# Final Study Report

## JOINT OBSERVATIONAL STUDY (JOS)

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


*Prepared by*

**JOS PROJECT MANAGEMENT TEAM**

*Under the direction of*

**KIJE SIPI LTD**

*and, under the technical leadership of*

**BMT FLEET TECHNOLOGY LTD**


*August 2009 – Final Version*

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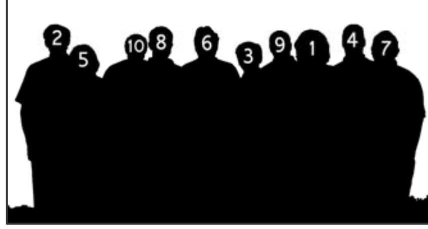

# JOS PROJECT MANAGEMENT TEAM DECLARATIONS

*The <u>content of this report generally mirrors in format the three (3)</u> **<u>JOS Annual Reports</u>** <u>while only summarizing their contents</u>; hence, it documents <u>only the essence</u> of all **JOS** project management and study activities during its entire mandate, covering the period of **October 2006** to **June 2009**. Specifically, this report summarizes all key **JOS Project Management Team** activities, decisions, technical findings, conclusions and recommendations and, <u>was in principle, unanimously approved by the</u> **<u>JOS Project Management Team</u>** <u>at its</u> **<u>June 24, 2009</u>** <u>meeting</u>.*

*Although the project started under an aura of residual animosities coming out of the litigation process, it quickly evolved into a concerted and dedicated effort to study and understand the issues at hand. The **<u>JOS Project Management Team</u>** <u>members are not only satisfied the mandate has been successfully completed</u>, but also wish to impress upon the reader that the seemingly simple initial project issues, were in fact more complex problems that did not deter the keenly engaged **Project Management Team** members from their study objectives.*

| | | | |
|---|---|---|---|
| *Tony David, SRMT* | *Carol Fenton, SLSDC* | *Ken Jock, SRMT* | *Stephen Kwok, SLSMC* |
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# ACKNOWLEDGEMENTS

*The successfully completion of the **JOS Study** was, in part, due to the important contribution of a dedicated group of people that were not directly involved in the study. Accordingly, the **JOS Project Management Team** members would like to express their gratitude and, hereby acknowledge the particularly significant technical contributions by **Jim Snyder** during the entire study. As well, the study team would also like to extend its appreciation to the following people who helped the project during the field surveys:*

***Craig Arquette***
***Daniel Benedict***
***Tira Benedict***
***Margaret George***
***Leo Fox***
***Diane Jobin***
***Scott Peters***
***Bob Stevens***
***Andrew Thomas***
***Randy Wagstaff***

*The **JOS Project Management Team** would also like thank the following agencies for their significantly contributions to the project:*

***Canadian Ice Service** (for the **RADARSAT** imagery)*
***Canadian Coast Guard** (for access to the ship)*

## TABLE OF CONTENTS

# 1. INTRODUCTION

**<u>Study Impetus, Mandate & Objective</u>**

The **Joint Observational Study** (**JOS**) was completed 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 **Saint Lawrence Seaway**. In particular, this was articulated in the *General Provision Clause 7.01* in the referenced **MOU** which indicates the purpose of the study "…*is to observe <u>physical effects</u> arising from the opening of the navigation season in the area from* ***Snell Lock*** *to the middle of* ***Lake Saint-Francis*** *when ice is present in that area*".

**<u>General Questions to be Studied</u>**

Do icebreaking activities and/or ship transits in ice conditions within the study area cause: 1) shoreline ice scour and/or, 2) land fast ice to break away from shore prematurely?

**<u>Initiating the Joint Observational Study</u>**

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** (**SC**) was later selected in **December 2006** to oversee the day to day activities of the study.

**<u>Reporting</u>**

This report summarizes all key **JOS** study activities, findings, conclusions and recommendations as well as **JOS PMT** decisions. Detailed information on all significant study activities is documented by year, for each of the three (3) years of the project and, is available in each of the **Annual Study Reports**. A copy of the

**Summary Section** of each of those three (3) reports is provided as **Appendices** to this report.

## 2. STUDY MANAGEMENT ACTIVITIES

The main **JOS PMT** study activities included:

### 2.1. Meetings

A total of twenty-one (21) meetings were held throughout the three (3) year study. A large majority of meetings brought together members of the **JOS PMT** while a few, being technical in nature, assembled only a sub-set of the group. Meetings were convened at critical points along the study and were generally well attended by all parties. The very low turnover of representative members on the **JOS PMT** undoubtedly contributed to the successful conclusion of the mandate.

The meetings were generally hosted on a rotating location basis, at each team member agency's workplace.

Minutes were prepared with an accompanying list of "**Action Items**" and unanimously approved at the following meeting. These are appended to the appropriate **Annual Report**. Note that accompanying materials were generally not included with the **Minutes**; however, were distributed to all **JOS PMT** members and are available in the study archives.

### 2.2. Financials

The study expenditures were rigorously tracked and monitored by the **JOS PMT** throughout the study and <u>did not exceed the allocated budget</u>. The **MOU** had stipulated a combined maximum financial contribution of **$130,000.00 US** from each of the two **Seaway** management agencies. In addition, in-kind contributions were

also provided by all participating agencies for personnel related activities such as attendance to meetings. Note that unless stipulated otherwise, any dollar values presented in all the study reports are in quoted in **Canadian** dollars.

The total charges against the study amounted to **$129,285.00** plus the applicable **GST**. All expenditures during the study consisted of payments to the **SC** (**Kije Sipi Ltd**), its sub-consultant, **BMT Fleet Technology Ltd.** 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**.

**In-Kind** contributions were tracked separately throughout the study and were based on estimated time and expenses. An approved per diem rate was adopted early in the study. Time and expenses were registered by the study coordinator based on approved claims by all **JOS PMT** members. **Table 2.1** shows the breakdown of all accounted **In-Kind** charges by agency while the total value reached **$50,920.50**.

## Table 2.1 In-Kind Study Cost

| ***JOS In-Kind Contributions Summary Report*** | | | **as of :** | **8/6/2009** |
|---|---|---|---|---|
| **Group** | **Days Worked** | **Time Claimed** | **Expense Claimed** | **In-Kind Claimed** |
| MCA | 13 | $ 3,250.00 | $ 100.00 | $ 3,350.00 |
| SLSDC | 28 | $ 7,062.50 | $ 468.71 | $ 7,440.50 |
| SLSMC | 17 | $ 4,125.00 | $ 690.00 | $ 4,815.00 |
| SRMT | 115 | $ 28,737.50 | $ 4,840.00 | $ 33,577.50 |
| TC | 7 | $ 1,687.50 | $ 50.00 | $ 1,737.50 |
| **Total In-Kind Contributions** | **179.45** | **$ 44,862.50** | **$ 6,148.71** | **$ 50,920.50** |

A detailed annual breakdown of both **Financials** and **In-Kind** charges are presented in each **Annual Report**.

## 2.3. Management, Correspondence & Documentation

The study benefitted from having a stable and dedicated management team as well as an experienced technical group throughout the mandate. This translated to fewer and more efficient meetings, plus focused and refined observation programs.

During the fall of **2007**, **BMT-Fleet Technologies Ltd**, a company specializing in ice related studies, was hired as sub-consultant to the **JOS-SC** to lead the technical work program and coordinate the various field observation tasks.

Several letters were distributed on behalf of the **JOS PMT** throughout the study. Most correspondence were appreciation letters – for access to the ice breaker and, provision of several **RADARSAT** satellite images. Memos were also distributed to the communities and various border and police agencies as a notification of the **JOS** field activities.

A protocol was also developed during the last year of the study regarding the archiving of camera imagery. The protocol also included a provision for distributing copies to law enforcement agencies.

A password-protected electronic document archive site was established during the first year of the study and was maintained throughout the project by the study coordinator. The site was accessible, via remote computer access, to the **JOS-PMT**. All relevant study documents including financials, meeting notes and technical reference information were maintained for retrieval only. A list of the archived documents is appended to the three (3) **Annual Reports**. Also, an electronic copy of the entire content of the archive was provided to each organization represented on the **JOS Project Management Committee**.

## 2.4. Issues

Only three (3) issues of significance were dealt with by the **JOS-PMT** during the study mandate. Two (2) of those were discussed and resolved during the first year of the study. The first issue dealt with a disagreement among the **JOS-PMT** members related to the definition and scope of the field observations. Ultimately, all parties agreed on limiting the scope to the “physical environment”, namely mechanical processes at the shoreline. The second issue dealt with an ice-breaking pilot project completed by **ALCOA** in the spring of **2007** on the **Grasse River**, an upstream tributary. The potential problems of having additional ice floes, including ice jamming, was averted by discussions with the **ALCOA** team in an effort to coordinate field activities. The third issue arose during the second year of the study and involved a landowner that refused to grant access to his property in order for a **JOS** observation team to complete shoreline measurements. Unfortunately, this occurred on the day of spring observations, while the icebreaker was clearing the channel; and consequently, one (1) of three (3) observation sites had to be eliminated. Closure was finally brought to this issue in the following days when representatives from both tribes clarified the situation with the landowner to ensure no ill-feeling. Furthermore, several **JOS-PMT** members apologized to their respective employees who were directly involved during this unfortunate event.

# 3. TECHNICAL WORK PROGRAM

A **Technical Work Plan** was developed in early **2007** in order to guide the study team members in organizing the mandated technical activities. **Figure 3.1** schematically depicts the logical sequence of all high-level activities that were completed during the study. The diagram was used during the study as a quick visual aide to monitor the **Work Program**’s state of completeness. The figure 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**.

**Figure 3.1** shows two (2) distinct groups of tasks that separate the observation activities of the first year of the mandate from those of the last two (2) years. The technical activities during the initial year (**2006/2007**) of the study included:

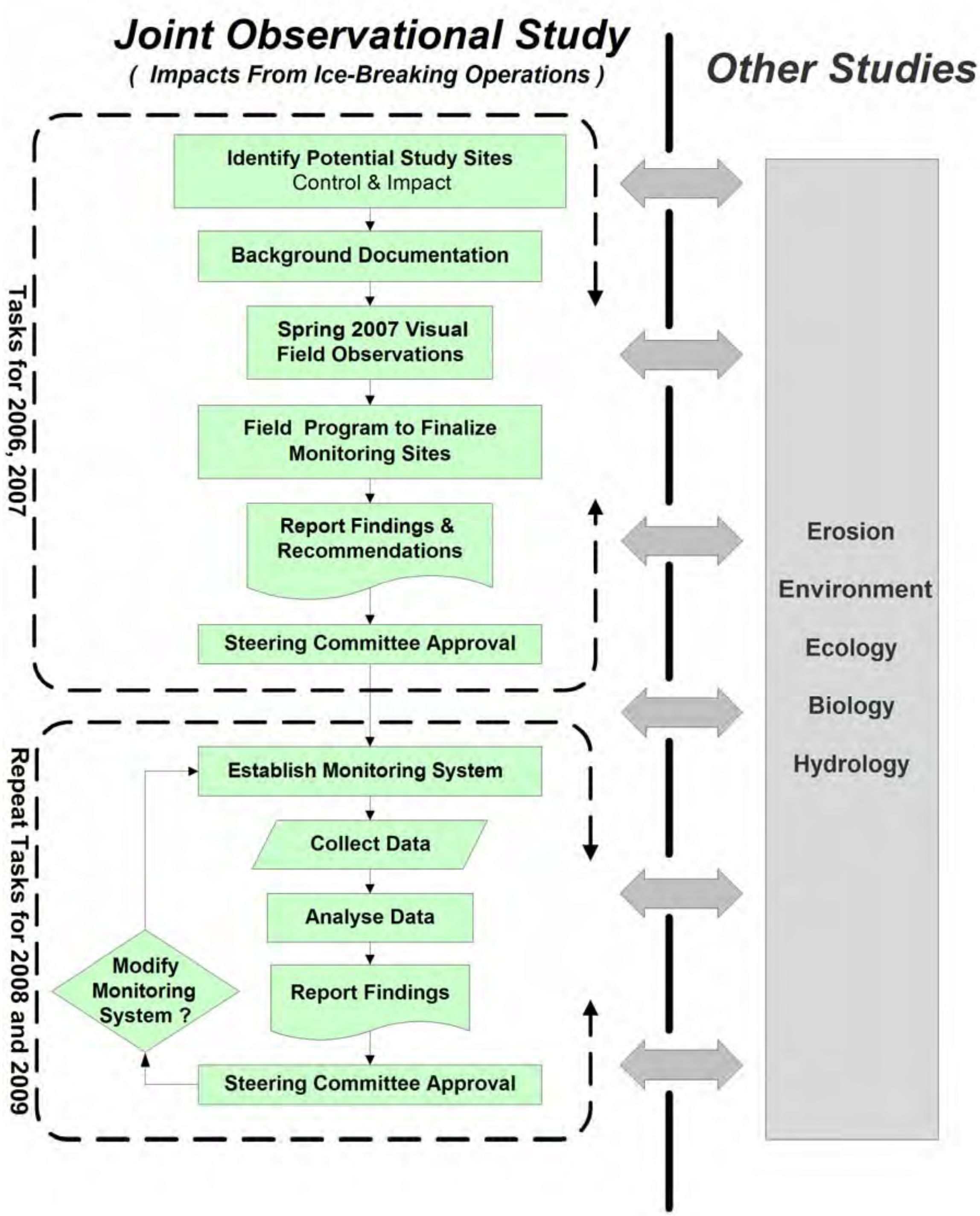
- Identification potential field observation sites
- Review background documentation
- Collect visual observations of the **Spring 2007** ice clearing
- Document findings

Following the initial spring observations, the study team was expanded to include a company specializing in ice-related studies. As previously mentioned, **BMT Fleet Technology Ltd.** was retained to generally oversee all elements of the **Technical Work Program** for the remainder of the study mandate. This addition led to the development of a revised field **Monitoring Program** in the fall of **2007** that included new sites and new field observation activities for the subsequent two (2) years of the study. This change is also reflected in **Figure 3.1** within the group of technical tasks located at the bottom of the diagram. Note the looped sequence of activities that allows modifications to the **Monitoring Program** following the previous year's experience.

The high-level technical activities that were completed during the last two (2) years (**2007/2008** and **2008/2009**) of the study included:

- Develop a new **Monitoring Program**
    - o Select new sites
    - o Develop field monitoring activities
- Complete fall field baseline surveys
- Collect and analyze spring observation data
- Document findings

**Figure 3.1: JOS Technical Work Plan**



The following two (2) report sections present a synopsis of the actual technical tasks completed under the approved **JOS Technical Work Program**. Details on approach, findings and issues are also presented. **Section 4** elaborates on shoreline surveys while **Section 5** describes winter/spring observations.

# 4. SHORELINE SURVEYS

## 4.1. Overview of Shoreline Surveys

The **Shoreline Survey Program** was established to observe ice-induced shoreline changes over the winter and along the study reach. This field program evolved over the course of the study but was only in place to monitor the last two winters of the study since the study technical team, including the **JOS-SC**, was only in place starting in **December 2006**.

**Table 4.1** lists all of the different types of shoreline survey activities (tasks) that were completed throughout the entire study. Four (4) different types of shoreline surveys were completed during the three (3) year mandate. As can be observed, each task entailed two (2) separate surveys: 1) a fall survey to establish baseline conditions and, 2) a spring survey to detect any changes from the baseline. The fall surveys were usually conducted as late as possible in order to capture the pre-freeze up conditions while the spring surveys were completed as soon as boat transportation was possible given that most sites were only accessible by water.

One of the initial tasks was the selection of appropriate sites for the **Shoreline Surveys**. The locations were established based on local knowledge, accessibility and representativeness of the phenomenon under investigation. **Figure 4.1** shows the site selection (yellow pins) for the **2007/2008** shoreline surveys. Note that these

locations were revised for the **2008/2009** surveys based on the previous year's experience and the new requirements of the revised **Shoreline Survey Program**.

## Table 4.1 Shoreline Survey Program

| Shoreline Surveys Tasks | | | | | | |
|---|---|---|---|---|---|---|
| | 2006/2007 | | 2007/2008 | | 2008/2009 | |
| Tasks | Fall | Spring | Fall | Spring | Fall | Spring |
| 1. Elevation Profile Surveys | | | ✔ | ✔ | | |
| 2. Dock Location Surveys | | | ✔ | NC | | |
| 3. Rip-rap Stone Position Surveys | | | ✔ | ✔ | ✔ | ✔ |
| 4. Shoreline Photographic and/or Video Surveys | | | ✔ | ✔ | ✔ | ✔ |

**Notes: NC = Not Completed**

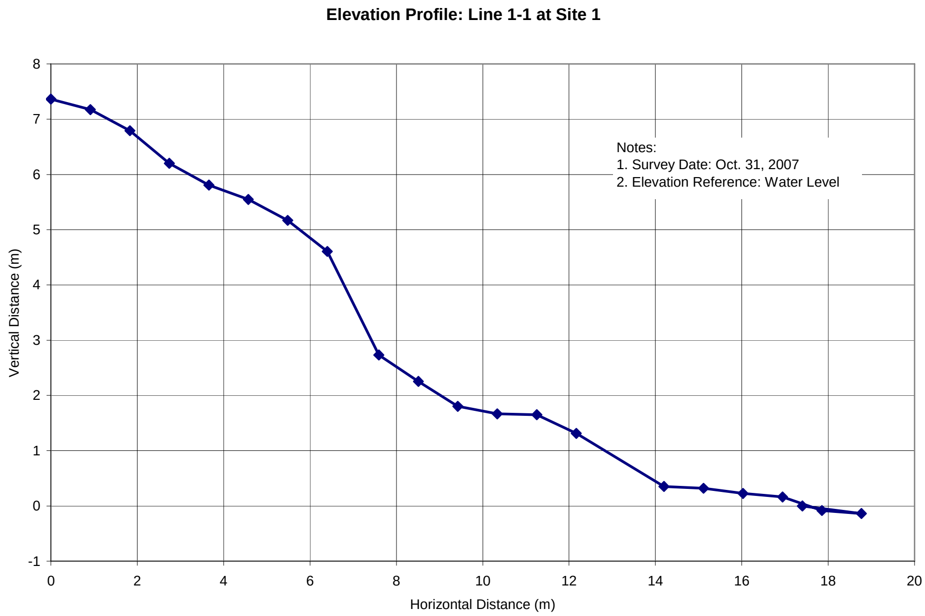
## Figure 4.1 Shoreline Survey Sites (2007/2008)

## 4.2. Elevation Profile Surveys

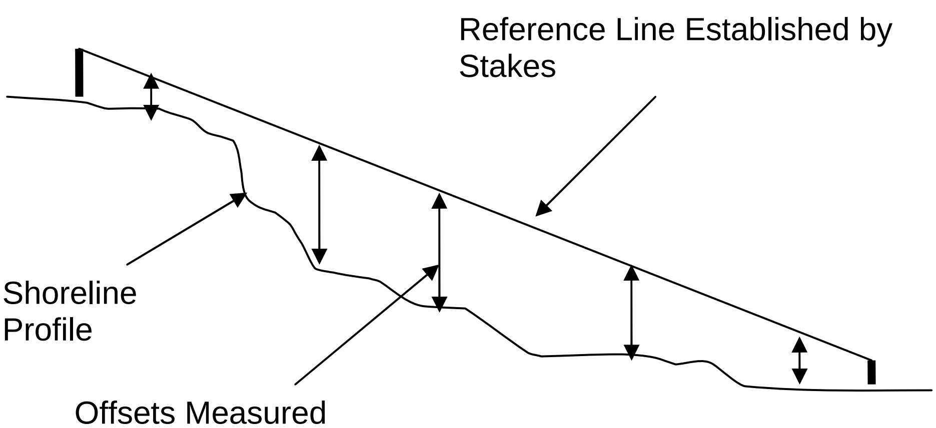
The main objective of this type of survey was to directly measure changes in the shoreline profile by comparing the shoreline cross-sections before and after ice clearing. Although vertical elevation profiles, as shown in **Figure 4.2a**, were intended to be surveyed at all sites, the task proved very time-consuming and ultimately only of peripheral interest because it was not focused on the water's edge, which was the specific area of interest. A simpler survey approach was devised using vertical offsets from a reference line (see **Figure 4.2b**) and eventually used on all but the first site surveyed; however, a number of limitations were experienced including difficulty in winter re-survey and inaccuracies in re-locating reference stakes. As a result, the **Elevation Profile Surveys** were only completed during the **Fall/Spring** of **2007/2008**, and they were not continued during the following year.

Nevertheless, no major shoreline changes were visually identifiable at each of the three (3) surveyed sites. No evidence of ice-induced shoreline damage, such as berms, ridges or scars were observed. Although variations in elevations were noted at several sites, these were considered well within the resolution of the survey technique and consequently not indicative of any slope movement.

# Figure 4.2a Elevation Profile Measurement Approach A




# Figure 4.2b Elevation Profile Measurement Approach B



## 4.3. Dock Location Surveys

The objective of this type of survey was to measure the movement of the ice cover near the shore by monitoring changes in the position of a strategically located structure such as a wharf that was left in the water over the winter. **Figure 4.3** shows the selected dock located on the south side of **Cornwall Island**. The task required precise monitoring of the readily accessible anchoring posts. The baseline position of each post was carefully measured in the fall of **2007**. Unfortunately, access to the dock was denied by the landowner in the following spring and consequently, <u>the planned spring observations could not be completed to verify if movement occurred.</u>

**Figure 4.3 Dock Selected for Location Surveys**

## 4.4. Rip-rap Stone Position Surveys

The main objective of this type of survey was to detect significant ice-induced movement along the shoreline at the water's edge. The principle used was to record the position of a series of readily identifiable rip-rap stones in the fall and, monitor any

changes in their location in the spring. **Figure 4.4** shows a typically marked (fluorescent spray paint) rip-rap stone during the first year the survey was completed.

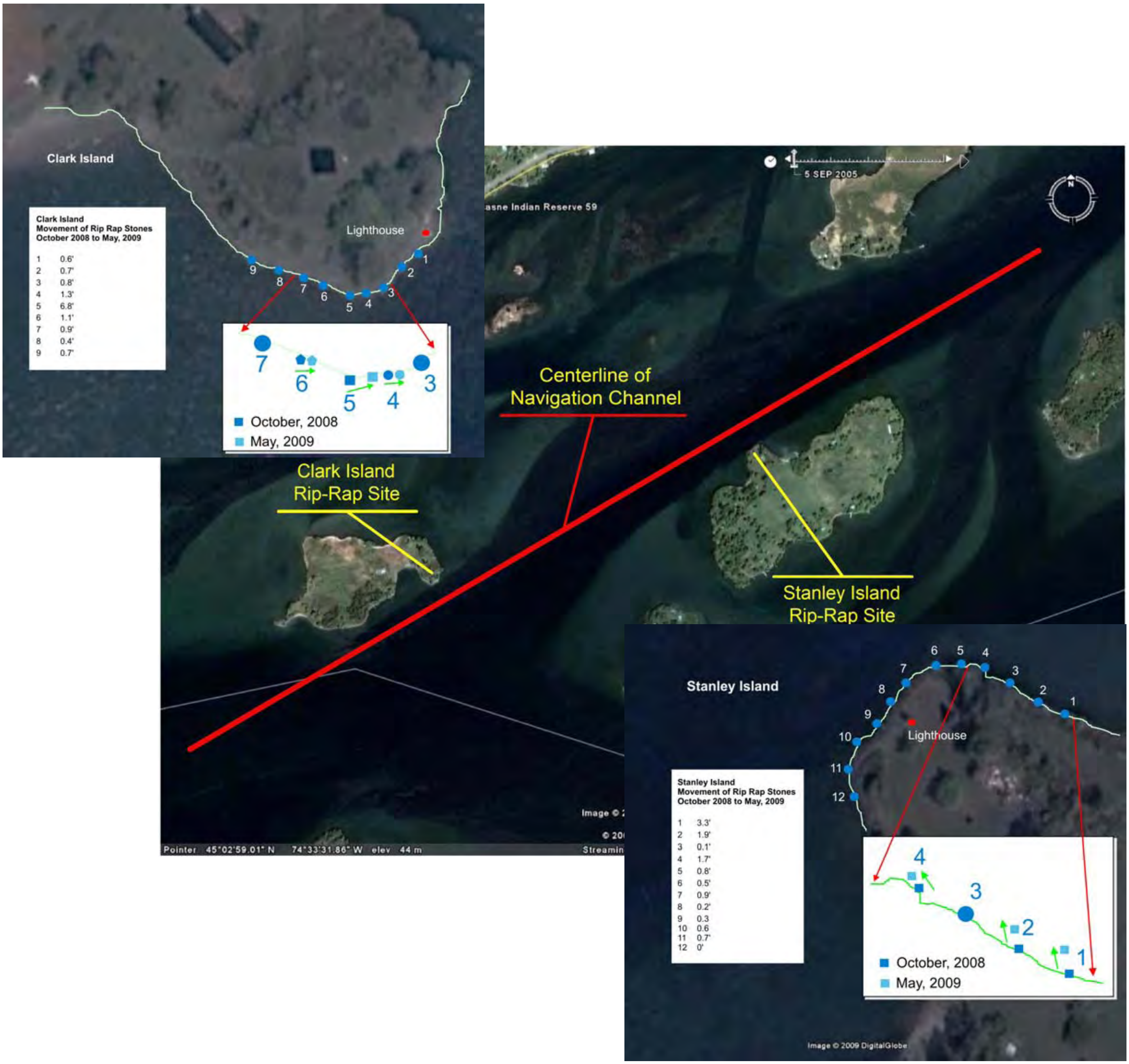
### Figure 4.4 Typical Marking of Rip-Rap Stone

Since only significant movement was of most interest for this project, high-precision surveys were not conducted, as the added effort that this would require was not deemed to be worthwhile.

**Figure 4.5** shows the location of the two (2) surveyed sites while the insets show the precise location of each rip-rap stones at each of the two sites (blue dot) during the **2008/2009** season. Only the **Stanley Island** site was surveyed in **2007/2008**.

# Figure 4.5 Locations of Rip-Rap Survey Sites & Stones – 2008/2009

**(Background imagery from Google Earth)**



The selected rip-rap stones were relatively small compared to most of the rocks along the shore of the two (2) sites. This was done deliberately so that the survey would generate conservative results, in that the selected stones were more likely to be moved than most of the ones along the shoreline. It should be further noted that the survey was focused on observing or measuring large-scale movements. Consequently, high precision survey methods were not considered to be necessary. Triangulation to fixed reference points was used to position each stone. Eight (8) stones were marked in the **2007/2008** season, along the shore at **Stanley Island** while twenty-one (21) stones were tagged during the **2008/2009** season, along shorelines near the shipping channel at **Clark** and **Stanley Islands**.

The surveys were successful in detecting movement on each of the two (2) years of measurements. Two (2) out of eight (8) stones showed significant movement during the **2007/2008** season while six (6) stones out twenty-one (21) moved 0.3 m or more during the **2008/2009** season (see **Figure 4.5** insets). During the **2007/2008** season, the largest measured movement was 1.6 m. The study team noticed that in most cases the stones shifted off-shore but remained in the same attitude (i.e. did not roll over). The observed stone movements also appeared to be localized as large-scale changes to the shoreline rip-rap were not observed.

A number of possible explanations for the rip-rap stone movements were elaborated following the **2007/2008** season. It was eventually concluded that ship-induced currents and waves were the most plausible causative factor. Several ship passages were observed during the two (2) spring surveys that generated waves of approximately 0.3 m in height (see **Figure 4.6**) with accompanying local surges and draw-downs in the mean shoreline water level. Noticeable currents were also produced along the shoreline by these local surges and draw-downs.

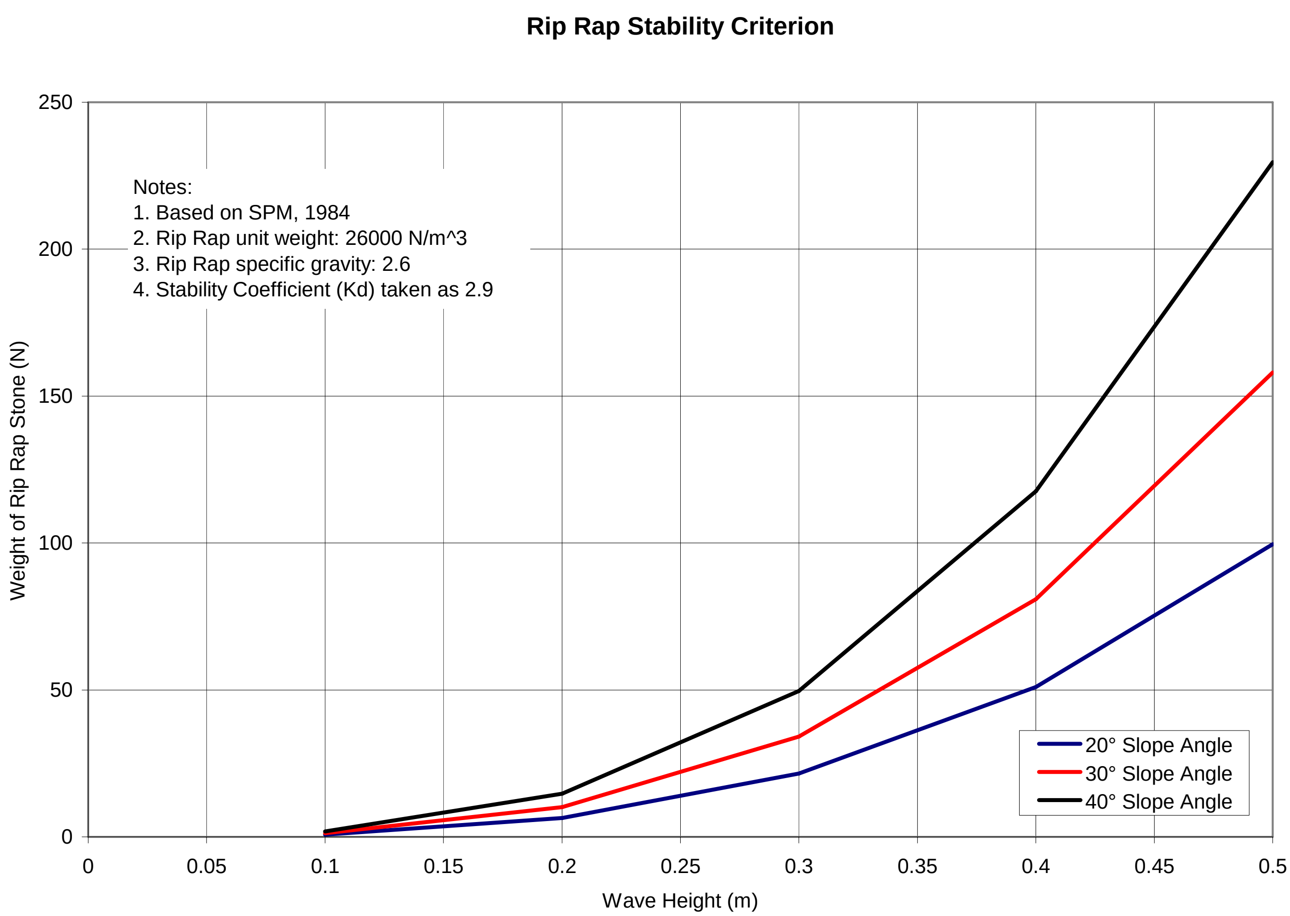
**Figure 4.6 Ship Generated Waves (Stanley Island Site May 14, 2008)**

A rip-rap stability analysis was completed during the **2007/2008** study season to test the hypothesis that the observed rip-rap stone movements might have been caused by ship-induced waves (see **2007/2008 Annual Report**, **Volumes I** and **II**). A well established technique developed by the **US Army Corps of Engineers** (**USACE**, **1984**) was used for the analysis and, when coupled with local site parameters generated a set of rip-rap stability criteria (see **Figure 4.7**). The results indicated that the hypothesis was a reasonable explanation as stones of the general size used for the monitoring program could indeed shift under the observed ship-induced wave action.

During the **2008/2009** season, the largest measured rip-rap stone movements were 1.0 m and 2.1 m at **Stanley** and **Clark Islands**, respectively (**Figure 4.5**).

Recognizing that icebreaking operations were not carried out in the spring of **2009** because a natural ice cover breakup occurred, the rip-rap stone movements observed in **2008/2009** may be considered to represent a baseline condition. It is believed that the observed rip-rap movements were most likely caused by ship-induced wave action rather than ice-related processes.

## Figure 4.7 Rip-Rap Stability Function (Stanley Island, May 14, 2008)



## 4.5. Shoreline Photographic Surveys

The main objective of this type of survey was to visually document significant ice-induced changes of the shoreline. It should be noted that photographs were also taken during practically all surveys as a means to visually record the given activity. As examples, **Figure 4.8** shows a photograph taken while measuring ice thickness (left photo) and also a typical shoreline photograph visually documenting the state of the shoreline at a site that was visited in the fall and spring of **2007/2008**.

During the second observation season, the shoreline photographic surveys were limited to recording only key sites while a more extensive photographic survey was conducted in **2008/2009**. In fact, the entire shoreline under study was photographed in the fall of **2008** using both video and still photography. This was accomplished using a boat as a vantage point. The shoreline was again inspected in the following spring for visible changes or evidence of ice-induced shoreline damage, such as berms, ridges or scars. <u>As in the previous year, the survey did not observe any significant changes to the shoreline</u>.

**Figure 4.8 Photographic Surveys**

# 5. WINTER/SPRING OBSERVATIONS

## 5.1. Overview of Winter & Spring Observations

A **Winter & Spring Observation Program** was established early in the study to directly observe and assess shoreline impacts due to the spring ice clearing operations in the **Seaway** navigation channel as well as to assess impacts from ship transits during this period. The program evolved significantly over the course of the study, taking advantage of the experience that was acquired, to adapt the survey methods to better suit the specific requirements of the study, particularly during the last season in order to better capture relevant data on the potential shoreline impacts from ship transits. Some ancillary study analyses were performed under this **Observation Program** to augment the direct field “observations” of the actual ice clearing operations which represented the main study focus. For instance, ancillary surveys and analyses were completed to characterize the ice conditions and the related environmental conditions such as weather conditions and river flows and elevations. This provided a better understanding of interactions between ice cover conditions, ice clearing operations and shoreline impacts.

**Table 5.1** lists all types of winter/spring activities (Observations) that were completed throughout the entire study. Six (6) different types of activities were completed during the three (3) year mandate. As can be observed, some of the tasks were completed throughout the winter and spring (either up to and, during the ice clearing operation or, after the ice cover had melted). Several analyses such as the **Water Level and Flows Analyses** were only completed later after the ice clearing operations.

# Table 5.1 Winter & Spring Observations

| Winter / Spring Observations | 2007 | | 2008 | | 2009 | |
|---|---|---|---|---|---|---|
| Tasks | Winter | Spring | Winter | Spring | Winter | Spring |
| 1. Ice Conditions Monitoring | | | | | | |
| - RADARSAT Satellite Imagery | | | ✔ | ✔ | ✔ | ✔ |
| - Aerial Flight Surveys | ✔ | ✔ | ✔ | ✔ | ✔ | ✔ |
| - On-ice Surveys (Ice thickness & Temperature) | | | ✔ | ✔ | ✔ | ✔ |
| - Video of Ice Cover | | | | | ✔ | ✔ |
| 2. Ship-based Observations | | ✔ | | ✔ | | |
| 3. Shoreline-Based Ice Movement Monitoring | | ✔ | | ✔ | | |
| 4. Freezing Degree Days Analyses | | ✔ | | ✔ | | ✔ |
| 5. Water Levels & Flows Analyses | | | | ✔ | | ✔ |
| 6. Landowner Report Monitoring | | ✔ | | ✔ | | ✔ |

Several of the field activities completed under the **Winter & Spring Observation Program** also required the selection of appropriate sites. This task was essentially completed at the same time as when the **Shoreline Surveys** sites were determined. However, the sites selected for the **Winter & Spring Observation Program** were not necessarily the same because they were intended to meet different objectives. The site locations also changed during the study. Planning, logistics and timing issues were of particular concern for several of the activities that were completed during the ice clearing operations. Nevertheless, even under sometimes adverse field conditions, the strong commitment among all technical field participants yielded the valuable data required for the **JOS** study.

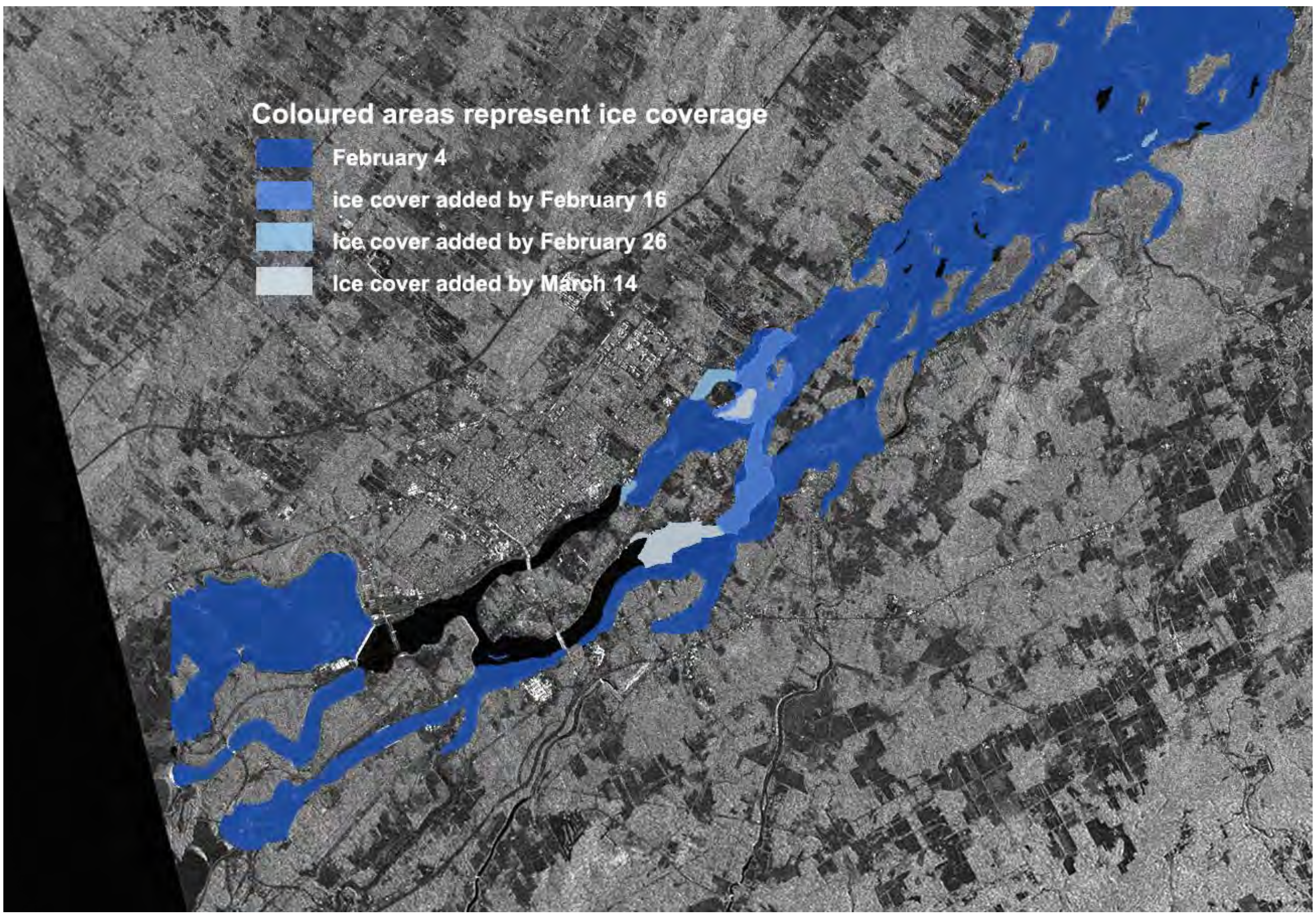
## 5.2. Ice Conditions Monitoring

It is well known that the development 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 and, of particular interest to this study, in the days leading up to ice clearing operations. Accordingly, four (4) different types of **Ice Conditions Monitoring** activities were completed during the study to characterize the formation and the evolution of the ice cover within the river reach of interest. However, it should be noted that comparatively fewer tasks were completed during the first year.

***RADARSAT*** *Satellite Imagery*

Satellite-based observations offer substantial advantages for monitoring changes over large areas and in particular, **RADARSAT** satellite imagery data, as shown in **Figure 5.1**, is well suited for observing the state and evolution of the ice cover. Fortunately, access to **RADARSAT** satellite imagery data was secured for the study from the **Canadian Ice Service** for the last two (2) observation seasons.

**Figure 5.1 RADARSAT Interpreted Growth of Ice Cover (2008)**




As anticipated, the imagery data provided significant insight on the growth of the ice cover, the location of the ice edge and the presence of any ridges or major cracks. The spatial distribution of the different types of ice structures was also delineated and

corroborated by aerial and land-based visual observations. Four (4) separate satellite images covering the study area were generated and analyzed during both the **2007**/**2008** and **2008**/**2009** seasons. As previously mentioned, the satellite imagery was particularly useful in mapping the evolution of the ice cover during the winter as shown on **Figure 5.1**. The figure highlights the progressive growth of the ice cover during the winter of **2008** with overlays of several interpreted results obtained by satellite images taken at different times during the winter. Each shade of blue represents the location of the ice cover at a specific time. Aerial fly-bys and ground surveys were used as an aid to interpret the satellite imagery by providing visual confirmation of the observable features as shown in **Figure 5.2**.

**Figure 5.2 RADARSAT Interpreted Ice Features (February 2, 2008)**

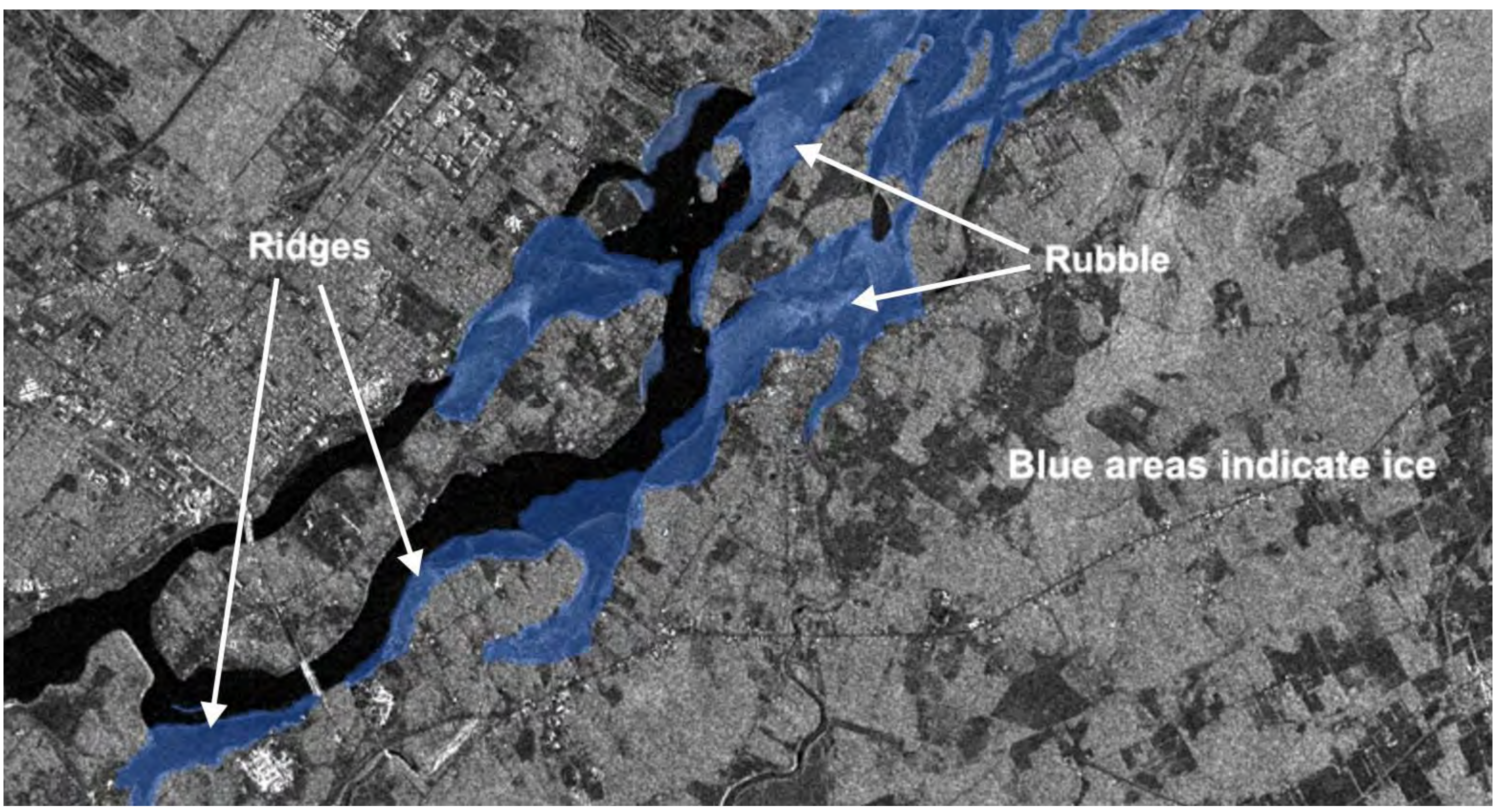
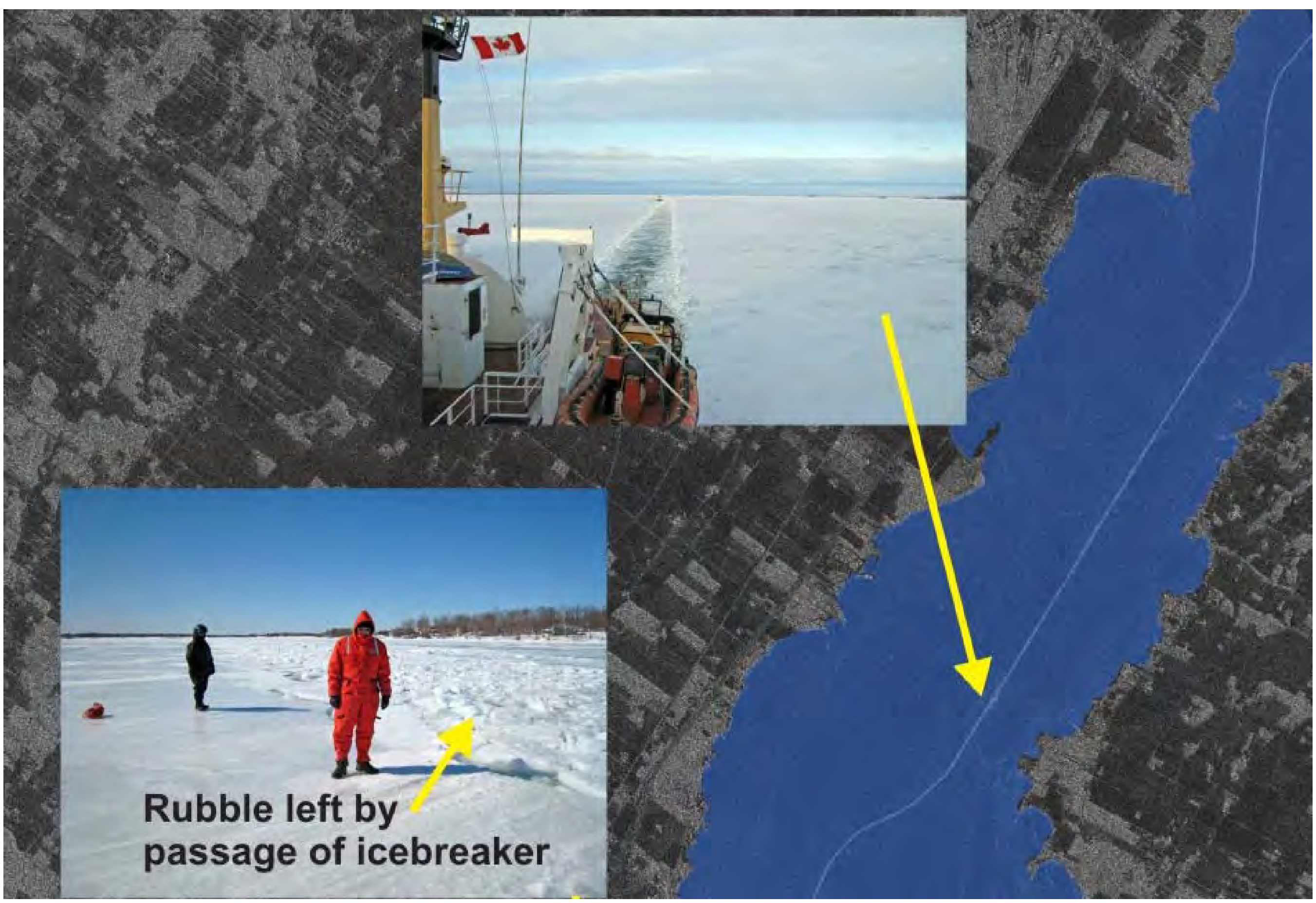


**Figure 5.2** shows the full extent of the ice cover on **February 2**, **2008** as a transparent blue overlay over the **RADARSAT** image. As can be observed, ice cover structures such as ice rubble fields (areas of broken and haphazardly piled blocks of ice) are clearly identifiable. Mapping the location of these particular features is useful for ice clearing operations since these areas are typically more difficult to clear.

The actual path of the ice-breaker can also be mapped by the high resolution satellite data as shown in **Figure 5.3**. The figure shows the particularly <u>clean and incised path in the ice cover created by the ice breaker</u> that was corroborated from two vantage points (insets).

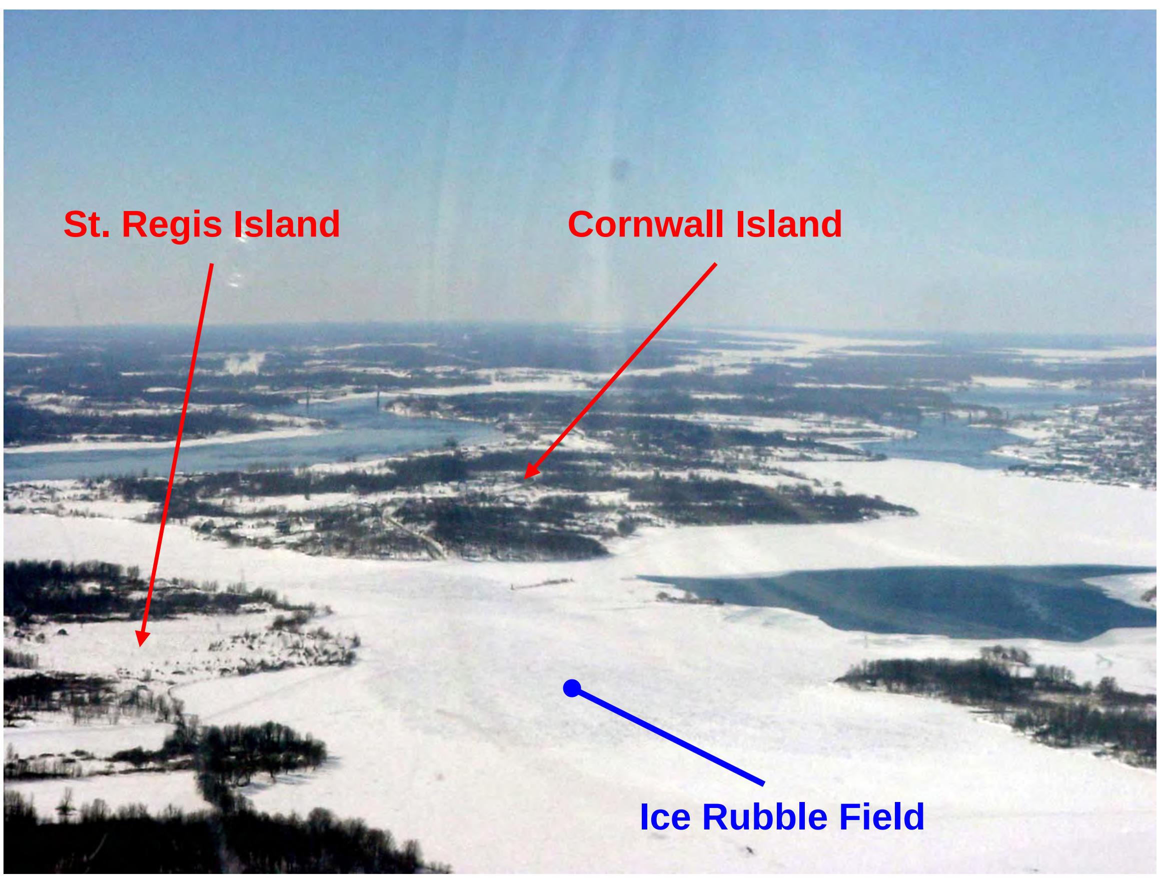
## Figure 5.3 RADARSAT – Path of Ice Breaker (March 21, 2008)



*Aerial Flight Surveys*

Fixed wing and helicopter surveys were also completed throughout the study in an effort to further track the evolution of the ice cover as well as to identify key ice features. The aerial surveys were "piggy-backed" on flights normally completed by the **Canadian Coast Guard** in support of ice clearing operations on the **Seaway**. Photographs and notes were taken during these flights over the navigation channel (see **Figure 5.4**). Seven (7) flights with fixed-wing aircraft plus two (2) helicopter reconnaissance missions were completed during the three (3) year study mandate. **Figure 5.4** shows typical information retrieved from aerial photographs; in this case, the location and extent of the ice rubble field lying immediately downstream of **Cornwall Island.**

**Figure 5.4 Aerial Photograph (February 16, 2008)**



One (1) of the aerial flight surveys in **2008** was completed one (1) week after the initial ice clearing operations on **March 20, 2009**. Shore-based and on-ice observations were also conducted during this period to complement the aerial finding of a post-cleared navigation channel. **Figure 5.5** shows that broken ice is constrained to the cleared channel and generally still attached to the shoreline, except at **Clark Island**. No signs of significant ice-induced post-clearing shoreline impacts were observed by these surveys.

## Figure 5.5 Aerial Photograph of Post-Cleared Channel (March 28, 2008)

**Lake Saint Francis W Looking East**

**North Shore of Stanley Island**

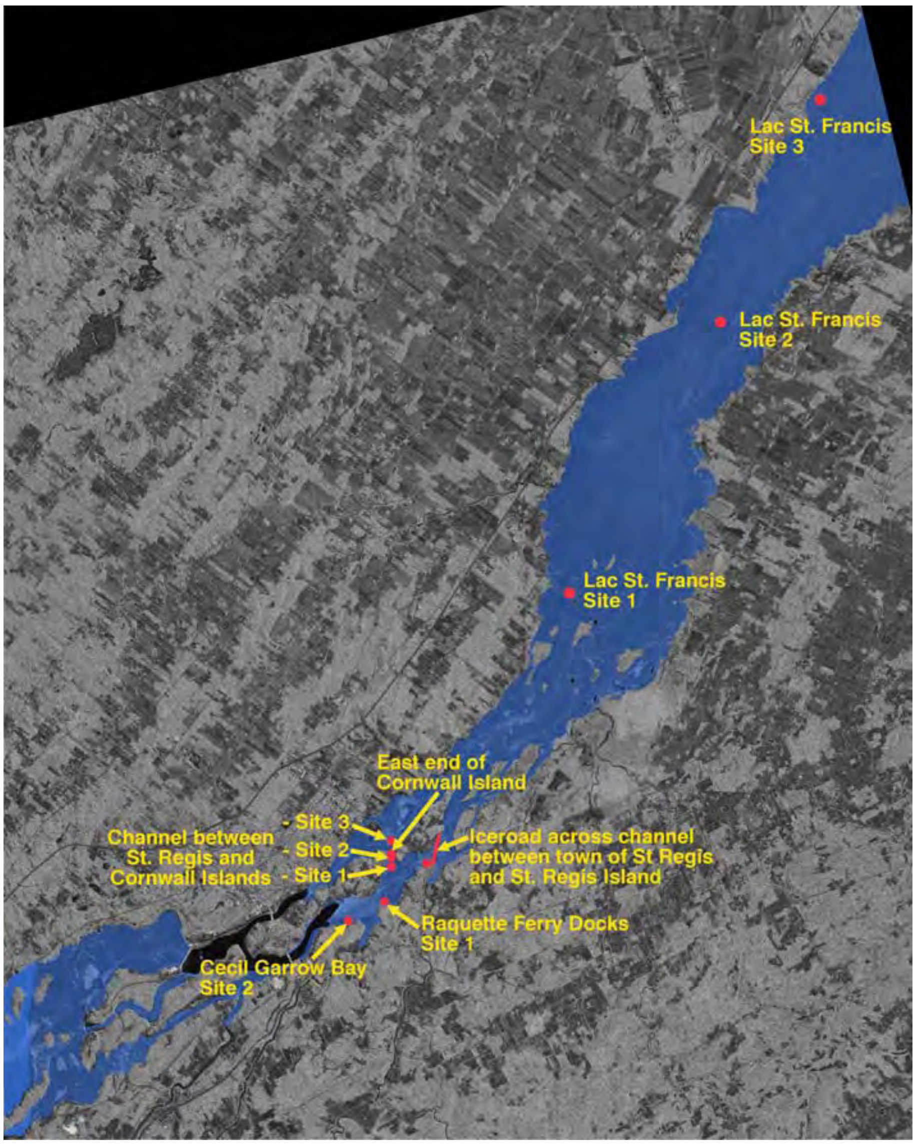
**South Shore of Clark Island**

**North of St-Regis & East of Cornwall Islands**

*On-Ice Surveys (Thickness & Temperature Profile)*

Several on-ice surveys were completed during the last two winter/spring seasons in order to characterize the ice's strength and structure during the winter and leading up to the ice clearing operations. Ice thickness and temperature profile measurements were taken at several sites during each of the two (2) seasons (see **Figure 5.6**).

**Figure 5.6 On-Ice Survey Locations (Winter/Spring 2008)**

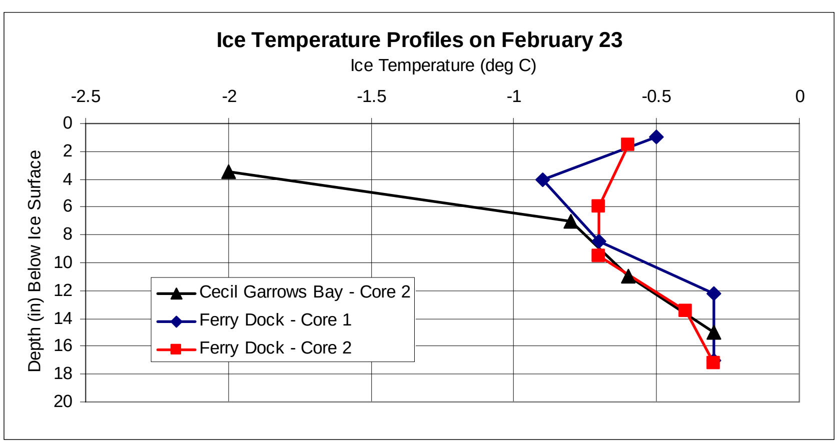



Photographs and notes were also taken to document the methodology, the observed ice structure and the local environmental conditions (see **Figure 5.7**).

## Figure 5.7 On-Ice Surveys (Winter/Spring 2008)

The field data was compiled and analyzed in combination with other information such as the accumulated **Freezing Degree Days** to generate a better understanding of the winter ice cover regime. **Figure 5.8** shows a typical data compilation, in this case, a graph of the ice temperature profiles taken at three (3) locations on **February 23**, **2008**.

## Figure 5.8 On-Ice Surveys (Winter/Spring 2008)



As expected, the ice temperature generally increased over the winter. As well, the ice temperature varied with depth in the ice, which also follows the expected trend. The maximum ice thickness that was measured during both observation seasons at the monitoring sites was approximately 52 cm in late winter while the minimum ice temperature recorded was -1.7° C in **2008** and -2.0° C in **2009**. However, the mean ice temperature increased to <u>nearly zero</u> degrees, indicating a reduced strength, during the last winter survey of **2008** (which took place a few weeks prior to the ice clearing operations).

*<u>Video of Ice Cover</u>*

Study findings from the **2007/2008** observation season suggested that ship-induced waves, rather than ice-related interactions could explain the documented movements of the near shore rip-rap stones that had been tagged for observations. As a result, the **Ice Conditions Monitoring** activities during the last observation season (**2008/2009**) were refocused to gather more information on this particular aspect. A video camera was also installed in **March 2009** to automatically record on-going changes of the ice cover. This high definition video camera was installed inside the **St. Regis Water Treatment Plant** with a field-of-view that monitored the navigation channel, looking downstream and centered between the eastern tip of **Cornwall Island** and the western tip of **St. Regis Island** as can seen in the top of each of the four (4) video frames in **Figure 5.9**.

No visual data on ship transits were obtained in **2009** due to the natural breakup of the ice cover that occurred more than three (3) weeks prior to the **Seaway Opening Date**. Nevertheless, the initial ice cover breakup that started on **March 8**, **2009** was fully recorded on video as can be seen in **Figure 5.9**. In fact, ice deterioration was first observed on **March 7** from the video camera records when a small patch of open water appeared around the navigation buoy in the camera's field of view. Shortly after, the ice cover in the channel between **St. Regis** and **Cornwall Islands** broke up

rapidly, over the course of the following day (see video sequence in **Figure 5.8**). Photos taken during a site visit on **March 17, 2009** showed that most of the navigation channel within the study area was ice-free.

## Figure 5.9 Natural Ice Cover Break up (March 2009)


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

### 5.3. Ship-Based Observations

The objective of this activity was to document first-hand the ice clearing operations while providing a ship-based vantage point to observe any potential ship-induced shoreline ice impact. These observations were only completed in the first two (2) springs of the study mandate because the navigational channel was totally ice-free when the **Seaway** was officially opened on **March 31, 2009**. Nevertheless,

significant observations were made during these first two (2) seasons. Photographs were the primary means of documenting the ice clearing operations by the study team aboard the **CCGS Martha L. Black** in **2007** (**Figure 5.10**) and again in **2008** (**Figure 5.11**).

**Figure 5.10 Ice Clearing (March 2007)**

**Figure 5.11 Ice Clearing (March 2008)**

Several significant and recurring findings on the ice clearing operations were observed during the ship-board surveys namely:

- The ice breaker’s speed was reduced upon approaching the eastern boundary of the **Akwesasne** islands;
- The width of the broken track left behind the **CCGS Martha L. Black** was close to the ship’s beam as shown in **Figure 5.10** and **Figure 5.11**;
- Shoreline impacts (e.g., large-scale ice movements) were not observed as no visible effects extended from the cleared channel to the islands;
- The ice breaker encountered forward motion resistance in the ice rubble fields (**Section 5.2**) adjacent to the **St. Regis** and **Cornwall Islands**. In fact, the resistance was great enough to halt the forward progress of the ship and to force the ship to “back and ram”, at which time, the ship backs up the broken channel to about 1.5 to 2.0 times its length, and then goes “full-ahead”, until its forward momentum is halted again. ”Backing and ramming” was necessary on several occasions in both years (**2007** and **2008**) in order for the ship to make forward progress;
- The average speed of the **CCGS Martha L. Black** while clearing ice varied from 2.9 to 6.5 knots in **2007** and 5.2 to 7.4 knots in **2008** (as obtained from the ship’s **AIS** system).
- An analysis of the ice-breaking forces was completed in **2008** considering the observed ice clearing operations. The results indicated that very low contact pressures and lineal forces would be expected to be transmitted to the shoreline. The calculated forces were considerably lower than those generated by a heavy wind blowing over the **St. Regis Channel**. This analysis helped corroborate the conclusions from the observations made, which indicated that significant effects on the shoreline did not occur.

## 5.4. Shoreline–Based Ice Movement Monitoring

Shoreline-based observations and ice movement measurements were only made in the spring of **2008** although this activity was planned for **2009**. It was not done during spring **2009** because a natural ice breakup occurred. The general objective of this task was to observe any changes in the ice conditions and to quantify any ice movement near the shore during the passage of the ice breaker - Ice movements are a necessary component of any significant shoreline impacts. Note that an attempt was made in the spring of **2007** to also measure the movement of ice by marking the ice surface with soluble die. Unfortunately, heavy rainfalls diluted the die and consequently, none was visible during aerial and field surveys immediately following the ice clearing operations. **Figure 5.12** shows the five (5) sites that were originally targeted for ice movement monitoring in the spring of **2008**.

**Figure 5.12 Shoreline-Based Ice Movement Monitoring Sites (2008)**

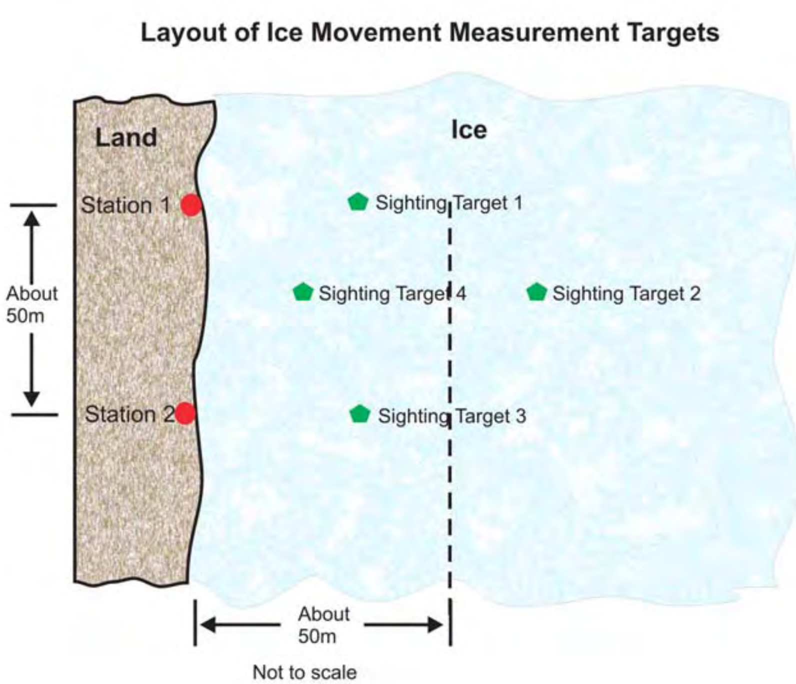
**Sites #1** and **#2** were eventually eliminated because the ice cover had not formed in that section of the river. Observations at the **Dock** site were also impossible due to access issues (previously discussed). Nevertheless, the remaining two (2) sites (**Site #3** & **Site #4**) were successfully instrumented on the day before the ship's passage and then re-surveyed early the next day. Unfortunately, direct visual observations were not possible during the actual ship's passage because the **CCGS Martha L. Black** arrived under the cover of darkness on the evening of **March 20, 2008.**

**Figure 5.13** shows the planned deployment pattern and a sample of the ice movement targets. The locations of the targets were determined prior to the ship's passage by measuring the distances to them from two shoreline stations, which were used to establish a reference baseline. Distances were subsequently measured using laser rangefinders. As previously mentioned, both sites were re-visited on the morning after the ice breaker had passed through, and the ice movement targets were re-surveyed. Also, the ice conditions at each site were observed and photographed.

Only one significant crack was observed, which ran parallel to shore (**Figure 5.14**). No ice displacements were observed on either side of the crack. This crack was uniform alongshore, and ran parallel to the shore for a long distance (as far as could be seen). This indicates that it was most likely produced by changes in water level.

No ice movements were recorded at either **Site #3** or **Site #4** within the measurement accuracy of the laser rangefinders used (which was about 1 m).

# Figure 5.13 Shoreline-Based Ice Movement Instrumentation (2008)




# Figure 5.14 Ice Crack Running Parallel to Shore (March 2008)

Ice conditions were further investigated on **March 21**, **2008** by venturing out to the broken track left by the **CCGS Martha L. Black** and the accompanying **USGC Penobscot Bay** (**Figure 5.15**). As noted by the observers onboard the ice breaker, the width of the broken track was only slightly larger than the beam of the vessels. The ice beyond the track was unbroken. On **March 21**, **2008** the broken track was clogged with ice pieces which were in the process of re-freezing together due to the sudden overnight drop in air temperatures.

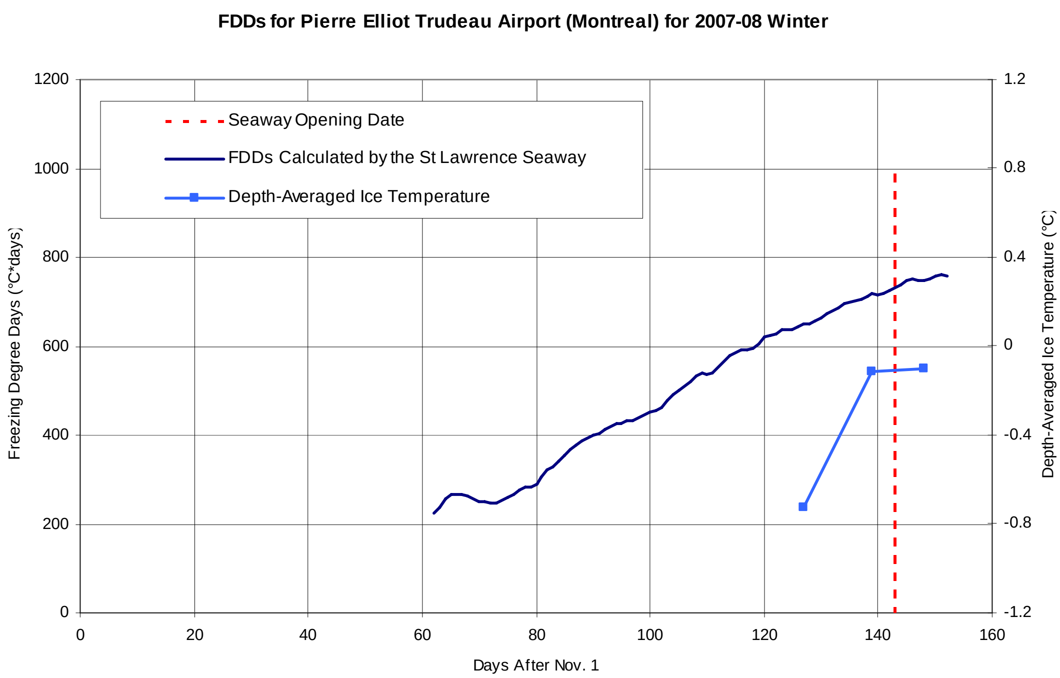
## 5.5. Freezing Degree Day Analyses

It is well understood that variations in air temperature during the winter have a significant impact on ice cover formation. In fact, the accumulated **Freezing Degree Days** (**FDDs)** throughout the winter is often used as an index for predicting the severity of the winter and, indirectly, the ice conditions. As would be expected, thicker ice is usually associated with a larger number of accumulated freezing days. **Figure 5.15** shows the **FDDs** computed by the **Seaway** formula for the winter of **2008** and based on air temperature data from the **Environment Canada** weather station located at the **Pierre Elliot Trudeau Airport** located in **Dorval**, **Quebec**. The **Seaway** formula is one (1) of two (2) similar **FDDs** methods used in the study and documented in the **2007/2008 Annual Report**, **Volumes I and II.**

The **JOS** study team began using this model in a similar capacity in **2007**; however, significant limitations were identified in **2008** and **2009** in using the **FDDs** as a single indicator of ice conditions. Extensive analyses indicated that other factors, such as fluctuations in water levels and flows, also have significant impacts on ice conditions. The analyses revealed that by applying the **FDD** method, the results erroneously indicated a more severe **2008/2009** winter/spring than was observed in **2007/2008**, as there were more **FDD**s in **2008/2009** as compared to **2007/2008** (i.e., maxima of 895 and 760 °C*days, respectively).

Considering that a natural ice cover breakup occurred in **2008/2009** at a much earlier date than the icebreaker-induced breakup in **2007/2008**, it was concluded, as previously mentioned, that other factors such as water levels and flows and the temporal variations of weather throughout the winter 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.

## Figure 5.15 Freezing Degree Days (2007/2008 Annual Report)



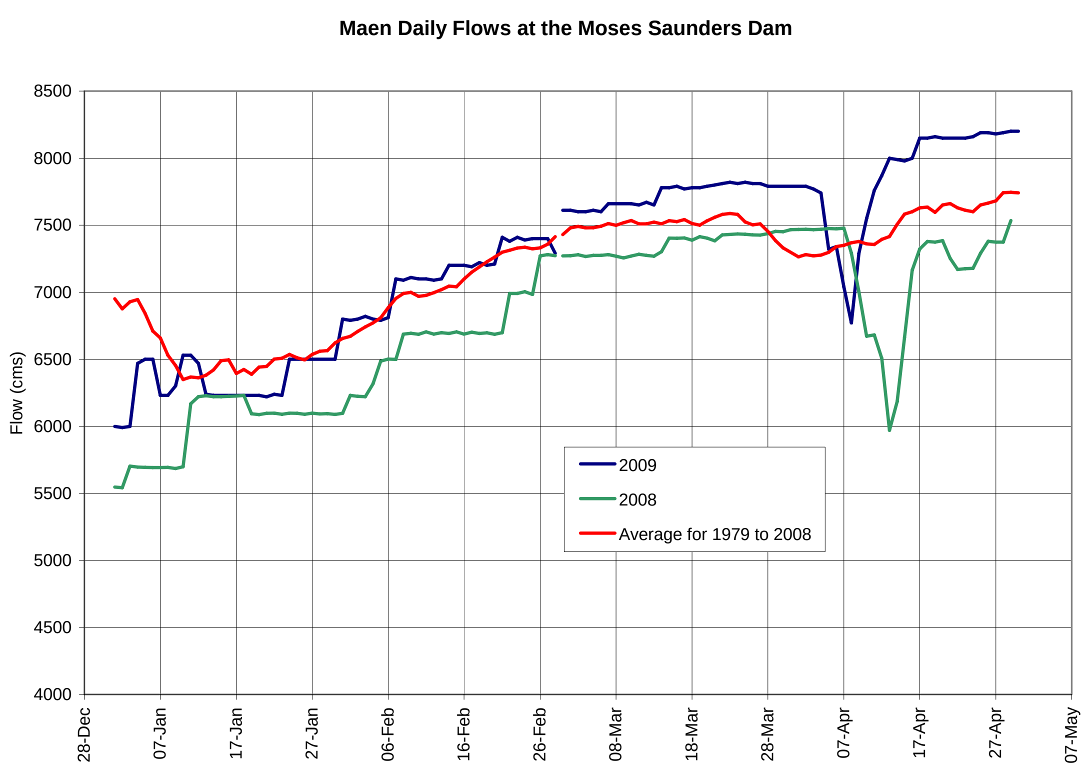

## 5.6. Water Level & Flow Analyses

Water levels and flows in the study reach were analysed for the last two (2) years of the study in order to gain a better understanding of their effect on the ice cover conditions.  The data was also used in conjunction with information regarding the

weather and the **Freezing Degree Days** to generate a more complete understanding of the ice conditions in the winter/spring of **2007/2008** and in particular **2008/2009**, when a natural ice cover breakup was observed.

Water level elevations and flow data for the tailrace of **Ontario Power Generation**'s (**OPG**) **Moses-Saunders Generating Station**, (which is located immediately upstream of the study area), as well as water level elevation data for the **Cornwall Harbor**, as provided by **Environment Canada** were used for the analyses. Both historical records and data for the study period were acquired for analysis. **Figure 5.16** shows the mean daily variations in flows at the **Moses-Saunders Dam** for the spring of **2009**.

## Figure 5.16 Mean Daily Flows – Moses-Saunders Dam (2008/2009



The analyses of the water elevation and flow data at the **Moses Saunders Dam** during the last two (2) springs of the study yielded important insight into the factors affecting ice cover conditions.  For example, it was noted that flows were less than the 30-year average during most of the **2007/2008** winter although closer to the long-term average in the period leading up to the ice clearing operations.  A mostly intact ice cover condition prevailed under these flows during the late winter of **2008** and during the ice clearing operations.  In contrast, flows during the early winter of **2009** were near the long-term average; however, a sharp increase in flows (i.e., about 300 cms higher) occurred during the month of **March 2009**.  This rapid increase in flows likely played a key role in the early ice cover breakup in **2009**, by de-stabilizing the ice cover and breaking it away from the shoreline.  The higher flows that prevailed at the time and throughout the **2008/2009** winter would also have facilitated "flushing" of the ice downstream as was documented by the onshore video camera (**Figure 5.9**).

## 5.7. Public Report Monitoring

Throughout the study, attention was given to informing the public of **JOS** study activities, particularly when field surveys were planned.  Notices were often provided to the police forces, the local media and radio.  Also, the **Seaway** published annually the **Seaway Opening Date** to warn landowners along the river of the impending ice clearing operations and the dangers of open water.  During the three (3) year mandate, no reports of any ice-induced shoreline physical impacts were received from landowners along the shoreline being studied.

# 6. STUDY CONCLUSIONS & RECOMMENDATIONS

The **Joint Observational Study** (**JOS**) was established to observe and document, over a period of three (3) years, within the reach extending from **Snell Lock** to the middle of **Lake St-Francis**, the potential physical impacts arising from icebreaking

activities in support of commercial navigation in the **Saint Lawrence Seaway**. Specifically, the central questions to be studied were: "Do icebreaking activities and/or ship transits in ice conditions within the study area cause: 1) Shoreline ice scour and/or 2) Land-fast ice to break away from shore prematurely?

As the **JOS** study progressed, the **SC** discovered how this seemingly simple mandate, was in fact complex, especially with respect to the differentiation between natural versus anthropogenic ice-related shoreline impacts. Nevertheless, it is strongly believed that the highly cooperative atmosphere and the active participation by all study team members was a determining factor in the successful conclusion of the **JOS**.

Based on the three (3) years of general observations including two (2) years with icebreaking operations, the following conclusions are directly pertinent to the central questions of the **JOS** study:

1. Icebreaking operations are not required every year to open the **Seaway**. In fact, the icebreakers were only required during two (2) years of the three (3) year study mandate.
2. Small scale, shallow water shoreline impacts occur with natural ice break-ups and clear-outs as was observed in the third year of the mandate. This is the baseline against which evaluations of the shoreline impacts resulting from icebreaking/iceclearing operations must be compared.
3. Ice-induced shoreline impacts, in comparison to the baseline for natural ice break-up and clear-out, were not observed for the two (2) years of the study during which icebreakers were used to clear the **Seaway**. This finding is corroborated by the results of analyses of the expected forces applied on the shoreline by the icebreaking operations, which indicated low contact pressures in relation to those at which ice failures tend to occur. Furthermore, the

calculations showed that the icebreaking forces transmitted to the shoreline, under similar operations and observed ice conditions, were significantly less than those expected to be produced under high wind conditions.

4. The **Freezing Degree Day** (**FDD**) method is not reliable as a standalone index to characterize the state of the ice cover or, to gauge the potential severity of shoreline impacts. Other important factors such as water levels and flows, air and ice temperatures as well as ice thickness must be considered. **Table 6.1** lists the type of information that was used during the study in order to characterize various aspect of the ice cover's condition. The table also indicates the type of proprieties each source of data is better suited to characterize the ice condition.

## Table 6.1 Sources of Data for Monitoring Ice Conditions

| Ice Condition Monitoring | Ice Condition Properties | | |
|---|---|---|---|
| Type of Information | Ice Cover Definition (i.e. Ice coverage by type and location) | Ice Strength & State (i.e. Degree of deterioration) | Ice Interaction with Shoreline (i.e. Cracks, ice bonding to shoreline) |
| 1. Ice Temperature & Thickness Profile | | ✔ | |
| 2. RADARSAT | ✔ | | |
| 3. Aerial Photo Surveys | ✔ | ✔ w/High Res Photos | |
| 4. Shore-based Video | ✔ local information | ✔ | ✔ local information |
| 5. Water Level and Flows | | ✔ | ✔ |
| 6. Shoreline Surveys (Visual Observations) | | | ✔ |
| 7 Weather Data & FDDs | | ✔ | |

Significant Input = ✔; Moderate Input = ✔

5. No shoreline physical impacts were reported by any landowners along the shoreline being studied during the three (3) year study.

Based on the study team's experience and findings, the following set of recommendations was developed:

1. An inclusive process should continue to be used when setting the **Seaway Opening Date**, during which all stakeholders are consulted.

2. Icebreaking operations should continue to use the same diligence and techniques that were employed during the 2 (two) years when icebreakers were used to open the **Seaway** during the study.
3. The **Freezing Degree Days** (**FDDs**) index method should be augmented with other sources of information such as ice thickness and temperature profiles, **RADARSAT** imagery, photographs from aerial fly-overs and, water levels and flows in order to obtain a more comprehensive assessment of the local ice conditions. The data should continue to be collected in an effort to build up local knowledge that would assist in identifying extreme conditions.
4. Efforts should be maintained in synthesizing these data with the aim of producing simple guidelines, so as to minimize the data collection that would be required in future years.

# 7. APPENDIX A: SUMMARY OF 2006/2007 ANNUAL REPORT

## 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.

Six (6) meetings were held throughout the fall, winter and spring of 2006/2007 to advance the study and prepare for the spring icebreaking observations. Minutes were taken at all meetings except the first informal October 2006 meeting. All minutes were unanimously approved as was the content of this first annual report.

The study coordinator maintained a register of all study expenses including the reported In-kind contributions by all parties. To-date, a total of **$11,939.85**, or approximately **8%** out of the currently allocated **$150,000.00** project funds were charged to the study. Also, a total of **$9,993.00** was recorded as **In-Kind** charges to the study during this initial reporting period.

A password-protected electronic document archive site was established early in the study and is actively maintained by the study coordinator and accessible via the internet by all members.

Two (2) letters were sent on behalf of the project management team: 1) A letter of appreciation to the commander, **Captain Martin Crête**, of the icebreaker/buoy tender **Martha L. Black** and, 2) a community notification memo.

Two (2) significant issues were discussed and resolved during this first year of the study. The first issue dealt with a disagreement among the **JOS-PMT** related to the definition and scope of the field observations. Ultimately, all parties agreed on a physical environment scope, namely mechanical processes at the shoreline. The

second issue dealt with an ice-breaking pilot project completed by **ALCOA** in the spring of 2007 on the **Grasse River**, an upstream tributary. The potential problems of having additional ice floes, including ice jamming, was averted by discussions with the **ALCOA** team in an effort to coordinate field activities.

A detailed **JOS Work Program** was developed and initiated in early **2007**. The main elements included:

- Identify potential study sites.
- Acquire background technical information.
- Organize a limited 2007 spring observational program.
- Establish a monitoring program for 2008 and 2009.

Only a limited 2007 field observation program could be organized and included the following tasks:

- Observed icebreaking operations aboard the icebreaker.
- Observe the icebreaking operations from two (2) locations along the shore.
- Mark the ice with readily visible dyes and observe any movement following icebreaking.
- Conduct three fly-bys to document the ice cover before, during and after icebreaking.
- Collect, document and report findings.

The pre-icebreaking conditions, as measured by the **Freezing-Degree-Days** indicated very mild winter and spring conditions hence a weak and relatively fragile ice cover was expected. This was not the case throughout the study reach. Indeed, a cold period immediately before the icebreaking operations generated a mix of ice covers including some areas of thick ice near the **Akwesasne** shores. Nevertheless, under the command of **Captain Martin Crête**, the navigation channel was opened without any apparent impacts on the shoreline. Several people on the shore were

witness to the icebreaking operations and none expressed any issues or complaints this spring.

The following conclusions were noted for this initial year of the study:

1. The simple and low cost technique of marking the ice with readily identifiable geometric patterns such as lines near the shoreline has great potential to identify ice movement during icebreaking operations. However, the use of water-soluble dyes alone, as was the case this year, proved ineffective as the dye was diluted by rainfall and eventually disappeared prior to icebreaking operations.
2. The simple **Freezing-Degree-Day** method that is currently used as input to the **Seaway Opening** and **Icebreaking Planning** processes has generally been satisfactory. However, in periods of highly variable daily temperatures (above and below freezing) especially towards the date of opening, as occurred this spring, limitations in accurately predicting the ice conditions were noted. Consequently, ice thicknesses were highly variable with some ice being thicker than was anticipated. Considering the importance of this index, efforts should be expended on improving the algorithm and/or general ice conditions estimation procedure.
3. Although difficult ice conditions were encountered this spring, good communications by all stakeholders, including on-board discussions with the icebreaker's captain, has demonstrated that the process of icebreaking the navigation channel can be successfully managed. A letter of appreciation was sent to **Captain Martin Crête** on behalf of the **JOS-PMT** for his actions during icebreaking operations near the study area.
4. No shoreline physical impacts were observed nor reported by stakeholders including people residing on **St-Regis Island**.

5. The working climate and attitude established in the course of the six (6) **JOS-PMT** meetings has resulted in a pro-active team approach that effectively communicates and shares information as well as addresses critical issues as they come forward. This team spirit, has undoubtedly indirectly contributed to this year's successful icebreaking operation.

Based on the **2006/2007** findings, conclusions and **JOS** activities, recommendations include:

1. The current **JOS PMT** is effective at moving forward the delegated mandate. The current participants should be retained to ensure ongoing progress.
2. The **Freezing**-**Degree-Day** method used to gauge the severity of ice conditions and serves as input to the **Seaway Opening** and **Icebreaking Planning** processes should be assessed for potential enhancements.
3. The opening date selection and icebreaking operations should continue to be an inclusive process for the current stakeholders and include risk assessment elements of icebreaking operations and ice conditions.
4. The ice marking technique used this spring should be improved to ensure the permanency of detection and movement during the icebreaking operations.
5. A third party technical consultant will be retained to work with the study coordinator to prepare and conduct a more comprehensive observation program for the spring **2008** icebreaking operations.

# 8. APPENDIX B: SUMMARY OF 2007/2008 ANNUAL REPORT

## 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. The study team has now successfully completed two (2) of the mandated three (3) years of observation.

Eight (8) meetings were held this year to review progress and prepare for the more comprehensive spring ice clearing observation program. Specifically, half of the meetings brought together the **Steering Committee** while the other meetings were technical discussions focussed on developing and organizing the field observation program. Minutes were taken at all meetings and were generally approved at the following meeting.

The study coordinator maintained a register of all study expenses including the reported **In-Kind** contributions by all parties. A total of **$60,711.22** was charged to the study this year bringing the total expenditures to-date to **$73,367.46**, or approximately **56.4%** of the currently allocated **$130,000.00**. Also, a total of **$23,765.00** was recorded as **In-Kind** charges to the study during this second reporting period bringing the total study **In-Kind** charges to **$33,758.00**. A significant portion of this year’s contributions are attributable to the **St. Regis Mohawk Tribe**. They repeatedly provided technical personnel and transportation for the field portion of the **Work Program**.

A password-protected electronic document archive site was established early in the study and is still actively maintained by the study coordinator and accessible via the internet by all members.

Four (4) letters in total were distributed this year. Two (2) letters of appreciation: one letter was sent to the captain of the CCGS **Martha L. Black** for welcoming on-board two (2) JOS team observers and, the other letter was forwarded to the **Canadian Ice Centre** for providing multiple **RADARSAT** imagery. Their superiors were also copied. Two (2) letters were also drafted and provided to border patrols and police agencies in order to accelerate transit between the countries. The letters also served notice of the frequent **JOS** field activities that could otherwise be construed as suspicious.

Only one (1) significant issue arose during this second year of the study. It involved a landowner that refused to grant access to his property in order for a **JOS** observation team to complete shoreline measurements. Unfortunately, this occurred on the day of spring observations, while the icebreaker was clearing the channel; and consequently, one (1) of three (3) observation sites had to be eliminated. Closure was brought to this issue in the following days when representatives from both tribes went to clarify the situation with the landowner to ensure no ill-feeling. Finally, several **Steering Committee** members apologized to their respective employees who were directly involved during this unfortunate event.

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

- Study Site Field Program.
- Establish a **Monitoring System** for the winter/spring of 2008.
- Collect and analyze observational data during the winter/spring of 2008.
- Report findings and conclusions and make recommendations.

This second year of the three-year mandate saw a dramatic increase in field activities. This is in part due to having acquired specialized technical resources

during the year and, as a result, the **JOS** study team was able to develop a more rigorous and comprehensive field observations plan. The technical findings are all documented in this annual report.

<u>In addressing the central question of this study it is concluded, in principle, that during the **2008** spring ice clearing operations of the **Seaway Channel** within the study area, there were no observable shoreline physical impacts.</u> This statement is supported by the many types of observations as outlined in the following list of specific conclusions:

**Shoreline Surveys**

1. Field surveys were completed during the fall of 2007 to ascertain if the potential observation sites identified during the previous year were feasible locations for the study. Accessibility and site representativeness requirements reduced this original set of sites. Eventually, only three (3) sites were retained for shoreline observations during ice clearing operations while other sites were selected for pre/post winter shoreline change assessments.
2. Although surveyed vertical elevation profiles were intended to be completed at each site, the task proved time-consuming and ultimately not focused on the water's edge where possible impacts might occur. A simpler survey approach was devised and eventually used on all but one site; however, a number of limitations were experienced including difficulty in winter re-survey and inaccuracies in re-locating reference stakes. This simplified method will require adjustment if the technique is retained for next year.
3. No major shoreline changes were visually identifiable at each of the three (3) surveyed sites. No evidence of ice-induced shoreline damage, such as berms, ridges or scars were observed.

4. Although variations in elevations were noted at several sites, these were considered well within the resolution of the survey technique and consequently not indicative of any slope movement.
5. All but two (2) of eight (8) marked shoreline stones that were originally surveyed in the fall of 2007 showed no significant movement over the course of the winter. Further analyses revealed that the movement of those two (2) stones might be explained by wave action rather than any ice impacts, their weight being less than that required for stability when considering the observed wave height of a passing ship during the spring survey.

**Ice Conditions Index - Freezing-Degree Days Evaluation**

6. Following last year's recommendations, the **Freezing Degree Days** (**FDDs**) index method was re-evaluated as a means to characterize the severity of winters and indirectly infer the ice conditions within the seaway channel. Two methods were assessed: (a) the method used by the **Canadian Ice Service** (**CIS**) and, (b) the method traditionally used by the **Saint Lawrence Seaway**. The "**Saint Lawrence Seaway**" method produced **FDDs** totals that were on average only 3 to 4% higher than those obtained from the **CIS** method. However, it is clear that the results from the two methods are closely related. Consequently, the same general trends would be obtained by using either method.
7. **FDDs** were also compared using meteorological data from **Massena**, **NY** versus **Dorval**, **QC** in order to investigate the suitability of each as the basis for an index. The **FDDs** at **Massena** and **Dorval** both exhibit the same trends. On average, the **FDDs** calculated for **Massena** were 4 to 5 % less than those at **Dorval**, although clearly, the results for each site are correlated with each other. Consequently, the same general trends would be obtained by using either method.
8. Historically, the accumulated **FDDs** on the **Seaway Opening Date** have varied greatly, from a minimum of less than 400, to a maximum of over 1000.

This reflects natural variability in winter conditions, as well as changes in the **Seaway Opening Date** from year to year. **FDDs** at **Dorval**, **QC** on the **Seaway Opening Date** for **2008** were slightly below the average for the **1984-1985** to **2007-2008** winters (712 vs 758 respectively, using the **CIS** method to calculate **FDDs**).

9. Two index methods using **FDDs** were investigated based on historical data (which unfortunately do not include ice temperature measurements) as they are both measures of the degree of deterioration that the ice sheet would have experienced on the **Seaway Opening Date**:

   (a) Number of days between the **Seaway Opening Date** and the date when the peak **FDDs** were reached.

   (b) Difference between the **FDDs** on the **Seaway Opening Date** versus the peak **FDDs** that were reached during the winter.

   Both of these indices showed significant scatter. For various reasons, they cannot be relied upon as independent measures. The most significant limitation is that information defining the winters in which significant ice-induced problems occurred, and didn't occur, is not available. This limits the extent to which the above "index" analyses can be used at present.

**Water Levels**

10. Water level records were reviewed this year. The spring **2008** water level data was 14-18 cm higher than the long-term average. Furthermore, the water level on the **Opening Date** was also higher, by 19-20 cm as compared to the previous years, dating back to **1984**.

**Evolutions of Ice Cover & Properties**

11. 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, aerial reconnaissance flights and ground-level (ice/land) observations. The aerial surveys and ground-level data were particularly useful to ground truth the

satellite data while the **RADARSAT** data itself was particularly useful to provide insight on the overall development and macro structure of the ice cover. A higher level of detail was also obtained from each aerial flight survey. These sources of information were practically essential to supporting field observations.

12. Ice thickness and temperature profiles were gathered several times during the winter and spring in order to evaluate ice strength leading up to the ice clearing operations. The data was also correlated with **FDDs** computations as a means to assess the indices. The minimum ice temperature (-1.7°C) was recorded on **March 6** while the average value was <u>near zero</u> on the day of ice clearing.

**Ice Clearing Observations**

13. The ice clearing operations on **March 20**, **2008** were again observed and documented this year from the vantage point of the icebreaker **CCGS Martha L. Black**; however, difficulties further downstream delayed the ship's arrival to the study area. The on-ship observers arrived under the full cover of darkness thereby limiting the direct recording of any shoreline impact near the target observation sites. Nevertheless, ice clearing immediately downstream of the study site (**Lac St. Francis**) was documented in daylight and yielded good insight on the ice clearing operations that day. It was noted that the **USCGC Penobscot Bay** followed the **CCGS Martha L. Black** and widened the broken channel by transiting along the northern edge of the track left behind by the **CCGS Martha L. Black**. The width of the broken track left behind the **CCGS Martha L. Black** was close (tight) to the ship's beam and it did not close in to the channel, indicating that the ice was not pressurized. Furthermore, significant ice cracking did not occur along the edges of the broken track, indicating that the ice was relatively weak and soft at the time.
14. A review of the icebreaker's speeds during the ice clearing operations indicated they were similar to those of last year. Furthermore, the ship had to

back-and-ram again this year. In both years, ramming was required in the reach defined by the **South of Cornwall Island** to **Raquette Point**. This area generally corresponds to the area of ice rubble build-up during ice cover formation that was previously identified on the **RADARSAT** imagery.

15. Improving on last year's simplistic ice marking technique, an array of stake-mounted targets was devised to be deployed at the three selected observation sites. Unfortunately, the site on **Cornwall Island** was abandoned when the landowner refused access to the shoreline. Nevertheless, the arrays were deployed at two sites and surveyed before the passage of the icebreaker and again the next day. No ice movement was detected at either of the two sites.
16. Although one significant crack was documented near and, running parallel to the shore, it was attributed to changes in water levels and not ice clearing operations. The resulting ice-cleared channel was further investigated on **March 21**, **2008** by venturing out onto the ice, alongside the broken track left by the **CCGS Martha L. Black** and the **USCGC Penobscot Bay**. As noted by the observers onboard the **CCGS Martha L. Black**, the width of the broken track was only slightly more than the combined width of the vessels while the ice beyond this track remained unbroken. The neatly cleared open ice channel was clogged with ice pieces, which were in the process of re-freezing together. Again, no cracks or movements were observed running from the channel to the shoreline.
17. It was recognized that ice-induced shoreline impacts could potentially occur after the ice-clearing operations due to moving ice floes created and "set free" by the icebreaking operations. This was investigated by using both aerial and land based observations in the week following the ice clearing operations. The study team did not observe any significant ice-induced post-clearing impacts.
18. Analyses were completed to estimate the actual forces applied on the shoreline during the icebreaking operations, especially those during **March 20,**

**2008**. These forces are of interest to the study team for obvious reasons as they have a significant effect on the magnitude of any potential shoreline impacts caused by the icebreaking. Using a conservative approach, the calculations revealed a very low range of contact pressures (0.2 to 0.4 kPa) that is about 1,000 to 10,000 times less than the pressures at which ice failures tend to occur. The icebreaking forces were also compared to the expected drag forces resulting from a strong wind blowing over an ice surface (60 knots). The exploratory calculations showed that the icebreaking forces applied to the shoreline were significantly less than those expected from wind drag.

19. Although difficult ice clearing conditions were encountered downstream of our study area this spring, good communications by all stakeholders, has demonstrated that the process of icebreaking the navigation channel can be successfully managed.
20. No shoreline physical impacts were reported by any landowners along the shoreline being studied.

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

1. The current **JOS Project Management Team** is effective at moving forward the delegated mandate; hence, the current participants should be retained to ensure ongoing progress during the final year of the study.
2. The **Freezing Degree-Days** (**FDDs**) index method, which was used to gauge the severity of ice conditions and to serve as an input to the selection of the **Seaway Opening Date** and the **Icebreaking Planning** processes should continue to be studied in conjunction with field observations in order to develop a more rigorous methodology. Guidelines on usage as a planning

tool should also be investigated and developed in order to maximize its potential benefits but also to articulate the method’s limitations.

3. The **Opening Date Selection** and icebreaking 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 and possibly mitigate the risk of potential ice impacts in clearing the navigation channel.
4. Considering the usefulness of the **RADARSAT** imagery to the stakeholders, the process of securing this type of data should be initiated with the appropriate government department in order to ensure on-going availability.
5. The greatly expanded and more rigorous field observation activities in **2008** yielded a large pool of information. This knowledge should be used to develop and also focus the **2009** spring observation activities during the last year of the study mandate. Priority should be given to the important and practical aspects of the field observation program for input in planning and monitoring.

# 9. APPENDIX C: SUMMARY OF 2008/2009 ANNUAL REPORT

## 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 maintained 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 third reporting period bringing the total study **In-Kind** charges to **$41,670.50**. Note that dollar values presented in the study reports are 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.

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

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

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 included:

- 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 based on the previous year's experience. Accessibility and site representativeness were key objectives during the selection process. Eventually, three to four (3 to 4) sites were selected for pre/post ice clearing observations of the near-shore ice cover. Other sites were also selected for shoreline change assessments.
2. Monitoring of the shoreline bank profiles was not completed this year as this time-consuming task did not provide meaningful information on the physical processes under study located near the water's edge.
3. A video survey of the shorelines along the study reach was completed in the fall. 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. 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 were attributed to baseline conditions that can be expected to occur under natural conditions. Furthermore, the wave impact analyses on shore armouring that was completed last year was also reviewed and, the conclusions were corroborated by the **Spring 2009** observations – thus supporting the hypothesis that the observed rip-rap movements were ship-induced.

### Ice Conditions Index - Freezing-Degree Days Evaluation

5. The **Freezing Degree Days** (**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 most severe winter/spring as compared to **2007/2008**. Considering the early ice cover breakup, 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 higher than average values throughout the year. Furthermore, a steady and significant increase in water level was noticed prior to the ice breakup and is surmised as playing a key role in the early ice cover breakup. It is hypothesized that the natural ice breakup 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**, **2009** 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 again accomplished using **RADARSAT** satellite imagery, an aerial reconnaissance flight, ground-level (ice/land) observations and, new for

this year, the continuous video record of the ice cover breakup. An aerial survey and ground-level data were particularly useful to ground truth the satellite data while the **RADARSAT** data itself was particularly useful to provide insight on 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 7, 2009** while open water was recorded by **RADARSAT** prior to **March 21, 2009** in our 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 29**, **2009**, did not occur this spring due to the natural breakup of the ice cover in the preceding week. 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 ice clearing operations. The study team did not observe any significant ice-induced post-clearing impacts.
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 the previous this year's findings, the following recommendations were developed:

1. As stated in the previous two **Annual Study** 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 and possibly 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 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 the **RADARSAT 1** imagery that was used in the previous year, since it provided a noticeable improvement in the ability to identify ice 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.

# 10. APPENDIX D: ARCHIVED JOS DOCUMENTS

## Archived JOS Documents

The following set of nine (9) disks contains the entire study archive consisting of documents, information and data that was amassed during the three (3) year **JOS** mandate. Note that the **RADARSAT** imagery files are not to be re-distributed for other purposes without permission of the **Canadian Ice Service**. The disks contain the following sets of documents:

**Disk 1: Reports & Project Management Files**

- All **Annual Reports** (**2007**, **2008** and **2009**)
- The **Final Study Report**
- All meeting documents including **Agendas**, **Minutes** and attachments
- Financial and In-kind Database & Report

**Disk 2: FTP Site Archives & References**

- Lake Francis Aerial Surveys (multiple docs from **1997** to **2006**)
- **NYPA** Erosion Study Report
- Seaway Ice Breaking Literature Reference List Document
- **NYPA** Habitat Figures
- **LandSat 7** Imagery
- Ice Sub-Consultant TOR
- **2007** and **2008 Seaway Opening Documents** consisting of:
    - **Grasse River** Issue
    - References
    - Aerial Photos
    - Ice Breaker Tracks
    - Field Observation Photos
    - Freezing Degree-Day Data
    - Ice Charts
    - Icebreaking Observational Report (aboard **Martha L. Black**)
    - Water Levels and Flow Data
    - Video Footage

**Disk 3: 2008 Shoreline Rip-Rap Survey Data**

**Disk 4: 2008 Shoreline Video Surveys**

**Disk 5: 2008 Seaway Opening Data**

- **RADARSAT** Imagery
- Multiple Photographs from Rip-rap and Shoreline Surveys
- Shoreline Survey Notes
- Location maps of Ice Movement and Ice Thickness Survey Sites

**Disk 6: 2008/2009 Shoreline Survey Data**

- Aerial Photos
- Ice Charts
- Cornwall Sediment Strategy
- NYPA Erosion/Sedimentation Study
- Field Observation Photos
- Temperature Data
- Various Meeting Notes
- Shoreline Surveys
- Video Footage
- Various Technical References
- Processed **RADARSAT** Imagery

**Disk 7: 2009 Seaway Opening Data (Disk 1of 5)**

- **RADARSAT** Imagery

**Disk 8: 2009 Seaway Opening Data (Disk 2of 5)**

- **RADARSAT** Imagery
- Multiple Photographs from Rip-rap and Shoreline Surveys

**Disk 9: 2009 Seaway Opening Data (Disk 3of 5)**

- Video of Spring **2009** Ice Cover Changes – March 6 to 13, 2009

**Disk 10: 2009 Seaway Opening Data (Disk 4of 5)**

- Video of Spring **2009** Ice Cover Changes – March 18 to 20, 2009

**Disk 11: 2009 Seaway Opening Data (Disk 5of 5)**

- **RADARSAT** Imagery (3 of 3 disks)