HATCH

Nalcor Energy

Final Report

For

Examination of 2017 Ice Jam Event

MFA-HE-CD-2000-CV-RP-0011-01
Rev. B2
September 18, 2017

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Nalcor Energy - Lower Churchill Project
Examination of 2017 Ice Jam Event
H354838

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MFA-HE-CD-2000-CV-RP-0011-01

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Executive Summary

This study examines in detail the 2017 ice jam flood event on the Churchill River at Mud Lake. It places this event in the context of similar historic events and examines in detail both this event and the very similar event of 2012.

The results of this detailed examination lead to the following.

- Archived newspaper articles reveal that spring ice jams have occurred at the outlet of the lower Churchill River into Goose Bay in each of eight years in the period from 1976 to 2016, prior to construction activities at Muskrat Falls. That is, the ice jam flooding event of 2017 is not unique.
- The review of both historic ice jam flood occurrences at Mud Lake and their causative factors strongly indicate that the 2017 jam was the consequence of naturally occurring antecedent and prevailing weather events. That is, the ice jam flooding would have been expected without there being any construction activities at Muskrat Falls.
- The operation of the Muskrat Falls facility did not increase the severity of the 2017 ice jam flood event at Mud Lake.

The details of studies and analyses leading to the foregoing points are described in the following report sections.

1. Introduction

In the early morning of May 16, 2017, an ice jam occurred on the lower Churchill River at the river's outlet into Goose Bay. The event produced a peak water level at the English Point Hydrometric Station that has been estimated to be approximately el. 4.9 m based on preliminary data provided by Water Survey of Canada. The event required evacuation of the Mud Lake community. Given the sensitivity of the issue, Nalcor requested that a more detailed review be conducted of the event.

The Hatch team was asked to review this event with a team including the following members:

Mr. Joe Groeneveld - Mr. Groeneveld is a senior engineer with an extensive background in hydraulics, developed through his 28 years of progressive experience within the water resources sector. He has considerable experience in ice engineering and is one of Hatch's leading experts in the formation and breakup of both lake and river ice. Mr. Groeneveld is a member of the Committee for River Ice Processes and the Environment (CRIPE) and has been responsible for the study of river ice conditions on many different river systems across Canada, including the Nelson River, the Burntwood River, the Red River, the Qu'Appelle River, the lower Churchill River, the Iskut River, and the Talston River. Joe acted as the lead investigator for Hatch.

Dr. Soheil Zare - Dr. Zare is a hydrotechnical specialist, working in the area of hydroelectricity and water power. The majority of his training and work has been focused on river and lake ice engineering, fluvial hydraulics and engineering, sediment transport, hydraulic structures and hydrology. Mr. Zare has participated in various projects involving the analysis and numerical simulation of river hydraulics and sediment transport under different hydraulic regimes (ice covered-open water) and hydrologic scenarios. Soheil provided technical support to the review team, including application of available numerical models.

Mr. Tom Lavender - Mr. Lavender has more than 55 years of experience in hydraulics, hydrology, river ice mechanics, hydro system operation analysis and power system planning. He has extensive experience in the hydraulics of ice covered rivers, including studies on the Peace, Athabasca, Bow River and Slave (Alberta & NWT), North Saskatchewan (Saskatchewan), the Nelson, Burntwood and Churchill (Manitoba), the Niagara, St. Clair, St. Lawrence, Mississagi, Magpie, Rideau, Jackfish, Mississigi and St. Mary's, Saugeen and Albany (Ontario), Susitna (Alaska), Saint John (New Brunswick), Exploits and Upper Salmon (Newfoundland), Lower Churchill (Labrador). This wealth of experience has provided him with unique insights into (i) the breakup process and the mechanics of ice jams, (ii) the assessment of ice-related flood risks. Tom acted as a senior peer reviewer for the team.

The assessment began with a review of the typical ice formation, and spring breakup processes in this area – a necessary step to better understand the historical context for ice formation and spring flood events on the river, and to help identify and understand any causative factors. This included a relatively thorough review of the historical records and archives to help better understand the key processes that may lead to flooding in the area. After identifying the natural processes and reviewing the historical records, the team looked closely at the 2017 event to better understand how it fits into this historical context.

The objective of this review was to answer three key questions:

- Is the jam at this location a pre-existing condition on the river, with past similar events?
- Was the 2017 event caused by natural processes (i.e., would the event have occurred with or without the construction of the Muskrat Falls project)?
- Could the operation of the Muskrat Falls project in 2017 have led to this event, or increased its severity in any way?

2. Summary of Winter Ice Processes

Ice processes on the lower Churchill River have been studied for many years by Nalcor and others. These studies have included comprehensive field investigations, yearly monitoring programs, and the setup and use of sophisticated ice simulation models to help understand the complex processes that occur on this river each year. The results of these studies are contained in various reports, and will not be repeated here. However, it would be of value to briefly review the typical ice formation and breakup processes that have been identified in the past for this reach of the lower Churchill River.

2.1 Description of Typical Ice Processes

As shown in **Figure 2-1**, the Muskrat Falls Project is located on the lower Churchill River in Newfoundland and Labrador. The reach of interest for this review actually begins at the outlet of Sandy Island Lake and ends at the river's outlet into Goose Bay. The river drops approximately 26 m along its 56 km course between Sandy Island Lake and Goose Bay, with most of this drop occurring over Muskrat Falls. The reach becomes considerably braided near Happy Valley-Goose Bay, and eventually empties into Goose Bay approximately 3 km downstream of the community of Mud Lake. Goose Bay is a very wide and deep receiving water body for the Churchill River flows. The average winter flow for the river is approximately 1810 m^3/s.

Ice formation on the lower Churchill River within this reach is a relatively complex process, and has been studied for many years. Under the pre-project winter regime, a cover usually develops early on the reach's bounding lakes (Sandy Island Lake and Goose Bay), while other faster sections of the river remain open, generating large volumes of frazil ice. With the onset of cold temperatures in the fall, an ice cover begins to form on Goose Bay relatively early in the winter. According to the Sea Ice Climatic Atlas thirty-year median, freeze-up for the Goose Bay area typically begins during the first half of November in the shorefast areas of the bay. By the first week in December, Goose Bay is typically entirely covered with a thin thermal cover or a thin layer of compact/consolidated ice inflowing from the Churchill River. This cover then gradually thickens over the course of the winter and remains in place until the spring break-up. Ice growth on Goose Bay was monitored by the Canadian Ice Services group from 1958 through to 1995, with recorded maximum thicknesses that ranged from 30 cm up to well over 1 m.

At the same time, the cold temperatures will lead to the formation of a thermal cover on the upstream lakes of Sandy Island and Gull Island. These lakes effectively trap and store ice being generated in the reach between Lake Winokapau and Gull Lake. Downstream of these lakes the relatively swiftly flowing water remains open. Frazil ice is generated in the open water sections of the river, and these generated flocs agglomerate into ice floes and eventually, into larger ice pans and sheets. These pans gradually grow in size with time of exposure, and distance travelled downstream. At the same time, border ice begins to grow from each bank (where velocities are low enough) gradually reducing the open water width of the river.

A similar process occurs downstream of Muskrat Falls and open water areas also generate significant frazil ice volumes. Initially, these ice pans and sheets continue to drift down river, adding to the ice volume in Goose Bay. Eventually, as the open water width narrows and generated ice pans become larger and larger, these ice sheets will typically lodge, or arch at a narrow section of the river, creating an ice bridge. This bridge typically forms on the river downstream of the Mud Lake community, and this permits the progression or advancement of an upstream ice cover. The date at which this ice bridge may form is generally near the end of November, but can be quite variable.

Once initiated, this cover advances upstream through a juxtaposition process. Observations of the ice cover indicate that the juxtaposition of the ice cover occurs relatively easily. In a few short sections, some thickening of the advancing ice cover by telescoping, or shoving, has been observed to occur but overall freeze-up in the reach is relatively uneventful. This is typical for a river with very gentle slope. The advancing ice cover then stalls for the season at the foot of Muskrat Falls, owing to the higher velocities present at this location. These high velocities cause ice pans generated in the upstream reach to pass over the falls, submerge and be carried under the leading edge, leading to the formation of a large hanging ice dam downstream of the rapids. As the hanging ice dam grows, it leads to increases in water levels at the foot of Muskrat Falls.

The ice continues to deposit over the course of the winter, causing water levels to rise by many meters locally downstream of the Falls. Downstream of the ice dam, however, water levels begin to gradually drop over the winter due to the smoothing of the cover with time. Based on ice modelling conducted in the reach, ice thicknesses in the lower portions of the river reach (downstream of the falls) are anywhere from 1 to 2 m.

In May, with the onset of warmer temperatures, and much stronger solar radiation, the ice begins to degrade and weaken. This leads to a number of events, as follows:

- The ice cover in the lower reach will typically break off from the much larger and thicker ice dam downstream of Muskrat Falls, and begin to slowly retreat as the cover weakens and begins to reconsolidate. This leads to two main ice bodies on the lower reach – the large, thick ice dam which remains entrenched and unmoving just below the falls, and the downstream cover which is characterized by a steadily retreating front.
- Border ice in the upstream reach will typically begin to release, and pass through Muskrat Falls. However, because the ice dam remains intact until much later in the season, it is expected that this released ice volume simply deposits within the intact ice dam and does not contribute to the downstream ice cover.
- Increasing flows in the Spring Freshet cause increasing water levels. The nature of breakup is somewhat dependent on the timing of the arrival of this freshet. If it rises

suddenly by an amount equal to or greater than the thickness of the cover, the cover can lose its contact with the river bank, leading to sudden mobilization of the cover to become a run downstream. If this occurs before the ice on Goose Bay has weakened, this run of ice is halted by the solid ice on Goose Bay – the Goose Bay ice may continue to have a very good load bearing capacity.

The ice in Goose Bay and Lake Melville will eventually weaken to the point of releasing. Residents in the area have maintained records of the date at which the Churchill River adjacent to the community of Happy Valley - Goose Bay has become ice free. This information is reported in the ice dynamics report, but has been reproduced for reference in **Figure 2-2**. It is interesting to note that records seem to indicate the ice release date has steadily decreased since records were first kept – possibility an indication of climate change induced impacts on ice release dates in these more northern environments.

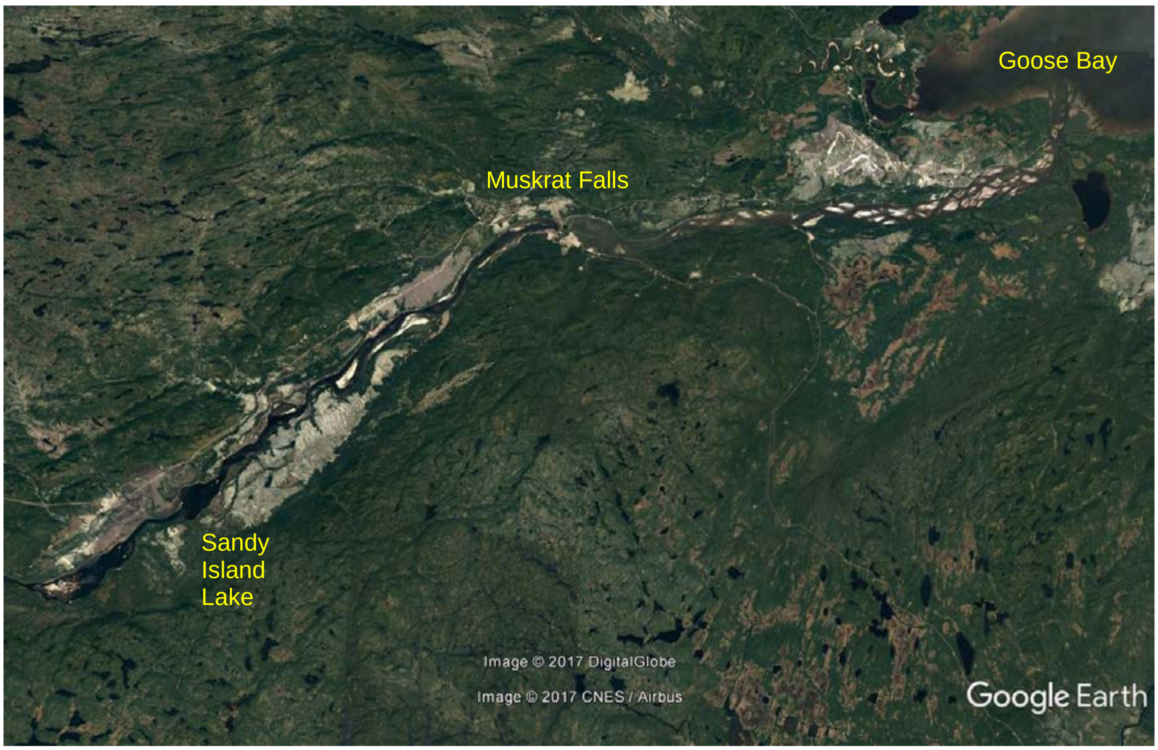


Figure 2-1: Study Area

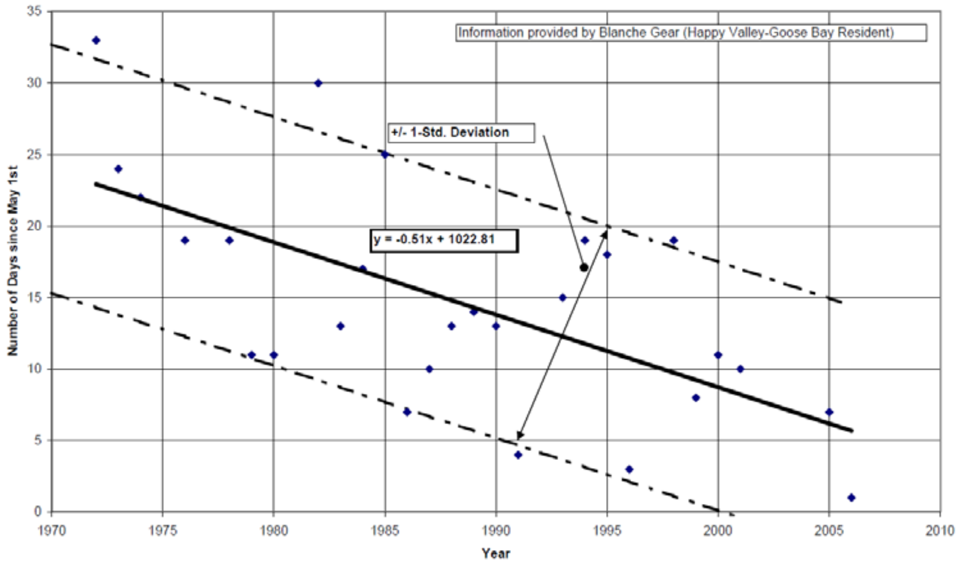


Figure 2-2: Date of First Ice Movement at Goose Bay

2.2 Estimation of Goose Bay Ice Thickness

The thickness and competency of the ice cover on Goose Bay will have a direct impact on jamming potential at the exit of the Churchill River into the larger water body of Lake Melville. If there is a strong, competent ice cover at the outlet with a good load bearing capability, this is a natural location for moving river ice to suddenly lodge, and for jam initiation to occur. Rivers with relatively flat slopes, like that of the lower Churchill River downstream of Muskrat Falls, are particularly susceptible to this occurrence.

Given its importance to the breakup process, it is critical that the nature and condition of the Goose Bay ice be well understood. The Canadian Ice Services monitored the thickness of ice on Goose Bay for a number of years. Unfortunately, the CIS stopped measuring this ice thickness in 1996, so measured values of ice thickness for years more recent than 1996 are not available.

However, various methods are available to simulate the growth of ice on a body of water given key input variables. They range in sophistication from simple temperature driven models, such as the Stefan equation, to more complete algorithms that also take into account the insulating effect of a snow cover, as well as possible heat transfer from water that may be flowing beneath the developing ice cover. In an earlier study for Nalcor, ice growth was simulated using the latter approach. The methodology used is described in Ashton (Ashton, 1986), and was used in earlier studies to assess ice growth on Goose Bay and in the project forebay.

These algorithms were entered into an Excel spreadsheet, creating a mathematical model to simulate the growth and decay of ice on a lake. The developed model required the input of a start date for the simulation, daily air temperatures, daily snow cover depths, solar radiation data, and a number of heat transfer variables, all of which were based on standard textbook values. Meteorological inputs were obtained from available EC records.

The model was tested and validated in earlier studies – **Figure 2-3** illustrates the match obtained with actual ice growth on Goose Bay for a particularly severe winter in 1985/86.

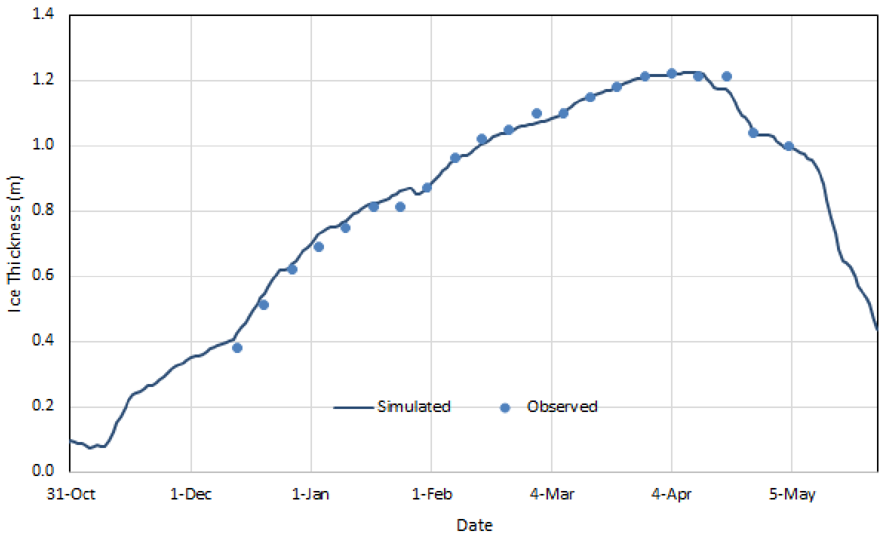


Figure 2-3: Sample Comparison Between Observed and Simulated Ice Thickness (1985/86)

Figure 2-4 illustrates the expected or computed thickness of ice for all winters since 1958. This figure provides a good summary of the range of thicknesses that can be expected on Goose Bay, and how variable it can be. The estimated thickness for 2017 has been highlighted as a heavy dashed black line since it represents the recent flood event. As shown the 2017 winter was particularly harsh, and predicted ice thicknesses are near the upper end of the historical range. In the early part of the winter, snow cover was quite light and this led to rapid thickening of the ice through most of December. This was similar to what happened in 1985/86 (dashed purple line), which represents the thickest estimated cover since records were being taken. In 2017, the continued cold weather through April also reduced the amount of degradation of the ice. Based on this assessment, it is felt that the Goose Bay ice was likely quite thick and competent at beginning of rapid melt period. It was estimated to be at a 1 in 20 year thickness. This heightens the chance that ice may jam at the river outlet.

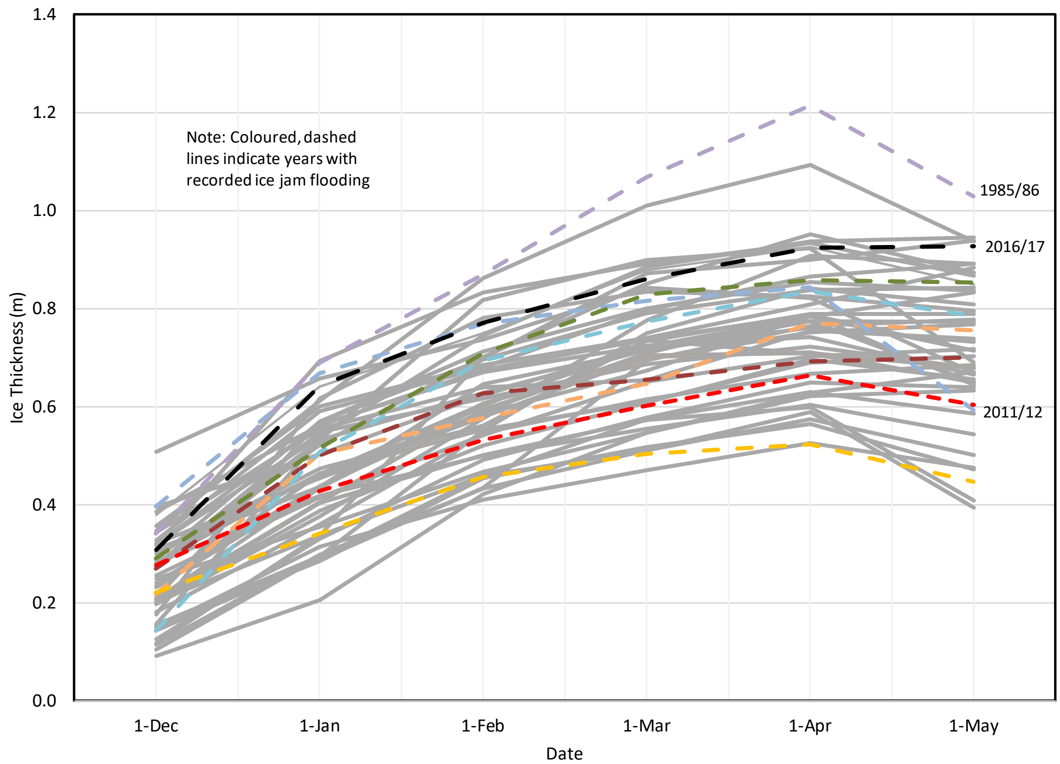


Figure 2-4: Summary of Goose Bay Ice Thicknesses

3. Historical Review of Spring Flood Events

3.1 Review of Archives

Based on a review of the typical ice processes and the river morphology in this area, it would seem that there are a number of adverse factors that may contribute to the formation of break up jam events on the lower Churchill River. The relatively flat slope of the river as it enters Goose Bay, and the wide, deep expanse of Goose Bay itself at the outlet can promote the formation of a relatively strong, load bearing ice sheet just downstream of the river. The presence of this cover could provide a point that may lead to the temporary stalling of an active ice run.

Given that the site would appear to lend itself to this type of event, the team then looked back at available literature in the archives to better understand the local flood hazard in this area – the archives were searched for descriptions of any past spring related flooding. This helps to understand how frequently flooding occurs in the reach, and helps to put the 2017 event into a historical context. In tandem with this, the team reviewed records at both available WSC gauges (WSC Gauge 03OE014 which is 6.15 km downstream of Muskrat Falls and WSC Gauge 03PC001 which is at English Point) and also searched available records for the Labradorian periodical (records were available from 1976 onward), along with other relevant records.

The search revealed that these types of spring ice events are not uncommon to the area, and have occurred relatively frequently in the past. Based on this search, ice related flooding has occurred in at least the following years:

- **1976** – In May, 1976, a run of river ice along the Churchill River led to damage and collapse of a 1500 ft long section of the river bank implying a very dynamic breakup event.
- **1978** – In late May, there was considerable flooding along the lower Churchill River due to "ice-buildup" during the spring runoff. This led to flooding of the MOT communications branch transmitter building, and extensive flooding of Birch Island Road.
- **1983** – In early May, the Goose River experienced a large ice jam that required "massive" blasting to alleviate upstream water levels. The residents of Mud Lake were on alert in the event that the rising water levels threatened their homes as well.
- **1986** – In early May, flooding conditions were recorded as being higher than ever seen before. In Mud Lake, four houses were evacuated due to the increased water levels. A Disaster Operations Committee in Happy Valley-Goose Bay maintained a close watch on the water levels in the event that Mud Lake required assistance. Ice jams caused the RCMP to close the North West Highway, isolating North West River from Happy Valley-Goose Bay.

- **1998 -** In Mid-May of 1998, ice "blockages" (jams) formed on the Churchill River, leading to the flooding of several nearby houses. A few days later the ice jams had increased water levels to the front steps of a local convenience store, and had flooded the business owner's garage in a few feet of water. Children in the area were riding their bicycles in two feet of water. One man stated "I haven't seen the water as high as this in 15 years". The Emergency Measures Organization local representative said there was nothing that could be done to clear the blockage, referring to the use of explosives.
- **2000** – In April of 2000, ice build-up on the Churchill River at Mud Lake and in the mouth of the Churchill River led to significant flooding of the Mud Lake Road (levels are quoted as rising by 5 ft). Concerns were raised regarding flooding of homes and basements, and it was reported that people were concerned because "historically this area does flood in the spring time".
- **2001 -** On May 13th, ice jams on the lower Churchill River caused water levels to rise and flood the home of a Mud Lake resident. Flooding in the basement rose to a depth of 44 inches of water. The resident stated "That was the highest it rose since 1985". This house and two other houses regularly flood. The resident indicated that the ice jams at the mouth of the Churchill River and once the ice moves, the water level drops off.
- **2012** – On May 16th of 2012 Mud Lake residents experienced flooding of homes as the water levels on the Churchill River increased over the river banks when there was an ice blockage along the river that would not let go. This event was quite similar to the recent 2017 flood event in many ways, and resulted in a peak water level of 4.0 m at the English Point WSC gauge. Because of its similarity to the 2017 event, it is described further in the next section.
- **2017** – The 2017 ice jam event took place from May 16th through to May 20th, and resulted in two flood peaks – an initial peak elevation of 4.4 m at English Point which prompted the evacuation of Mud Lake residents, and a second peak of 4.9 m approximately one day later that lasted 30 minutes.

Copies of the articles describing the flood events are included in Appendix A. Based on this information, it would appear that the area is susceptible to ice related flooding. The blue diamonds shown in **Figure 3-1** all represent unusual ice related runoff events, and the timeline shows that these events have occurred at least nine times in the past 42 years – or approximately once every 4 to 5 years on the average.

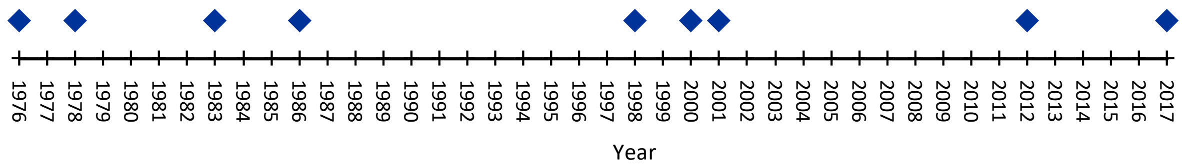


Figure 3-1: Timeline of Ice Related Flood Events

3.2 2011/ 2012 Ice Jam Event

Based on the archival review, it was noted that in 2012, a very significant ice event occurred. It led to stage increases that were quite similar to the initial stage increase experienced in 2017, and within 0.9 m of the final peak level recorded in 2017 as referenced at the English Point hydrometric station. Given the severity (and recent vintage) of the 2012 ice jam event, the team reviewed the available existing anecdotal observations and quantitative information on this flood event to better understand the antecedent conditions that preceded the flood event, and to decipher the important causes or contributing factors to the actual event.

3.2.1 Review of Winter Formation and Antecedent Conditions

Ice formation for the 2011 winter began in November, as it typically does. Air temperatures began to fall in mid November, and by November 20th were consistently below zero degrees centigrade. Ice began forming on Goose Bay, and frazil production began in the lower Churchill River. The ice cover was able to begin advancing up from Goose Bay into the lower Churchill River by approximately November 24th, as evidenced by the marked increase in water level recorded at the English Point hydrometric station at this time (**Figure 3-2**). Flows at the time of freeze-up were estimated to be approximately 1800 m^3/s and were relatively steady.

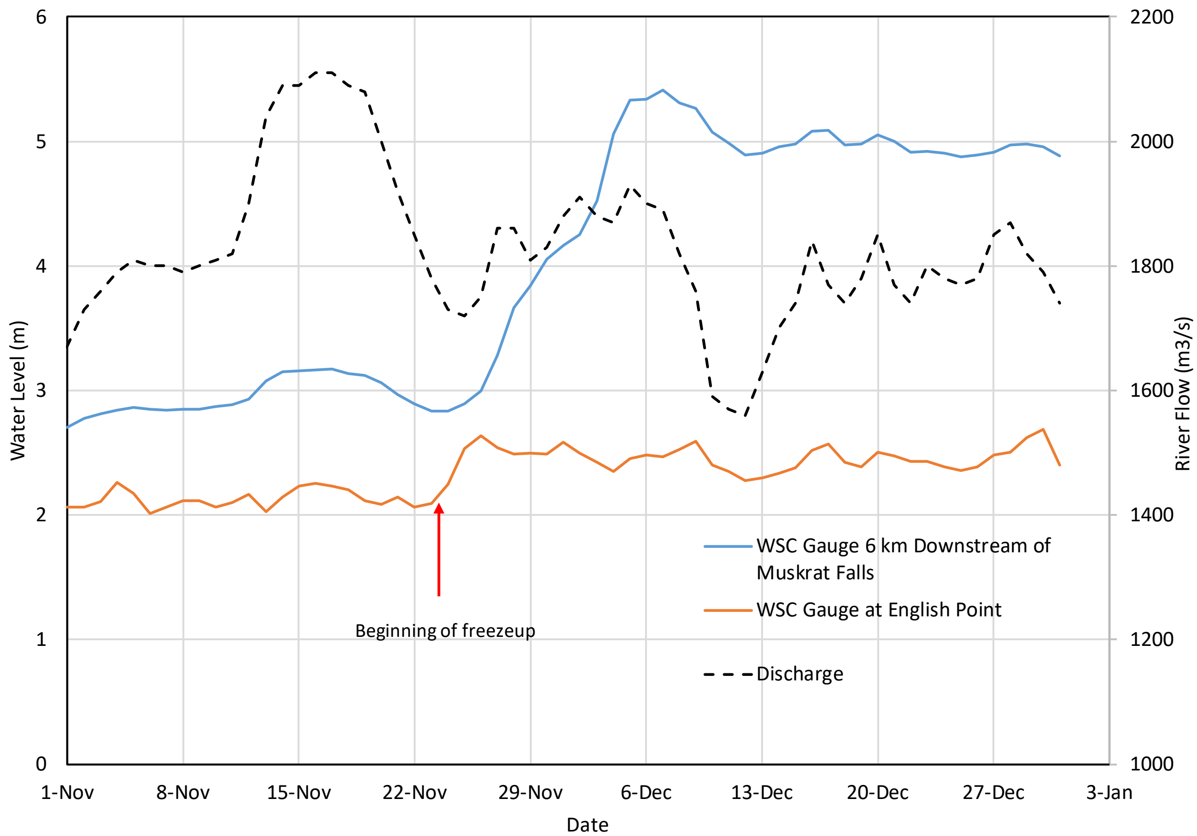


Figure 3-2: Summary of Flows and Water Levels at Freeze-up in 2011

The juxtaposed cover advanced upstream, and as shown in **Figure 3-2**, likely passed the upstream WSC gauge (6 km downstream of MF project) in early December (i.e., within approximately one week). It is at this time that water levels appeared to reach a peak at this gauge. Over the course of the winter, ice generated upstream of Muskrat Falls passed through the rapids and continued to collect in a very large ice dam downstream of the project, as it typically does.

The snow cover for this year arrived early, and was quite deep. Snow depths recorded at the Goose A MSC gauge indicate snow depths were upwards of 50 cm in early December, and climbed to almost 150 cm by the end of January. These high snow depths would help to insulate the ice sheets on both Goose Bay and also on the Churchill River, slowing the overall thermal growth of the cover.

The approximate thickness and competency of the ice cover on Goose Bay was estimated for the 2011/12 winter using the ice simulation model described earlier. The model was updated to reflect the 2011/12 meteorological data, including recorded daily air temperatures, daily snow cover depths, and solar radiation data. Meteorological inputs were obtained from available EC records at the Goose A MSC station. The analysis indicated that in 2011/12, the Goose Bay winter ice initially began forming quite quickly, but the high snow pack likely limited its ultimate thickness to approximately 65 cm. The 2012 ice thickness is shown in **Figure 2-4** as the thick, red, dashed line. Warmer weather at the end of April resulted in some early degradation of the cover thickness. Therefore, at the time of breakup, the load bearing capacity of the cover had likely dropped somewhat. This degradation of the cover is shown quite clearly in site photos, taken the day before the ice jam event occurred. **Figure 3-3** shows a photo taken at approximately the location of English Point looking downstream towards Goose Bay, and **Figure 3-4** shows a photo taken looking upstream. In both cases the ice cover is beginning to show signs of melt and degradation.

Figure 3-5 shows a satellite image taken on May 15, just one day prior to the jam event. It clearly shows that the ice front had already separated from the main ice dam at the base of Muskrat Falls and had begun a slow retreat down river. The ice cover's leading edge was below the Veteran's Memorial Bridge location just before the river ice mobilized.

Finally**, Figure 3-6** shows a photo taken downstream of the Muskrat Falls site, looking upstream towards the falls. The photo clearly shows i) that the ice dam remained in place below the falls, and ii) that the ice that would have formed upstream of the falls had already mobilized and flushed downstream through Muskrat Falls prior to the ice jam event.

Figure 3-3: May 15, 2012 – Photo at English Point Looking Downstream

Figure 3-4: May 15, 2012 – Photo Near English Point Looking Upstream

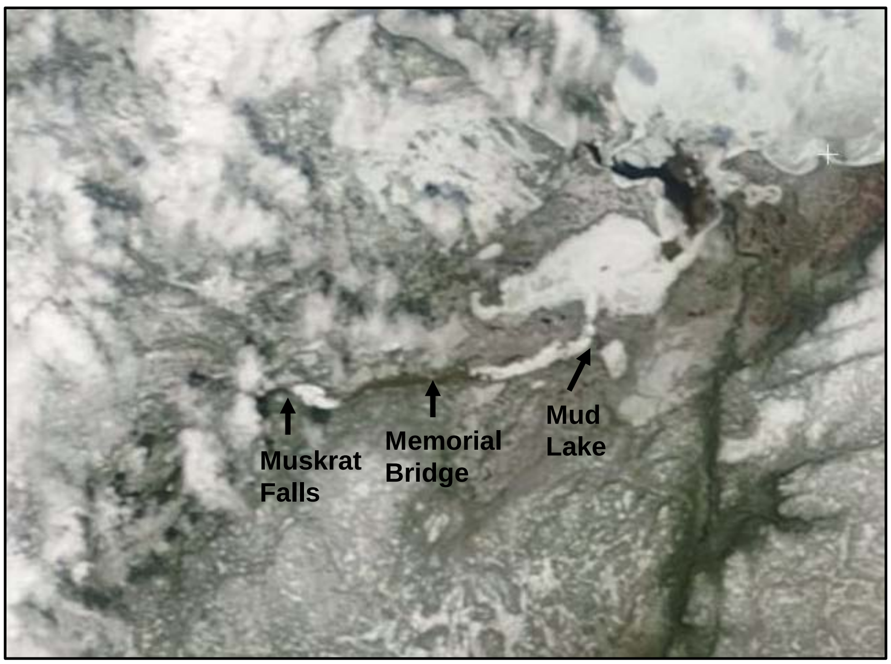


Figure 3-5: May 15, 2012 – Satellite Image Showing Ice Cover Location Just Prior to Jam

Figure 3-6: May 15, 2012 – Photo Looking Upstream at Muskrat Falls

3.2.2 Ice Jam Event

The ice jam event in 2012 occurred on May 16, the same day as in 2017. **Figure 3-7** summarizes the recorded water level and river flow data associated with the 2012 ice jam event. In reviewing this plot, the following observations can be made:

- As noted in this figure, the runoff associated with the spring freshet began at the end of April, and continued to climb throughout the first three weeks of May. The peak flow of 5960 m^3/s reached on May 19 represents a flood with a return period of approximately 1 in 20 years. Therefore, this was a relatively high runoff year, driven in large part by the abnormally high snowpack in the basin.
- Considering the water level trace at WSC Gauge 03OE014, the ice front appears to have begun moving downstream past the gauge location, and past the Veteran Memorial Bridge (VMB), by May 13. There is a relatively noticeable drop in water level at this time, despite the fact that flows are continuing to increase. The satellite image taken on May 15th of this year (shown in **Figure 3-5**) shows that the ice front had indeed moved past the bridge by May 15. The subsequent rise in level observed at this gauge after the ice jam event had released was due to the very high flows associated with the passage of the spring freshet.
- The ice likely began moving in the reach downstream of the VMB shortly thereafter, jamming against the still competent Goose Bay ice cover in the early morning hours of May 15 (as shown by the sharp rise in level evident at WSC gauge 03PC001 at English Point). The water level began to rise at 6:00 am on May 15, reaching a peak value of 4.0 m on May 16.

- Flows continued to rise due to the developing freshet, and this rising flow eventually caused the jam to release and flush ice into Goose Bay.

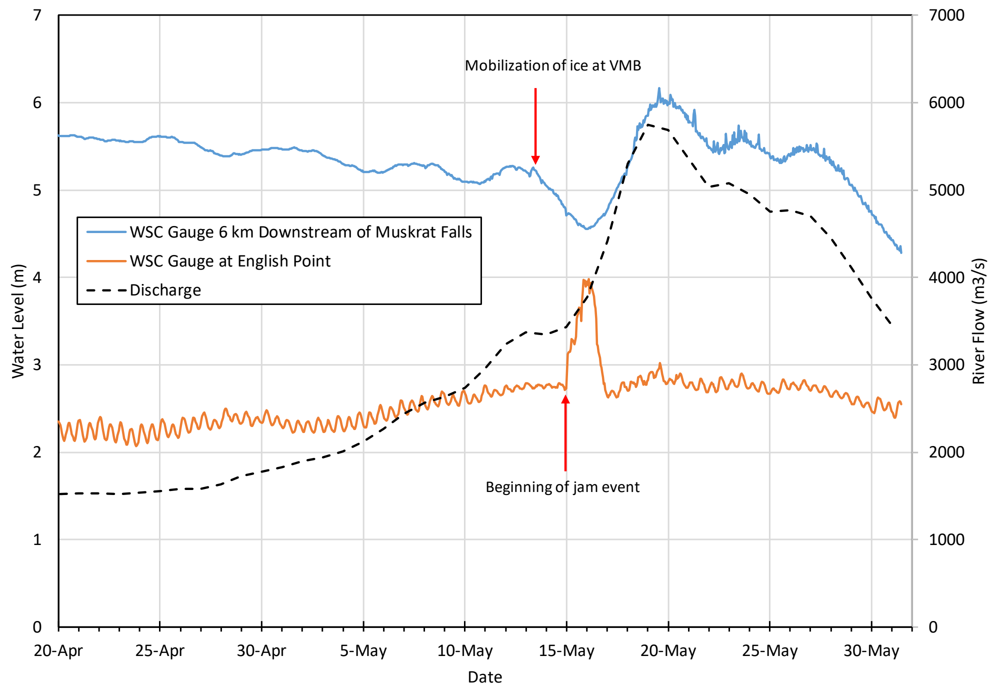


Figure 3-7: Summary of Flows and Water Levels During Spring in 2012

It is judged that the jam likely had a similar toe location as in 2017, but that it may have been smaller in its overall length. Given the high snow cover depth, and the pictorial evidence of degradation of the cover prior to its mobilization, the overall volume of ice on the river available for mobilization was likely reduced, when compared to the 2017 event.

As a part of this review, Hatch estimated the likely volume of ice contained in the 2012 jam event. This was done using the existing HEC-RAS backwater model.

The assessment involved the following steps:

- A detailed HEC-RAS model, previously set up to support the design of the project, was re-mobilized and modified to represent the 2012 event. This comprehensive model was set up to include all available cross sectional data, and calibrated successfully to match open water profiles and stage-discharge rating curves throughout the reach.
- Since the model was previously only used for open water conditions, it was then necessary to input appropriate ice parameters to the model. The parameters to be entered included the initial sheet ice thickness, the hydraulic roughness of the cover (main channel and floodplains), the porosity of the jam, the internal strength of the jam,

the longitudinal to lateral ratio of internal forces, the maximum velocity under the jam, and the nature of the cover (jam vs ice sheet). Of these, most parameters were initially assigned values based on the judgement of our modellers, and on the experience gained from past model applications on the river. The final parameter set utilized included the following:

- Ice jam toe: was estimated to be near the mouth of the river, at a narrow point located approximately 1 km downstream of the English Point hydrometric station. The downstream water level at this point was assumed to remain at local datum el. 2.8 m (or GSC el. 0.5 m), which is the approximate stage in the river immediately prior to the jam event.
- The river discharge was estimated to be between 3500 and 4000 m^3/s at the peak of the jam.
- The hydraulic roughness (Manning coefficient) for the ice cover was set to be 0.05. This is considered to be near the low end of the range of values considered for an ice jam event involving partially degraded or weakened ice floes.
- The internal strength of the ice was set to 48 degrees. This is approximately 3 degrees higher than the default values suggested by the USACE developers of the model, but was necessary to better match the observed level at the English Point hydrometric station.
- The total jam length was assumed to be approximately 5 km from toe to head, based on admittedly grainy satellite imagery taken on May 15.

The results of the simulation are shown in **Figure 3-8** below. A reasonable match was obtained with the observed peak water level of 4.0 m at the English Point hydrometric station – the model predicted a value of 4.4 m at this location. Based on this simulation, the overall ice volume was estimated to be approximately 23 million m^3.

Given that the ice volume in the downstream reach at the end of winter was likely to be more than 100 million m^3 (based on past ICESIM runs), the downstream reach contained more than enough ice to create the jam without any augmentation due to ice being released from the reach upstream of Muskrat Falls.

In reviewing this, it is judged that flooding in 2012 could have actually been significantly more severe if the Goose Bay ice had been thicker and more competent at the time of the event. It may have delayed the release of the jam if the load bearing capacity of the Goose Bay ice had been greater. The deep snow cover may have limited the overall thickness of the ice, and thereby the strength, of both the river and lake ice. Also, flows continued to rise, and this rising flow eventually caused the jam to release and flush ice into Goose Bay.

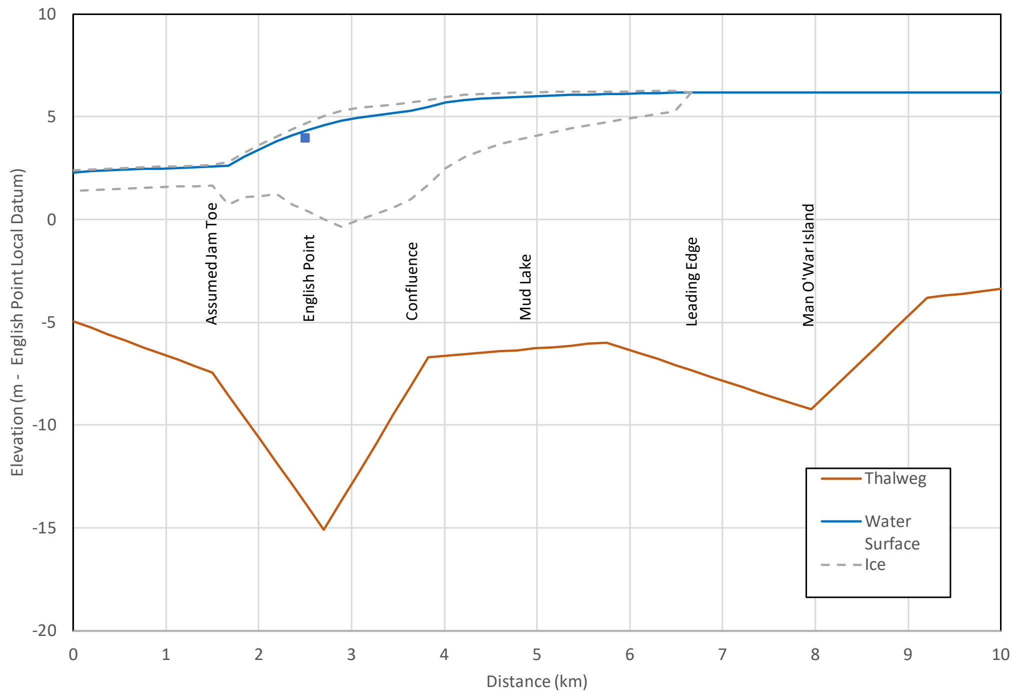


Figure 3-8: HEC-RAS Simulated Ice Jam Profile of 2012 Jam Event

3.3 Meteorological Predictors

The tendency for ice related flood events to occur is often closely linked to antecedent meteorological events. This is because the occurrence of ice jam flooding requires both an adequate supply of ice to form a jam and a flow rate in the river exceeding a certain value.

Given the lengthy reach of river between the Muskrat Falls site and its outlet into Goose Bay, at the end-of-winter there will always be an adequate supply of ice in the Muskrat Falls to Mud Lake reach of the river to form a jam at or downstream of the community.

The supply of water to the river and its rate of flow subsequent to the end-of-winter is year to year, however, highly variable, being dependent upon the intensities of rainfall and snowmelt. These intensities are dependent upon the nature of weather systems passing over the river basin.

Given the year to year variability of the rate of rainfall and snowmelt, past studies have indicated that it may be possible to distinguish 'non-ice jam flood' years from 'ice jam flood' years by comparison of annual rainfall plus snowmelt records. This has been done for the Churchill River basin for the period of years 1976 to 2017 inclusive. Adequate records of rainfall and snowmelt were found to be available from three weather stations in and adjacent to the Churchill River basin; namely, Goose Bay - Happy Valley, Wabush and Riviere au Tonnere. These data have been formatted as shown in **Figure 3-9**.

This chart shows the day by day trajectory of the accumulation of the sum of daily rainfall and snowmelt for each year of record. The slope of the lines thus represent the rate of water supply afforded to the river by rainfall and snowmelt in mm/day.

With the separate plotting of the annual data sets as ‘flood’ and ‘non-flood’ years after a pro-ration of the weather station data sets to represent the relative contributions of the drainage area represented by each weather station, the data can be separated into two separate charts, shown in **Figure 3-10** and **Figure 3-11**. The heavy red broken line common to both figures indicates the lower bound or envelope for all identified flood years. All traces shown in **Figure 3-10** represent the historical flood years identified in the archival review. All traces shown in **Figure 3-11** represent “non-flood” years from 1976 to 2017. Thus, if the (Rainfall + Snowmelt) trajectory for a given year lies above the dividing line after about April 12, there is a significant risk that ice jam flooding may occur on the Churchill River. It should be noted that this relationship is considered to be preliminary, and that it can perhaps be improved in the future with the collection of additional data, and the possible incorporation of other variables. For example, there is still significant overlap between the flood and non-flood year families in the region above the red dividing line. This is to be expected given that there are other variables that can lead to an increase in flood risk that are not taken into account in this simple relationship – the ice thickness on Goose Bay for example. It is possible that a multi-variate regression analysis could help to better segregate the two families.

Nevertheless, **Figure 3-10** provides an interesting insight into the 2017 flood year. Of note is the position of the estimated 2017 totals. Although this information is provisional, it indicates that the 2017 totals are likely to fall within the high risk zone of this plot. That, combined with the very thick, competent ice on Goose Bay, appear to make this a very high risk year for an ice event, with or without the operating Muskrat Falls project.

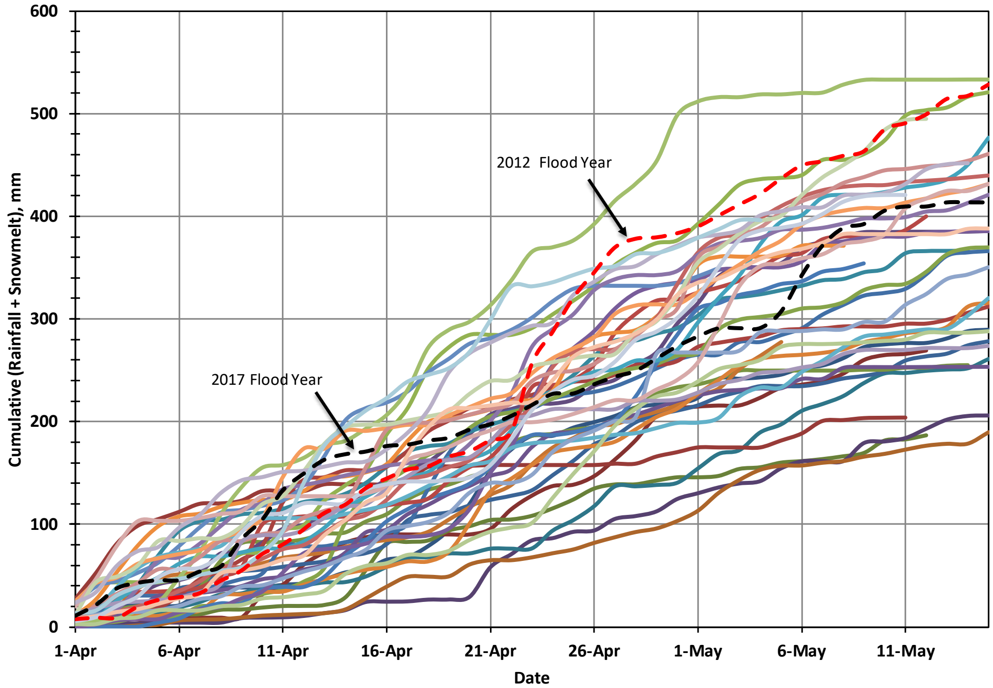


Figure 3-9: Accumulated Snowmelt and Rainfall for all Years (1976-2017)

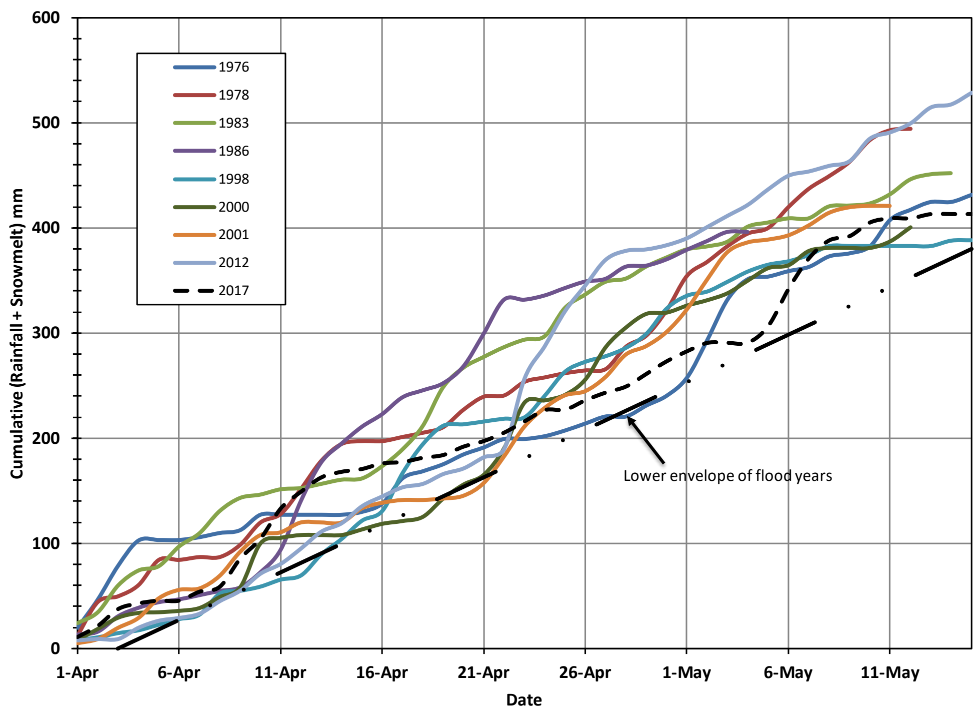


Figure 3-10: Accumulated Snowmelt and Rainfall for all Flood Years (1976-2017)

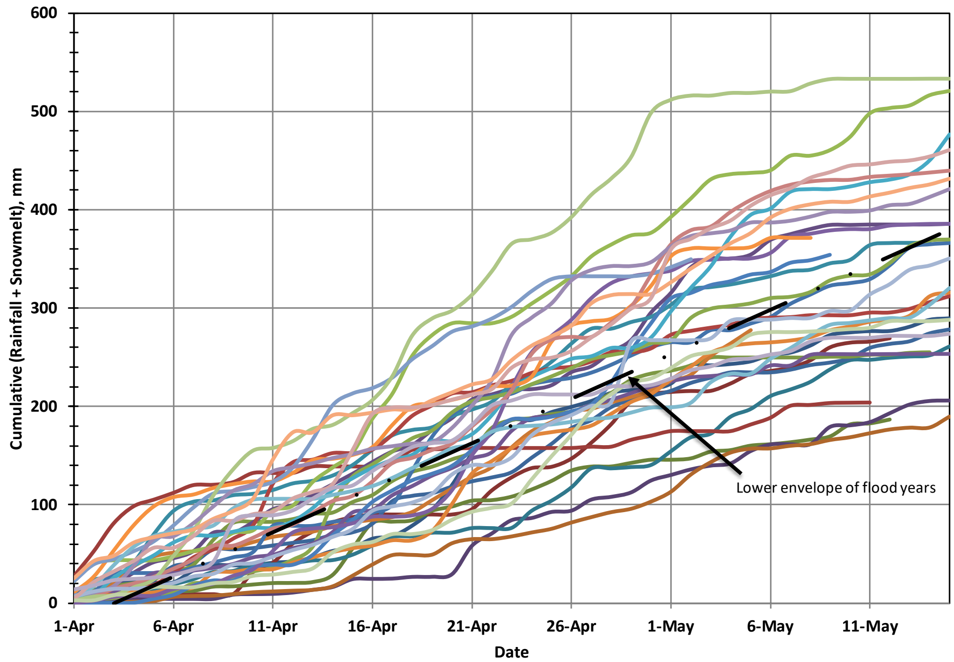


Figure 3-11: Accumulated Snowmelt and Rainfall for all Non-Flood Years (1976-2017)

4. Review of 2016/2017 Ice Jam Event

As a next step in the assessment, the team reviewed available observations and quantitative information on the 2017 flood event.

The three specific objectives of the review were to:

- better understand the antecedent conditions that preceded the flood event, including information on any significant meteorological events that may have contributed both to spring flows and strength/thickness of the ice floes that comprised the jam;
- decipher the important causes or contributing factors to the actual event, like the nature of the winter ice cover, the breakup process upstream, and the extent of the ice jam (toe location, etc.); and
- assess whether operations at the upstream Muskrat Falls facility may have in any way impacted peak water levels experienced at Mud Lake.

4.1 Ice Formation

Ice formation for the 2016 winter began in November, as it typically does. Daily average air temperatures hovered at or just below zero degrees for the first few weeks of November, but then fell consistently and significantly below zero degrees by November 24. It was at this time that ice would have begun forming in the quiet back-bays of both Lake Melville and Goose Bay. Although grainy, satellite imagery taken on November 24 (**Figure 4-1**) shows little evidence of ice growth, whereas imagery from November 28 (**Figure 4-2**), shows that ice formation had begun in the reach. A later image taken on November 30 (**Figure 4-3** and **Figure 4-4**) shows that at this time the ice cover had begun advancing up into the Churchill River and that the ice dam had already begun forming downstream of the Muskrat Falls site. The ice cover's advancement up from Goose Bay into the lower Churchill River is clearly captured on the WSC gauge recording for the English Point station, shown in **Figure 4-5**. Once an ice bridge had been established, the juxtaposed cover then advanced upstream, and as shown in **Figure 4-5**, likely passed the upstream WSC gauge (6 km downstream of MF project) by December 7, or within approximately 10 days. It is at this time that water levels appeared to reach a peak at this gauge.

There were two significant events that occurred in November that warrant comment. First, on November 18, Nalcor began lowering the level in the Muskrat Falls reservoir to facilitate the implementation of remedial measures that were required for one of the sites cofferdams. The water level in the upstream reservoir (i.e., upstream of the upper falls) was reduced over a 2-day period releasing approximately 100 million m^3 of storage from the upper reservoir. This increased peak instantaneous flows above their base levels by as much as 2500 m^3/s, and increased the 12 hour average flow by up to 1900 m^3/s. Water levels at the WSC gauge located 6 km downstream of the Falls were seen to rise by approximately 1 m at the peak flow release (shown in **Figure 4-5**), and there was no discernable impact on the recorded water levels at the English Point hydrometric station. Water levels and flow rates in the river returned to normal conditions shortly after the water was released from the reservoir (within 2 days of first release). The possible impact of this on ice formation is discussed further in Section 5. Following this, as shown in **Figure 4-5**, water levels began to rise again (most noticeably at the upper WSC hydrometric station 03OE0114) as flows again began to increase. This second increase was due to the passage of a natural runoff event created by a heavy rainfall event that had taken place across central Labrador over the period from November 17 to the 22. During this period, a large storm system dropped approximately 37 mm of rain in Happy Valley-Goose Bay, and over 33 mm of rain at the Churchill Falls site. In addition, the upstream Churchill Falls project had ramped up power/generation output at about this time, also augmenting river flows at the site. The impact of both of these events can be seen in **Figure 4-6**. In this figure, past recorded freezeup discharges are also shown to provide context to the 2016 estimated flows. As shown, although high, the flows experienced this fall were not unprecedented. **Figure 4-7** provides a summary of the water levels recorded at English Point in the fall of 2016 compared to water levels observed at the gauge since it was first established in 2010. As shown, the water levels in 2016 were initially approximately 0.1 m higher than the highest peak level recorded in the past 6 years. However, as shown, levels then returned to their normal values by the end of December.

Figure 4-1: Satellite Image of the Lower Churchill River on November 24, 2016

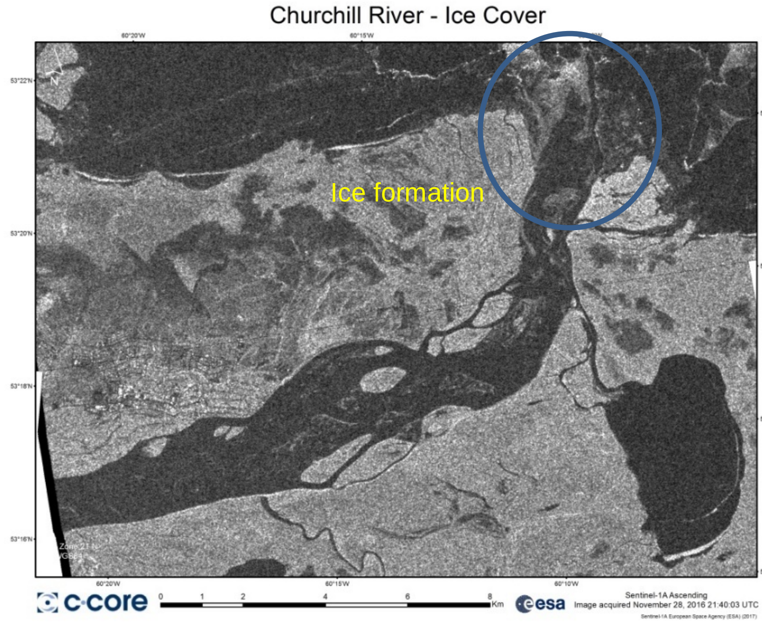


Figure 4-2: Satellite Image of the Lower Churchill River on November 28, 2016

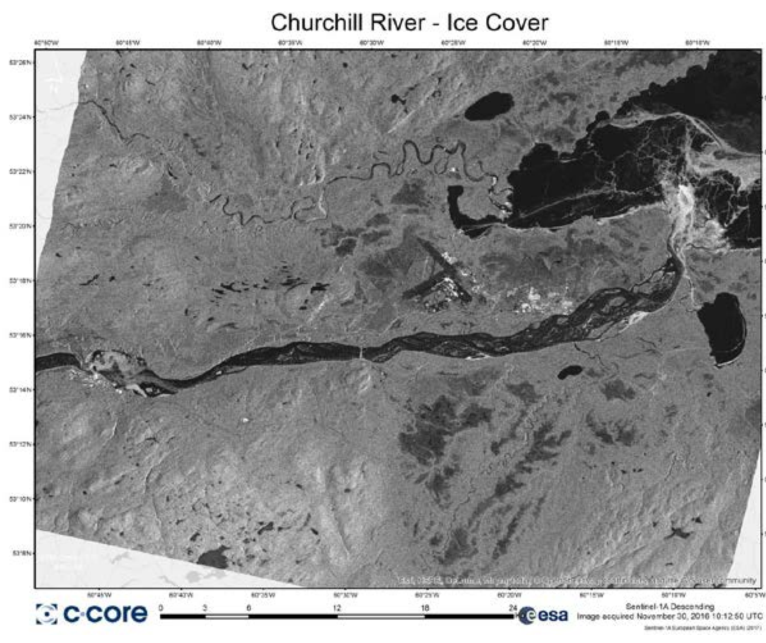


Figure 4-3: Satellite Image of the Lower Churchill River on November 30, 2016

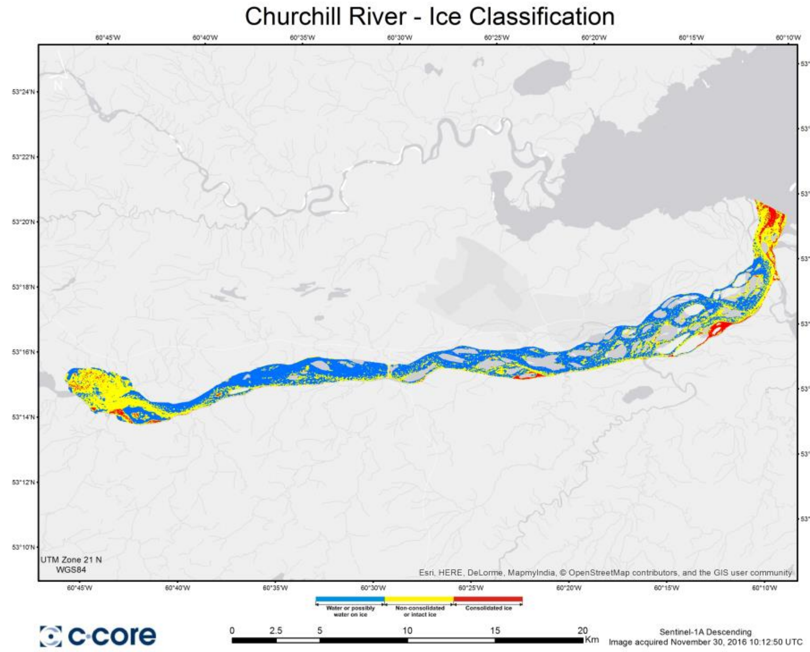


Figure 4-4: C-Core Interpretation of Ice Extent on November 30, 2016

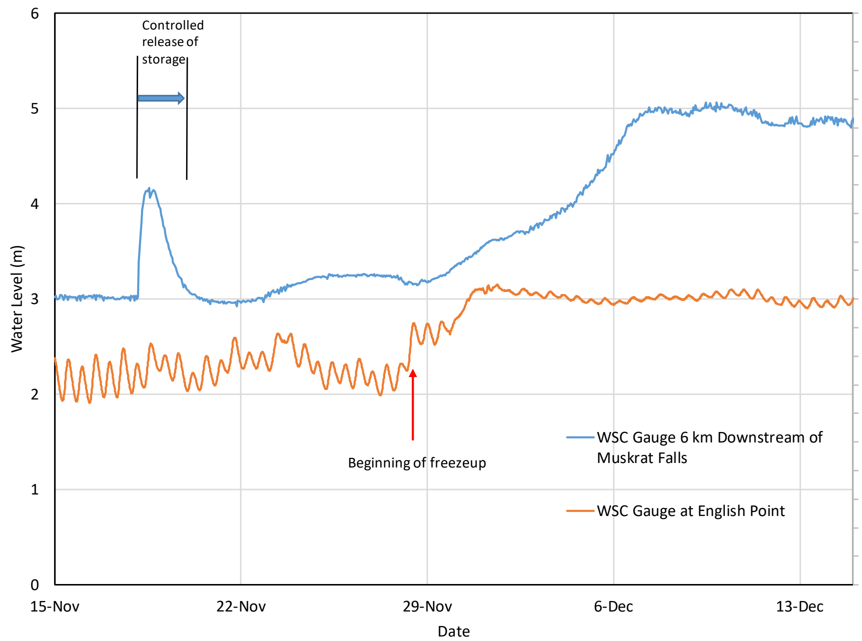


Figure 4-5: Summary of Water Levels during Freeze-up, 2016

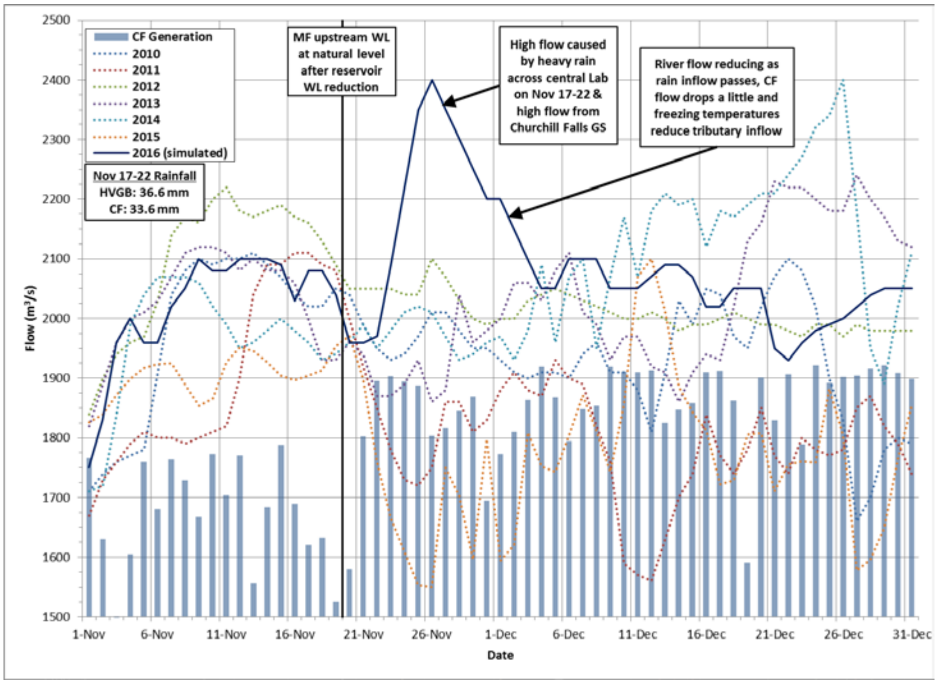


Figure 4-6: Summary of Flows during Freeze-up, 2016

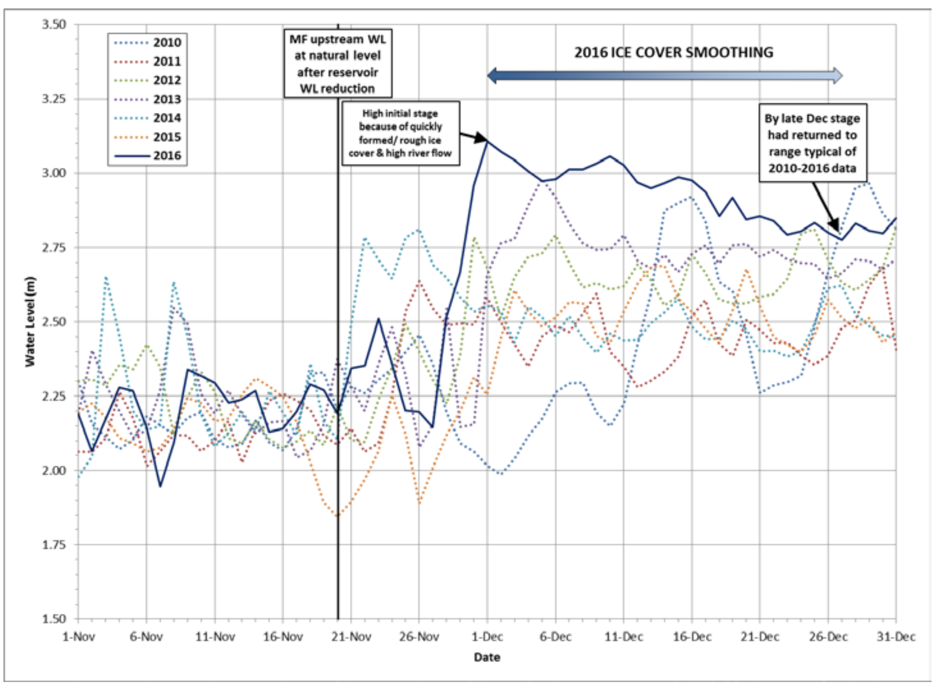


Figure 4-7: Summary of Water Levels during Freeze-up, 2016

Following initiation of the cover, over the course of the next few months the cover continued to form and grow in much the same way as it has in the past. Water levels upstream of the project were maintained at their natural level up until late January. During this period of time ice generated in the reach between Sandy Island lake and Muskrat Falls passed through the spillway and continued to collect in a very large ice dam which formed downstream of the project, as it typically does. Water levels continued to rise at the foot of the falls due to this accumulating ice. This resulted in maximum water levels just below Muskrat Falls of up to 7 m.

In late January, the water levels upstream of the project were steadily increased to promote the formation of a cover upstream of the project. This was needed to help manage the steadily rising water levels downstream of the project. In mid February, a cover was formed upstream of the project, effectively cutting off the supply of ice to the downstream ice dam. This curtailed the rising water levels, and indeed led to a reduction in level as the ice dam continued to smooth over the winter. Hatch's ICEDYN model was used as a real-time support tool during this period to help predict the expected staging magnitudes and patterns during this time. **Figure 4-8** illustrates the simulated ice profile downstream of the project immediately after upstream bridging had taken place.

The approximate thickness and competency of the ice cover on Goose Bay was also estimated for the 2016/17 winter using the ice simulation model described earlier. The model was updated to reflect the 2016/17 meteorological data, including recorded daily air temperatures, daily snow cover depths, and solar radiation data. Meteorological inputs were obtained from available EC records at the Goose A MSC station.

Figure 2-4 illustrates the computed thickness of ice for the 2016/17 winter, along with thicknesses computed for all years from 1958 through to present. As shown the 2017 winter initially began developing a relatively thick ice cover early - the snow cover for this year arrived later than usual, leaving little insulation on the growing ice cover. The cover likely reached a maximum thickness of approximately 94 cm. This is near the high end of all winters simulated, and is estimated to be a 1 in 20-year ice thickness based on earlier work. In addition, relatively cold weather in April resulted in very little thinning or degradation of the ice cover, meaning it was likely quite competent at the beginning of the melt period in May. Therefore, at the time of breakup, the load bearing capacity of the cover was likely still quite good.

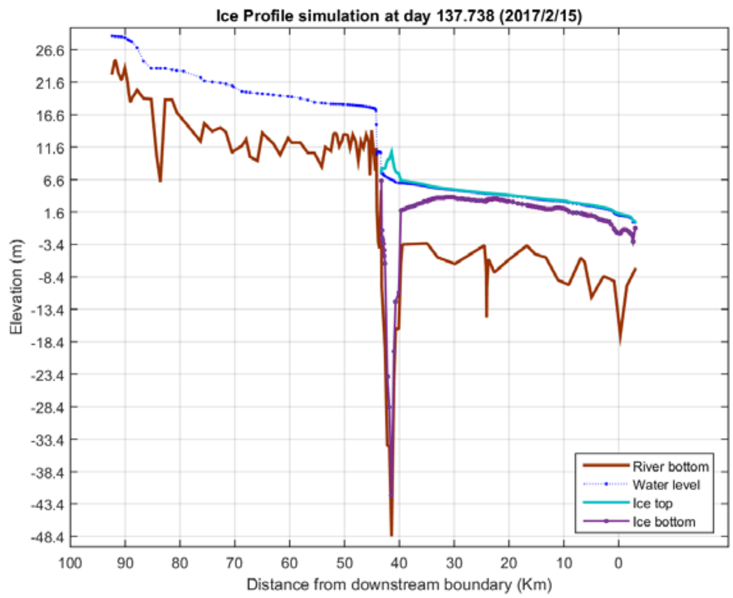


Figure 4-8: Approximate Ice Profile Downstream of Muskrat Falls on Feb 15, 2017

4.2 Antecedent Conditions and Events

The preceding section provides a summary of the ice formation events that occurred in the winter of 2017. The review team also looked more closely at events that occurred in the shorter 4-week period leading up to the formation of the ice jam.

Meteorological Conditions and River Flows

In 2017, the spring was marked by an abnormally cold April – the average temperature recorded by the Goose A MSC gauge was only -2.8 degrees C in 2017. This is almost 2 degrees lower than the historical average temperature of -1.1 degrees C for April. This delayed the melt and ripening of the snowpack, and also led to a reduced amount of degradation of the thick Goose Bay ice cover (**Figure 2-4**).

However, as shown in **Figure 4-9**, in May, the weather suddenly warmed, and day time highs began to increase to more than 20 degrees C. This led to a rather rapid increase in local runoff, a depletion of the snowpack, and a rapidly rising flow in the lower Churchill River. The peak of this flow occurred almost coincidentally with the ice jam event. This is shown in **Figure 4-10**. In this figure, there are two traces shown. The first is the recorded outflow from the Muskrat Falls Spillway. The second trace represents a simulated hydrograph in which the Muskrat Falls flows have been routed through to the English Point gauge location. The latter hydrograph was estimated by dynamically routing the Muskrat Spillway release hydrograph from the project site down to English Point using an existing HEC-RAS model. The HEC-RAS model had been set up as a part of previous initiatives to represent the pre-project, or natural condition. Although this is simply a predictive tool, it is considered to be quite representative of the lag and attenuation in flow that likely took place as these releases travelled downriver. From this assessment, it appears the travel time to reach English Point is about 12 hours. The spring freshet arrived at site on approximately May 10 and peaked on or about May 16.

During the period the gauge also recorded over 40 mm of rainfall from May 2 through to May 10. This would have helped to accelerate the ripening and melt of the area snowpacks.

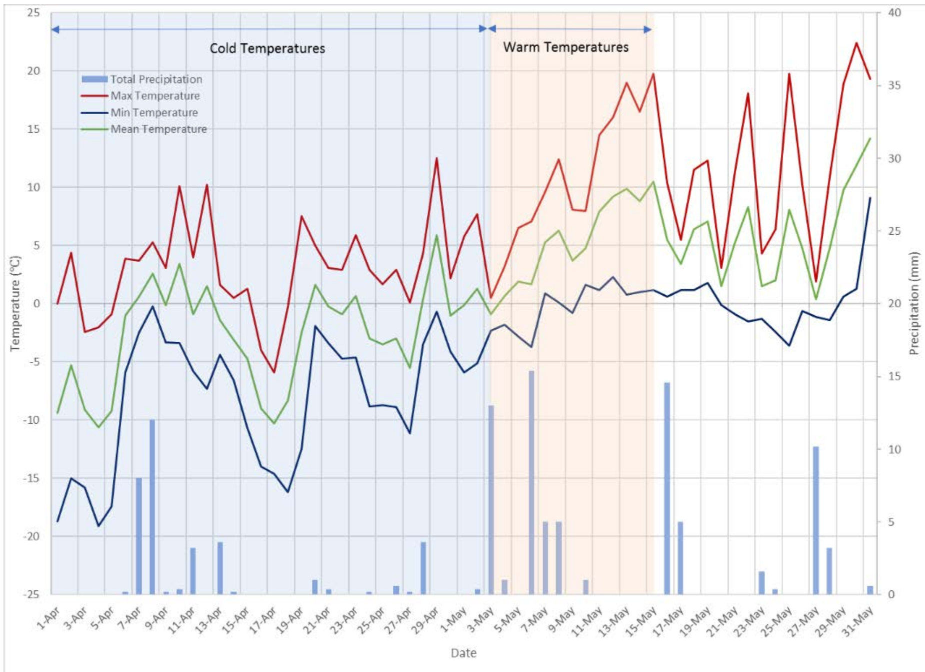


Figure 4-9: Meteorological Data for the Goose A MSC Station, Spring 2017

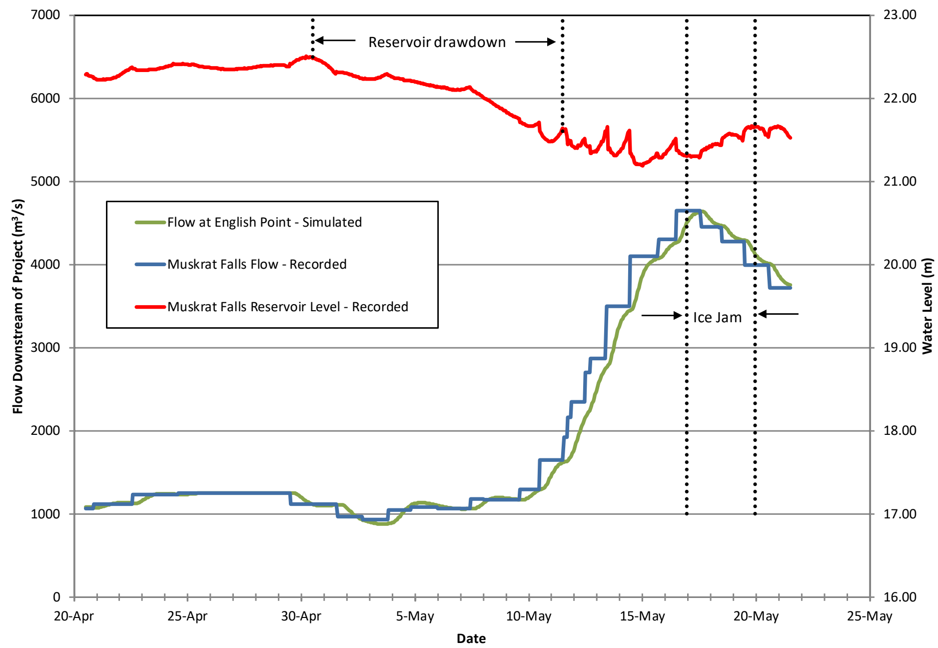


Figure 4-10: Summary of Flows and Levels

Regional Ice Jam Events

Prior to the jam event occurring on May 16 on the lower Churchill River, there were similar jam events that occurred on both McKenzie River and on Goose River. **Figure 4-11** and **Figure 4-12** show images of the McKenzie River ice jam event, while **Figure 4-13** shows images of the Goose River event. The McKenzie River ice run was observed on May 11, 2017, after daily air temperatures had risen and small rivers responded relatively quickly with increasing flow. Likewise, Route 520 was flooded on May 13 as result of an ice jam on the Goose River near the outlet to Goose Bay. The photo shown in **Figure 4-13** depicts a section of the ice jam on the Goose River on May 14. These events occurred just days before the larger ice jam event on the lower Churchill River and were completely natural events.

Figure 4-11: McKenzie River Ice Jam Event, May 14, 2017

Figure 4-12: McKenzie River Ice Jam Event, May 14, 2017

Figure 4-13: Goose River Ice Jam Event near Highway 520, May 14, 2017

Release of Upstream Ice Cover

Each year, significant border ice builds up along the banks of the river upstream of the Muskrat Falls site. Each spring, this ice releases and passes over Muskrat Falls with the arrival of the spring freshet. This year was no different. Ice in the upper forebay was noted to have released on May 11 as the spring freshet arrived. This led to a steady discharge of ice through the spillway, and this ice very likely became trapped in the large ice dam downstream of the project and was not likely to migrate any further downstream. The ice dam itself has a large capacity to "store" incoming ice floes being passed through the falls or spillway, and given that the ice dam remained intact throughout the early May period, and through the ice jam event, these floes were unlikely to migrate past the dam in any sufficient quantity. This is discussed further in Section 5.

Forebay Level Drawdown

The reservoir level for the Muskrat Falls project was gradually reduced from el. 22.5 m down to approximately el. 21.5 m over a 12-day period extending from April 30 to May 11. This action was taken in advance of the spring freshet to bring the reservoir level down to the lower limit of this winter's operating range, and thereby provide an additional buffer for operators to work within when passing the freshet. As shown on the project's stage-storage curve in **Figure 4-14**, this operation released approximately 48 million m^3 of storage. In doing so, the Spillway discharge was increased by, on average, approximately 55 m^3/s above the natural inflows. This operation is shown in **Figure 4-10** and the increase in flow equates to about 5% of the pre-breakup flows. This operation predated the actual jam event by approximately 5 days. This is discussed further in Section 5.

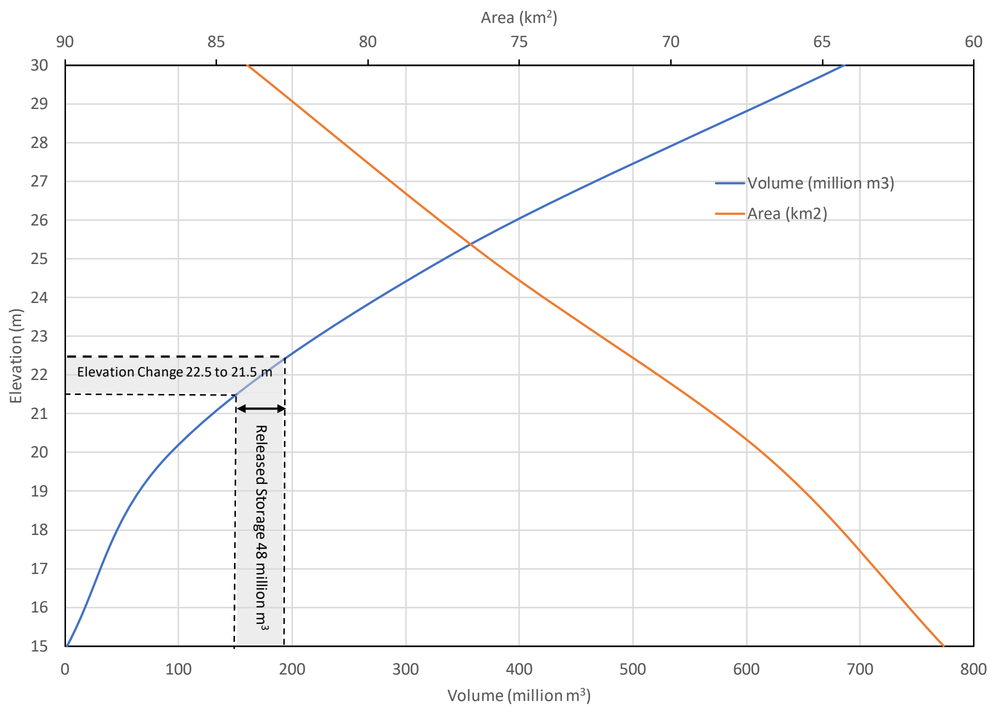


Figure 4-14: Project Stage Storage Relationship

Condition of Ice Cover

As noted earlier, the temperature records indicate that the basin was subjected to a colder than normal April, and a very warm period in early May. This led to a rapid loss of the snow cover, and rapid rise in inflow. It is hypothesized that because of the unusual nature of this melt, the ice in the river was likely to be relatively strong and competent at the time of the ice jam event. This is supported by review of available site photos, taken as a part of a regular observation program conducted by Nalcor in the spring. **Figure 4-15** to **Figure 4-21** summarize the nature of the ice cover in the lower reach of the Churchill River just one day before the ice jam event occurred. In reviewing these photos, a number of observations can be made:

- Ice in the area looked to be quite solid, with minimal degradation. **Figure 4-15** and **Figure 4-16** illustrate the condition of the ice in the Mud Lake area. As shown, it looks to be quite strong, and agrees with numerical ice calculations which indicated it would still be quite thick and competent.
- **Figure 4-16** also shows some lateral and longitudinal cracks in the cover. This suggests it had been subjected to some stage increases with rising flow before May 15.

- The ice cover was still very much intact upstream of the Veteran Memorial bridge. Some consolidation of the cover can be seen upstream of the bridge in **Figure 4-17**. **Figure 4-18** actually shows some rafting of ice on the upstream causeway. Both photos suggest the cover was beginning to move downriver with the increased flow and drag associated with the high flows of the freshet.
- **Figure 4-20** shows a C-Core image processed from a satellite image that was taken on May 15, just one day prior to the jam event. It shows that the ice front had already separated from the main ice dam at the base of Muskrat Falls and had already begun a slow retreat down river. This is very typical and occurs almost every year.
- **Figure 4-21** shows that the Muskrat Falls ice dam remained intact. Of interest, one can see in this photo the remnants of some of the upstream forebay ice that was passed through the spillway. The marked bands of accumulated ice that can be seen next to the open water lead area were not present in earlier photos – evidence that much of this ice was likely retained within the ice dam.

Figure 4-15: Looking Upstream Towards Mud Lake (1 km) – May 15

Figure 4-16: Looking Downstream at 20 km

Figure 4-17: Looking Upstream Towards Memorial Bridge (23 km)

Figure 4-18: Looking Across Veteran Memorial Bridge on May 15

Figure 4-19: Looking Upstream Towards Muskrat Falls (35 km)

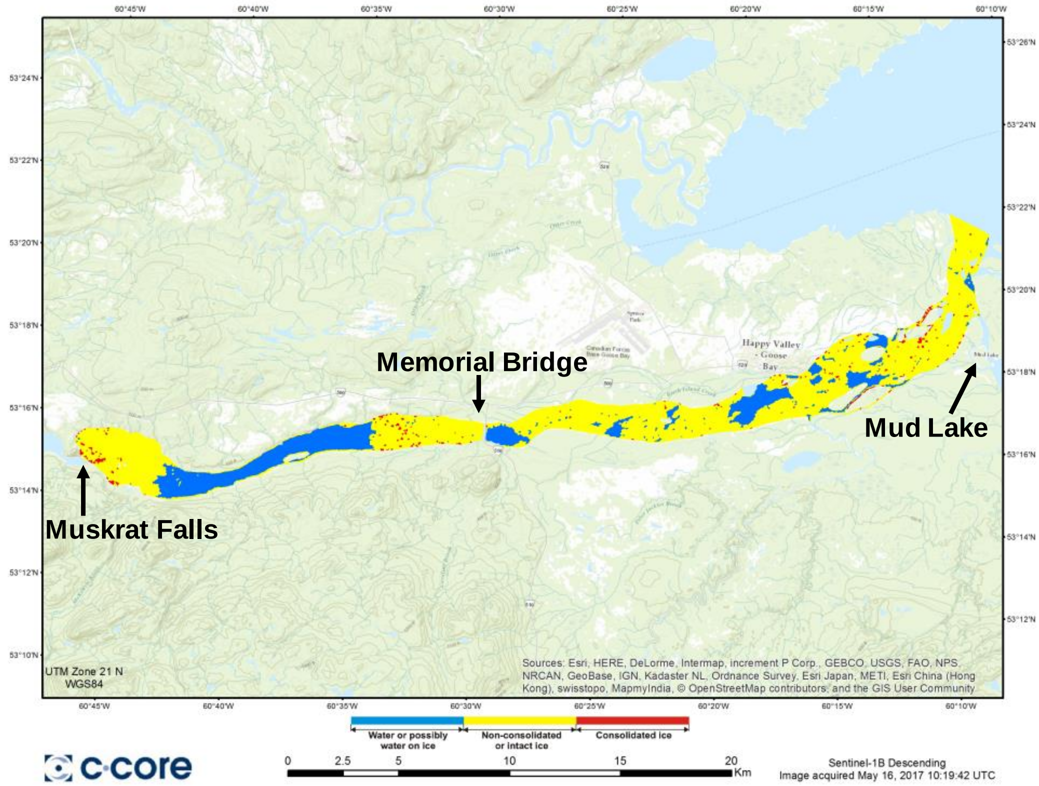


Figure 4-20: C-Core Image Showing Ice Configuration on May 16

Figure 4-21: Looking Upstream Towards Muskrat Falls (42 km)

4.3 Ice Jam

Water levels and flows recorded during the 2017 ice jam event are summarized on **Figure 4-22**. In terms of timeline, the event proceeded as follows:

- As shown in **Figure 4-22**, the runoff associated with the spring freshet began on approximately May 10th and rose steadily and rapidly. **Figure 4-23** shows the back-calculated inflow at the Muskrat Falls site compared to other ice flood years. The peak flow of 4650 m^3/s reached on May 16 represents a flood with a return period of approximately 3 years. Although the peak value was nothing unprecedented, at its worst, the inflows were rising at a rate of 900 m^3/s per day. This is one of the highest daily increases experienced at this site. For each yearly hydrograph shown in **Figure 4-23**, the solid portion of the line indicates the river flow prior to the jam event occurring. The dashed portion of the line indicates the flow that may have occurred after the jam had formed, or been subsequently released. As shown, ice jams have typically formed at river discharges of between 3000 and 5000 m^3/s.
- As noted earlier, a processed satellite image taken on May 16 of this year (shown in **Figure 4-20**) shows that the ice front and cover was still upstream of the VMB and very much intact at the time of the image.
- The rising river flows began to increase drag forces on the ice cover located upstream of the Veterans Memorial Bridge and embankment. This led to the rafting of ice evident in **Figure 4-18** on May 15 – one day before the jam occurred. At this point the ice cover was losing bank resistance and very near to mobilizing.
- Considering the water level trace at WSC Gauge 03OE0114 (6 km downstream of Muskrat Falls), the ice front likely began moving downstream past the gauge location, and past the VMB by noon of May 16. This is shown quite clearly in **Figure 4-24**, where there is a relatively noticeable drop in water level at this time, despite the fact that flows are continuing to increase.
- The ice likely began moving in the reach downstream of the bridge shortly thereafter. It should be noted that at the time the ice cover released upstream of the bridge, the stage had increased by almost 3 m above the pre-freshet level. This magnitude of increase was likely more than sufficient to reduce the cover's contact with the river bank and consequently its resistance to movement thereby - allowing it to mobilize. The moving ice floes subsequently jammed against the still competent Goose Bay ice cover in the late evening hours (23:30 hours) of May 16 (as shown by the sharp rise in level evident at WSC gauge 03PC001 at English Point). The water level rose by 1 m to reach a peak of 4.4 m.
- Subsequently the water level began to slowly drop, reaching a level of 3.9 m by 15:00 hours on May 18. After 15:00 hours on May 18, the jam appears to have shifted, potentially due to tidal effects, or a shift in the toe location to an area of more competent

ice on Goose Bay. This led to a secondary peak that caused the level to rise very briefly to approximately el. 4.9 m. The level then fell again to 4.6 m, and finally dropped to el. 2.6 m by 15:30 on May 20.

The resulting ice jam can be clearly seen in a satellite image that was taken on May 18, and shown in **Figure 4-25**. As shown, the jam likely had a toe location estimated to be 1.5 km downstream of English Point. Given the low snow cover depth, and the very cold month of April, the overall volume of ice on the river was likely quite high and the Goose Bay ice cover was strong, with a high load bearing capacity. These factors would suggest that ice volumes available for mobilization at the time of the jam would be quite significant.

It was possible to make a rough estimate of the volume of ice in the downstream reach (prior to the arrival of the spring freshet) using the calibrated ICEDYN model. As noted earlier, this model had been run this past winter to support river management operations, and was able to simulate the staging patterns observed just downstream of the Muskrat Falls project with good success. These model results were checked to estimate the volume in the cover downstream of the 03OE014 WSC gauge (which is six kilometres downstream of the project site). Based on this simulation, it was estimated that the ice cover volume contained in this river reach was approximately 100 million m^3 just after freeze-up occurred in the upstream river.

As a second step, the HECRAS backwater model was again set up and used to estimate the likely volume in the 2017 ice jam. For this run, the final parameter set utilized identical parameters to those used in the 2012 simulation:

- The ice jam toe was estimated to be near the mouth of the river, at a narrow point located approximately 1 km downstream of the English Point gauge. The downstream water level at this point was assumed to remain at el. 3.2 m (local English Point gauge datum), which is the approximate stage in the river immediately prior to the jam event.
- The river discharge was estimated to be 4400 m^3/s at the time of the second peak of the jam (as shown in **Figure 4-22**).
- The Manning hydraulic roughness coefficient for the ice cover was again estimated to be 0.05.
- The internal strength of the ice was set to 48 degrees.
- The head of the jam was estimated to be approximately 3.5 km upstream of the Mud River confluence based on satellite imagery taken on May 18 (see **Figure 4-25**). The total jam length was therefore assumed to be approximately 5.5 - 6 km from toe to head.

The results of the simulation are shown in **Figure 4-26** below. As noted, a reasonably good match was obtained with the observed peak water level of 4.9 m at the English Point hydrometric station. The model predicted a level of 5.17 m, and based on this simulation, the overall ice volume for the jam was conservatively estimated to be 30 million m^3. This represents a volume that is roughly one third of the river ice volume initially contained in the downstream reach.

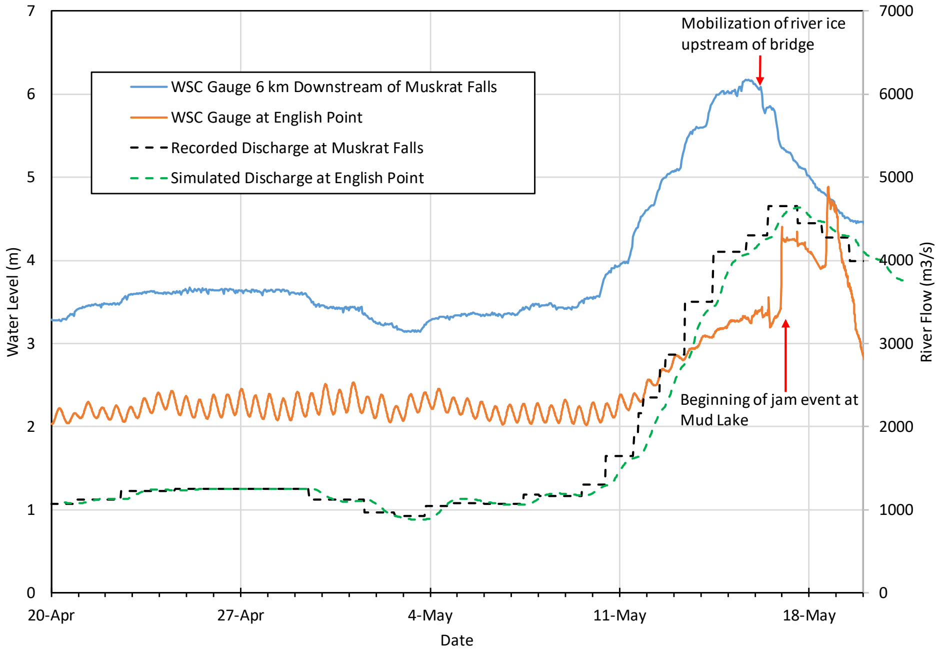


Figure 4-22: Summary of Area Water Levels and Flows, Spring 2017

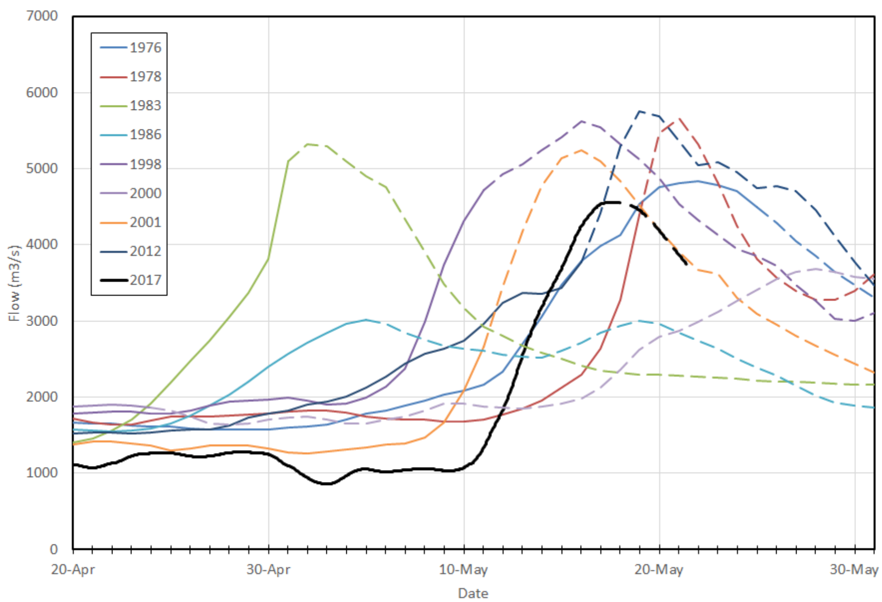


Figure 4-23: Historical Flows during Spring Ice Jam Events

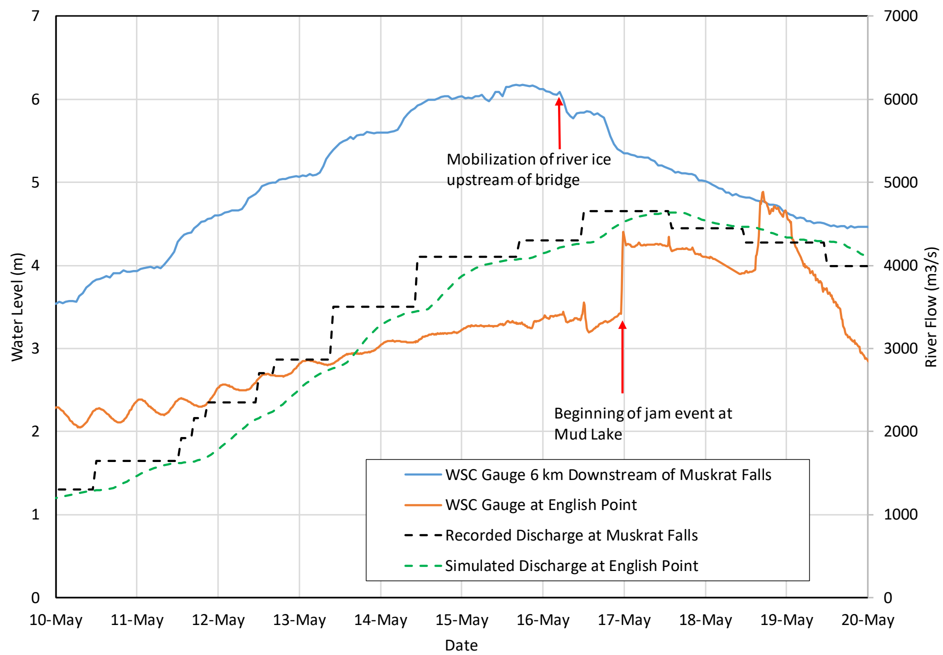


Figure 4-24: Summary of Water Levels and Flow during Passage of Spring Freshet, 2017

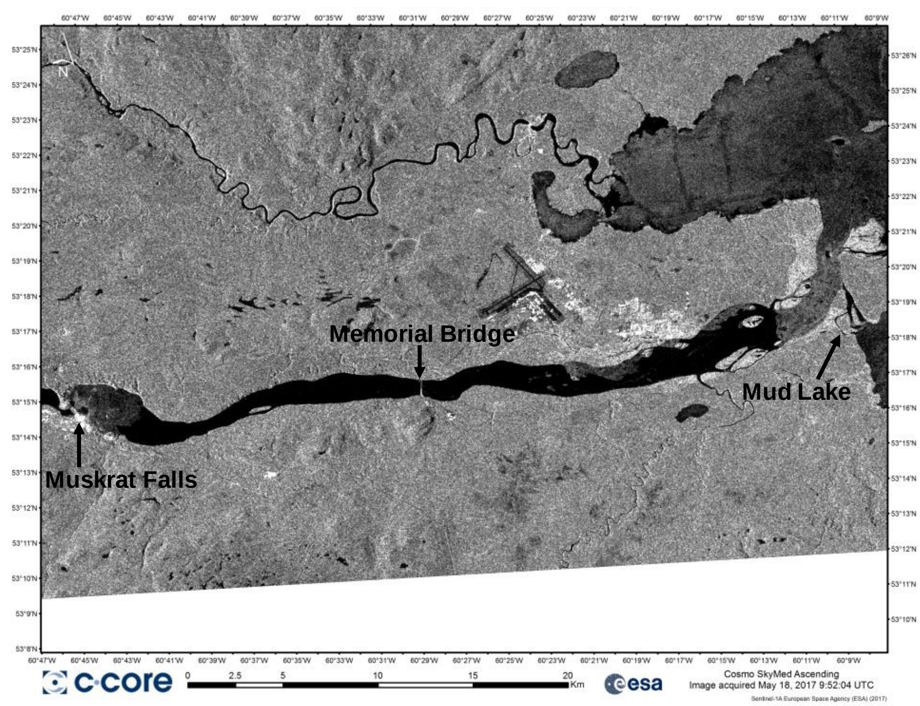


Figure 4-25: Satellite Image Showing Ice Configuration on May 18

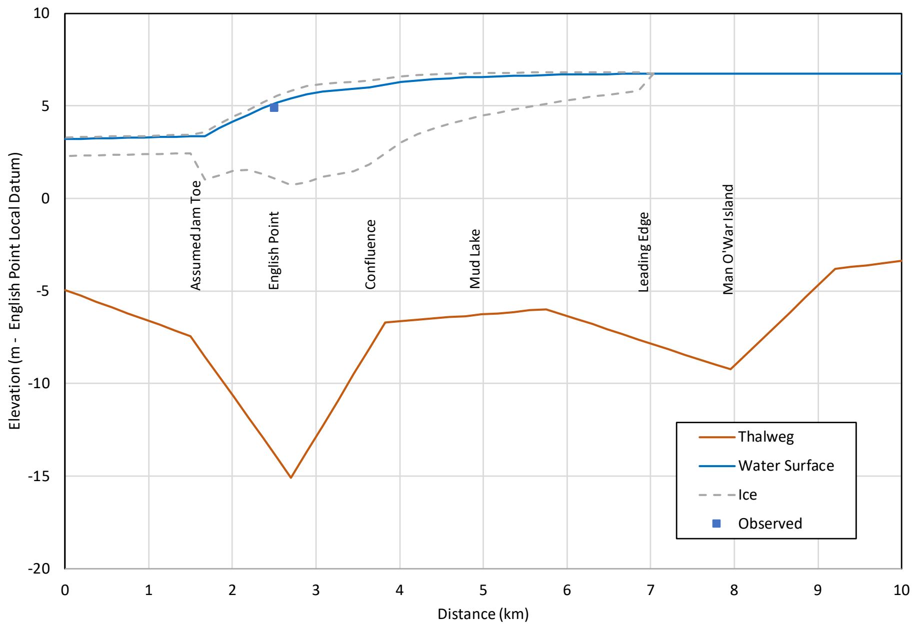


Figure 4-26: HEC-RAS Simulated 2017 Ice Jam Profile (May 19 peak)

4.4 Comparison of 2012 and 2017 Events

As noted above, the two most significant ice jam events noted within the historical record occurred in 2012 and in 2017 respectively – approximately 5 years apart. Of the two events, the 2017 ice jam event produced higher water levels at the English Point hydrometric station. Given the similar nature of each event, it was of interest to compare the two more closely to understand what processes may have contributed to the higher stage increases observed in 2017.

To aid in this comparison, **Table 4-1** has been prepared to summarize some of the key characteristics of each event, and **Figure 4-27** and **Figure 4-28** were prepared to compare the water levels and flows associated with each event. Finally, **Figure 4-29** compares photographs taken from similar vantage points during the two different flood events. Of interest, the water levels in the two photographs appear to be very similar.

Table 4-1: Comparison of 2012 and 2017 Ice Jam Events

No.	Description	2012	2017
1	Goose Bay Ice Thickness at end of April (m)	0.65	0.94
2	Estimated river flow at time of ice jam (m^3/s)	3750	4300
3	Approximate ice cover jam length (km)	5 km	5.5 km
4	Date of first ice jam	May 16	May 16
5	Peak instantaneous level at English Point WSC (m)	4.0	4.9
6	Average temperature last two weeks in April (degrees C)	+0.4	-2.7
7	Average temperature first two weeks in May (degrees C)	+4.6	+4.7
8	Location of ice front on May 15th (km downstream of Muskrat Falls)	20	13

Upon comparing these two events, in our opinion, it is quite understandable why the water levels in 2017 may have exceeded those experienced during the earlier 2012 jam event. The primary reasons for this are as follows:

- End of winter Goose Bay ice thickness: The predicted Goose Bay ice thickness was quite different for the two events. In 2012 the ice growth was limited due to the presence of a deeper and earlier snow pack. The ultimate ice thickness was estimated to be approximately 65 cm, which is typical of most winters. The 2017 ice thickness was estimated to be 94 cm, which is a 1 in 20-year ice thickness. The presence of this very thick ice cover at the end of winter in 2017 would not only increase the risk of a jam event occurring once the river ice mobilized, it would also influence the severity of the jam (since the mobilized river ice would also be thicker and more competent). The increased load bearing capacity of the thicker Goose Bay lake ice would have allowed the jam to remain in place under greater spring runoff flows, which it did.
- Antecedent conditions: The weather conditions leading up to the 2012 event and the 2017 event were quite different, particularly during the month of April. The end of April in

2012 was quite warm, and therefore there was some early degradation of the ice cover thickness both on Goose Bay and on the lower Churchill river ice. Because of this, and given the reduced ice thickness on Goose Bay (discussed in the preceding bullet), the load bearing capacity of the cover had likely dropped significantly just prior to the jam. In contrast to this, in 2017 the region experienced a colder than average April. This caused a delay of the melt and ripening of the snowpack, and less degradation of the Goose Bay ice cover (as shown in **Figure 2-4**).

- River flows at breakup: In 2012, the peak flow at the time of the jam event was estimated to be approximately 3750 m^3/s. Although flows continued to rise above this in subsequent days, the weaker ice cover (both in the jam and on Goose Bay) was not robust enough to withstand the increasing hydraulic forces that were being applied to the jam by the rising flow. The jam released shortly after it formed. In 2017, the runoff associated with the spring freshet occurred over a considerably more concentrated period during the first two weeks in May. The quick increase in runoff did not allow the cover to degrade thermally to the same extent that it did in 2012 prior to jam formation. Since the cover was stronger, it was also able to withstand higher freshet flows during the jam event. In 2017, the jam was estimated to form at a flow of between 4300 and 4600 m^3/s. Jam formation at these higher flows would lead to higher peak stages.

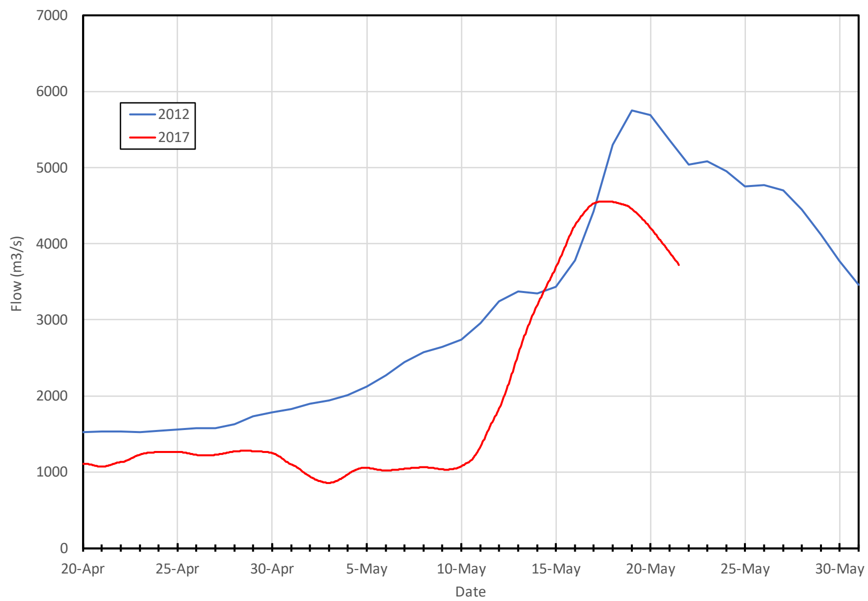


Figure 4-27: Comparison of 2012 and 2017 River Flows

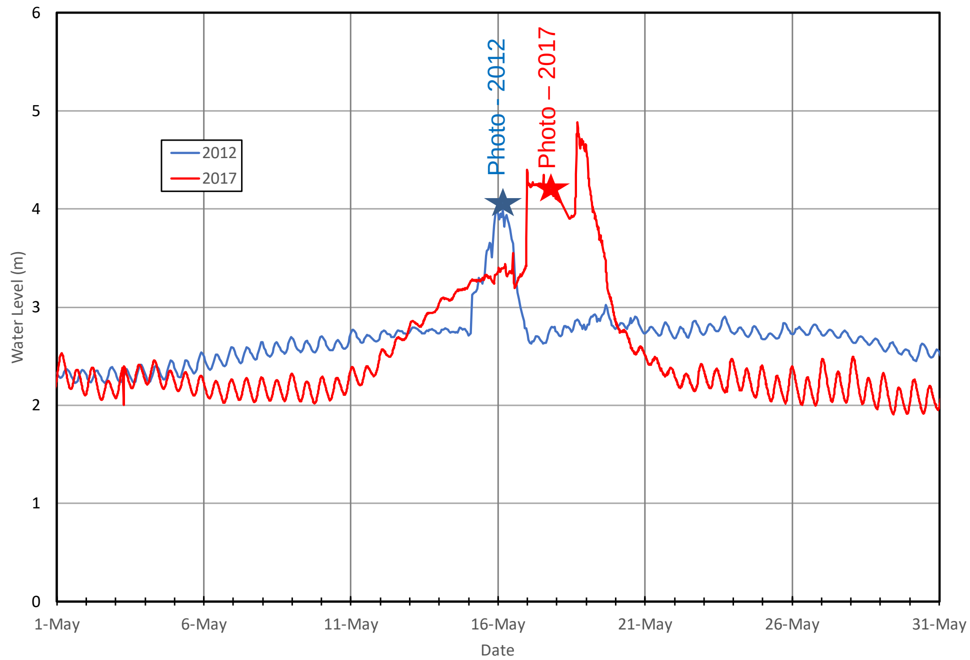
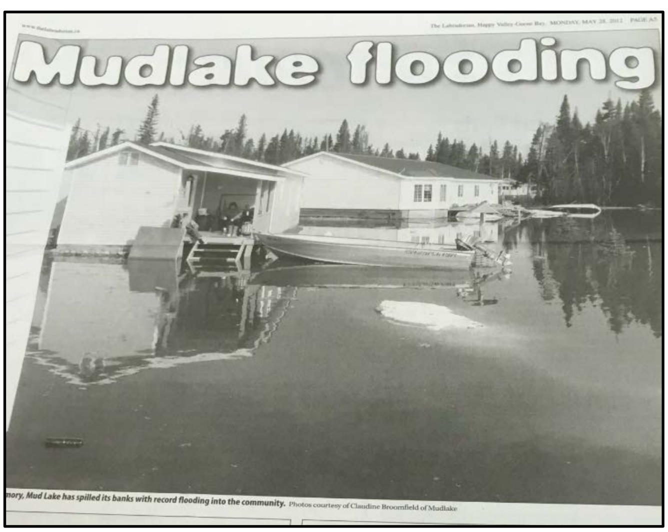


Figure 4-28: Comparison of 2012 and 2017 Water Levels – English Point

* Note photo times are approximate only



a) 2012 **b) 2017**

Figure 4-29: Comparison of 2012 and 2017 Photos

5. Discussion on Muskrat Falls Operation

As noted earlier, the archival review has indicated that ice jams have formed a number of times in the past at the mouth of the lower Churchill River. These ice jams have led to sudden increases in water level, that have in turn led to flooding along this reach of the lower Churchill River, most recently and notably in 2012. Because of these precedents, it is considered to be a naturally occurring phenomenon in this area. This is not an uncommon situation, and is caused by the presence of a strong lake type of ice at the outlet to the river. If this ice is very competent, and has a good load bearing capacity, it can often create an initiation point for a jam of mobilized river ice. The severity of the jam is a function of the river flow at the time of the event, and the nature of the ice in the river and on Goose Bay.

In 2017, the Goose Bay ice was likely very thick, and with the cold temperatures which persisted throughout the month of April, the cover likely maintained a strong load bearing capacity throughout the first few weeks of May when the jam occurred. This would have heightened the risk of ice jam formation this spring. In addition, the meteorological conditions this spring resulted in a very rapid runoff event, which also would have exacerbated or heightened the risk of jam formation. This is demonstrated indirectly by comparing the estimated snowmelt and rainfall totals in 2017 with the precedent chart shown in **Figure 3-9**. Therefore, it is judged that the 2017 ice jam event was a natural occurrence, and would have been at risk of forming with or without the presence of the Muskrat Falls project.

However, since the Muskrat Falls project was in operation at the time of the event, one must also consider if (or how) operation of the project's spillway could have contributed to the severity of the jam. With this in mind, the project's operations during 2016/17 were reviewed and are discussed below.

5.1 Release of Reservoir Storage in November

It has been speculated by others that the sudden release of storage in November to aid in cofferdam remediation measures may have helped to initiate the spring event by affecting initial ice formation processes. This led to a sudden but temporary increase in flow in the downstream reach just prior to the ice formation period. As a part of this study, this scenario was reviewed.

As noted earlier, the reduction in the project forebay level took place from November 18th to November 20, and released approximately 100 million m^3 of storage from the upper reservoir. This temporarily increased flows above their base hourly levels by up to 2500 m^3/s. This release was done in a controlled manner, with an intention to minimize any impact on levels in sensitive areas such as Mud Lake. As noted earlier in **Figure 4-5**, water levels at the WSC gauge located 6 km downstream of the project were seen to rise by approximately 1 m at the peak flow release, and there was no significant or discernable impact on the recorded water levels in the Mud Lake area. At the English Point hydrometric station the impact was somewhat masked by the natural tidal fluctuation, but it is estimated that the impact was unlikely to be more than a 20 cm increase in water level at this downstream location. Water levels and flow rates in the river returned to their normal conditions shortly after the water was released from the reservoir (within 2 days of first release). This is demonstrated in **Figure** 4-7**,** which shows the daily average water level recorded at the English Point hydrometric station in 2016 along with the water levels associated with past freeze-up events.

It is important to note that ice formation on the lower Churchill River and Goose Bay area had not yet started at the time of the reservoir release. As noted in Section 4, temperature records and satellite imagery suggest the river remained free of ice until at least November 24, 2016. The water level records indicate ice cover formation and advancement did not begin until November 28. Therefore, the release of water from the Muskrat Falls reservoir preceded the river freeze up by 10 days and water levels remained within the typical historical range during that 10-day period prior to freeze up.

Given that i) the release did not significantly affect water levels in the Mud Lake area, and ii) the release predated the ice formation period by 10 days, it is very unlikely that this release of water would have had any bearing or impact on the early ice formation processes.

5.2 Drawdown of Reservoir in Early May

The reservoir level for the Muskrat Falls project was gradually reduced from el. 22.5 m down to approximately el. 21.5 m over a 12-day period extending from April 30 to May 11. This action was taken in advance of the spring freshet to bring the reservoir level down to the lower limit of this winter's operating range, and thereby provide an additional buffer for operators to work within when passing the freshet. As shown on the project's stage-storage curve in **Figure 4-14**, this operation released approximately 48 million m^3 of storage. The flow releases at the Muskrat Falls project are shown on **Figure 5-1**, and also shown is the expected natural outflow hydrograph at the site for this spring (i.e., the simulated trace without regulation by Muskrat Falls). The latter trace represents a back-calculated hydrograph showing what natural flows at the site would most likely have been had the project not been in place. It was estimated by:

- Back-calculating inflows to the reservoir, based on recorded hourly reservoir levels and the recorded Muskrat Falls spillway outflow.
- These back-calculated inflows were then routed dynamically through an existing HEC-RAS model to estimate what the natural flows at the project site would have been this spring. The HEC-RAS model had been set up as a part of previous initiatives to represent the pre-project, or natural condition.

On this figure, one can see that river flows were increased by, on average, approximately 55 m^3/s above the natural inflows during the drawdown period. Daily flow increases ranged from 30-100 m^3/s greater than natural flows would have been during the water level reduction. This increase in flow equates to about 5% of the pre-breakup flow, and a stage increase of no more than 0.2 to 0.3 m in downstream levels at WSC gauge 03OE014. This drawdown operation also predated the actual jam event by approximately 5 days. Given the approximately 12-hour travel time from Muskrat Falls to Goose Bay, these additional flows would have passed through the downstream reach well before the occurrence of the actual jam event. It is noted that over the course of the subsequent operation, the forebay level appears to drop by an additional 0.1 m over the last few days leading up to breakup – from May 12 through to May 15. This would have released approximately 7 million m^3 of additional storage (on top of natural flows), and would equate to an average increase in discharge of 27 m^3/s, or about 0.8% of the incoming flows on the Churchill River at the time of the jam event – a negligible increase.

Following the initial drawdown operation, operators worked diligently to maintain the project forebay within a relatively tight 0.2 m range despite the rapidly rising flows. At times inflows were increasing quickly, and to match the high inflow rate, relatively large gate operations were required to match the steeply rising curve. Two of the largest gate movements occurred on May 13 and 14, the steepest period of the freshet hydrograph in which inflows were rising at a rate of approximately 900 m^3/s per day. The relatively rapid increase did not appear to adversely affect the downstream cover, and in fact the downstream cover did not show any signs of mobilizing until almost 3 days later, after water levels upstream of the Veteran's Memorial bridge had risen by almost 3 m above their starting level. Given that the cover in this area was likely no more than 1 to 2 m in thickness at the beginning of the event, it was this stage increase that likely led to a loss in bank resistance, and eventual movement downstream of the cover.

Figure 5-2 summarizes expected flows at the jam location near English Point in 2017 for two scenarios: i) the "post project" condition this spring (including all Muskrat Falls gate operations), and ii) the natural or "pre-project" condition. Each of these two hydrographs was simulated using the HEC-RAS model described earlier. By comparing the red (post project) and the blue (pre-project) traces on this plot, it is possible to assess the magnitude of impact that the gate operations at Muskrat Falls may have had on flows and water levels at the jam location. The difference between the two lines presents the overall magnitude or impact of gate operations on flow conditions in passing this year's freshet. As shown, the difference between these two lines was quite small, particularly during the ice jam formation period.

Given these considerations, it is our opinion that the operation of the Muskrat Falls project during this year's spring freshet did not adversely impact the stability of the downstream ice cover before or during the jam event.

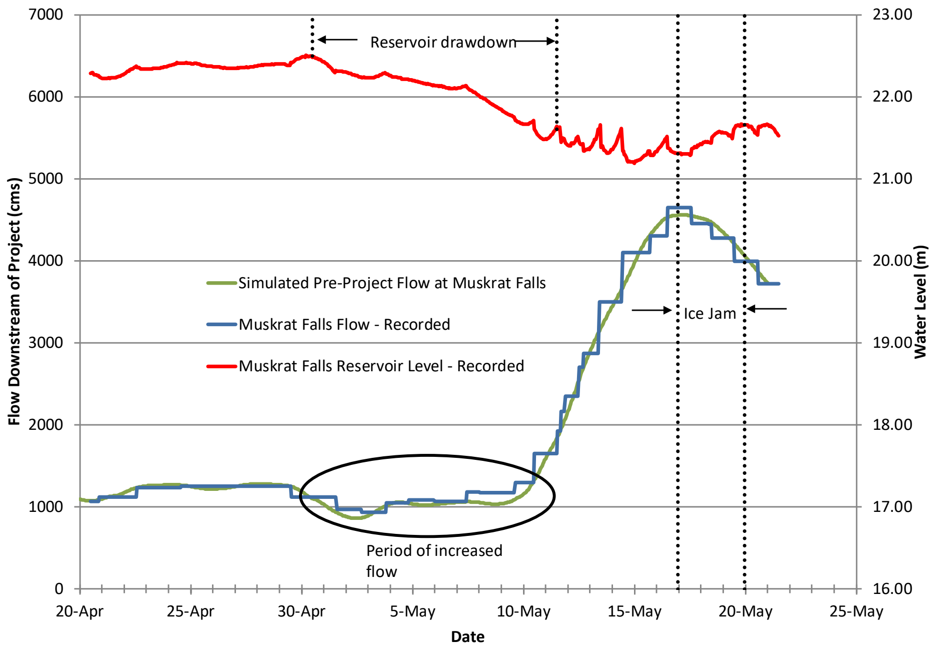


Figure 5-1: Summary - Release of Upstream Storage in Early May

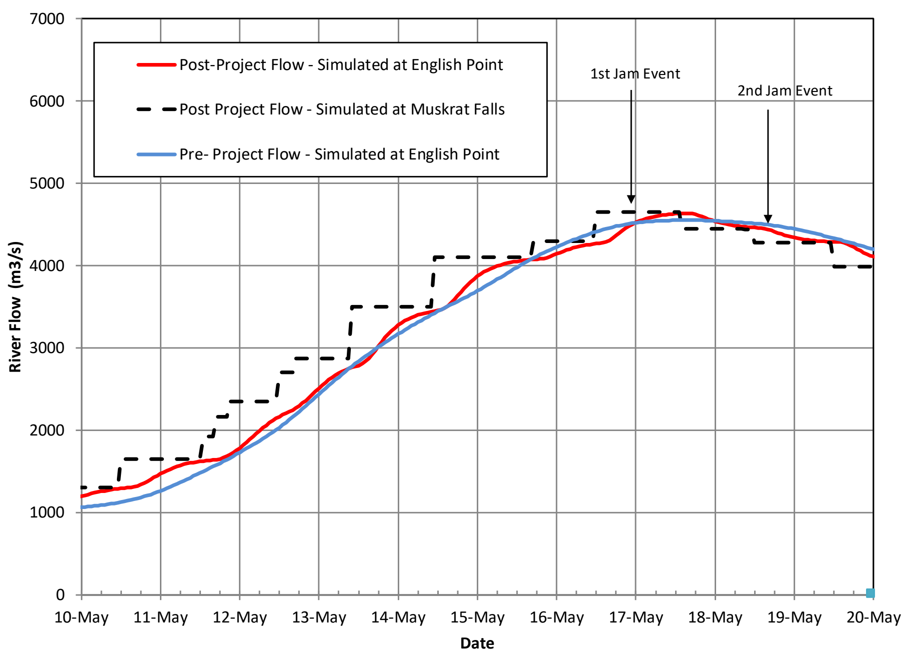


Figure 5-2: Comparison of Flow Hydrographs at English Point

5.3 Passage of Upstream Ice Cover

As noted earlier, on approximately May 11, or 5 days prior to the jam event, the ice cover upstream of the Muskrat Falls site mobilized and began to pass through the Muskrat Falls spillway. This migration of upstream ice actually occurs each year at about this time as the large border ice strips, which typically form in the upstream reach, begin to break off due to increasing flows/water levels associated with the spring freshet. This year; however, the ice cover volume was increased marginally since a juxtaposed cover was able to form and advance up the river in between the two strips of border ice growth that had formed along each bank. This did not occur until mid February, and this juxtaposed cover then began to grow thermally, likely reaching a thickness of only 0.2 m or so by winter's end. Because it was much thinner, the ice had likely begun to degrade just prior to its release, and was reduced to small pieces and chunks in the very turbulent flow of the spillway. **Figure 4-21** shows a photo of the area immediately downstream of Muskrat Falls after the release of the upstream cover, and the remnants of any ice sheets passing through the spillway can be clearly seen. This release of this ice predated the downstream ice jam event by 5 to 6 days. The added volume due to the formation of the juxtaposed cover was likely no more than 2 million m^3.

In reviewing the water level traces at the downstream WSC gauges on **Figure 4-24,** there is no dramatic, or even discernable jump or response to the passing ice floes on May 11 – only the steady rise in levels caused by the increasing spring flows. There is a good reason for this – it is expected that almost all of the upstream ice passing through the spillway this spring would have simply become deposited within the massive ice dam in the area immediately downstream of the project and did not travel as far as the WSC gauge. This ice dam has a very large capacity to store incoming ice volumes. Although the ice dam began forming this winter as it normally does, its growth was abruptly curtailed after the upstream cover formed in mid February, cutting off the supply of ice to the dam. Water level stages downstream immediately dropped. Since the ice dam was not saturated, it was almost certainly able to absorb the incoming ice volumes this spring. In addition, as noted earlier, the volume of ice contained in the downstream cover was more than sufficient to supply the ice dam this spring.

Given these considerations, the release of additional forebay ice this spring is not considered to have contributed to the downstream ice jam event.

6. Summary and Conclusions

The 2017 flood event has been reviewed based on available historical documentation, site observations, and through application of the HEC-RAS model. The assessment has resulted in the following findings:

- A search of available newspaper articles has indicated that ice jams have occurred at the outlet of the lower Churchill River into Goose Bay on a number of occasions. Over the period from 1976 to present (42 years), spring ice jams have been reported in 9 different years: 1976, 1978, 1983, 1986, 1998, 2000, 2001, 2012 and now in 2017. Although the 2017 jam event resulted in high water levels in the Mud Lake community, jam events in other years have also been high (e.g., 2012)
- The geographic features of the site lend itself well to this sort of dynamic ice breakup event. The thickness and competency of the ice cover on Goose Bay will have a direct impact on jamming potential at the exit of the Churchill River into the larger water body of Goose Bay. If there is a strong, competent ice cover at the outlet with a good load bearing capability, this is a natural location for moving river ice to suddenly lodge, and for jam initiation to occur. Rivers with relatively flat slopes, like that of the lower Churchill River downstream of Muskrat Falls, are particularly susceptible to this type of event.
- The occurrence and severity of any jam at this location is also governed by the timing and magnitude of the spring flow relative to competence of the ice cover (competence dependent on temperature of the ice i.e. progression of the melt). A simple nomograph has been proposed in this study to help evaluate the potential for an ice jam to occur on the lower Churchill River based on meteorological inputs. The nomograph tracks the accumulated snowmelt/rainfall in a reach and identifies high risk jam years based on these accumulated totals.
- In 2017, there were a number of natural factors that contributed to the ice jam event. The two most significant factors include:
  - Low snow packs in the early part of the winter, which then led to the formation of a very thick ice cover in Goose Bay (estimated to be 0.94 m thick at its peak). This ice cover maintained a considerable load bearing capacity into the spring period and provided a good, strong lodging point for any mobilized river ice flows.
  - Cold spring temperatures which persisted through most of April, were followed by a very rapid warming spell in early May. This resulted in a very concentrated runoff period and rapidly rising inflows. The resulting runoff hydrograph therefore reached its peak before significant degradation of the Goose Bay ice cover could take place.

- Ice jam formation was also noted on a nearby tributary to the Churchill River in 2017 (McKenzie River) and an adjacent river (Goose River), indicating that this was a naturally occurring, regional phenomenon. Neither river system would be impacted by events on the lower Churchill River.
- The historic occurrences, characteristic ice breakup/mobilization behavior, and ice jam modeling strongly indicate that the 2017 jam was a natural phenomenon. The ice jam would have been at risk of forming with or without the presence of the Muskrat Falls project.
- Since the Muskrat Falls project was in operation at the time of the event, the team also considered if (or how) operation of the project's spillway could have in some way contributed to the severity of the jam. That review did not find any link between the reservoir operation at Muskrat Falls and the formation of the jam.

Key conclusions arising from this review include:

- There is a pre-existing risk of ice jam formation on the Churchill River. This is supported by the historical record of past ice events, and the physical characteristics of the Churchill River where it flows into Goose Bay.
- The historical occurrences, characteristic ice breakup/mobilization behavior, and ice jam modeling strongly indicate that the 2017 ice jam was a natural phenomenon that would have occurred this year regardless of whether the Muskrat Falls project was operating.
- The operation of the Muskrat Falls facility did not increase the severity of the ice jam event.
- The magnitude of water level increase in 2017 was the result of the combination of an intense runoff period and a very thick and competent ice cover on Goose Bay.

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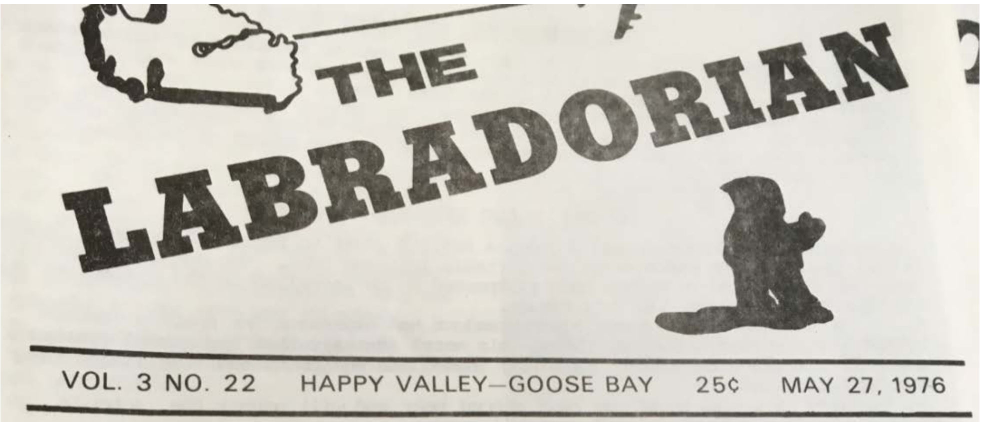
Appendix A
Historic Review of Ice Jams on the Lower Churchill River and Goose River

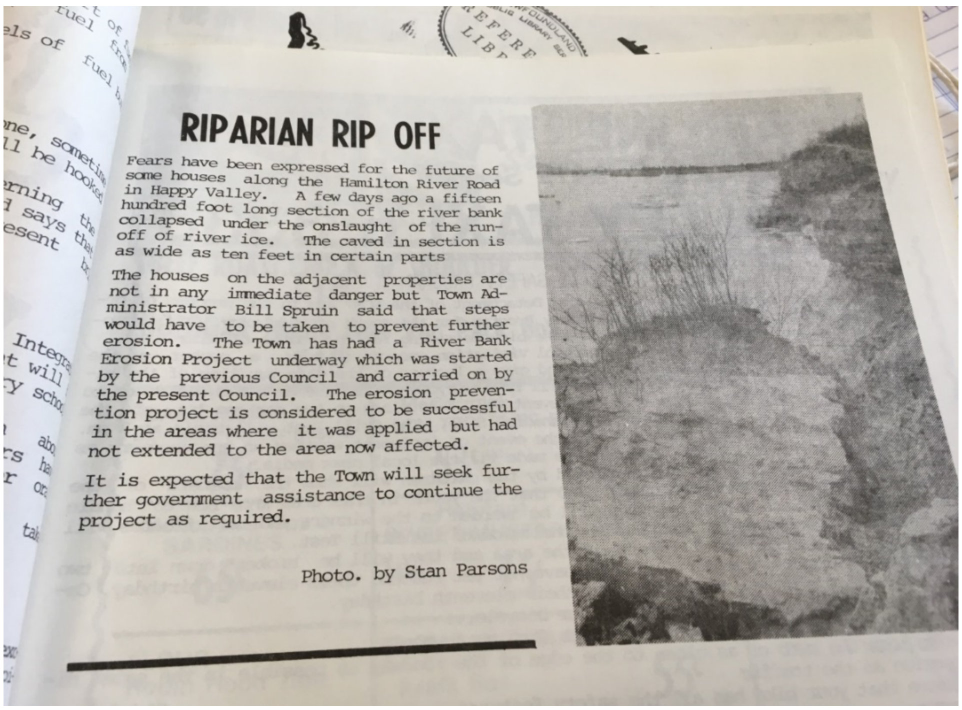
Nalcor Energy - Lower Churchill Project
Examination of 2017 Ice Jam Event
H354838

The Labradorian - May 27, 1976



THE LABRADORIAN

VOL. 3 NO. 22 HAPPY VALLEY—GOOSE BAY 25¢ MAY 27, 1976



RIPARIAN RIP OFF

Fears have been expressed for the future of some houses along the Hamilton River Road in Happy Valley. A few days ago a fifteen hundred foot long section of the river bank collapsed under the onslaught of the run-off of river ice. The caved in section is as wide as ten feet in certain parts

The houses on the adjacent properties are not in any immediate danger but Town Administrator Bill Spruin said that steps would have to be taken to prevent further erosion. The Town has had a River Bank Erosion Project underway which was started by the previous Council and carried on by the present Council. The erosion prevention project is considered to be successful in the areas where it was applied but had not extended to the area now affected.

It is expected that the Town will seek further government assistance to continue the project as required.

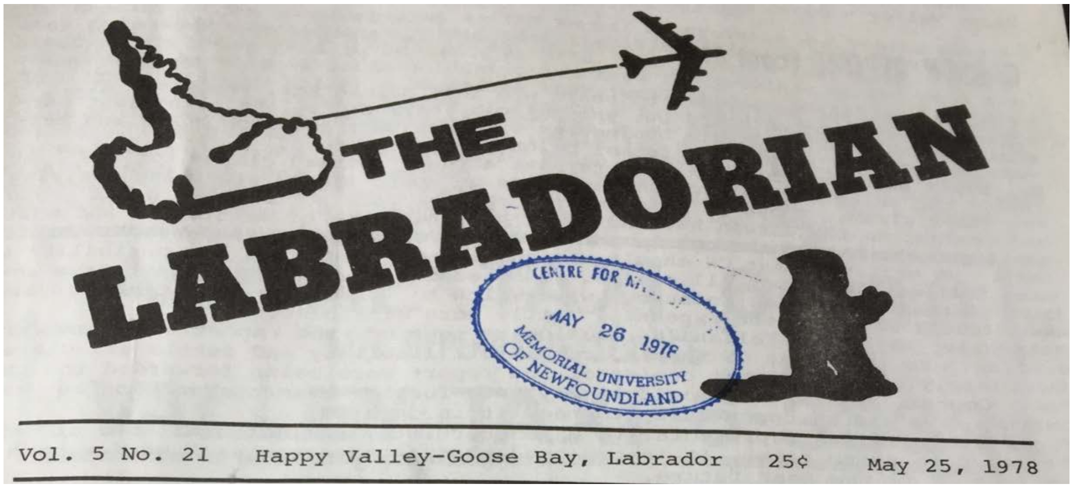
Photo. by Stan Parsons

Riparian Rip Off

In late May of 1976, a fifteen-hundred-foot-long section of the river bank along Hamilton River Road in Happy Valley collapsed because of the movement of the river ice.

Prior to the event, the town had implemented a river bank erosion prevention project which had been successful in the areas where it was applied however the program had not been extended to the area that collapsed. Fears were expressed for houses along Hamilton River Road however there was no damage to the properties adjacent to the collapsed section of the river bank.

The Labradorian – May 25, 1978



RIVER BANKS FLOODED

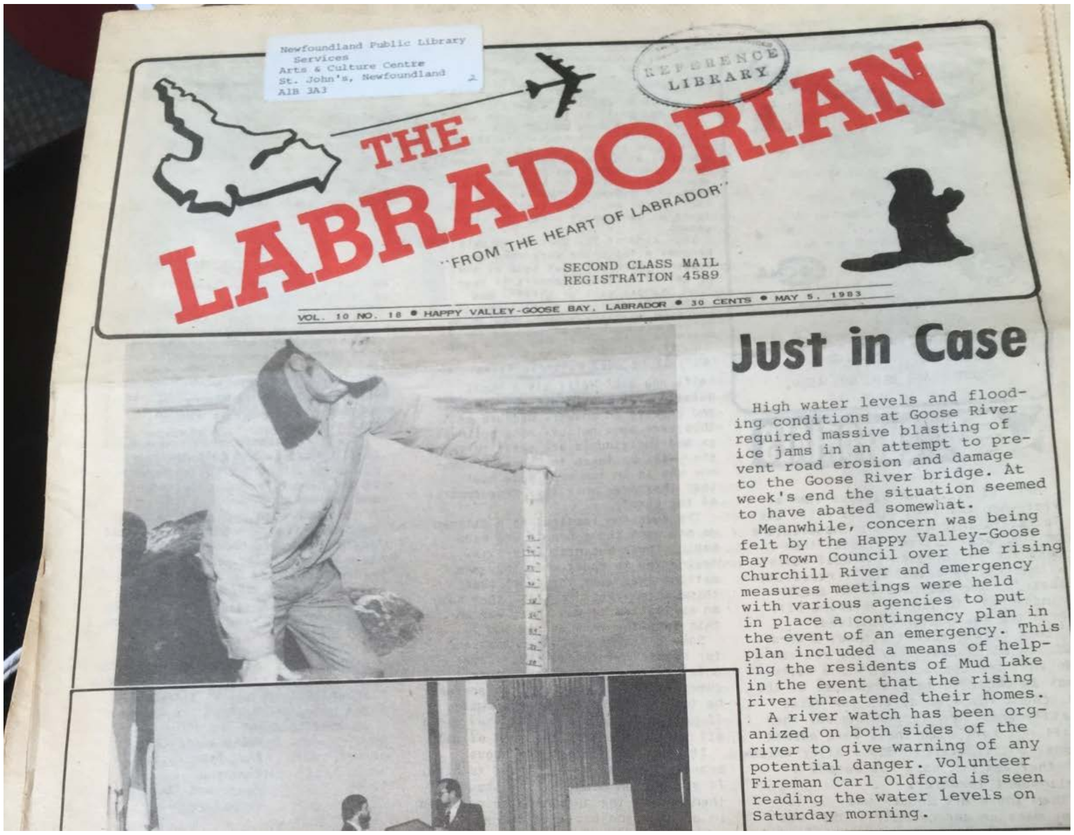
Spring run-off and ice congestion resulted in flooding conditions along the banks of the Churchill River in Happy Valley the past weekend and, up to Tuesday evening, the conditions still existed.
The Birch Island road from the area of the Town Garage to the Pump House on the Island was completely under water and has washed away. The road to the MOT Pump House at the bottom of the hill was also mostly under water and the exact damage to the road could not be determined.
There were several boats located on Birch Island and some were apparently, swept away by the flood. Other boat owners were able to get to the Island in boats and rescue their craft.
The Telecommunications Branch of MOT have a transmitter building down this road and the water reached a depth of 14 to 15 inches inside the building. Area maintenance Supervisor, Gerry Croucher said that most all of the equipment was kept "on the air" despite the flooding but technicians had to use a canoe to get to the site. He said that the marine transmitters had not yet been turned on for the navigation season but had they been in use, they would have been forced out of operation by the flooding. The water level in the building had receded by Tuesday but a canoe was still required to get to the building.
It was reported that a boat also had to be used for men to get to the MOT pumphouse, also down the same road. The exact extent of the flood damage, cannot be determined until water levels drop. It is expected that the erosion of the river bank will be even more extensive than anticipated because of the unusually high water levels.

River Banks Flooded

In late May of 1978, the river banks along the Churchill River experienced flooding conditions which lasted several days due ice build-up and spring run-off. An area along the Birch Island Road was completely underwater and had washed away, while the Communications Branch of the MOT experienced 14 to 15 inches of water inside of the transmitter building and was only accessible by canoe. Several boats were swept away by the flood. Water levels had not yet dropped and the extent of damage was undetermined on the date that the article was printed. The erosion of the river bank was expected to be extensive because of the unusually high water levels.

HATCH

The Labradorian – May 5, 1983



THE LABRADORIAN

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VOL. 10 NO. 18 • HAPPY VALLEY-GOOSE BAY, LABRADOR • 30 CENTS • MAY 5, 1983

Just in Case

High water levels and flooding conditions at Goose River required massive blasting of ice jams in an attempt to prevent road erosion and damage to the Goose River bridge. At week's end the situation seemed to have abated somewhat.

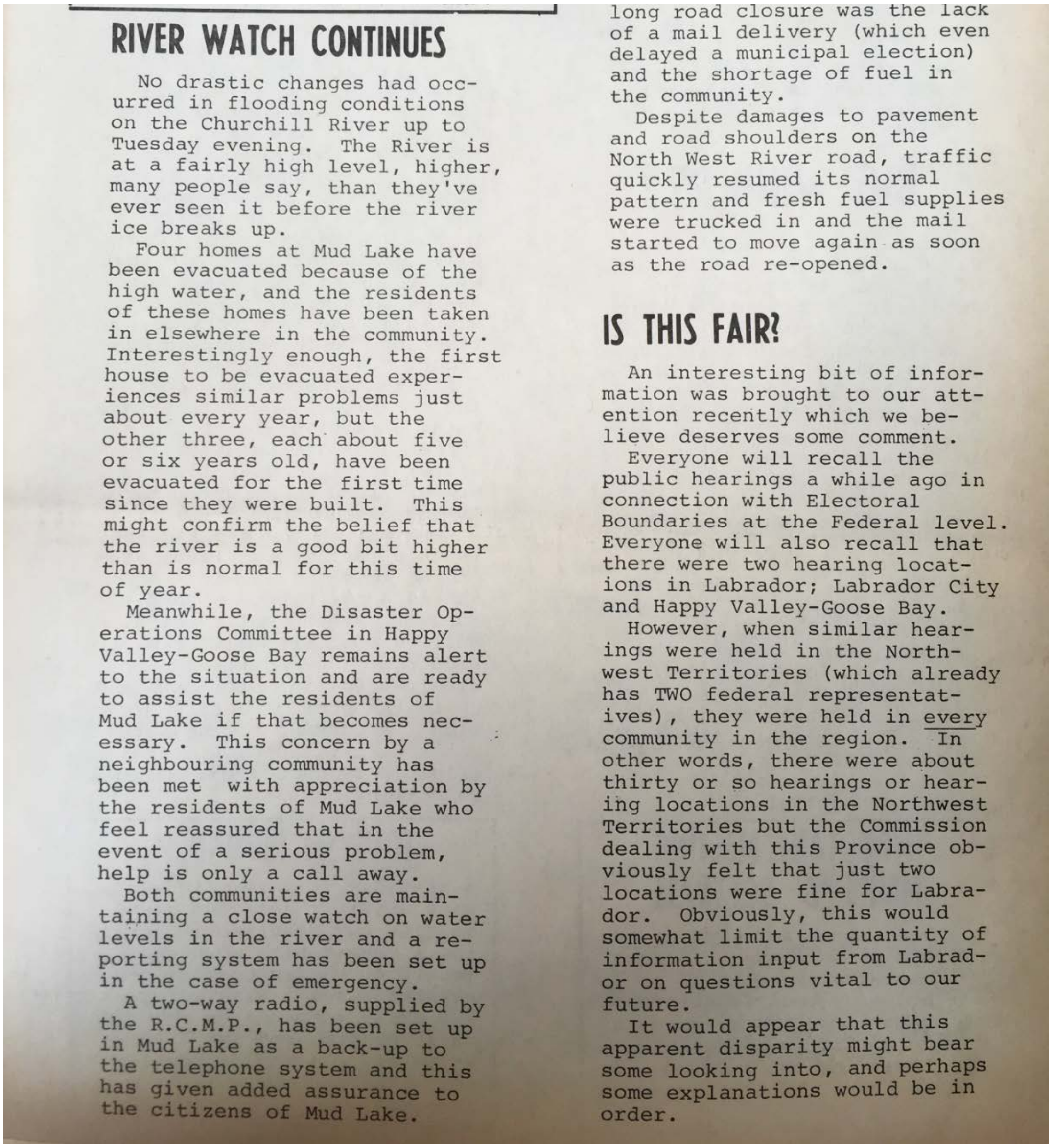
Meanwhile, concern was being felt by the Happy Valley-Goose Bay Town Council over the rising Churchill River and emergency measures meetings were held with various agencies to put in place a contingency plan in the event of an emergency. This plan included a means of helping the residents of Mud Lake in the event that the rising river threatened their homes.

A river watch has been organized on both sides of the river to give warning of any potential danger. Volunteer Fireman Carl Oldford is seen reading the water levels on Saturday morning.

Just in Case

In early May of 1983, flooding conditions were observed at Goose River which required massive blasting of the ice jam to prevent damage to the Goose River Bridge and erosion of the road. Emergency measures meetings were held by the Happy Valley-Goose Bay town council and various agencies to put in place a contingency plan which included a means of helping residents of Mud Lake if flood conditions threatened their homes.

The Labradorian – May 5, 1983 Continued



RIVER WATCH CONTINUES

No drastic changes had occurred in flooding conditions on the Churchill River up to Tuesday evening. The River is at a fairly high level, higher, many people say, than they've ever seen it before the river ice breaks up.

Four homes at Mud Lake have been evacuated because of the high water, and the residents of these homes have been taken in elsewhere in the community. Interestingly enough, the first house to be evacuated experiences similar problems just about every year, but the other three, each about five or six years old, have been evacuated for the first time since they were built. This might confirm the belief that the river is a good bit higher than is normal for this time of year.

Meanwhile, the Disaster Operations Committee in Happy Valley-Goose Bay remains alert to the situation and are ready to assist the residents of Mud Lake if that becomes necessary. This concern by a neighbouring community has been met with appreciation by the residents of Mud Lake who feel reassured that in the event of a serious problem, help is only a call away.

Both communities are maintaining a close watch on water levels in the river and a reporting system has been set up in the case of emergency.

A two-way radio, supplied by the R.C.M.P., has been set up in Mud Lake as a back-up to the telephone system and this has given added assurance to the citizens of Mud Lake.

long road closure was the lack of a mail delivery (which even delayed a municipal election) and the shortage of fuel in the community.

Despite damages to pavement and road shoulders on the North West River road, traffic quickly resumed its normal pattern and fresh fuel supplies were trucked in and the mail started to move again as soon as the road re-opened.

IS THIS FAIR?

An interesting bit of information was brought to our attention recently which we believe deserves some comment.

Everyone will recall the public hearings a while ago in connection with Electoral Boundaries at the Federal level. Everyone will also recall that there were two hearing locations in Labrador; Labrador City and Happy Valley-Goose Bay.

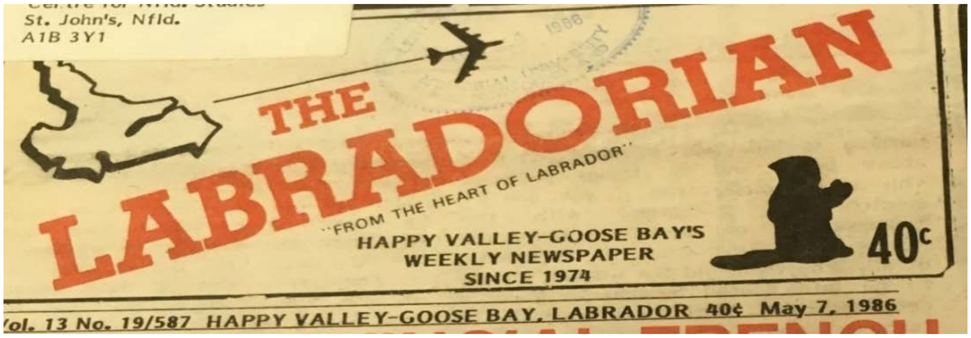
However, when similar hearings were held in the Northwest Territories (which already has TWO federal representatives), they were held in every community in the region. In other words, there were about thirty or so hearings or hearing locations in the Northwest Territories but the Commission dealing with this Province obviously felt that just two locations were fine for Labrador. Obviously, this would somewhat limit the quantity of information input from Labrador or on questions vital to our future.

It would appear that this apparent disparity might bear some looking into, and perhaps some explanations would be in order.

River Watch Continues

Flooding conditions were believed to be higher than ever seen before the river ice breaks up. In Mud Lake, four houses were evacuated due to the increased water levels. The first house evacuated experiences similar problems just about every year. The other three houses had been evacuated for the first time since they were built about 5 or 6 years prior. A Disaster Operations Committee in Happy Valley-Goose Bay maintained a close watch on the water levels in the event that Mud Lake required assistance.

The Labradorian – May 7, 1986



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THE LABRADORIAN
"FROM THE HEART OF LABRADOR"
HAPPY VALLEY-GOOSE BAY'S
WEEKLY NEWSPAPER
SINCE 1974
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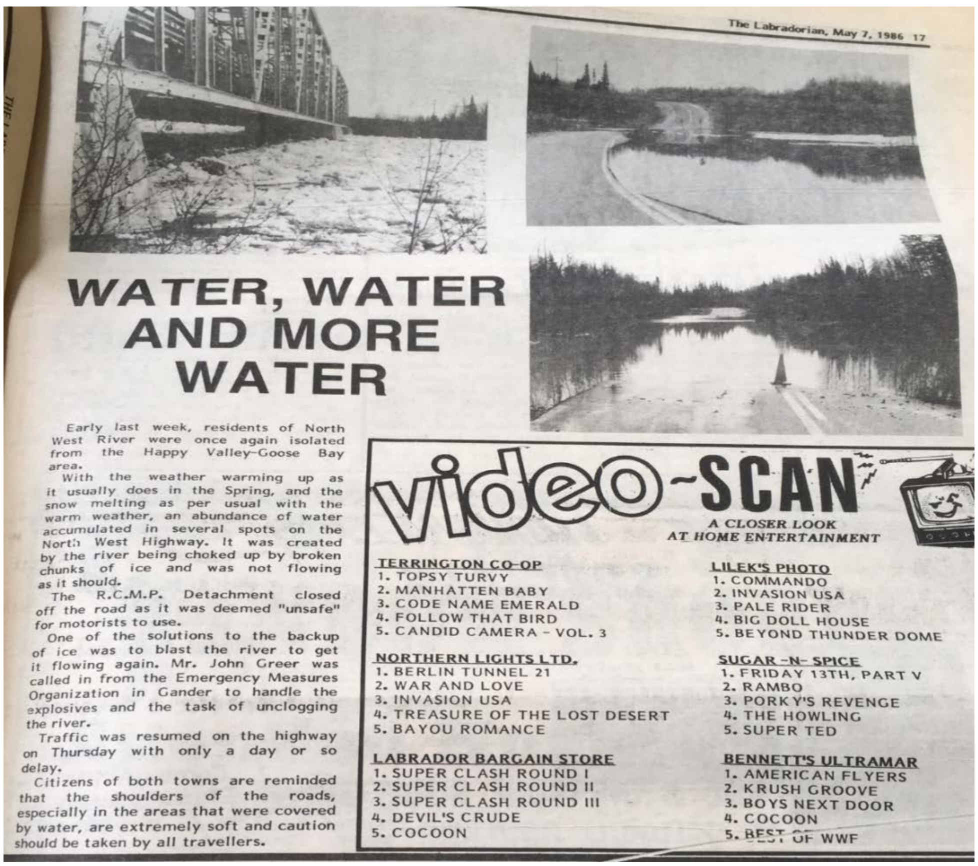
Vol. 13 No. 19/587 HAPPY VALLEY-GOOSE BAY, LABRADOR 40¢ May 7, 1986



The Labradorian, May 7, 1986 17

WATER, WATER AND MORE WATER

Early last week, residents of North West River were once again isolated from the Happy Valley-Goose Bay area.

With the weather warming up as it usually does in the Spring, and the snow melting as per usual with the warm weather, an abundance of water accumulated in several spots on the North West Highway. It was created by the river being choked up by broken chunks of ice and was not flowing as it should.

The R.C.M.P. Detachment closed off the road as it was deemed "unsafe" for motorists to use.

One of the solutions to the backup of ice was to blast the river to get it flowing again. Mr. John Greer was called in from the Emergency Measures Organization in Gander to handle the explosives and the task of unclogging the river.

Traffic was resumed on the highway on Thursday with only a day or so delay.

Citizens of both towns are reminded that the shoulders of the roads, especially in the areas that were covered by water, are extremely soft and caution should be taken by all travellers.

video~SCAN
A CLOSER LOOK
AT HOME ENTERTAINMENT

TERRINGTON CO-OP
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3. CODE NAME EMERALD
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4. TREASURE OF THE LOST DESERT
5. BAYOU ROMANCE

LABRADOR BARGAIN STORE
1. SUPER CLASH ROUND I
2. SUPER CLASH ROUND II
3. SUPER CLASH ROUND III
4. DEVIL'S CRUDE
5. COCOON

LILEK'S PHOTO
1. COMMANDO
2. INVASION USA
3. PALE RIDER
4. BIG DOLL HOUSE
5. BEYOND THUNDER DOME

SUGAR -N- SPICE
1. FRIDAY 13TH, PART V
2. RAMBO
3. PORKY'S REVENGE
4. THE HOWLING
5. SUPER TED

BENNETT'S ULTRAMAR
1. AMERICAN FLYERS
2. KRUSH GROOVE
3. BOYS NEXT DOOR
4. COCOON
5. BEST OF WWF

Water, Water and More Water
In early May of 1986, the North West Highway experienced areas of water accumulation due to the warmer temperatures and the river being choked with large pieces of ice. The RCMP deemed the North West Highway as 'unsafe' and closed the road, which isolated residents of North West River from Happy Valley-Goose Bay. Explosives were used to blast the backup of ice in the river. The Emergency Measures Organization was called in from Gander to handle the explosives and unclog the river.

The Labradorian – May 18, 1998

The Labradorian
VOL. 25 NO 20 MONDAY, MAY 18, 1998 $1.25 (HST included)

Churchill overflows banks

- Tense Moments For Convenience Store Owner -

Ramsey White, owner of T&R Marina at 1 Hamilton River Road, waits patiently to see if the shore of the Churchill River will rise, and cause any further damage to his business. Within 24 hours, the river went back down to normal levels. See more photos on Page 4.

(Keats photo)

By BRAD KEATS
The Labradorian

The T&R Marina convenience store/gas bar was still located at 1 Hamilton River Road at press time Thursday.

The threat that the Happy Valley-Goose Bay business might be submerged by a rising Churchill River subsided last Tuesday, as the mighty river's shoreline receded gradually from the store's parking lot.

While owner Ramsey White was still concerned Thursday, it looked as if the river was continuing to drop.

"It looks like it's keeping on going back, but it could start to rise again," he said.

There was an echo of White's sigh of relief from the owners of some nearby houses- several basements were flooded.

But it was a different story on Monday. Ice blockages at narrow locations down river inched the water up the front steps of the business. Only the garage, which sits flat on the shore and is nearer to the water, had a few feet of water in it. Store staff managed to move the equipment in the garage to higher ground. Meanwhile, in the adjacent lot, there was a rush to move some piles of logs that had already started to float away. This, along with the added attraction for kids to ride their bicycles in two feet of water, drew many spectators.

"I haven't seen the water as high as this in 15 years," said one man to a group of others.

"The store's going to be floating away this time tomorrow," said another.

Many in the crowd, including White, questioned what was being done to help the situation.

"I'd like to know if they're going to blast that'll get the river going again," White said.

"At the time, there was nothing that could be done - we just had to let nature take its course," explained Bob MacAulay, local representative of Emergency Measures Organization, noting the situation was still being monitored Wednesday. "It's a bit of a different year for the ice. Usually, the ice that comes down the river piles up on top of the bay ice. This year, the river ice seems to be going underneath the bay ice."

MacAulay said the reason might be that this year the river ice is softening up sooner than usual, and by the time it hits the bay ice it's turned to slob - forcing its way underneath.

Section A Page 4 The Labradorian, Happy Valley-Goose Bay, May 18,

Close call

Continued from page 1

"Setting charges wouldn't have done much - the river is too wide."

The biggest concern during the situation was that there was a chance the Mud Lake channel could be blocked off, preventing residents from getting to Happy Valley-Goose Bay in case of an emergency. Also, there was one house that had a significant amount of water totally around it - it looked like a little island by itself.

"Human lives was our main priority," said MacAulay. "Not saying we're not concerned about property damage. But we felt the main concern should be on human lives. So we made sure the Mud Lake residents knew where to call in case they needed to be evacuated."

However, Mother Nature acted gracefully. The threat of flooding at T&R Marina turned out to be the climax.

White said wishes the crowds that turned up would have meant an increase in sales, but said he's relieved to have gotten away so lucky from such a close call.

T&R Marina owner Ramsey White, and a few bystanders, wait around to see if the Churchill River would rise any further. This was about as high as it got.

The road leading to Birch Island disappears last Monday.

KEATS PHOTOS

looks calm, but the river is clearly in control, as ice blocked narrower sections fur-

Logs piled up across from the T&R Marina are moved further up the shore - a handful floated away overnight. The process attracted many a spectator.

Churchill Overflows Banks

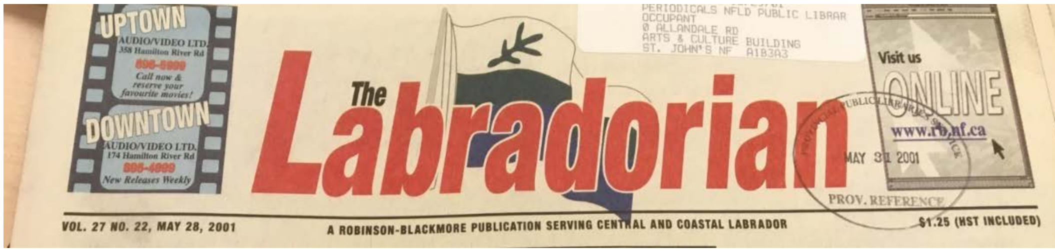
In Mid-May of 1998, a convenience store located on Hamilton Road expressed concern of becoming submerged by the rising water levels of the Churchill River on a Thursday. Several nearby houses had basements that were flooded. By that Monday, ice blockages down river had increased water level to the front steps of the business and flooded the business owner's garage in a few feet of water. Children in the area were riding their bicycles in two feet of water. One man stated "I haven't seen the water as high as this in 15 years". The Emergency Measures Organization local representative said there was nothing that could be done to clear the blockage, referring to the use of explosives.

CBC NEWS – April 24, 2000

https://www.youtube.com/watch?v=cLlEDoeq1zw&t=22s

During late April of 2000, high winds caused a build-up of ice on the Churchill River at Mud Lake and toward the mouth of the Churchill River, which in turn caused flooding of the Mud Lake Road when the water levels increased by five feet. Mud Lake Road resident Eugene Mesher stated flooding like this was unusual for the time of year (i.e. April). Residents of Mud Lake expressed concern over the possibility of flooding in the basements of their homes. There was a fear that flooding in the spring would completely wash away the already flooded section of Mud Lake Road. Once winds speeds subsided the water level receded several inches but was still several feet above normal at the time of the media coverage. The CBC reporter stated people were concerned because "historically, this area does flood in the spring time".

The Labradorian – May 28, 2001



Jordan Hope of Mud Lake sits in his canoe in 44 inches of water that had flooded his basement May 13. Mr. Hope said this was the worst flood he's seen since 1985.
(Submitted photo)

Canoeing in the basement

By BONNIE McLEAN
The Labradorian

You know your basement is flooded when you can go for a canoe ride. That was the scene in Jordan Hope's house in Mud Lake recently.

"The water rose to 44 inches in the basement and about six inches from the main power switch," said Mr. Hope. "That was the highest it rose since 1985."

Mr. Hope lives about 100 feet away from the channel that runs from the Churchill River and empties into Mud Lake. The water came right in over the bank.

Mr. Hope's basement started to flood on the afternoon of May 13, and by that evening, the water had risen dramatically.

"We had a pump on it to try to get the water out, but we couldn't gain — it was just coming in through the door," said Mr. Hope.

REGULAR OCCURRENCE

Mr. Hope said that his house, along with two others next to his, regularly flood every year, with the exception of last year.

"The ice jams out to the mouth of the river and as soon as the ice moves, the water drops back down," said Mr. Hope.

Mr. Hope said there wasn't much damage done to his house, but he did lose some caribou meat before he was able to move his deep freeze into his shed.

The water stayed high until May 22, when it gradually started to drop back down.

"The water still has to go down about another foot-and-a-half before everything is back to normal," said Mr. Hope. "but it's good compared to what it was."

Mr. Hope said there will also be a lot of cleaning up to do.

"There's a big mess around the door," said Mr. Hope. "If you have wood in your basement, everything is floating around. Cleaning up the basement after the water goes back is a couple of days work.

Canoeing in the Basement
On May 13th, 2001 Mud Lake resident, Jordan Hope, had flooding in his basement that rose to a depth of 44 inches of water. Mr. Hope stated "That was the highest it rose since 1985". Mr. Hope's house and two other houses next to his regularly flood. The ice jams at the mouth of the Churchill River and once the ice moves, the water level drops off. The water level stayed high until May 22nd when the levels eventually began to drop back down.

CBC NEWS – May 17, 2012

http://www.cbc.ca/labradormorning/episodes/2012/05/17/flooded-homes-in-mud-lake/

In Mid-May of 2012 Mud Lake residents experienced flooding of their homes as the water levels on the Churchill River increased over the river banks when there was an ice blockage along the river that would not let go.

The Labradorian – May 28, 2012

709-896-5317

Labrador's top cop
See Page A3

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The Labradorian

Mud Lake flooding
:More pictures on A5

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Mudlake flooding

For the first time in recent memory, Mud Lake has spilled its banks with record flooding into the community. Photos courtesy of Claudine Broomfield of Mudlake

Mud Lake Flooding
For the first time in recent memory, Mud Lake has spilled its banks with record flooding into the community.

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