

Badger Flood 2003

Situation Report

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1. Background

The Town of Badger has a long history of flooding dating back to 1916. However, the February 15 event was the most severe in terms of depth of inundation and damages to the town. The mechanism was also different, particularly with respect to the rate of rise of the water level.

This report provides a description of the event, outlines the data that is available to carry out further investigations, describes the response of the Water Resources Management Division (WRMD) and other agencies to the flood event and makes conclusions and recommendations. This report identifies areas where further study will be required to detail the flood mechanism. However, further analysis should be carried out only when all the data available has gone through a quality control process.

The area discussed in this report extends from Grand Falls in the east to Exploits Dam in the west as shown in Figure 1.

2. Antecedent Conditions

a Meteorological Data

The following meteorological data available for the study:

- mean daily temperatures and total daily precipitation Grand Falls,
- mean daily temperatures and total daily precipitation at Exploits Dam,
- hourly air temperatures and wind speed and direction at Exploits River below Noel Pauls Brook,
- temperature, precipitation data and wind speed and direction at Badger.

This data is necessary to analyze the conditions that caused the ice cover to develop prior to the flood and the redevelopment of the ice cover upstream of Badger after flood. The locations of these climate stations are shown in Figure 1. The relevant time period runs from December 1, 2002 to March 31, 2003. This data has been collected and is available from the Department of Environment (DOE).

Other supplementary weather data for the region can be obtained from climate stations which are somewhat removed from the study area. These stations include Buchans, Star Lake and Burgeo Road in the west, and Wooddale-Bishop's Falls, Rattling Brook and Gander in the east.

i. Air Temperature

Air temperature data were compared to the monthly normals for Exploits Dam, Exploits River below Noel Paul's Brook, Badger and Grand Falls. The locations of these stations are shown in Figure 1. The data for Badger is presented in Figure 2 and for the other stations in Appendix A. The data shows that in the week preceding the flood the temperatures were up to 12° C degrees

Exploits River - Grand Falls to Exploits Dam

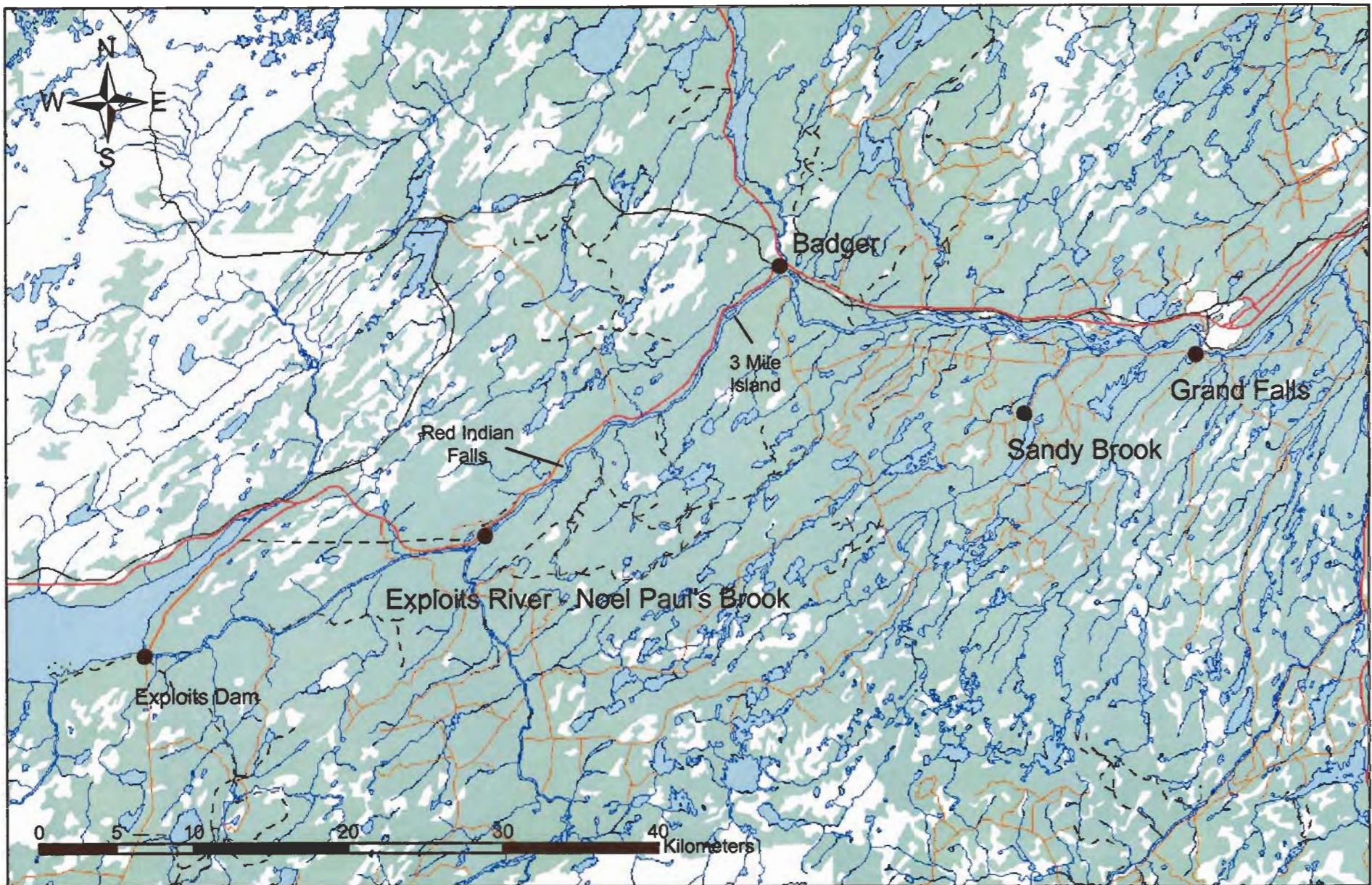


Figure 1 - Location Map



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Legend
● Hydrometric Stations

below the normal for that period while in the week before that the temperatures were up to 10° C degrees above the normal.

ii. Wind Speed and Direction

Mean daily wind speed is shown in Figure 3 for the Badger climate station and in Appendix A, Figure A-1 for the Exploits River below Noel Pauls Brook site. Wind direction is available for the Badger station. Normals of wind speed and direction are not available for Badger or Noel Paul's Brook. The closest climate station with wind normals is at Gander. The wind speeds do not appear to be unusually high in the week preceding the flood.

iii. Precipitation

Precipitation data was available at the Grand Falls, Badger and Exploits Dam locations. All daily data are plotted in Figure 4. Monthly totals for the Badger climate station are compared to the normals in Figure 5. The total was about 30 mm higher than the normal for February.

b Streamflows / Discharges

Streamflows in the Exploits River Basin at Badger include regulated and unregulated flows. The portion of the basin upstream of the outlet of Red Indian Lake, which represents 70 per cent of the drainage area above Badger, is controlled at Exploits Dam by Abitibi Consolidated Company of Canada (Abitibi).

Further downstream, the Exploits River is gauged for flow below the confluence with Noel Pauls Brook. Flows at Grand Falls are calculated by Abitibi based on power generation. For the two weeks preceding the flood event the flows at the Noel Paul gauge fluctuated from initially being below the normal, then going above the normal to fall back below the normal just prior to the flood. These flows are shown in Figure 6.

Sandy Brook at Sandy Brook Powerhouse makes a small (about 5-10%) contribution to the flow of the Exploits River just upstream of Grand Falls. Streamflows at these gauges are compared to their averages in Figures B-1 to B-4 in Appendix B. All streamflows are plotted concurrently in Figure B-5.

There are a number of other active and discontinued streamflow gauges in and around the region. Data from these stations may be useful in analyzing this flood and its relationship to previous floods in Badger.

c Water Levels

The relevant water level stations for analyzing the Badger flood are near the arena in the Town of Badger and Exploits River below Noel Pauls Brook which is situated about 20 km upstream of Badger. The daily average water levels for these two stations are plotted concurrently in Figure 7.

Badger (AUT) Environment Canada ID # 8400301
Mean Daily Air Temperatures

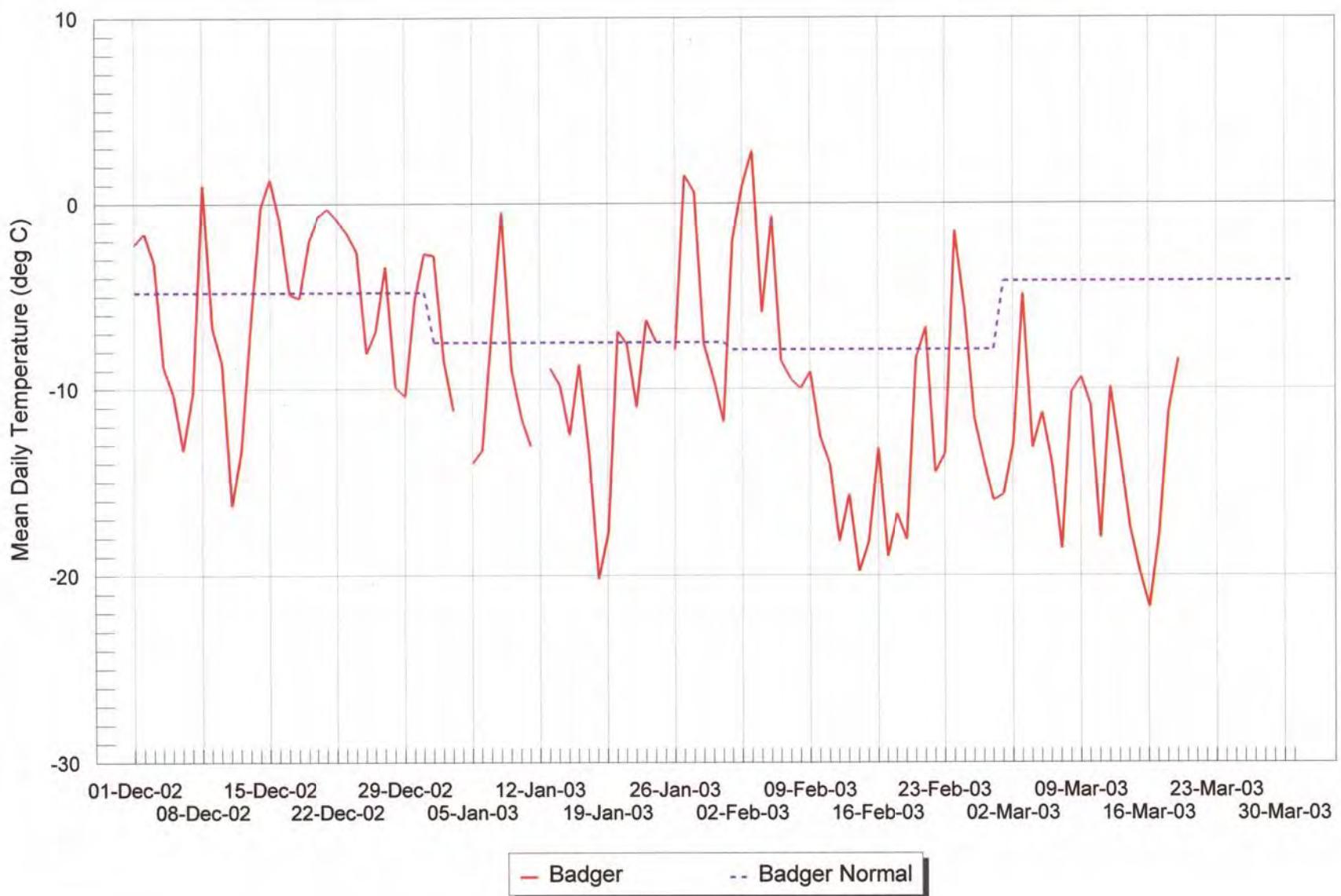


Figure 2 - Badger Air Temperature Data

Badger (AUT) Environment Canada ID # 8400301

Mean Daily Wind Speed

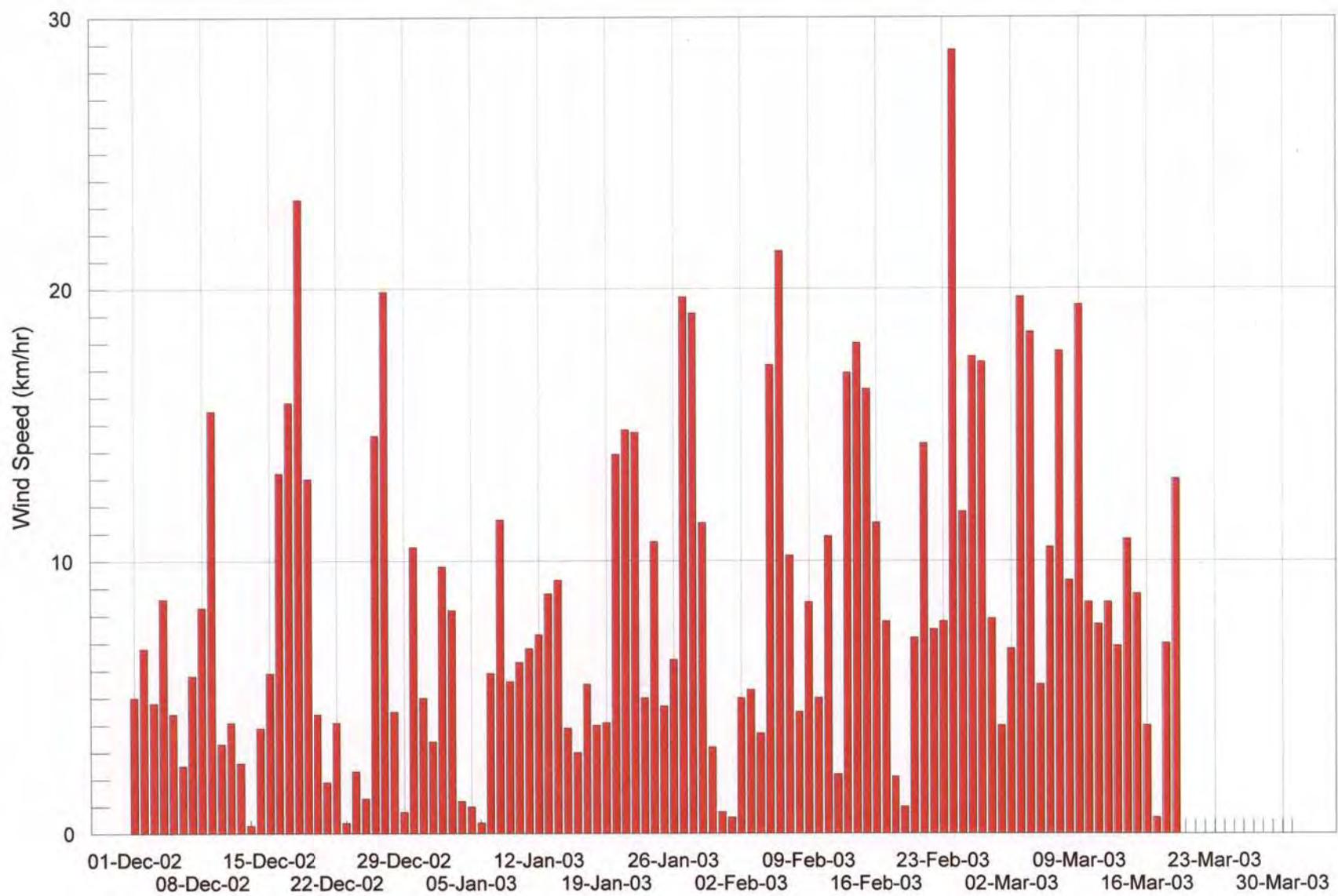


Figure 3 - Badger Wind Speed Data

Daily Precipitation

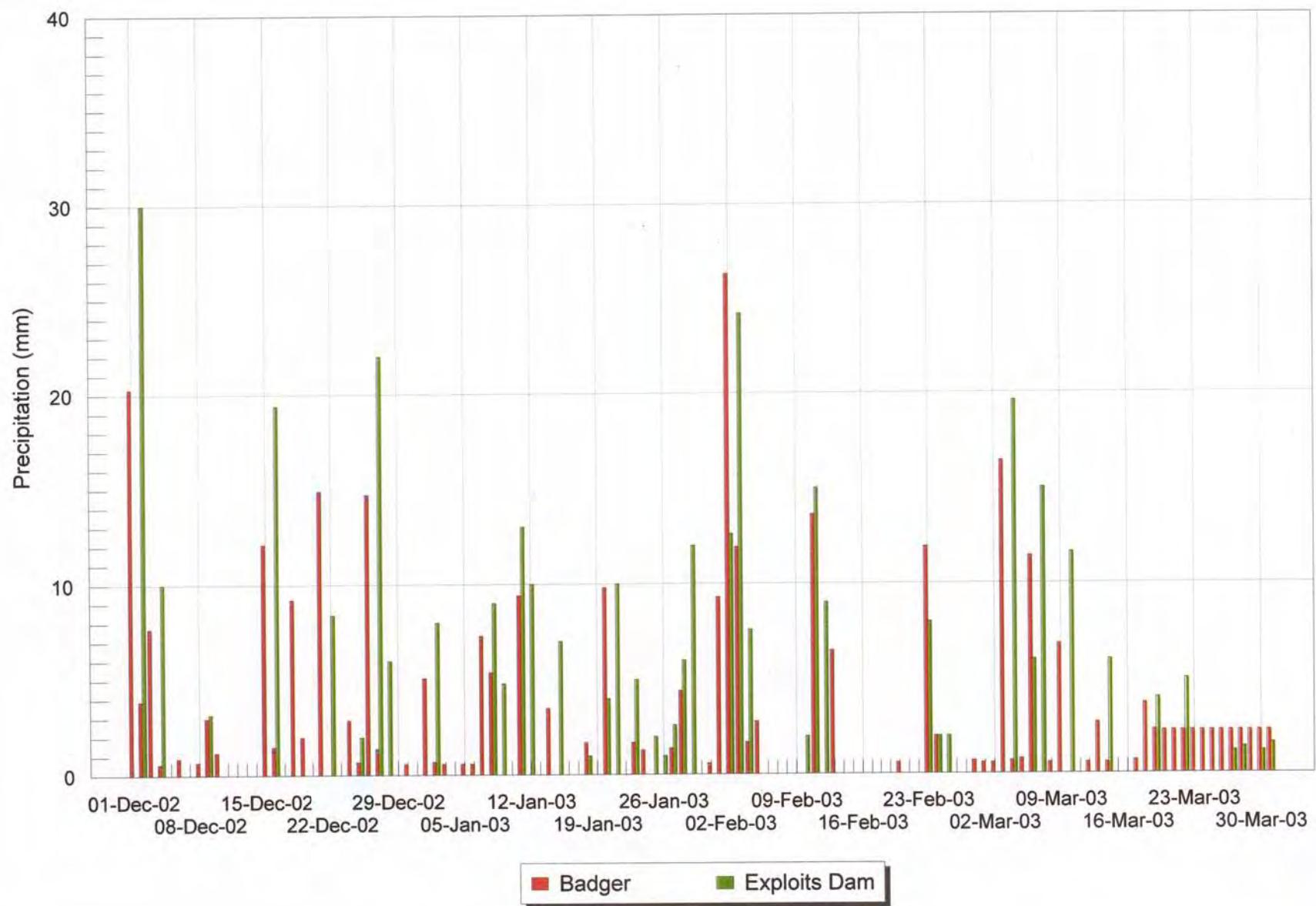


Figure 4 - Daily Precipitation Data

Badger (AUT) Environment Canada ID # 8400301
Monthly Total Precipitation



Figure 5 - Badger Precipitation Data

Daily Flow Comparison

Exploits River below Noel Paul's Brook ID # 02YO011

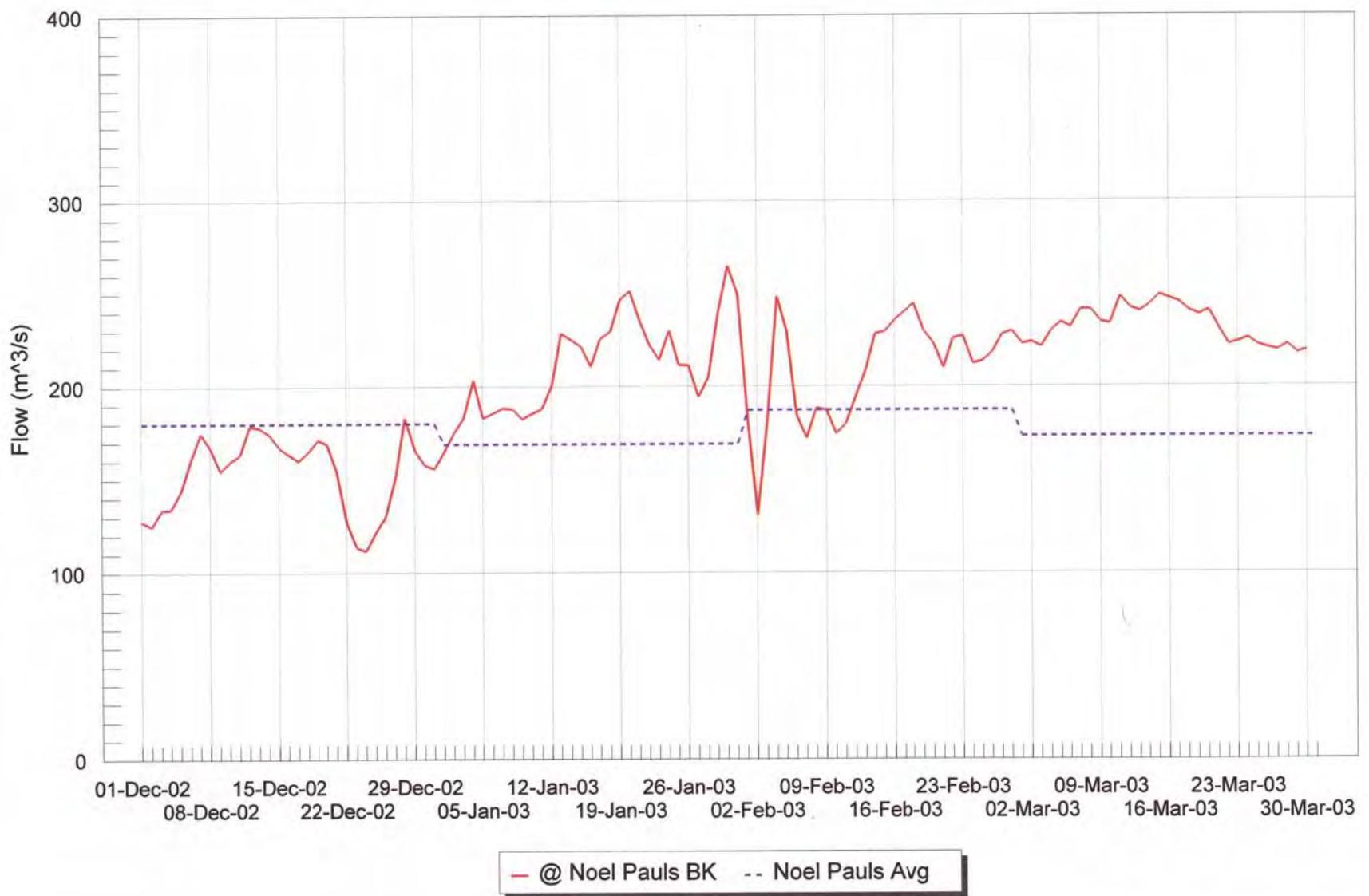
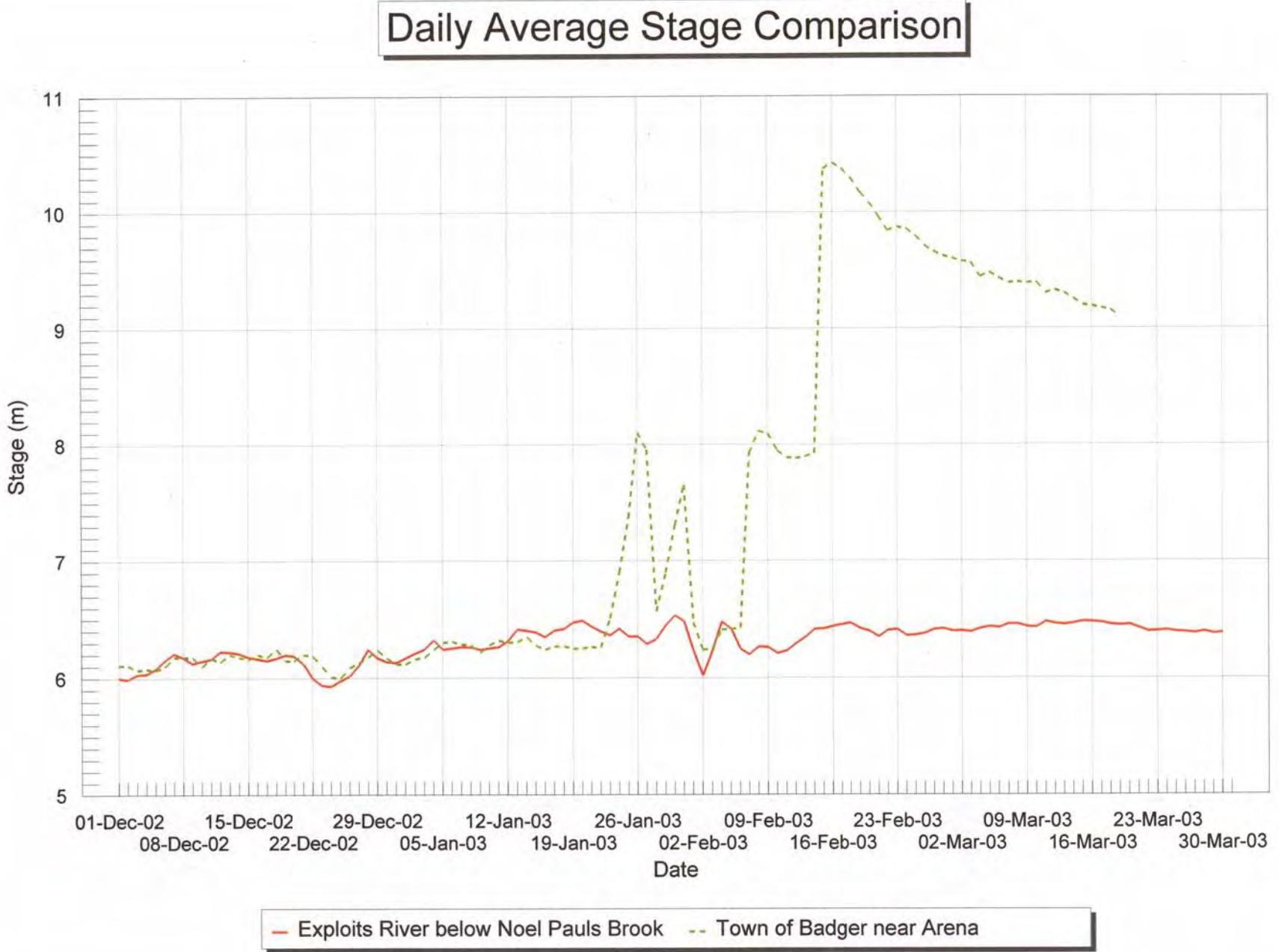


Figure 7 - Daily Average Stage Comparison



Exploits River below Noel Pauls Brook

Air and Water Temperatures

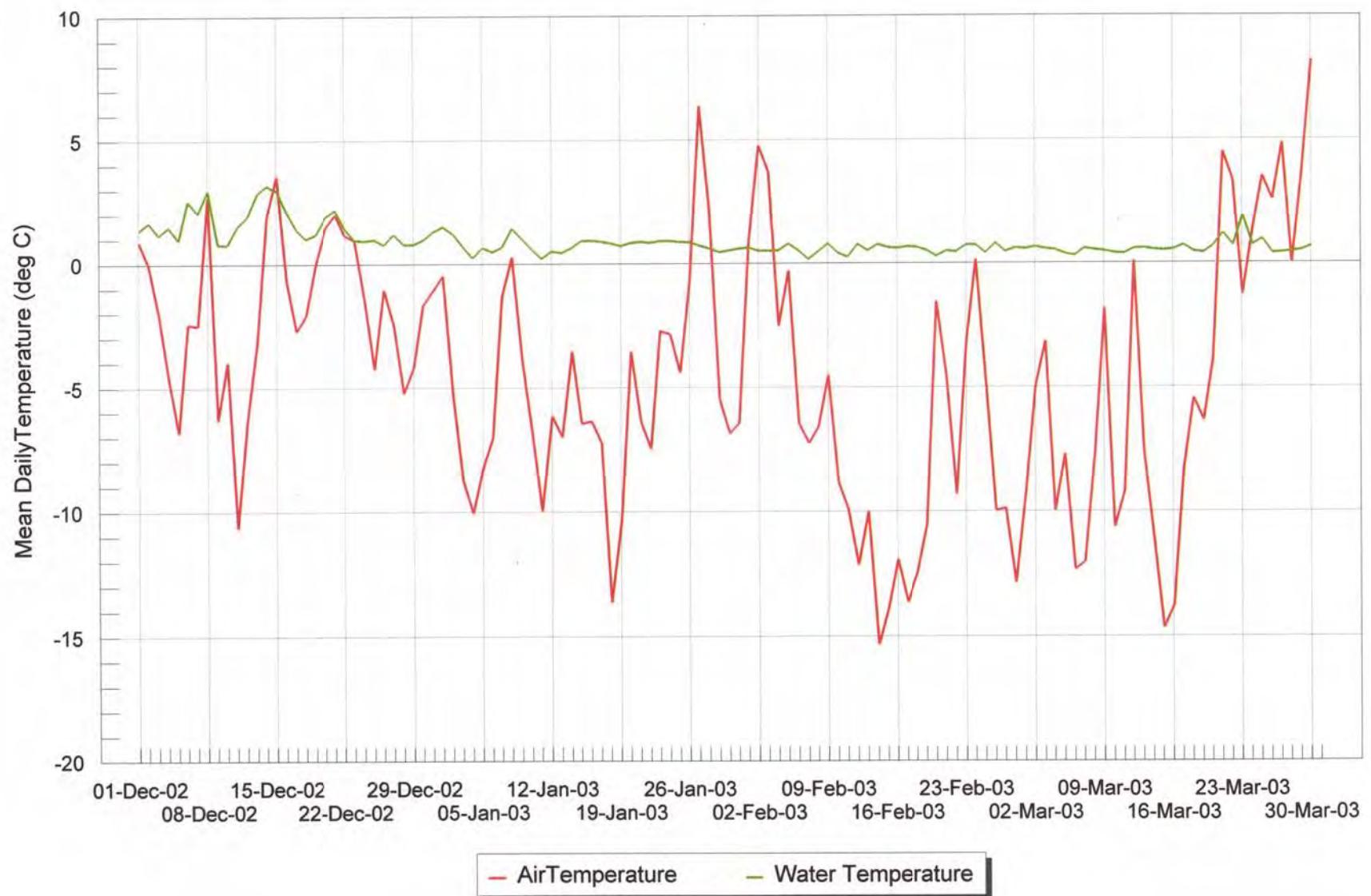


Figure 8 - Air and Water Temperatures

d Water Temperature

Hourly water temperature data is recorded at the Exploits River below Noel Paul's Brook station. Water temperatures are plotted alongside air temperatures for the Noel Pauls Brook station in Figure 8 and on their own in Figure A-2 in Appendix A. The only other source of water temperature information in the region is at the Gander River at Big Chute hydrometric station. It could be used as a proxy for water temperature at the outlet of Red Indian Lake.

3. Ice Formation and Flood Forecasting

a Ice Progression

For ice progression tracking and flood forecasting the river has been divided into 32 segments, these segments are shown in Figures 9 & 10. The ice progression in the Exploits River for this winter season is described below:

December 4-7: The ice modelling described below indicated that an ice cover was established at Grand Falls (Segment 32) on December 5, however, field observation indicated that the ice cover was established on December 4. Using satellite imagery, the ice cover was confirmed to be at Segment 31 on December 7.

December 13-18: The ice cover opened on December 13 and started to fill back in on December 18.

January 3-7: On January 3 the ice front was below Aspen Brook (Segment 26). By January 7, 2003 the ice front was located above Aspen Landing (Segment 26).

January 8-9: On January 8 the ice front was below Aspen Landing, and on January 9 the ice front was back up to Aspen Landing.

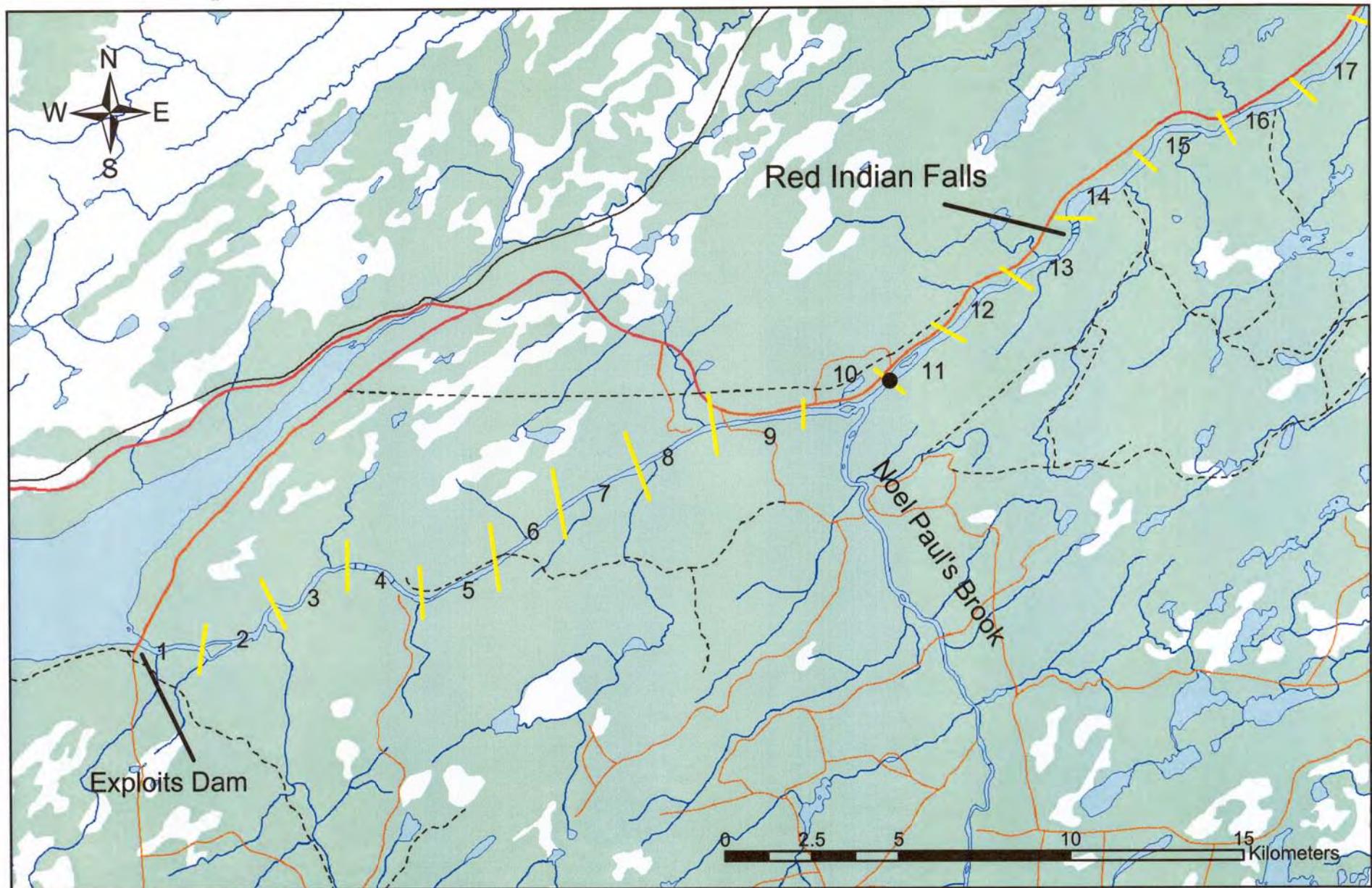
January 13-20: On Jan 13 the ice cover moved from Aspen Landing up to Badger Chute (Segment 24). On January 16 the ice front moved downstream to Segment 25. On January 20 the ice front was back up to Badger Chute.

January 24-28: The ice front first arrived at Badger (Segment 21) on January 24. The stage shot up nearly 2 metres from the pre-ice elevation of 96.2 metres to 98 metres on January 26.

January 29: The ice front regressed downstream below Badger. The stage retruned to about 96.5 metres (Segment # not known)

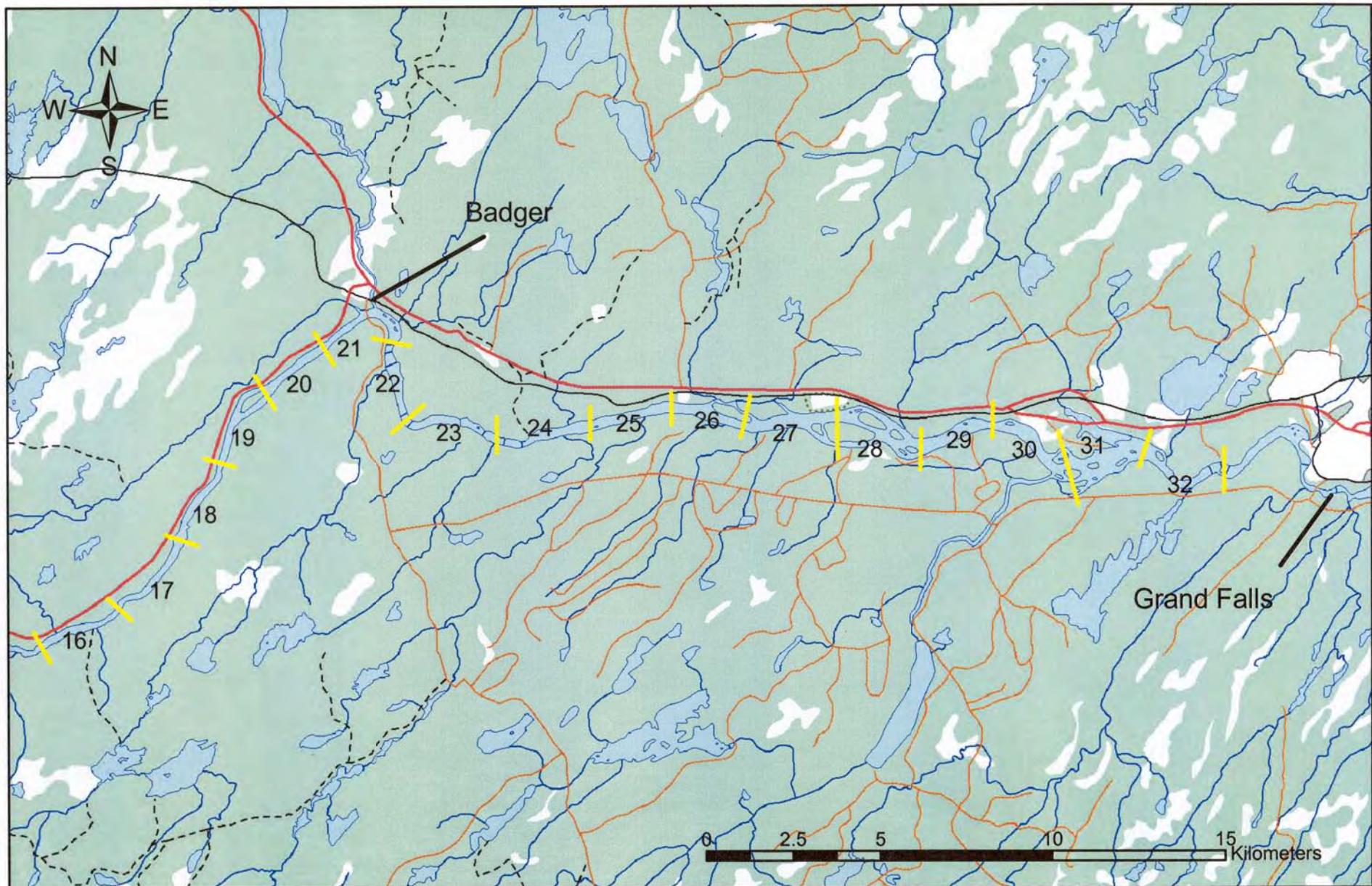
January 30-February 7: The ice front moved past Badger on January 30, below Badger on January 31, above on February 1, below on February 2 and above again on February 7. (Segment #'s not

Exploits River - River Segment Numbers



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Exploits River - River Segment Numbers



known) The water level increase to 97.6 metres on January 31 and dropped to 96.1 on February 2.

February 8-14: The ice cover progressed rapidly upstream until it reached Segment 15 on February 14. The water level rose sharply on February 8 to 98 metres, slowly receded to 97.8 on February 14.

February 15: On February 15, the ice cover above Badger moved downstream resulting in the 1:100 year level being exceeded at Badger, from Segment 15/16 to Segment 19. By February 17 the ice front was located between Segment 17 and 18. On February 15 the water level shot up to 100.3 metres and gradually increased to 100.5 metres.

February 15-25: The ice front reached Red Indian Falls on February and did not progress past the Falls (Segment 13). Water levels in the Falls area increased as frazil ice moved under the ice cover threatened to flood some cabins in the area. At Badger the water levels continued to drop slowly and were down by 0.87 m on February 25.

b Ice Production

The principal driving force behind frazil ice generation is sub-zero temperature. Ice generation can be greatly enhanced by high winds. The freezing degree days for this ice season and the wind chill factor, derived from mean daily and forecasted wind speeds at Badger, which were used by the model are shown in Appendix C.

The total volume of ice generated from Red Indian Lake to Grand Falls is shown in Figure 11 and the total amount of ice generated from Segments 1 to 21 (Red Indian Lake to Badger) is shown in Figure 12. The ice generated in Segments 1 to 21 affects the freeze up elevation at Badger when the ice front is located immediately below Badger.

Figure 13 shows the location of the ice cover extent based on the ice model and the actual location where it is known. The model does not account for the regression of the ice cover.

c Flood Forecasting

The WRMD operates a flood forecasting system for the Town of Badger. Initially this system was set up after the flood in 1977. The methodology has evolved over the years and is reviewed and updated annually. In 1995 a major review by an outside consultant was carried out. [2]

The current system uses a mathematical model developed in the studies [1,2] to calculate the volume of ice generated in the open sections of the Exploits River. For this purpose, and as described above, and shown in Figures 9 and 10, the river was divided into 32 sections between Grand Falls and the Exploits Dam at the outlet of Red Indian Lake. Once the ice is generated, the

Exploits River from Red Indian Lake to Grand Falls

Total Ice Generated

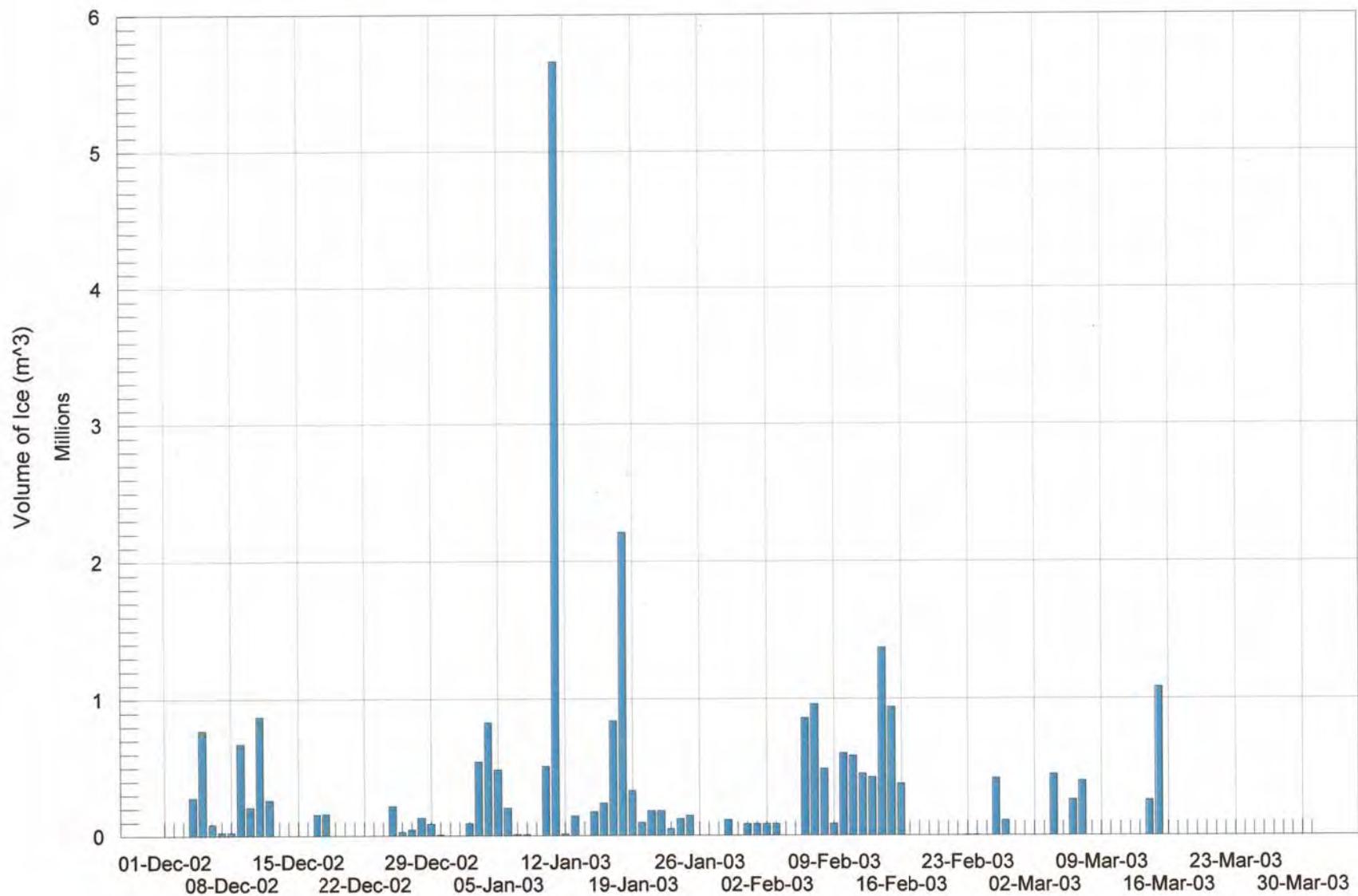


Figure 11 - Total Ice Generated - Exploits River

Exploits River from Red Indian Lake to Badger

Ice Generated Segments 1-21

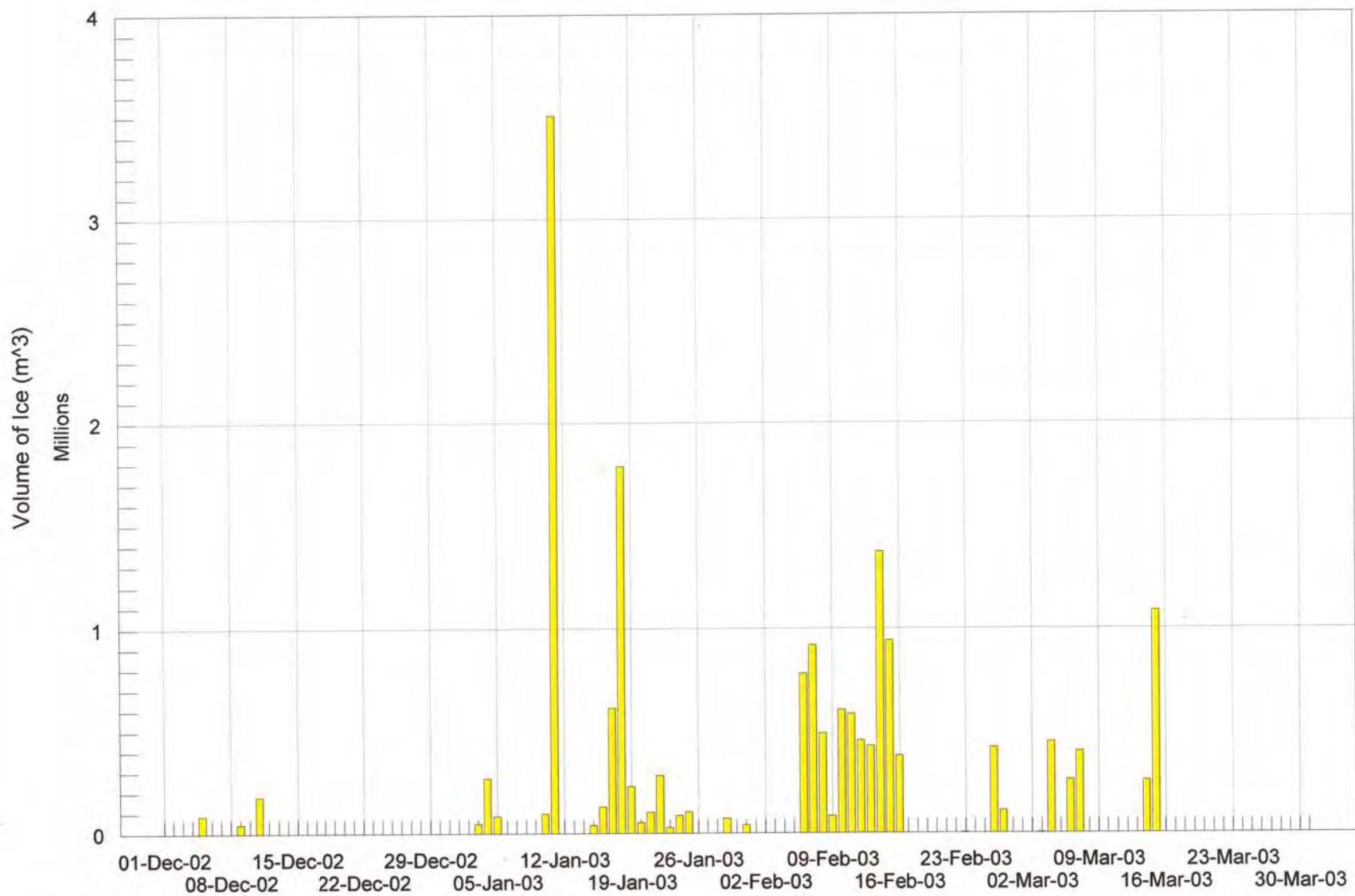
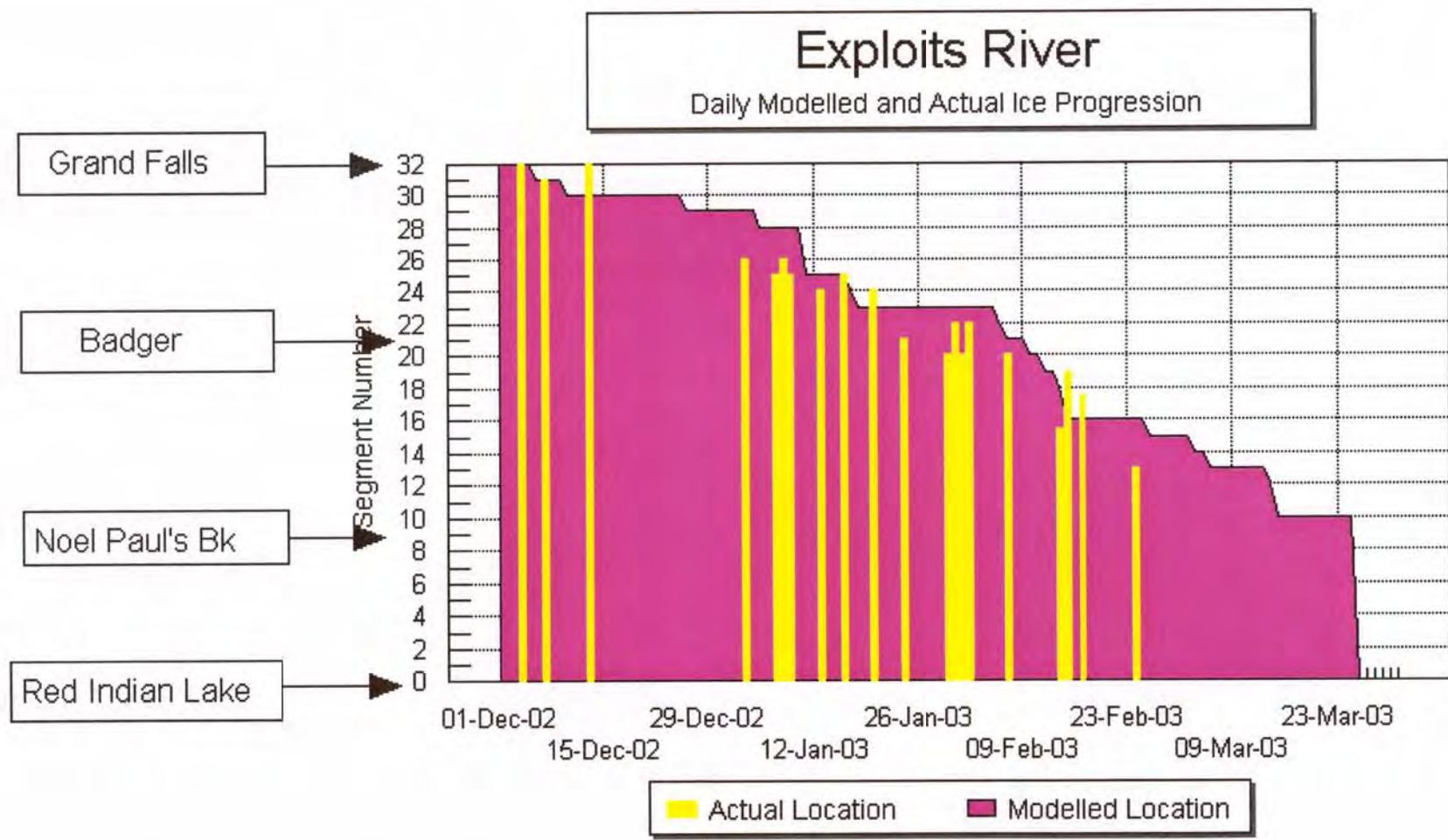


Figure 13 - Ice Progression



model tracks the progression of ice cover as it fills the segments from Grand Falls towards Red Indian Lake.

Two model runs were made on February 14, 2003. The morning model run forecasted 2.6 MCM (million cubic meters) of ice being generated and coming down the Exploits River between Red Indian Lake and the Town of Badger. The alert level for WRMD is 2 MCM. The afternoon forecast run estimated 3.1 MCM to be generated.

The Town of Badger and Abitibi were advised by telephone and EMD by fax that there was a considerable amount of ice coming down the Exploits tonight but that there would be no change expected in the water level. The Town and Abitibi were agreed that since the ice front was confirmed to be at least to Three Mile Island (about 5 km upstream) that there was little cause for concern.

Historically, the danger to Badger would have passed once the ice front travels upstream past Three Mile Island. As of February 14, the rafted ice at Badger had not moved in over a week. This gave the impression that the ice cover was stable.

d Noel Pauls Brook

The ice cover on Noel Pauls Brook broke up and flowed into the Exploits River during the mild spell early in February. The event was observed by local residents and showed up as a sharp increase in the water level at the Exploits River below Noel Pauls Brook station on February 4, 2003. Ice shear walls along the sides of the stream and an ice free channel were observed along Noel Pauls Brook for a distance of 8 km from the Exploits confluence. This indicated that all the ice in that section of the river moved out into the Exploits River. Where this ice wound up and what effect it had on the flooding of Badger is unknown at this time.

4. Flood Description

Based on the data from the water level gauge at Badger, the flood started on February 15 between 8:00 am and 9:00 am. Residents of the area report the time between 8:00 and 8:30. The water level rose 2.3 metres in the first hour, rose an additional 0.3 in the next two hours and peaked at an elevation of approximately 100.5 metres (Geodetic). The flood led to the evacuation of the Town and the declaration of a State of Emergency. The state of emergency was not lifted as of the writing of this report.(March 31, 2003) The levels prior to the event, during the event and after are shown in Figure 14.

The ice cover prior to the flood had reached Segment 15 near the transmission line approximately 14 km above Badger. After the ice stopped moving, the ice cover was just upstream of Three Mile Island suggesting that the ice cover had collapsed all the way from the transmission line. The ice jammed across the river restricting flows causing water to flood into the town. The thickest part of the ice jam appeared to be downstream of Badger in the area known as Badger Rough Waters.

Hourly Stage Comparison - Exploits River

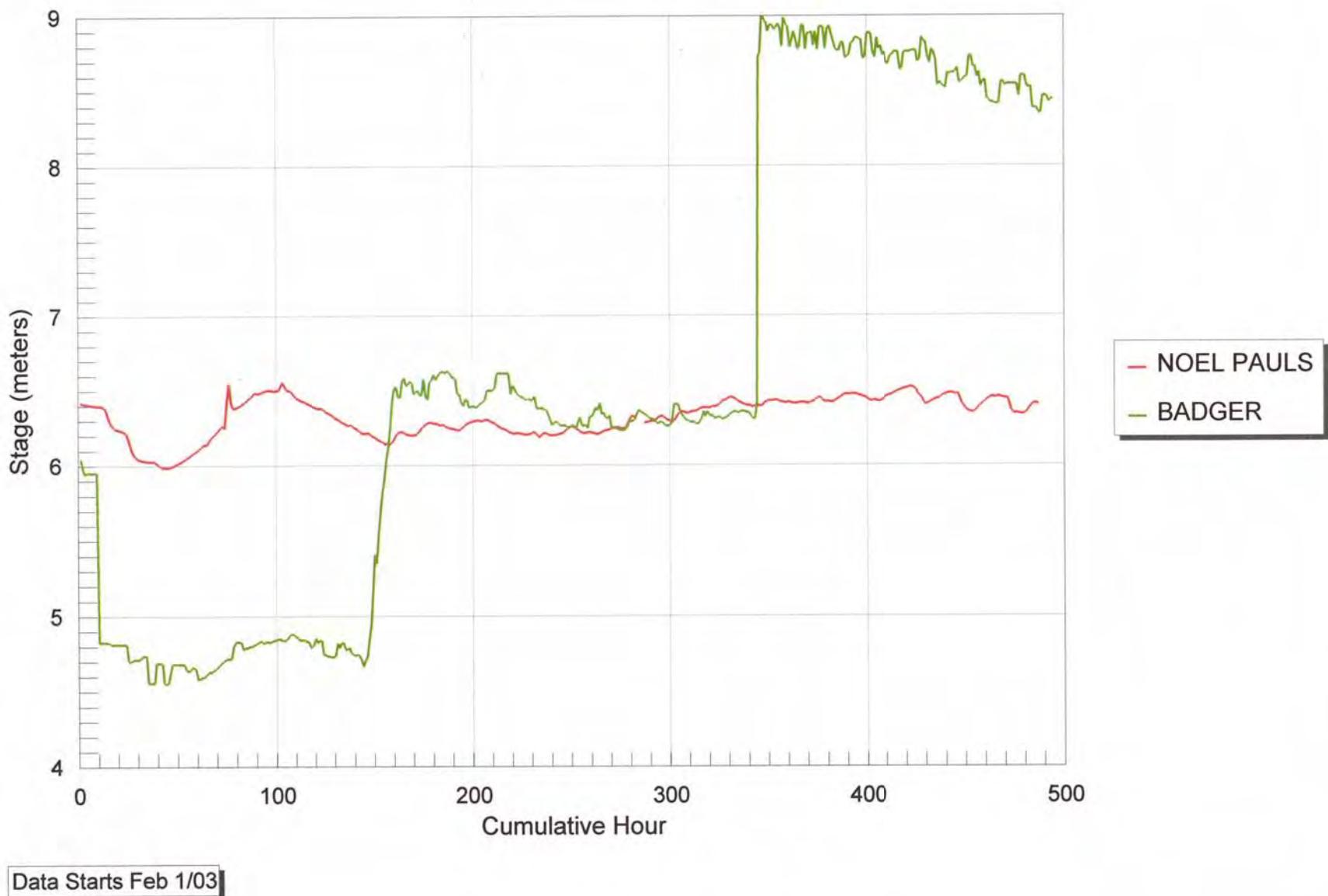




Photo 1 - Ice Movement - Badger Flood

The immense forces created by the ice movement caused ice from the Exploits River to be pushed up Badger Brook almost to the TCH bridge and up Little Red Indian Brook. See Photo 1.

As noted above the flood waters reached a maximum elevation 100.5 metres at the gauge near the arena. This level is slightly above the 1:100 year flood level of 100.42 metres for the Main Street area that was determined in the 1985 report [1].

The temperatures on the days following the flood were very cold with high wind chill values. This combination caused the water in the town to freeze causing further damage and delaying clean up and repair operations.

The areal extent of the flooding was compared in the field with the areas shown on the flood risk map prepared for Badger based on the recommendations of the 1985 study[1]. The areas corresponded very closely with the areas predicted by the map. A Public Information version of the map is shown in Figure 15.

The extent of the damages is currently being assessed by the Department of Municipal and Provincial Affairs, Emergency Measures Division. As of March 14, of the 353 houses in Badger, 147 did not receive any damage, 68 received minor damage, 59 received major damage and 79 had yet to be inspected due to the ice conditions in the areas around these houses. It is likely that most of the 79 will have suffered major damage. The Town Council office and fire hall, the arena and various municipal services in the Town were also damaged. Many businesses were damaged and/or suffered losses of revenue.

In terms of the current flood risk zones, 63 houses were located in the 1:20 year flood zone and 140 were located in the 1:100 year zone.

In non monetary terms, the lives of everyone living in the Town was disrupted and for many, is still being disrupted and will be so for some time to come.

5. Flood Response

As noted earlier a state of emergency was declared on the morning of February 15, 2003 by the Town of Badger. The Emergency Measures Division (EMD) of the Department of Municipal and Provincial Affairs set up a command center and an Emergency Operations Committee (EOC) up at the Central Training Academy outside the flooded area in the Town of Badger to direct appropriate response.

The DOE was informed of the situation by EMD at approximately 11.30 AM. Staff of the Hydrologic Modelling (HM) Section and Water Investigation Sections (WI) were called back to the office to review the situation and modeling work and to forecast the ice generation. A decision was taken to dispatch a team to Badger. The managers of the WI and HM sections assembled a response kit and drove to Badger on February 16, 2003 and made their services available to the EOC.

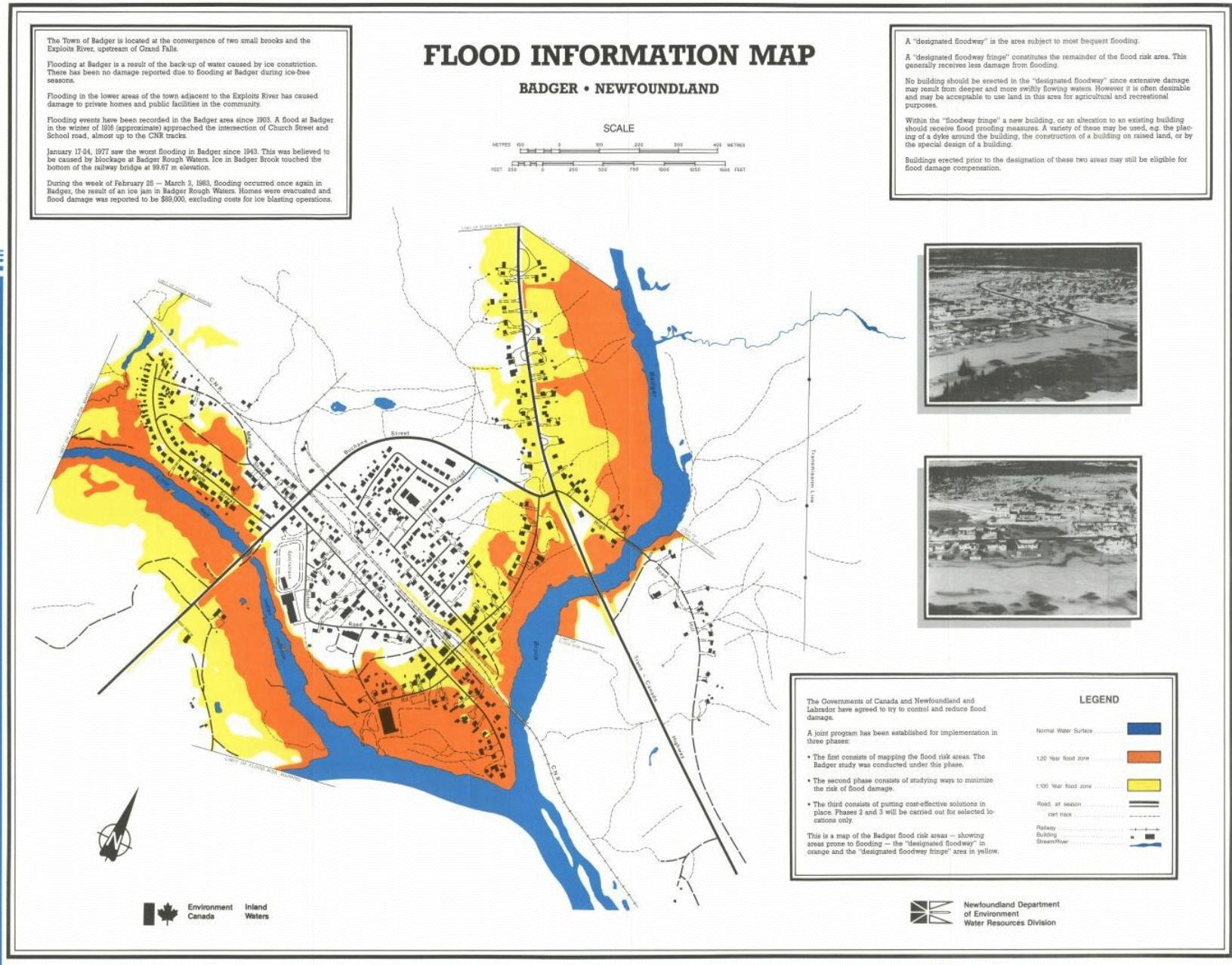
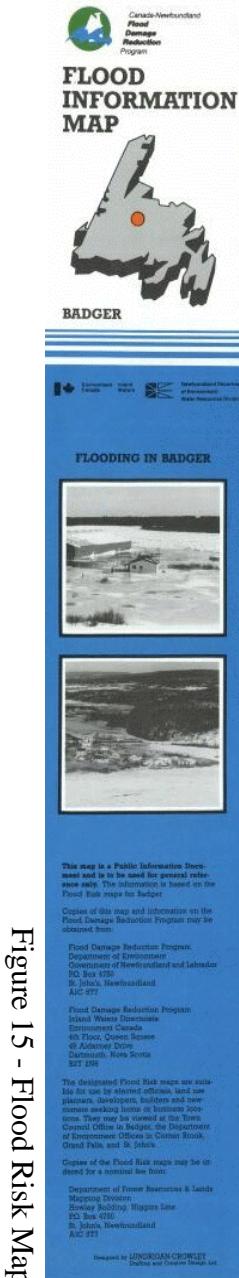


Figure 15 - Flood Risk Map

On the first day a download center was set up in the command office that allowed on call dialing into the water level station at Badger since the town's download computer was lost in the flood. A survey of the flooding was undertaken to delineate the extent of the flooding. The WRMD team also flew the river with town and Abitibi Consolidated Company of Canada officials to survey the situation and reported back to the EOC.

In the subsequent days the WRMD team fly twice a day to survey the river, reported to the EOC, helped evaluate various remedial measures, provided support to the ice clearing operation and provided expert opinion on other issues related to the water and ice conditions. The WRMD on the request of EOC also answered media enquires relating to the water levels.

On two occasions the water level station was secured by the WRMD team. On the first occasion due to ice movement the telephone wire to the station had to be extended and on the second occasion Water Survey of Canada (WSC) helped secure the station by removing ice from inside the station, removing ice from the instruments, relocating instruments within the station and by removing an extra nitrogen cylinder from the station.

The WSC team assisted the WRMD team to setup four temporary water level monitoring stations. The equipment was provided and installed by WSC. The temporary monitoring stations were installed to allow better observation of water levels and to provide advance warning of any significant change in conditions. The WRMD team downloaded data on a daily basis from these stations, analyzed them and presented the results to the EOC. The locations of the monitoring stations is shown in Figure 16. The station at 8 Mile was dismantled on March 27 after the ice shifted and pulled out the sensing line.

Continuous support was provided to the WRMD team in Badger by staff in the St. John's office. Ice forecasting was done twice a day in the St. John's office back on information gathered by the WRMD team in Badger. Data analysis support was also provided to the WRMD team and EOC in Badger.

The WRMD team was constantly in touch with ice experts to ensure that all possible remedial measures were being taken. On the recommendation of ice experts the WRMD started videotaping the ice conditions on a daily basis to provide a record for analysis of the flood.

Staff from the Community and Water and Wastewater (CWW) section were also available to assist the town and EOC in assessing, rehabilitating and securing the water supply and sewer systems. The situation was also reviewed by the Manager of the CWW section. The manager of the Groundwater section also assisted EMD by sampling the water supply and by aerially surveying the possible impact on the water supply recharge area. The Minister of the Department of Environment also visited Badger to ensure that all possible support was being provided by the DOE.

When the conditions had stabilized, regional staff from the WRMD took over the monitoring and videotaping of ice conditions, and downloading of data from the temporary water level stations. The data is being e-mailed to St. John's where it is analyzed and feedback is provided to EOC. Videos of the daily ice conditions are sent by courier to St. John's where they are reviewed.

Temporary Monitoring Sites - Badger

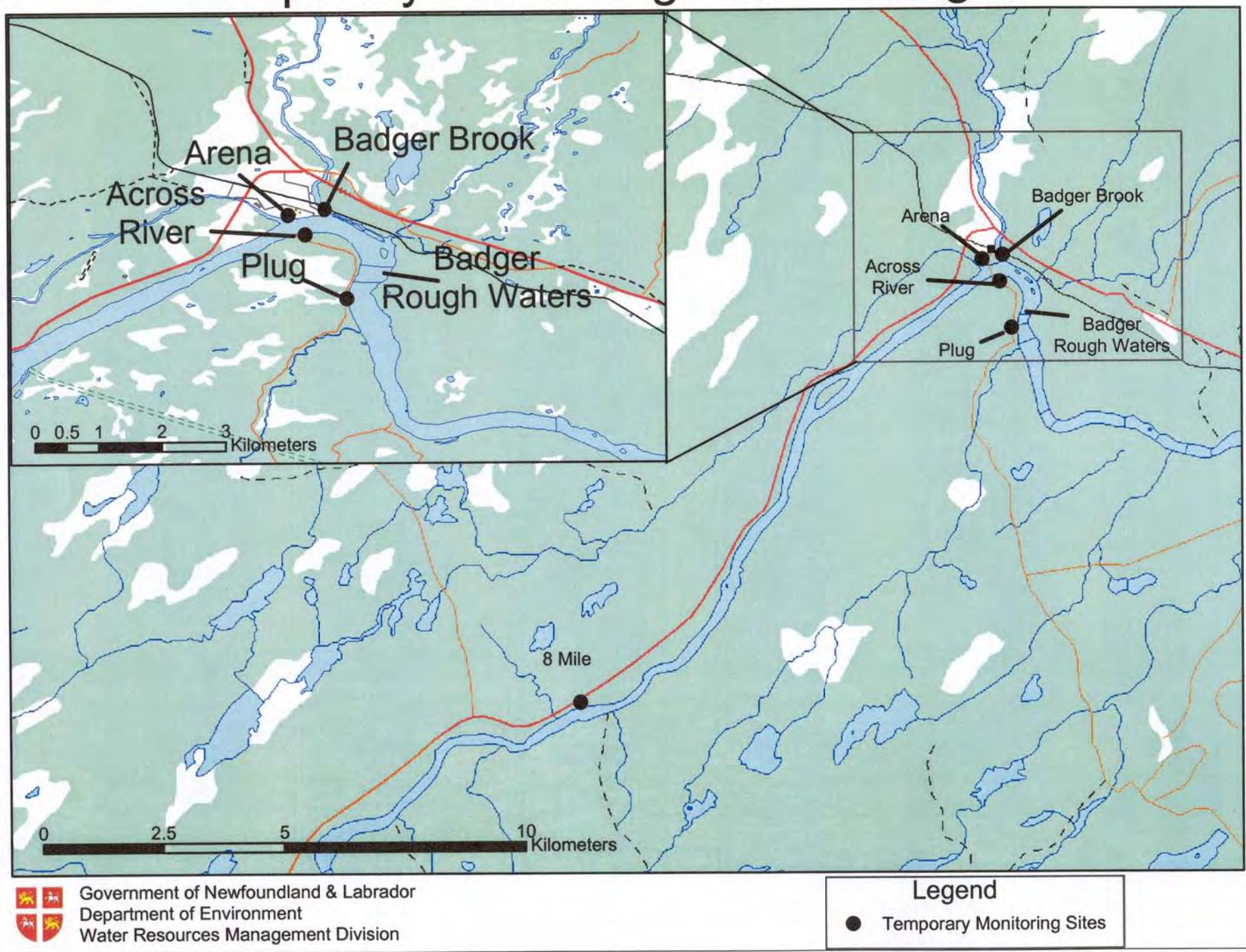


Figure 16 - Temporary Monitoring Stations

6. Current Situation

The water level on the Exploits has remained steady for the past few days at about 98.8 metres, about 1.7 metres below the maximum flood level. The recent warm weather has started to open leads above and below the main ice jam area but there has been no noticeable change in the area just below the ice jam to Three Mile Island.

Daily briefings (seven days a week) with the forecasters at the Gander Weather Centre are continuing and will continue until the danger has passed. The forecasters prepare a specific forecast for the Badger-Exploits River basin. The major concern at this point is larger amounts of rainfall (>15 mm) and temperatures higher than zero for extended periods (>24 hours). The briefings should give three to four days warning of the approach of low pressure systems or mild weather.

Over flights by helicopter are still being carried out once or twice a week, or as conditions warrant, on the recommendation of the WRMD.

Outflows from Red Indian Lake are adjusted by Abitibi on a daily basis to maintain flows in the range of the post event freeze up flows. The goals in maintaining flows at this level are to maintain the stability of the ice cover, to ensure that the passages through the ice jam area are kept open and to lower the water level in Red Indian Lake provide storage. The storage will be used in the event of a rapid melt or rainfall event to store water and keep the flows on the Exploits River at Badger as close to the freeze up flows as possible. This course of action was taken on the advice of the WRMD.

7. Discussion

Antecedent weather condition were clearly a factor in the formation of the ice cover that preceded the flood. The temperatures and wind speed combined to produce high wind chill values and freezing degree days in the week preceding the flood. The milder temperatures prior to that caused the ice cover to progress and regress in reach of the river near Badger.

Precipitation was higher than the normal for February. The effect of this is not clear at this time.

Figure 17 shows the flows past Grand Falls, the releases from Red Indian Lake (not received at the writing of this report), the water levels at Badger and the Exploits River at Noel Pauls Brook for the period from February 1 to 8:00 am February 15. The shows the passage of the ice cover through Badger on February 7 and the small spike on February 3 is likely the time when the ice cover from Noel Pauls Brook broke up and moved downstream.

The flood forecasting model provided valuable information on the formation of a large volume of ice prior to the flood. However, this information was not used to issue a flood alert to the residents since all stake holders felt, based on previous recorded flood events at Badger, that there was a very low risk of flooding once the ice cover has advanced past Three Mile Island. Even if the

Exploits River

Hourly Stages and Daily Flows

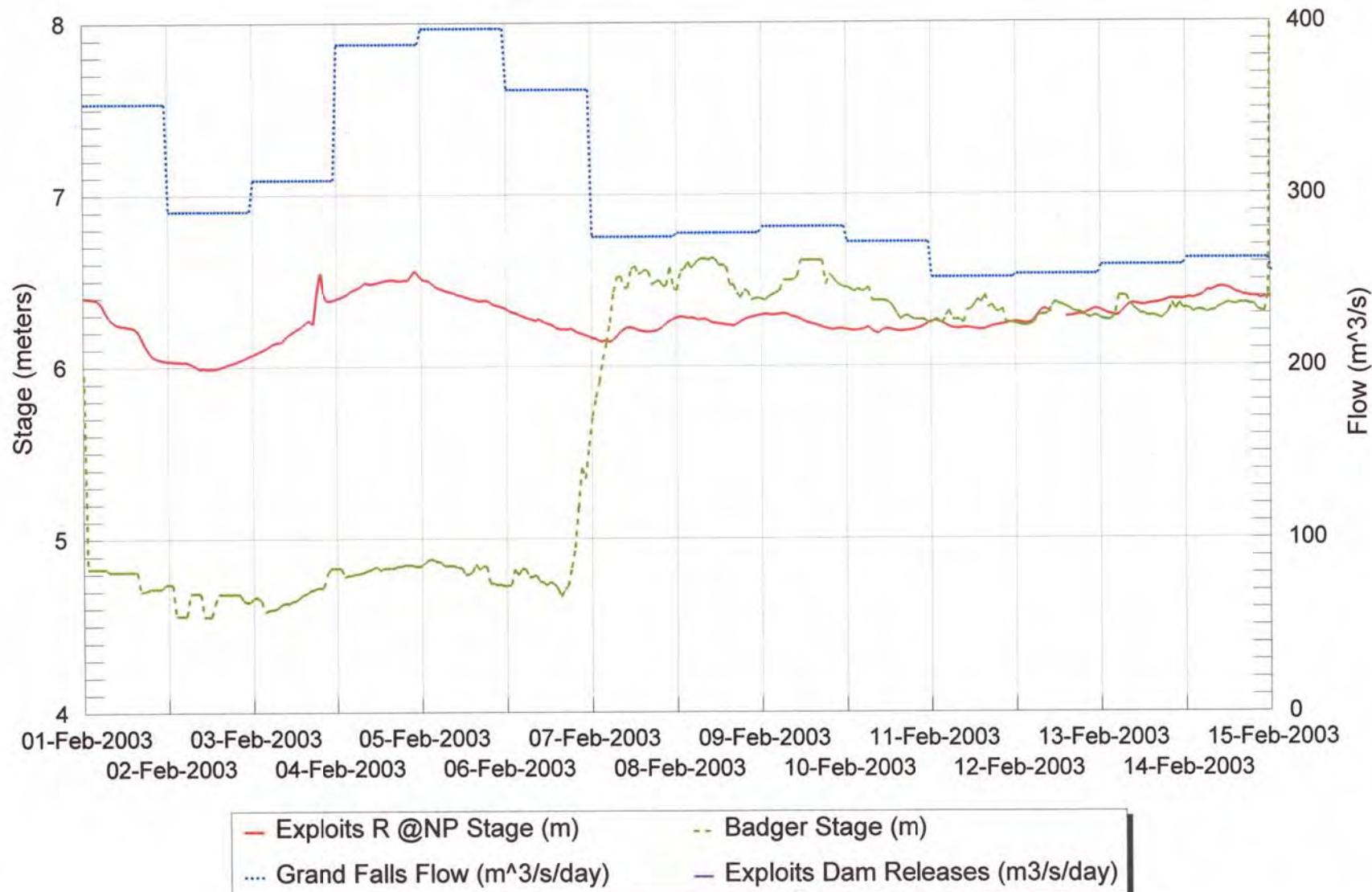


Figure 17 - Stage - Flow Comparison

flood forecast had been used to issue an alert, the past alert procedures, that were based on an assumption that a flood would develop over a period of six to eight hours, would have failed to alert the residents since the flood occurred in less than one hour.

This flood event also highlighted a number of shortcomings in the flood forecasting system. For modelling purposes, it is important to know the location of the ice front. However, this is difficult to know at all times since many river reaches are inaccessible. Ice observations are usually obtained from Abitibi and the Town. During the past two ice forecast seasons satellite images, when available, have been obtained over the Internet to assist in ice observation. A sample image is provided in Appendix C. The images are not high resolution, are not available in realtime, and cannot see through clouds. RADARSAT, a Canadian earth observation satellite, can see through clouds, can provide several images per day in realtime with a resolution of 6 metres. The reach of the Exploits River between Red Indian Lake and Grand Falls is up to three hundred metres wide and it should be able to accurately show the location of the ice front on a continuous basis using scheduled satellite images. In the past, there was a significant cost involved in obtaining these images, however, recently the images are available to the province at a reduced rate which makes this technology more cost effective.

Another limitation of the ice model is that the model does not simulate the regression of the ice front which happened a number of times during this season and has occurred in other seasons.

Air temperatures are fairly well represented in the region with four reporting stations. There are some weaknesses in the hydrological network as it relates to river ice generation and flood forecasting at Badger. Water temperature monitoring is lacking at Exploits Dam.

In order to manage the flood response and to provide early flood warning while water levels were still high after the event, it became necessary to install temporary water level gauges. This demonstrates the need for additional hydrometric stations within the basin.

The ground survey of the extent of flooding indicated that the flood risk mapping was very accurate. However, an initial evaluation of the flood damage indicates that some houses may have been constructed in the 1:20 flood zone. This is against the policy of the Canada-Newfoundland Flood Damage Reduction Program.

While this report does not attempt to investigate the mechanism that caused the shift in the ice cover which, in turn, caused the flooding, initial interviews with residents confirm that the ice cover progressed upstream of Badger at an unusually fast rate.

The response of the Town, particularly the Volunteer Fire Department, and the EMD was very well organized and professional.

Proposed Flood Warning System - Badger

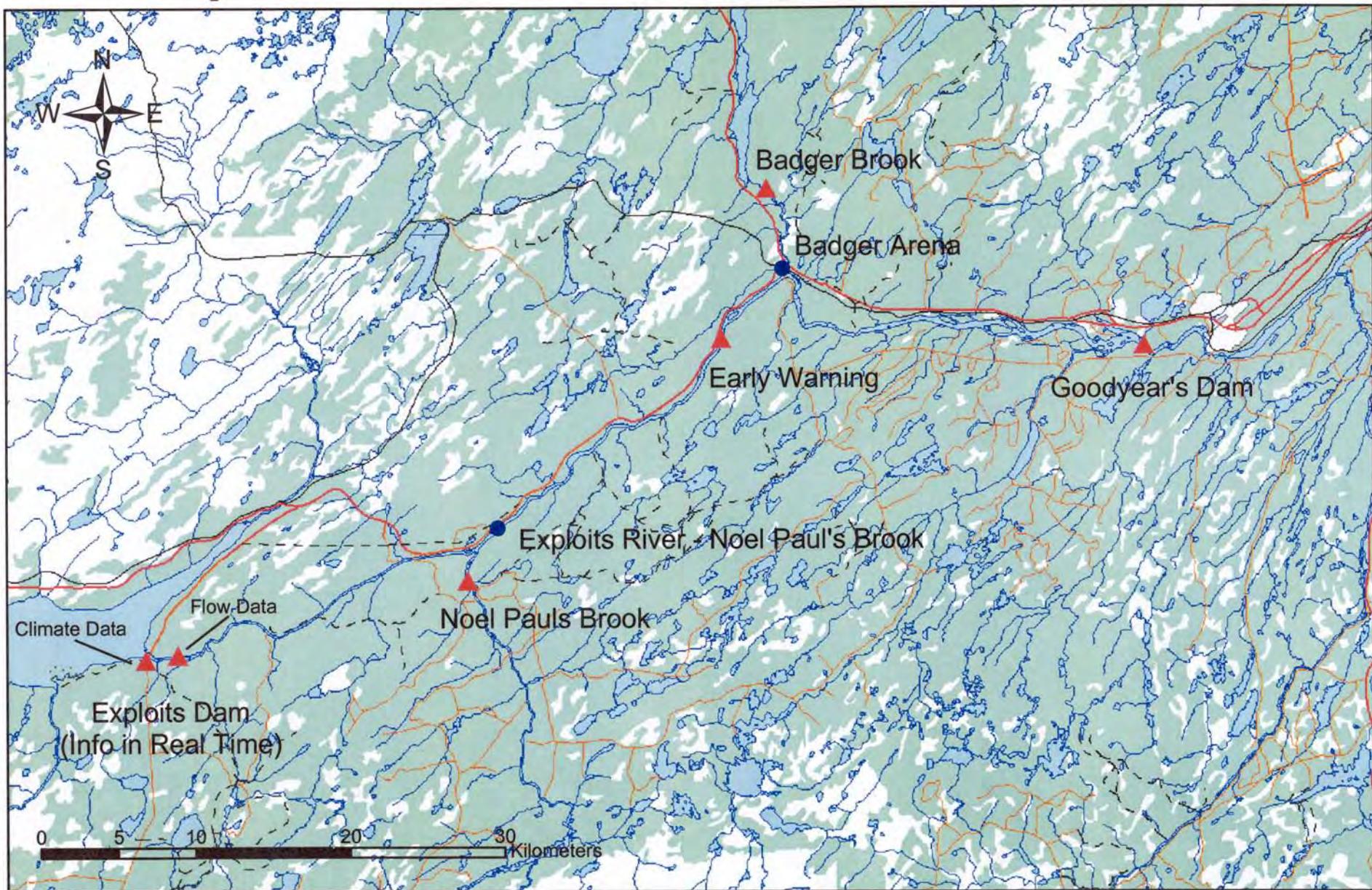


Figure 18 - Proposed Flood Warning System



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- Existing Monitoring Sites
- ▲ New Monitoring Sites

8. Conclusions

The rate of the water level increase was much faster than any of the major flooding events recorded at Badger since 1916. The mechanism of ice movement that led to the flooding at this point in time also seems to be different. This needs to be further investigated.

In the past, it was believed that once the ice cover was past Three Mile Island for a week or so that the danger of flooding was over in Badger. This event has shown that this is not the case.

As with the past floods, the event occurred after a mild spell was followed by an intense cold snap.

There is no indication in the hourly water level data from the Exploits River below Noel Pauls Brook that a sharp increase in water levels, either natural or due to the operation of Exploits Dam, occurred prior to the flood event.

Water levels on the Exploits River (Exploits River below Noel Pauls Brook) rose from 6.173 m at 8:00 am on February 7 to 6.391 m at 8:00 am on February 15, just before the flood - an increase of only 0.218 metres over the seven days. A stability analysis of the ice cover using mathematical models will be required to determine whether this increase in level contributed to the breakup of the ice cover that resulted in the flood at Badger.

The present flood forecasting system was not designed to forecast floods that occurred with the rapidity of the event that occurred on February 15, 2003. Also, improvements are required in the hydrometric network to support an upgraded flood warning system that would have the capability to provide a warning for these types of floods and for the management of the flood response after a flood event.

The information provided by the staff at the Gander Weather Centre has been vital in managing the post flood management of flows in the Exploits River and providing an advance warning of adverse weather conditions.

While the current flood risk mapping is accurate, the flood event was slightly higher than the 1:100 year return interval level used in the map. Further study needs to be carried out to check the validity for the 1:20 and 1:100 year levels. This information will be required to provide the design parameters for any remedial measures that are proposed.

9. Recommendations

A detailed hydrotechnical study needs to be carried out to establish the cause or causes of the flood that occurred on February 15. This study must also review the 1:20 and 1:100 year levels for Badger that were established in the 1985 study to determine if these levels are now reasonable.

Appropriate levels are required so that remedial measures can be designed to protect against an appropriate flood level.

The remedial measures proposed in the 1985 study need to be reevaluated using a new economic analysis based on the flood damages from the February 2003 flood.

An outside consultant should be hired to carry out the two previous recommendations based on a terms of reference to be prepared by the DOE, in consultation with other stake holders.

Improvements need to be made to the flood forecasting system, particularly to improve the flood warning capabilities. The monitoring network needs to be expanded as shown in Figure 18. The gauges upstream of Badger need to be equipped with a real time transmitter that can initiate a warning when the water level changes rapidly. Other improvements to be considered, include:

- improve the processing of wind speed, gust and direction from the Noel Pauls Brook wind gauge,
- develop equations for estimating missing data from nearby stations,
- upgrade the equipment at the Badger water level gauge,
- acquire and use realtime satellite imagery (RADARSAT) to monitor ice cover progression,
- purchase previously recorded images for the analysis of this and past events,
- calculate normals for all nearby climate stations, based on available data,
- update ice forecast model more frequently, up to once every 3 hours.

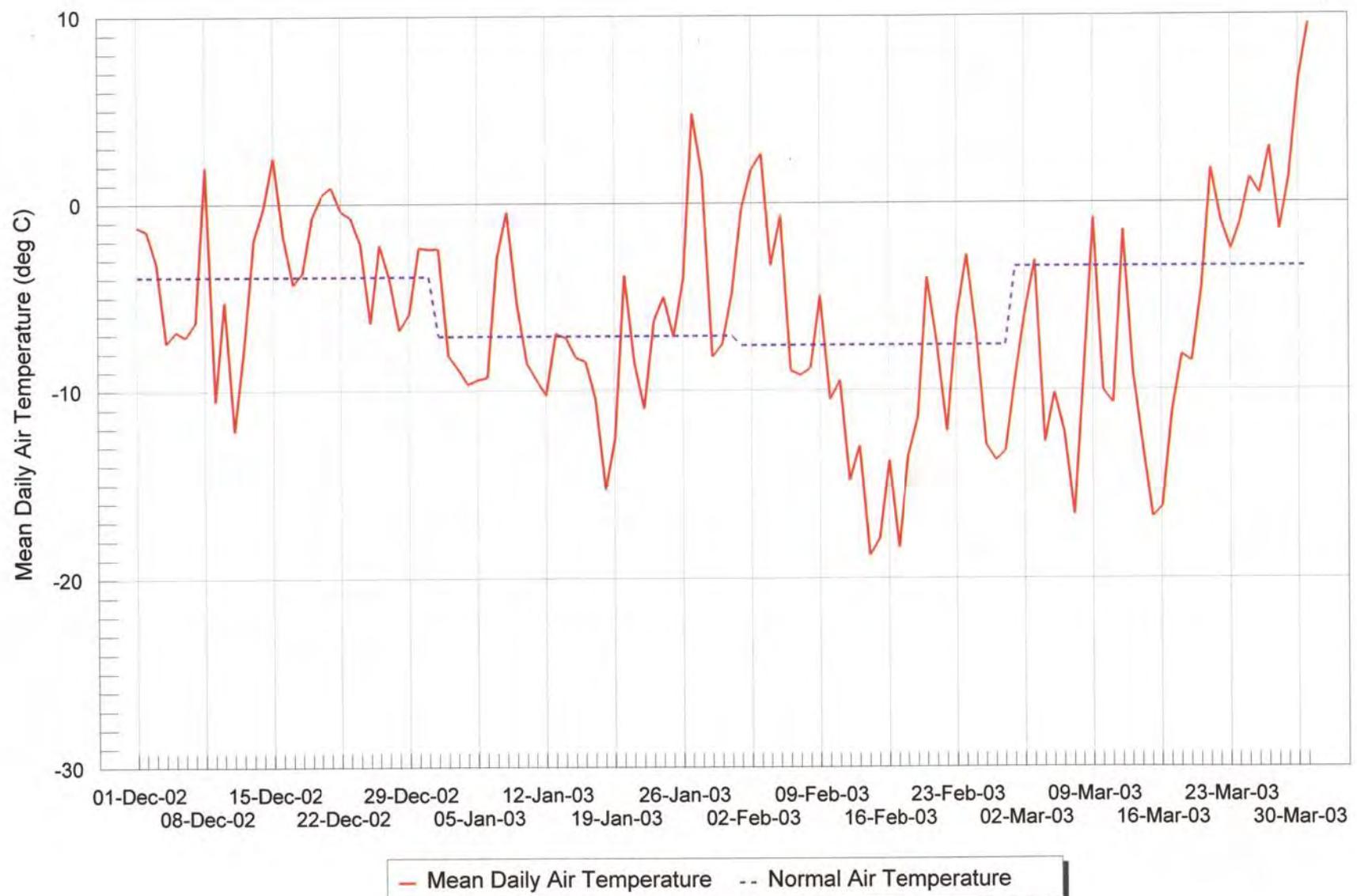
Abitibi should be approached to discuss the cost sharing of the improvements to the flood forecasting system noted above.

The recommendations above are based on the current situation in Badger and may be subject to revision depending on the remedial measures that are implemented

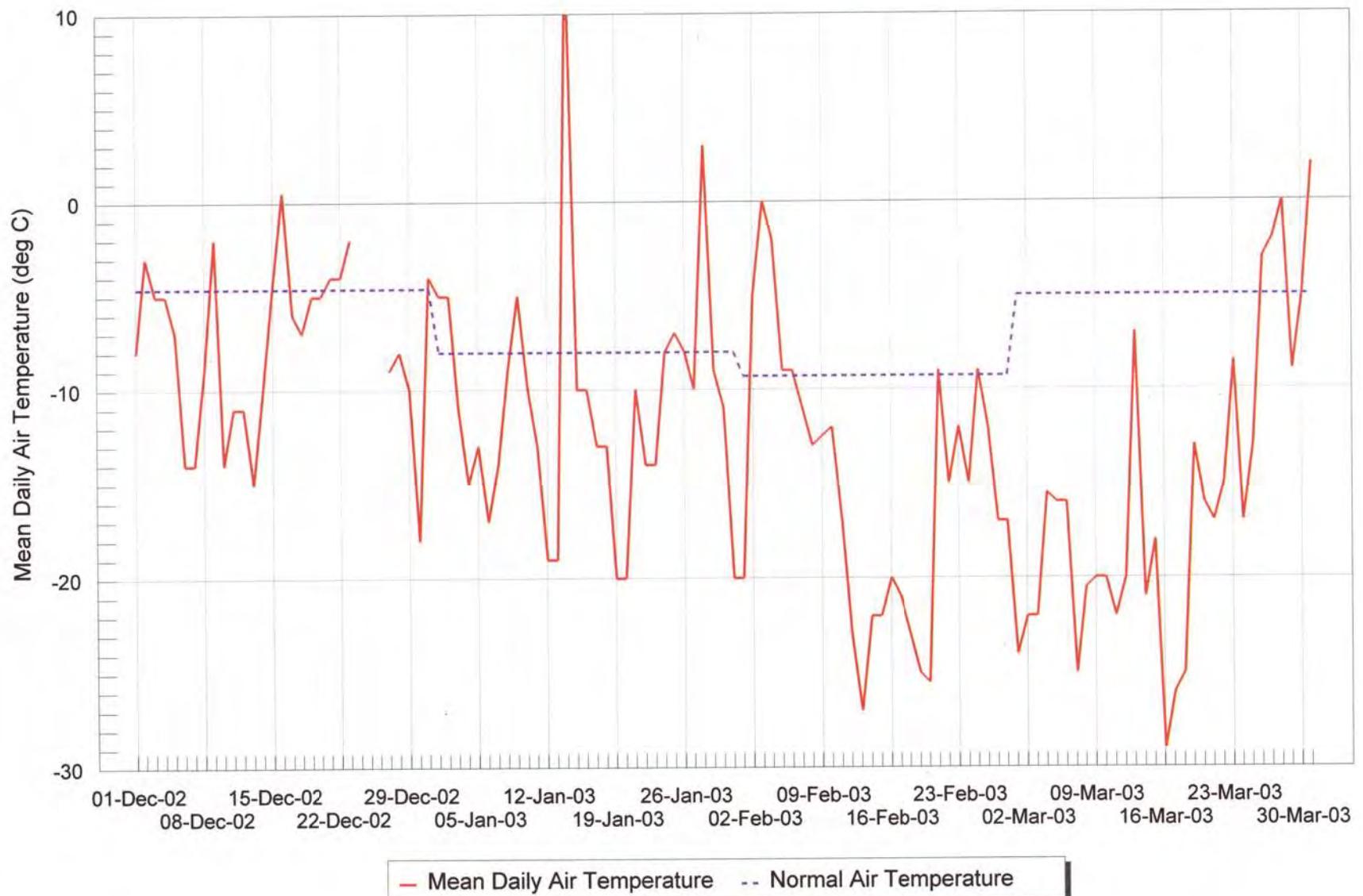
Appendix A

Climate Data

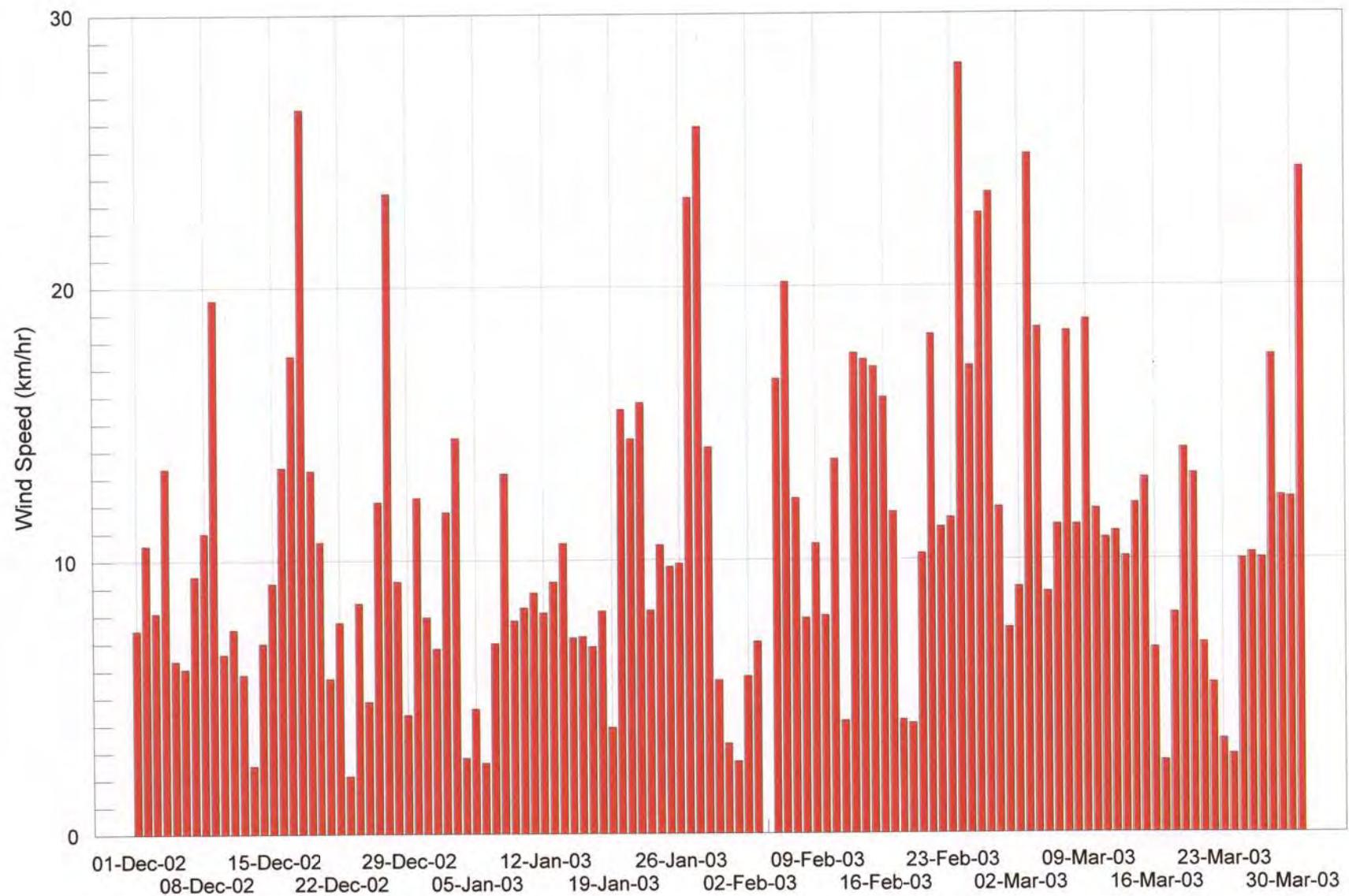
Grand Falls
Mean Daily Air Temperatures



Exploits Dam
Mean Daily Air Temperatures

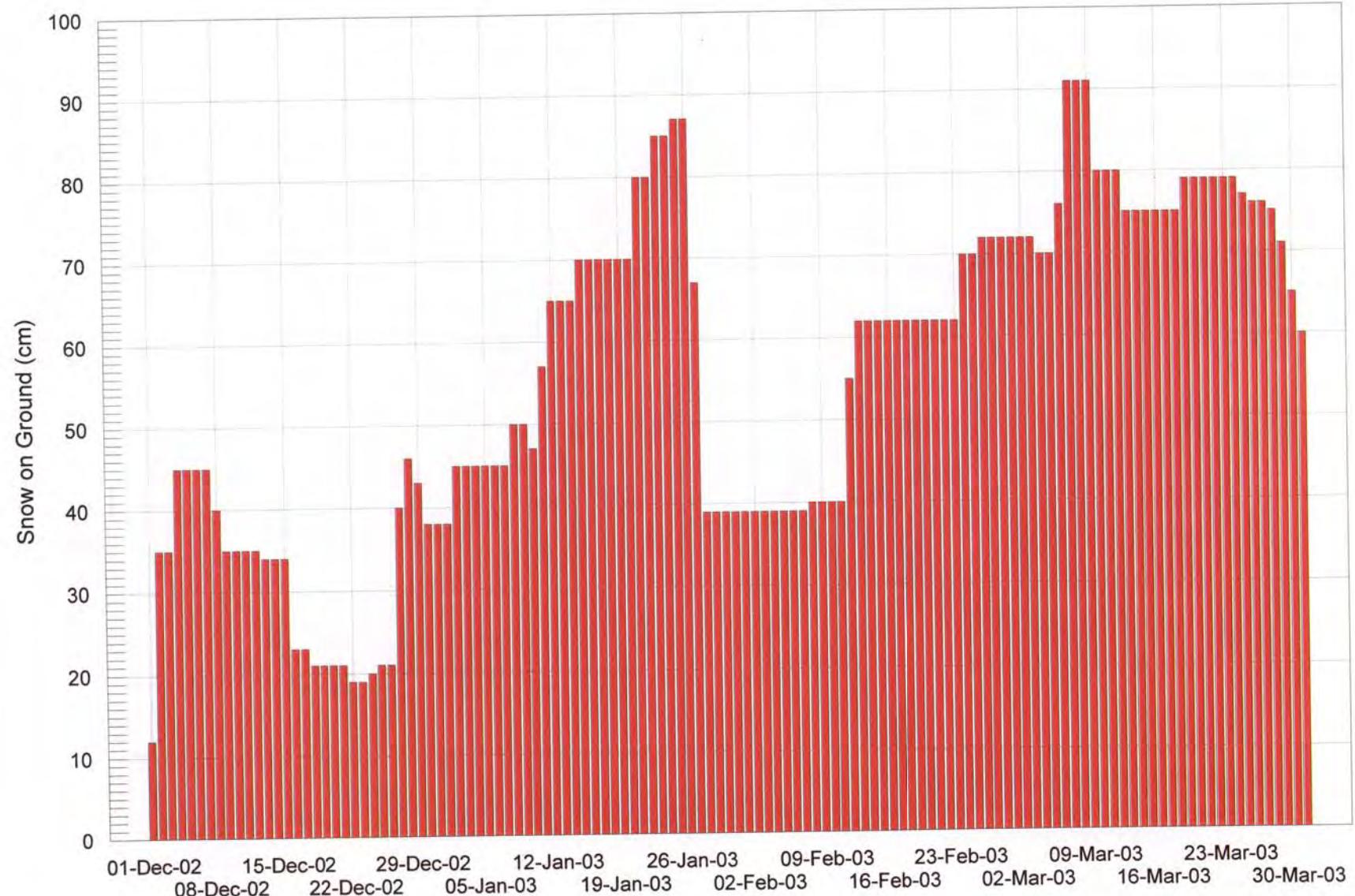


Grand Falls
Mean Daily Wind Speed



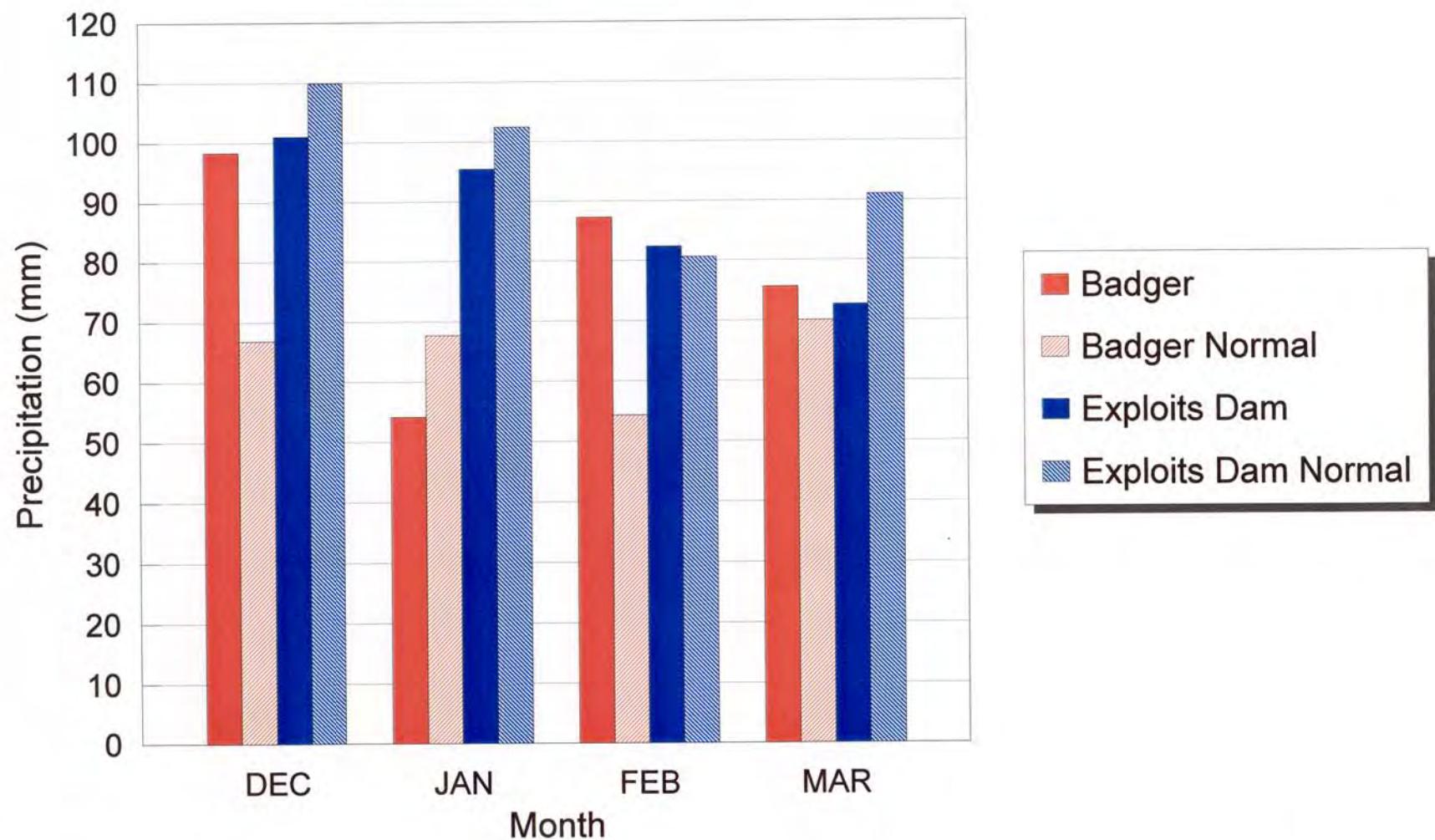
Exploits Dam

Snow on Ground



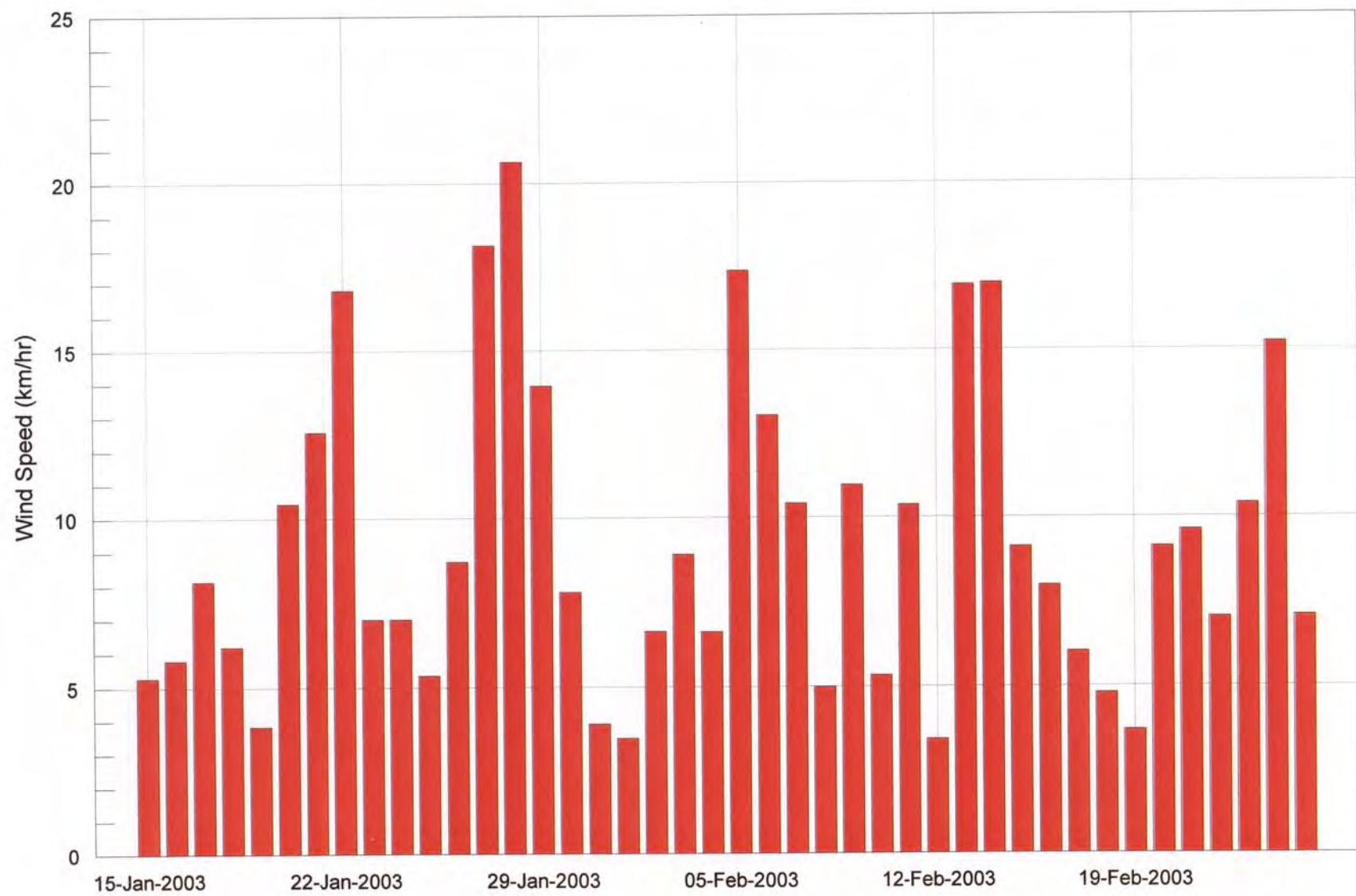
Monthly Total Precipitation

December 2002 to March 2003



Exploits River below Noel Pauls Brook

Mean Daily Wind Speed



Appendix B

Streamflow/Discharge Data

Data is available from
Department on request.

Appendix C

Ice Modelling/Progression

Data is available from
Department on request.