuming the same lake level regulation strategy used in 2014 (2000 Rule Curves, targeting lower 25% of band on each lake in early April, mid-band thereafter). It is important to note that the timing of specific rainfall events was not changed, only the quantity of the rainfall. All other conditions in the watershed, such as temperature, antecedent moisture conditions, and the flows resulting from snowmelt were unchanged.

The results of the simulations are presented in Figures 4.9 and 4.10. In each figure, the base scenario is simulated using the inflow generated by the WATFLOOD model with 100% precipitation (i.e. the simulation of actual flows in 2014). This results in a lake level pattern that differs somewhat from the base simulations in scenarios S1-S5 which use actual 2014 inflows.

The simulation results suggest that Namakan Lake could have been maintained within the Rule Curve band, and Rainy Lake could have been held at or below the IJC All Gates Open level, if the watershed received less than 75% of the precipitation that actually occurred from April through June. 75% of the April 1- July 1, 2014 rainfall corresponds to 270 mm (10.6 in), an amount exceeded in this time period once every five years, on average (80th percentile). As precipitation increases beyond this amount, the scenarios show that the inflow exceeds the outflow capacity of the lake outlets for a sufficient length of time to push the lakes above the emergency levels defined by the IJC. These results also show that greater rainfall results in longer duration of

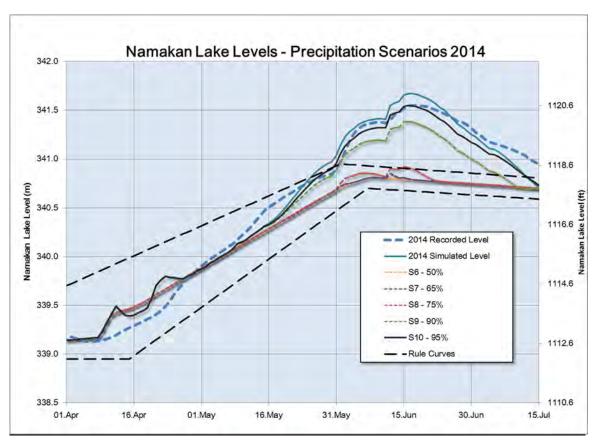


Figure 4.9. Namakan Lake Precipitation Scenario Simulations. Each Scenario simulates the resulting level that would occur under a reduced percentage of May 1-July 1 rainfall.

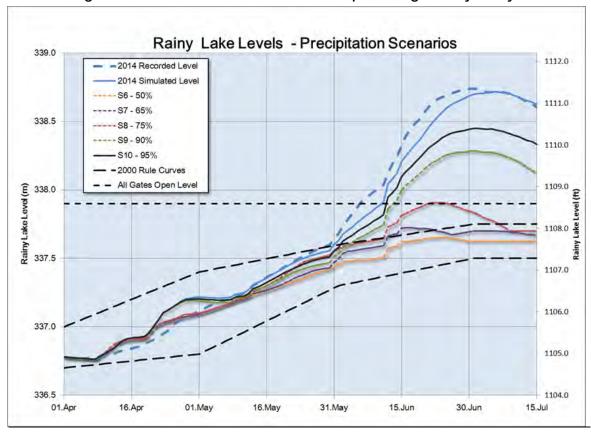


Figure 4.10. Namakan Lake Precipitation Scenario Simulations. Each Scenario simulates the resulting level that would occur under a reduced percentage of May 1-July 1 rainfall.

high water conditions on both lakes.

Although the total quantity of rainfall is the principal factor contributing to high inflows in June, the timing of each rainfall event also plays an important role. Had all of this precipitation fallen more evenly from April through June, the inflow pattern may have been more manageable, since higher water levels earlier in the spring would have allowed for higher outflow early on.

4.7 Rainy River Considerations

In early June, heavy rainfall produced an extraordinary rise in flow out of the Big Fork and Little Fork rivers into Rainy River below Fort Frances-International Falls. As detailed in Section 2, the combination of these flows with the maximum flows being passed out of the Rainy Lake dam pushed Rainy River to a record high level. As Rainy River was rising, the WLC had to address pressing problems along the river and at the dam.

The potential for flooding at the Town of Rainy River was a significant concern, with the town declaring an emergency on June 13. The WLC decision on June 14 to not reduce outflow from Rainy Lake was made with all of the available facts and the latest forecasts, and with direct communication with officials from the Town of Rainy River. It was the view of the WLC at the time, and is in retrospect, that any reduction in outflow from Rainy Lake would have increased the risk of flooding on the lake with little potential benefit to the Town of Rainy River given the extreme local flows into the river. The Town did not request a reduction in outflow, but did request assistance with forecasting the timing of the crest of the river to assist with their flood protection efforts. On June 18, IJC Commissioner Rich Moy, WLC members and engineering advisors visited the Town of Rainy River to meet with town officials and see the extent of the damage and protective efforts.

At the Rainy Lake dam, the rising level of the Rainy River also created problems. The rising water below the dam entered the Boise Paper powerhouse, threatening the turbines. On June 17, there was the potential for still greater rainfall in the short term in the Rainy River watershed and it was likely that more rainfall would bring the level of the river above the sandbagged berms protecting the generators. The WLC's recommendation to close two dam gates that day in order to test the effect of reduced outflow on the level of the tailwater was approved by the IJC so that, if necessary to protect the generators in the short term, the decision on the number of gates to close would be made with sound data. In the view of the WLC, it would have been necessary to close the gates if the turbines were in imminent danger of flooding. In the short term, this would have resulted in the level of Rainy Lake rising more quickly, but in the longer term, perhaps on the order of many weeks, the outflow capacity lost by a shutdown of the Boise Paper turbines would have resulted in a prolonged period of high water. Fortunately, the tailwater subsided and no dam outflow reductions beyond the two-hour test period were necessary. However, this event demonstrates that the Boise Paper powerhouse turbines remain vulnerable to extremely high Rainy River flows.

4.8 Communications

From winter through to the return to normal water levels in August, the WLC used a variety of communication tools to convey important information about water levels to the public and officials of various levels of First Nation, state, provincial, and municipal authorities. These efforts included the following:

• The IRLWWB's Basin Data page was updated each business day, as usual, with the latest water level and flow conditions in the basin, as well as details on the number of dam gates opened at Rainy Lake and logs in sluices at the Namakan Lake dams. Updates were extended to twice daily, seven days a week from early June to early July.

- Beginning in April, the WLC and the IRLWWB issued media releases to area news outlets, organizations, and individuals concerned with water level management in the basin, as well as posting them on the IJC's IRLWWB website. From April 2 to June 23, ten such releases were made, advising of the latest basin conditions and important developments, such as the flow reduction test on June 16. Three more were issued following the peak in lake levels in August to advise of declining lake levels.
- Lee Grim, local U.S. member of the WLC and IRLWWB, provided updates on basin conditions over the radio every Tuesday and Thursday, from April 22 to July 22. These spots, which ran for 5-8 minutes, were sponsored by Boise Paper, and aired early each morning and again after noon, for a total of 58 spots.
- Mid-June to mid-July, the Canadian Engineering Advisors to the WLC, based in the Lake of the Woods Secretariat, issued Special Bulletins seven days a week that provided the latest details on current lake levels and forecasts, expanded to include Rainy Lake. This was distributed to the media contact list, posted on the web, and emailed to an ad hoc list of basin interests such as town officials and individual property owners. The Lake of the Woods Secretariat's Recorded Phone Message Service also provided the latest Special Bulletin details through a toll-free number.
- The Canadian Engineer Advisors to the WLC attended fourteen briefing calls of Emergency Management Ontario to provide the latest updates on forecasted water levels. These calls brought together representatives of various communities affected by high water with provincial and federal agency representatives to identify and address emergencies related to rising water levels.
- Engineering advisors provided information to NOAA, EC and the Ontario Surface Water Monitoring Center on lake level forecasts during the high water period.
- IJC Commissioner Rich Moy joined WLC members and engineering advisors to visit critical areas on June 16. The group briefed the Koochiching County Flooding Emergency Meeting in International Falls, met with officials from the Town of Rainy River to survey the damages there, inspected the flooded turbine room at the Boise Paper powerhouse, and met with town officials in Fort Frances to review shoreline defences and threats to the town wastewater treatment plant. They also visited properties on both American and Canadian shores of Rainy Lake and along the Rainy River to see the rising water conditions.
- The Canadian co-chair of the IRLLWB toured the Fort Frances-International Falls area with the local US Member of the WLC on June 20 and attended the Koochiching County Flooding Emergency Meeting.
- WLC members and engineering advisors responded to many phone calls and emails from the public, as
 well as First Nations and municipal representatives concerning the high water conditions. In addition,
 Tom Worth of the Rainy Lake Sportfishing Club was very helpful in sharing information provided by the
 WLC through social media.
- Several dozen media interviews were given by WLC members and engineering advisors to advise on the latest water level conditions. Media outlets ranged from the Twin Cities to Thunder Bay, including radio and press.
- IJC Commissioners, IRLWWB members and WLC members and engineering advisors hosted a public meeting on the evening of August 12 in International Falls. The American co-chair of the IRLWWB and WLC gave a presentation on the high water event and answered questions from the audience, which numbered about 90 persons.

Based on feedback from various officials from both countries involved in the high water response, the information provided through these various communication efforts was useful and relied upon. Before the Special Bulletins were issued on a daily basis, there were concerns expressed to the IRLWWB about the provision of timely water level forecast information and the availability of this information online. At the public meeting hosted by the IJC in August in International Falls, one member of the public stated that there should be a mechanism in place to alert property owners who live outside the region of high water conditions.

Staff of the Water Survey of Canada and the United States Geological Survey worked tirelessly under difficult conditions to take measurements and to ensure the ongoing operation of water level gauges in the basin, some of which were threatened by rapidly rising water. Their efforts and communications were much valued and appreciated by the WLC and were essential to ongoing water level forecasting efforts and to the dissemination of timely information.

4.9 Coordination and Communication under Emergency Conditions

During the period of extremely high inflow in June and July, the Water Levels Committee and its engineering advisors were actively engaged with basin residents and various levels of government in both countries. In reviewing its response to the event, the Water Levels Committee notes that there is no defined mechanism in place for communication under Emergency Conditions between the various stakeholders, the Water Levels Committee, the IRLWWB and the IJC. The development of contact lists, the Special Bulletin, etc. described above were done on an impromptu basis, and the WLC received some criticism that it was not proactive in advising communities of the likely development of high water levels.

The WLC recommends that the IJC review the management of information during Emergency Conditions, including more clearly defining the responsibilities of the WLC and the IRLWWB. It further recommends that the IJC consider the development of a protocol for communications with various levels of government, First Nations, tribes and the general public for use in future Emergency Conditions.

5. Role of the 2000 Rule Curves

Since 1949, the levels of Rainy Lake and Namakan Lake have been regulated by the IJC through the use of Rule Curves. In 2000, the IJC promulgated new Rule Curves for Rainy Lake and Namakan Lake to replace those previously established in 1970. This change followed several years of extensive study and public input. The largest differences between the 1970 and 2000 Rule Curves are for Namakan Lake, including the end-of-winter level (mid-band is 90 cm (35.4 in) higher on April 1 under the 2000 Rule Curves) and the refill target date (start of June under 2000 Rule Curves versus last week of June under 1970 Rule Curves). The differences for Rainy Lake are relatively minor. Comparisons of the Rule Curves sets are presented in Figure 5.1.

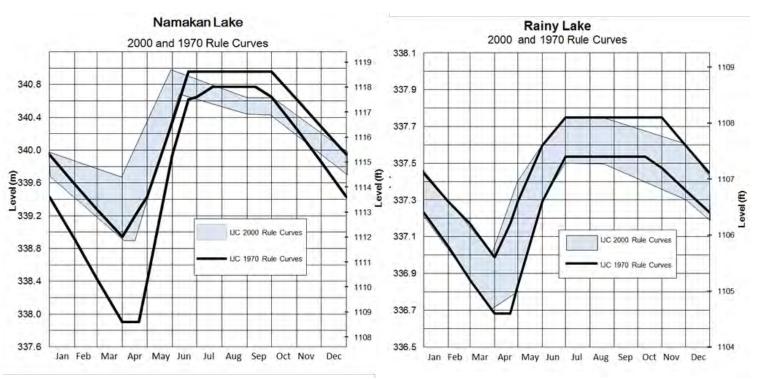


Figure 5.1 1970 and 2000 IJC Rule Curves for Namakan Lake and Rainy Lake

Regulation of Rainy Lake and Namakan Lake levels during 2014 was conducted under the IJC's 2000 Rule Curves. With the exception of targeting the lower 25% for Rule Curve bands on each lake at the start of April, the lakes were regulated with a target of mid-Rule Curve band before high water developed in June.

This section addresses the direction by the IJC to examine the role that the 2000 Rule Curves played in the development of high water conditions in 2014, as well as to determine the effects of the 1970 Rule Curves on the 2014 high water conditions, had they been in place.

5.1 Simulation of 1970 and 2000 Rule Curve Operations in 2014

In order to evaluate what effect operating under the 1970 Rule Curves might have had on peak water levels in 2014, two scenarios were simulated:

S11. Operation under the 1970 Rule Curves, targeting mid-band of Rule Curves from April 1 through summer. Since Namakan Lake under the 1970 Rule Curves has a much lower end-of-winter target, this scenario assumes that mid-band would be targeted in early April, rather than the lower 25% of the Rule Curve band as occurred in 2014.

\$12. Operation under the 1970 Rule Curves, targeting lower 25% of Rule Curve bands on April 1, mid-band afterwards. This scenario is included to evaluate how providing additional storage at the start of spring under the 1970 Rule Curves would affect the peak summer level.

The results of these scenarios are summarized in Figures 5.2 and 5.3, with peak elevations compared to actual 2014 values provided in Table 5.1.

Table 5.1 Summary of 1970 vs. 2000 Rule Curve Scenario Results

Scenario	Description	Rainy Peak	Namakan Peak
S1	Simulation of actual high 2014 opera- tions. Target 25% of Rule Curve bands at start of April, then mid-band	338.73 m 1111.32 ft	341.55 m 1120.57 ft
S11	1970 Rule Curves, targeting mid-band on April 1 then mid-band	338.67 m 1111.12 ft	341.46 m 1120.28 ft
S12	1970 Rule Curves, targeting lower 25% of band April 1 then mid-band	338.67 m 1111.12 ft	341.46 m 1120.28 ft
2014 Actual	Actual 2014 peak lake levels	338.74 m 1111.35 ft	341.55 m 1120.57 ft

In scenarios S11 and S12, where the 1970 Rule Curves are followed, the simulation directs minimum outflow from Namakan Lake in early April to hold the lake level above the lower Rule Curve. This quickly changes, however, as freshet flows develop in April. By the last week of April, the simulation fully opens the Namakan Lake dams in an attempt to keep the lake within the middle portion of the rising Rule Curve. The simulation keeps the dams fully open from late April through July. The early move to fully opened dams is due to the lake level being so much lower in the spring in the 1970 Rule Curves. In both S11 and S12 scenarios, this limitation results in lower outflow than was achieved in 2014 under the 2000 Rule Curves throughout May and into June until past the peak lake level. The lower starting elevation under the 1970 Rule Curves, therefore, affords limited protection against the high water levels, reducing the peak elevation in the simulated scenarios by 9 cm (3.5 in) compared to the actual 2014 peak.

For Rainy Lake, the S11 and S12 scenarios indicate a 6 cm (2.4) in reduction in the peak Rainy Lake level in 2014 had the 1970 Rule Curves been in place. In both scenarios, the simulated level of Rainy Lake tracks the middle of the Rule Curve band until the end of May as outflow from Namakan Lake is limited by the lower water level there. The simulation is set up to aggressively target the mid-band, and releases maximum outflow from the Rainy Lake dam beginning May 15 (S11) or May 20 (S12). At the end of May, the total inflow quickly increases and the simulated lake level rises until the peak at the beginning of July.

The results of these simulations once again point to the limited effect that a lower starting level before freshet would have had on the peak summer elevation in 2014. For Namakan Lake, the 1970 Rule Curve are substantially lower at the start of April than under the 2000 Rule Curves. As stated previously, lower lake levels correspond to lower outflow capacity from the dams at both lakes. It is apparent in the S11 and S12 scenarios that inflow is rising rapidly, but without the higher lake elevations greater outflow cannot be attained, and therefore the level of Namakan Lake rises quickly.

At the conclusion of the Rule Curve review process in 1999, it was recognized that operation under the 2000 Rule Curves would result in somewhat higher levels during years of high inflow. This was considered accepta-

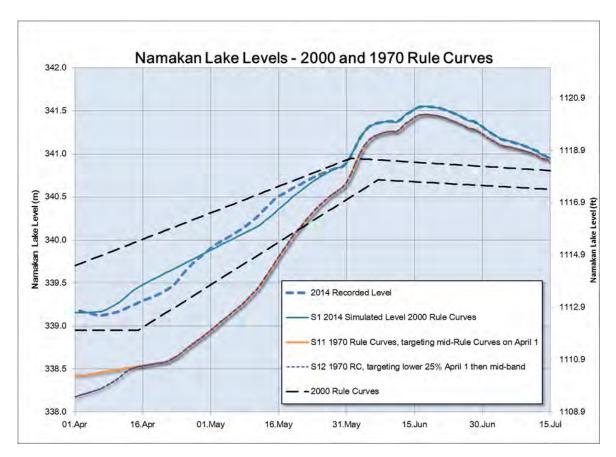


Figure 5.2. Simulation of Namakan Lake levels under 1970 and 2000 Rule Curves, compared with actual 2014 level and simulated 2014 level.

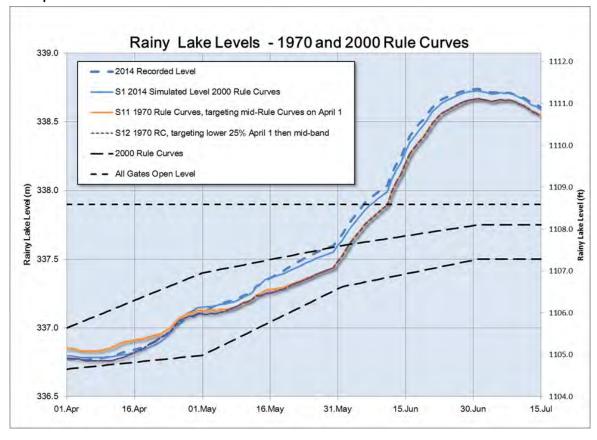


Figure 5.3. Simulation of Rainy Lake levels under 1970 and 2000 Rule Curves, compared with actual 2014 level and simulated 2014 level.

ble when weighed against the expected benefits the modified Rule Curves would provide in normal flow years (see "Final Report: Review of the IJC Order for Rainy and Namakan Lakes", Appendix B). The simulation results presented here are consistent with this and with the findings of the former International Rainy Lake Board of Control in its reviews of the 2001 and 2002 high water events.

5.2 Hydrologic Response Model - 1970 vs. 2000 Rule Curves

The S11 and S12 scenario results described above address the IJC's directive to investigate the potential effects of the 1970 Rule Curves, had they been in place. This question was also evaluated by Environment Canada's Boundary Waters Issues Unit using a different, independent simulation model called the Hydrologic Response Model. This model was developed in 2013 to support the IJC's review of the 2000 Rule Curves. It provides comparative sets of simulated, quarter-monthly lake levels since 1950 for both lakes under the 1970 and the 2000 Rule Curves. The model period was extended to include data through the summer of 2014 in order to evaluate the potential effects on the 2014 peak lake levels of the 1970 Rule Curves, had they been in place. Because the model is designed to simulate the entire period since 1950, the target level employed by the model is the mid-point of the Rule Curve at all times. As a result, the model does not begin the spring of 2014 with lower target levels in either the 1970 or 2000 Rule Curve simulations. The results of the Hydrologic Response Model for summer 2014 are presented in Table 5.2.

Table 5.2 Results of Hydrologic Response Model—1970 vs. 2000 Rule Curves

Scenario	Description	Rainy Peak	Namakan Peak
Simulated 2000	Simulated 2000 Simulation of 1950-2014 using 2000		341.46 m
Rule Curves	Rule Curves	1110.99 ft	1120.28 ft
Simulated 1970	Simulation of 1950-2014 using 1970	338.62 m	341.43 m
Rule Curves	Rule Curves	1110.96 ft	1120.18 ft
2014 Actual	Actual 2014 peak lake levels	338.74 m	341.55 m
	Actual 2014 peak lake levels	1111.35 ft	1120.57 ft

The simulated results for peaks on both lakes are nearly the same whether operated under the 1970 or 2000 Rule Curves, and both are roughly 10 cm (4 in) lower than the actual peaks observed in 2014. The discrepancy between the simulated 2000 Rule Curve results and the actual data for Rainy Lake may be partly explained by the fact that actual Rainy Lake outflow in June was below theoretical maximum. This was due to the high level of the Rainy River below the dam which restricted the operation of the turbines in both powerhouses. The model is not designed to incorporate this, and assumes maximum outflow is achieved as required. Despite this discrepancy, these simulation results indicate that the peak summer water levels for Rainy Lake and Namakan Lake in 2014 would not have differed significantly had the 1970 Rule Curves been in place.

6. Review of Watershed / Outlet Changes

This section addresses the directive by the IJC to describe any physical changes to the landscape and structures made since the original IJC order that could have reduced (or changed) the outflow capacity at the Fort Frances/International Falls dam and the Namakan Lake outlet.

Following the high water event in 2001, the IRLBC investigated whether there had been structural changes made at the Fort Frances/ International Falls dam that could have reduced the outflow capacity there. This investigation was motivated by the fact that the turbines in the Boise Cascade powerhouse had been taken offline for an extended period due to the threat of flooding of the turbines that year, but had apparently been kept operational during similar conditions along the Rainy River in 1950 and 1974. The only structural change identified at that time was the refurbishment of the Boise Cascade powerhouse turbines in the early 1990s, which was thought to increase the outflow capacity. There have been no structural changes to the dams since the review by the IRLBC in 2001 that would influence outflow capacity.

In 2014, despite the record crest of the Rainy River and the very high water levels below the dam, the turbines were not taken offline for an extended period. The measures taken in the early 2000s to protect the turbines under high tailwater conditions proved effective, though the level of water in the powerhouse in 2014 did come close to exceeding these measures.

The records of the IRLBC were also reviewed for evidence of watershed changes that might affect the outflow capacity of these lakes. The only related reference found was a statement made by an Abitibi Bowater official in 2009 that some 100,000 cords of wood were estimated to be at the bottom of the upper Rainy River above the dam. The presence of significant log deposits could affect the hydraulic characteristics of the channel by reducing the cross sectional area and increasing channel bed roughness. A detailed three-dimensional survey was completed of the channel bottom of the upper Rainy River by the Water Survey of Canada in 2009 to support a detailed hydraulic model of the outlet of Rainy Lake and the Upper Rainy River (see "Rainy River 2D Hydrodynamic Model Conveyance Study", National Research Council, 2010). The results of this survey and the model did not provide conclusive evidence that there is, or is not, a significant deposit of wood in the upper river. The possible effect on the outlet capacity due to this wood has not been evaluated.

From a hydraulic perspective, changes to the watershed landscape will not directly affect the capacity of the outlets from Namakan Lake and Rainy Lake. However, landscape characteristics play an important role in defining the hydrological character of a watershed. A watershed with a higher percentage of impervious surfaces (e.g. roads, parking lots), for example, will generally have more rapid runoff than an identical watershed with a greater percentage of pervious surfaces (e.g. forested or grassland areas). The watershed of the Rainy River basin, however, is not highly developed. Since the original IJC order and the establishment of the Rule Curves in 1949, it is likely that, on a whole, the landscape changes have been limited and more in the direction of reduced runoff as forestry practices have evolved, demand for tree harvesting has declined, and the extent of conserved lands has increased through the creation of parks.

Other changes to the landscape, such as forest fires, blowdown of trees, and damming by beavers will alter the local hydrologic characteristics of the watershed, but the extent of these changes on a basin-wide basis was not investigated in detail for this report (some investigators have examined changes in the land cover in the watershed, for example see Edlund *et. al.*, 2014, Appendix B). Such changes are likely far less important than changing climatic conditions as factors contributing to the frequency and magnitude of high water events.

7. Answers to Frequently Asked Questions

Throughout the spring and summer of 2014, the WLC received many inquiries and complaints regarding high water, as did the IRLWWB and IJC at the public meeting held in International Falls on August 12. Several common questions emerged, answers to which are provided below.

Q: The flooding of the Boise turbine room was a problem back in 2001. Why hasn't this been fixed?

A: Following the 2001 high water event, Boise Cascade (now Boise Paper) had an engineering study completed to examine the problem of turbine room flooding due to high Rainy River levels and develop a plan for mitigating against high tailwater levels in the future. This study was submitted to the IRLBC, which accepted the results.

Boise followed an approach recommended by the study, which included, among other things, constructing a water-tight, concrete berm around the turbine pits. In the event of extremely high tailwater levels, the powerhouse area downstream of this barrier would be allowed to be inundated to a specified level, and pumps would be employed to prevent overtopping of the barrier. In 2014, the Rainy River crested one foot higher than the previous record, set in 1950. The water level in the powerhouse reached the berms but did not overtop them. The turbines remained operational as conditions allowed, and were not taken offline due to the high tailwater level.

Q: This winter was one of the worst on record, so why weren't the dams opened early on to make room in the lakes for all of the water that was coming?

A: This was, in fact, what happened. As detailed in Section 2, the WLC directed the companies to target the lower 25% of the Rule Curve band on each lake for the start of April to provide additional storage room for snowmelt. The simulation model analysis in Section 4 indicates that this action was neither sufficient nor necessary to affect the peak water levels in 2014, however, since the main driver of high water was the exceptionally large amount of rainfall in June.

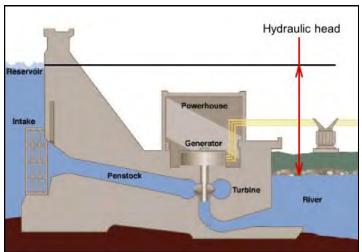
Q: Are there people or organizations that could provide better forecasts?

A: Meteorological forecasts have improved over the years, but cannot reliably predict the location and amount of rainfall beyond five to seven days in most cases. Hydrologic forecasts can be no better than the meteorological forecasts that they rely upon. The hydrological model used by the WLC to make lake level forecasts in 2014 was enhanced to include inputs from a range of over 20 forecasts produced by the Meteorological Service of Canada (MSC) as well as a forecast product produced jointly by the U.S. National Weather Service and MSC (the North American Ensemble Forecast System). This provided more information on the risk of certain sized rainfall events occurring. In addition, the WLC engineering advisors regularly discussed forecasts with the meteorologists at the Environment Canada's Ontario Storm Prediction Centre during the high water period to better refine hydrologic forecasts.

Even with the best available forecasts, unexpected significant rainfall can develop. For example, the early July rainfall event that paused the decline recession on Rainy Lake was predicted by only one of the twenty-one forecasts. The inability to accurately forecast rainfall weeks into the future will remain a reality of inflow forecasting for water management.

Q: Why are the turbines in the powerhouses at the Rainy Lake dam designed so that they can't operate at full capacity under high water conditions experienced this summer? Can't they be fixed?

A: Conventional hydroelectric facilities generate electricity by converting the kinetic energy of falling water into mechanical energy that spins the turbine runners. The amount of energy available is determined by how far the drop of water through the dam is. This vertical distance, referred to as hydraulic head, is the difference between the water level above the dam in the reservoir and the water level below the dam in the tailwater (see Figure 7.1). In general, the greater the head more flow that can pass through the turbines and the more electricity that can be generated. This is why dams were typically built at waterfalls. At the Fort Frances—International Falls dam, the head is the difference between the water level in the Figure 7.1. Schematic of Hydraulic Head across a dam upper Rainy River above the powerhouses and the water Source: Tennessee Valley Authority level in the lower Rainy River below the dam.



Downstream of the dam, high flows out of the Little Fork river can cause a backwater effect in the Rainy River, raising the level of the river all the way back to the dam. With higher level below the dam, the head is reduced. At the same time, an effect of passing maximum flow is generally the lowering of the water level just upstream of the dam. The result of lower water above the dam and higher water below the dam is reduced hydraulic head, and therefore reduced flow passing through the turbines. Under very low head conditions, when the head is substantially less than the design rating of the turbines, attempting to operate the turbines puts them at risk of damage. As a result, the turbines are taken offline to ensure that, when the head is sufficient again, they can continue to operate.

Q. Since the 2000 Rule Curves came into effect, there have been many high water years on Rainy Lake. Why is this?

Since 2000, there have been six years where the IJC All Gates Open level (337.9 m / 1108.6 ft) for Rainy Lake was exceeded (2001, 2002, 2005, 2008, 2013, 2014). In contrast, this level was exceeded four times in the thirty year span between 1970 and 1999 (1970, 1974, 1985, and 1996).

To understand why there have been more high water years since 2000 than in the previous two or three decades requires an examination of inflow patterns over the period of record. Figure 7.2 shows the span of time since IJC Rule Curve regulation began in 1949, a total of sixty-six years. Bars on the chart indicate the average inflow for May through July, with the top 25% (the sixteen years with the highest inflow) shown in red. Also shown on the chart are the peak June-July Rainy Lake levels for each year. Those years with peak levels above the IJC All Gates Open level are marked by an asterisk.

This chart reveals an important relationship. With the exception of 1962, every year since 1949 where May-July inflow ranked in the top 25% saw the level of Rainy Lake exceed the IJC All Gates Open level in June or July. Conversely, in all but two of the seventeen years where the IJC All Gates Open Level was exceeded in June or July, May-July inflow ranked in the top 25% (the exceptions were in the 1950s, before the All Gates Open Level had been established).

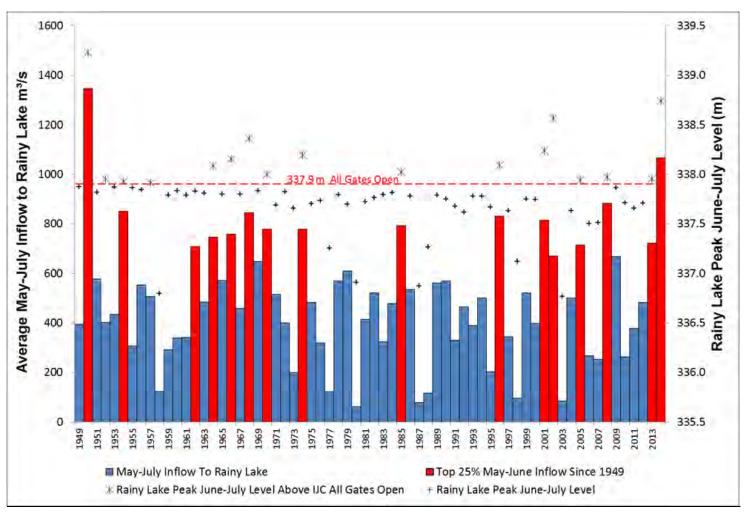


Figure 7.2. Average May-July inflow to Rainy Lake by year and Rainy Lake peak June-July level since 1949

The relationship between high May-July inflow and high water levels holds true in every decade. There have been more frequent high water years when the 2000 Rule Curves have been followed (2000-present) than in the years where the 1970 Rule Curves were followed, but there have also been more frequent high May-July inflow years, and these years correspond exactly.

These statistics, and simulation results presented in Section 5 examining operation under 1970 Rule Curves in 2014, suggest that it is the inflow pattern, not the change in Rule Curve operations, that is responsible for the greater frequency of high water years since 2000. The pattern of more frequent high water and inflow years since 2000 is not unprecedented; a similar frequency was experienced in the 1960s.

Q: There have been more high inflow years in the last 15 years than previously. Is this due to climate change? If so, what can be done to prevent high water events in the future?

Compared to the 1970's, 1980's, and 1990's, there have been more frequent high inflow and high water years since 2000. The Minnesota Climatology Working Group has noted a trend in this region towards warmer winters with high minimum temperatures, longer open-water seasons with earlier ice-out dates, higher dewpoints with a greater frequency of tropical-like atmospheric vapour, and greater moisture leading to more frequent, intense thunderstorms (see Seely, 2011). The direct effects of these trends on peak summer water levels in this watershed have not been examined and are beyond the scope of this report.

Fundamentally, however, the effects of climate change do not alter the reality of water management in this

watershed: due to limitations in outflow capacity from the outlets of Namakan Lake and Rainy Lake, high water conditions will develop in years of prolonged, high inflow. If the inflow is extremely high, as it was in 2014, there is no apparent operational approach that will prevent high water conditions from developing (see simulation results in Section 4). If climatic conditions result in more frequent years with extremely high inflow, high water conditions will occur with greater frequency.

Q: How did Rainy Lake outflow affect high water on the Rainy River and its tributaries in 2014?

Rainy River crested in mid-June at a level unprecedented in eighty-five years of record-keeping. In the week leading up to this crest, the flow rate in the Rainy River rose dramatically, while the flow from the fully opened Rainy Lake dam increased by only a small amount. The swift rise in river flow was driven by the rainfall in early June, which fell heaviest south of Rainy River in the Big Fork and Little Fork River watersheds. Little Fork River reached its highest June flow since 1970 while the flow at Big Fork River was the highest ever recorded in June, and highest for year-round flows since 1997. While the Rainy Lake dam was fully opened in early June, outflow from it was less than half of the Rainy River flow measured at Manitou Rapids.

There have been several years since 2000 where the Rainy Lake dam was fully opened with flow entering the Rainy River at the rate seen in mid-June, but the level of Rainy River in those years did not approach the record of this year as the other tributary flows were not as great in these years (e.g. 2009).

Q. Water went over the spillway at the Fort Frances—International Falls dam in the summer of 2014 for the first time since 1950. Is this dangerous or damaging to the dam?

The spill crest is designed to pass additional flow under high water conditions. It operated as designed and this did not pose a risk to the structure.

Q. There are a number of dams beside those at the outlet of Namakan Lake that can help controls the flow entering Rainy Lake. Did the IJC look at reducing flow out of other control structures and dams during the high water period? If not, why not?

There are a number of water control structures in the Rainy Lake watershed in Ontario. These include several hydrolelectric dams along the Seine River system owned and operated by H2O Power LP, as well as six smaller, non-hydroelectric control structures owned by the Province of Ontario and managed by OMNRF in the northwest area of Rainy Lake. These facilities are not regulated by the IJC and regulate minor storage volumes compared to the dams at Namakan Lake and Rainy Lake.

Dam releases in the Seine River system are routinely monitored by the WLC's engineering advisors. During the high water conditions in June, flows out of Sturgeon falls and Raft Lake were above the 95th percentile, and the level of Raft Lake exceeded the maximum required under the Province's Water Management Plan for this system.

Releases from the OMNRF structures are not routinely monitored by the WLC during normal conditions. During high water conditions in 2014, the WLC discussed the operation of the Esox Dam on the Manitou River system with OMNRF in late June to determine whether any flow reductions were feasible. OMNRF had been monitoring conditions in this system closely throughout the high water event and had been operating the dam to consider both upstream and downstream impacts. At the time of the WLC inquiry, 50% of the Esox Dam's logs had been in for two weeks despite the high water levels above the dam. At this setting, with the stable, but very high water level above the dam, there was limited room to store additional water without risking the integrity of an earthen dam that connects the structure to the shoreline. As a result, OMNRF de-

termined that it could not reduce flows out of this system any further at that time. Flows from the Manitou River, which is ungauged, were estimated by OMNRF to be roughly ten percent of the total inflow to Rainy Lake in late June.

Q. Since the outlets of Namakan Lake and Rainy Lake can't pass enough outflow at lower lake elevations to avoid high water in a wet spring, doesn't it make sense to enlarge them so this isn't a problem?

The WLC has not taken a position on this question, as no specific proposals have been put forth. It is likely, however, that any project to increase the outflow capacity will have the potential to negatively affect areas downstream during periods of extremely high inflow. Any proposals to alter the outlets of these lakes should be investigated thoroughly to ensure the full range of effects is recognized and understood.

8. Floodplain Management

The water levels experienced in 2014 on Rainy Lake and the Namakan Chain of Lakes were the highest since 1950 and 1968, respectively. This is the third year since 2000 where very high water levels have occurred, and the sixth for Rainy Lake where water levels above the IJC All Gates Open level were recorded.

The 2014 high water levels, though higher than many current property owners have experienced, were well below the record peaks on these lakes that occurred in 1950 and also below high years from the early 20th century. However, there is nothing preventing a return to 1950 levels or higher in the future. With a sufficiently long period when inflow is in excess of the outflow capacity of the lakes, the levels will continue to climb. At the start of July, 2014, just as the level of Rainy Lake was peaking and the level of Namakan Lake had begun declining, a major rain event to the west of the watershed led to significant flooding in Manitoba. If this system had tracked further south and east into the Rainy River watershed, the levels of Rainy Lake and Namakan Lake would likely have peaked much higher.

Following the 2001 high water event, the IRBLC reported that, "Although floodplain and hazard land delineations exist to one extent or another in both the U.S. and Canada, there does not appear to be a solid or widespread understanding or awareness by basin interests of these delineations or of the ramifications and responsibilities associated with development within the floodplain or hazard land." (see "Report on Year 2001 High Water Levels in the Rainy/Namakan Basin"). In the 2002 report on high water, this Board again lamented the general lack of awareness or understanding of the historic levels experienced on these lakes and it stressed the need for improved communication and education on this topic. While the IRLBC, and the WLC that succeeded it, have regularly emphasized at public meetings and in dealings with the public that high water levels will occur from time to time in this watershed, it is apparent from the variety of opinions shared with the WLC, IRLWWB, and the IJC during this year's high water event that many either do not understand this or do not agree that this is the case. Some who suffered damages in 2014 and in other high water years since 2000 have stated that high levels could be avoided if only the dam operations were better managed. This is simply not the case in years of extremely high inflow (see Section 4). This watershed has the proven potential to deliver inflows well in excess of the capacity of the outlets, and when this happens there is no control over rising lake levels. Because there is no way to accurately predict in which years these conditions will develop, it is important for property owners to familiarize themselves with the range of historic levels and flows and to adapt their property to a level of risk that they can accept.

For shoreline structures such as docks and boathouses, there is an inherent trade-off between building at a level that is useful during normal years, but building high enough so that damage is minimized in moderately high years. Unless such structures are built above the historic high water levels, which would likely limit their usefulness in most years, they will inevitably be inundated and likely suffer some damage in years of extremely high inflow. When building or repairing structures that are not designed to withstand some degree of inundation, such as cabins or homes, local regulations that define hazard land elevations should be followed.

9. Summary and Recommendations

The winter of 2013-2014 was exceptionally cold and provided a very substantial snowpack in early April. On March 7,the Water Levels Committee directed both lakes be lowered for the start of freshet in early April to accommodate some of this water. By the middle of May, snow in the basin was largely gone, and most tributary flows were running high. The basin was wet, but forecasts pointed to drier conditions developing. The companies operating the dams at these lakes passed the maximum flow possible in late May, or very close to it to keep the lakes within the IJC Rule Curve bands. Record rainfall in June in the basin, however, drove inflows to exceptionally high levels for several weeks, and the fully opened outlets of these lakes could not pass water nearly as quickly as it was entering. The lakes climbed higher with each additional rain event, not peaking until the rain abated in late June. Though a relatively dry July allowed the lakes to recede to normal levels, Emergency Conditions had persisted for nearly a month and a half.

As a result, shoreline erosion, damaged docks, boathouses and boats, lost business and the expense of flood fighting and cleanup were all significant around these lakes. For many in the watershed, the water levels experienced in 2014 were the highest in their lifetime. However, much higher levels have occurred in the past, and are possible in the future. Current forecasting technology is inadequate to give much warning of when such high water events will occur.

Based on the results of the review presented in this report, the Water Levels Committee of the International Rainy-Lake of the Woods Watershed Board draws the following conclusions and recommendations:

- The high water conditions experienced in 2014 were due principally to record rainfall that resulted in extremely high inflow to these lakes. Had the quantity of rainfall between April and June been 25% lower, simulation results suggest that levels on the lakes would have remained below the IJC All Gates Open levels.
- 2. The companies, H2O Power LP and Boise Paper, operated the dams at the outlets of the lakes in a responsible, timely fashion, reaching maximum flow in Namakan Lake in mid-May and nearly maximum flow from Rainy Lake at the same time. Lake levels were too low in May to allow outflow to match or exceed the inflow. The companies operated the dams in full compliance with the IJC Order.
- 3. The Water Levels Committee's directive to target the lower portion of the Rule Curve bands on both lakes in early April had no effect on the peak levels in late June and early July.
- 4. Operating the lakes under the 2000 Rule Curves likely contributed to peak lake levels that were a few centimeters higher than would have occurred under the 1970 Rule Curves. This is in line with expectations when the 2000 Rule Curves were adopted that slightly higher peak levels will likely occur in high inflow years. No realistic operation policy, including operating under the 1970 Rule Curves, would have avoided Emergency Conditions on either lake in 2014 because inflow in June was overwhelmingly large for the sizes of the lakes and their outflow capacities.
- 5. The Water Levels Committee is not aware of any changes to the watershed or the outlets of the lakes since 1949 that would have resulted in a decrease in outflow capacity.
- 6. Public awareness of the vulnerability of these lakes to high lake levels during periods of extremely high inflow could be improved. The IJC and the IRLWWB should explore approaches for doing this with the local governments which have the authority over designating hazard land levels and municipal zoning

- regulations. The IJC, IRLWWB, and WLC should also consider working with local First Nations, Tribes, municipal governments and non-governmental organizations to improve the public's understanding of the risk of high water levels in these lakes.
- 7. In the upcoming review of the 2000 Rule Curves, consideration of proposed alternatives to the 2000 Rule Curves should give substantial weight to avoiding conditions that would increase the likelihood of Emergency Conditions due to high water.
- 8. The WLC recommends that the IJC provide a clearer definition of the responsibilities of the WLC under Emergency Conditions, and that it also consider the development of a protocol for communications with First Nations, tribes, government agencies at various levels, and the general public for use in future emergencies.

<u>APPENDICES</u>

Appendix A—Map of the Rainy River Watershed

Appendix B— References

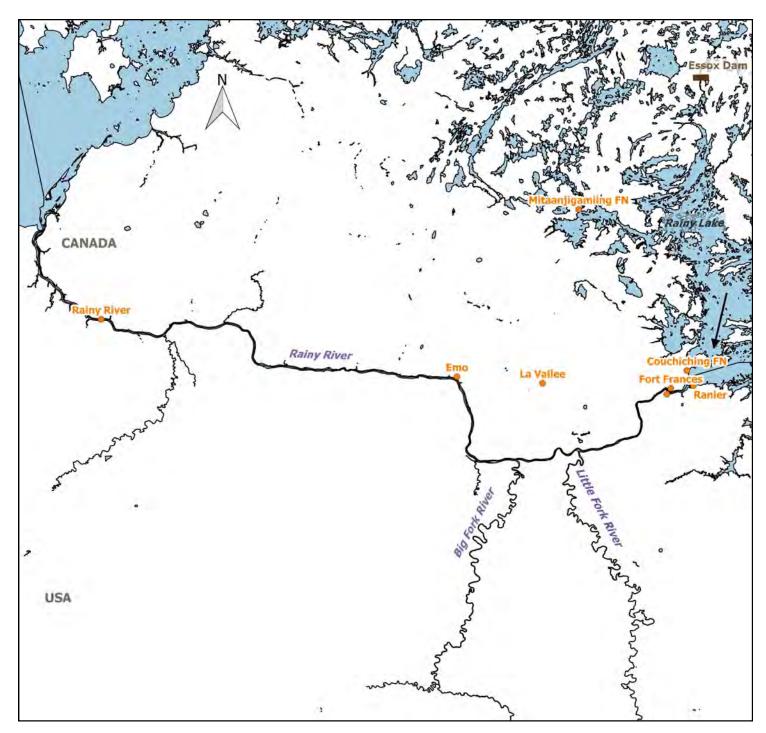
Appendix C— List of Acronyms

Appendix D—Glossary of Technical Terms

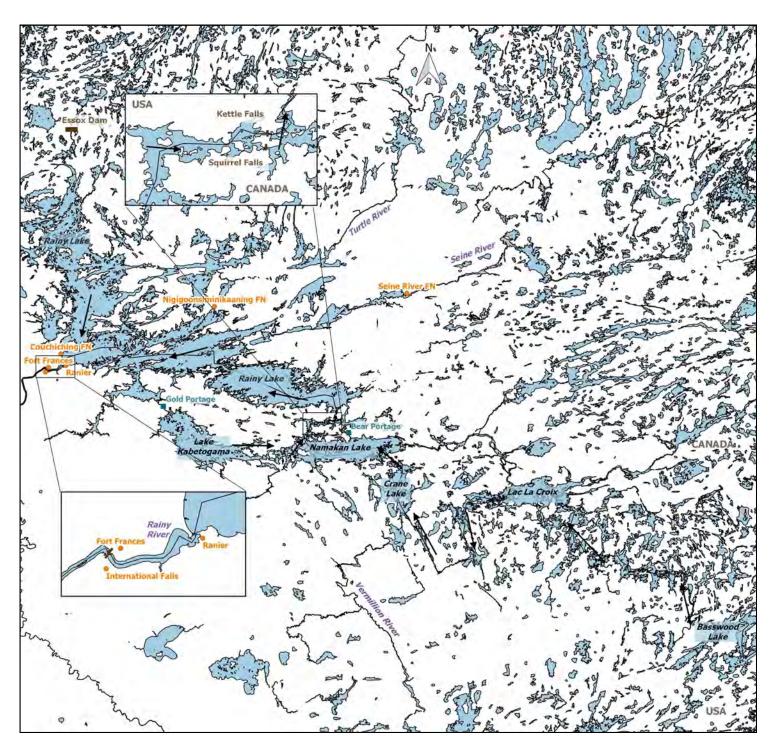
Appendix E— Water Quantity Management in the Rainy River Basin

Appendix F— Hydraulics of Outflow from Namakan Lake and Rainy Lake

Appendix G— 2014 Water Level and Flow Graphs



Rainy River from Rainy Lake to Lake of the Woods



The Namakan Chain of Lakes, Rainy Lake, and Tributaries

Appendix B – References

- 1. Edlund, Mark B., Claire A. Serieyssol Bleser, Larry W. Kallemeyn, and Dan R. Engstrom. **2014**. "Determining the Historical Impact of Water-level Management on Lakes in Voyageurs National Park". Natural Resource Technical Report National Park Service.
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Appendix C – List of Acronyms

EC - Environment Canada

IJC – International Joint Commission

IRLBC – International Rainy Lake Board of Control

IRLWWB – International Rainy-Lake of the Woods Watershed Board

LWCB - Lake of the Woods Control Board

MSC—Meteorological Service of Canada

NOAA – U.S. National Oceanic and Atmospheric Administration

NRC—National Research Council

OMNRF – Ontario Ministry of Natural Resources and Forestry

SNODAS — Snow Data Assimilation System by the National Snow and Ice Data Center

USACE - United States Army Corps of Engineers

USGS – United Stated Geological Survey

WLC - Water Levels Committee of the International Rainy-Lake of the Woods Watershed Board

Appendix D – Glossary of Technical Terms

Antecedent Moisture Conditions— in hydrology, the degree of moisture in the soils of a watershed ahead of a precipitation event. The antecedent moisture conditions can significantly affect the flows that develop in a watershed in response to a rain event.

CaPA - The Canadian Precipitation Analysis, an Environment Canada product, is the data source for all precipitation maps used in this report. CaPA combines different sources of information on precipitation into a single, near real-time analysis. Sources of information include surface monitoring stations, satellite and radar data, and atmospheric models. CaPA records for the Rainy River basin data back to 2003.

Drainage Basin (Basin) - See Watershed.

Freshet—The period in spring when snowmelt contributes to rising flows in a watershed.

Headpond— The area of water directly upstream of a dam where water may be stored.

Hydraulic Head (Head)— In open channel hydraulics, a measure of the energy of water, given as the height of water above a certain elevation. In this report, the head at the outlets of Namakan Lake and Rainy Lake is directly related to the maximum outflow rate that can be achieved, the higher the lake level (head), the higher the outflow capacity.

Inflow— In this report, inflow refers to the rate of water flowing into a lake. Inflows in the watershed are computed through a simple water balance equation, where known quantities are the change in volume of a lake over a specified time period and the outflow from the lake over the same period.

Median—In statistics, the middle value in a ranked group of values, the 50th percentile. May be different from the average, or mean, of the same group of values.

Normal— In this report, the normal range for a historical data set is considered to be data falling between the 25th and 75th percentile, representing the middle 50 % of historic data.

Outflow— In this report, outflow refers to the rate that water is released from a lake through a dam. Outflow is computed based on the hydraulic characteristics of the control structure and the elevation of the lake surface (head).

Percentile— In statistics, denotes the relative position of a value in a set of ranked values. A 75th percentile lake level or river flow is greater than 75 % of all other values recorded at the same time of year, but is less than the remaining 25 %. A 25th percentile lake level or river flow is greater than 25% percent of all other values recorded at the same time of year, but less than the remaining 75%. In this report, percentiles for water levels and flows are relative to values for a specific time of year recorded in the 30-year period from 1981 -2010.

Percentiles indicate how often a particular lake level or flow has occurred historically. A 50th percentile value, known as median, indicates that values have been higher than this value 50 % of the time, and lower than this value 50 % of the time. In other words, values have historically been at or above the 50th percentile one year in every two, and lower than this value one year in every two. Similarly, for a 75th percentile lake level value, 75% of the time the values have been lower, and 25% of the time values have been higher. The 75th percentile was reached or exceeded one year in four, on average. A 90th percentile lake level has been

reached or exceeded, on average, once every ten years, and a 95th percentile once every twenty years.

A 25th percentile value has been reached or exceeded 75 % of the time. In other words, values at or *lower* than the 25th percentile have occurred, on average, once every four years while a 10th percentile or lower has been reached once every ten years.

Snow Water Equivalent— The quantity of water contained in the snowpack. It can be thought of as the depth of water that would theoretically result if the snowpack were melted.

Tailwater– The waters immediately downstream from a dam.

Watershed - In hydrology, the extent of land from which water drains to a given location such as a lake or river.

Appendix E - Water Quantity Management in the Rainy River Basin

The International Joint Commission (IJC) was created in 1909 by the signing of the Boundary Waters Treaty between Canada and the United States. The IJC functions as an independent and objective advisor to both governments to help prevent and resolve disputes under the Boundary Waters Treaty for the common good of both countries. For example, the IJC approves projects affecting the boundary or transboundary waters and may regulate the operation of these projects. Three Commissioners are appointed by the Governor-in-Council in Canada, and three by the President of the United States. The IJC has established more than twenty boards and task forces established to assist in its work.

In 1938, the United States and Canada signed the Rainy Lake Convention, granting the IJC certain powers within the Rainy River watershed. It empowered the IJC to determine when Emergency Conditions exist in the basin, whether by high or low water, and to adopt control measures with respect to the existing dams at Kettle Falls and the dam at International Falls-Fort Frances. The IJC created the International Rainy Lake Board of Control (IRLBC) in 1941, with the purpose of examining and reporting on the issue of Emergency Conditions. The IRLBC completed a detailed study and, based on its recommendations, the IJC issued the Order Prescribing the Method of Regulating Boundary Waters in June 1949. This Order established single Rule Curves for the levels for Rainy Lake and Namakan Lake, established with the aim of avoiding Emergency Conditions on these lakes, whether by low or high water. The Rule Curve defined a single target water level for each day of the year. The Rule Curves were modified with subsequent Orders in 1957, 1970 and 2000, and now include a target level range for each day of the year as well as specific elevations above which the outlets from these lakes must be fully opened (known as the All Gates Open level). With the adoption of the 2000 Rule Curves, the IJC directed the IRLBC to review the effect of revised regulation in fifteen years. Studies to support this review have been underway for several years. The formal review process is scheduled to commence in 2016.

In April 2013, the International Rainy-Lake of the Woods Watershed Board (IRLWWB) was created, merging the responsibilities of the IRLBC and the International Rainy River Water Pollution Board. The IRLWWB's mandate includes ensuring compliance with the IJC's Order, as well as monitoring and reporting on the ecological health of the boundary waters. Within this new board, the water regulation responsibilities were delegated to the Rainy and Namakan Lake Water Level Control Committee (Water Levels Committee).

The Water Levels Committee is comprised of two members each from Canada and the United States: one local watershed member and one member from the respective federal governments who serve as co-chairs (the Commander of the U.S. Army Corps of Engineers St. Paul District, and a water resources engineer from Environment Canada). These co-chairs are also the co-chairs of the International Lake of the Woods Control Board (ILWCB), responsible for the regulation of Lake of the Woods water levels under high or low conditions. Each country provides engineering advisors to the Water Levels Committee. In Canada, they are staff engineers with the Canadian Lake of the Woods Control Board's Secretariat. In the United States, they are staff of the United States Army Corps of Engineers, St. Paul District.

The day-to-day operation of the dams at the outlets of Rainy Lake and Namakan Lake are directed by the dam owners, H2O Power LP in Canada, and Boise Paper in the United States. These companies are required, under the IJC Order, to change the rate of outflow from these dams so as to target the middle portion of the ranges defined by the 2000 Rule Curves for Namakan Lake and Rainy Lake. They do so by monitoring basin

conditions, developing inflow forecasts, then determining and cooperatively executing the appropriate outflow changes from the outlets of these lakes.

The Water Levels Committee regularly monitors conditions in the watershed, advising the IRLWWB and the IJC on compliance with the Rule Curves by the Companies. If conditions warrant, the Water Levels Committee has the authority under the Order to direct the companies to target outside of the middle portion of the Rule Curve band for either Rainy Lake or Namakan Lake, but it does not have the authority to set a target outside of the Rule Curve range. If such a step were deemed necessary, a Supplementary Order from the IJC would be required.

Appendix F— Hydraulics of Outflow from Namakan Lake and Rainy Lake

This appendix provides a plain language review of the configuration and operation of the outlet controls at Namakan Lake and Rainy Lake. The concepts presented here are important in understanding the operation of these dams under the IJC Rule Curves.

Namakan Lake

The Namakan reservoir is a chain of five lakes. The main water bodies are Namakan Lake to the east and Kabetogama Lake to the west with the upper lakes, Sand Point, Little Vermilion and Crane, to the south of the main lakes. Outflow from the Namakan Chain of Lakes has been controlled since 1914 by two small dams located in the main channels on either side of Kettle Island. At these points the two lakes are very close together; water flows out of Namakan Lake directly into Rainy Lake. The dam at Squirrel Falls is completely within Canada and is known as the Canadian Dam, while the dam at Kettle Falls straddles the border and is known as the International Dam. Both dams have five stop-log controlled sluices, one of which is much narrower than the other four because it was originally designed as a fish passageway, although never used for that purpose.

In addition to the two main channels, there are two natural overflows from the Namakan Chain of Lakes into Rainy Lake. Bear Portage is to the east of Kettle Falls and Gold Portage is at the western end of Kabetogama Lake. These channels, although relatively small, permit uncontrolled flow from Namakan to Rainy when Namakan Lake is at higher levels. The flow through all outlets is computed daily, and together they make up the total outflow from the Namakan Chain of Lakes.

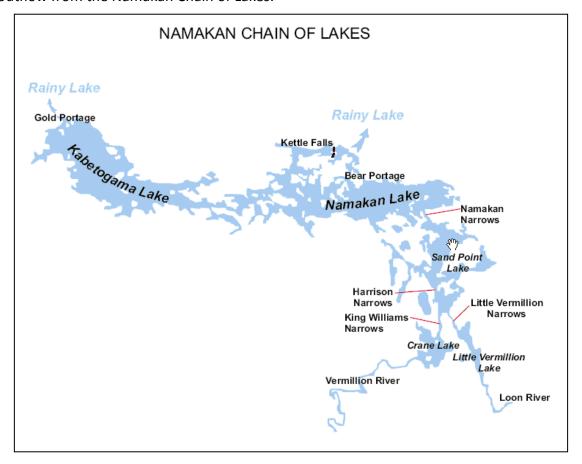


Figure A.1. Outlets from the Namakan Chain of Lakes

The rate of outflow from Namakan Lake is limited by number of logs in the two dams and the lake level. For a given setting (i.e. without changing the number of stop logs in the dam) an increase in the lake level will result in an increased flow out of the dam. A higher column of water has more pressure, or head, to push water at a faster rate through the dam sluices. Once all logs are pulled from the dams, the rate of flow is only a function of the water level and the only way that outflow can be increased is for the lake level to rise.

Rainy Lake

The Fort Frances-International Falls dam is located several kilometres downstream of the outlet of Rainy Lake on the Rainy River. The dam is U-shaped, with the apex pointing upstream, and there are hydroelectric powerhouses on each side of the border. Current owners of the facilities are Boise Paper in Minnesota and H2O Power LP in Ontario.

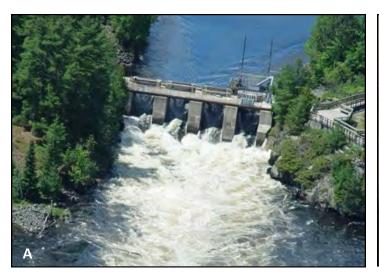
The H2O Power powerhouse has eight turbines, while the Boise Paper powerhouse has seven. On the Canadian side of the dam, between its apex and the powerhouse, there are ten gate-controlled sluices. Also on the Canadian side are five gate-controlled sluices that pass water through a canal located between the shore and the powerhouse. (The canal was originally designed for navigation although it was never used for that purpose.) The apex of the dam and its USA side are designed as a spillway or overflow section to discharge additional water at exceptionally high levels, as in 1950 and 2014.

Outflow from the dam is adjusted by the companies to target the middle portion of the Rule Curve band set by the IJC. When the required outflow is greater than the capacity of the turbines, the companies begin spilling water through the canal gates. The canal gates are generally opened first as they are the farthest away from the H2O Power powerhouse, and therefore have the least effect on the headpond water level directly in front of the powerhouse (lower headpond levels reduce the potential for generating electricity). Once all five canal gates are opened, additional outflow is accomplished by opening the sluice gates at the dam.

In addition to the dam, there are natural features in the river channel between the lake outlet and dam that restrict the rate of flow out of Rainy Lake. These natural features are Ranier Rapids near the rail bridge, a narrows at Point Park and the historical rapids at Koochiching Falls near the international bridge upstream of the dam. These locations, along with the gate and powerhouse positions, are presented in Figure A.1.

The rate of flow out of Rainy Lake and past these natural features is dependent on the lake level. The higher the lake level, the greater the energy available to overcome the resistance to flow that these natural features present. Over the years, the former IRLBC and the Companies observed that opening many dam gates when the lake is not at a high level does not increase the flow rate out of the dam, but only serves to lower the level of the river between the lake outlet and the dam. This is because, at moderate flows, only a few gates are needed to keep pace with the rate of flow leaving the lake; going beyond this simply lowers the river above the dam.

In 2009, the IJC commissioned a research project to examine this phenomenon and other questions related to the hydraulics of the Upper Rainy River. The Canadian Natural Research Council (NRC) created a detailed two-dimensional hydrodynamic model of the outlet of Rainy Lake and the Upper Rainy River above the dam. One aim of the investigation was to develop a quantitative relationship between the number of open dam gates and the maximum flow rate from Rainy Lake for a given lake level (see Appendix B for reference). To illustrate the relationship between gate openings, lake level, and lake outflow, the NRC developed an interactive animation tool that is now available on the IRLWWB website. Figures A.2 - A.4 are images from this tool, and provide an example of flow limitations at the outlet of Rainy Lake.







- A. The International Dam at Namakan Lake. B. Log sluice with logs in to prevent flow.
- C. The dam at International Falls-Fort Frances on the Rainy River. Photos: Lee Grim

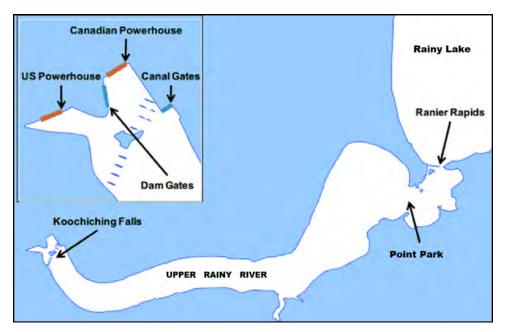
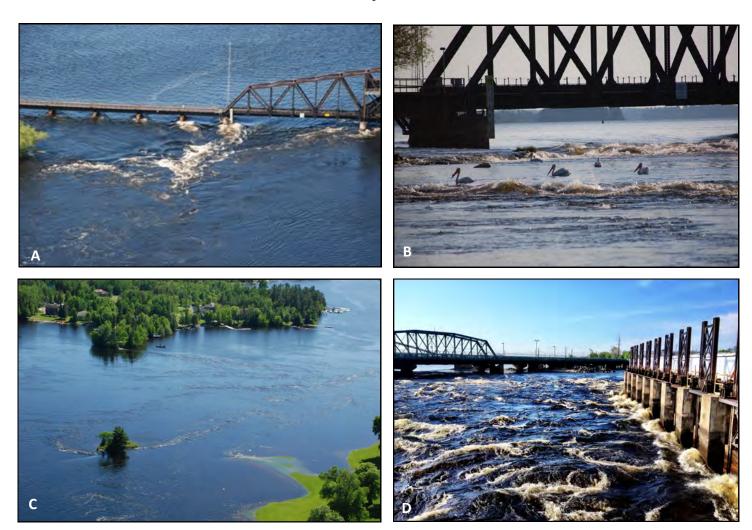


Figure A.2. Natural channel features in the Upper Rainy River that restrict flow from Rainy Lake



Natural channel features restrict flow at A., B. Ranier Rapids at the outlet of Rainy Lake C. Point Park

D. Former Koochiching Falls above near bridge above dam. Photos: Lee Grim (A,C) and Matt DeWolfe (B,D)

In this example, the level of Rainy Lake is 337.75 m, the IJC Upper Rule Curve level in June. With seven of the fifteen gates open (Figure A.2), the river is relatively high because, at this setting, the dam is not releasing water at the rate that can be released by the lake. By opening a total of eleven gates however (Figure A.3), the level of the river drops as the flow through the dam increases to match the maximum flow rate from the lake, approximately 825 m³/s. Opening any additional gates, however, does not increase the outflow rate from the lake at this lake level. This is shown in Figure A.4 where all gates are open but the flow rate is the same as in Figure A.3 which has only eleven open gates.

Although the flow is not affected by opening the last gates in this example, there is a change: the water level at the dam drops dramatically, particularly on the Canadian side where the gates are located (Canadian forebay illustrated in dark blue, American forebay in light blue).

Very low water levels in front of the dam are problematic for two reasons. First, if the water level in front of the dam is low, power generation declines. (The potential to generate electricity through the turbines is directly related to how far the water falls through the dam, which is why hydroelectric dams are built at waterfalls, and why there is no hydroelectric facility at the Namakan Lake dams where there is little drop in water). Second, if the water level in the forebay of the dam gets low enough, air begins to enter the turbines, leading to damaging cavitation and vibrations, which could result in turbines being shut down and a resulting loss in total flow capacity. Opening more gates than are needed to pass the water at the rate it is arriving at the dam, therefore, only has the potential to *reduce* the outflow from the lake due to lost turbine flow.

Only once the lake level gets above the IJC All Gates Open Level, 337.9 m, does opening all of the dam gates achieve maximum outflow. Even at this level, the additional flow from opening the last gates is very small, it is not until the lake is significantly higher still that they pass substantial flows. This is illustrated in the next example, where the level of Rainy Lake is above the IJC All Gates Open level. The flow rate with 11 gates open is slightly below 900 m³/s (Figure A.5), while the flow rate with all fifteen gates open is just over 900 m³/s (Figure A.6). As in the previous example, the water level in the forebay of the dam declines with the opening of the last few gates.

In summary, the rate of flow out of Rainy Lake is controlled under normal lake levels by the natural features in the upper Rainy River above the dam. The dam cannot be used to release water any faster than the maximum rate that is set by these natural features. The sluice gates at the dam may be opened to keep pace with the rate of water released from the dam, but at normal lake levels this only requires a few dam gates. Only at levels above the IJC All Gates Open level is it useful to open all of the fifteen sluice gates at the dam.

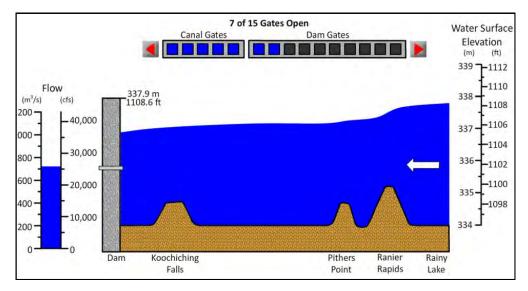


Figure A.2. Water Level in Upper Rainy River: Rainy Lake at Upper Rule Curve with 7 dam gates open, flow ~ 725 m³/s.

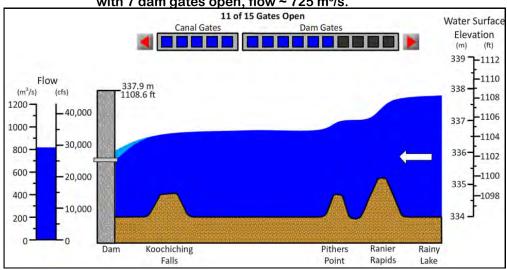


Figure A.3. Water Level in Upper Rainy River: Rainy Lake at Upper Rule Curve with 11 dam gates open, flow ~ 825 m³/s.

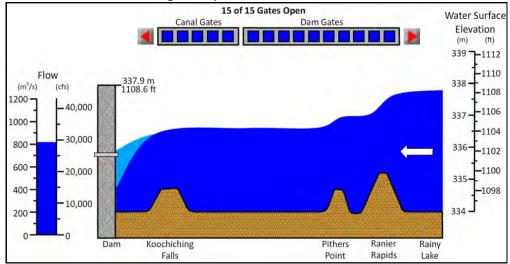


Figure A.4. Water Level in Upper Rainy River: Rainy Lake at Upper Rule Curve with all 15 dam gates open, flow ~ 825 m³/s.

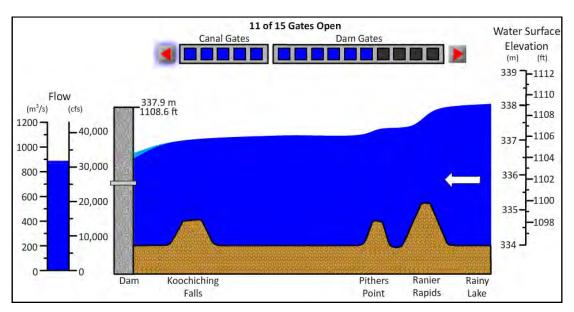


Figure A.5. Water Level in Upper Rainy River: Rainy Lake above All Gates Open level with 11 dam gates open, flow ~890 m³/s.

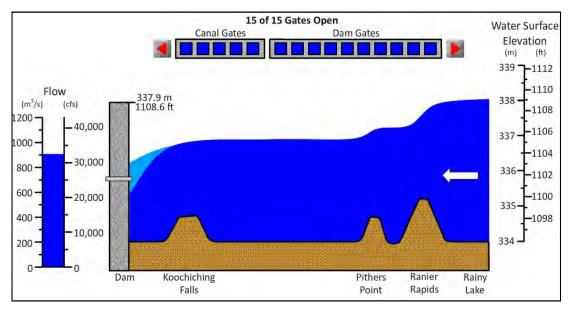
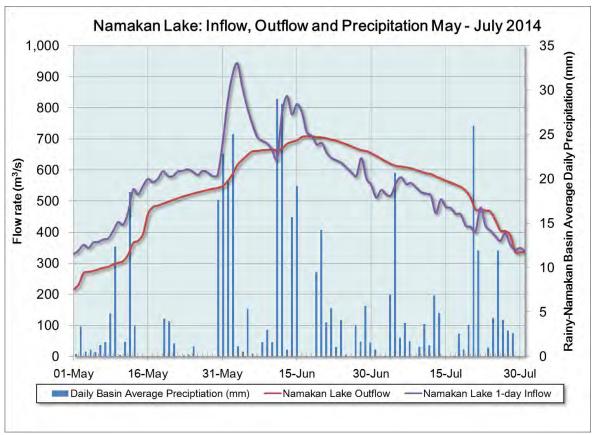
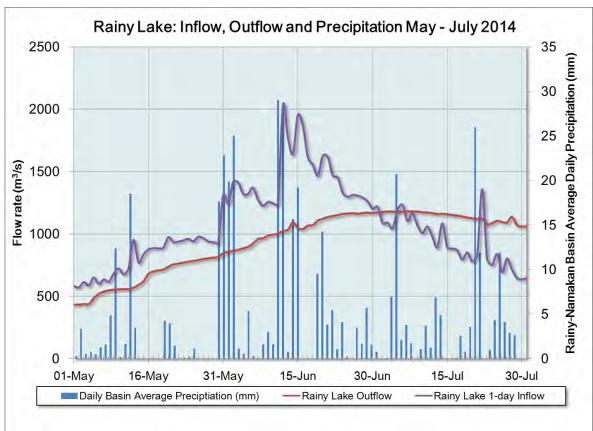


Figure A.6. Rainy Lake above All Gates Open level with all 15 dam gates open, flow ~910 m³/s.

Appendix G — 2014 Water Level and Flow Graphs

This appendix provides plots of the water levels, precipitation and flows of key lakes and rivers discussed in this report. .





WATER LEVELS & FLOWS

Actual Data



Actual data for the dates shown

- levels are 1-day means plotted daily
- inflows are 7-day means plotted daily
- outflows are daily values

Rule Curves (Namakan & Rainy Lakes)

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IJC 2000 Upper & Lower Rule Curves

IJC 2000 Drought Line

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IJC Upper Emergency Level

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IJC "All Gates Open" Level

Statistical Data

50

Maximum level/flow recorded and its year of occurrence



Level/flow has been above this line 10% of time.



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Normal level/flow range

- level/flow has been above this range 25% of time
- level/flow has been within this range 50% of time
- level/flow has been below this range 25% of time



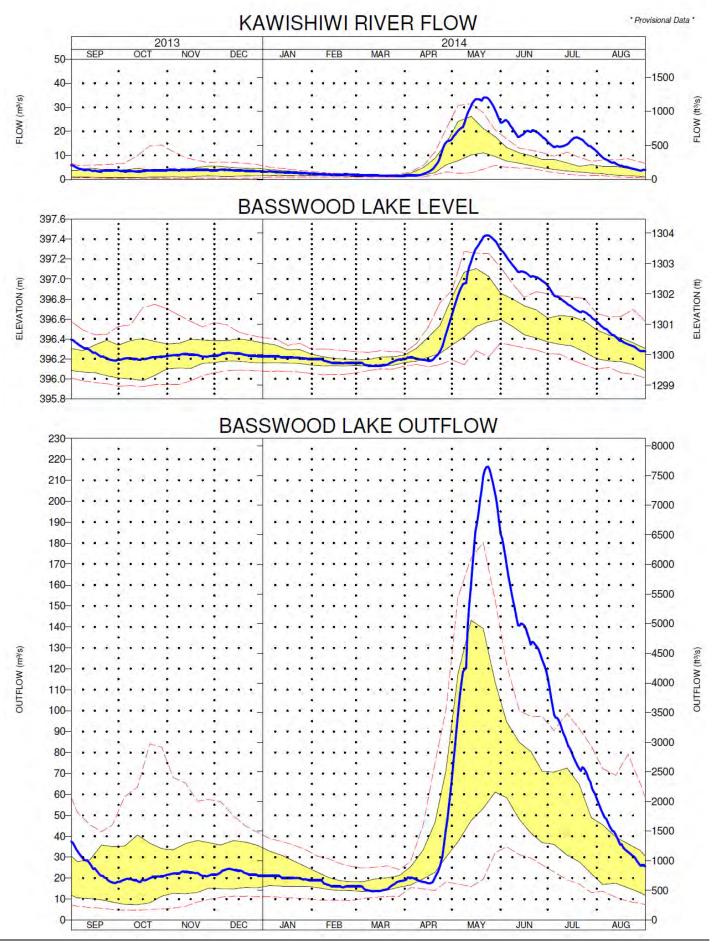
Level/flow has been below this line 10% of time

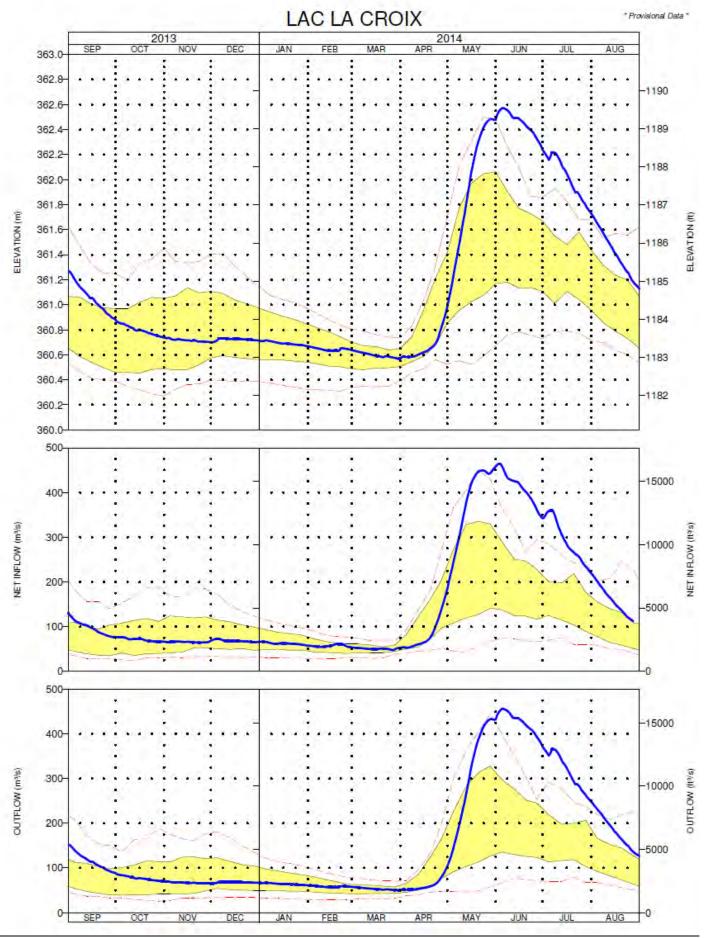
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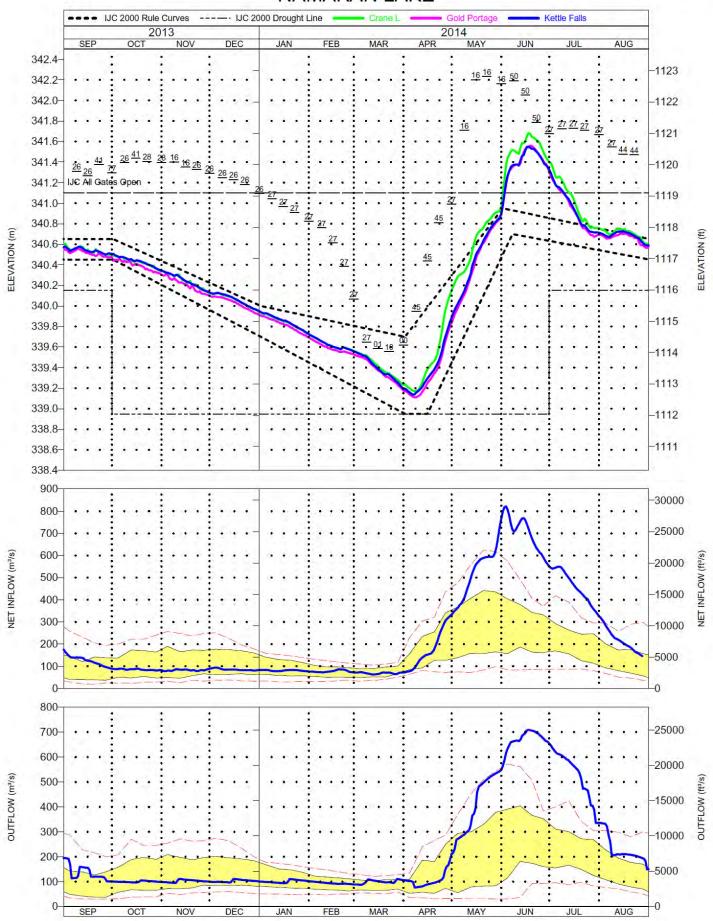
Minimum level/flow recorded and its year of occurrence

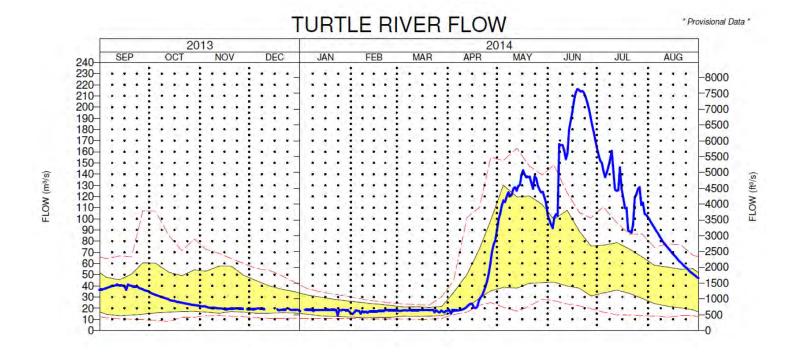
All statistical levels are based on 3-day means at month quarter points. All statistical flows are based on quarter-monthly means.

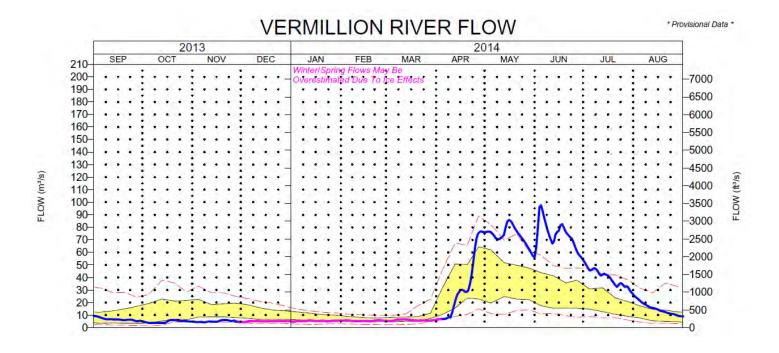
In general, percent data is based on the period 1981-2010, while maximums and minimums are based on each site's period of record up to 2010.

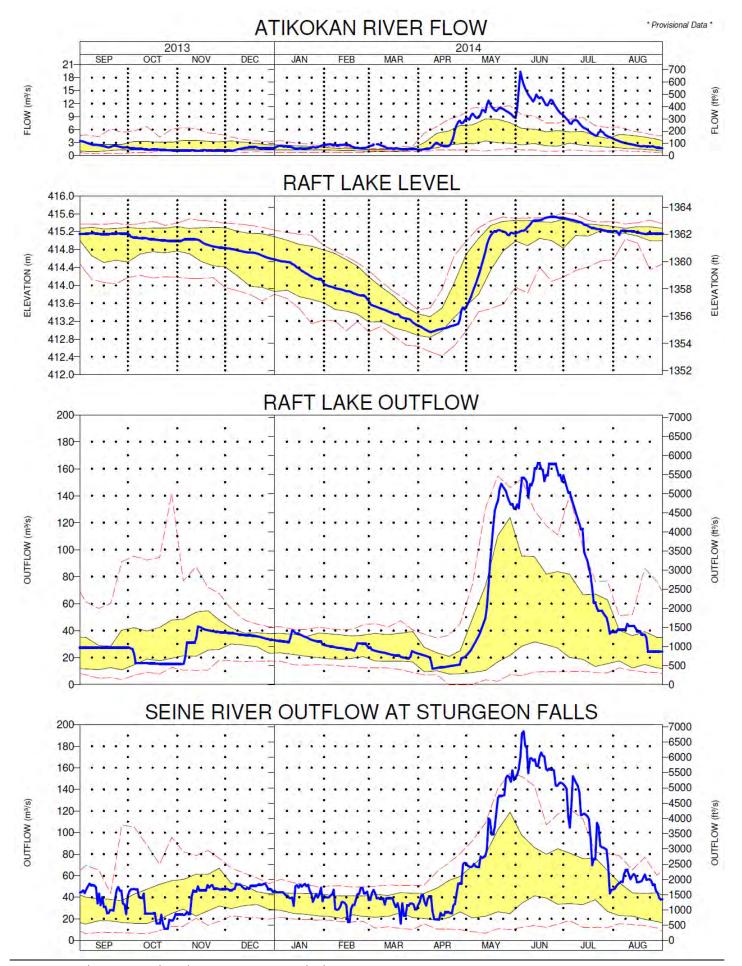


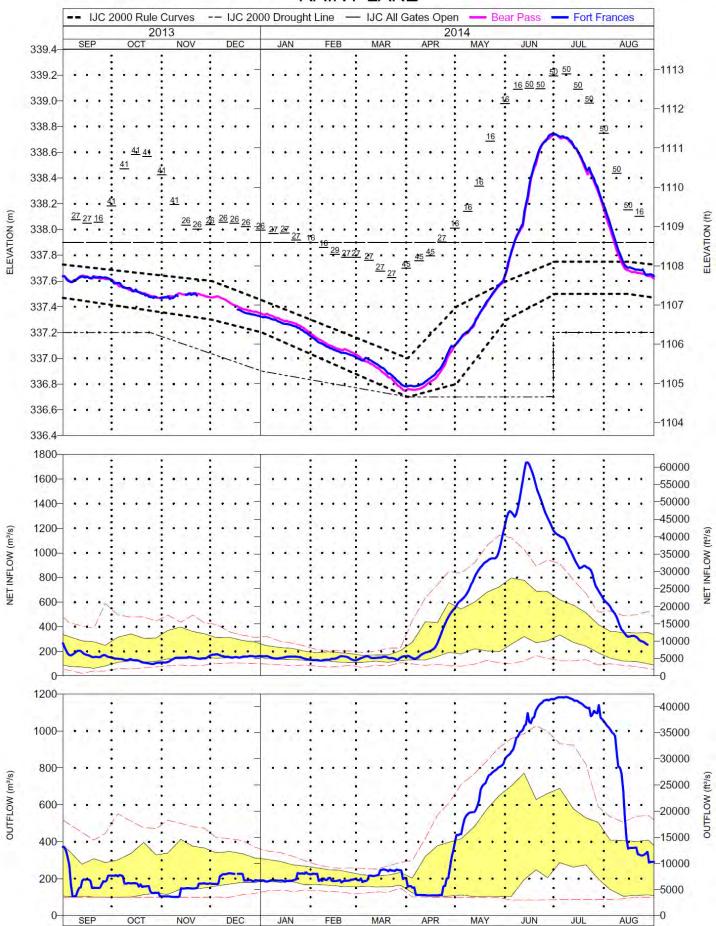


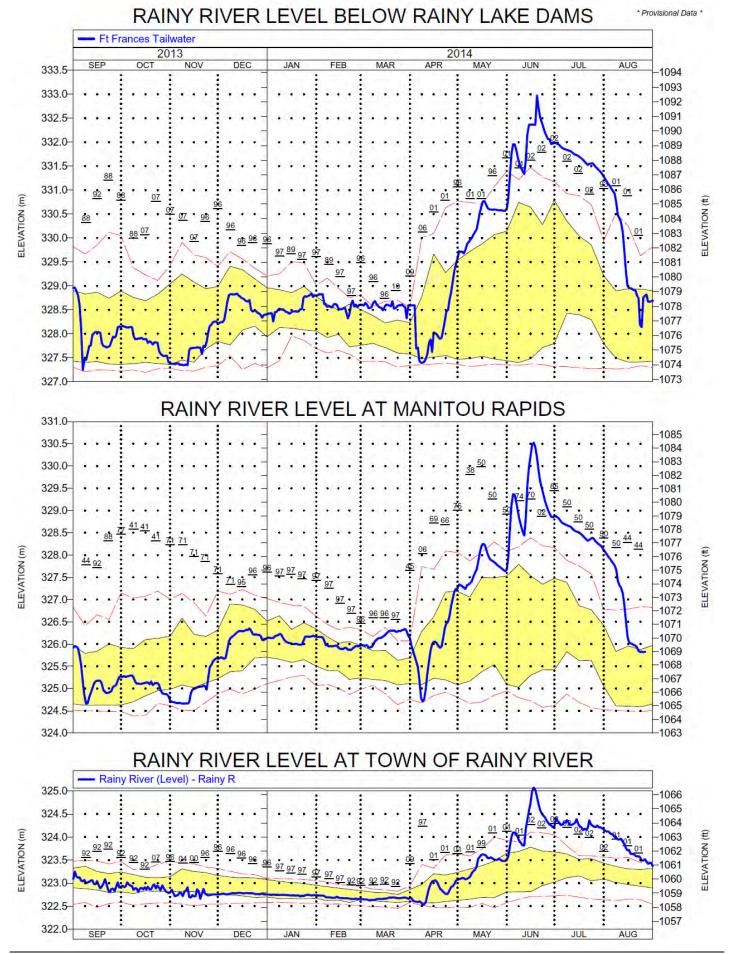


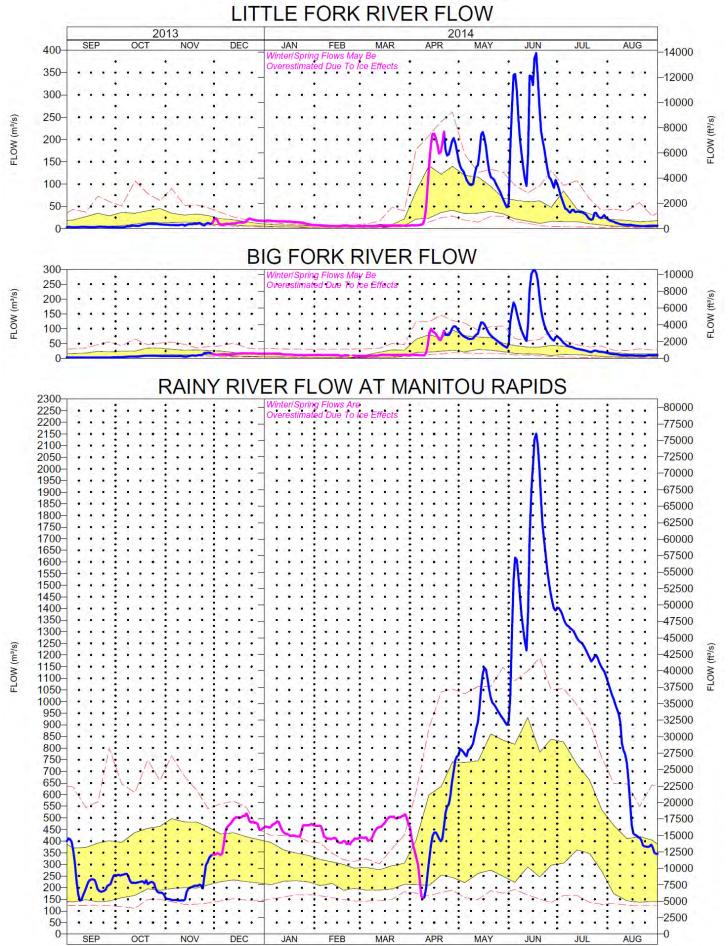








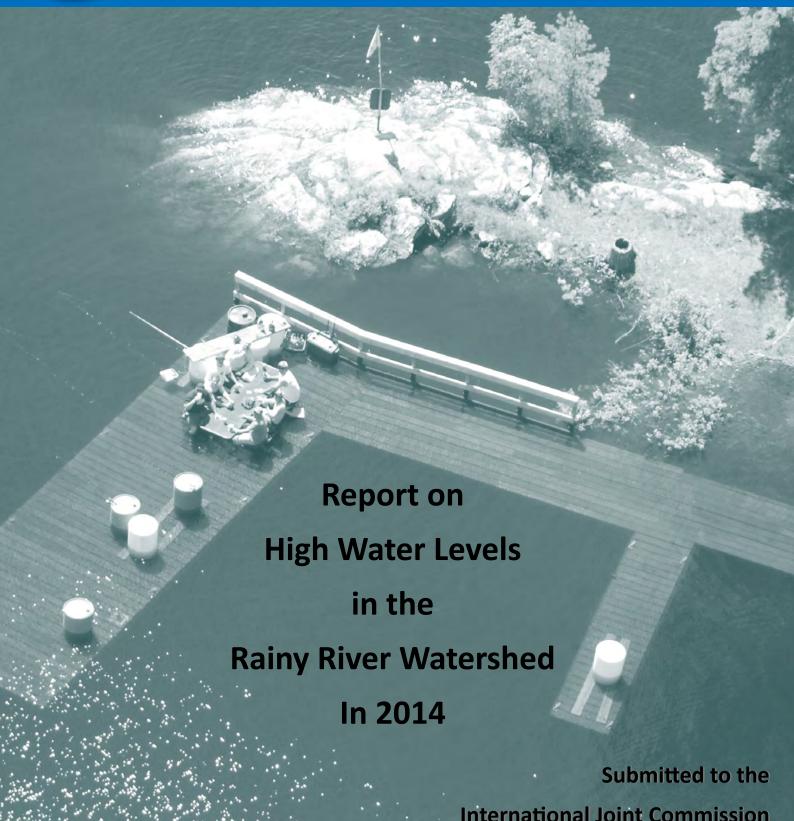




Report on High Water Levels in the Rainy River Watershed in 2014



Water Levels Committee of the International Rainy-Lake of the Woods Watershed Board



International Joint Commission April, 2015