2008/2009 Annual Report
Volume I

JOINT OBSERVATIONAL STUDY (JOS)

Seaway Shoreline Icebreaking Impacts Between Snell Lock & Lake St-Francis

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Prepared by

JOS PROJECT MANAGEMENT TEAM

Under the direction of

KIJE SIPI LTD

and under the technical leadership of

BMT FLEET TECHNOLOGY LTD

June 2009

JOS PROJECT MANAGEMENT TEAM MEMBERS

Saint Lawrence Seaway Development Corporation (U.S.)

Carol Fenton, Deputy Associate Administrator

Thomas Lavigne, Director of Engineering & Maintenance

Saint Lawrence Seaway Management Corporation (Canada)

Stephen Kwok, Director, Operations & Technical Services

Luc Lefebvre, Manager, Operational Services

Transport Canada

Karen Westerlaken, Senior Policy Advisor

Mohawk Council of Akwesasne

Henry Lickers, Director, Department of Environment

St. Regis Mohawk Tribe

Ken Jock, Director, Environmental Division

Tony David, Manager, Water Resources Program

JOS PROJECT COORDINATOR

Kije Sipi Ltd

Daniel Jobin, President & CEO

ICE CONSULTANT

BMT Fleet Technology Ltd

George Comfort, Manager of Cold Regions Technology Centre

JOS PROJECT MANAGEMENT TEAM DECLARATION

The content of this report summarizes all JOS Project Management and study activities during the third year of its three year mandate, covering the period from July 2008 to June 2009. Specifically, the annual report reflects all JOS Project Management Team activities, decisions, technical findings, conclusions and recommendations and, was in principle, unanimously approved by the JOS Project Management Team at the June 24th 2009 meeting.

TABLE OF CONTENTS

Note: All appendices are located in **Volume II** of this report.

1. SUMMARY

As stipulated in the **2006 *Memorandum of Understanding*** a project management structure was established in the autumn of **2006** to oversee the three (3) year observational study. This included the selection of a study coordinator in **2006** and the addition of an ice specialist in **2007**. This third and last **Annual Report** summarizes all pertinent study activities during the 2008/2009 study period. Note that a separate, **Study Report**, summarizes all study activities and, perhaps more importantly, brings forward conclusions and recommendations that are based on observations taken during the entire three (3) year mandate.

Only three (3) **Steering Committee** meetings were held this year to review progress and prepare for the spring ice-clearing observation program. This significant reduction in the total number of meetings, as compared to last year, is partly due to the efficiency gained by the experienced study team and, the early natural ice cover breakup that occurred this spring. Minutes were taken at all meetings and, in most instances, approved at the following meeting.

The study coordinator maintains a register of all study expenses including the reported **In-Kind** contributions by all parties. A total of **$28,415.17** was charged to the study this year bringing the total expenditures to-date to **$105,883.88**, or approximately **81.4%** of the allocated **$130,000.00**. Also, a total of **$7,912.50** was recorded as **In-Kind** charges to the study during this second reporting period bringing the total study **In-Kind** charges to **$41,670.50**. Note that dollar values presented in the study reports are in quoted in **Canadian** dollars.

A password-protected electronic document archive site was established early in the study and was maintained by the study coordinator in **2008**/**2009**. It is accessible via

the internet by all study team members. A video data archiving and distribution protocol was developed in the spring and provided to all study team members.

Only one (1) letter was sent this year – a letter of appreciation to the **Canadian Ice Centre** for providing multiple **RADARSAT** images.

There were no significant management issues during this reporting period; however, the observation program was altered due to the early and natural breakup of the ice cover within the navigation channel.

A detailed **Technical Work Program** was developed and approved by the **Steering Committee** in early **2007**. The document again served as a guide for all study team activities in **2008/2009**. The main components of the program that were initiated or completed this year include:

- Revise and establish a **Monitoring Program** for the winter/spring of **2009**.
- Collect and analyze observational data during the winter/spring of **2009**.
- Report findings and conclusions.

This last year of the three-year mandate saw an experienced team efficiently prepare for the spring ice-clearing observation activities that actually never occurred. Mild temperatures and high water levels leading up to the **Seaway Opening Date** deteriorated the ice cover to such a point that the navigation channel was entirely cleared of ice by the time the icebreaker passed through the study area. Consequently, no new information regarding the direct physical impacts of anthropogenic ice-clearing was collected in **2009**. Nevertheless, the **Steering Committee** directed the observation team to collect baseline information on the natural breakup of the ice cover.

The key technical findings are presented and summarized in the following list of specific conclusions:

Shoreline Surveys

1. Field surveys were completed during the fall of **2008** in order to select appropriate observation sites for ice impact observations based on the previous year's experience. Two key criteria for site selection were the accessibility of the site, and the degree to which that location was representative. Eventually, three to four (3 to 4) sites were selected for pre/post ice-clearing observations of the near-shore ice cover. However, ice cover movement observations during ice-clearing operations were not carried out this year because an early and natural ice cover breakup occurred.
2. No monitoring of the shoreline bank profiles was done this year as this time-consuming task did not provide meaningful information on the physical ice-induced processes under study that occur near the water's edge.
3. An extensive photographic survey of the shorelines was conducted along the full study reach in the fall using both video and still photography. This was completed using a boat as a vantage point. The shoreline was again inspected in the spring for visible changes or evidence of ice-induced shoreline damage, such as berms, ridges or scars - none were observed.
4. Rip rap stones at **Clark** and **Stanley Islands** were marked and surveyed prior to, and after the winter. Several of twenty-one (21) marked rip-rap stones along **Stanley** and **Clark Islands** that were originally surveyed in the fall of **2008** showed some level of movement over the course of the winter/spring. Considering the entire ice cover was cleared by natural means in **2009**, the movement of those stones can be considered to represent the baseline conditions expected to occur under natural conditions. Furthermore, the armour stone stability analyses that were completed last year were reviewed and, the conclusions were generally corroborated by the **Spring 2009** observations – thus supporting the hypothesis that "the observed rip-rap movements were ship-induced" is still a valid explanation.

Ice Conditions Index - Freezing-Degree Days Evaluation

5. The **Freezing Degree Day**(**s**) index method was again used as a means to evaluate the severity of winter and indirectly infer the ice conditions within the seaway channel. The application of the **FDD** method this winter indicated a more severe winter/spring than observed in **2007/2008**, as there were more **FDD**s in **2008/2009** than in **2007/2008** (i.e., maxima of 895 and 760 °C*days, respectively). Considering that a natural ice cover breakup occurred in **2008**/2009 at an earlier date than the icebreaker-induced breakup in **2007**/**2008**, it is concluded that other factors such as water levels and flows and, weather are equally important in characterizing the state of the ice cover; hence, the **FDD** method should not be used exclusively as a gauge of the ice conditions.

Water Levels and Flows

6. Water level and flow records were again reviewed this year. The data indicated the values in **2008**-20**09** were slightly higher than the 30-year average over most of the winter. During the time leading up to the break-up of the ice cover, the flow was about 300 cms higher than the 30-year average. Furthermore, a steady and significant increase in water level of about 15 cm occurred prior to the ice break-up and is surmised as playing a key role in the early ice cover breakup. It is hypothesized that the natural ice break-up and clear-out that occurred in **2009** was precipitated by a 15 cm rise in water level that occurred in the week prior to the break-up of the ice cover on **March 8** in the channel between **St. Regis** and **Cornwall Islands**. This would have acted to de-stabilize the ice cover, by breaking it away from the shoreline. Also, it would have facilitated "flushing" of the ice downstream by the higher flows that prevailed at the time and throughout the **2008/2009** winter.

Evolutions of the Ice Cover

7. The formation of an ice cover over the course of a winter plays an important role in defining its state at any given time within the winter. Consequently, observations were made during the winter to track the development of the ice cover. This was accomplished using **RADARSAT** satellite imagery, an aerial reconnaissance flight, ground-level (ice/land) observations and, new for this year, a continuous video record of the ice cover and its breakup. The aerial survey and the ground-level data were particularly useful for ground-truthing the satellite data, while the **RADARSAT** data itself was particularly useful to providing information regarding the overall development and macro structure of the ice cover. A higher level of detail was also obtained from the aerial flight survey. These sources of information were important in supporting field observations. The initiation of the ice breakup was detected by video surveillance on **March 7th** while open water was recorded by **RADARSAT** prior to **March 21st** in the study reach.
8. Comparisons with long-term data regarding the duration of the ice cover along the **Seaway** indicates that the **2008/2009** winter was not unusual with respect to the date of first ice deterioration or the ice-free date.

Ice-clearing Observations

9. As previously mentioned, the planned ice-clearing operation within the study reach that was scheduled on approximately **March 29th, 2009**, did not take place this spring because a natural breakup of the ice cover occurred in the preceding two to three weeks. Consequently, no ice-clearing observations were made this spring.
10. It was recognized last year that ice-induced shoreline impacts could potentially occur due to moving ice floes during the ice cover breakup process. This was investigated by using boat based observations in the weeks following the natural ice cover breakup. The study team did not observe any significant ice-induced impacts, such as scours, scars, or berms.

11. No shoreline physical impacts were reported by any landowners along the shoreline being studied as a result of the natural breakup of the ice cover.

Based on this year's findings, the following recommendations were developed:

1. As stated in the previous two **Annual Reports**, the **Opening Date Selection** and ice-clearing operations should continue to be an inclusive process for the current stakeholders and include risk assessment elements of icebreaking operations and ice conditions. Incorporating better planning tools such as **RADARSAT** satellite imagery, aerial and land-based surveys plus usage of an improved **FDDs** methodology can only improve the knowledge of field conditions; hence, mitigate the risk of potential ice impacts in clearing the navigation channel.
2. The **Freezing Degree-Days** (**FDDs**) index method, which was again used to gauge the severity of ice conditions and serves as a planning tool, must be used in conjunction with other observations, namely, water levels and flows, ice thickness data, and, ice temperature profiles in order to increase the reliability of results. The development of a knowledge base should also be considered in order to enhance the interpretation.
3. Considering the usefulness of the **RADARSAT** imagery to the stakeholders, access to this type of data should be secured with the appropriate government department in order to ensure on-going availability. Furthermore, the study team recommends using **RADARSAT 2** imagery, rather than **RADARSAT 1** imagery, as was used last year, since it provides a noticeable improvement in the discrimination of ice cover conditions.
4. The **2009** field observation activities yielded significant information on the natural breakup of the ice cover within the study reach. This knowledge should be used to better understand all the processes involved in the breakup of the ice cover.

2. INTRODUCTION

Study Impetus, Mandate & Objective

The **Joint Observational Study** (**JOS**) arises as a commitment by all signatory parties to the **May 29, 2006 *Memorandum of Understanding*** (**MOU**) to observe and document potential physical impacts arising from icebreaking activities in support of commercial navigation in the **St. Lawrence Seaway**. In particular, this is articulated in the *General Provision Clause 7.01* in the reference **MOU** which indicates that the purpose of the study "*is to observe physical effects arising from the opening of the navigation season in the area from **Snell Lock** to the middle of **Lake St-Francis** when ice is present in that area*".

General questions to be studied

Do icebreaking activities and/or ship transits in ice conditions within the study area cause:

- Shoreline ice scour and/or,
- Landfast ice to break away from shore prematurely?

Initiating the Joint Observational Study

As stipulated in the previously mentioned **MOU**, a **JOS Project Management Team** (**JOS PMT**) was established in late **2006** with representative members from all signatory parties to the **MOU**. A third party **Study Coordinator** was later selected in **December 2006** to oversee the day to day activities of the study.

2006/2007 Annual Report

The content of the ***2006/2007 Annual Report*** is not included in this report. Please consult the separate document for details on the initial observation period.

2007/2008 Annual Report

A copy of the "***Summary***" section of the ***2007/2008 Annual Report*** is provided for reference in **Appendix A**. All four (4) recommendations listed in last year's report were addressed throughout the **2008/2009** study activities and included:

- Moving efficiently forward with the mandate. In this regard, the same **JOS Steering Committee** members were again actively involved in the study this year. This is an important issue for this type of study. The successful completion of highly technical studies demands a stable and engaged management team.
- Reassess the Freezing Degree-Day Index Method. The recommended **Freezing Degree-Days** (**FDDs**) method was again utilized in **2008**/**2009**.
- Continuance of "Inclusive" **Opening Date** Selection Process. As envisioned in the **MOU**, participation by a wider representation of stakeholders occurred again this year and included representation by the **Mohawk Tribes**. Planning tools such as the **FDD** were again used to provide insight on ice conditions.
- Improved Field Observation Techniques. The collective experience of the group's past two spring observations was tapped in developing a refined **2009 Spring Observation Program**. As a result, this year's program included a new method of marking target stones to ensure survivability; the addition of video to detect shoreline changes as well as to document the ice breakup; the elimination of above-water shoreline slope profiling surveys as well as a need to directly observe the near-shore ice movement during the passage of the icebreaker.

2008/2009 Annual Report

This report documents and summarizes all key **2008/2009 JOS** activities, findings, conclusions, recommendations as well as **JOS PMT** decisions.

3. 2008/2009 JOS PROJECT MANAGEMENT TEAM ACTIVITIES

The **JOS PMT** activities in **2008/2009** included:

3.1. Meetings

A total of only three (3) **JOS Steering Committee** meetings were held this year throughout the **2008/2009** season. This is a substantial reduction in the total number of meetings, as compared to last year (eight meetings), and is most likely due to the increased efficiency the group has achieved with time as well as the reduced spring observation activities caused by an early, natural ice breakup within the navigation channel.

As in the past years the meetings were held on a rotating location basis, at each team member agency's work place. The meetings were held on:

October 2nd 2008
January 27th 2009
June 24th 2009

Minutes of each meeting are included in **Appendix C** of this report. All **Minutes** were unanimously approved except those for **June 24th, 2009** (Draft **Minutes** are attached). Note that accompanying notes and materials are generally not included with the **Minutes** however, were distributed to all **JOS PMT** members and are available from the study archives.

3.2. Financials

The study expenditures were again tracked and monitored by the **JOS PMT** this year. As of the **19th of May 2009** a total of **$28,415.17** was charged this year to bring the total study expenditures to **$105,883.88** or, **81.4%** of the allocated budget of **$130,000.00**. All study expenditures during this third and last year of the study

mandate consisted of payments to the **Study Coordinator** (**SC**) **Kije Sipi Ltd**, the sub-consultant **BMT-Fleet Technology** as well as one (1) disbursement to the **St. Regis Mohawk Tribe** (**SRMT**) for video camera support services that was approved by the **Steering Committee**. Note that dollar values presented in all the study reports are quoted in **Canadian** dollars.

In-Kind contributions were again tracked this year using the established formula. Time and expenses were registered by the study coordinator based on approved claims by all **JOS PMT** members. As of the **19th of May 2009**, a total of **$7,912.50** was recorded as **In-Kind** charges to the study during this reporting period while the total amount accrued against the study has now reached **$41,670.50**. The reduced annual **In-Kind** contributions this year are partly explained by the small number of meetings as well as a reduction in the field activities.

Appendix B presents a breakdown of both **Financials** and **In-Kind** charges. Note that the study charges presented in this report are accrued expenditure values that were available to the editor at the time the report was written.

3.3. Management, Correspondence & Documentation

The study benefitted from having a stable management team and an experienced technical group this year. This contributed to fewer meetings and a refined observation program.

Only one (1) letter was distributed this year – a letter of appreciation to the **Canadian Ice Centre** for again providing multiple **RADARSAT** imagery.

A protocol was also developed this year regarding archiving camera imagery and included a provision for distributing copies to law enforcement agencies.

The password-protected **FTP** document archive site was again maintained this year and augmented with all relevant study documents including financials. **Appendix G** lists the current content of the archive.

3.4. Issues

There were no significant issues during this reporting period apart the fact that no ice-clearing operations were observed this year since the ice cover receded under natural conditions.

4. TECHNICAL WORK PROGRAM

A **Work Plan** was developed in early **2007** in order to guide the team members in organizing the mandated activities. This section of the report briefly discusses the status of the **Work Plan** at the end of **May 2009** while **Figure 4.1** schematically depicts all completed study tasks.

Figure 4.1: JOS Work Plan

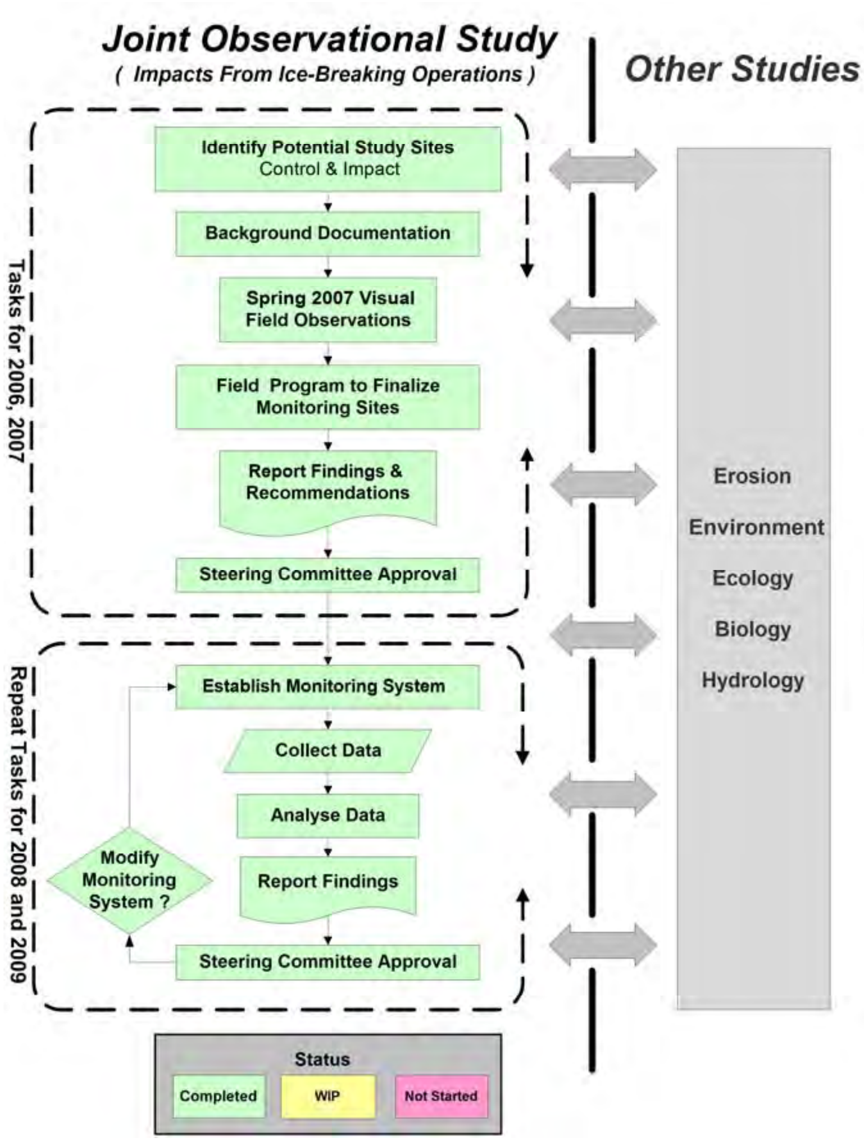


Figure 4.1 shows all **JOS** tasks in color-coded boxes, each color identifying the state of completion. The diagram essentially indicates that all study tasks have been completed and also situates the **JOS**–mandated physical shoreline ice impact focus within a broader context that encompasses other studies such as the **NYPA – Erosion and Sedimentation Study** completed in **2001**. All identified **Work Plan** tasks for **2006** and **2007** were completed (highlighted in green) as well as all the **2007/2008** season observation tasks. These included:

- Identification of potential study sites
- Review background documentation
- 2007 spring field observations
- Report 2007 spring ice-clearing observations
- Develop new **Monitoring Plan**
  - Select new sites
- Complete 2007 fall field baseline surveys
- Collect & analyze 2008 spring observation data
- Report 2008 spring ice-clearing observations

In addition, the following tasks were completed during this reporting period:

Establish 2008/2009 Monitoring System (Completed)

Capitalizing on the previous year's field observation experience, a revised **Monitoring Plan** was development by the technical team and subsequently adopted by the **JOS Steering Committee** for implementation during the **2008/2009** observation season. The revised plan included the following tasks:

- review and optimize the selection of the observation sites;
- photograph and video shoreline (fall and spring);
- setup and organizing real time video recording of the ice breakup;
- analyze evolution of ice cover from satellite imagery (winter and spring);
- on-ice target installation and monitoring (before and after ice-clearing);
- setup of "just below water" marker stone network and displacement survey;
- complete ice conditions aerial reconnaissances;
- complete ice temperature and thickness surveys (winter and spring);
- analyze **Freezing Degree-Day** findings;
- observe ice-clearing aboard icebreaker, and;
- document study findings.

<u>Collect & Analyze Data (2008/2009) (Completed)</u>

Following the approval of the **2008/2009 Monitoring Plan**, the study team initiated the fall field baseline and setup tasks. All winter and several spring monitoring tasks were also completed as planned; however, since the ice cover disappeared prior to the **Seaway** clearing operations, the spring observation program was modified to document the natural, rather than an anthropogenic ice cover clearing process. The actual **2008/2009 Observation Program** included the following tasks:

- photograph and video shoreline (fall and spring);
- setup and organizing real time video recording of the ice breakup;
- analyze evolution of ice cover using **RADARSAT** satellite imagery;
- setup of "just below water" marker stone network and displacement survey;
- complete ice conditions aerial reconnaissance;
- complete ice temperature and thickness surveys (winter);
- document findings, and;
- analyze **Freezing Degree-Day** findings.

<u>Report (2008/2009) Findings & Prepare Recommendations (Completed)</u>

This document reports all **Steering Committee** activities during the **2008**/**2009** season (**Chapter 3** and **4**) along with all observations and analyses (**Chapter 5** and **6**). The report also outlines conclusions and recommendations (**Chapter 7**).

5. SHORELINE SURVEYS

5.1. Objectives and Overview of Survey Scope

5.1.1 Objectives

A program was set up to observe ice-induced shoreline changes over the winter along the shipping channel. The lessons learned during the **2007/2008** shoreline observation program (ref: ***2007/2008 Annual JOS Report***) were applied in defining the scope and approach for the **2008/2009** program. As previously mentioned, detailed elevation profile surveys were not completed at points along the shoreline. Instead, the survey approach was focused on observing larger-scale changes and processes, which ice-related processes would be expected to produce at or near the waterline.

The shoreline survey program consisted of two general components (**Table 5.1)** as summarized below:

(a) Boat-based transits were made along both shorelines (i.e., north and south) of the shipping channel from **Cornwall Island** to **Stanley Island**. A transit was first made before the winter (on **October 22, 2008**) during which both sides of the entire shoreline were photographed using still and video cameras. The intention was to repeat these photographic surveys: (i) after or during ice break-up, and also; (ii) after the winter. However, because icebreaking operations were not necessary to open the **Seaway** in **2009** (described subsequently), the scope of the post-winter surveys was reduced to only a boat-based transit along both shorelines in springtime (on **May 4, 2009**).

(b) Rip-rap stones were identified, marked, photographed, and located using land-based surveys at points along the shorelines of **Clark** and **Stanley Islands** that were closest to the shipping channel. These islands were

selected because the shipping channel is closest to land at these points. See **Figure 5.1** for a location map for **Stanley** and **Clark Islands**. The rip-rap stone surveys were first done on **October 23**, **2008**. The sites were re-visited after the winter on **May 4**, **2009**.

Table 5.1 General Summary of Shoreline Survey Program

Time Conducted	General Description	General Scope
Pre-Winter (October 2008)	Boat-based Video and Photographic Survey along the shorelines	The entire shoreline from Cornwall Island to Stanley island was photographed on October 22, 2008 using still and video cameras. This was done by traveling in a boat along both shorelines (i.e., north and south of the shipping channel).
	Rip-rap Surveys at Stanley and Clark Islands	Rip-rap stones were marked, photographed and located using survey techniques on October 23, 2008 as follows: (a) Stanley Island – twelve rip-rap stones were marked and located. (b) Clark Island – nine rip-rap stones were marked and located.
Post-Winter (May 2009)	Boat-based transit along the shorelines	A boat-based transit was made on May 4, 2009 along the entire shoreline from Cornwall Island to Stanley island. Visual observations were made. Because no evidence of ice-induced shoreline damage was observed, photographic or other surveys were not done to follow up this transit.
	Rip-rap Surveys at Stanley and Clark Islands	The marked rip-rap stones at Stanley and Clark islands were found, photographed, observed and positioned using survey techniques.

5.2. Observations and Results from Boat-Based Transits along the Shorelines

Emphasis was placed on observing large-scale features at or near the waterline because this is the type of shoreline change that ice-induced processes tend to produce. No large-scale shoreline changes were observed.

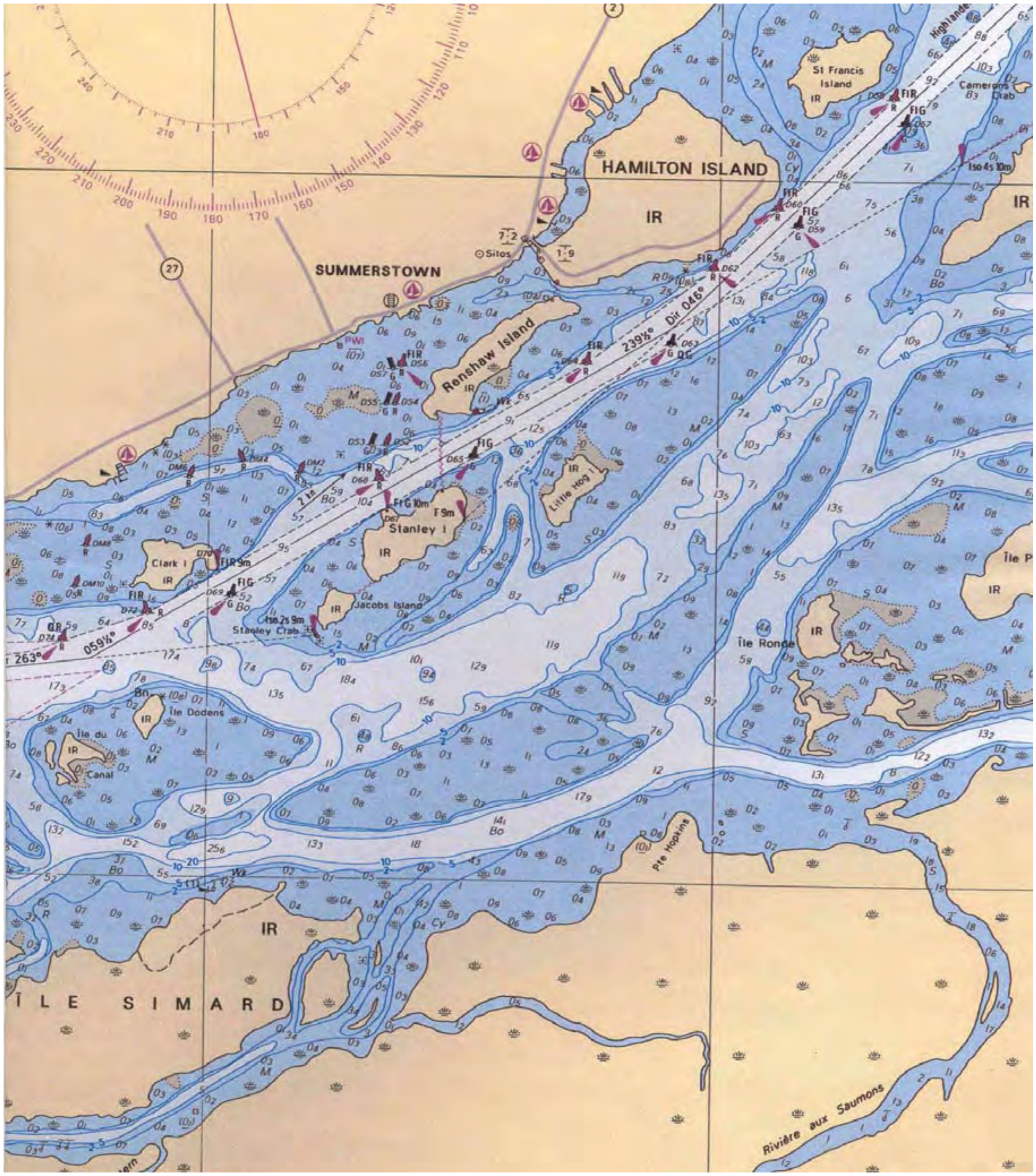


Figure 5.1 Location Map: Stanley and Clark Islands
(source: Canadian Hydrographic Service Chart 1432)

5.3. Shoreline Rip-Rap Surveys at Stanley Island

5.3.1 Survey Techniques

Twelve (12) rip-rap stones were marked, observed, and positioned with a location survey on **Stanley Island**: (a) before the winter on **October 23, 2008**, and; (b) after the winter on **May 4, 2009**. This site was not visited during the winter or ice breakup because icebreaking operations were not necessary to open the **Seaway** (described subsequently).

Because large movements are of most interest for this study, a high-precision survey was not conducted, as the added effort this would have required was not deemed appropriate. The survey was conducted by:

(a) Identifying suitable rip-rap stones for the survey. They were then marked with a combination of wires wrapped tightly around the stones and tie-wraps attached to the wires. Spray paint markings were also put on upslope stones that were out of the splash zone. This system worked well as all of the marked rip-rap stones were re-located during the **May 4, 2009** survey without difficulty. Photographs of some of the marked rip-rap stones are provided in **Figure 5.2.**

(b) Measuring the locations of the marked rip-rap stones. This was done by measuring the distances to them from fixed points on **Stanley Island** such as the lighthouse and various trees.

(c) Photographing the stones such that changes with respect to their overall layout could be identified, should they occur.

The surveyed rip-rap stones were all located on a point that is almost adjacent to the nearest edge of the shipping channel (**Figures 5.1** and **5.3**). This is one of the points between **Snell Lock** and **Lake St. Francis** where the shipping channel is closest to shore.

General View of Shoreline at Stanley Isl.

General View of Shoreline at Stanley Isl.

Marked Rip-rap (#1): October 23, 2008

Marked Rip-rap (#1): May 4, 2009

Marked Rip-rap (#4): October 23, 2008

Marked Rip-rap (#4): May 4, 2009

Figure 5.2 Marked Rip-Rap Stones at Stanley Island

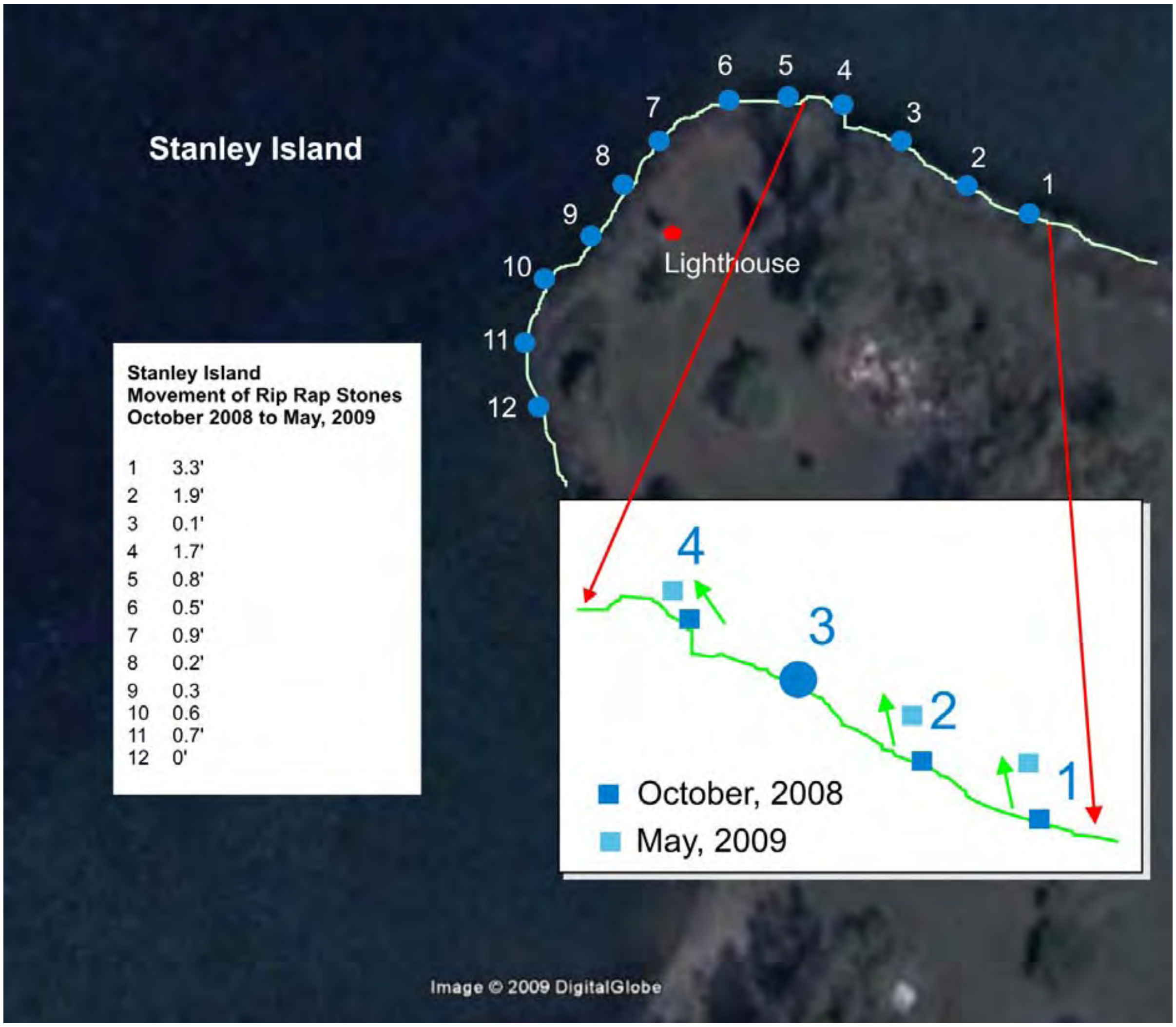


Figure 5.3 Marked Rip-Rap Stones at Stanley Island

5.3.2 Results: Movements of the Marked Rip-Rap Stones

Movements ranging from nil to 3.3 feet were measured over the period from **October 23, 2008** to **May 4, 2009** (**Figure 5.3**). The stones with the largest movements were all located on the east side of the promontory of **Stanley Island** that was surveyed. The movements were all either alongshore, or away from shore.

5.4. Shoreline Rip-Rap Surveys at Clark Island

5.4.1 Survey Techniques

Nine (9) rip-rap stones were marked, observed, and positioned with a location survey on **Clark Island**: (a) before the winter on **October 23, 2008**, and; (b) after the winter on **May 4, 2009**. As with the **Stanley Island** site, this site was not visited during the winter or ice breakup because icebreaking operations were not necessary to open the **Seaway** (described subsequently).

The same techniques used for **Stanley Island** were employed at **Clark Island** as well. Photographs of the marked rip-rap stones at **Clark Island** are provided in **Figure 5.4**

The surveyed rip-rap stones were all located on a point that is almost adjacent to the nearest edge of the shipping channel (**Figures 5.1 and 5.5**). This is one of the points between **Snell Lock** and **Lake St. Francis** where the shipping channel is closest to shore.

5.4.2 Results: Movements of the Marked Rip-Rap Stones

Movements ranging from 0.3 to 6.8 feet were measured over the period from **October 23, 2008** to **May 4, 2009**. The stones with the largest movements were all located on the south side of the promontory of **Clark Island** that was surveyed. This location is closest to the shipping channel. The movements were all generally alongshore (**Figure 5.4**).

General View of Shoreline at Clark Isl.

General View of Shoreline at Clark Isl.

Marked Rip-rap (#5): October 23, 2008

Marked Rip-rap (#5): May 4, 2009

Marked Rip-rap (#6): October 23, 2008

Marked Rip-rap (#6): May 4, 2009

Figure 5.4 Marked Rip-Rap Stones at Clark Island

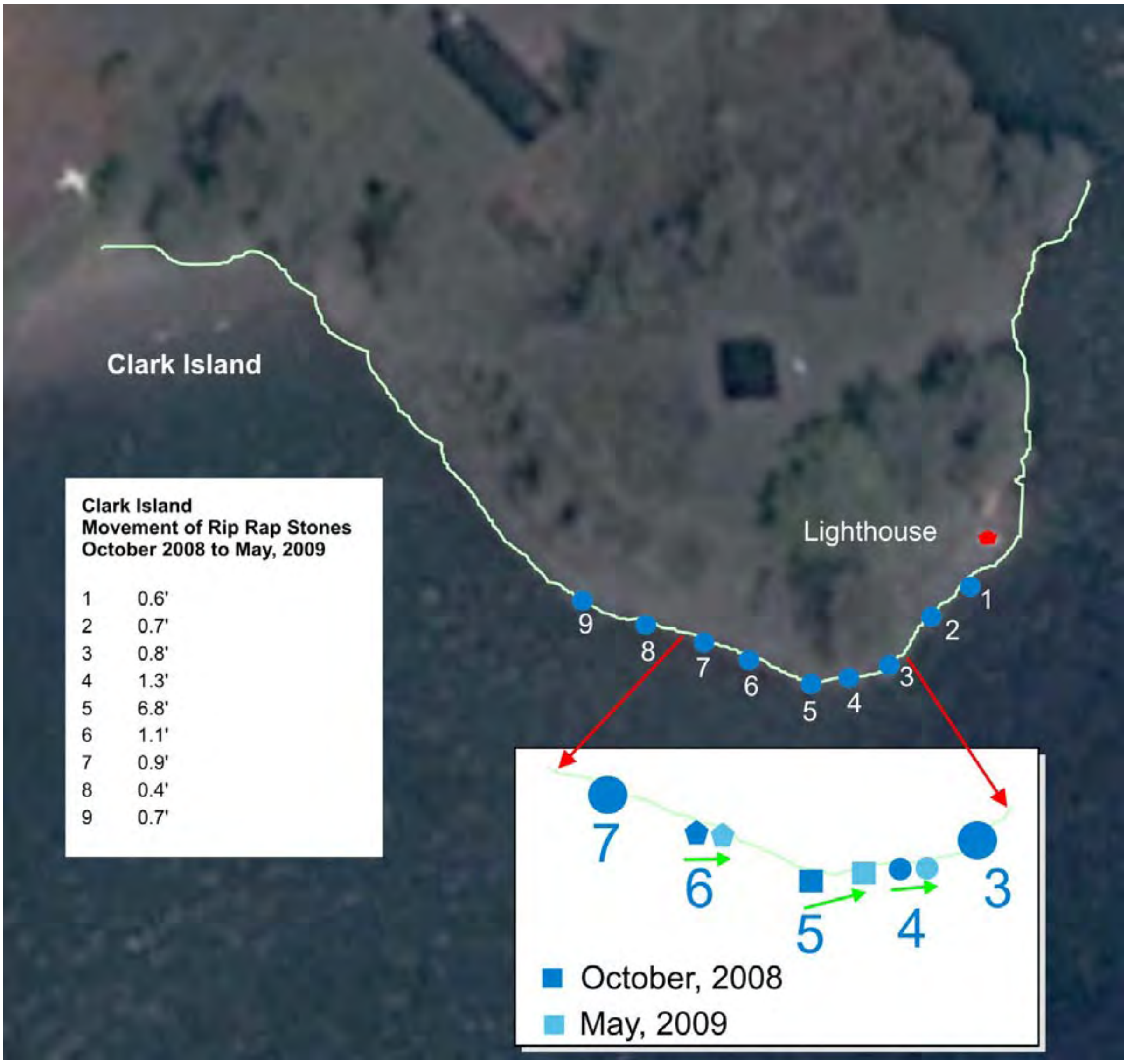


Figure 5.5 Marked Rip-Rap Stones at Clark Island

Larger movements were measured at **Clark Island** compared to **Stanley Island** (see **Figures 5.3** and **5.5**). This is believed to be mainly due to the fact that the rip-rap stones tended to be smaller at **Clark Island**, as may be seen from the general photographs shown in **Figures 5.2** and **5.4**.

5.5. Field Observation Program Summary and Discussion

5.5.1 Summary

Movements have been observed for some of the marked rip-rap stones at both sites, as summarized below:

(a) **Stanley Island** – three (3) of the twelve (12) marked stones moved 1 foot or more. The largest measured movement was 3.3 feet.

(b) **Clark Island** - three (3) of the nine (9) marked stones moved 1 foot or more. The largest measured movement was 6.8 feet. Thus, larger movements were observed at **Clark Island**. This is believed to be due to the fact that the rip-rap stones tended to be smaller at **Clark Island**.

The above movements are in the same range as those that were observed during the **2007/2008** season, when two (2) of the rip-rap stones at **Stanley Island** were measured to move by amounts of about 3 and 5 feet, respectively (ref.:***2007/2008 JOS Annual Report***).

Recognizing that icebreaking operations were not carried out in the spring of **2009** to open the **Seaway** (described subsequently), the observed movements represent a baseline condition that can be expected to occur under natural conditions. This baseline must be kept in mind when evaluating potential shoreline impacts created by icebreaking operations.

5.5.2 Possible Explanation for the Observed Rip-Rap Movements

A number of possible explanations for the rip-rap movements that were observed during the spring of **2008** were elaborated last year. It was concluded during that observation period that ship-induced currents and waves were the most plausible causative factor (ref.: ***2007/2008 Annual JOS Report***).

Ship passages again occurred at both **Stanley** and **Clark Islands** when the project team was onsite (**Figures 5.6** and **5.7**, respectively). These ship passages produced:

(a) Waves along the shorelines that were about 1 foot high (**Figures 5.6** and **5.7)**, and;

(b) Local surges and draw-downs in mean shoreline water level as the ship approached and then passed. Noticeable currents were produced along the shoreline by these local surges and draw-downs.

Ship Approaching Stanley Island

Waves Generated by Ship Passage

Figure 5.6 Ship-Induced Waves at Stanley Island

Ship Approaching Clark Island

Waves Generated by Ship Passage

Figure 5.7 Ship-Induced Waves at Clark Island

As part of the ***2007/2008*** study season (ref.: ***2007/2008 Annual JOS Report***), preliminary investigations were completed by referring to the **Shore Protection Manual** (**SPM**) developed by the **US Army Corps of Engineers** (**USACE**, **1984**). **Figure 5.8** was developed during last years analyses as a stability criterion for the rip-rap stones and is based on **SPM** methods (ref.: ***2007/2008 Annual JOS Report***).

Simple checks with the **2009** spring observations (e.g., based on the approximate sizes of the rocks) suggest that this criterion would still be applicable, and thus, the hypothesis that the observed rip-rap movements were ship-induced is still considered to be a valid one.

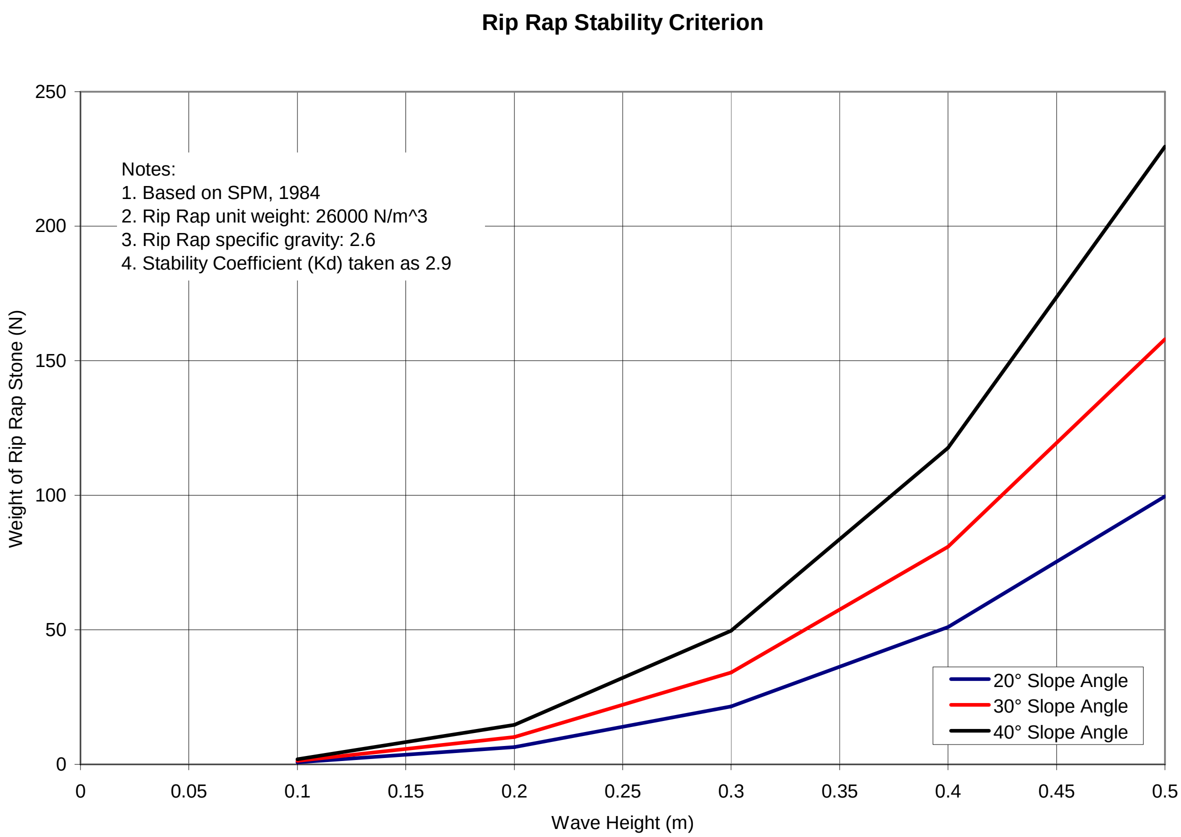


Figure 5.8 Rip-Rap Stability Criterion from the SPM (USACE, 1984)

6. 2008/2009 WINTER/SPRING OBSERVATIONS

6.1. Scope of Winter & Spring Observations

6.1.1 Overview

The planned **Seaway Opening Date** this year was set as **March 31, 2009**. It was one of the later **Opening Date**s, as later openings have only occurred in five (5) of the past 26 years (**Figure 6.1**).

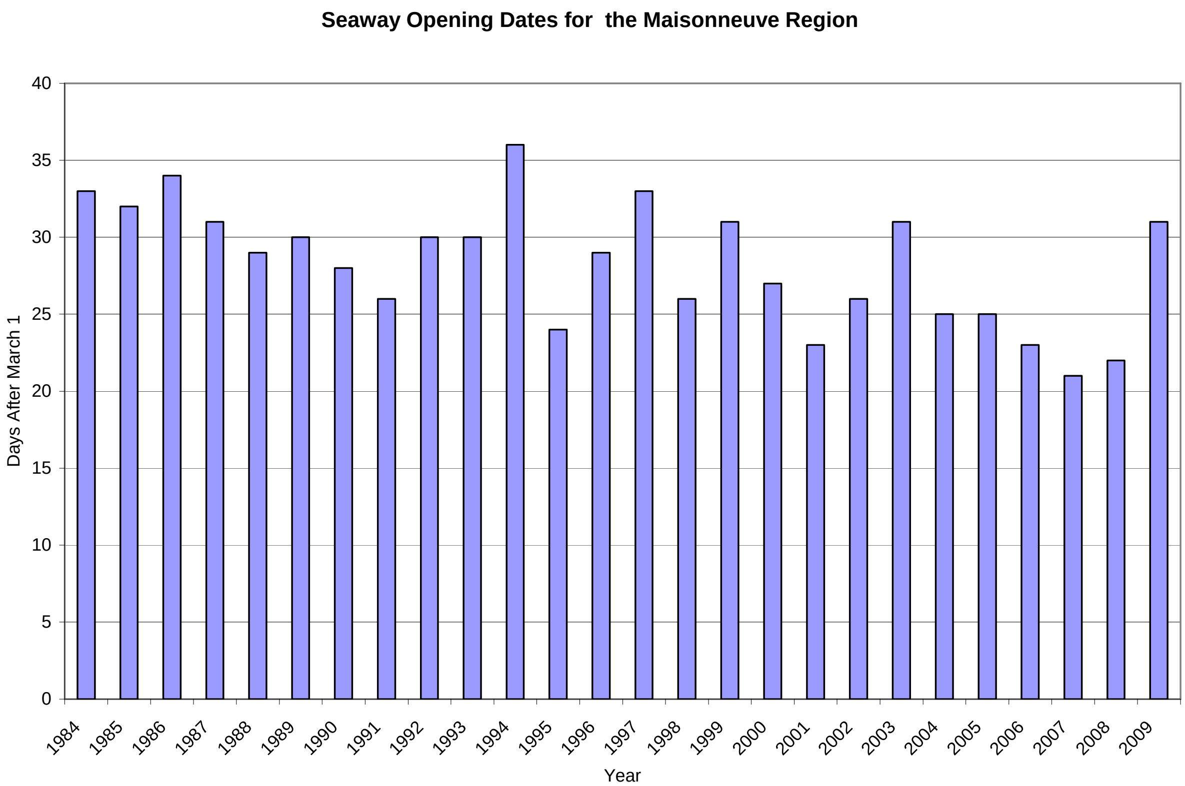


Figure 6.1 Comparison of Seaway Opening Dates

It is noteworthy that the ice in the shipping channel had broken up and largely cleared out due to natural processes in the three (3) weeks prior to the **Seaway Opening Date**. As a result, ice-clearing operations, using icebreakers, were not conducted along the main shipping channel of the study reach in **2009**. Thus, the ice-clearing processes that occurred during the spring of **2009** represent natural ice breakup and clear-out processes.

6.1.2 Overview of Observation Program

The scope of observations undertaken within the **2008/2009 Joint Observational Study** (**JOS**) was affected by the fact that a natural ice breakup and clear-out occurred. For example, icebreaking operations were not carried out, and thus, no observations were made while the icebreaker transited the shipping channel. The actual completed work is summarized in **Table 6.1**.

Table 6.1 General Summary of Observation Program

Time Conducted	**General Description**	**General Scope**
Pre and Post Winter	• Rip-rap stone surveys • Photographic surveys and general shoreline observations	• Described in Section 5
Throughout the Winter	▪ General Observations Regarding the development of the ice cover	• A video camera was placed in the water treatment plant at Cecil Garrow Bay. This was recorded continuously from February 24 to March 20. • RADARSAT satellite imagery – four images were obtained and analyzed. • photographs were obtained from an aerial fly-over that was conducted by the SLSMC on Feb. 24. • site visits were made on February 23 and March 17.
Throughout the Study Period	▪ Factors affecting ice conditions at and before the Seaway opening	▪ Basic observations and analyses were done as an aid to understanding the processes involved. This included: (a) measurements of basic ice properties data (i.e., ice thicknesses and temperatures) were made a number of times during the winter; and, (b) historical analyses were done regarding the Freezing Degree Days, flows, and water levels for past Seaway Openings. Basic comparisons were made to the 2009 Opening.

6.2. Environmental Data for the 2008-2009 Winter

The following environmental data were investigated as they have a significant effect on ice conditions and its behavior:

(a) Air temperatures and **Freezing Degree Days** (**FDD**s)

(b) Hydraulic data – the following was obtained and analyzed:

  a. water level elevations at the tailrace of the **Moses Saunders Dam** and at **Cornwall Harbour** and,

  b. flows measured at the **Moses Saunders Dam**.

*6.2.1 Air Temperatures and **FDD**s during the 2008-2009 Winter*

*(i) **FDD**s for the 2008-2009 Winter*

Figure 6.2 shows the accumulated **FDD**s at **Pierre Elliot Trudeau** (**PET**) **Airport** in **Montreal** over the winter of **2008**-**2009**. The **FDD**s accumulated fairly steadily over the **2008-2009** winter, in a pattern that is similar to that observed for past winters (see ***2007***/***2008 Annual JOS Report***).

It should be noted that the **FDD** values shown in **Figure 6.2** were obtained from the **St. Lawrence Seaway Management Corporation** (**SLSMC** – **L. Lefebvre**, **SLSMC**, personal communication), and thus they were calculated using the **SLSMC**'s usual approach. As shown in the **2007/2008 JOS Report** (ref.: ***2007***/***2008 Annual JOS Report***), the **FDD** calculation approaches differ to some extent among investigators which does result in somewhat different values. For consistency, the results discussed here are based on the **SLSMC**'s usual approach for calculating **FDD**s. This assumption is not crucial as similar conclusions and trends would be expected based on each **FDD** calculation approach.

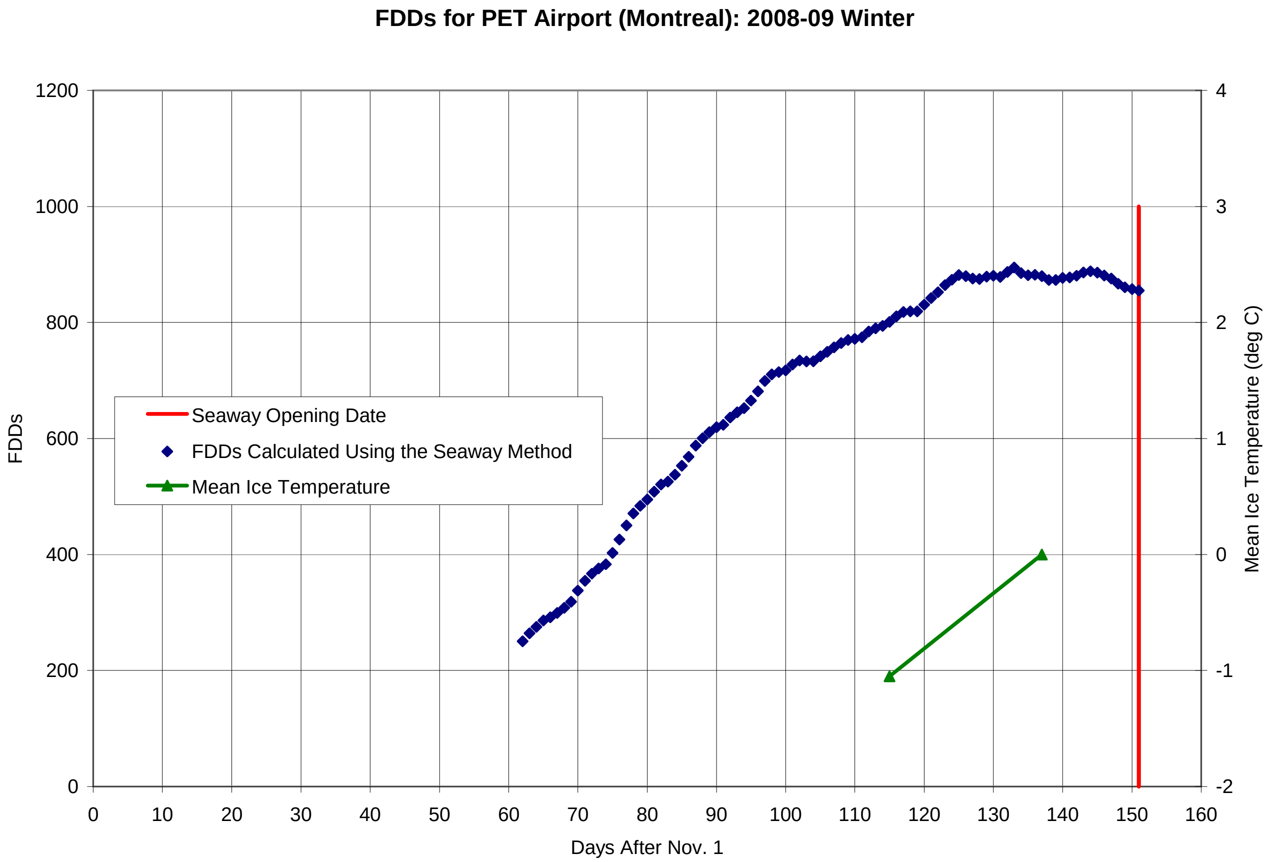


Figure 6.2 FDDs at PET Airport for the 2008-2009 Winter

The following values were obtained from the **FDD** analyses:

(a) maximum accumulated **FDD**s over the **2008/2009** winter: 895 °C*days

(b) **FDD**s on the **Seaway Opening Date** (of **March 31, 2009**): 855 °C*days

The following trends and conclusions are evident from **Figure 6.2**:

(a) The **2009 Seaway Opening** (which took place on **March 31, 2009**) occurred after the accumulated **FDD**s had peaked.

(b) the mean ice temperature (data presented subsequently) was increasing while **FDD**s were accumulating, and at the time when the **FDD**s peaked (**March 13** – 133 days after **November 1**, **2008**), the ice temperature was close to 0°C through the full ice thickness. (The ice temperature was measured on **February 23**, **2009** and **March 17**, **2009** – described subsequently). This helps to substantiate the fact that there is not a direct relationship between the ice temperature and the accumulated **FDD**s**.** This same observation was made during last years analyses, as the **FDD**s in **2008** also peaked after the ice temperature had warmed up to about 0°C through the full ice thickness (ref.: ***2007*/*2008 Annual JOS Report***).

(c) recognizing that strong ice is more likely to cause shoreline damage than weak ice, this shows that the accumulated **FDD**s are not a reliable index, as a standalone measure, for assessing vulnerability to ice-induced shoreline impact damage. The strength of the ice (during the decay phase) is related to many factors including the ice temperature, the length of time that has elapsed since the ice became isothermal at the freezing point, and the amount of solar radiation absorbed by the ice, which is affected by the latitude, the cloud conditions and the albedo of the ice. Should ice movements occur when the ice is strong, there is a greater risk of ice-induced shoreline damage. Attention must be given to the relative strength of the ice as well as the accumulated **FDD**s. It is hard to speculate regarding the relative strength of the ice in **2008** versus **2009**, especially since no ice was present during the **2009** opening. Hypothetically, had ice been present during **2009**, it is suspected that it would have been somewhat weaker in **2009** on the **Opening Date** (i.e., **March 31**) than for the **March 22 Opening Date** in **2008**, due to the later opening date in **2009**. This supposition is supported by the fact that drainage channels were seen in the ice blocks removed on **March 17**, **2009** (for ice temperature measurement-described subsequently), whereas these features (which indicate ice decay) were not seen for **2008**.

(d) these same trends and conclusions were also seen for the **2008** winter.

*(ii) Comparisons with Previous Winters Regarding the Accumulated **FDD**s*

Comparisons were made based on the maximum **FDD**s that accumulated during the winter, and also, based on the accumulated **FDD**s at the **Seaway Opening Date**. Using either measure, the **2008/2009** winter was slightly colder than normal (**Figures 6.3** and **6.4**, respectively).

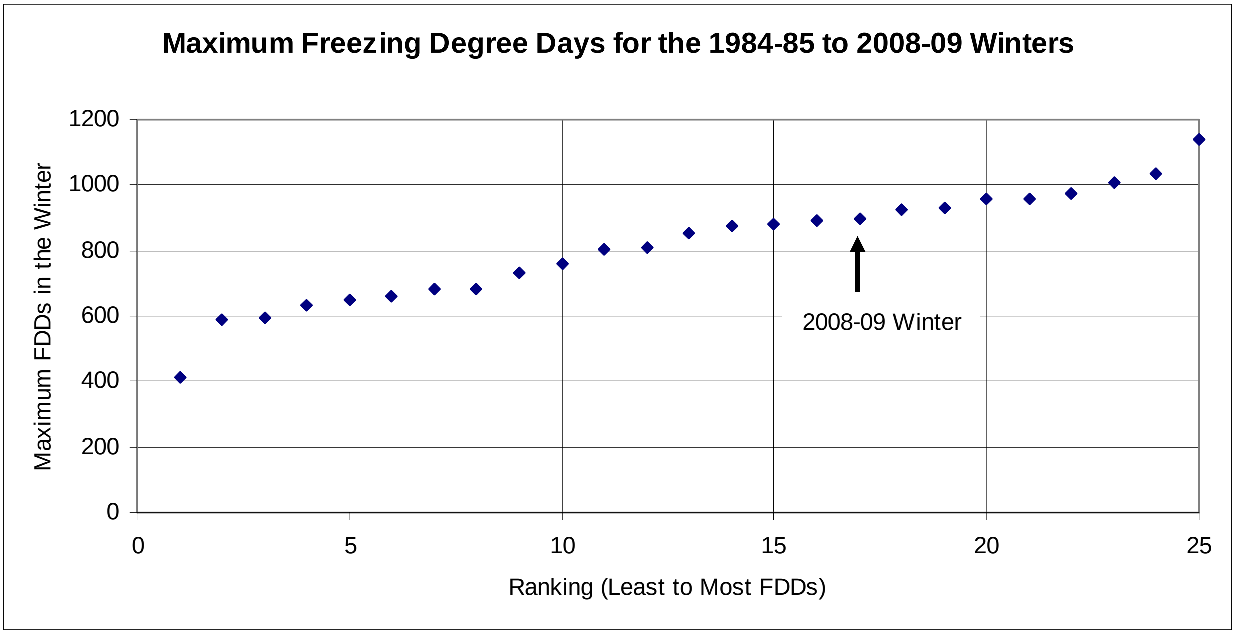


Figure 6.3 Maximum FDDs at PET Airport over the Winter

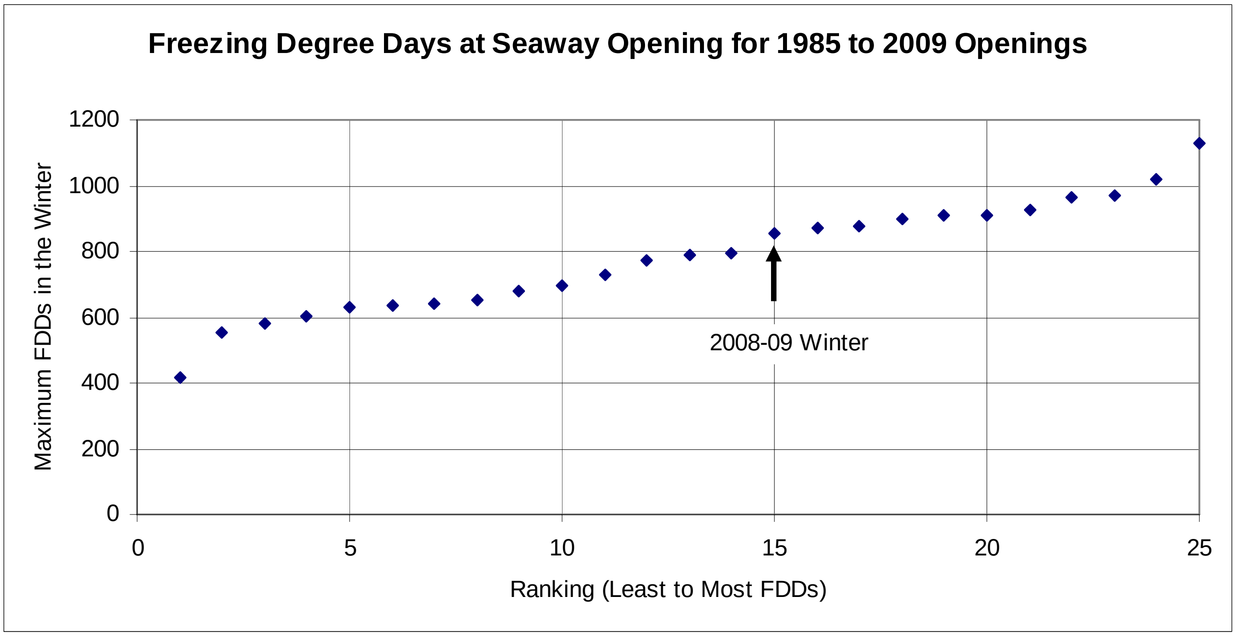


Figure 6.4 FDDs at PET Airport on the Seaway Opening Date

*(iii) Comparisons with Previous Winters: Timing of the **Seaway Opening Date** in Relation to the Peak **FDDs***

During the spring of **2008**, the timing of the **Seaway Opening Date** was compared to the time when the **FDD**s peaked for each winter in an effort to help develop a knowledge base for understanding the likely ice strength, and potential shoreline impacts. For the winters from **1984-85** to **2006-07**, it was found that (ref.: ***2007*/*2008* *Annual JOS Report***):

(a) The **Seaway Opening Date** occurred before the peak **FDD**s for 3 (i.e., 13%) of the 23 winters, in **2001**, **2002**, and **2005**. However, for these winters, the **Seaway Opening Date** was relatively close in time of the peak **FDD**s (i.e., 3 days before). In comparison, the **2009 Seaway Opening Date** occurred 18 days after the date of the peak **FDD**s. (The **2009 FDD**s peaked at 897 °C*days on **March 13**, and the **Seaway Opening Date** was **March 31**).

(b) the **Seaway Opening** took place within +/- 5 days of the date on which the peak **FDD**s occurred for 10 of the 23 winters (i.e., 43 %) and;

(c) the **Seaway Opening Date** occurred after the peak **FDD**s for 10 of the 23 winters (i.e., 43 %).

This comparison shows that, for the **2008/2009 winter**, the **FDD**s peaked significantly before the **Seaway Opening Date**. Thus, for **2008/2009**, if there had been any ice present in the shipping channel at the time of the **Opening**, it is expected that the ice would have been significantly deteriorated. This statement is also supported by the fact that the ice temperature was isothermal at the freezing point for at least 2 weeks prior to the **Opening Date** (data described and presented subsequently).

6.2.2 Water Levels and Flows during the 2008-2009 Winter

(i) Objectives and Information Sources

It is well known that ice conditions are significantly affected by water levels and flows. Water levels and flows were initially investigated for previous winters during the **2007/2008** season (ref.: ***2007/2008 Annual JOS Report***) based on the following:

(a) Water level elevations and flows at the tailrace of **Ontario Power Generation**'s (**OPG**) **Moses Saunders Generating Station** – these data were supplied by **OPG** and,

(b) water level elevations at **Cornwall Harbor** – these data were provided by **Environment Canada**.

This work was continued during the **2008/2009 JOS**. One of the objectives was to investigate potential reasons or explanations for the natural ice cover breakup that occurred in the spring of **2009** (described subsequently).

(ii) *Flows at the Tailrace of the Moses Saunders Dam*

The flows at the Moses Saunders dam over the **2008/2009** winter are plotted in **Figure 6.5**. It can be observed that:

(a) the flows over most of the **2008/2009** winter were slightly higher than the 30-year average (for **1979** to **2008**). Also, the flows in **2008/2009** were about 500 cms higher, and often more, than the flows during the **2007/2008** winter, which were considerably less than the 30-year average (for **1979** to **2008**).

(b) a rapid increase in flow of about 300 cms occurred over the **February 28 - March 1** period. This occurred about 1 week prior to the time when the ice cover in the channel between **St. Regis** and **Cornwall Islands** broke up, and was mostly flushed downstream. (This information is described in further done with the video records that were obtained). detail in a subsequent section, which presents the results of the analyses

To obtain further information, the flows were compared based on:

(c) the mean daily flow on the **Seaway Opening Date** for each winter, and;

(d) the average mean daily flow for a 10-day period extending from 5 days before the **Seaway Opening Date** to 5 days after it.

Each basis of comparison showed that the mean daily flow in **2008**/**2009** was considerably higher than normal (**Figures 6.6 and 6.7**, respectively).

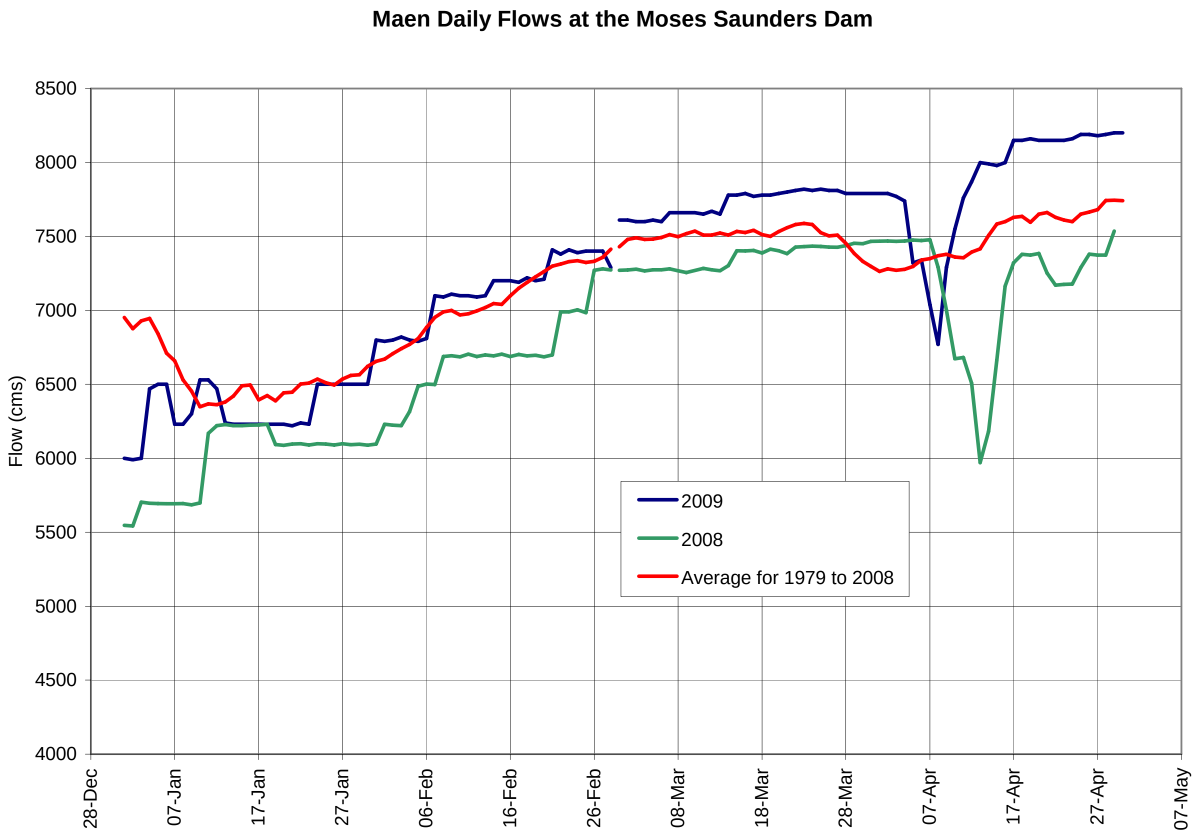


Figure 6.5 Mean Daily Flows at the Moses Saunders Dam

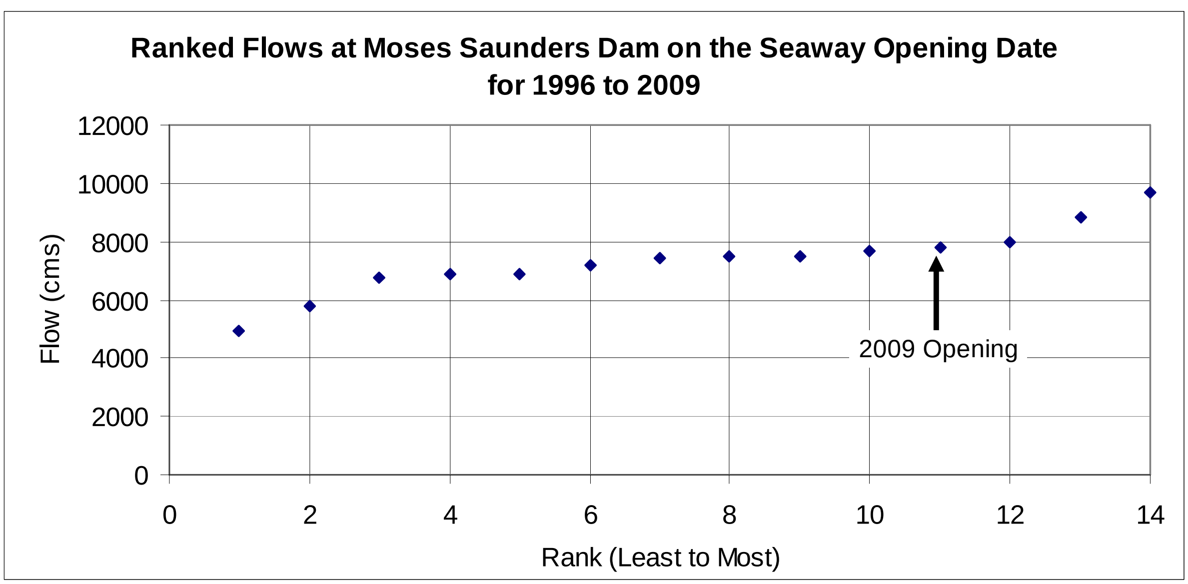


Figure 6.6 Ranked Mean Daily Flows at Moses Saunders Dam on the Seaway Opening Date

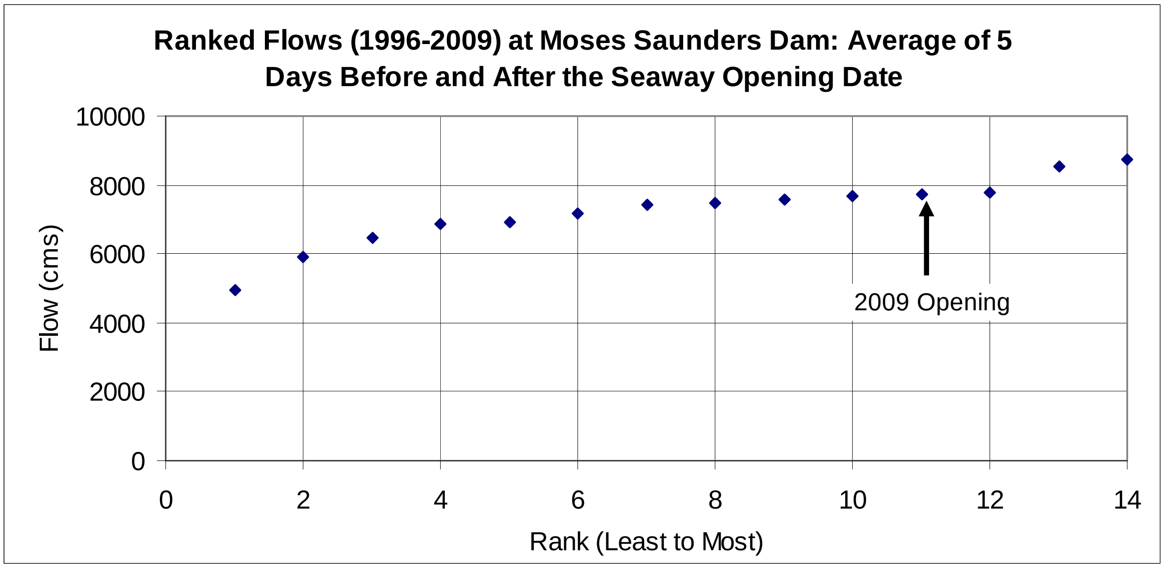


Figure 6.7 Ranked 10-Day Average Mean Daily Flows at the Moses Saunders Dam

(iii) Water Levels at the Moses Saunders Dam Tailrace and in Cornwall Harbour

Water levels over the **2008/2009** winter at **Cornwall Harbour** are plotted in **Figure 6.8**. It can be seen that:

(a) a relatively steady increase in water level elevation of about 15 cm occurred over the **February 28 - March 9** period.

(b) up to about **March 9**, the water level elevations in **2008/2009** were generally higher than both the 30-year average (from **1979** to **2008**), and those for the **2007/2008** winter. **March 9** is considered to be a significant date for the **2009** ice study because the video records showed that the ice cover in the channel between **St. Regis** and **Cornwall Islands** broke up on **March 8**, and was essentially completely flushed downstream by **March 9** (presented subsequently).

(c) after about **March 9**, the water level elevations in **2008/2009** were generally lower than the 30-year average and those in **2007/2008**.

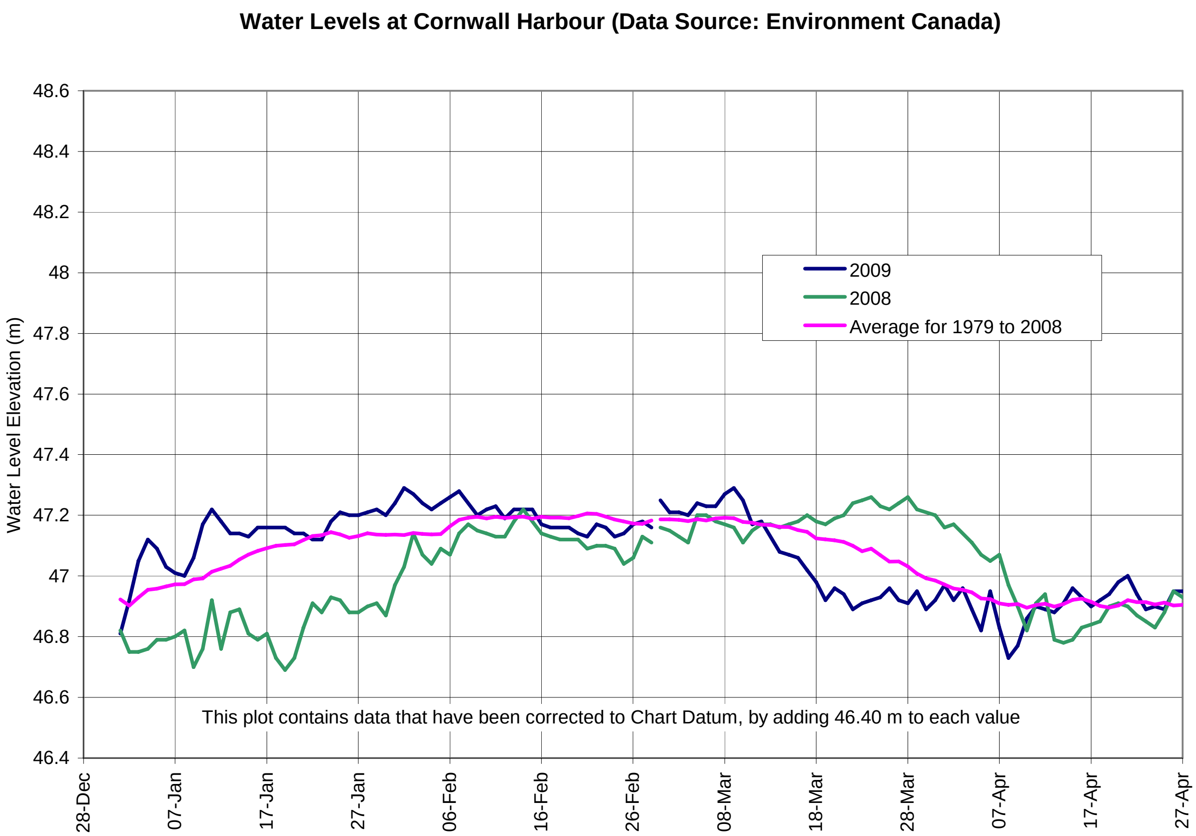


Figure 6.8 Water Levels at Cornwall Harbour

Mean daily water level elevations over the **2008/2009** winter at the tailrace of the **Moses Saunders** dam are plotted in **Figure 6.9**. It can be seen that:

(a) the water level elevations in **2008/2009** tended to be slightly higher than the 30-year average (for **1979** to **2008**) and considerably higher than those for the **2007/2008** winter;

(b) a relatively rapid increase in water level elevation of about 15 cm occurred over the **February 28 - March 1** period. The water level elevation then remained high for the week leading up to the date when the ice cover in the channel between **St. Regis** and **Cornwall Islands** broke up and was flushed downstream.

This is discussed further in a subsequent section, with respect to potential reasons or explanations for the natural ice breakup that occurred in **2008/2009**.

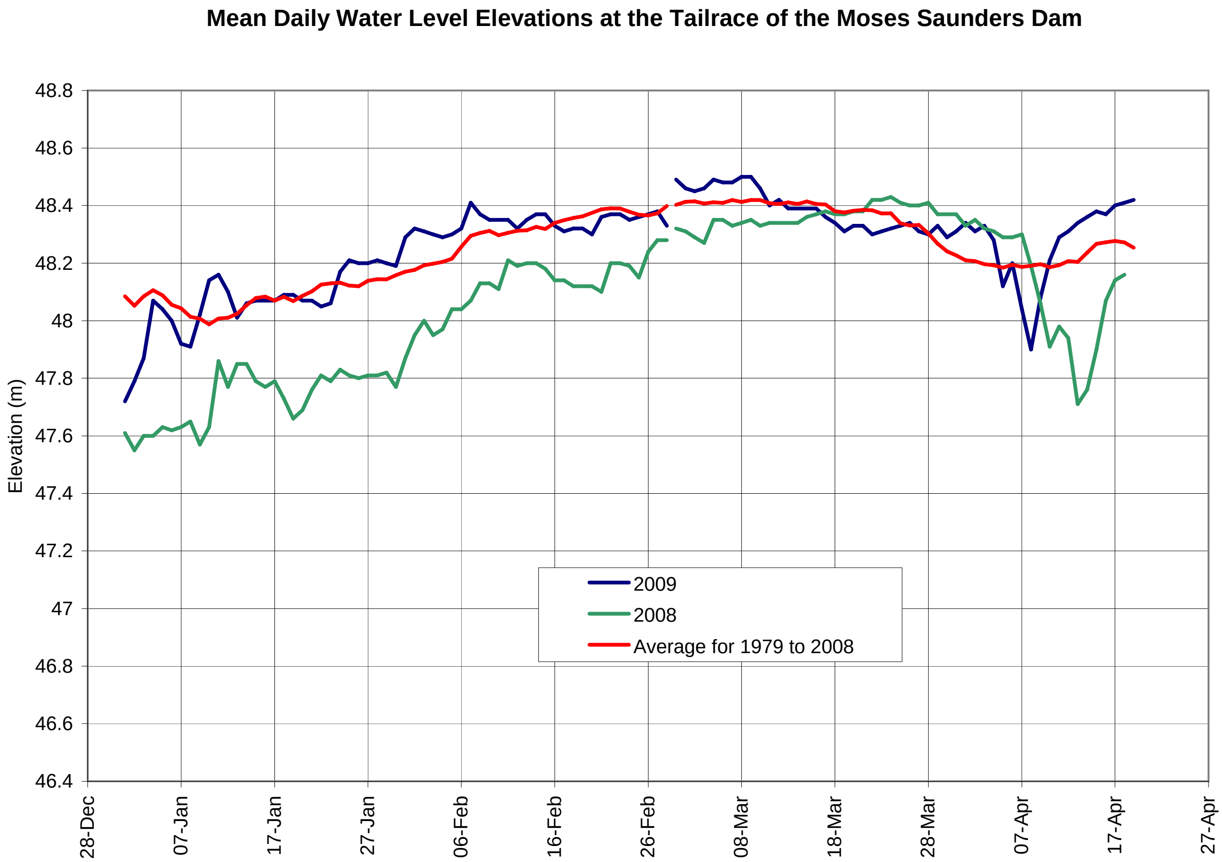


Figure 6.9 Water Levels at the Moses Saunders Dam Tailrace

For further information, the mean daily flows and tailrace elevations for the **Moses Saunders** dam were plotted together for **2009** (**Figure 6.10**).

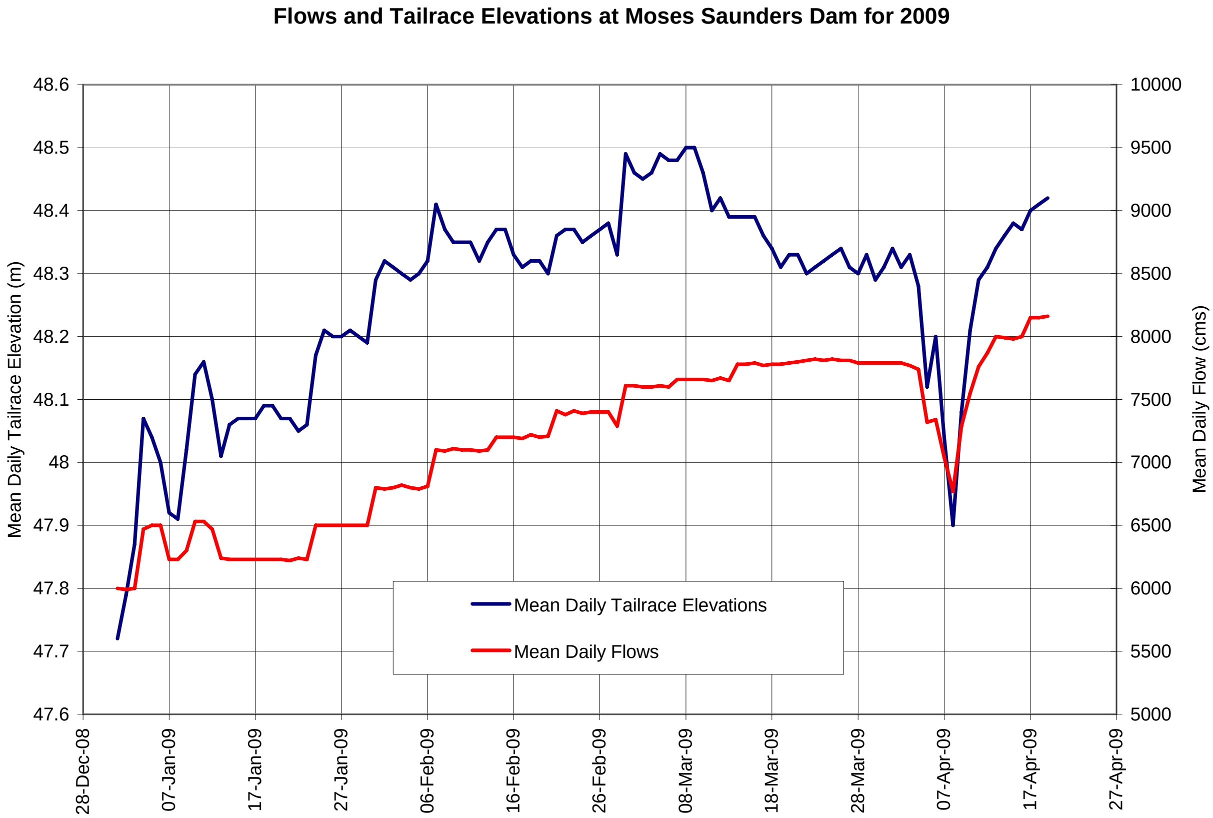


Figure 6.10 2009 Water Levels and Flows at the Moses Saunders Dam

As expected, these two parameters generally track each other. The mean daily flow and the mean daily tailrace elevation both increased during the week leading up to the break-up of the ice cover, which occurred on **March 8**.

6.3. Ice Cover during the 2008-2009 Winter

This section of the report is divided into two parts listed below:

(a) ice cover development up to early **March** (about **March 7**) and,

(b) ice cover breakup and clear-out which took place after early **March.**

It should be noted that because the ice cover had mainly cleared out of the shipping channel by the **Seaway Opening Date** (i.e., **March 31**), icebreakers were not

required to aid in breaking up or clearing out the ice. Thus, the **2008/2009** winter was a natural ice breakup and clear-out.

6.3.1 Objectives and Summary of Observations Made

It is well known that the development process for an ice cover over the course of a winter plays an important role in defining its state at any given time within the winter. Consequently, observations were made during the winter to track the development of the ice cover, as summarized in **Table 6.2**.

Table 6.2 Summary of the Ice Observation Program for the 2008-2009 Winter

Observation Type	General Output	Scope
Video camera	Continuous time-lapse photography, from a video camera that was set up in the water treatment plant at Cecil Garrow Bay. See Figure 6.11 for a drawing showing the camera's field of view.	The video camera provided continuous coverage of the channel between St. Regis and Cornwall Islands from February 24 to March 20.
Aerial reconnaissance with fixed-wing aircraft	Notes and photographs defining the ice conditions	A mission was conducted on February 24
RADARSAT imagery	High-resolution maps of the ice conditions in the whole region from Lake St Francis to Snell Lock	RADARSAT imagery was obtained for: (a) February 10; (b) February 25; (c) March 21, and; (d) March 28
Ice-based observations	Observations of the ice conditions as well as ice properties data (described subsequently)	Site visits were made on: (a) February 23, and; (b) March 17.

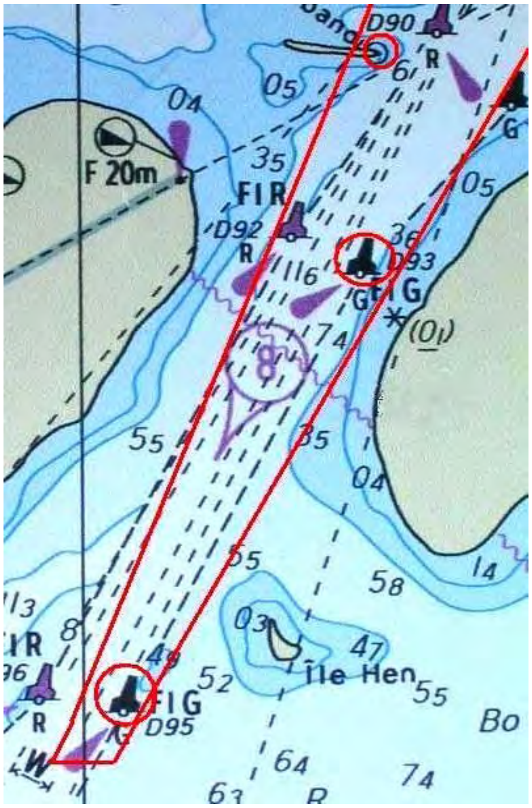


Figure 6.11

Field of View for Video Camera

6.3.2 Freeze-Up to Mid-Winter (Up to Early March)

Figures 6.12 and **6.13** show large-scale **RADARSAT** maps of the ice cover from **Cornwall** to **Lake St Francis** on **February 10** and **February 25** respectively. These **RADARSAT** images have been annotated (by **BMT FTL**) to show the ice cover (in blue). As well, these figures include relevant photos for ground truth. A complete record of annotated **RADARSAT** images is provided in **Appendix E**, including information for **Lake St. Francis**.

The shipping channel was never fully ice-covered from **Lake St. Francis** to **Snell Lock** over the **2008/2009** winter. The data also shows that there was little change in the location of the upstream ice edge between **February 10** and **February 25**, as it was located south of the eastern part of **Cornwall Island** on both dates. Compare

Figures 6.12 and **6.13**. The ice cover extent shown in these annotated **RADARSAT** images is probably close to the maximum that was reached during the entire **2008/2009** winter.

This is supported by the information from the video camera, which showed that the channel between **St. Regis** and **Cornwall Islands** was fully ice-covered until **March 7**, when a small amount of open water first appeared around the navigation buoy in the foreground of the camera's field of view. **Appendix H** presents a full record of the information obtained from the video camera including selected screen captures.

No major ridges or cracks were observed in the ice cover. The data show that ice rubble was present along the channel from south of **Cornwall Island** to north of **St. Regis Island** on both **February 10** and **February 25**, which is indicated by the lighter-coloured portions in the images. This likely represents ice rubble on the ice surface, which was formed due to "ice packing", where ice pieces are shoved under or over the leading ice edge causing ice rubble on the surface. This is the same general location where ice surface relief and packing has been observed during previous years of the **JOS**, which forced the **CCGS Martha L. Black** to back and ram in order to transit through it.

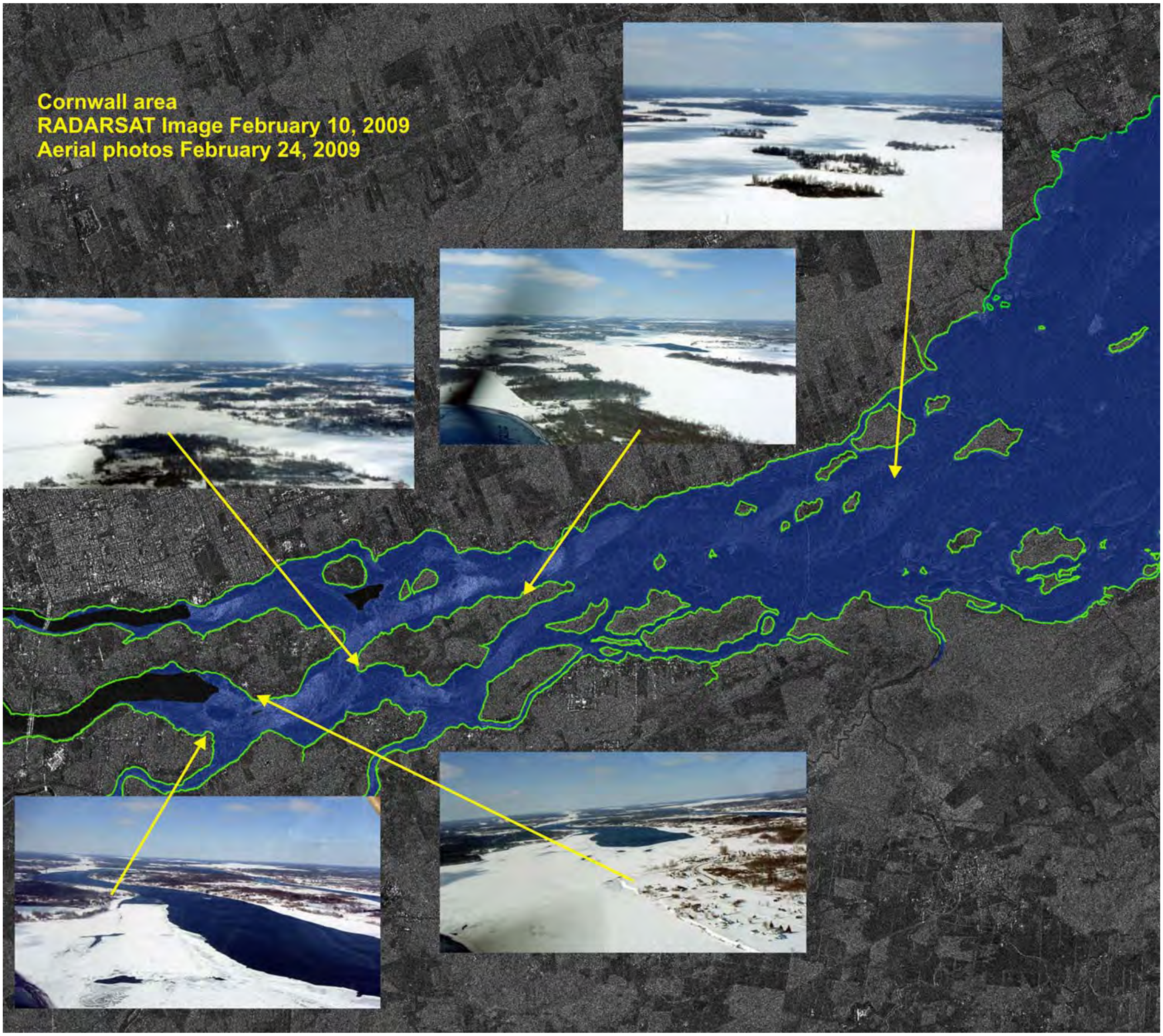


Figure 6.12 Annotated RADARSAT Image: February 10, 2009

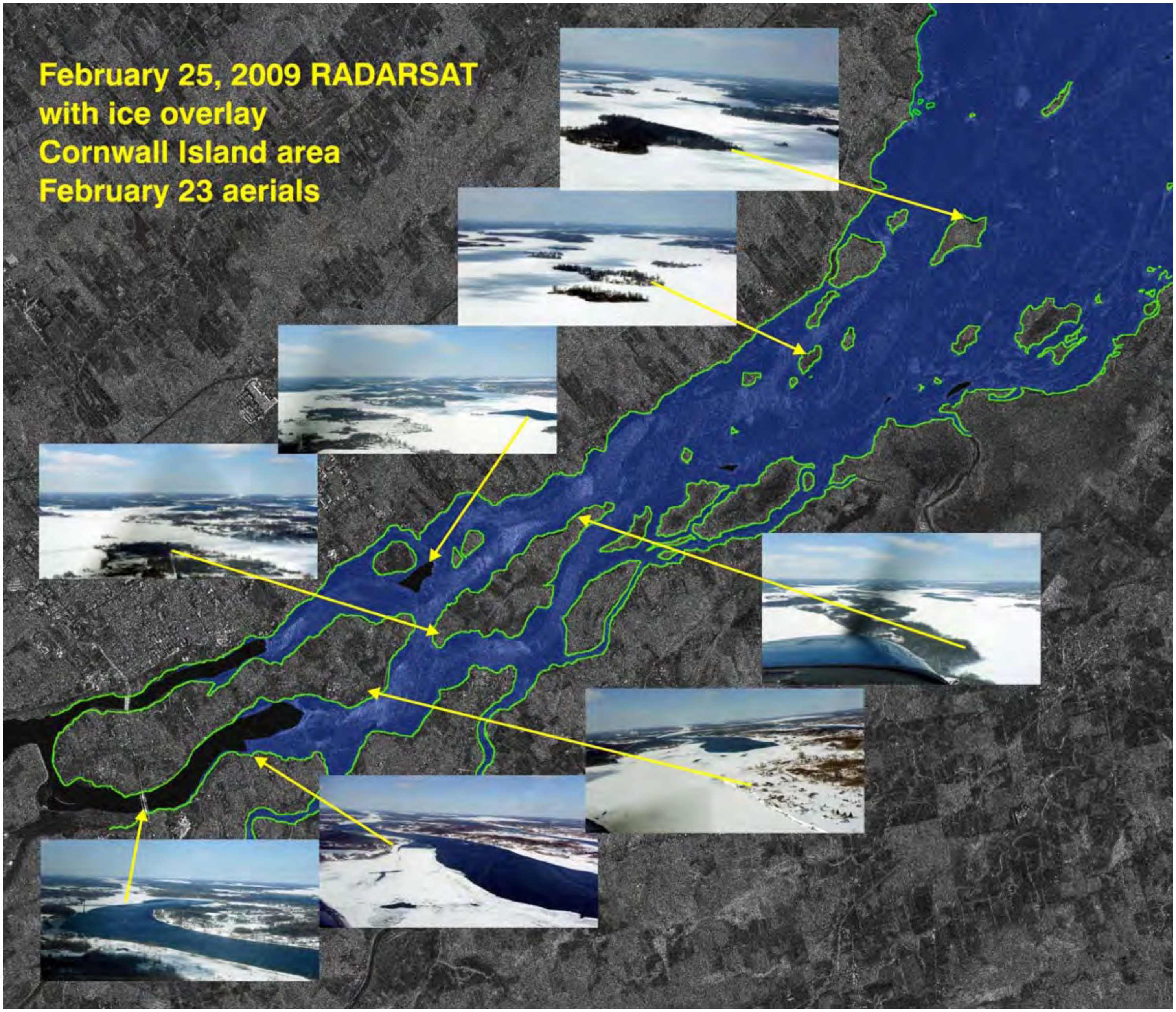


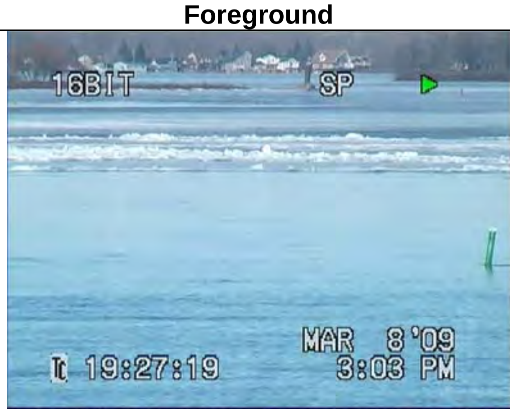
Figure 6.13 Annotated RADARSAT Image: February 25, 2009

6.3.3 Ice Cover Break-Up and Clear-Out (After Early March)

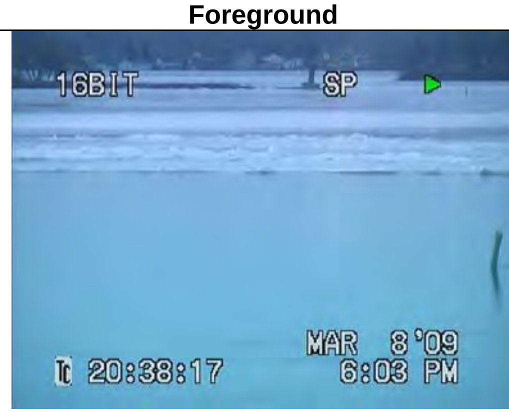
Ice deterioration was first observed on **March 7** this spring from the video camera records when a small patch of open water appeared around the navigation buoy in the camera's field of view. Following that, the ice cover in the channel between **St. Regis** and **Cornwall Islands** broke up rapidly, over the course of the following day (**Figure 6.14**). See also **Appendix H** for a detailed analysis of the video records.

08:03 March 8: Initial Rubbled Ice in Foreground

13:33 March 8: Increased Rubbled Ice in Foreground



15:03 March 8: Extensive Open Water – Open Water from Foreground to Ice Edge



18:03 March 8: Extensive Open Water – Open Water from Foreground to Ice Edge

Figure 6.14 Ice Cover Breakup Between St. Regis and Cornwall Islands

The ice cover breakup commenced with the formation of a small amount of rubble in the southern part of the channel. The amount of rubble increased rapidly, as the ice sheet behind it failed progressively. By 15:00 on **March 8**, about half the channel was open.

Ice breakup and clear-out continued after **March 8**. By **March 10**, the channel between **St. Regis** and **Cornwall Islands** was almost entirely ice-free, as the ice coverage was estimated to be less than 5 % (see **Appendix H**).

Photos taken during a site visit made on **March 17** (**Figure 6.15**) showed that:

(a) the channel between **St. Regis** and **Cornwall Islands** was almost entirely ice-free, and;

(b) the shipping channel north of **St. Regis Island** was also almost entirely ice-free.

Between St. Regis and Cornwall Islands | **Looking East along the Shipping Channel**

Figure 6.15 Views From the Eastern Tip Of Cornwall Island: March 17, 2009

Figure 6.16 shows an annotated **RADARSAT** image that was taken on **March 21, 2009**. This image shows that very little ice (which has been shaded in blue by **BMT FTL**) remained at that time.

The **RADARSAT** imagery showed that the only area along the full shipping channel with any significant ice cover was the western end of **Lake St. Francis**, where ice had been "packed" into it (see **Appendix E**).

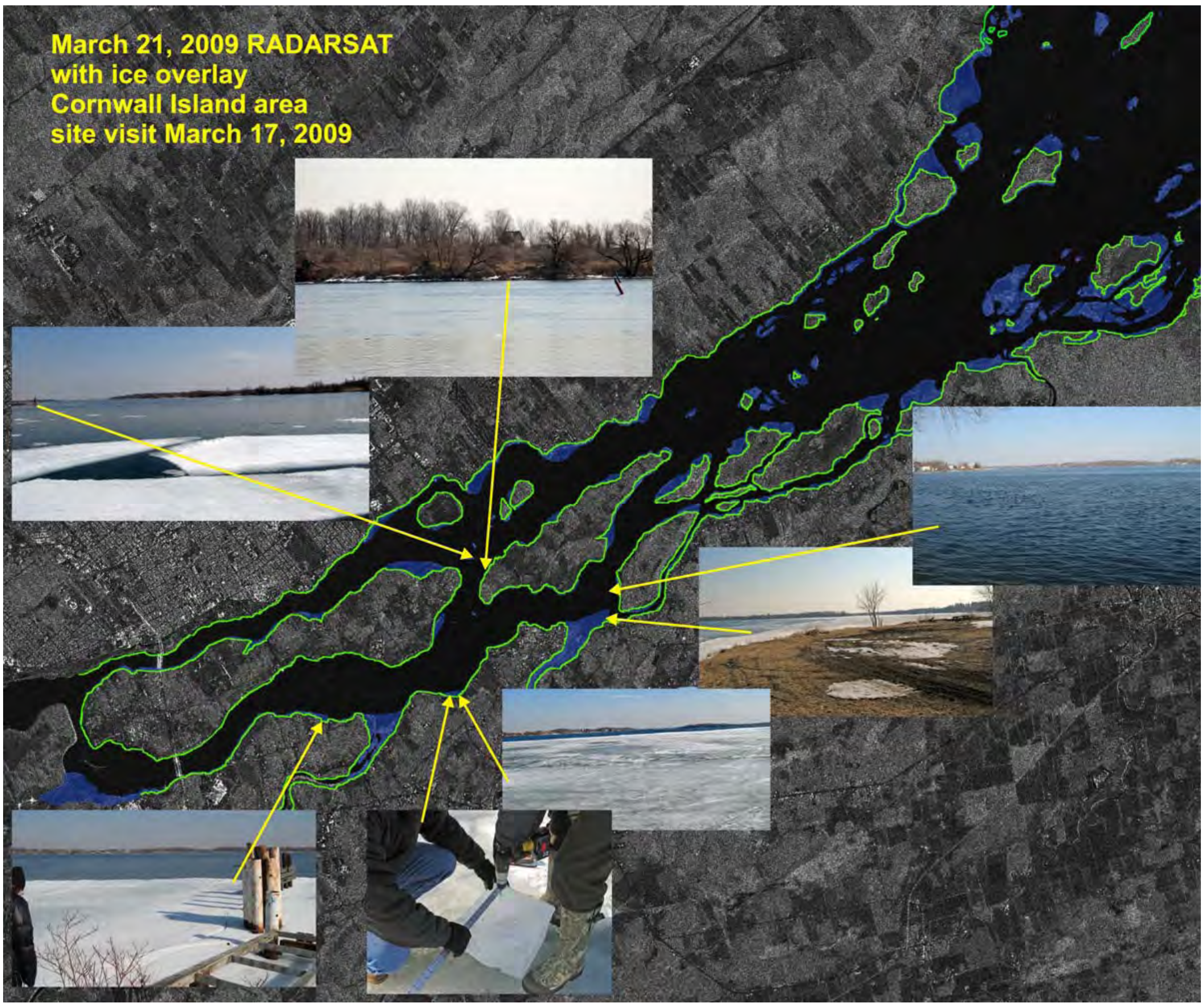


Figure 6.16 Annotated RADARSAT Image: March 21, 2009

Figure 6.17 shows an annotated **RADARSAT** image that was taken on **March 28, 2009**. This image shows that the ice extent (which has been shaded in blue by **BMT FTL**) had decreased slightly from that on **March 21**.

The **March 28 RADARSAT** imagery also showed that the only area along the full shipping channel with any significant ice cover was the western end of **Lake St. Francis**, where ice had been “packed” into it (see **Appendix E**).

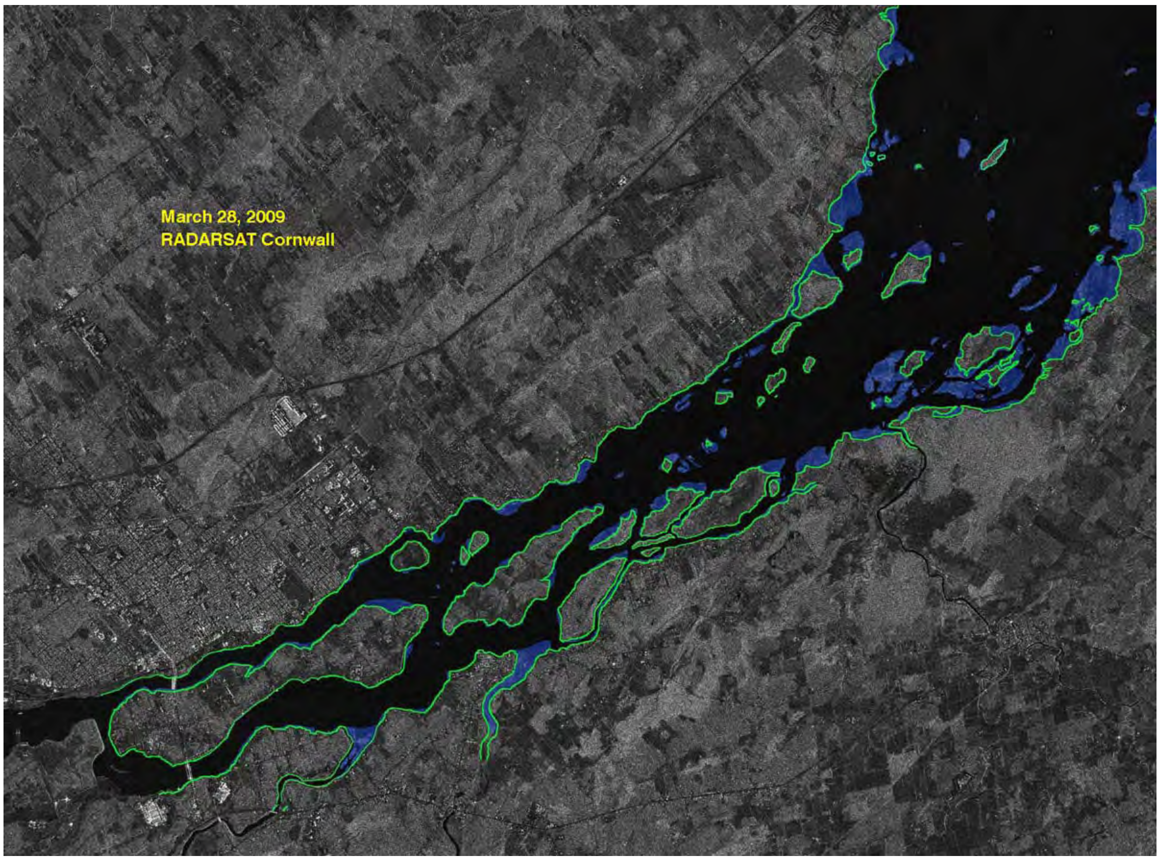


Figure 6.17 Annotated RADARSAT Image: March 28, 2009

6.4. Ice Properties

6.4.1 Objectives and Scope

The following basic ice properties were measured:

(a) the ice thickness – this was measured for obvious reasons.

(b) the ice temperature profile – this was measured as an aid to evaluating the relative strength of the ice over the study period. This information is helpful for conducting general evaluations of the shoreline impacts.

6.4.2 Ice Thickness and General Structure

The ice thickness was measured at various locations over the duration of the winter, as summarized in **Table 6.3**. Of course, the ice thickness varied with time and location.

Table 6.3 Summary of Ice Thickness Measurements

Location	Date	Ice Thicknesses
Raquette Ferry Docks (Site for Ice Temperature Measurements)	• February 23 • March 17	• 2 cores – 19.75" & 19.5" thick • No data – conditions were unsafe to go on the ice
Cecil Garrow Bay (Site for Ice Temperature Measurements)	• February 23 • March 17	• 1 core – 18" thick • 2 cores – 12.5" & 11" thick

Note: The term "core" is used throughout, although in practice, ice blocks were cut out of the ice sheet for ice temperature measurement.

In all cases, the ice sheet consisted of a single layer. During the latter trip, on **March 17**, the ice was clearly in the process of deteriorating, as drainage channels were evident in the blocks that were cut out of the ice sheet (see **Appendix F** for photos).

6.4.3 Ice Temperature Profile

(i) Scope

Ice temperature measurements were made at the **Raquette Ferry Docks** and at **Cecil Garrow Bay**. Each site was visited on **February 23**, and, **March 17**. This measurement program provided data for:

(a) times during the winter that spanned the range from before the ice cover broke up, to after its breakup. (As described previously, the video records showed that the ice cover broke up on **March 8**).

(b) the range of snow conditions encountered.

(ii) Measurement Technique

The same techniques used in the **2007/2008** winter (ref.: ***2007/2008 Annual JOS Report***) were employed this spring. Photographs are provided in **Appendix F** which show the approach used to measure the ice temperature profile. In brief, the ice temperature profile was measured by:

(a) cutting an ice block (termed core in this report) out of the ice sheet using a chain saw. At each measurement site, ice temperature profiles were measured for bare ice, and also for snow-covered ice.

(b) inserting a direct-reading temperature probe into the ice core, and recoding the temperature in a field book. Ice temperatures were measured at several depths within the ice core to determine the ice temperature profile.

(iii) Results

The results for the **February 23** and **March 17** surveys are summarized in **Appendix F**, and plotted in **Figures 6.17** and **6.18**, respectively. As expected, the ice temperature increased over the survey period. As well, the ice temperature varied with depth in the ice, which also follows the expected trend. The minimum ice temperature recorded (near the surface) was -2.0°C on **February 23**.

The depth-averaged ice temperature was computed for each core. The mean temperature increased from a minimum of -1.5°C on **February 23** to 0.0°C on **March 17**, as summarized in **Table 6.4**.

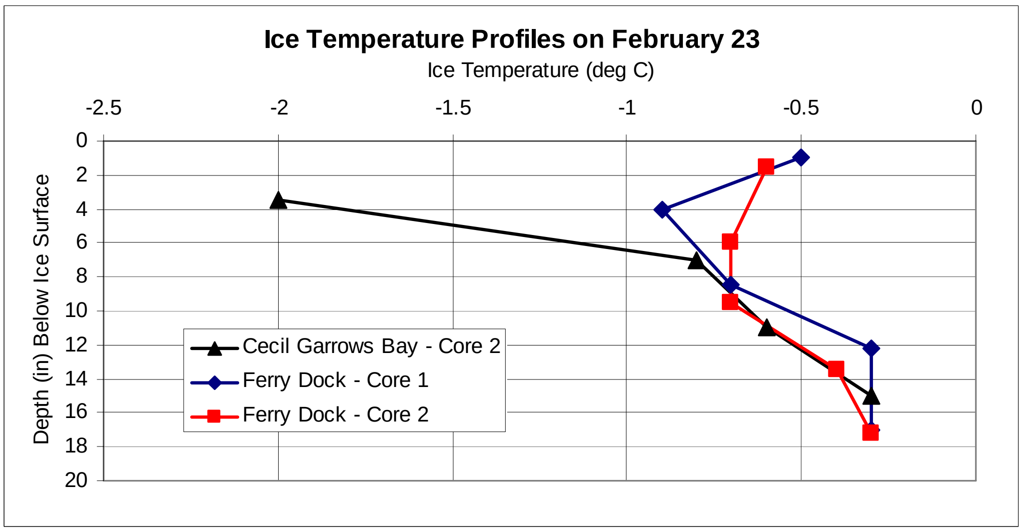


Figure 6.18 Ice Temperature Profiles on February 23, 2009

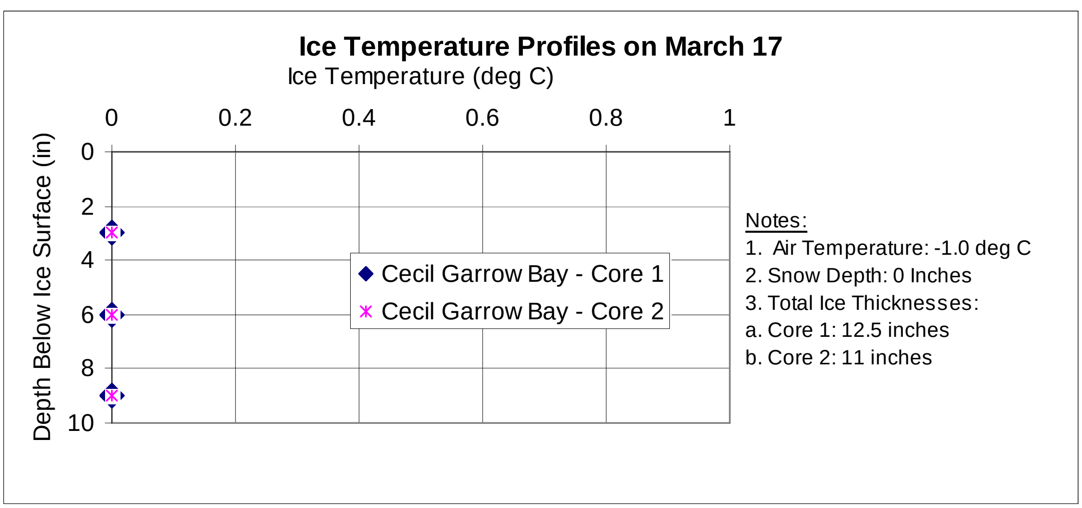


Figure 6.19 Ice Temperature Profiles on March 17, 2009

Table 6.4 Mean Ice Temperatures Through the Ice Thickness

Location	Date	Depth-Averaged Mean Ice Temperatures
Raquette Ferry Docks (Site for Ice Temperature Measurements)	• February 23 • March 17	• 2 cores: -0.6°C and -0.6°C, respectively • No data: Conditions were unsafe to go on the ice
Cecil Garrow Bay (Site for Ice Temperature Measurements)	• February 23 • March 17	• 1 core: -1.5°C • 2 cores: -0.0°C and -0.0°C, respectively

6.5. Comparative Investigations for the 2008/2009 Winter

6.5.1 Objectives

As previous mentioned, the **2008/2009** winter differed from **2007/2008** in that a natural ice breakup and clear-out occurred in **2008/2009** and icebreakers were not used to assist in opening the **Seaway** for **2008/2009**.

Investigations were done in an effort to understand the differences between the **2007/2008** and **2008/2009** winters which may have led to the natural breakup that occurred in **2008/2009**. It was hoped that this would contribute to the build-up of a useful knowledge base for the future.

6.5.2 Scope of Analyses

The following parameters were investigated and compared:

(a) **FDD**s for the **2008/2009** winter versus previous winters, including **2007/2008**.

(b) water level elevations over the **2008/2009** winter versus previous winters, including **2007/2008**.

(c) flows over the **2008/2009** winter versus previous winters, including **2007/2008**.

(d) weather conditions (i.e, snowfalls, rainfalls, mean daily temperatures at Cornwall) for the **2008/2009** winter versus the **2007/2008** winter.

(e) historical records regarding ice-free dates that are on file at the **St. Lawrence Seaway Management Corporation** (**SLSMC**)

6.5.3 Comparisons: FDDS and Ice Temperatures

As described in **Section 6.2**, the maximum accumulated **FDD**s over the **2008/2009** winter, and the **FDD**s on the **Seaway Opening Date** (of **March 31, 2009**), were 895 °C*days, and 855 °C*days, respectively. For the **2008 Seaway** opening, the comparable values for the accumulated **FDD**s were 760 and 731 °C*days, respectively. This suggests that the **2008/2009** winter was considerably colder than the **2007/2008** one.

Comparisons were also made versus long-term data based on the maximum **FDD**s that accumulated during the winter, and also, the accumulated **FDD**s at the **Seaway Opening Date**. Using either measure, the results indicate that the **2008/2009** winter was colder than normal as compared to the long-term average.

Other trends and conclusions were as follows:

(a) the **2009 Seaway Opening** (which took place on **March 31, 2009**) occurred after the accumulated **FDD**s had peaked.

(b) the mean ice temperature was increasing while **FDD**s were accumulating, and at the time when the **FDD**s peaked (on **March 13**), the ice temperature was close to 0°C through the full ice thickness. (The ice temperature profile was measured on **February**. **23**, **2009** and on **March 17**, **2009**). This shows that there is no direct relation between the ice temperature (which is related to its strength) and the accumulated **FDD**s. This same trend was observed during the **2008 JOS** (ref.: ***2007/2008 Annual JOS Report***).

6.5.4 Comparisons: Flows and Water Level Elevations

(i) Flows

As described in **Section 6.2**, the following trends were found regarding the flows at the **Moses Saunders** dam over the **2008/2009** winter:

(a) the flows over most of the **2008/2009** winter were about 500 cms higher than the longterm average (for **1996** to **2008**). Also, the flows in **2008/2009** were about 500 cms higher, and often more, than the flows during the **2007/2008** winter.

(b) a rapid increase in flow of about 300 cms occurred over the **February 28 - March 1** period. This occurred about 1 week prior to the time when the ice cover in the channel between **St. Regis** and **Cornwall Islands** broke up, and was mostly flushed downstream.

(ii) Water Level Elevations

Water level elevation data are presented and discussed in **Section 6.2**

At **Cornwall Harbour**, the water level elevations up to about **March 9, 2009** were generally higher than both the long-term average (from **1979** to **2008**), although there exceptions to this statement as for the **February 15**-**28** period, the water level in 2009 was less than the 30-year average. The water levels for the **2007/2008** winter were consistently less than the 30-year average for the full period up to **March 9**. After about **March 9**, the water level elevations in **2008/2009** were generally lower than the long-term average and those in **2007/2008**. A relatively steady increase in water level elevation of about 15 cm occurred over the **February 28 - March 9** period, which is believed to be significant, which is discussed subsequently.

At the tailrace of the **Moses Saunders Dam**, the water level elevations in **2008/2009** tended to be higher than the 30-year long-term average (for **1979** to **2008**) and for the **2007/2008** winter. A rapid increase in water level elevation of about 15 cm occurred over the **February 28 - March 1** period. The water level elevation then remained high for the week leading up to the date when the ice cover in the channel

between **St. Regis** and **Cornwall Islands** broke up and was flushed downstream. This is believed to be significant and will be discussed further.

6.5.5 Weather Conditions in Cornwall

The local weather conditions at **Cornwall** were compared for **2008/2009** versus **2007/2008** with respect to mean daily air temperatures and also snowfalls and rainfalls. These comparisons showed that:

(a) mean daily air temperatures (**Figure 6.19**) – for the **2008/2009** winter, an increase in mean daily air temperature of about 18 degrees **Centigrade** occurred between Julian day 62 and 66, which is the period just before the ice cover in the **St. Regis/Cornwall** channel broke up. As described previously, this ice cover broke up on **March 8** (**Julian** day 67).

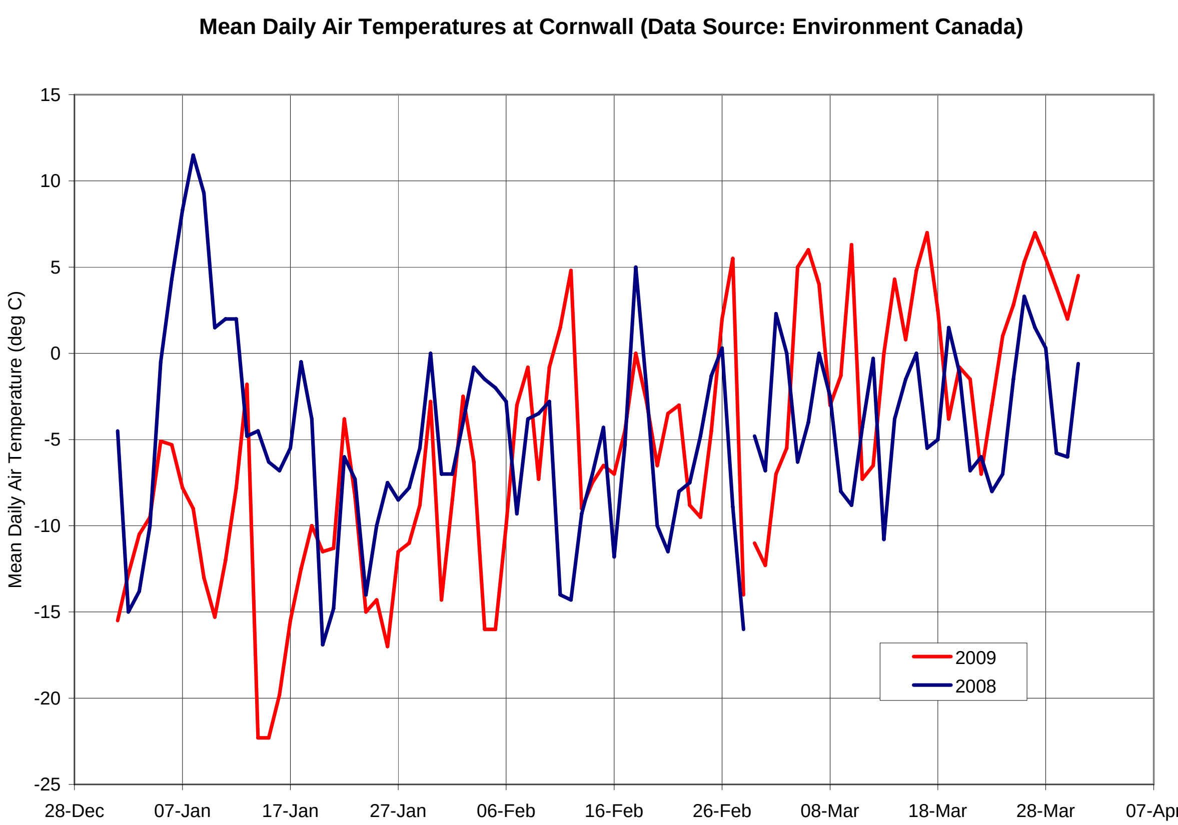


Figure 6.19 Mean Daily Air Temperatures at Cornwall

Figure 6.19 also shows that the mean daily air temperatures at **Cornwall** varied considerably over the winter in both **2009** and **2008**. The average of the mean daily air temperatures at **Cornwall** for the **January** to **March** period were -4.6 and -5.3 degrees **Centigrade** in 2008 and 2009 respectively. In the later part of the winter (i.e., after about **March 3**), the mean daily air temperatures at **Cornwall** were warmer in **2009**.

(b) snowfalls and rainfalls – the daily snowfalls and rainfalls at **Cornwall** during **2009** and **2008** are plotted in **Figures 6.20** and **6.21**, respectively.

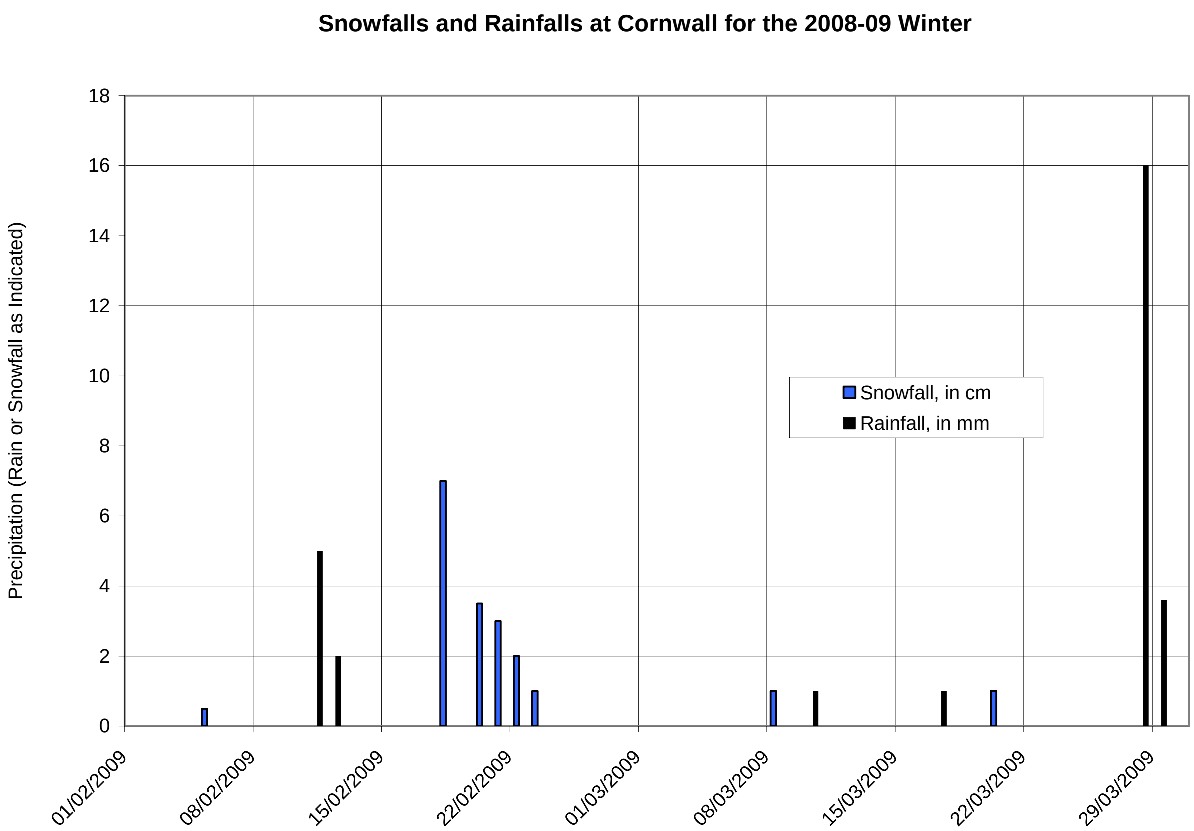


Figure 6.20 Snowfalls and Rainfalls at Cornwall for 2009

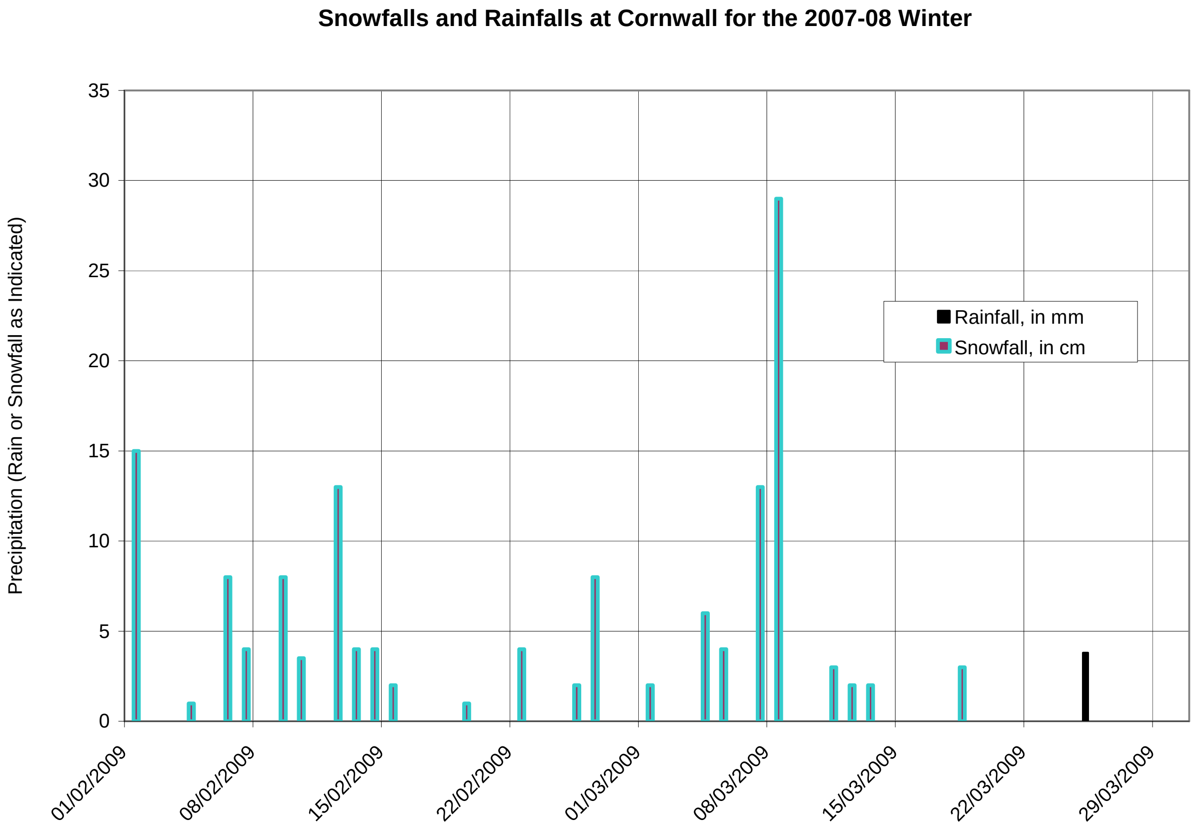


Figure 6.21 Snowfalls and Rainfalls at Cornwall for 2008

No major snowfalls or rainfalls occurred in **2009** during the time when the ice cover between **St. Regis** and **Cornwall Islands** broke up (**Figure 6.20**). This suggests that precipitation was not a factor contributing to the natural breakup that occurred in **2009**.

The **2007/2008** winter differed from the one in **2008/2009** (**Figure 6.21**) in that in **2007/2008**: (i) more snowfalls occurred, and; (ii) rainfalls did not occur.

6.5.6 Comparisons Versus Long Term Ice Data

Long-term records on file at the **St Lawrence Seaway Management Corporation** (**SLSMC**) regarding the duration of the ice cover were obtained (**L. Lefebvre**,

SLSMC, personal communication) and analyzed. This was done in an effort to place the occurrence of the natural ice breakup observed in **2009** in a historical context.

The **SLSMC** records for **Lake St Francis** from **1977/1978** to **2004/2005** were analyzed with respect to the dates when: (a) the first ice deterioration was observed, and; (b) **Lake St. Francis** was ice-free. These data are plotted in **Figures 6.22** and **6.23** respectively.

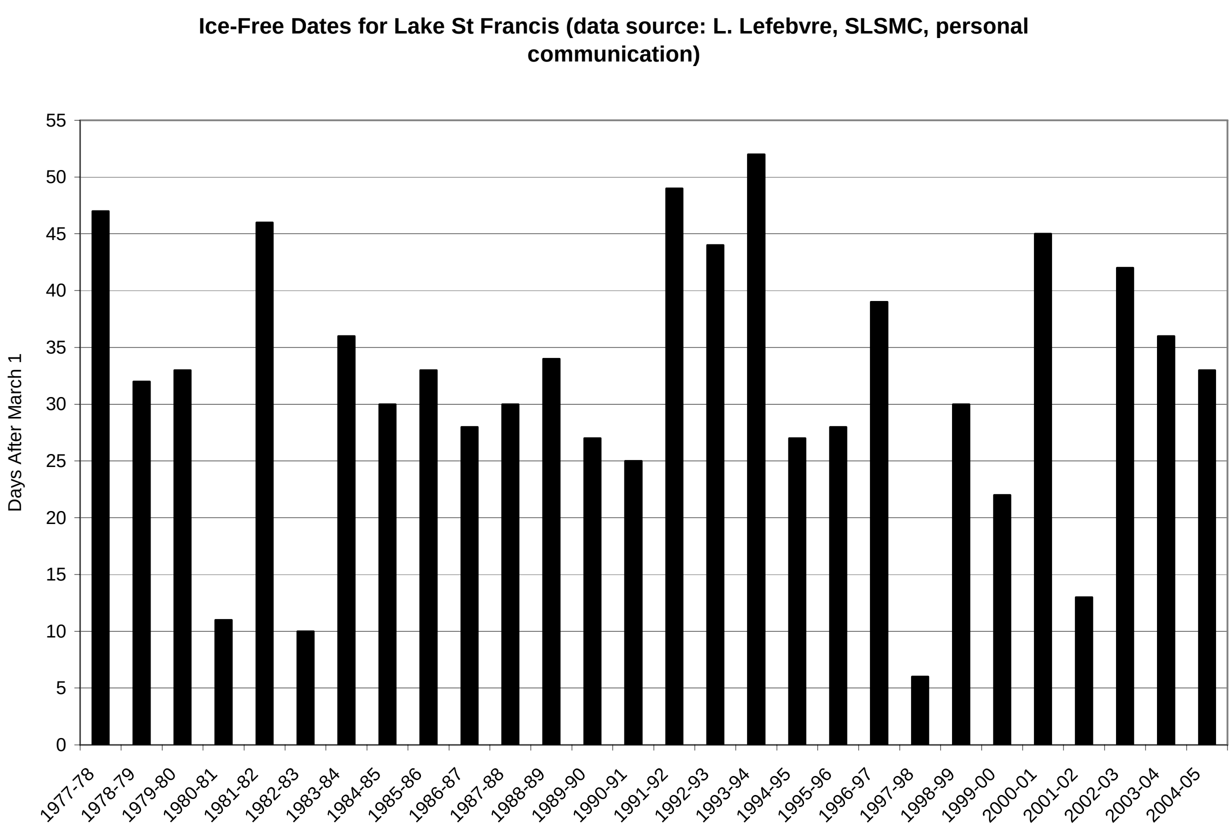


Figure 6.22 Ice-Free Dates for Lake St Francis

Dates of First Ice Deterioration for Lake St Francis
(Data source: L. Lefebvre, SLSMC, personal communication)

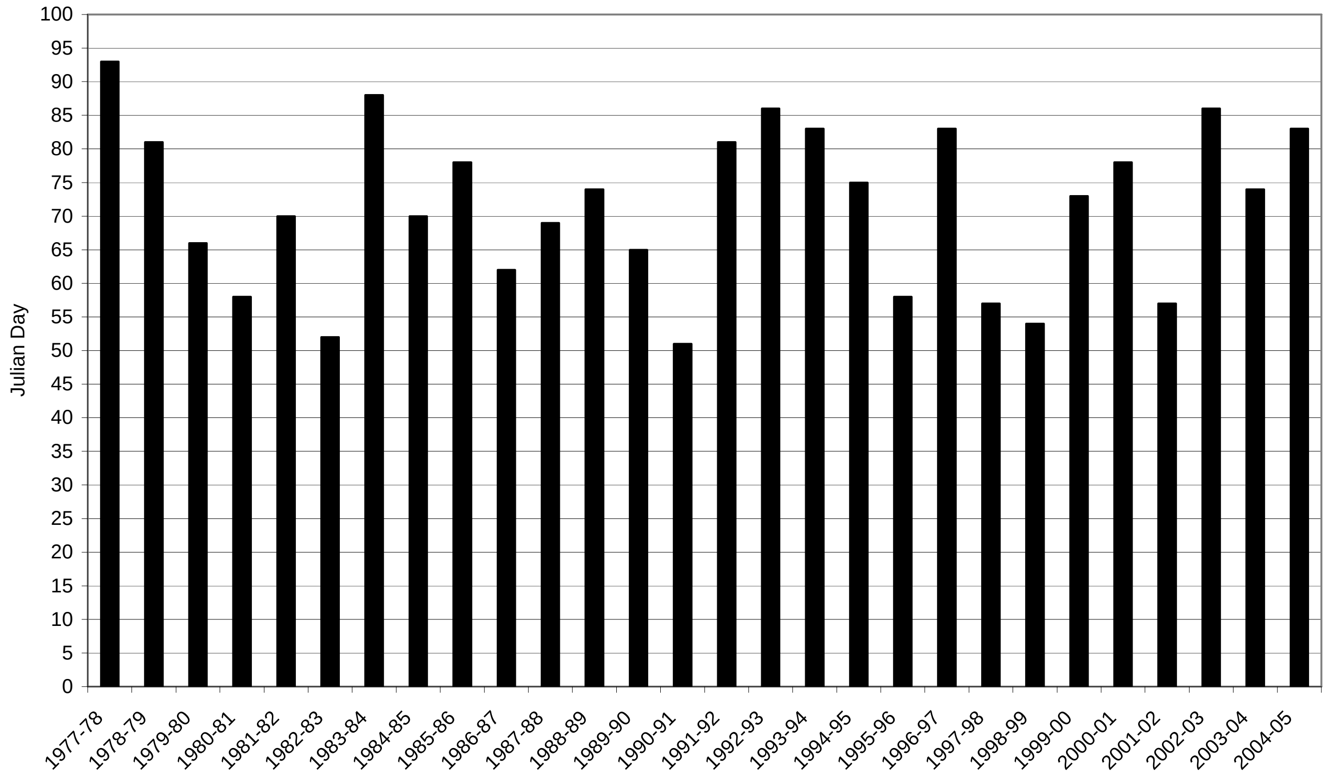


Figure 6.23 Dates of First Ice Deterioration for Lake St Francis

The date of first ice deterioration precedes the ice-free date, by about 2 weeks to one month.

The results show that there is considerable variability with respect to both dates. The ice-free date for **Lake St. Francis** has ranged from **March 6** to **April 24** (**Figure 6.24**). The date of first ice deterioration for **Lake St Francis** has ranged from **February 20** to **April 3** (**Figure 6.25**).

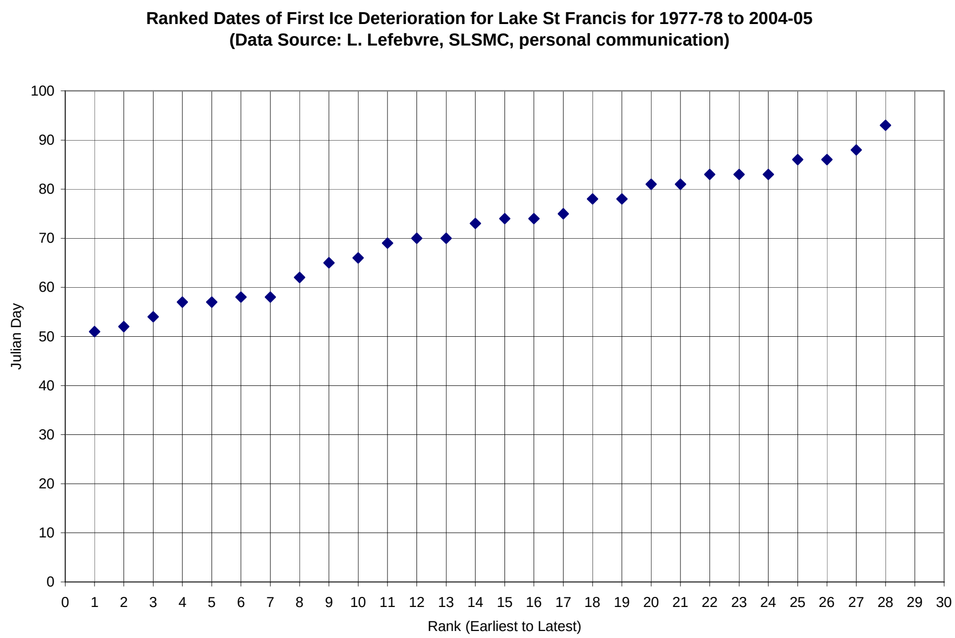


Figure 6.24 Ranked Dates of First Ice Deterioration

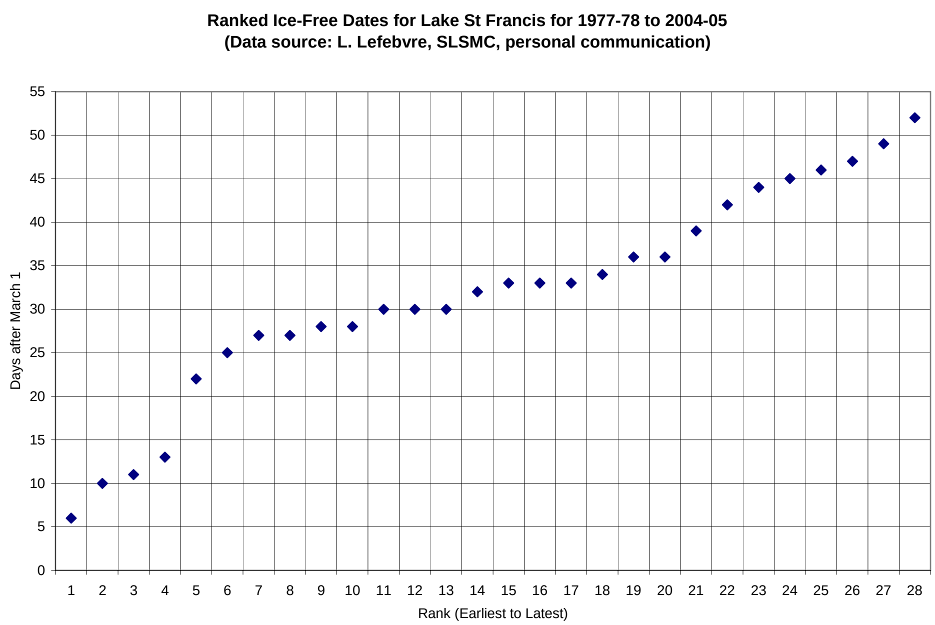


Figure 6.25 Ranked Ice-Free Dates for Lake St Francis

Comparisons with the **2008/2009** winter are somewhat difficult to make, but the following information provides some basis for comparison:

(a) date of first ice deterioration – information is not available for **Lake St. Francis**, so direct comparisons are not possible. However, considering that the video records showed that a small patch of open water first appeared around the navigation buoy on **March 7**, this is considered to be a reasonable choice. This would classify the **2008/2009** winter in the mid-range (see **Figure 6.24**).

(b) ice-free date – the **RADARSAT** imagery showed that **Lake St. Francis** was not ice-free by **March 28**, as the eastern end of it was packed with ice (see **Appendix E**). This suggests that the ice-free date for **Lake St. Francis** for **2008/2009** should be considered to be after **March 28**. This would also put the **2008/2009** winter generally in the mid-range category (see **Figure 6.25**).

Thus, on an overall basis, these comparisons generally indicated that the **2008/2009** winter was not unusual with respect to the date of first ice deterioration or the ice-free date.

6.5.7 Overall Assessment

The flows and water level elevations for the **2008/2009** winter appear to have been at most variance from past winters, and **2007/2008** in particular, compared to the other environmental parameters of relevance.

It is hypothesized that the natural ice break-up and clear-out that occurred in **2009** was precipitated by the 15 cm rise in water level that occurred in the week prior to the break-up of the ice cover on **March 8** in the channel between **St. Regis** and **Cornwall Islands**. This would have acted to de-stabilize the ice, by breaking it away from the shoreline. Also, it would have facilitated “flushing” of the ice

downstream by the higher flows that prevailed at the time and throughout the **2008/2009** winter.

6.6. Summary of Key Points and Observations

The following summarizes the key points for the **JOS** for the **2008/2009** winter:

(a) the **Seaway Opening** took place on **March 31, 2009**. The **2009 Opening** was one of the later ones over the past 26 years.

(b) a natural ice break-up and ice clear-out occurred in **2009**. It was not necessary to conduct icebreaking operations to open the Seaway in **2009**, and thus they were not done. Consequently, any shoreline impacts that may have occurred were not related to ice-clearing operations.

(c) the ice cover in the channel between **St. Regis** and **Cornwall Islands** broke up on **March 8**. The ice in the shipping channel cleared out rapidly after that. By **March 21-28**, the only ice remaining in the shipping channel consisted of ice pieces and floes that had been packed into the western end of **Lake St. Francis**.

(d) the **2008/2009** winter was colder than normal, based on **FDD**s measured at **PET** airport in **Montreal**.

(e) the **FDD**s peaked before the **Seaway Opening**, and melting was occurring, as evidenced by the fact that the accumulated **FDD**s were decreasing at that time. Ice temperature measurements showed that the ice temperature had been at the freezing point for more than two weeks prior to the **Seaway Opening Date**, which would have caused the ice to be in an advanced state of decay by the time of the **Seaway** officially opened.

(f) the flows throughout the **2008/2009** winter were slightly higher than the 30-year average over most of the winter. During the time when ice breakup occurred, the flow was about 300 cms higher than the 30-year average. Furthermore, the water level elevations were higher than the 30-year average.

(g) a rise in water level of about 15 cm occurred during the week prior to the date when the ice cover broke up. It is believed that this was a factor in de-stabilizing the ice, and contributed to the ice breakup.

(h) comparisons with long-term data regarding the ice cover duration along the Seaway indicate that the **2008/2009** winter was not unusual with respect to the date of first ice deterioration or the ice-free date.

7. CONCLUSIONS & RECOMMENDATIONS

Although the third and last year of the three-year study mandate yielded no new information regarding the direct physical impacts of anthropogenic ice-clearing, the circumstances presented a unique opportunity to collect and document baseline data on the natural breakup of the ice cover. This situation presented itself because the navigation channel was already cleared of ice, due to a combination of mild temperatures, and higher than normal (based on the 30-year average) flows. As a result, an icebreaker was not required to open the shipping channel in the study area this year.

Based on the study team's observation and analyses this season, the following conclusions were elaborated:

Shoreline Surveys

1. Field surveys were completed during the fall of **2008** in order to select appropriate observation sites for ice impact observations based on the previous year's experience. Two key criteria for site selection were the accessibility of the site, and the degree to which that location was representative. Eventually, three to four (3 to 4) sites were selected for pre/post ice-clearing observations of the near-shore ice cover. However, ice cover movement observations during ice-clearing operations were not carried out this year because an early and natural ice cover breakup occurred.
2. No monitoring of the shoreline bank profiles was done this year as this time-consuming task did not provide meaningful information on the physical ice-induced processes under study that occur near the water's edge.
3. An extensive photographic survey of the shorelines was conducted along the full study reach in the fall using both video and still photography. This was completed using a boat as a vantage point. The shoreline was again

inspected in the spring for visible changes or evidence of ice-induced shoreline damage, such as berms, ridges or scars - none were observed.

4. Rip rap stones at **Clark** and **Stanley Islands** were marked and surveyed prior to, and after the winter. Several of twenty-one (21) marked rip-rap stones along **Stanley** and **Clark Islands** that were originally surveyed in the fall of **2008** showed some level of movement over the course of the winter/spring. Considering the entire ice cover was cleared by natural means in **2009**, the movement of those stones can be considered to represent the baseline conditions expected to occur under natural conditions. Furthermore, the armour stone stability analyses that were completed last year were reviewed and, the conclusions were generally corroborated by the **Spring 2009** observations – thus supporting the hypothesis that "the observed rip-rap movements were ship-induced" is still a valid explanation.

Ice Conditions Index - Freezing-Degree Days Evaluation

5. The **Freezing Degree Day**(**s**) index method was again used as a means to evaluate the severity of winter and indirectly infer the ice conditions within the seaway channel. The application of the **FDD** method this winter indicated a more severe winter/spring than observed in **2007/2008**, as there were more **FDD**s in **2008/2009** than in **2007/2008** (i.e., maxima of 895 and 760 °C*days, respectively). Considering that a natural ice cover breakup occurred in **2008**/2009 at an earlier date than the icebreaker-induced breakup in **2007**/**2008**, it is concluded that other factors such as water levels and flows and, weather are equally important in characterizing the state of the ice cover; hence, the **FDD** method should not be used exclusively as a gauge of the ice conditions.

Water Levels and Flows

6. Water level and flow records were again reviewed this year. The data indicated the values in **2008**-20**09** were slightly higher than the 30-year average over most of the winter. During the time leading up to the break-up of the ice cover, the flow was about 300 cms higher than the 30-year average. Furthermore, a steady and significant increase in water level of about 15 cm occurred prior to the ice break-up and is surmised as playing a key role in the early ice cover breakup. It is hypothesized that the natural ice break-up and clear-out that occurred in **2009** was precipitated by a 15 cm rise in water level that occurred in the week prior to the break-up of the ice cover on **March 8** in the channel between **St. Regis** and **Cornwall Islands**. This would have acted to de-stabilize the ice cover, by breaking it away from the shoreline. Also, it would have facilitated "flushing" of the ice downstream by the higher flows that prevailed at the time and throughout the **2008/2009** winter.

Evolutions of the Ice Cover

7. The formation of an ice cover over the course of a winter plays an important role in defining its state at any given time within the winter. Consequently, observations were made during the winter to track the development of the ice cover. This was accomplished using **RADARSAT** satellite imagery, an aerial reconnaissance flight, ground-level (ice/land) observations and, new for this year, a continuous video record of the ice cover and its breakup. The aerial survey and the ground-level data were particularly useful for ground-truthing the satellite data, while the **RADARSAT** data itself was particularly useful to providing information regarding the overall development and macro structure of the ice cover. A higher level of detail was also obtained from the aerial flight survey. These sources of information were important in supporting field observations. The initiation of the ice breakup was detected by video surveillance on **March 7th** while open water was recorded by **RADARSAT** prior to **March 21st** in the study reach.

8. Comparisons with long-term data regarding the duration of the ice cover along the **Seaway** indicates that the **2008/2009** winter was not unusual with respect to the date of first ice deterioration or the ice-free date.

Ice-clearing Observations

9. As previously mentioned, the planned ice-clearing operation within the study reach that was scheduled on approximately **March 29th**, **2009**, did not take place this spring because a natural breakup of the ice cover occurred in the preceding two to three weeks. Consequently, no ice-clearing observations were made this spring.
10. It was recognized last year that ice-induced shoreline impacts could potentially occur due to moving ice floes during the ice cover breakup process. This was investigated by using boat based observations in the weeks following the natural ice cover breakup. The study team did not observe any significant ice-induced impacts, such as scours, scars, or berms.
11. No shoreline physical impacts were reported by any landowners along the shoreline being studied as a result of the natural breakup of the ice cover.

Based on this year's findings, the following recommendations were developed:

1. As stated in the previous two **Annual Reports**, the **Opening Date Selection** and ice-clearing operations should continue to be an inclusive process for the current stakeholders and include risk assessment elements of icebreaking operations and ice conditions. Incorporating better planning tools such as **RADARSAT** satellite imagery, aerial and land-based surveys plus usage of an improved **FDDs** methodology can only improve the knowledge of field conditions; hence, mitigate the risk of potential ice impacts in clearing the navigation channel.
2. The **Freezing Degree-Days** (**FDDs**) index method, which was again used to gauge the severity of ice conditions and serves as a planning tool, must be

used in conjunction with other observations, namely, water levels and flows, ice thickness data, and, ice temperature profiles in order to increase the reliability of results. The development of a knowledge base should also be considered in order to enhance the interpretation.

3. Considering the usefulness of the **RADARSAT** imagery to the stakeholders, access to this type of data should be secured with the appropriate government department in order to ensure on-going availability. Furthermore, the study team recommends using **RADARSAT 2** imagery, rather than **RADARSAT 1** imagery, as was used last year, since it provides a noticeable improvement in the discrimination of ice cover conditions.
4. The **2009** field observation activities yielded significant information on the natural breakup of the ice cover within the study reach. This knowledge should be used to better understand all the processes involved in the breakup of the ice cover.