



## PART IV: PHYSICAL ENVIRONMENT



**REGIONAL CUMULATIVE  
EFFECTS ASSESSMENT  
PART IV  
PHYSICAL ENVIRONMENT**

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# ACRONYMS, ABBREVIATIONS AND UNITS

Acronym/Abbreviation	Term/Unit
%	percent
AEMP	Aquatic Effects Monitoring Plan
CAMP	Coordinated Aquatic Monitoring Program
cfs	cubic feet per second
cms	cubic metres per second
CRD	Churchill River Diversion
CS	Control Structure
DFO	Department of Fisheries and Oceans
EIS	Environmental impact statement
<i>et al.</i>	and others
FEMP	Federal Ecological Monitoring Program
ft	feet
GIS	Geographic Information System
GS	Generating Station
<i>i.e.</i>	in other words
km	kilometre
km <sup>2</sup>	square kilometre
LWCNRSB	Lake Winnipeg, Churchill and Nelson Rivers Study Board
LWR	Lake Winnipeg Regulation
m	metre
m/y	metre per year
m <sup>3</sup>	cubic metre
m <sup>3</sup> /m	cubic metre per metre
MB	Manitoba
MCWS	Manitoba Conservation and Water Stewardship
MEMP	Manitoba Ecological Monitoring Program
mi	mile
MW	megawatts
NFA	Northern Flood Agreement
NHP	National Hydrometric Program
PEMP	Physical Environment Monitoring Program



<b>Acronym/Abbreviation</b>	<b>Term/Unit</b>
RCEA	Regional Cumulative Effects Assessment
SIL	Southern Indian Lake
TSS	Total Suspended Solids
WPLP	Wuskwatim Power Limited Partnership
WSC	Water Survey of Canada

## 4.0 PHYSICAL ENVIRONMENT

### 4.1 INTRODUCTION

The physical environment has been altered by past hydroelectric development within the RCEA Region of Interest. The RCEA will document current understandings about the effects of past hydroelectric developments on the physical environment. This includes changes to the water and ice regimes and the associated changes to shoreline erosion (both mineral soil and peatland) and sedimentation. It will also include physical changes to the land resulting from development of the principal structures, supporting infrastructure, and transmission line rights-of ways associated with hydroelectric development.

Phase I includes a general description of Manitoba Hydro's hydraulic operations and associated effects on water and ice regimes, as well as an estimate of the flooded area associated with each generation facility in the Region of Interest. The Phase I water regime description is based on data records that contain sufficient water level and flow data for both pre- and post-hydroelectric development. Past studies and previous documentation are also referenced, where appropriate. For the ice regime, and in cases where data are more limited, the effects of hydroelectric development are described where possible, but are more qualitative in nature. Erosion and sedimentation is also discussed in Phase I based on a review and synthesis of available information and existing studies for the Region of Interest.

The availability of long-term data varies for the different physical parameters. For the topics of water and ice regime, there has been long-term monitoring of hydrometric data within the Region of Interest that has facilitated the analysis of water level and flow data within distinct hydraulic zones. Similarly, there have been historical studies of shoreline erosion that support the description of physical changes over time relating to hydroelectric development. For physical changes to the land resulting from permanent generation and transmission infrastructure, there has been considerably less work done to monitor and assess these changes in a cumulative manner within the Region of Interest. For this reason, the description of physical changes to the land will be undertaken as part of the Phase II analysis.

Phase II of the RCEA will include a more detailed description of Manitoba Hydro's operations, including short-term operations such as plant cycling. The level of additional analysis in Phase II will vary across the Region of Interest based on the complexity of the hydraulic zone and the availability of data to conduct detailed analyses of change over time. Phase II will include a more in depth analysis of hydrological conditions to better understand the impact of hydroelectric development and, in some cases, this may include simulating water levels and flows that would have occurred without hydroelectric development. Phase II will also include detailed mapping of the flooded areas and other permanent infrastructure associated with hydroelectric development. For shoreline erosion and sedimentation, Phase II will involve further analysis and a summary and synthesis of the findings on the impacts associated with hydroelectric development.

## 4.2 WATER REGIME

This section describes the effect of hydroelectric development on the water regime and ice regime in the RCEA Region of Interest.

Waterbodies (lakes, rivers, streams, creeks, *etc.*) and their associated water and ice regimes are part of the physical environment. The term 'water regime' refers to the pattern and frequency of water levels and flows in a river system. The water regime is driven by the amount of precipitation in a river system's drainage basin or watershed, which is the area of land that drains into a river system. Other factors that can affect the water regime include upstream water regulation, water withdrawals, evaporation and groundwater flow. During winter and spring, ice also plays a significant role, including periods of freeze-up and spring break-up. Man-made components such as channel excavations, control structures, diversions, and forebays also affect the water regime.

The RCEA Region of Interest covers part the Churchill, Burntwood and Nelson River systems which have been affected by hydroelectric development. The region includes the area affected by LWR from the outlet of Lake Winnipeg to Hudson Bay and the area affect by the CRD Project. Most of the inflow to these two major river systems is also influenced by upstream regulation from other agencies. The Rat-Burntwood River system is included because it is impacted by the CRD and is a tributary to the Nelson River.

Within the RCEA Region of Interest, Manitoba Hydro operates the following components that affect the water regime:

- The CRD diverts the majority of the Churchill River flow into the Rat River-Burntwood River-Nelson River system to augment the hydroelectric potential of generating stations along the route. This project diverts flow from one river to another, causing increased water levels and flows on one river system and decreasing water levels and flows on the other;
- LWR is a series of channels that increase the Lake Winnipeg outflow capacity by about 50% and a control structure to regulate the outflow. LWR was built for flood reduction on Lake Winnipeg and to enhance power production, especially during the winter;
- Three control structures regulate outflows as part of CRD and LWR and six generating stations (Jenpeg is both a generating station and a control structure). A forebay or impoundment area is created immediately upstream from each generating station or control structure; and
- Three weirs each with a different function. The Cross Lake Weir increases the average water level and reduces the range of water levels on Cross Lake. The Manasan Falls Control Structure, which includes a weir, reduces the risk of ice jam flooding in Thompson. The Churchill Weir increases upstream water levels on the Churchill River to enhance access, improve and maintain fish habitat, and ensure a potable water source for the Town of Churchill.

A summary of hydroelectric development along the Churchill, Burntwood, and Nelson rivers is provided in Table 4-1. Flooded areas represent Manitoba Hydro's current estimate based on available topographic information. To help describe the effects of these projects, Manitoba Hydro divided the Region of

Interest into 12 zones as shown in Map 4-1. Each of the 12 zones is affected by hydroelectric development in a unique way. Zones 1, 2 and 3 are within RCEA Area 1; zones 10, 11 and 12 are within RCEA Area 2; zones 4, 6, 7, 8 and 9 are within Area 3; and zone 5 is in RCEA Area 4 (see Map 1-4). Each Water Regime zone is described in the following sections along with a corresponding map of the area.

**Table 4-1: Summary of Hydroelectric Developments along the Churchill and Nelson Rivers**

Project	RCEA Area	Water Regime Zone	Capacity [MW]	Year Completed	Flooded Area (sq. mi.)	Normal Maximum Forebay Level (ft)
<b>Upper Nelson River</b>						
LWR	Area 1	Zone 1	N/A	1976	25	N/A
Jenpeg GS	Area 1	Zone 1	125	1979		714.0
Kelsey GS	Area 1	Zone 3	292	1961	63.5	605.0
<b>Churchill River Diversion / Burntwood River</b>						
CRD	Area 3	Zone 4,6	N/A	1976	293	N/A
Wuskwatim GS	Area 3	Zone 8	214	2012	<0.2	767.7
<b>Lower Nelson River</b>						
Kettle GS	Area 2	Zone 11	1220	1974	85.3	463.0
Long Spruce GS	Area 2	Zone 11	980	1979	5.6	362.0
Limestone GS	Area 2	Zone 11	1350	1992	0.8	280.0
Total		-	4181	-	473.4	-

Hydrometric data refer to water levels and flows obtained from gauging stations operated by either Water Survey of Canada or Manitoba Hydro. Both agencies are part of the National Hydrometric Program (NHP); a cooperative endeavor between the federal, provincial, and territorial governments to provide accurate, timely, and standardized data and information on the current and historic availability of surface water. The parties recognize the value of cooperative water monitoring activities for reasons including operational and cost efficiencies. Final data, or published data, is generated through several levels of reviews to verify compliance to applicable standards.

Water Survey of Canada (WSC) gauge data is accessible online at:

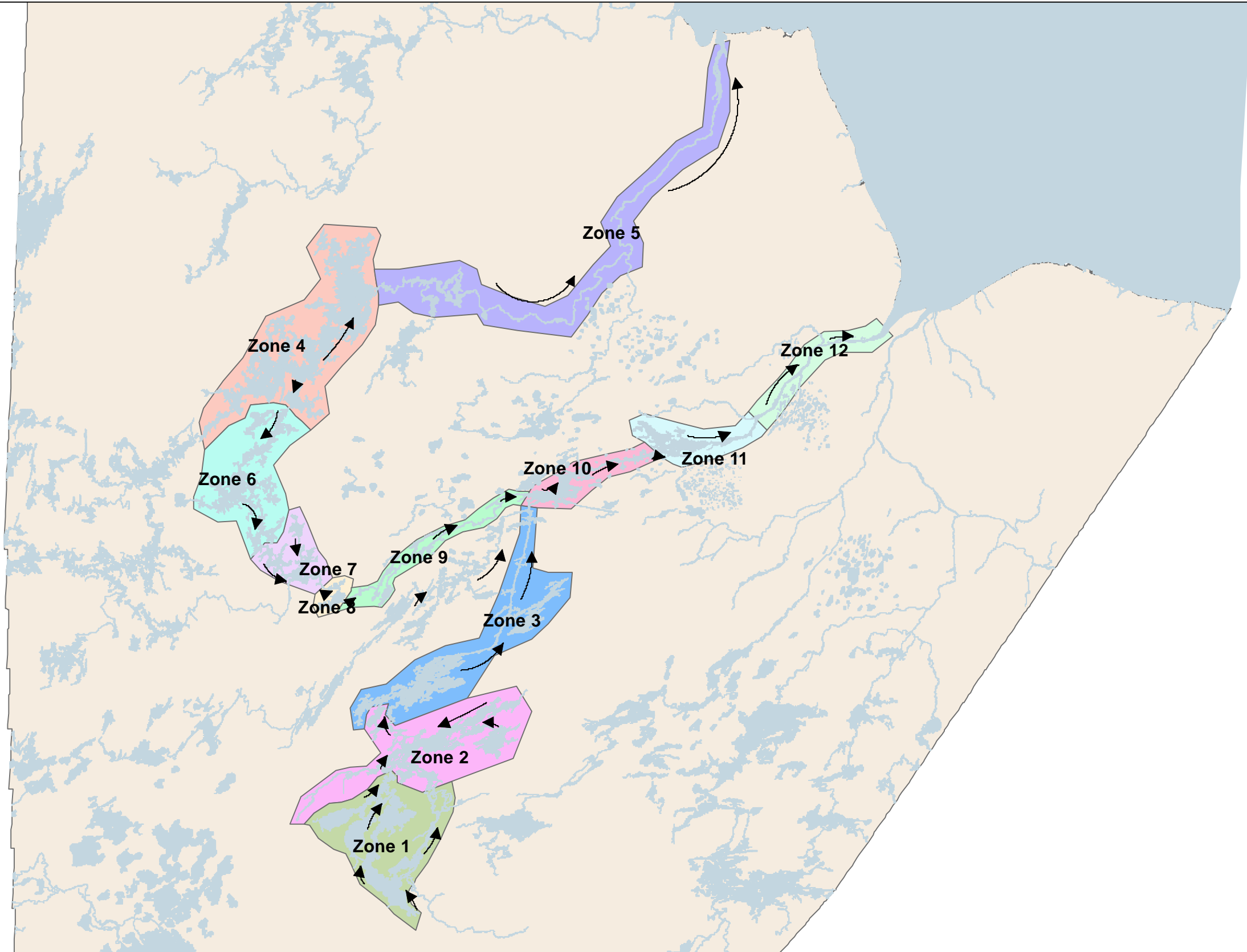
- [http://www.wateroffice.ec.gc.ca/index\\_e.html](http://www.wateroffice.ec.gc.ca/index_e.html).

Manitoba Hydro also monitors water levels in the forebay and discharge at each of its generating stations. Data from gauges operated by Manitoba Hydro is accessible online for the current year at:

- [http://www.hydro.mb.ca/corporate/water\\_regimes/hydrological\\_data.shtml](http://www.hydro.mb.ca/corporate/water_regimes/hydrological_data.shtml).

The collection of hydrometric data is critical for understanding the availability, variability, and distribution of water resources. It provides the basis for decision making on the management of the resource. In some cases, historic hydrometric data also provide the ability to quantify changes to water and ice regimes on waterways affected by hydroelectric development. The Phase I water regime description is based on data records which contain sufficient water level and flow data pre- and post- hydroelectric development. Gauges with longer records are used where available and provide better estimates of the effects of development. The amount of pre-development data is limited because other than longer term records at a few sites, many gauging stations in Northern Manitoba were established in the 1950s and 1960s, sometimes only a few years before hydroelectric development. These earlier records contain data gaps and were often more limited because of access and recording equipment issues. In cases where the data is more limited, the effects of hydroelectric development on the water regime are described where possible but are more qualitative. Also, comparisons of data can sometimes lead to incorrect conclusions regarding the effects of hydroelectric development. This is because differences in hydrological conditions in the periods of record pre- and post-development can affect flows and water levels regardless of whether hydroelectric development took place. More in depth analysis will be investigated in Phase II of this study.

Phase II of the RCEA will include a more detailed description of Manitoba Hydro's operations, including short-term operations such as plant cycling and their effect on the water regime. The level of detail in Phase II will vary across the zones based on the complexity of the water regime. As a result, Phase II of the study may in some cases include more in depth analysis, including simulating water levels and flows that would have occurred without hydroelectric development. Phase II will also include detailed mapping of all the flooded area associated with hydroelectric development.



DATA SOURCE: Manitoba Hydro		
CREATED BY: Hydraulic Operation Department Hydraulic Licencing and Support		
COORDINATE SYSTEM: UTM NAD 1983 Z14N	DATE CREATED: 13-May-14	REVISION DATE: 27-MAY-14
0 30 60 Kilometres 0 25 50 Miles	VERSION NO: 1.0	QA/QC: BSS/RDB/ZZZ

**Legend**

- ↙ ↘ Flow Direction
- Hydraulic Zones**
- Zones**
- Zone 1 (Green)
- Zone 2 (Pink)
- Zone 3 (Blue)
- Zone 4 (Orange)
- Zone 5 (Purple)
- Zone 6 (Cyan)
- Zone 7 (Light Purple)
- Zone 8 (Light Orange)
- Zone 9 (Light Green)
- Zone 10 (Light Pink)
- Zone 11 (Light Blue)
- Zone 12 (Light Cyan)

**RCEA Hydraulic Zones**



### 4.2.1 ZONE 1 – OUTLET LAKES AREA

This zone begins at the northeast end of Lake Winnipeg, and extends approximately 60 mi (100 km) north to just upstream of Jenpeg. The Outlet Lakes Area includes the East and West Channels of the Nelson River (Map 4-2). The Nelson River West Channel includes Playgreen Lake, Kiskittogisu Lake, Kiskitto Lake and the Jenpeg forebay. The Nelson River East Channel begins at Little Playgreen Lake and extends 60 mi (100 km) until reaching Pipestone Lake, immediately upstream of Cross Lake. The Nelson River West Channel accounts for approximately 85% of the outflow from Lake Winnipeg, while the unregulated East Channel carries the remaining 15%.

LWR was completed in 1976 and the final unit at Jenpeg was commissioned in 1979. The Outlet Lakes Area includes the following major LWR channels and structures:

- Diversion Channels;
  - Two-Mile Channel;
  - Eight-Mile Channel; and
  - Ominawin Bypass Channel.
- Jenpeg Control Structure and Generating Station; and
- Kiskitto Dam.

Two-Mile Channel provides a second outlet for water to flow out of Lake Winnipeg to Playgreen Lake. Eight-Mile Channel avoids a flow constriction on the Nelson River West Channel by connecting Playgreen Lake with the southern end of Kiskittogisu Lake and uses Kiskittogisu Lake as a second flow path for Lake Winnipeg outflows. The Ominawin Bypass Channel and work completed in the Kisipachewuk Channel upstream from Jenpeg provide additional outflow capacity from Kiskittogisu Lake to the West Channel of the Nelson River. The control structure at Jenpeg regulates the Nelson River West Channel portion of Lake Winnipeg's outflow. The Kiskitto Dam and Inlet Control Structure prevent flooding of Kiskitto Lake from backwater effects of the Jenpeg forebay, while regulating inflow. An outflow diversion channel, along with the Black Duck Control Structure, provides an outflow from Kiskitto Lake.

#### 4.2.1.1 MANITOBA HYDRO OPERATIONS

LWR was an initiative of the Province of Manitoba that Manitoba Hydro implemented to reduce flooding on Lake Winnipeg, while enhancing the generation of hydroelectric power, especially during the winter. The diversion channels listed above that make up LWR allow about 50% more water to flow out of Lake Winnipeg. In wet periods, LWR has increased the flow of water from Lake Winnipeg and has kept the water level of the lake lower than it would have been without LWR in place. LWR is important to energy production in Manitoba because it provides Manitoba Hydro the ability to time Lake Winnipeg outflows and generation along the Nelson River with seasonal load requirements. Because it takes several weeks for the effect of flow changes at Jenpeg to reach the lower Nelson River, LWR is not useful for short-term operations but rather is used to match seasonal load requirements.

When the water level on Lake Winnipeg is between 711 ft and 715 ft (216.7 m and 217.9 m), system energy requirements drive LWR operations. When the water level on Lake Winnipeg exceeds 715 ft, Manitoba Hydro must maximize the discharge of water at Jenpeg until the level is restored to 715 ft. If the water level drops below 711 ft on Lake Winnipeg, the Minister of Conservation and Water Stewardship determines how outflows should be managed.

#### **4.2.1.2 DATA**

Manitoba Hydro measures water levels in the Jenpeg forebay and measures discharge through the Jenpeg powerhouse and spillway. The following gauging stations contain continuous water level or flow data both prior to and after hydroelectric development:

- Water Level
  - 05UB001 – Nelson River at Norway House (1913-2013);
  - 05UB005 – Playgreen Lake at Entrance to East Nelson River (1967-2013);
  - 05UB007 – Kiskittogisu Lake near Norway House (1967-1987);
  - 05UB017 – Kiskittogisu Lake at Whiskey Jack Landing (1987-2013); and
  - 05UB013 – Kiskitto Lake near Norway House (1971-2013).
- Flow
  - 05UB008 – Nelson River East Channel below Sea River Falls (1967-2013).

#### **4.2.1.3 JENPEG FOREBAY**

LWR increased the average water level in the Jenpeg forebay and increased the range of water levels from 7 ft (2.1 m) (681-688 ft) to 12 ft (3.7 m) (702-714 ft). The impoundment resulted in about 25 sq mi (65 sq km) of flooding, all of which is contained in the Jenpeg forebay which extends from Jenpeg upstream to the outlets of Kiskittogisu Lake (Manitoba Hydro 2007). This area experiences wetting and drying with varying water levels depending on water supply conditions and Jenpeg operations. Cycling of flows at Jenpeg will be investigated as part of Phase II of this study.

Water levels in the Jenpeg forebay range between 702 ft and 714 ft (214.0 m and 217.6 m) approximately 95% of the time (Figure 4-1). Operations differ between the open water and winter periods with water levels typically much higher during the open water period than during the winter. Water levels are above 710 ft (216.4 m) during the open water period 70% of the time and are below this during high flow periods to increase discharge out of Lake Winnipeg. Water levels are below 706 ft (215.2 m) during the winter period 70% of the time with higher forebay levels occurring during low flow periods to reduce Lake Winnipeg outflows. These high or low flow periods can persist over a period of years.

During very low flow years, the Jenpeg GS forebay is generally kept higher all year to reduce outflows from Lake Winnipeg. This causes water levels in the channel upstream of Jenpeg GS to be higher despite the low flow conditions. Conversely, during high flow years when Lake Winnipeg is near or above 715 ft

(217.9 m), the Jenpeg GS forebay is lowered to maximize discharge out of Lake Winnipeg as required by licence. As a result, despite the high flows, water levels in the Jenpeg GS forebay are lower.

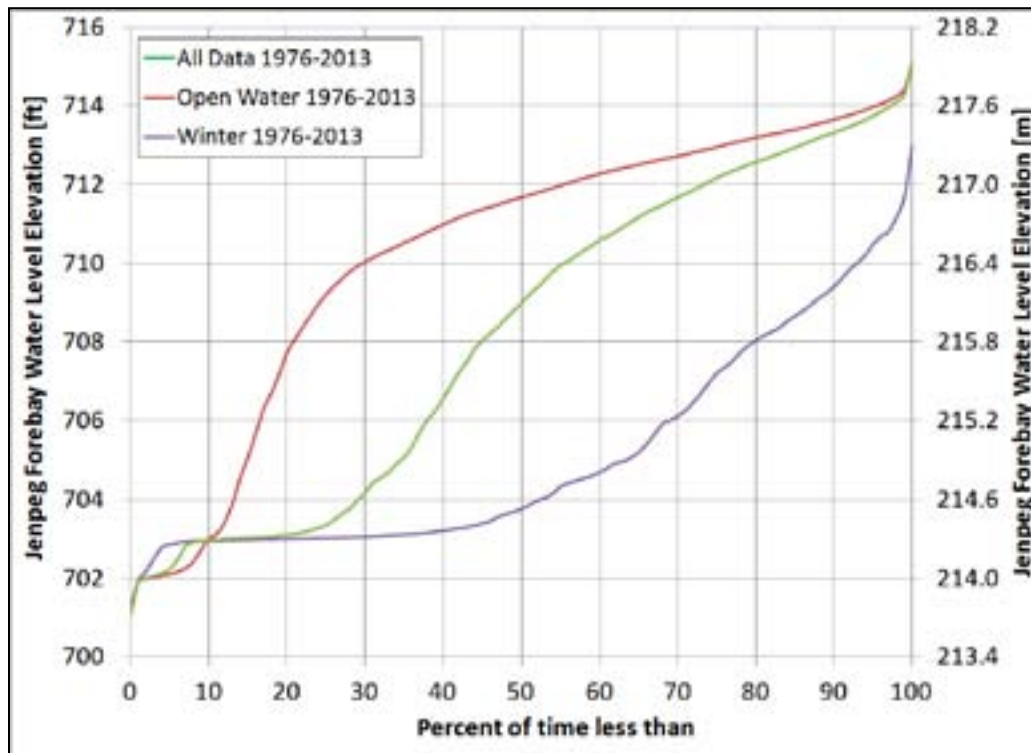


Figure 4-1: Jenpeg Forebay Daily Water Level Duration Curve

#### 4.2.1.4 LAKE WINNIPEG TOTAL OUTFLOW

LWR allows for regulation of the majority of Lake Winnipeg's outflow along the Nelson River West Channel through operation of Jenpeg. Prior to LWR, the Saskatchewan Nelson Basin Board published a monthly record of total outflow from Lake Winnipeg from 1913-1967 (Canada, Alberta, Saskatchewan and Manitoba 1972). Using a similar methodology, Manitoba Hydro developed a record of total Lake Winnipeg outflow from 1967-1976 using the record of Lake Winnipeg water levels (Ad Hoc Committee on Lake Winnipeg Datum 1982) and Canadian Inland Water Branch rating curves (Inland Waters Branch 1969). Total outflow post-LWR is calculated as the sum of the total Jenpeg outflow and the flow in the East Channel of the Nelson River from WSC station 05UB008. The total outflow from Lake Winnipeg post-LWR has been higher on average in the winter and more consistent throughout the year (Figure 4-2). Although LWR can affect the seasonal timing of Lake Winnipeg outflows, it does not affect the long-term average. Rather, differences in hydrology have caused the long-term average outflow post-LWR to be approximately 4.4% higher than the pre-LWR period.

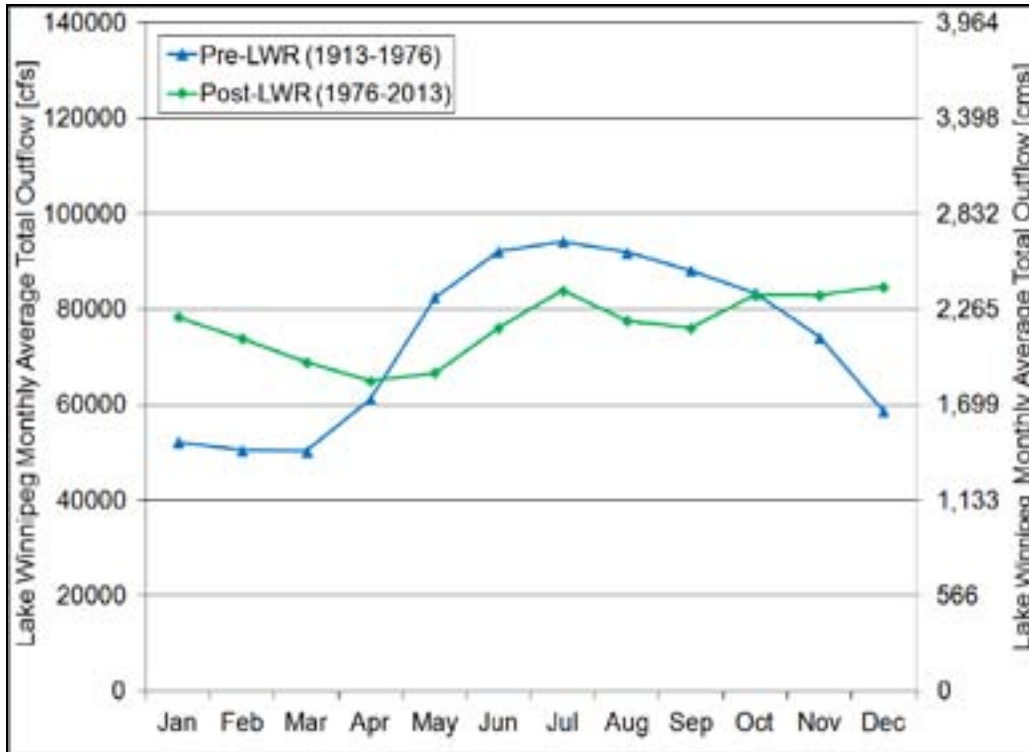


Figure 4-2: Monthly Average Lake Winnipeg Total Outflow

#### 4.2.1.5 KISKITTOGISU LAKE

Prior to LWR, Kiskittogisu Lake had a single inlet at the north end with water levels in the lake primarily influenced by a backwater effect from the Nelson River West Channel. The water regime of Kiskittogisu Lake changed to become a flow-through system with the addition of Eight-Mile Channel. Post-LWR, the Jenpeg forebay water level and flow in the Nelson River West Channel affect water levels on Kiskittogisu Lake. The pre-LWR water level record at WSC station 05UB007 includes open water data from 1967-1970 and data all year from 1971 to July 1975 when water levels were affected by the removal of the final plug in the Ominawin Bypass Channel. In this period, in which there were generally above average inflows from Lake Winnipeg, mean monthly Kiskittogisu Lake levels averaged 710.7 ft (216.6 m) (range: 709.1-712.9 ft or 216.1-217.3 m). Post-LWR, water levels were collected on Kiskittogisu Lake at station 05UB007 from 1976 to 1987 until WSC relocated the gauge in 1987 to station 05UB017. The mean monthly water level with LWR is 711.1 ft (216.7 m) (range: 706.2-714.2 ft or 215.3-217.7 m). Pre- and post-LWR monthly averages in Figure 4-3 suggest that LWR increased the range of water levels on Kiskittogisu Lake, creating higher summer water levels and lower winter water levels.

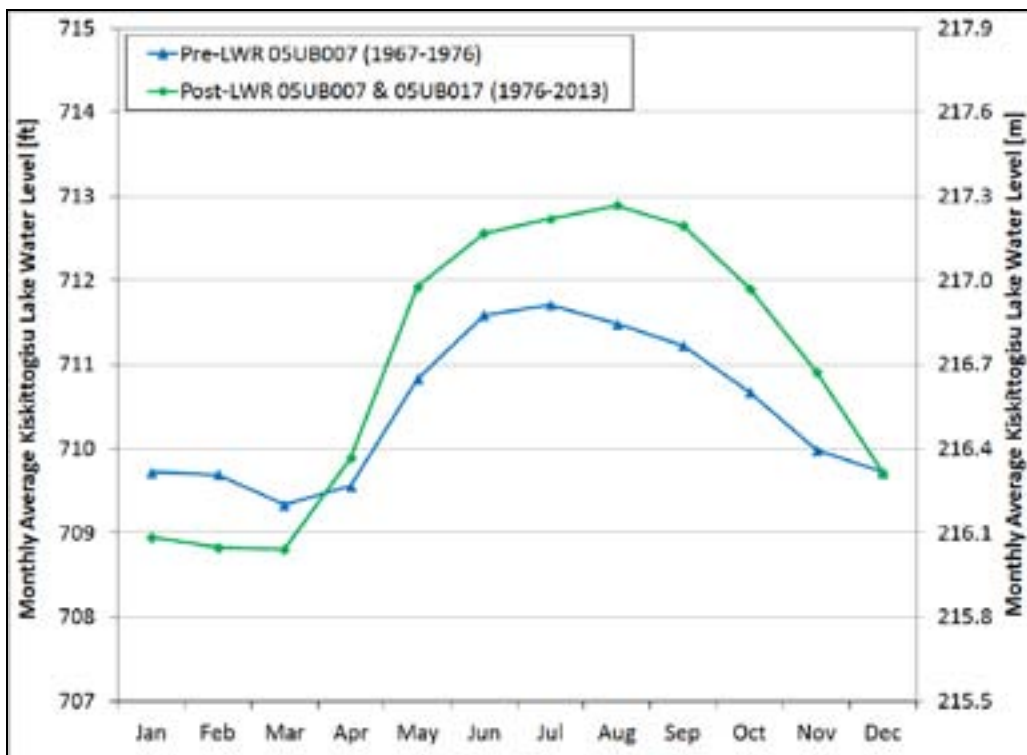


Figure 4-3: Monthly Average Kiskittogisu Lake Water Levels

#### 4.2.1.6 PLAYGREEN LAKE

Prior to LWR the water level on Lake Winnipeg drove the water level on Playgreen Lake. Post-LWR, Lake Winnipeg remains the primary driver of water levels on the lake; however, some influence is now also provided by the Jenpeg forebay. Water level records for the southern basin of Playgreen Lake at WSC station 05UB005 prior to LWR are only available for parts of a few summers. For this reason, station 05UB001 (Nelson River east channel at Norway House) is used as a proxy for Playgreen Lake levels as it has been in operation since 1913 and water levels at the two locations have a strong correlation (Figure 4-4). Prior to LWR, the mean monthly water level at station 05UB001 was 712.1 ft (217.0 m) and the water level range on the lake was between 708.8 ft (216.0 m) and 716.5 ft (218.4 m). Post-LWR, the mean monthly water level is 0.5 ft (0.15 m) higher at 712.6 ft (217.2 m) and the water level range on the lake is reduced to between 710.4 ft (216.5 m) and 715.4 ft (218.1 m). Lake Winnipeg outflows are 4.4% higher post-LWR so based on the data it is not clear whether the higher levels are because of LWR or wetter conditions in the post-LWR period (Figure 4-2). This will be investigated further as part of Phase II of this study. As shown in Figure 4-5, the seasonal water level pattern has remained the same.

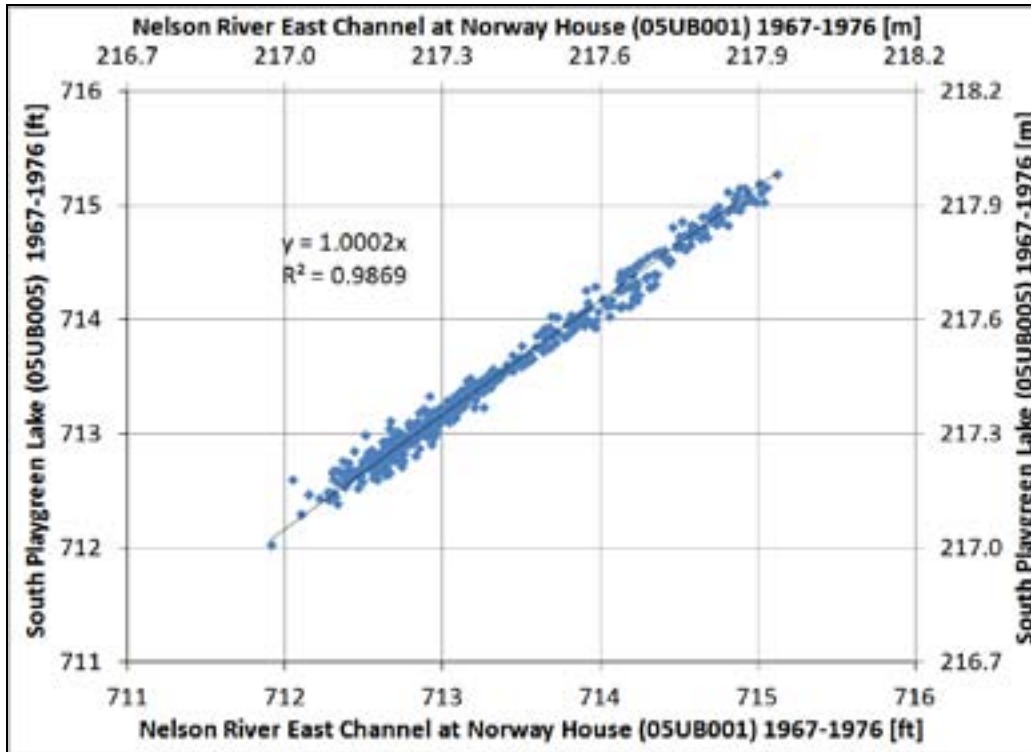


Figure 4-4: Correlation Between Water Levels at Stations 05UB001 and 05UB005

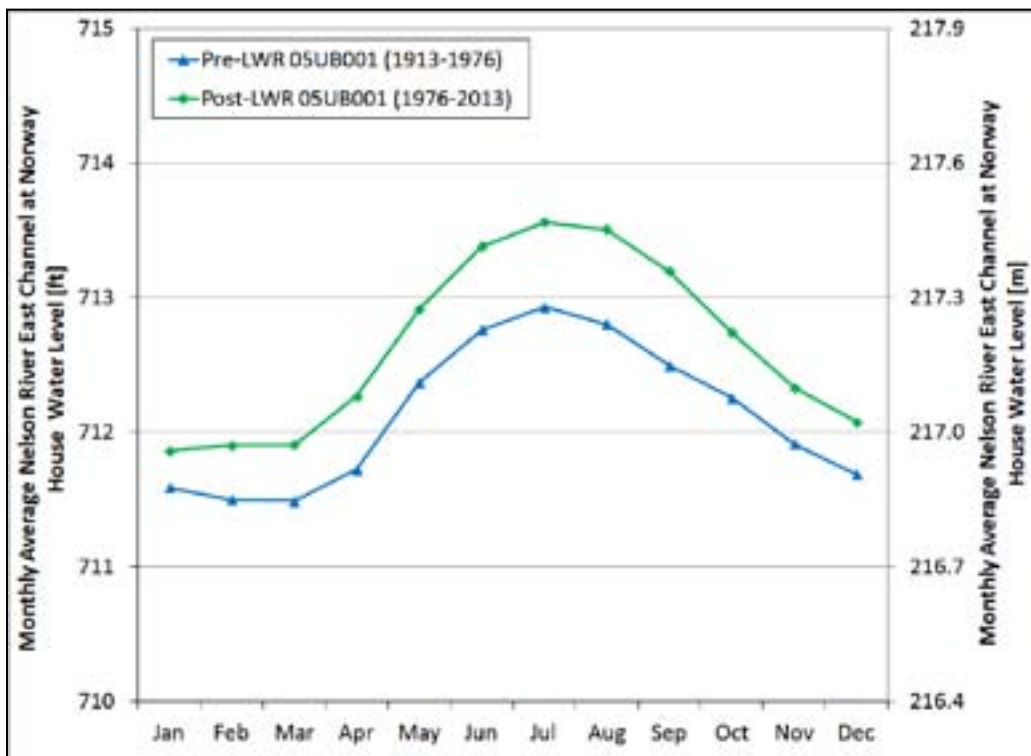


Figure 4-5: Monthly Average Nelson River East Channel at Norway House Water Levels



#### 4.2.1.7 NELSON RIVER EAST CHANNEL

Flow in the Nelson River East Channel is unregulated and remains a function of the upstream water level in Playgreen Lake. As a result, LWR influences flow in the channel when Jenpeg operations affect the water level on Playgreen Lake. Although WSC has reported flows for the Nelson River East Channel at station 05UB008 since 1967, WSC currently reports flows based on the water level at upstream station 05UB001 (Nelson River East Channel at Norway House). As a result, the longer record of water levels at station 05UB001 can be used as a proxy for flows along the East Channel. LWR has therefore reduced the range of flows along the Nelson River East Channel, while keeping the seasonal pattern the same (Figure 4-5). The available data also indicates that East Channel flows have been slightly higher post-LWR. However, because Lake Winnipeg outflows are 4.4% higher since regulation began in 1976, it is not clear whether higher East Channel flows are because of LWR or wetter conditions in the period of record post-LWR. This will be investigated further as part of Phase II of this study.

#### 4.2.1.8 KISKITTO LAKE

WSC reports water level data for Kiskitto Lake at station 05UB013. The control structures operating at Kiskitto Lake maintain water levels within the natural historical range of 686.6 ft (209.3 m) and 702.0 ft (214.0 m) as shown in Figure 4-6 (Lake Winnipeg, Churchill and Nelson River Study Board 1975).

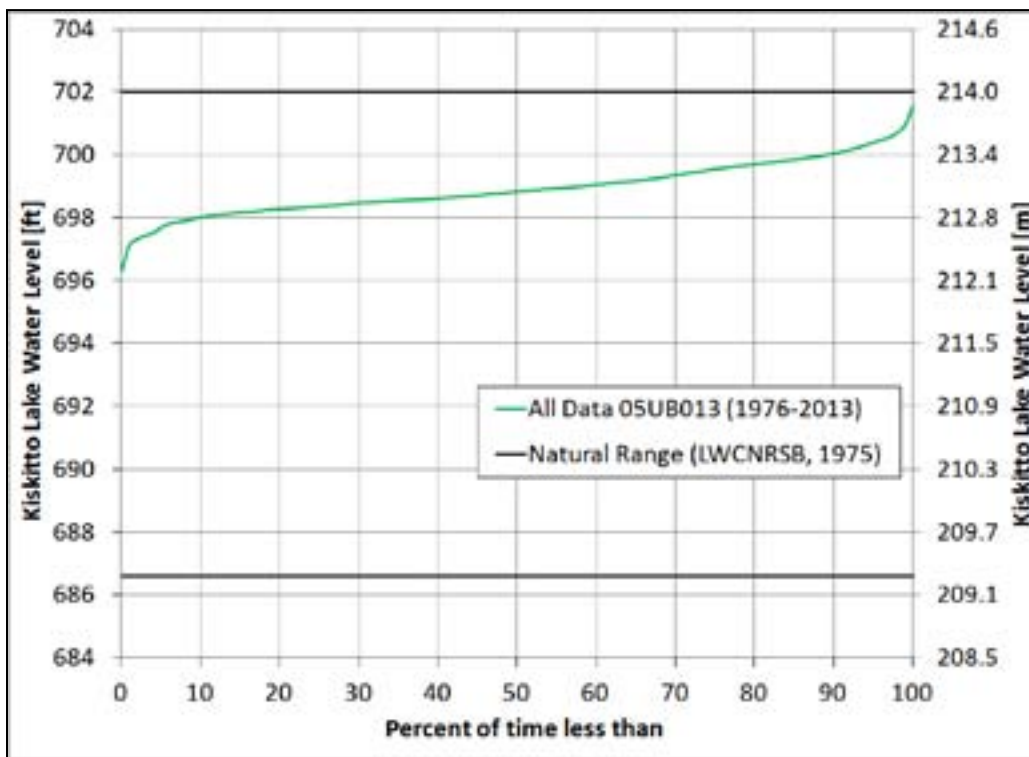
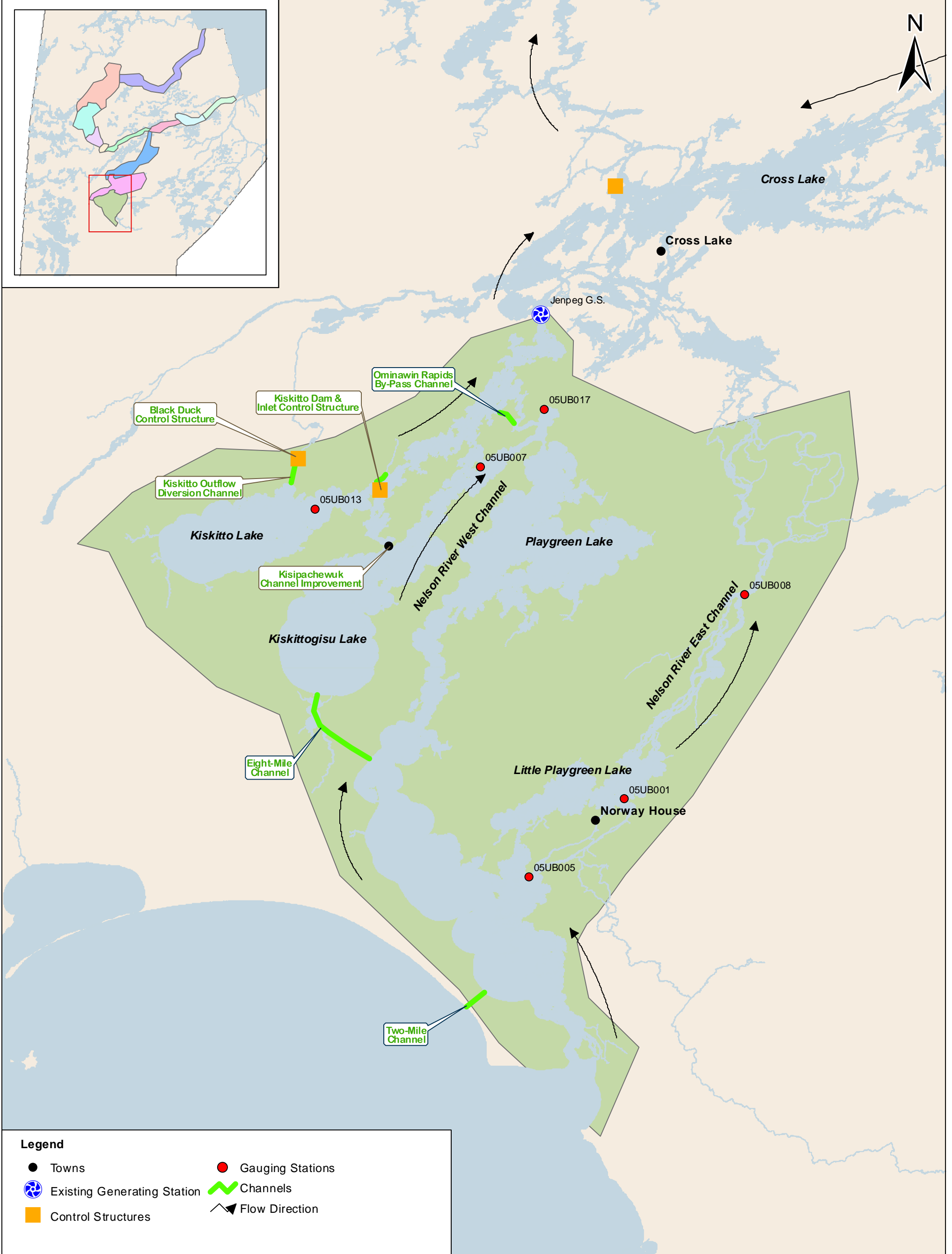


Figure 4-6: Kiskitto Lake Daily Water Level Duration Curve Compared to Natural Range from LWCNRSB 1975 Report

#### **4.2.1.9 ICE CONDITIONS**

During the design of LWR, Manitoba Hydro recognized that a flow reduction could be required each year to decrease water velocity, allowing a stable ice cover to form in the channels upstream from Jenpeg. River sections that remain open allow ice crystals called frazil ice to form and be carried downstream where they may be deposited along the channel causing a flow restriction or a clog in GS intakes. The LWR Ice Stabilization Program was initiated in 1984 following a major ice blockage in 1983. Reductions of flow due to ice jams in the channels upstream of Jenpeg can also result in significant loss of generation at all stations downstream from Jenpeg GS along the Nelson River.

The primary objective of the Ice Stabilization Program is to maximize Lake Winnipeg discharge capabilities during the winter months. The program also considers flow on the lower Nelson River during freeze-up, performance at the Jenpeg GS during freeze-up and through the winter, and the safety and well-being of other waterway users. The Ice Stabilization Program involves detailed monitoring of water levels, water temperatures, weather forecasts and ice conditions in the Outlet Lakes Area and on Cross Lake. Another component of the program is the Jenpeg Ice Boom, originally installed in 1988. The ice boom provides a leading edge that initiates the upstream progression of ice while virtually eliminating ice accumulation in front of the Jenpeg powerhouse (Zbigniewicz 1997). The flow reduction as part of the Ice Stabilization Program has varied each year depending on flow and weather conditions. In lower flow years, when flows are below 60,000 cfs (1,700 cms), a flow reduction is not required because water velocities are low enough to allow formation of a stable ice cover. In higher flow years, the flow reduction can be as high as 35,000 cfs (990 cms) and the duration is typically one to two weeks.



**Legend**

- Towns
- Existing Generating Station
- Control Structures
- Gauging Stations
- ▬ Channels
- ▬ Flow Direction

**Manitoba Hydro**

DATA SOURCE: Manitoba Hydro		
CREATED BY: Hydraulic Operations Department Hydraulic Licencing and Support		
COORDINATE SYSTEM: UTM NAD 1983 Z14N	DATE CREATED: 05 May 14	REVISION DATE: 27-MAY-14
0 5 10 Kilometers 0 4 8 Miles	VERSION NO: 1.0	QA/QC: BSS/RDB/ZZZ

## Zone 1 - Outlet Lakes Area RCEA Area 1

## **4.2.2 ZONE 2 – CROSS LAKE AND SURROUNDING AREA**

Zone 2 begins just downstream from the Jenpeg GS at Cross Lake and extends downstream along the Nelson River to just upstream from Sipiwesk Lake (Map 4-3). Waterbodies within this zone include Duck Lake, Pipestone Lake, Cross Lake and Walker Lake. The Cross Lake Weir, constructed in 1991, is the only Manitoba Hydro structure in this zone.

### **4.2.2.1 MANITOBA HYDRO OPERATIONS**

Manitoba Hydro affects the water regime in this zone through operation of LWR and Jenpeg (previously described in Section 4.2.1). The downstream boundary of Zone 2 is located upstream from any hydraulic influence of the Kelsey GS.

### **4.2.2.2 DATA**

Continuous water level data is available for Cross Lake at WSC station 05UD001 (Cross Lake at Cross Lake) from 1918-present. The monthly record of total Lake Winnipeg outflow (Figure 4-2) represents the inflow to Cross Lake with the exception of some minor local inflow. Continuous water level records are not available for Pipestone Lake, Walker Lake, or Duck Lake prior to LWR.

### **4.2.2.3 CROSS LAKE**

Prior to LWR, Cross Lake water levels followed a typical seasonal pattern (Figure 4-7) with generally higher levels in the summer months and lower levels during the winter months. The mean monthly water level was 679.7 ft (207.2 m) (range: 674.7-685.0 ft or 205.6-208.8 m).

The LWR project altered the Cross Lake water regime by changing the seasonal timing of water levels and increasing water level fluctuations. The average monthly water level variation increased from 0.6 ft (0.2 m) pre-LWR, to 1.0 ft (0.3 m) post-LWR but before installation of the Cross Lake Weir (1976 to 1991). Post-LWR, there are higher average flows and water levels in winter and lower average flows and water levels during summer as compared to pre-LWR conditions (Figure 4-7).

During the post-LWR period but prior to installation of the Cross Lake Weir (described in Section 4.2.2.4), the average Cross Lake water level was 678.6 ft (206.8 m), which is 1.1 ft (0.3 m) lower than the pre-LWR record. The long-term average Lake Winnipeg total outflow during this period was approximately 61,100 cfs (1,730 cms), 17% lower than the long-term pre-LWR average (Figure 4-7). Mean monthly water levels post-LWR but before installation of the Cross Lake Weir were approximately 4 ft (1.2 m) lower during the mid-summer months (June to August) and over 1 ft (0.3 m) higher in the winter months (December to February). The lowest water levels observed during this period occurred during the summer and were 673.0 ft (205.1 m), 1.7 ft (0.5 m) lower than the lowest levels in the pre-LWR record. However, WSC did not operate station 05UD001 from September 1933 through June 1950, which coincides with the lowest recorded water levels on Lake Winnipeg and would have produced very low water levels on Cross Lake. As part of an environmental impact assessment study completed in 1986, The Nelson River Group estimated that the lowest mean monthly pre-LWR water level would have been 673.2 ft (205.2 m) in April 1941 (Nelson River Group 1986). The maximum water level remained the

same as the maximum pre-LWR at 685.0 ft (208.8 m). Lower water levels and the seasonally reversed water level pattern prompted the Cross Lake Weir Project discussed below.

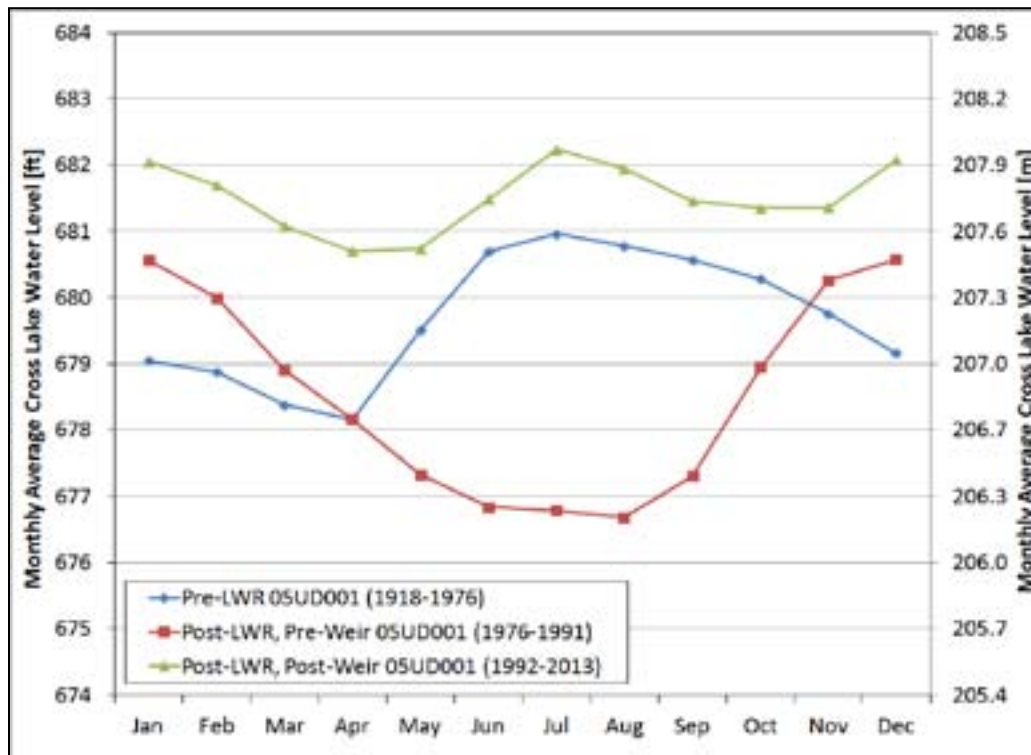


Figure 4-7: Monthly Average Cross Lake Water Levels

#### 4.2.2.4 CROSS LAKE WEIR PROJECT

The Cross Lake Weir was developed to mitigate the effects of LWR by increasing the average water level and reducing the range of water levels on Cross Lake. Construction of the weir was completed in 1991 and modified the lake's main outlet channels by filling in a portion of the centre channel and excavating a portion of the east channel. The mean monthly water level after completion of the weir rose to 681.5 ft (207.7 m), 1.8 ft (0.5 m) higher than the pre-LWR average. The increase is partially attributable to the weir but also partially because since 1992 the average total Lake Winnipeg outflow has been 19% higher than the pre-LWR average because of wetter conditions. Also, since installation of the weir, the seasonality of water levels has more closely resembled natural conditions (Figure 4-7). A seasonal flow reversal is still found to occur in low to average flow years, while in high flow years the seasonal flow pattern remains similar to the natural condition (Figure 4-8). The Cross Lake weir helps to mitigate the effects of higher flows by allowing greater discharge at high lake levels than was possible under natural conditions. Installation of the weir reduced the magnitude of water level variations, including those experienced during the Ice Stabilization Program. The average monthly water level variation reduced from 1.0 ft (0.3 m) post-LWR prior to installation of the weir to 0.7 ft (0.2 m) with the weir, which is close to the pre-LWR average of 0.6 ft (0.2 m).

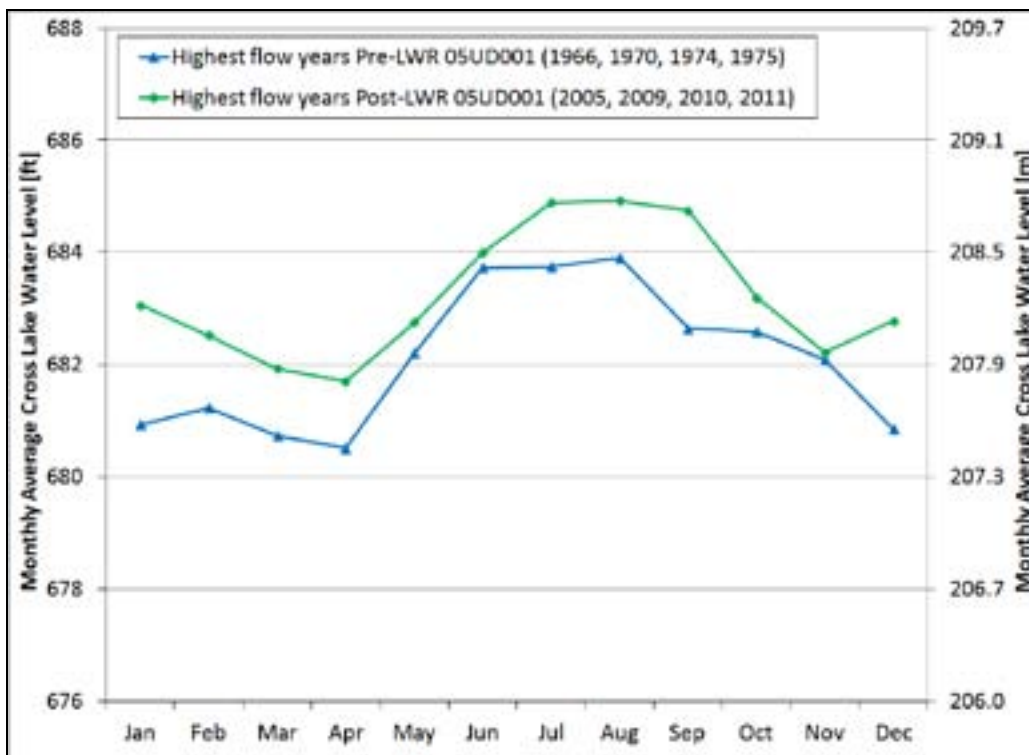


Figure 4-8: Monthly Average Cross Lake Water Levels During High Flow Years

#### 4.2.2.5 PIPESTONE, WALKER, AND DUCK LAKES

Pipestone Lake is located on the East Channel of the Nelson River just upstream from Cross Lake. Water levels on Pipestone Lake are generally a function of water levels on Cross Lake, while flow in the Nelson River East Channel also has a minor influence on lake levels. As a result, LWR impacts Pipestone Lake in a similar manner to Cross Lake.

Walker Lake is located approximately 25 mi (40 km) east of Cross Lake and is connected to it by the Walker River. Midway along the Walker River between Cross Lake and Walker Lake is a set of rapids that have long been known to be reversing. The flow direction on Walker River depends on the elevation of Cross Lake relative to Walker Lake. When Cross Lake elevation is above 681 ft (207.6 m) it has a direct influence on the level of Walker Lake (Manitoba Hydro 1998). When Cross Lake is below this level, Walker Lake level is only a function of local inflows. As a result, LWR periodically affects Walker Lake because LWR affects the frequency, duration, and timing of high water level events on Cross Lake.

Duck Lake is located downstream from Cross Lake along an area where the Nelson River splits into two channels, just upstream from Sipiwesk Lake. LWR affects Duck Lake in a similar manner to Cross Lake including a changed seasonal flow pattern and greater water level variation.

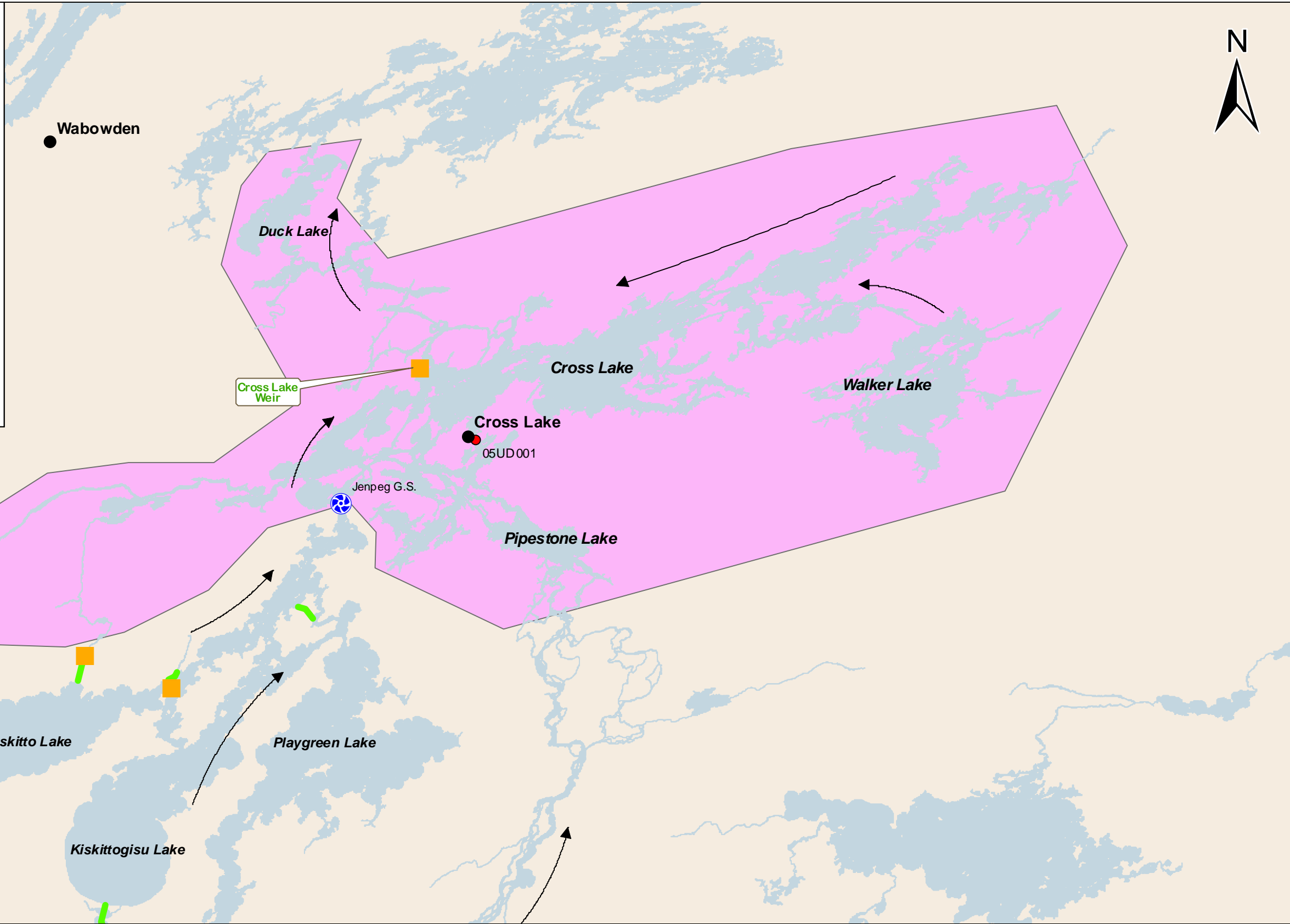
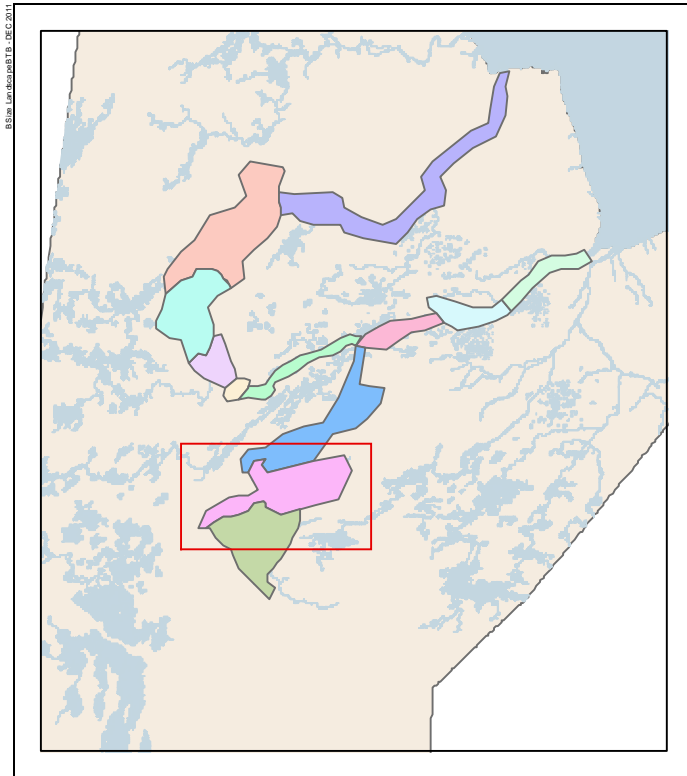


#### 4.2.2.6 ICE CONDITIONS

The Ice Stabilization Program discussed in Section 4.2.1 can affect ice conditions on Cross Lake. This is because Jenpeg operations can increase water level fluctuations and potentially contribute to the formation of slush ice on Cross Lake. As the lake is heavily used during the winter for transportation, operating decisions are made in a manner that attempts to reduce the potential to create slush ice. Large increases in water levels on Cross Lake after freeze-up can also increase the amount of slush ice on the lake. As a result, Manitoba Hydro now increases Jenpeg outflows to the target winter flow prior to freeze-up to allow Cross Lake to freeze at a higher level. Other factors such as heavy snowfall during the freezing period can also influence slush ice conditions.

An ice thickness study was undertaken for Cross Lake in 1983 to establish whether or not Lake Winnipeg Regulation contributed to the severity of slush ice by reducing ice thickness:

The study demonstrated that in many areas, including the western main body of the lake, the northern area, downstream from the East Channel entrance and the southern part of the community, the increased West Channel flow with LWR has resulted in increased ice thickness. Throughout the rest of the lake including the central and northern reaches within the community, none of the natural or Manitoba Hydro influenced factors considered seemed to have a consistent effect on ice thicknesses one way or another (Manitoba Hydro 1983).



DATA SOURCE: Manitoba Hydro		
CREATED BY: Hydraulic Operation Department Hydraulic Licencing and Support		
COORDINATE SYSTEM: UTM NAD 1983 Z14N	DATE CREATED: 05-May-14	REVISION DATE: 27-MAY-14
0 5.5 11 Kilometres 0 4.5 9 Miles	VERSION NO: 1.0	QA/QC: BSS/RDB/ZZ

<b>Legend</b>	
● Towns	● Gauging Stations
⊕ Existing Generating Station	↗ Channels
■ Control Structures	↔ Flow Direction

**Zone 2 - Cross Lake and Surrounding Area**  
**RCEA Area 1**

### **4.2.3 ZONE 3 – SIPIWESK LAKE TO KELSEY GS**

Zone 3 includes Sipiwesk Lake and Nelson River from the outlet of Sipiwesk Lake to the Kelsey GS (Map 4-4). Some of the other lakes in this zone include Landing, Hunting, Prud'homme, Cauchon, and Goose Hunting lakes, which are all tributaries to the Nelson River. The Kelsey GS was constructed between 1957 and 1961 to supply the International Nickel Company's mining and smelting operations and to supply electricity to the City of Thompson.

#### **4.2.3.1 MANITOBA HYDRO OPERATIONS**

Operation of both LWR and the Kelsey GS affect the water regime in this zone. LWR affects the seasonal timing of inflows to Sipiwesk Lake. Kelsey affects water levels on the Nelson River and surrounding lakes upstream to and including Sipiwesk Lake. For the first 16 years of operation (1960 to 1976) Kelsey had no effect on flows because it was operated as a run-of-the-river plant, using the flow of the river as it occurred. Starting in 1977, Kelsey operations became more integrated in the whole hydroelectric system and were:

modified to more effectively utilize the pondage (reservoir storage of limited capacity) of Kelsey's forebay on an infrequent basis to supplement flows over a period of about a month or so, or to increase the gradient out of Sipiwesk Lake to alleviate winter hydraulic restrictions (Manitoba Hydro-Split Lake Cree Joint Studies 1996).

Flow changes at Kelsey immediately affect the water level upstream from the GS and the effect moves progressively upstream to Sipiwesk Lake. Hourly water level variations at the Kelsey forebay generally influence water levels from the generating station to the outlet of Sipiwesk Lake. Changes to the daily average flow at Kelsey can affect Sipiwesk Lake and several other lakes which are tributaries to the Nelson River.

#### **4.2.3.2 DATA**

Manitoba Hydro has a continuous record of daily water levels in the Kelsey forebay since August 1957. Flows in this zone have been monitored at WSC station 05UE004 (Nelson River below Sipiwesk Lake) from 1951-1958, and by Manitoba Hydro at Kelsey since 1960. Water levels have also been monitored at WSC station 05UD006 (Sipiwesk Lake at Forestry Dock) since 1965.

### 4.2.3.3 KELSEY GS

Based on the short record of data available, impoundment of the Kelsey forebay increased water levels by approximately 30 ft (9.1 m). Impoundment flooded 63.5 sq mi (164.5 sq km) of land, increasing the surface area of the rivers and lakes between Sipiwesk Lake and Kelsey from approximately 233 to 297 sq mi (603 to 769 sq km). Since construction was completed in 1961, the Kelsey forebay is normally controlled to operate just below its upper licensed limit of 605 ft (184.4 m) to optimize power production (Figure 4-9). For power production reasons, the forebay is drawn down periodically but typically not below 600 ft (182.9 m) (Figure 4-9).

The monthly average discharge at Kelsey pre- and post-LWR in Figure 4-10 shows that LWR increased winter flows at Kelsey. Although LWR can also increase flows during the open water season under flood conditions, the available record indicates that on average LWR decreased open water flow. Long-term average flow, which is not affected by hydroelectric development, is approximately 89,000 cfs (2,520 cms) in the pre-LWR period (1951-1976) and 78,000 cfs (2,210 cms) in the post-LWR period (1977-2013).

Manitoba Hydro completed a more detailed characterization of the water regime in this zone in 2005 including an assessment of the potential effects of the Kelsey Re-running Project which was completed in 2013 (Manitoba Hydro 2005).

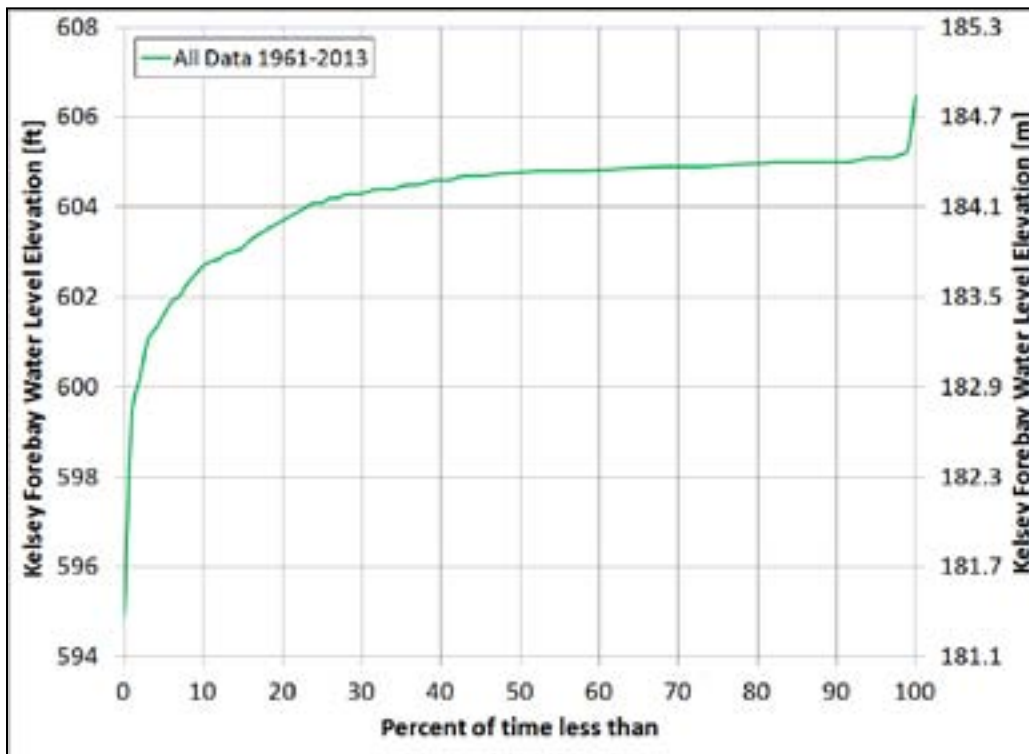


Figure 4-9: Kelsey Forebay Daily Water Level Duration Curve

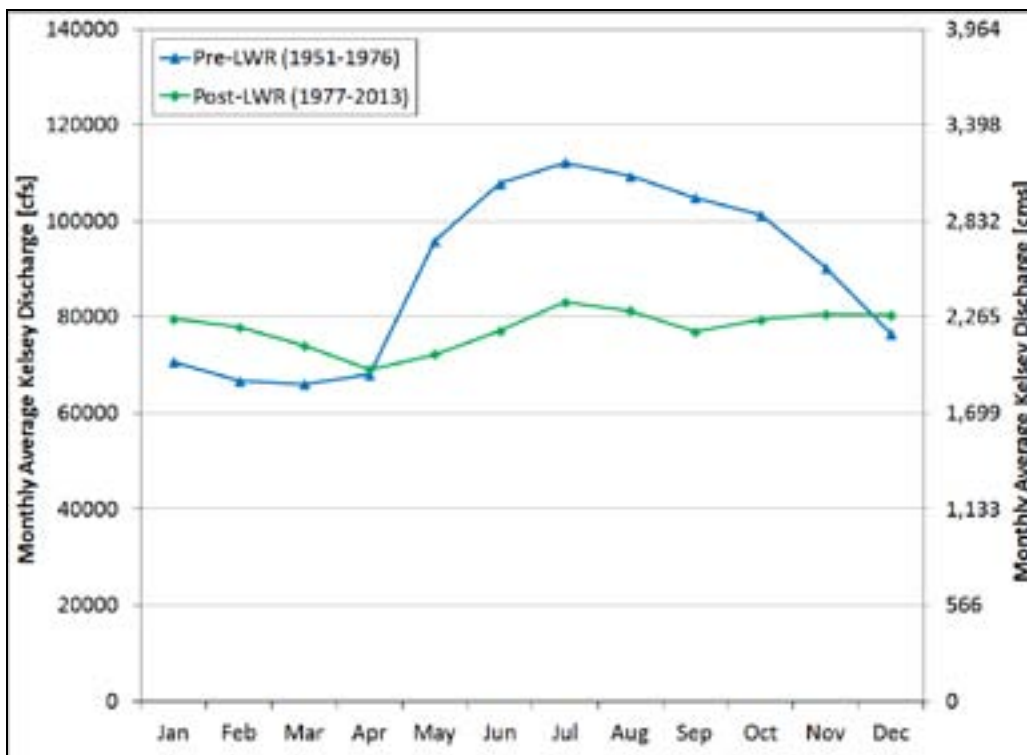


Figure 4-10: Monthly Average Kelsey Discharge

#### 4.2.3.4 SIPIWESK LAKE

Water level data for Sipiwesk Lake is only available prior to impoundment of the Kelsey forebay during parts of 1952 and 1954. Flow measurements were also taken at a location 4 mi (6.4 km) below Sipiwesk Lake during the 1952 and 1954 hydrometric program (Manitoba Department of Mines and Natural Resources 1952, 1954). Comparing water levels prior to and after Kelsey impoundment under similar flow conditions, it appears that the Kelsey GS increased the average water level on Sipiwesk Lake by approximately 10 ft (3.0 m). The Federal Ecological Monitoring Program (FEMP) estimated that that impoundment of the Kelsey GS increased the water level on Sipiwesk Lake by 3.3 to 6.6 ft (1.0 m to 2.0 m) (Environment Canada, Department of Fisheries and Oceans 1992). In a Post-Project Assessment of Kelsey and Lake Winnipeg Regulation Impacts on Wabowden, it is estimated that, prior to the development at Kelsey, the long term median monthly level of Sipiwesk Lake was 596.0 ft (181.7 m) (MacKay *et al.* 1990). The long-term median monthly level is 610.6 ft (186.1 m) in the available record after 1965.

The available data presented in Figure 4-11 is divided into years pre- and post-LWR. Similar to the effects on Cross Lake, LWR has reversed the seasonal water level pattern on Sipiwesk Lake in low to average flow years. Based on the available data, it would appear that the average water level on Sipiwesk Lake was higher prior to LWR. However, these higher water levels were the result of flows being approximately 25% higher in the pre-LWR period of record (1965-1976) when compared to the post-LWR period of

record (1976-2013). Based on the available record of data, the Sipiwesk Lake average monthly water level variation increased from 0.7 ft (0.2 m) pre-LWR to 1.1 ft (0.3 m) post-LWR.

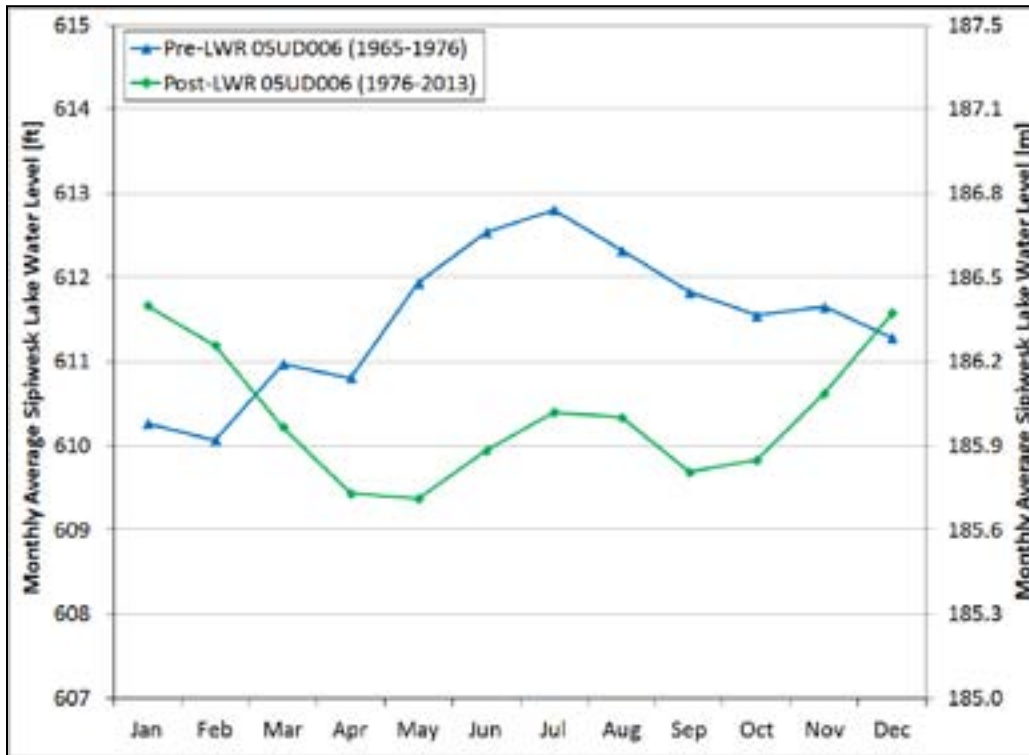
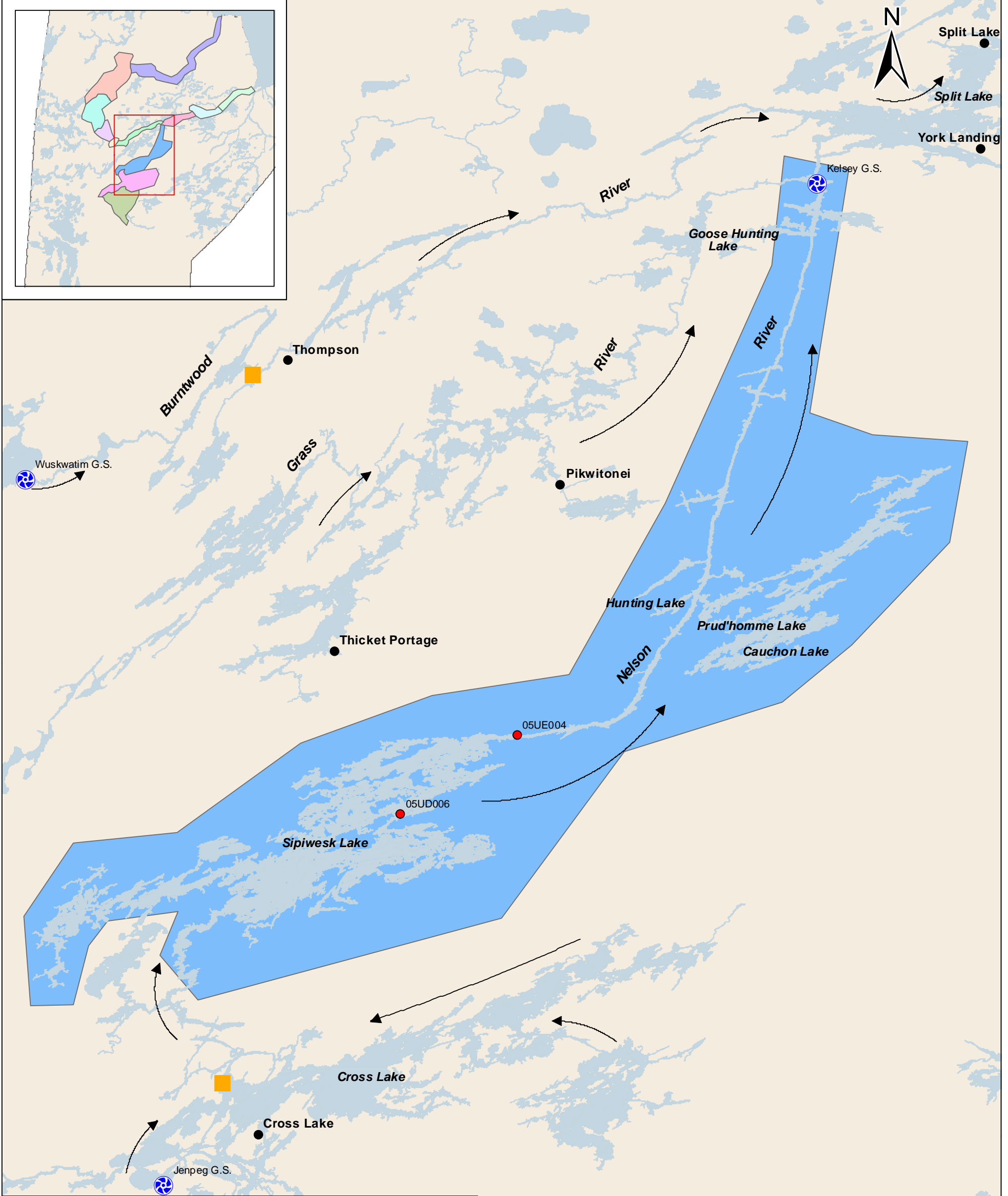


Figure 4-11: Monthly Average Sipiwesk Lake Water Levels

#### 4.2.3.5 ICE CONDITIONS

Impoundment of the Kelsey forebay decreased water velocities between Sipiwesk Lake and Kelsey. As a result, rapids areas that used to remain open year round now freeze over with a stable thermal ice cover. Also, in years with large water level variations in the Kelsey forebay during the winter, ice conditions may be affected including potentially contributing to slush ice conditions.

LWR has the potential to contribute to slush ice conditions by increasing water level fluctuations on Sipiwesk Lake.



**Legend**

- Towns
- Gauging Stations
- ⊕ Existing Generating Station
- ⚡ Channels
- Control Structures
- ↔ Flow Direction

	DATA SOURCE: Manitoba Hydro		
	CREATED BY: Hydraulic Operations Department Hydraulic Licencing and Support		
	COORDINATE SYSTEM: UTM NAD 1983 Z14N	DATE CREATED: 05 May 14	REVISION DATE: 27-MAY-14
		VERSION NO: 1.0	QA/QC: BSS/RDB/ZZZ

## Zone 3 - Sipiwesk Lake to Kelsey G.S. RCEA Area 1

#### **4.2.4 ZONE 4 – LEAF RAPIDS TO SOUTHERN INDIAN LAKE**

Zone 4 includes the upper Churchill River from Leaf Rapids to Southern Indian Lake (SIL) (Map 4-5). Starting from Leaf Rapids, the Churchill River runs approximately 20 mi (32 km) before reaching Opachuanau Lake, which is connected to SIL.

Two of the three main components of the CRD are located in this zone. The Missi Falls Control Structure (CS) controls the outflow at the natural outlet of SIL and raised the water level on the lake. The South Bay Diversion Channel is an excavated channel from the South Bay of SIL to Issett Lake and creates a new outlet to allow Churchill River water to flow into the Rat River and Burntwood River System. The Notigi CS is the third main component of CRD and is described in Section 4.2.6.

##### **4.2.4.1 MANITOBA HYDRO OPERATIONS**

Following joint federal-provincial studies (Canada, Manitoba 1965), Manitoba Hydro in February 1966 announced its intention to divert the Churchill River as part of an overall plan of northern hydro development. Instead of harnessing the hydroelectric potential by building plants right on the Churchill River, a considerable economic advantage was gained by diverting most of the Churchill River water into the Burntwood and Nelson River systems to use at the generating stations on the lower Nelson River.

CRD is a key feature of hydroelectric development in Manitoba and is responsible for on average 25% of the flow to Manitoba Hydro's system. Manitoba Hydro controls all outflow from SIL through operations at the Missi Falls CS and Notigi CS. The majority of flow is diverted through Notigi while discharge at both Missi Falls and Notigi typically remain constant for long periods of up to several months at a time. SIL is used as a seasonal reservoir as it is typically filled during the open water period to store water for use during the winter when the lake is typically drawn down. Operating decisions are made such that flow releases through Notigi and Missi control structures result in maximized system generation, while staying within applicable limits for flows and water levels. This is especially important during winter when Lake Winnipeg outflows are restricted by ice. Flow conditions on the Nelson River also influence CRD operating decisions. For example, CRD flows through Notigi are sometimes reduced during periods when the Nelson River is experiencing flood conditions. In these instances, water is either stored in SIL (if license conditions permit) or released at Missi Falls CS into the lower Churchill River.

##### **4.2.4.2 DATA**

WSC reports a continuous water level record for SIL since 1956 at station 06EC001 (Southern Indian Lake near South Indian Lake). Manitoba Hydro also measures water levels in the Missi Falls and Notigi forebays and has measured discharge through the control structures since 1976.

##### **4.2.4.3 SOUTHERN INDIAN LAKE**

CRD increased the average water level on SIL by 9 ft (2.7 m) and increased the area of SIL from 843 to 898 sq mi (2,180 to 2,330 sq km) by flooding approximately 55 sq mi (140 sq km) of land. Increased water levels also created a backwater effect that influences water levels as far upstream as the outlet of Granville Lake at Leaf Rapids. Granville Lake is not considered an affected waterbody because, based on



hydraulic modeling, backwater effects greater than 0.1 m (0.3 ft) have occurred less than 10 percent of the time (Manitoba Hydro 2010). Backwater effects on Granville Lake only occur when low flow conditions on the upper Churchill River are combined with high water levels on SIL. CRD also affects flow patterns within SIL. While all of the water used to flow out the natural outlet at Missi Falls, the majority of inflowing water now flows south via the South Bay Diversion Channel. As shown in Figure 4-12, the available data indicates that the seasonal water level pattern on SIL is similar to the pre-CRD pattern. Pre-CRD data also includes effects from the Island Falls GS in Saskatchewan which was completed in 1930 and results in higher winter flows than natural conditions.

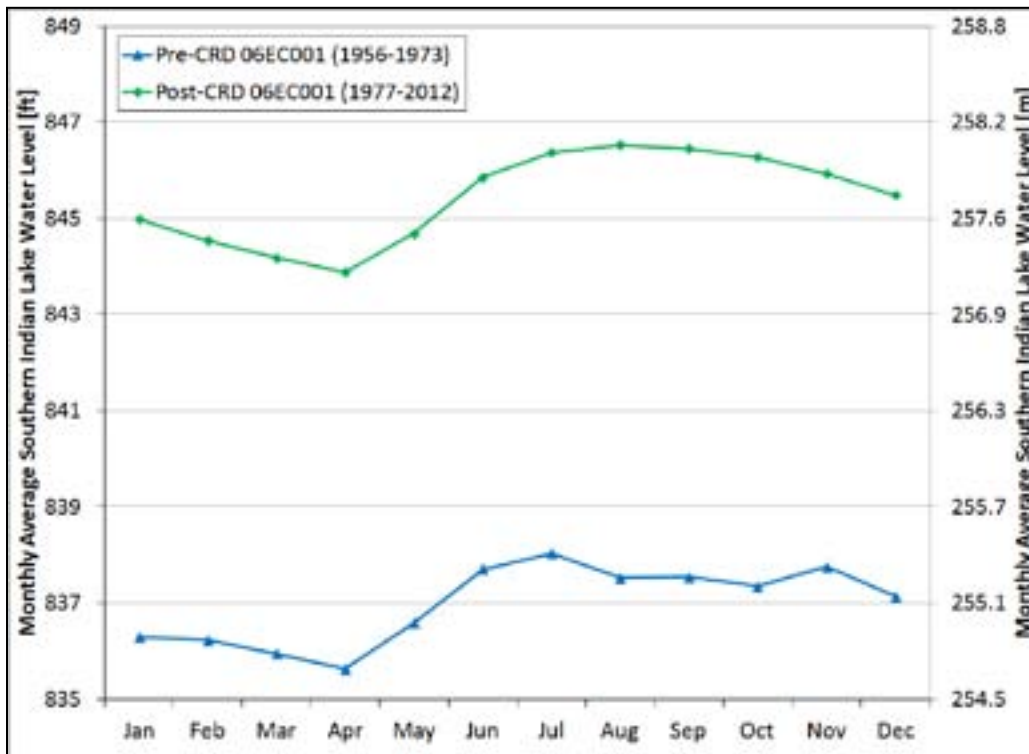
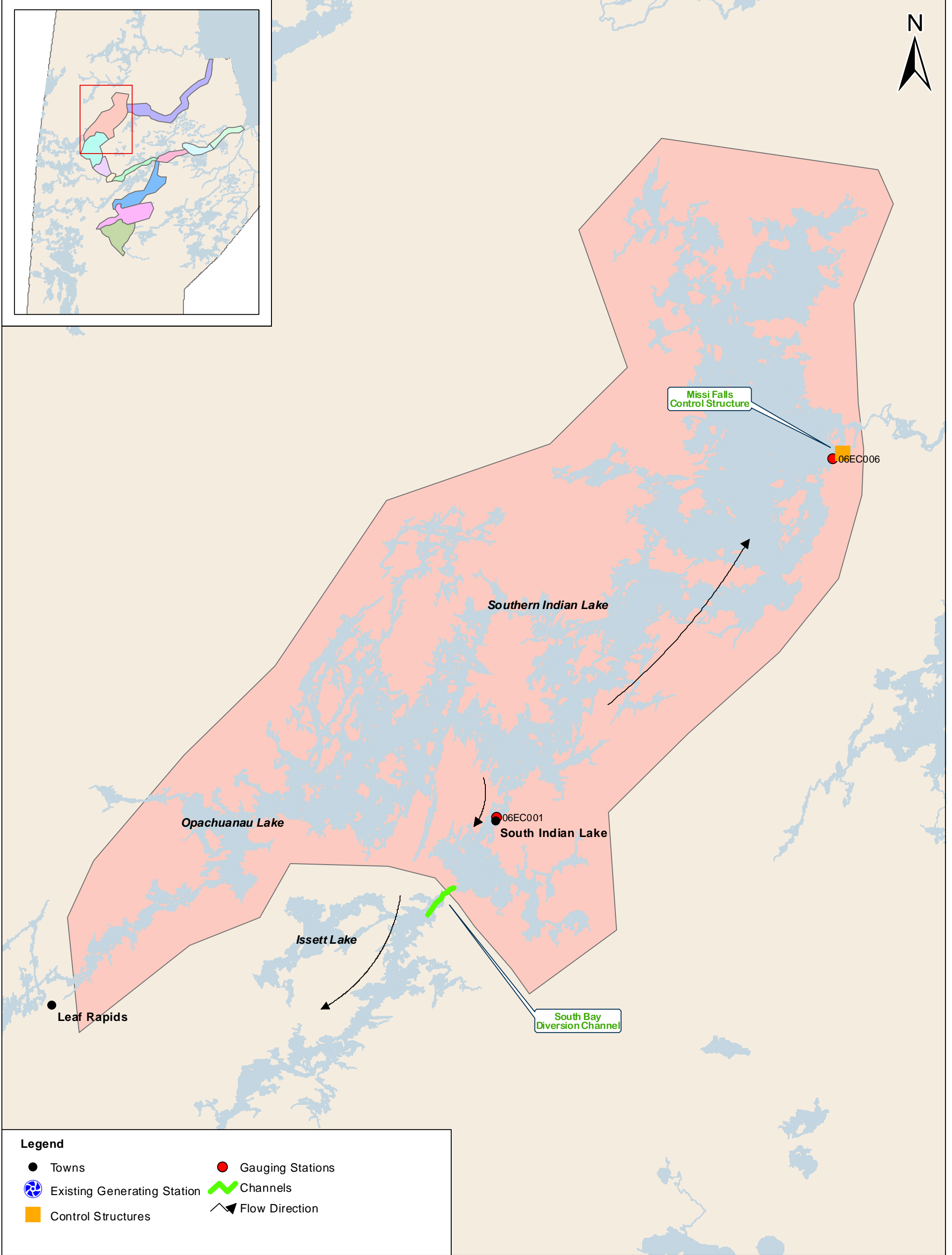


Figure 4-12: Monthly Average Southern Indian Lake Water Levels

#### 4.2.4.4 ICE CONDITIONS

Pre-CRD, the ice cover on Southern Indian Lake was usually formed in late fall and used extensively as a road bed for winter transportation especially in the vicinity of the settlement, South Indian Lake. Post-CRD, the only forecasted change to ice cover was in the vicinity of the South Indian Lake Settlement where the ice cover was expected to be poor or non-existent (Lake Winnipeg, Churchill and Nelson Rivers Study Board 1975).



**Legend**

- Towns
- Gauging Stations
- ⊕ Existing Generating Station
- ⚡ Channels
- Control Structures
- ↔ Flow Direction

	DATA SOURCE: Manitoba Hydro		
	CREATED BY: Hydraulic Operations Department Hydraulic Licencing and Support		
	COORDINATE SYSTEM:	DATE CREATED:	REVISION DATE:
	UTM NAD 1983 Z14N	05 May 14	28-MAY-14
		VERSION NO:	QA/QC:
		1.0	BSS/RDB/ZZ

**Zone 4 - Leaf Rapids to Southern Indian Lake  
RCEA Area 3**

## **4.2.5 ZONE 5 – LOWER CHURCHILL RIVER**

Zone 5 covers the lower Churchill River from the Missi Falls CS to the Churchill Weir just upstream from the Churchill River Estuary (Map 4-6). Major lakes in this zone include Partridge Breast, Thorsteinson, Northern Indian, and Fidler.

### **4.2.5.1 MANITOBA HYDRO OPERATIONS**

The operation of CRD substantially reduces average inflows to the lower Churchill River from Southern Indian Lake resulting in lower water levels in both the lakes and river sections. Despite the reduction in inflows, high flow conditions still occur in some years on the lower Churchill River and operation of CRD sometimes causes rapid flow increases. This will be investigated in more detail as part of Phase II of this study.

### **4.2.5.2 DATA**

WSC measures lower Churchill River discharge at two locations in this zone. Station 06FB001 (Churchill River below Fidler Lake) and station 06FD001 (Churchill River above Red Head Rapids) have operated since 1960 and 1971 respectively.

### **4.2.5.3 LOWER CHURCHILL RIVER DISCHARGE**

On average, 28,000 cfs (790 cms) is diverted from the Churchill River system into the Nelson River system at SIL. Flow contributions from the remainder of the Churchill River basin between SIL and Hudson Bay are such that average flow below Fidler Lake is 9,200 cfs (260 cms) and above Red Head Rapids is 12,900 cfs (370 cms). Figures 4-13 and 4-14 show that river discharge pre- and post-CRD have a similar seasonal pattern with peaks occurring during the open water season and the lowest flows observed during the winter.

### **4.2.5.4 CHURCHILL WEIR**

The Churchill Weir is a mitigatory structure designed to increase water levels on the Churchill River to ensure a potable water source and to enhance recreation and aquatic habitat. The structure was built 10 km (6.21 mi) south of the Town of Churchill, just upstream of Mosquito Point. The structure consists of an overflow section and two dyke sections. The overflow section also features a fishway segment at the lowest point of the weir. The east dyke incorporates the Goose Creek fishway and an emergency flood relief section. These works were completed in October 1999.

### **4.2.5.5 ICE CONDITIONS**

CRD resulted in reduced winter discharge and reduced water velocities along the lower Churchill River. Lower velocities result increased area with ice cover. There would also be less ice accumulation by shoving and thickening at the leading edge which typically occurs downstream of fast flowing open water river sections.

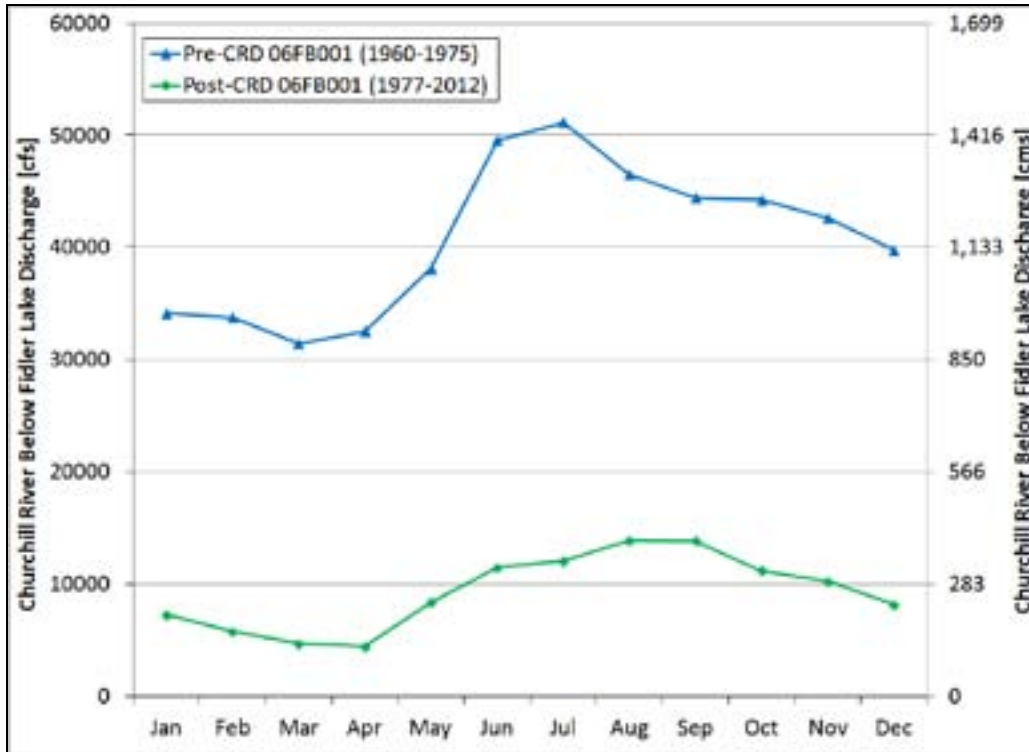


Figure 4-13: Monthly Average Churchill River Below Fidler Lake Discharge

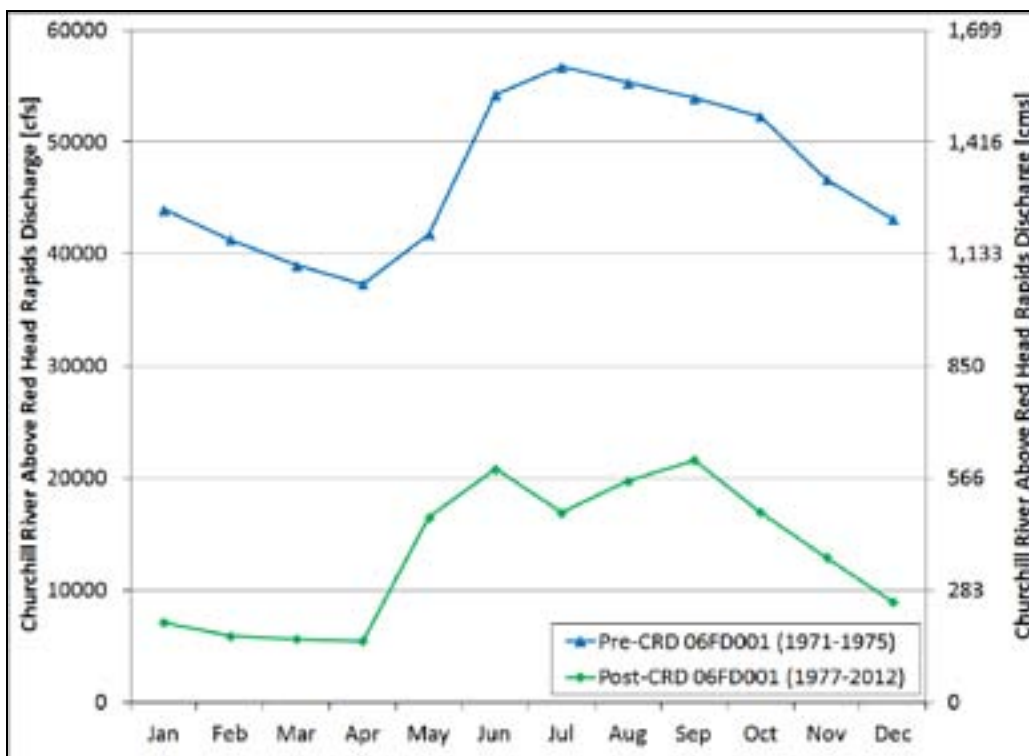
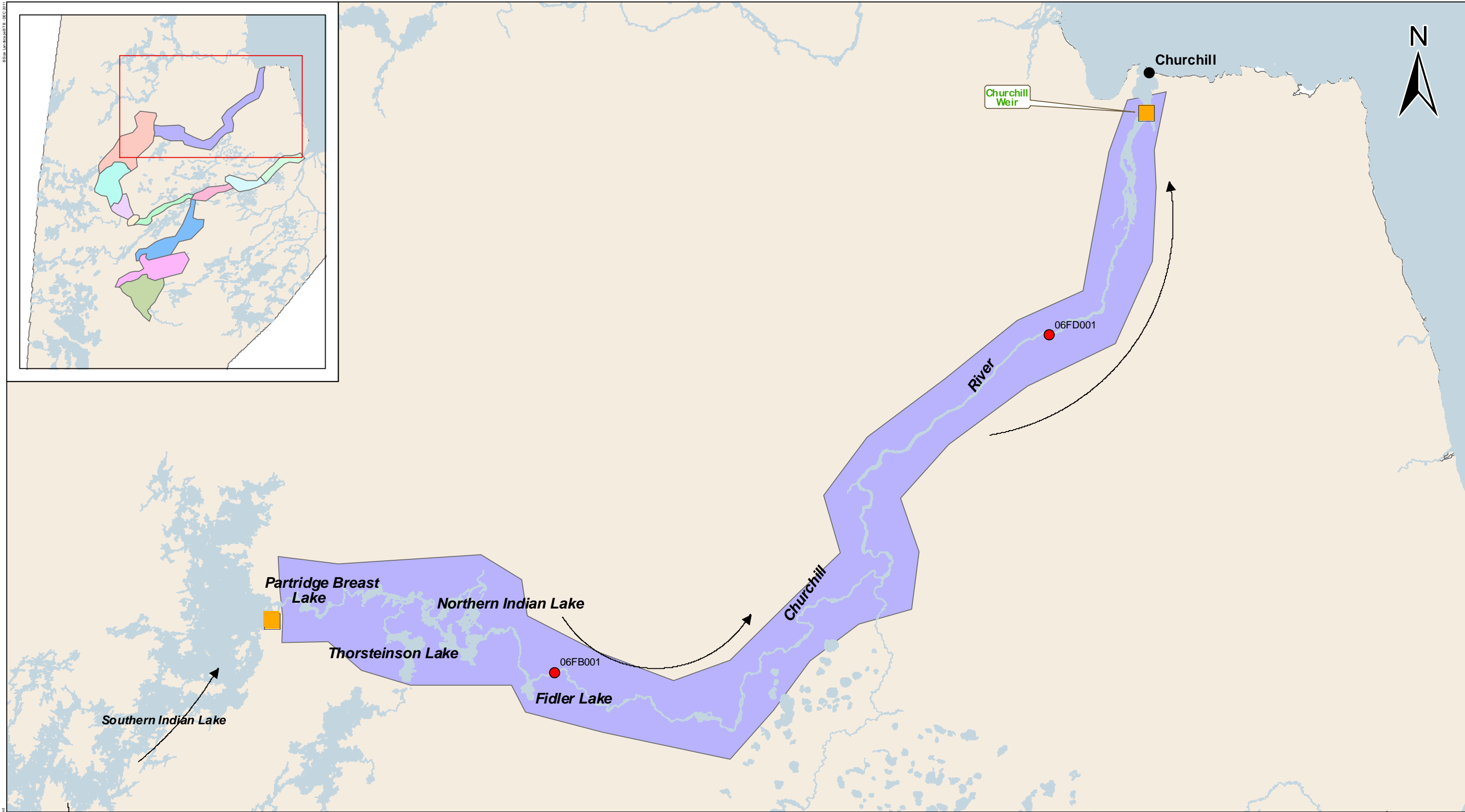
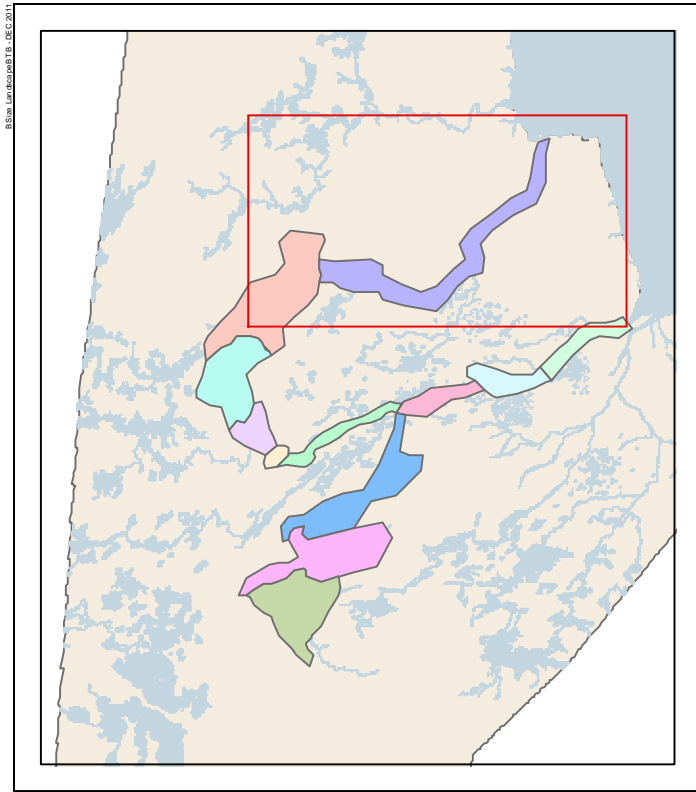


Figure 4-14: Monthly Average Churchill River Above Red Head Rapids Discharge



DATA SOURCE: Manitoba Hydro		
CREATED BY: Hydraulic Operation Department Hydraulic Licencing and Support		
COORDINATE SYSTEM: UTM NAD 1983 Z14N	DATE CREATED: 05-May-14	REVISION DATE: 27-MAY-14
0 10 20 Kilometres 0 9.5 19 Miles	VERSION NO: 1.0	QA/QC: BSS/RDB/ZZZ

Legend	
● Towns	● Gauging Stations
⊕ Existing Generating Station	↗ Channels
■ Control Structures	↘ Flow Direction

**Zone 5 - Lower Churchill River  
RCEA Area 4**

## **4.2.6 ZONE 6 – SOUTH BAY CHANNEL TO NOTIGI CONTROL STRUCTURE**

This zone covers the Rat River system from the excavated outlet at the South Bay of SIL to the Notigi CS (Map 4-7). Major lakes in this zone include Issett, Rat, and Notigi.

Notigi CS is the third main component of CRD. It is a control structure on the Rat River that regulates the diversion flow from SIL into the Burntwood-Nelson River system. The other components of CRD including the Missi Falls CS and the South Bay Diversion Channel are described in Section 4.2.4.

### **4.2.6.1 MANITOBA HYDRO OPERATIONS**

A general description of CRD is provided in Zone 4 Section 4.2.4.1, including descriptions of Notigi CS operations.

### **4.2.6.2 DATA**

Manitoba Hydro maintains a record of daily water levels in the Notigi forebay since just before impoundment in 1974. There are four months of continuous data from January to April, 1974, in this area prior to first impoundment. Manitoba Hydro has also monitored discharge through Notigi since CRD began operation.

### **4.2.6.3 ISSET LAKE – RAT LAKE – NOTIGI FOREBAY AREA**

The majority of flooding as a result of the CRD Project occurs in this zone. Increased flows through the area and increased water levels because of impoundment upstream from the Notigi CS caused 175 sq mi (453 sq km) of flooding. Based on limited data before impoundment of Notigi, it appears that CRD increased water levels approximately 50 ft (15.2 m) just upstream from the Notigi CS. The mean monthly post-CRD water level in Notigi CS forebay has ranged between 834.5 and 847.3 ft (254.4 and 258.3 m), while the seasonal pattern has been to peak in late summer and decline throughout the winter (Figure 4-15). Mean monthly discharge at Notigi has ranged between approximately 14,000 cfs and 35,000 cfs (400 and 990 cms). Figure 4-16 shows that Notigi discharge is typically higher in the winter months and lower in the spring and summer. Figure 4-17 shows that 70% of the time Notigi discharge has been between 25,000 cfs and 35,000 cfs (710 and 990 cms) .

### **4.2.6.4 ICE CONDITIONS**

CRD resulted in an increase of water level upstream of Notigi CS, thus reducing the water velocity in most upstream areas and improving ice cover formation during the winter. Immediately upstream of Notigi, velocities are higher and an open water zone exists throughout the winter.

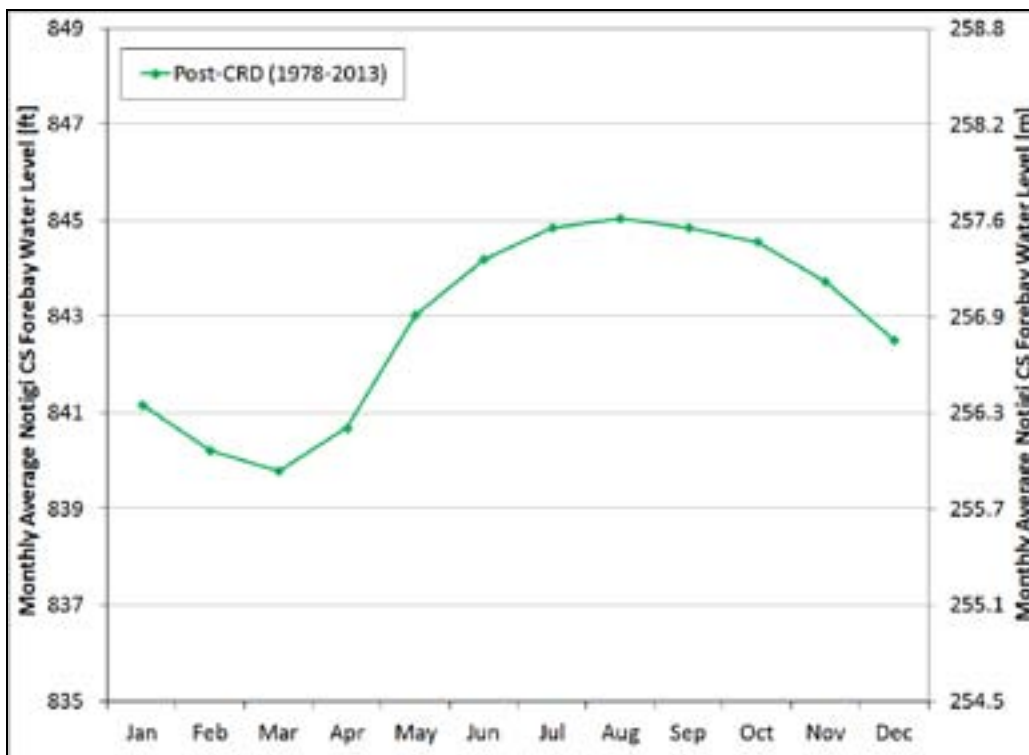


Figure 4-15: Monthly Average Notigi Forebay Water Levels

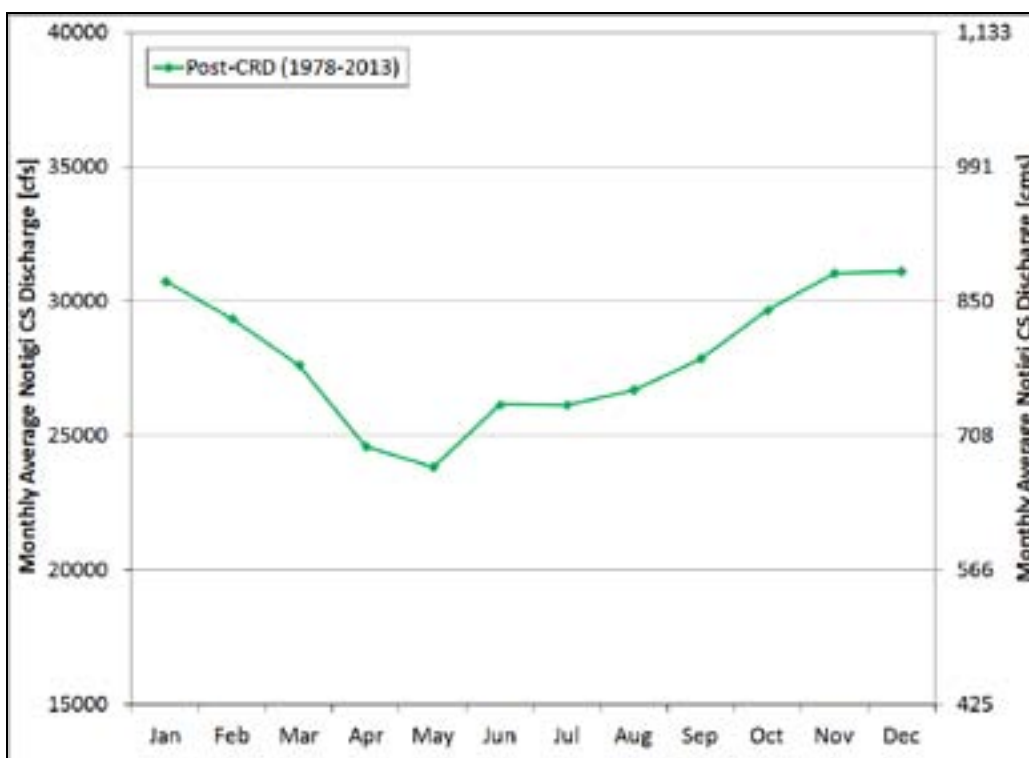


Figure 4-16: Monthly Average Notigi Discharge

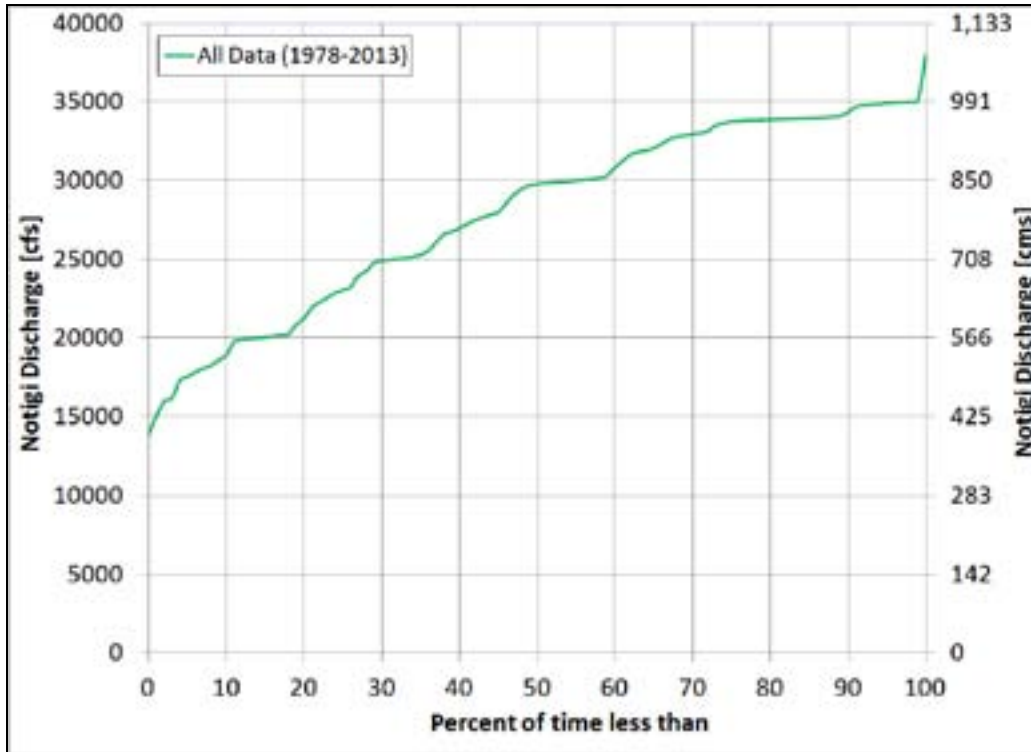
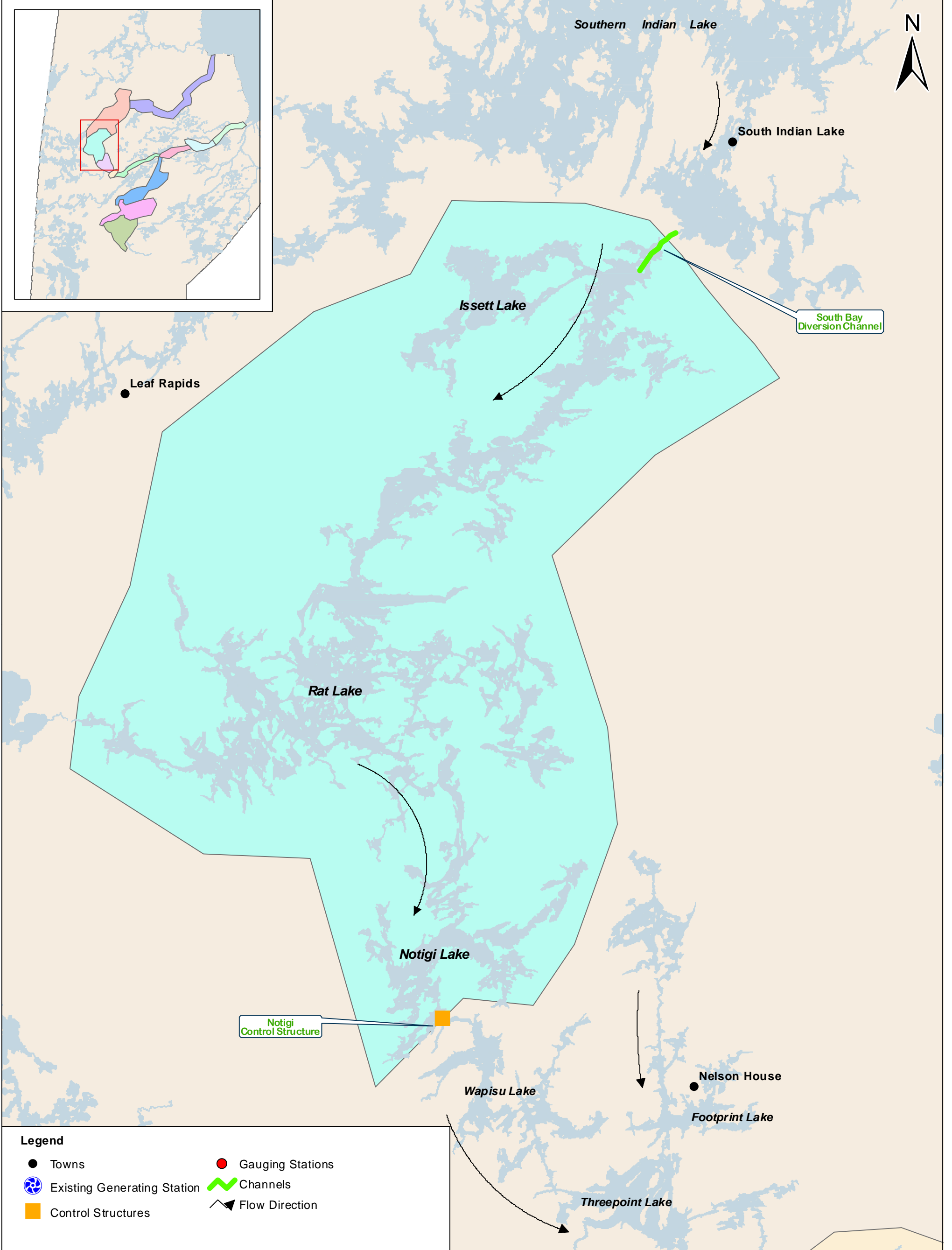



Figure 4-17: Notigi Discharge Duration Curve





**Legend**

- Towns
- Gauging Stations
- ⊕ Existing Generating Station
- ⚡ Channels
- Control Structures
- ↘ Flow Direction



DATA SOURCE: Manitoba Hydro		
CREATED BY: Hydraulic Operations Department Hydraulic Licencing and Support		
COORDINATE SYSTEM: UTM NAD 1983 Z14N	DATE CREATED: 05 May 14	REVISION DATE: 28-MAY-14
0 4.5 9 Kilometers 0 3.5 7 Miles	VERSION NO: 1.0	QA/QC: BSS/RDB/ZZ

**Zone 6 - South Bay to Notigi Control Structure  
RCEA Area 3**

## **4.2.7 ZONE 7 – NOTIGI CONTROL STRUCTURE TO EARLY MORNING RAPIDS**

Zone 7 covers the Rat/Burntwood River system from the Notigi CS to Early Morning Rapids (Map 4-8). Major lakes in this zone include Wapisu Lake, Threepoint Lake, Footprint Lake and Osik Lake.

### **4.2.7.1 MANITOBA HYDRO OPERATIONS**

Manitoba Hydro operation of CRD, specifically Notigi CS, regulates the inflow to this zone. This zone is upstream of the water level influence from the Wuskwatim GS. CRD resulted in substantially higher flows in this zone and therefore increased water levels above the natural range. The operation of Notigi CS has resulted in a reversal of seasonal flow patterns depicted by higher flows during the winter than in summer (Figure 4-16). Higher water levels also created a backwater effect up the Burntwood River to Gate Falls and up the Footprint River to Osik Lake. From the Notigi CS to Split Lake, CRD flooded 31.6 sq mi (81.8 sq km) of land.

### **4.2.7.2 DATA**

The only continuous water level data available in this zone prior to operation of CRD is located at Footprint Lake station 05TF001 which has been operated by WSC since 1960.

### **4.2.7.3 FOOTPRINT LAKE**

Analysis of the available data indicates that CRD raised the average water level of Footprint Lake by 14.3 ft (4.4 m), from 782.3 ft to 796.6 ft (238.4 m to 242.8 m). Figure 4-18 shows that CRD changed the seasonal pattern so that higher water levels typically now occur in the winter while they used to occur during the summer. Figure 4-19 shows that 90% of the time the pre-CRD range of water levels was 8.3 ft (2.5 m) while post-CRD the range has been reduced to 6.8 ft (2.1 m). The monthly average water level variation on Footprint Lake also reduced from 1.2 ft (0.4 m) pre-CRD to 0.9 ft (0.3 m) post-CRD.

### **4.2.7.4 ICE CONDITIONS**

Higher flows created by CRD in this zone resulted in higher velocities along part of the Burntwood River, which likely resulted in larger areas remaining ice free year-round. The Wuskwatim EIS contains a detailed description of ice conditions along the Burntwood River in this zone.

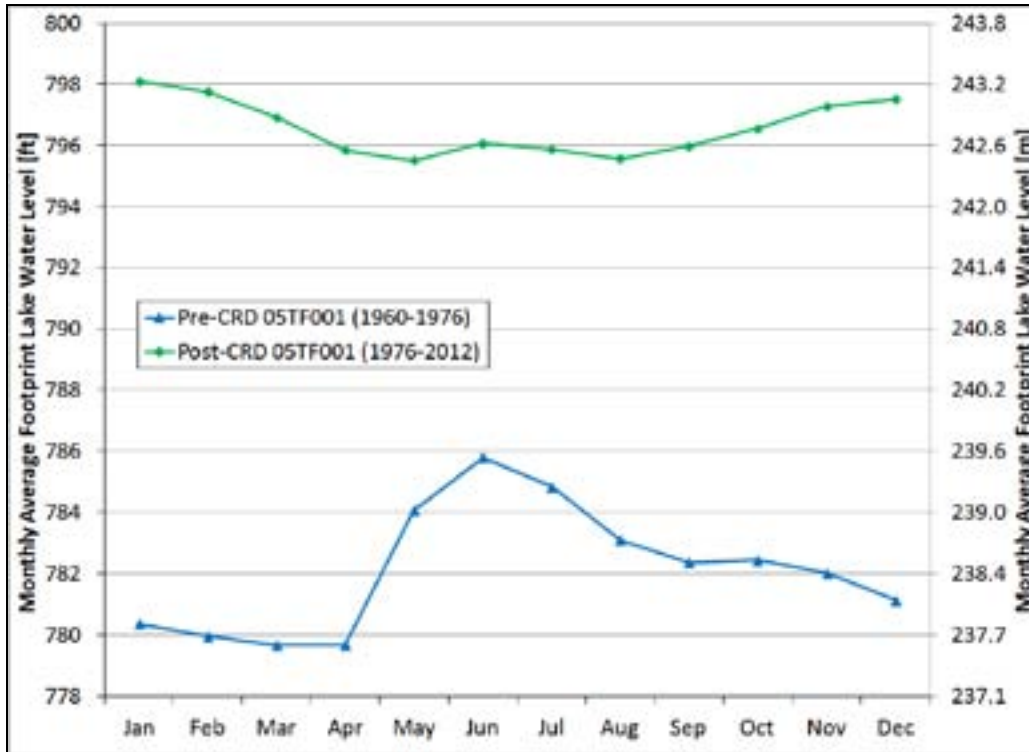


Figure 4-18: Monthly Average Footprint Lake Water Levels

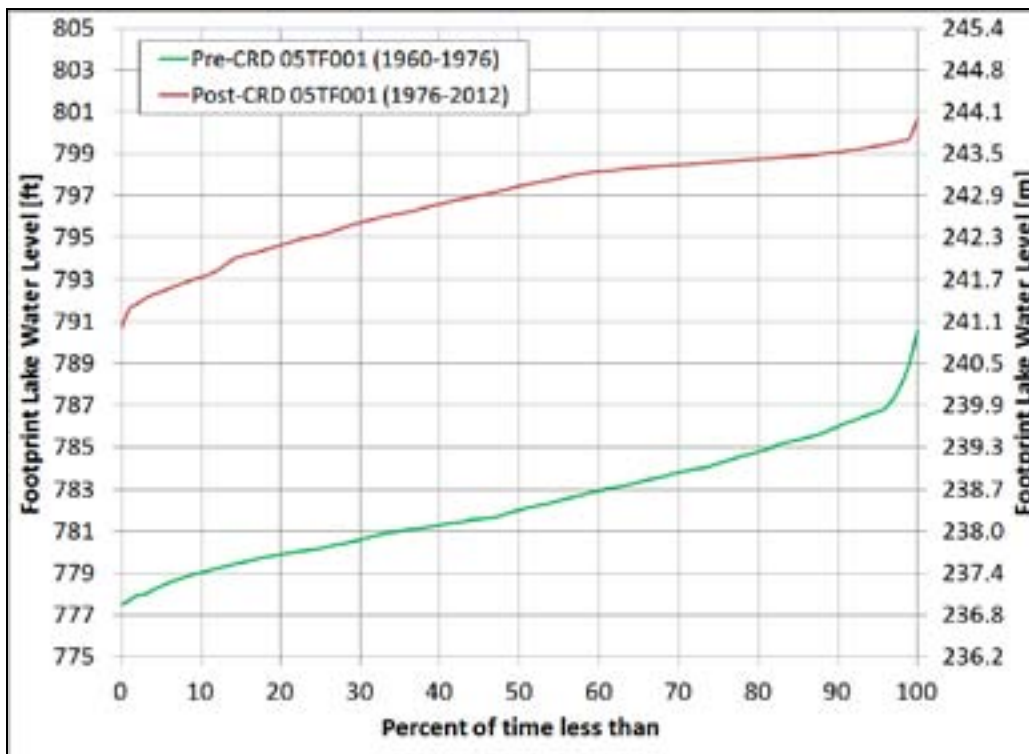
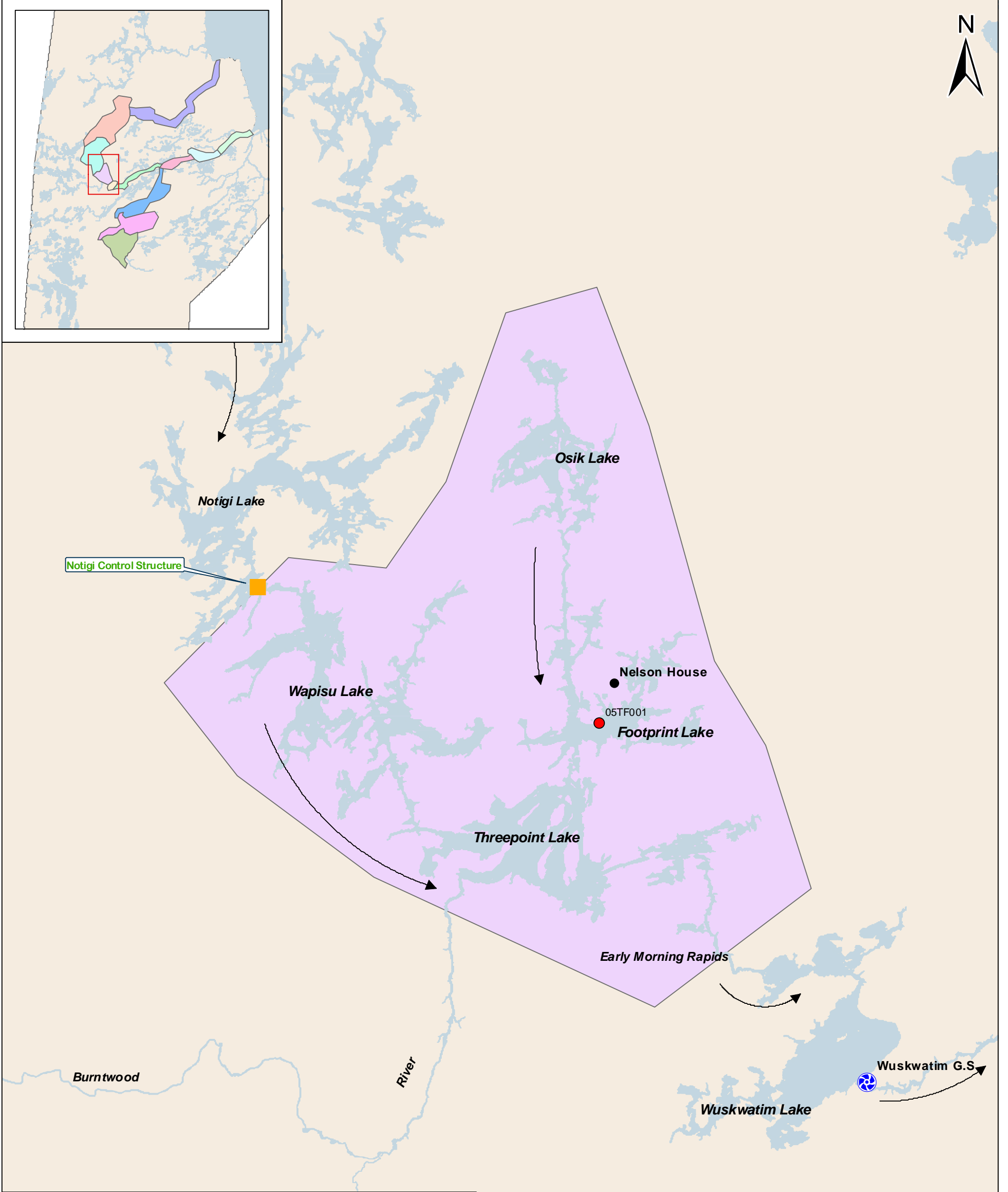


Figure 4-19: Footprint Lake Water Level Duration Curve



**Legend**

- Towns
- Gauging Stations
- ⊗ Existing Generating Station
- ⚡ Channels
- Control Structures
- ↘ Flow Direction

	DATA SOURCE: Manitoba Hydro		
	CREATED BY: Hydraulic Operations Department Hydraulic Licencing and Support		
	COORDINATE SYSTEM: UTM NAD 1983 Z14N	DATE CREATED: 05 May 14	REVISION DATE: 28-MAY-14
		VERSION NO: 1.0	QA/QC: BSS/RDB/ZZ

**Zone 7 - Notigi Control Structure to Early Morning Rapids  
RCEA Area 3**

## **4.2.8 ZONE 8 – EARLY MORNING RAPIDS TO WUSKWATIM GS**

Zone 8 covers the portion of the Burntwood River between Early Morning Rapids and the Wuskwatim GS, which includes Wuskwatim Lake (Map 4-9). The Wuskwatim GS was completed in 2012 and is owned by the Wuskwatim Power Limited Partnership (WPLP), a legal entity involving Nisichawayasihk Cree Nation and Manitoba Hydro.

### **4.2.8.1 MANITOBA HYDRO OPERATIONS**

CRD operations cause increased flows and water levels, flooding 11 sq mi (28 sq km) in this zone. Also, because inflows from Notigi are typically higher in the winter as shown in Figure 4-16, CRD resulted in a seasonal change where water levels are now typically higher along the Burntwood River during the winter. Before CRD, water levels were highest in the summer. Operation of Wuskwatim GS affects water levels as far upstream as the downstream end of Early Morning Rapids.

### **4.2.8.2 DATA**

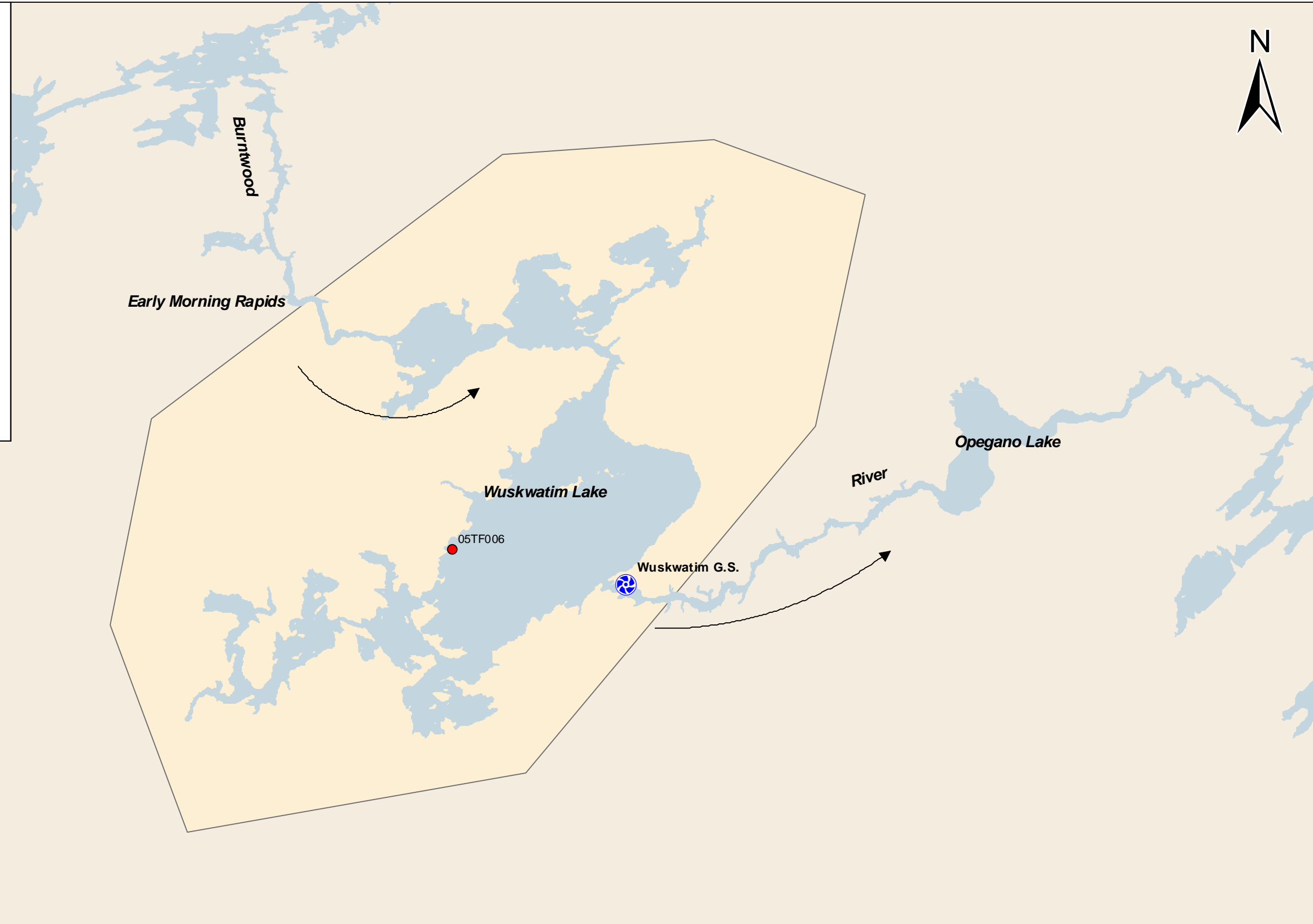
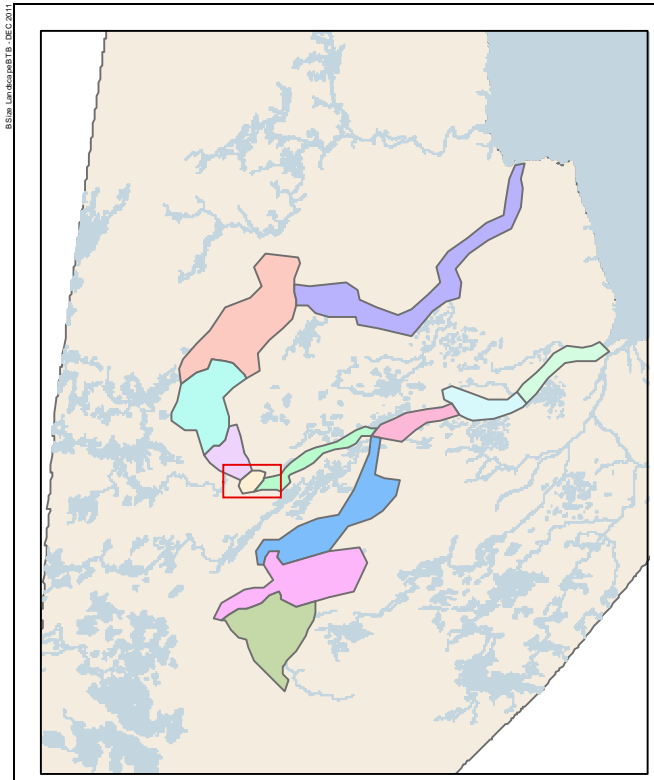
There is no continuous data available for this zone prior to operation of CRD. WSC reports a water level on Wuskwatim Lake since 1995 at station 05TF006 (Wuskwatim Lake near Thompson). Manitoba Hydro now monitors the water level of Wuskwatim Lake as part of operating the Wuskwatim GS.

### **4.2.8.3 WUSKWATIM GS AND LAKE**

Impoundment of the Wuskwatim forebay resulted in less than 0.5 sq km (less than 0.2 sq mi) of flooding between Wuskwatim Lake and the generating station. Operation of the Wuskwatim GS eliminated the seasonal variance of water levels on Wuskwatim Lake as water levels are kept within a 0.25 m (0.8 ft) range between 233.75 m and 234.0 m (766.9 ft and 767.7 ft). Water levels on Wuskwatim Lake ranged 1.8 m (5.8 ft) from 232.7 m to 234.4 m (763.3 ft to 769.1 ft) prior to construction of the Wuskwatim GS but post-CRD. The Water Regime Section of the Wuskwatim EIS contains more detailed information on conditions before and after construction of Wuskwatim GS (Manitoba Hydro and Nisichawayasihk Cree Nation 2003).

### **4.2.8.4 ICE CONDITIONS**

Higher flows created by CRD in this zone resulted in higher velocities along parts of the Burntwood River, which likely resulted in larger areas remaining ice free all year. The Wuskwatim EIS contains a detailed description of ice conditions along the Burntwood River and any effects of the Wuskwatim GS on ice conditions.



DATA SOURCE: Manitoba Hydro		
CREATED BY: Hydraulic Operation Department Hydraulic Licencing and Support		
COORDINATE SYSTEM: UTM NAD 1983 Z14N	DATE CREATED: 05-May-14	REVISION DATE: 27-MAY-14
0 1.5 3 Kilometres 0 1 2 Miles	VERSION NO: 1.0	QA/QC: BSS/RDB/ZZZ

Legend	
● Towns	● Gauging Stations
⊕ Existing Generating Station	↗ Channels
■ Control Structures	↘ Flow Direction

**Zone 8 - Early Morning Rapids to Wuskwatim G.S.  
RCEA Area 3**

## **4.2.9 ZONE 9 – WUSKWATIM GS TO SPLIT LAKE INLET**

This zone covers the portion of the Burntwood River downstream from the Wuskwatim GS to the inlet of Split Lake (Map 4-10). Major lakes in this zone include Opegano, Ospwagan, Birch Tree, Mystery, and Apussigamasi.

### **4.2.9.1 MANITOBA HYDRO OPERATIONS**

Manitoba Hydro operation of CRD regulates the inflow to this zone which is the main driver for water levels. CRD causes substantially higher flows in this zone and has therefore increased water levels above the natural range, flooding 20.2 sq mi (52.3 sq km) of land. Wuskwatim GS operations also contribute to minor water level fluctuations as far downstream as Birchtree Lake (Manitoba Hydro 2003).

### **4.2.9.2 DATA**

In this zone WSC has operated flow station 05TG001 (Burntwood River near Thompson) since 1956. Based on the available record, CRD has increased flows in the Burntwood River from a long-term average of approximately 4,000 cfs to 30,000 cfs (110 cms to 850 cms). Also, CRD has changed the seasonal flow pattern so that the highest flows typically now occur during the winter while flows used to peak during the summer (Figure 4-20).

### **4.2.9.3 MANASAN FALL CONTROL STRUCTURE**

The Manasan Falls Control Structure is a passive control structure designed to reduce the risk of inundation due to ice in the City of Thomson on the Burntwood River. The project consists of an ice boom across the river upstream of a groin/gap structure, a by-pass channel with a concrete overflow weir and a flood channel protected with a fuse plug dyke. The project was initially constructed in 1976 followed by rehabilitation in 1986 and an incorporation of safety features in 1988.

### **4.2.9.4 ICE CONDITIONS**

The higher flows created by CRD in this zone results in higher velocities along the Burntwood River, which likely resulted in larger areas remaining ice free all year.

The present water regime consists of fast flowing reaches, which remain ice free, and connecting lakes or slow velocity reaches which freeze over early in the winter. Each year, a competent ice cover quickly forms on major lakes in this reach, including Wapisu Lake, Threepoint Lake, Wuskwatim Lake, Opegano Lake, and Birch Tree Lake. Other sections of the river remain open, and produce large volumes of frazil ice, which either accumulate on the leading edge of the downstream ice cover, resulting in advancement of the cover upstream, or deposits under the cover forming a hanging ice dam (Manitoba Hydro 2003).

The Wuskwatim EIS contains a detailed description of ice conditions along the Burntwood River and any effects of the Wuskwatim GS on ice conditions.

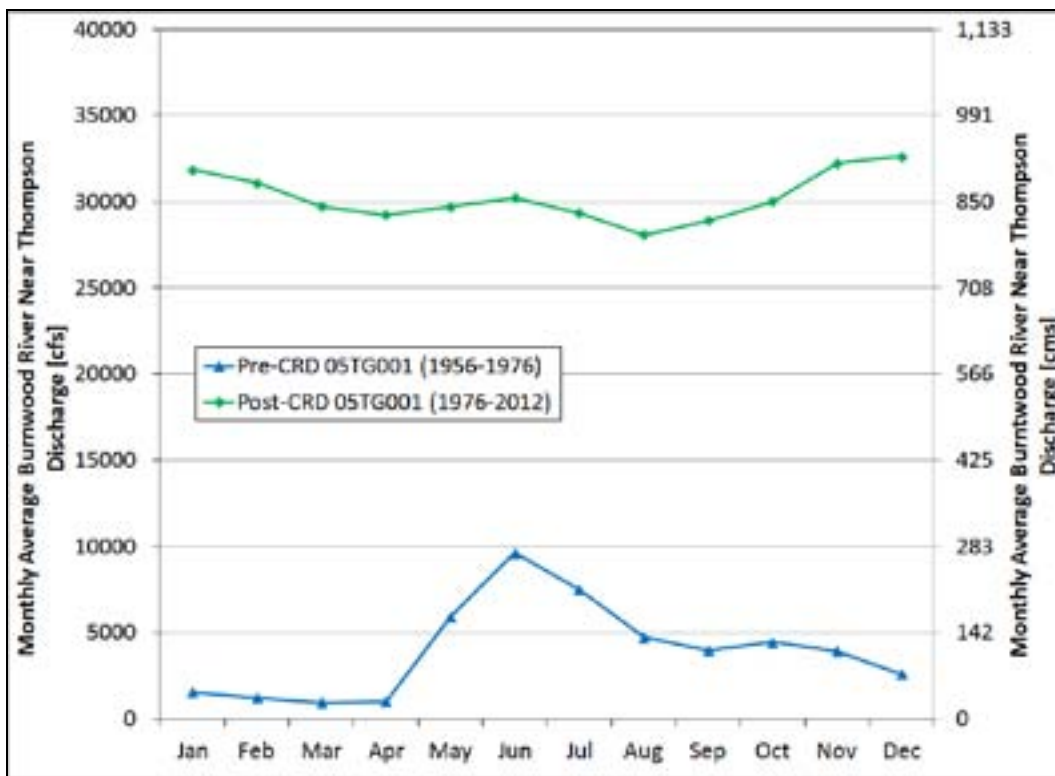
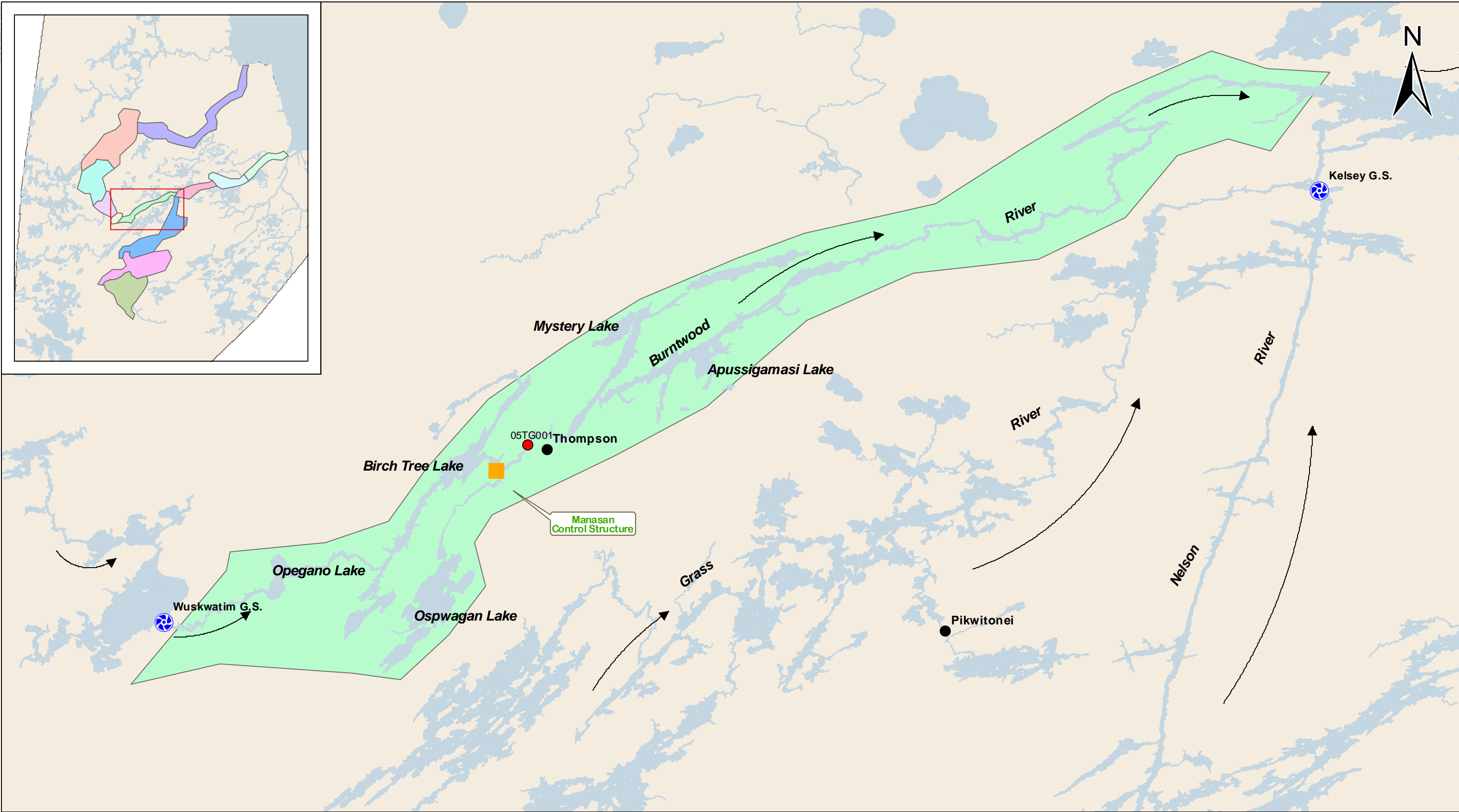
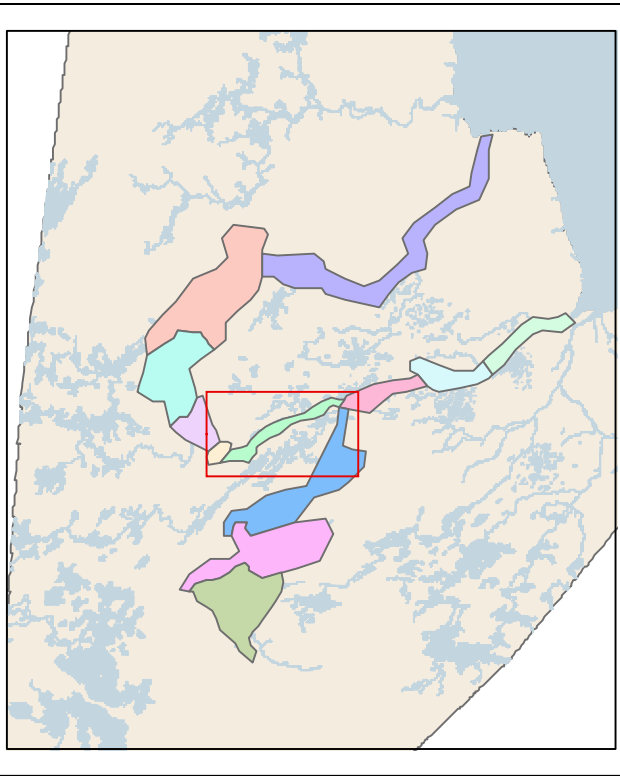


Figure 4-20: Monthly Average Burntwood River Near Thompson Discharge





DATA SOURCE: Manitoba Hydro		
CREATED BY: Hydraulic Operation Department Hydraulic Licencing and Support		
COORDINATE SYSTEM: UTM NAD 1983 Z14N	DATE CREATED: 05-May-14	REVISION DATE: 27-MAY-14
0 4.5 9 Kilometres 0 3.5 7 Miles	VERSION NO: 1.0	QA/QC: BSS/RDB/ZZZ

- Legend**
- Towns
  - Gauging Stations
  - ⊕ Existing Generating Station
  - Control Structures
  - ▬ Channels
  - ↔ Flow Direction

**Zone 9 - Wuskwatim G.S. to Split Lake Inlet  
RCEA Area 3**

## **4.2.10 ZONE 10 – SPLIT LAKE TO GULL RAPIDS**

Zone 10 covers the lower Nelson River including Split Lake to just upstream of Stephens Lake (Map 4-11). Major lakes in this zone include Split, Clark, and Gull lakes. There are currently no structures related to hydroelectric development in this zone, although the proposed Keeyask GS would be located at the downstream end of this zone at Gull Rapids.

### **4.2.10.1 MANITOBA HYDRO OPERATIONS**

Manitoba Hydro's operation of CRD, LWR, and Kelsey GS influences inflows to this zone. LWR changes the seasonal timing of Nelson River inflows to match seasonal load requirements at Manitoba Hydro's major generating stations along the lower Nelson River. CRD increases the average inflow and also influences the seasonal timing of inflows from the Burntwood River. Kelsey had no effect on inflows to this zone prior to 1976 because it was operated as a run-of-the-river plant. Starting in 1977, Kelsey operations were:

modified to more effectively utilize the pondage (reservoir storage of limited capacity) of Kelsey's forebay on an infrequent basis to supplement flows over a period of about a month or so, or to increase the gradient out of Sipiwesk Lake to alleviate winter hydraulic restrictions. Kelsey operations can have short duration effects on Split Lake water levels and flows (Manitoba Hydro-Split Lake Cree Joint Studies 1996).

### **4.2.10.2 DATA**

WSC reports the daily average water level for Split Lake since 1954 at station 05UF003 (Split Lake at Split Lake).

### **4.2.10.3 SPLIT LAKE**

The Keeyask Hydropower Limited Partnership reports that:

Split Lake is relatively large with numerous small islands and an approximate surface area of 116 sq mi (300 sq km). Water levels are influenced by the amount of water flowing in to the lake and the narrow constriction at the outlet that controls the lake's discharge. The levels on Split Lake typically fluctuate between 545 ft and 551 ft (166.1 m and 167.9 m) in any given year, but water levels may vary greatly from one year to the next, depending on the water supply from the Nelson River drainage basin and CRD (Keeyask Hydropower Limited Partnership 2012).

From the outlet of Split Lake to Stephens Lake, which is located just below Gull Rapids, there are both lake and river sections which are described in more detail in the Keeyask EIS along with the potential effects of the Keeyask GS. The average Split Lake water level was 547.4 ft (166.8 m) pre-CRD/LWR. Post-CRD/LWR, the average Split Lake water level is 1.2 ft (0.4 m) higher at 548.6 ft (167.2 m). The seasonal pattern was changed post-CRD/LWR as the highest water levels typically now occur during the winter, while they used to occur during the summer (Figure 4-21).

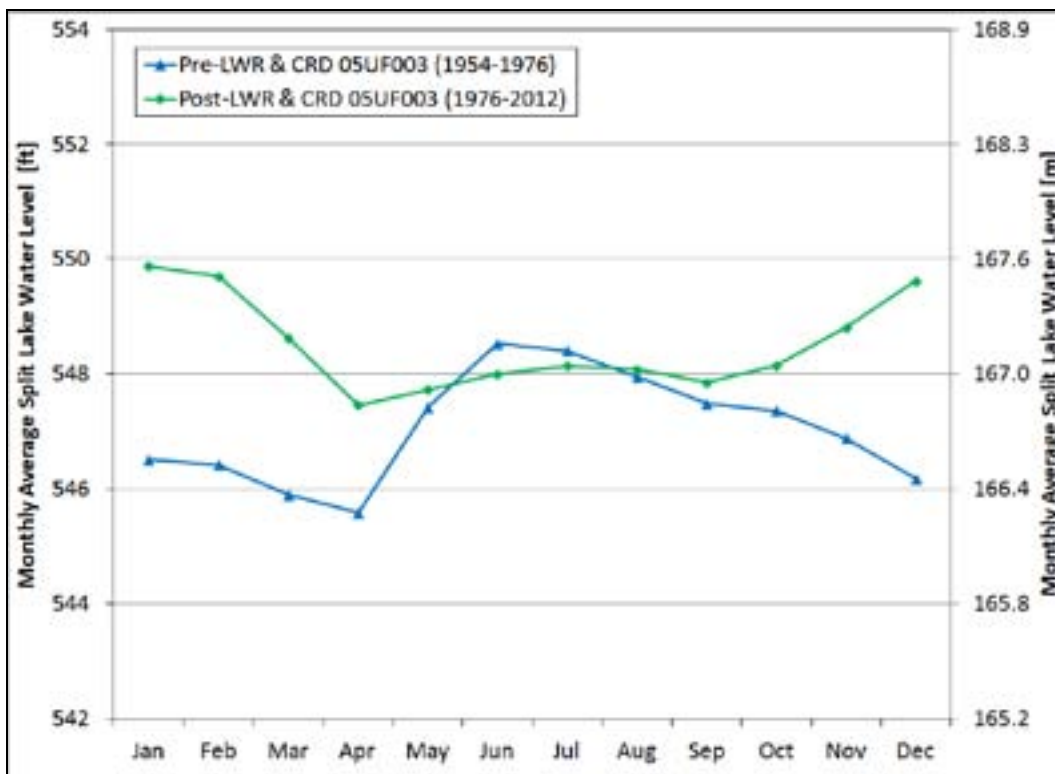
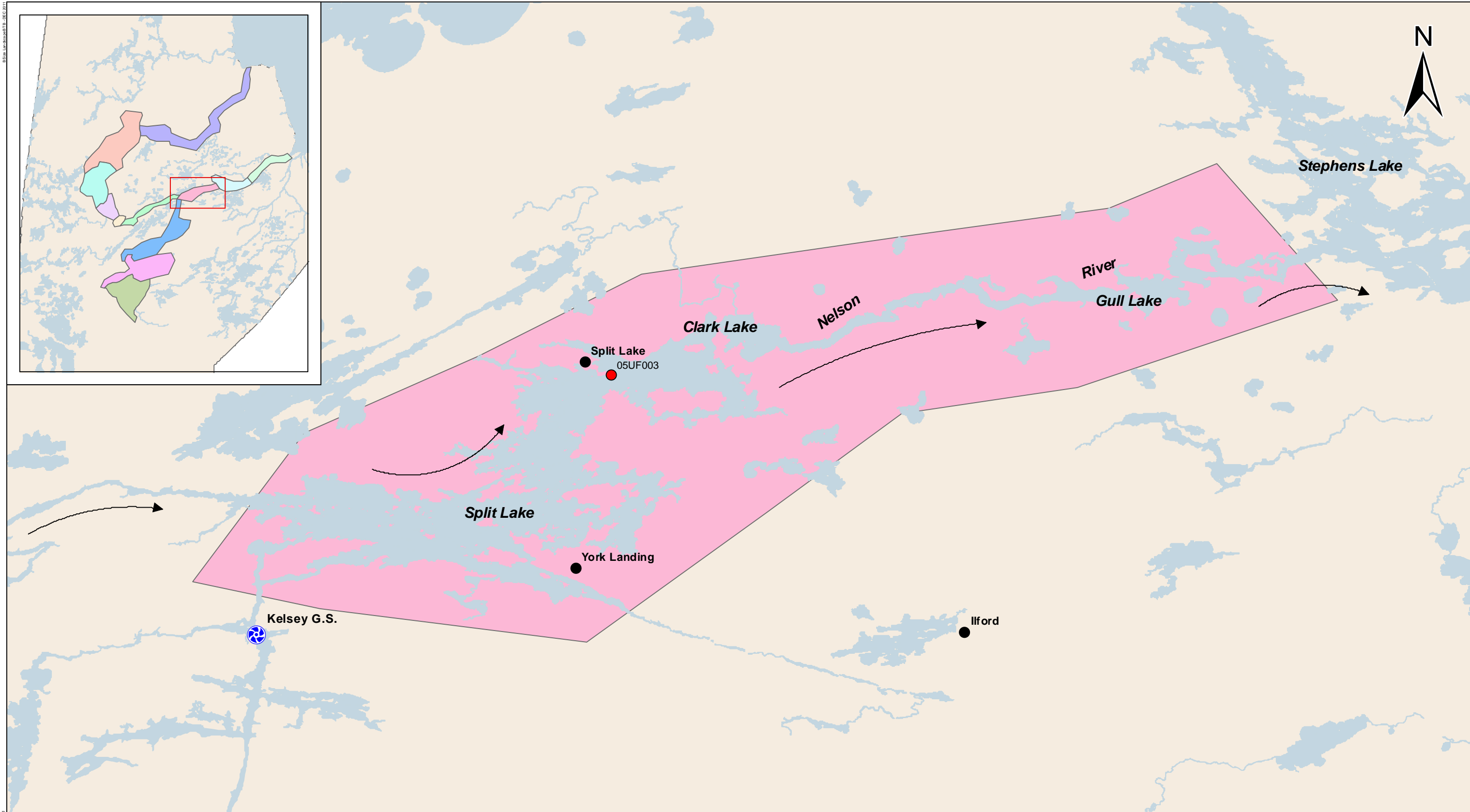


Figure 4-21: Monthly Average Split Lake Water Level

#### 4.2.10.4 ICE CONDITIONS

On Split Lake, water level fluctuations can cause thin ice, slush ice, and premature breakup. Drops in water levels can leave thin ice attached to shores (Manitoba Hydro 1996). A detailed description of existing ice conditions from Split Lake to Stephens Lake is contained in the Keeyask EIS which indicates that higher velocities in this reach have a substantial impact on overall ice formation processes (Keeyask Hydropower Limited Partnership 2012). Hydroelectric development caused higher winter flows and velocities, which would likely have resulted in larger areas remaining ice free all year.



DATA SOURCE: Manitoba Hydro		
CREATED BY: Hydraulic Operation Department Hydraulic Licencing and Support		
COORDINATE SYSTEM: UTM NAD 1983 Z14N	DATE CREATED: 05-May-14	REVISION DATE: 27-MAY-14
0 3.5 7 Kilometres 0 2.5 5 Miles	VERSION NO: 1.0	QA/QC: BSS/RDB/ZZZ

<b>Legend</b>	
● Towns	● Gauging Stations
⊕ Existing Generating Station	↗ Channels
■ Control Structures	↘ Flow Direction

**Zone 10 - Split Lake to Gull Rapids  
RCEA Area 2**

## **4.2.11 ZONE 11 – STEPHENS LAKE TO LIMESTONE GS**

Zone 11 covers Stephens Lake and the lower Nelson River downstream to the Limestone GS. Zone 11 includes Manitoba Hydro's three biggest generating stations, Kettle, Longspruce and Limestone, and their associated forebays (Map 4-12). The Kettle GS is located just downstream from Stephens Lake near the town of Gillam and was completed in 1974. The Long Spruce GS is located 10 mi (16 km) downstream from Kettle GS and was completed in 1979. The Limestone GS is located 14 mi (23 km) downstream from Long Spruce GS and was completed in 1992.

### **4.2.11.1 MANITOBA HYDRO OPERATIONS**

Operation of Kettle GS, Long Spruce GS, and Limestone GS controls water levels in the zone regardless of inflows to Stephens Lake. Long Spruce and Limestone are operated as a run-of-the-river generating stations, while flow is governed by releases from Kettle GS. The level of Stephens Lake is controlled for optimum energy production within the Manitoba Hydro system through operation of Kettle GS. This includes a daily and weekly cycling pattern that allows Manitoba Hydro to match energy production to consumption patterns. Flows are increased each morning during the work week and maintained until late afternoon or evening when they are decreased to reach lowest levels overnight. There is a similar daily pattern on the weekend although flows are lower because there is less energy demand. On a weekly cycle Stephens Lake is generally drawn down during the work week when energy demand is higher and the lake is re-filled over the weekend.

### **4.2.11.2 DATA**

There is no continuous water level data in this zone prior to hydroelectric development. Manitoba Hydro has records of forebay water levels and discharge at Kettle, Long Spruce, and Limestone since the stations were completed. Discharge data is also available through WSC.

### **4.2.11.3 STEPHENS LAKE / KETTLE FOREBAY**

The Kettle GS increased water levels on the Nelson River immediately upstream by approximately 103.3 ft (31.5 m) (Manitoba Hydro-Split Lake Cree Joint Studies 1996) and flooded approximately 85.3 sq mi (221 sq km) of land, creating what is now known as Stephens Lake. The part of Stephens Lake just upstream from Kettle GS is known as the forebay. The current normal maximum forebay elevation is 463 ft (141.1 m), while the minimum operating level is 453 ft (138.1 m), although 95% of the time the forebay elevation is above 457 ft (139.3 m) as (Figure 4-22). Prior to 2001, the forebay was rarely operated above 461 ft (140.5 m) during the open water season due to freeboard deficiencies, which were corrected during the summer of 1998.

### **4.2.11.4 LONG SPRUCE FOREBAY**

Impoundment of the Long Spruce forebay is mostly contained within the natural river banks and flooded approximately 5.6 sq mi (14.5 sq km) to just downstream from Kettle GS. The forebay is typically operated at just below 361 ft (110.0 m) during the open water period and just below 362 ft (110.3 m)

during the winter. Water levels remain above 359 ft (109.4 m) in the forebay 95% of the time (Figure 4-23).

**4.2.11.5 LIMESTONE FOREBAY**

The majority of the Limestone forebay is contained by the natural river banks. The project flooded 0.8 sq mi (2.2 sq km) of land, affecting water levels to just downstream of Long Spruce GS. The Limestone GS forebay is typically operated between 278 ft and 280 ft (84.7 m and 85.3 m) (Figure 4-24).

**4.2.11.6 ICE CONDITIONS**

Prior to hydroelectric development, ice generated along the fast flowing Nelson River resulting in an ice cover generally progressing upstream from the Nelson River Estuary (Carson 1982). Impoundments created by these three generating stations reduced water velocities and allowed most of the forebay areas, including Stephens Lake, to freeze over with stable thermal ice covers. The areas immediately downstream from the generating stations typically remain open for a short distance because of higher water velocities and turbulence.

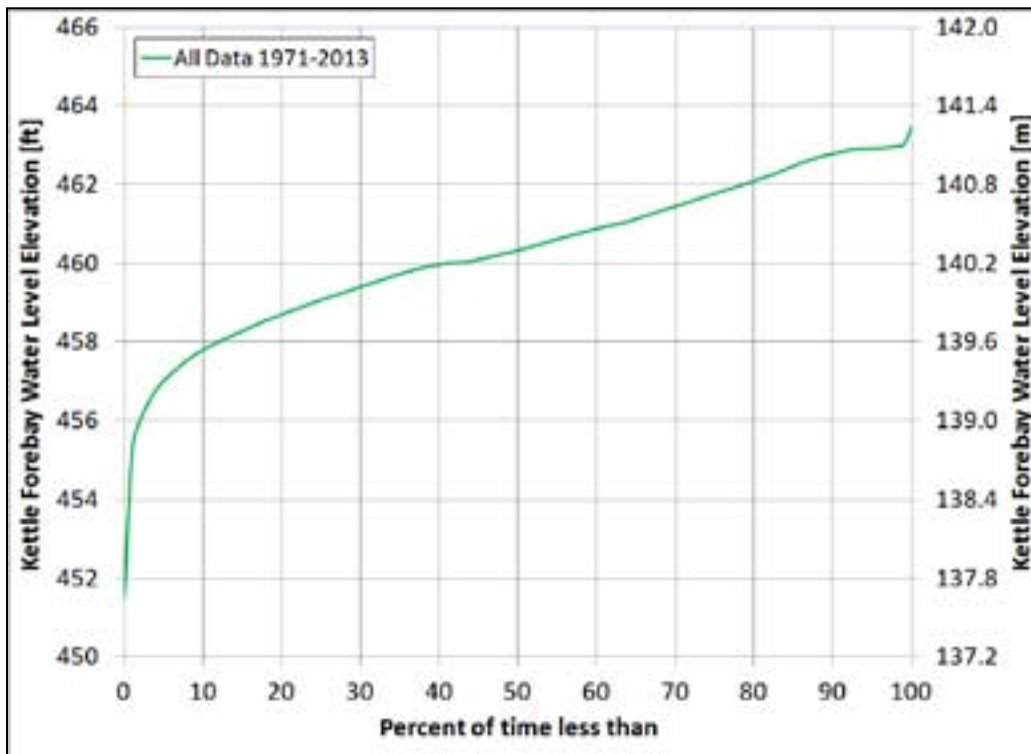


Figure 4-22: Kettle Forebay Daily Water Level Duration Curve

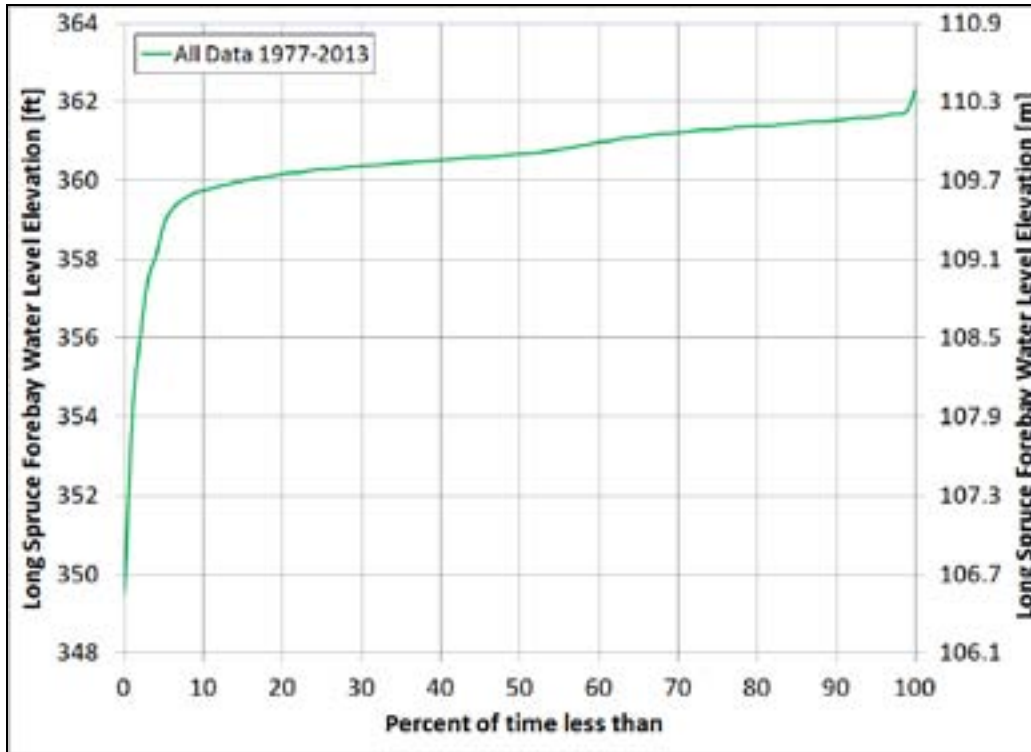


Figure 4-23: Long Spruce Forebay Daily Water Level Duration Curve

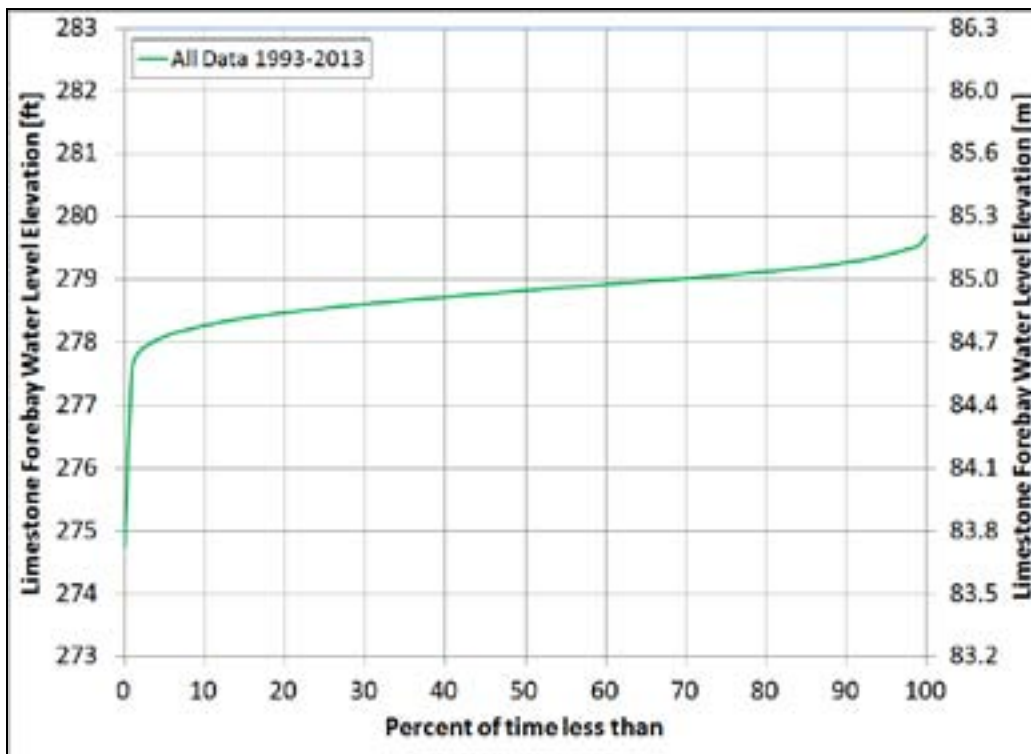
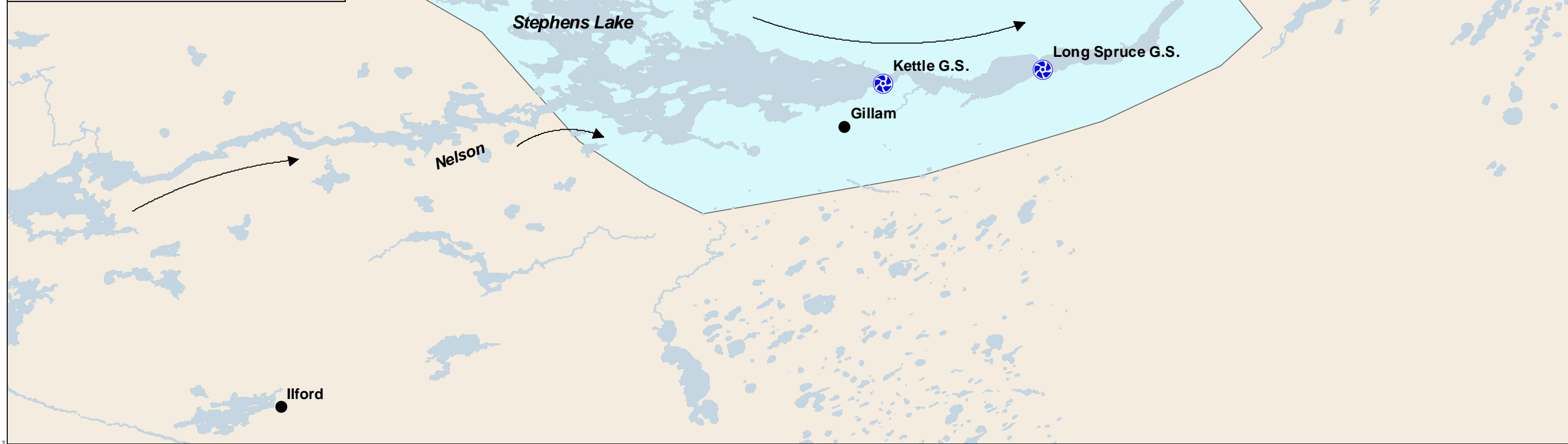
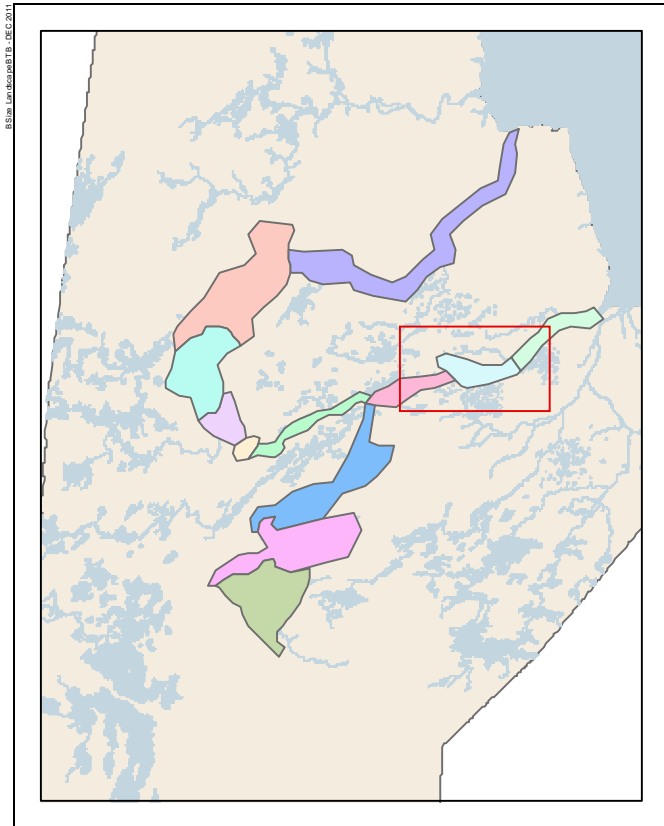


Figure 4-24: Limestone Forebay Daily Water Level Duration Curve





DATA SOURCE: Manitoba Hydro		
CREATED BY: Hydraulic Operation Department Hydraulic Licencing and Support		
COORDINATE SYSTEM: UTM NAD 1983 Z14N	DATE CREATED: 05-May-14	REVISION DATE: 27-MAY-14
0 4.5 9 Kilometres 0 3.5 7 Miles	VERSION NO: 1.0	QA/QC: BSS/RDB/ZZZ

Legend	
● Towns	● Gauging Stations
⊗ Existing Generating Station	↗ Channels
■ Control Structures	↘ Flow Direction

**Zone 11 - Stephens Lake to Limestone G.S.**  
**RCEA Area 2**



## **4.2.12 ZONE 12 – LIMESTONE GS TO GILLAM ISLAND**

Zone 12 covers the lower Nelson River from the Limestone GS to Gillam Island (Map 4-13). There are no major lakes in this zone. Gillam Island is the upstream extent of tidal influence from the Nelson River Estuary. There are currently no hydroelectric structures located in this zone although the planned Conawapa GS would be located approximately 18 mi (29 km) downstream from the Limestone GS.

### **4.2.12.1 MANITOBA HYDRO OPERATIONS**

Operation of CRD, LWR, and the three generating stations along the Lower Nelson River affect water levels and flows in this zone. CRD and LWR affect the magnitude and seasonal pattern of flows, while short term fluctuations are caused by operations at Kettle, Long Spruce, and Limestone generating stations.

### **4.2.12.2 DATA**

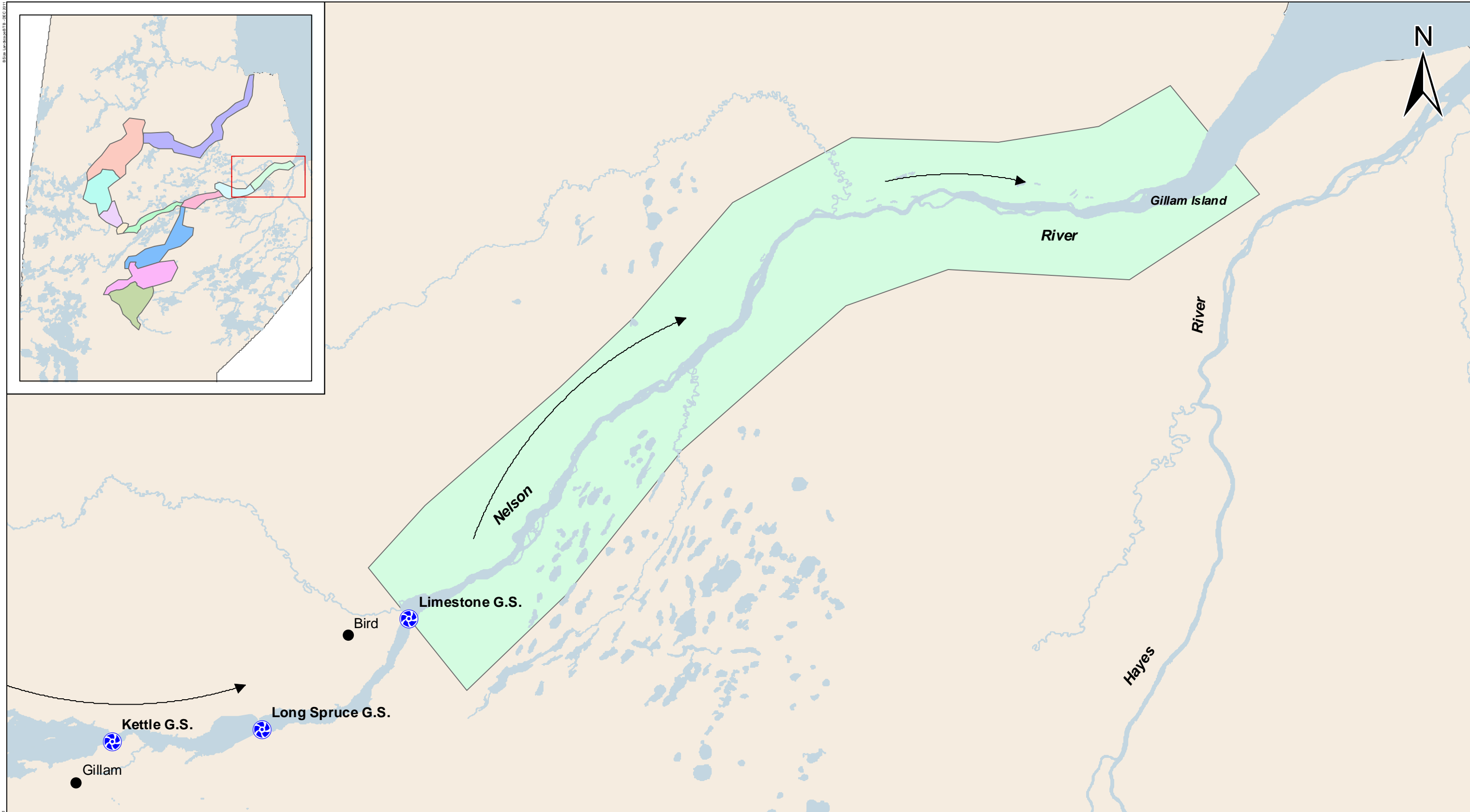
There is no continuous water level data in this zone prior to hydroelectric development. Manitoba Hydro measures the discharge at Limestone GS, which is the primary inflow to the zone, and the water level immediately downstream from the generating station since 1990. Manitoba Hydro has also measured water levels for a number of seasons at several locations in this zone as part of baseline studies for the planned Conawapa GS.

### **4.2.12.3 LIMESTONE TO GILLAM ISLAND**

Manitoba Hydro development has increased daily water level fluctuations and average flows and water levels in this zone. Flows are also higher in the winter than under natural conditions and water level variations are increased due to flow releases at Limestone GS, which are driven by outflow from Kettle GS and routed through Long Spruce GS.

### **4.2.12.4 ICE CONDITIONS**

Prior to hydroelectric development, the ice cover generally progressed upstream from the Nelson River Estuary. This process was the result of ice accumulation at the leading edge, shoving and thickening with ice generated from the fast flowing upstream open water river sections. While this process still occurs, the amount of time required for the ice cover to progress upstream has typically increased. Forebay impoundments created by hydroelectric development reduced the amount of fast flowing river sections that generated ice and contributed to the ice cover progression. Hydroelectric development also increased water level fluctuations during the ice-covered period and this can affect the strength and stability of the ice cover and change surface ice conditions (Environment Canada, Department of Fisheries and Oceans Canada 1992).



DATA SOURCE: Manitoba Hydro		
CREATED BY: Hydraulic Operation Department Hydraulic Licencing and Support		
COORDINATE SYSTEM: UTM NAD 1983 Z14N	DATE CREATED: 05-May-14	REVISION DATE: 27-MAY-14
0 4.5 9 Kilometres 0 3.5 7 Miles	VERSION NO: 1.0	QA/QC: BSS/RDB/ZZZ

Legend	
● Towns	● Gauging Stations
⊕ Existing Generating Station	↗ Channels
■ Control Structures	↘ Flow Direction

**Zone 12 - Limestone GS to Gillam Island  
RCEA Area 2**

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