Ice and Marine Shipping Assessment
Mary River Iron Ore Project
North Baffin Island Nunavut
Revision 2

Information Integration Innovation

Prepared for

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Abstract:
This study provides a description of the ice conditions that occur along the access route to potential port sites for the Mary's River iron ore project at Milne Inlet, Nanisivik, East Coast of Baffin Island (collectively the North Baffin Sites) and Steensby Inlet Nunavut.

Key Words:
Shipping assessment, ice study, iron ore

Supplementary Notes:

Distribution/Availability:
Subject to terms of release by Baffinland Iron Mines Corporation

Executive Summary

This study provides a description of the ice conditions that occur along the access route to potential port sites for the Mary's River iron ore project. This project was completed by Enfotec Technical Services for Baffinland Iron Mines Corporation.

A comparison of ice conditions was made among the Milne Inlet, East Coast of Baffin Island and Nanisivik (the North Baffin Sites) and the Steensby Inlet options for the project.

Conclusions for the North Baffin Sites

Milne Inlet Port Option

Due to the presence of high concentrations of old ice in Baffin Bay and Eclipse Sound, a vessel of minimum ice class PC 3 is required for year-round access to Milne Inlet. However, special care would be required in route selection for this vessel and a PC 2 vessel may be more suitable. The shipping season for vessels of Baltic ice class design spans from August 1 to the end of September. Higher Baltic ice classes of Type C to A can extend the navigation season into the first 10 days of October. Due to the nature of the sea ice in the Canadian Arctic, there is little to be gained by using higher Baltic ice classes. The 125 nautical miles of shore fast ice to be transited from Pond Inlet to Milne Inlet includes a 30 nautical mile section in Eclipse Sound that does contain, on occasion, concentrations of old ice that could make multiple track selections difficult in the mid-winter.

Nanisivik Port Option

As is the case with Milne Inlet, access to Lancaster Sound and Admiralty Inlet, a vessel of minimum ice class PC 3 is required for year-round access to Nanisivik and the same proviso that a PC 2 vessel may be more suitable. Although Nanisivik is within Zone 13 (the same as Milne Inlet) the conditions can be considerably more difficult. There can be an extensive shear zone across Lancaster Sound that could only be avoided by transiting through Pond Inlet and Eclipse Sound, an option not likely to be gain support from local residents.

Old ice from Nares Strait migrates towards Lancaster Sound as early as October, and can persist throughout the ice season.

Access to Nanisivik from Lancaster Sound is via Admiralty Inlet, an area heavily travelled by the residents of Arctic Bay (among others) for traditional pursuits. Although we have not considered social or cultural imperatives in this study, we are very aware of the need to ensure community concerns are addressed.

The shipping season for vessels of Baltic ice class design spans from August 1 to the end of September. Higher Baltic ice classes of Type C to A can extend the navigation

season into the first 10 days of October. Due to the nature of the sea ice in the Canadian Arctic, there is little to be gained by using higher Baltic ice classes. As mentioned above, prior to transiting the 220 nautical miles of what is effectively fast ice from Baffin Bay to Nanisivik the vessel must negotiate the shear zone in Lancaster Sound. This area may have inclusions of multi-year ice and such ice would be very difficult to identify, and avoid, in consolidated ridges. This would likely result in much wider track being made as the conditions evolve over the winter months.

East Coast of Baffin Island Port Option

The assumption is a location would be chosen adjacent to Mary River and on the East Coast of Baffin Island, close to the entrance to Pond Inlet. As such, the vessel would have to contend with the same ice conditions in Baffin Bay as would any vessel proceeding to either Milne Inlet or Nanisivik. In our opinion, the class of vessel required would be the same as for Milne Inlet or Nanisivik.

As is the case with both Milne Inlet and Nanisivik, the nominal shipping season for vessels of Baltic ice class design spans from August 1 to the end of September. And so comments as to class of ships required are the same. Depending on the location of the site selected, it could be that the season for Baltic class ships would be about a month shorter in this area compared to either Nanisivik or Milne Inlet. The reason being, the area under consideration may either be in Zone 9 or Zone 13 of the APPR (see **Erreur ! Source du renvoi introuvable.**). For the purposes of this exercise, it has been assumed that the site selected will be within Zone 13. Thus access dates are nominally the same (by regulations) for each of these options

Ice navigation along the Baffin Coast can present considerable challenges as the full weight of the Baffin pack can descend on the coast south of Pond Inlet. The resulting ridging and shear zones, the locations of which would be dynamic would make route selection to the port subject to constant changes.

Conclusions for the Steensby Inlet Port Option

Due to the presence of lower concentrations of old ice in eastern Hudson Strait in the mid-winter and in central Foxe Basin in the late fall and winter, a vessel of minimum ice class PC 5 is required for year-round access to Steensby Inlet. However, patches of old ice could exceed 2/10 concentration so special routing care would be required. A PC 4 vessel may be a more suitable vessel. The shipping season for vessels of Baltic ice class design spans from August 10 to the third week of October. As is the case with Milne Inlet, there is little to be gained by using higher Baltic ice classes.

Comparison of the North Baffin Sites and the Steensby Inlet Port Option

The port option to Steensby Inlet would require a vessel two ice classes lower (PC 4/5) compared to the other sites studied (PC 2/3). This is owing to the much lower concentrations of old ice found along the route to Steensby Inlet than is the case for Milne Inlet. It should be noted that the MV Arctic attempted early winter voyages into the eastern Canadian Arctic in early December in both 1986 and 1989 and had to abandon the voyages because of the heavy old ice concentrations and pressure in Baffin Bay just north of the entrance to Pond Inlet (the Canadian Coast Guard vessel CCGS Louis St. Laurent was with the MV Arctic in 1986 and the CCGS Sir John A MacDonald in 1989 and they both were also unable to contend with the ice conditions). However, the same MV Arctic now trades all winter to Deception Bay on the south side of Hudson Strait independently without icebreaker escort through essentially similar ice conditions as those that lead to Steensby Inlet. This is an operational example of the difference between the ice conditions to these two port options.

The season for Baltic ice class vessels starts later for the Steensby Inlet option (August 10 as opposed to August 1 for Milne) but also extends later in the season to near the end of October which is almost a month later than for East Coast Baffin (assuming the location is in Zone 13) Nanisivik or Milne Inlet. This provides Steensby an average of a three week longer "open water" shipping season than East Coast Baffin (assuming the location is in Zone 13) Nanisivik or Milne Inlet.

However, remnant drift ice in scattered ice floes remains longer in the access channels to Steensby Inlet than to the North Baffin Sites during the "open water" period. However, access to Nanisivik can be hampered by persistent landfast ice in Admiralty Inlet. All things considered, there is a longer season of access by conventional vessels to Steensby Inlet than the other options.

The access to Milne Inlet contains 125 nautical miles of shore fast ice while the access to the port in Steensby Inlet is through about 60 nautical miles of fast ice, giving Milne 65 nautical miles more fast ice in which the vessels will have to manage multi ship transits in winter. In addition, the Steensby Inlet fast ice appears level with no shear ridge at the entrance and rare inclusions of old ice. The shore fast ice of Eclipse Sound is subject to ridging during freeze-up and often contains old ice inclusions. For these reasons Steensby Inlet has much more favourable fast ice conditions for winter navigation than the fast ice leading to Milne Inlet and to any site in North Baffin.

The access to Nanisivik contains up to 220 nautical miles of effectively fast ice (compared to about 60 miles at Steensby). Additionally, because of the relatively large area across Lancaster Sound, this area can be subject to dynamic changes even while the ice is nominally 'fast'. The presence of old ice within this area will make route selection through the fast ice a challenge.

The access to a site on the Baffin Coast may be restricted by remnants of the Baffin pack. The area in question can be one of the last areas to clear in the summer.

The potential effects of Climate Change were considered as well. The conclusion being that changes in ice conditions due to Climate Change will be relatively consistent in the areas in question. There is nothing to indicate that Climate Change will effectively alter the localised patterns of ice development, indicating to us that ice conditions will remain significantly more difficult along routes to North Baffin compared to Foxe Basin.

Given the significantly more difficult ice conditions at the North Baffin Sites at present and in the future, our recommendation is to pursue shipping through the Foxe Basin.

Table of Contents

List of Figures

List of Tables

Ice and Marine Shipping Assessment
Mary River Iron Ore Project
North Baffin Island Nunavut Final Report

1 Introduction

This report describes the ice data analysis completed by Enfotec for the marine operations component for the Mary River Iron Ore Project.

This present work considered four port options for the Mary' River Iron Ore development. The first port option is in the southern reaches of Milne Inlet accessible via northern Baffin Bay, Pond Inlet and Eclipse Sound. Other sites considered are at Nanisivik and at a site on the coast of Baffin Island more or less adjacent to the Mary River deposit. In many cases, the reference herein will be to North Baffin Sites where applicable commentary can encompass all three sites. The other port option is in Steensby Inlet accessible via Hudson Strait and the Foxe Basin. Figure 1 shows the routing options analysed for this study.

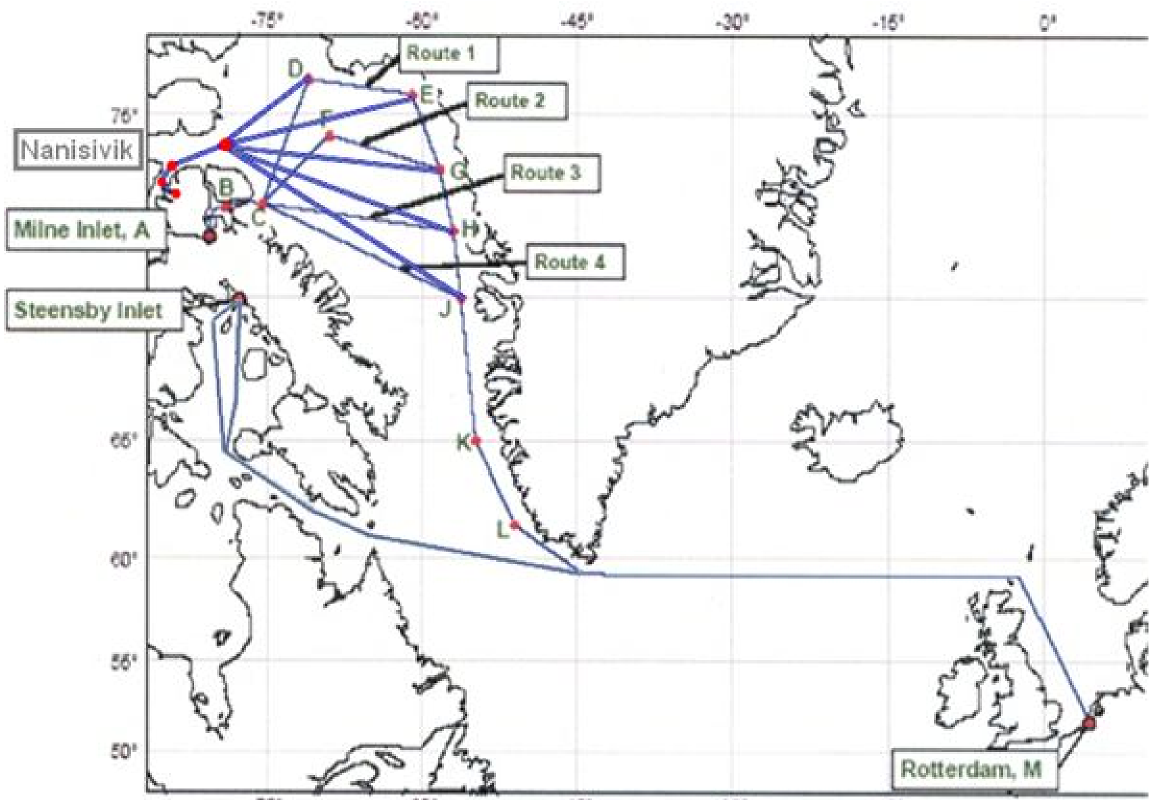

Figure 1: Routing options to Mary's River deposit.

1.1 Objectives and Work Program

The objectives of the present work were to follow on previous work done on the Milne Inlet and Steensby site options and expanding options to assess the relative ease of navigation with additional options of Nanisivik and a site on the East Coast of Baffin Island. A detailed analysis of the series of winter ice atlases of the region compiled by the Canadian Ice Service since 1990 was completed. These ice atlases are based on high resolution synthetic aperture radar (SAR) image from aircraft (1990 to 1995) and RADARSAT (from 1998 to 2010). The image data in the atlases allow for the delineation of areas of old ice concentration as well as ridged and pressured ice. In addition, shear zone locations show up well on the SAR imagery contained in the atlases. Enfotec augmented this analysis with satellite image data contained in the Company's image archive acquired from supporting shipping operations in this region since the early 1980's.

The output from this task is an image map showing the ice regime zones where ice of varying type and deformation exist along leading to the different port options. Specific features mapped were:

- Shear zones and areas of recurring ice pressure.
- Zones of old ice occurrence including range of concentrations (based on our interpretation of the images).
- First year ice thickness profile estimates within each zone with ranges.

The results of this work are provided in this report.

1.2 Results of the Image-based Review of Ice Conditions

The image-based review was completed separately for each of the Milne Inlet and Steensby routes. Each route is described separately below.

1.2.1 Access to Milne, Nanisivik and East Coast Baffin Island (collectively North Baffin Sites)

A detailed month-by-month analysis of the ice conditions leading to North Baffin sites has been done. A summary of the mid-winter ice conditions that occur along the shipping corridors to these sites is provided in Figure 2 below. The images used for Figure 2 are the RADARSAT Ice Atlas mosaic of the eastern Canadian Arctic from February 1, 1999 and February 1, 2004, produced by the Canadian Ice Service (CIS 1999) and are representative of the typical mid-winter ice conditions leading to the North Baffin Sites. A typical mid-winter ice chart is also included (Figure 3).

Seven ice regime zones of similar ice conditions have been defined by Enfotec based on the analysis of this study. These Zones are marked A to G on Figure 2.

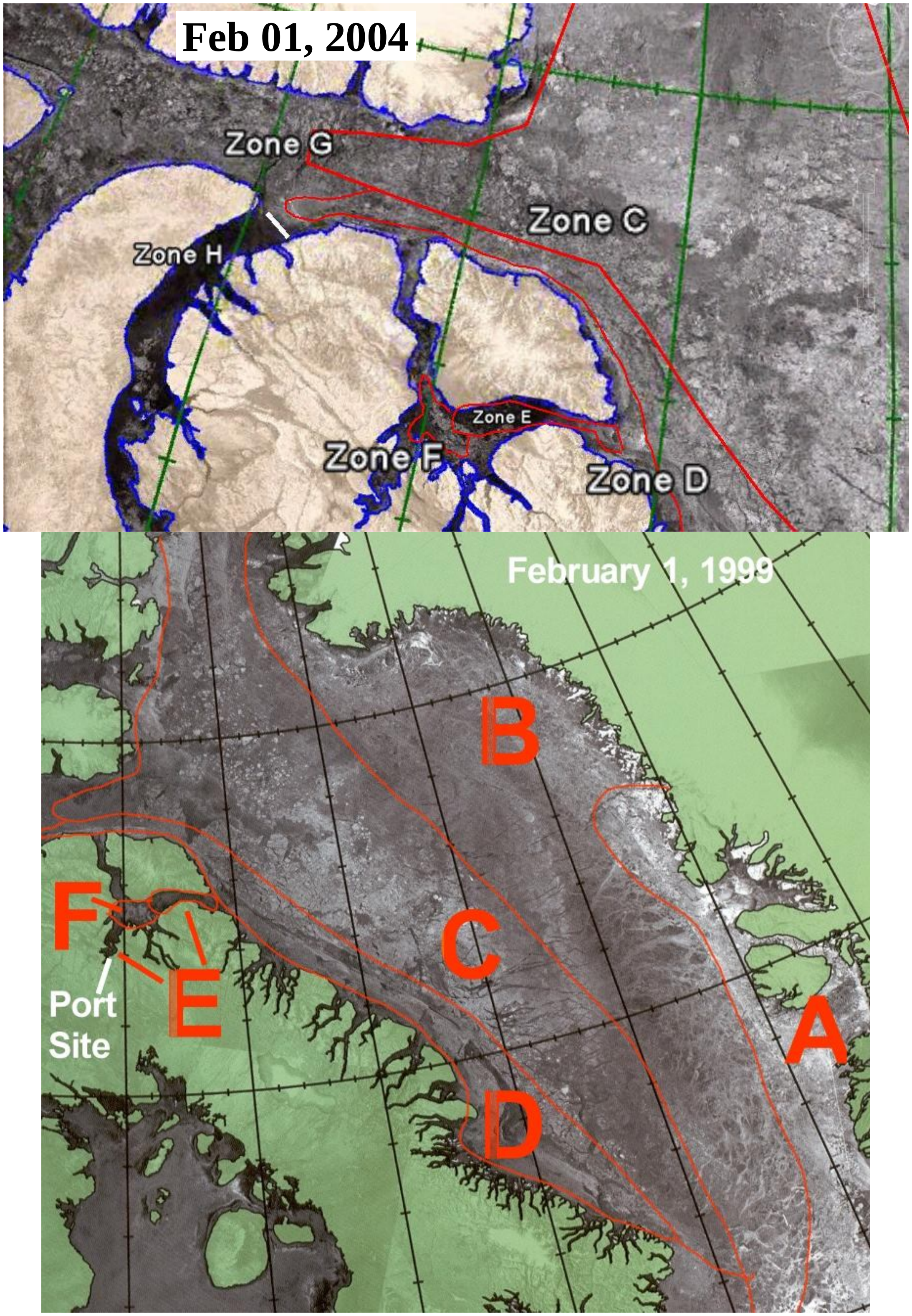

Figure 2: Ice Zones in the shipping channels leading to North Baffin Sites.

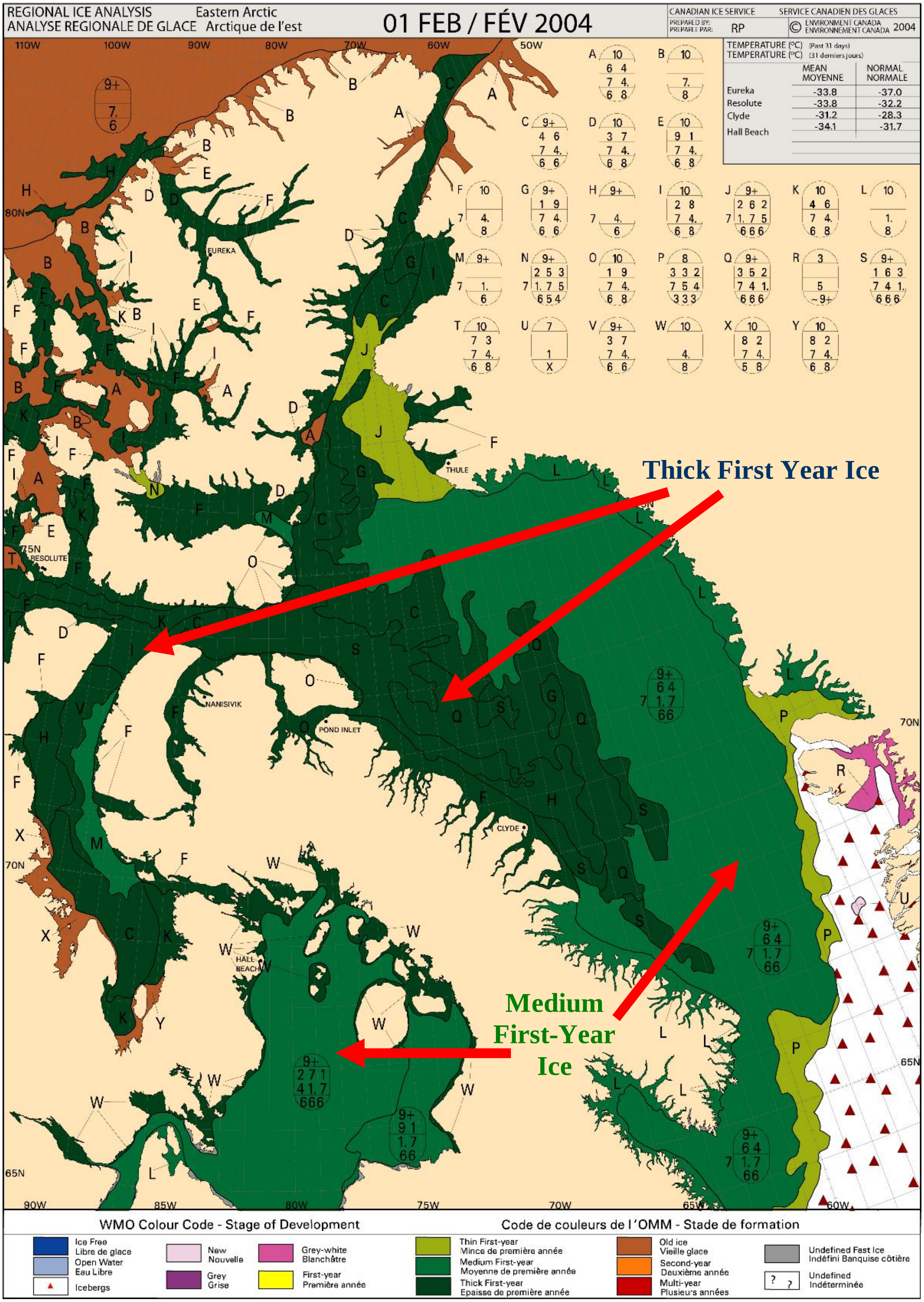

Figure 3: Typical Ice Condition during mid-winter time in North Baffin Sites. Dark Green shows the extensive area of Thick First Year Ice in access to North Baffin Sites while Mild Green shows the area of Medium First Year Ice in Steensby Inlet access.

Zone A – West Greenland Lead

Zone A marked on Figure 2 defines the ice conditions influenced by the West Greenland Current of south-eastern Baffin Bay. A relatively warm north-flowing current from the North Atlantic Ocean follows the west coast of Greenland northward to the Disko Island area of Greenland. This current maintains an open water and thin ice lead in this area of south-eastern Baffin Bay. This current reduces as it travels north gradually dispersing westward across Baffin Bay. This current causes the early clearing of ice in the spring and summer along the west coast of Greenland north of Disko Island. The currents of Baffin Bay play an important role in the distribution of ice in Baffin Bay and are shown here schematically in Figure 4.

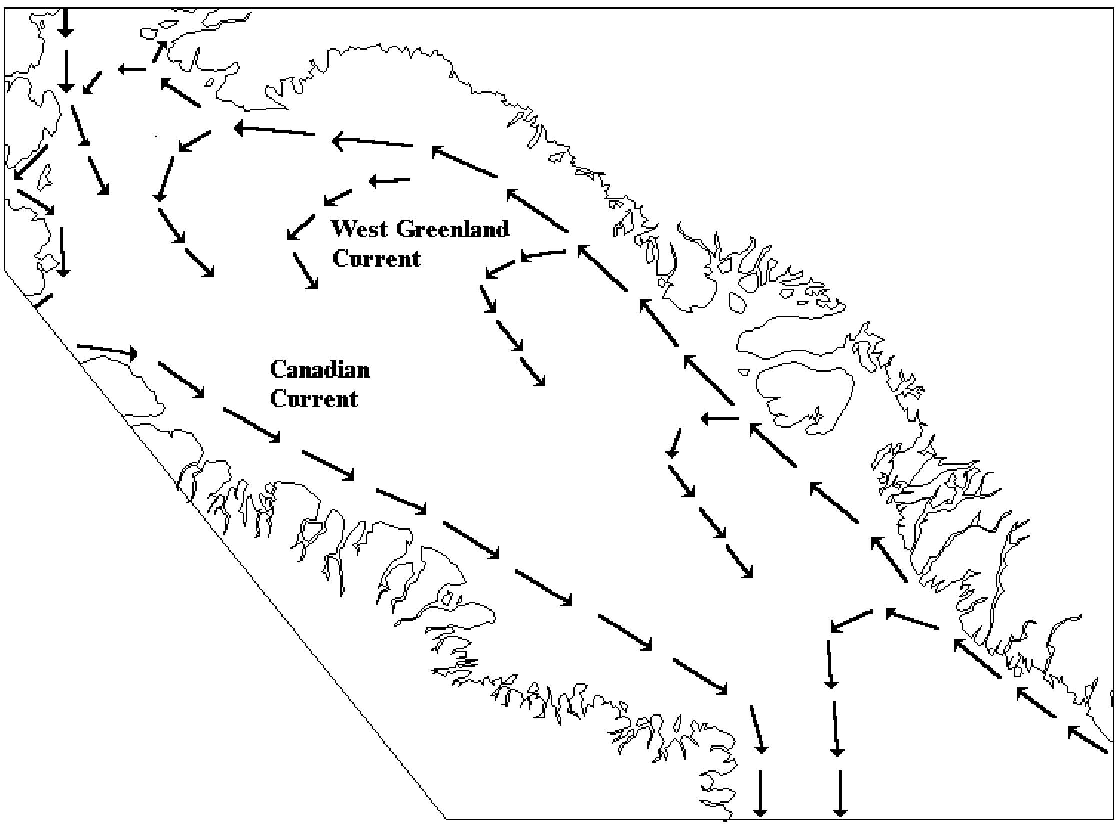

Figure 4: Currents of Baffin Bay

In addition to sea ice, the West Greenland Current pattern is also responsible for distributing icebergs that calve primarily from Disko and Melville Bays of western Greenland across Baffin Bay. **Figure 5** is a landmark analysis done by the US Coast Guard ice patrol in 1949. The US Coast Guard undertook an intense aerial survey of Baffin Bay in August of 1949 counting every iceberg. The concentration of icebergs coming out of the Disko Bay – Upernavik area and Melville Bay areas clearly shows the pattern of iceberg dispersal across Baffin Bay.

It should be noted that the occurrence of icebergs does not restrict shipping in a shipping channel. Icebergs form point targets that require special operating procedures to avoid but do not limit access.

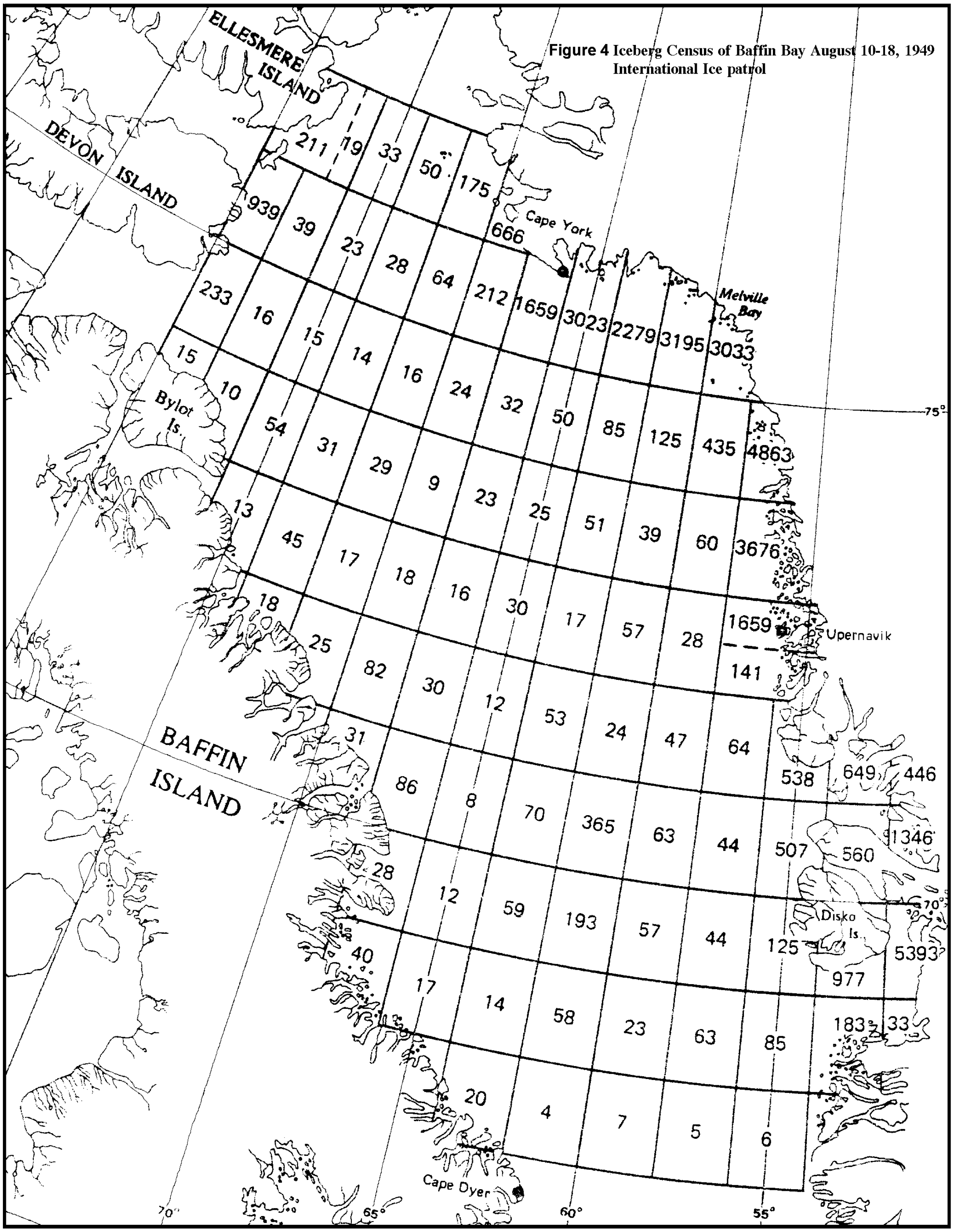

Figure 5: Iceberg Census of Baffin Bay, August 10-18, 1949. (International Ice Patrol)

Zone B – East Baffin Bay Level First Year Ice

Area B as defined in Figure 2 occupies the eastern portion of Baffin Bay and defines an area of relatively level thick first year ice in giant floes sizes in the mid to late winter period. The relatively light and diverging ocean currents in this part of Baffin Bay produces little pressure or ridging on the ice cover over the winter period. First year ice thicknesses well in excess of 2.0 metres can be encountered in the fast ice area of Melville Bay at the extreme northern end of this regime by the end of the winter period. Throughout most of this regime ice thickness of 1.2 to 1.4 metres are more typical by the end of the winter.

Zone C – Central and Western Baffin Bay Deformed First Year and Old Ice Field

The most difficult ice regime for shipping in the eastern Canadian Arctic occurs in central and western Baffin Bay in the winter period, as defined by Zone C on Figure 2. Old polar ice from the Arctic Ocean drifts south through Nares Strait between Greenland and Ellesmere Island each summer. As the summer melt season wanes in late September this old ice advances into northern Baffin Bay and crossing the eastern entrance to Lancaster Sound by late October and is joined by old ice drifting eastward from the Queen Elizabeth Islands through Lancaster Sound. This southward advance continues through the central and western portions of Baffin Bay as the old ice is carried by the south-flowing Canadian Current found along the western side of Baffin Bay (see Figure 4). The southward advance of old ice reaches Cape Dyer by mid-February and the eastern entrance to Hudson Strait in Davis Strait by mid-March. It was the pressured old ice field in this zone that forced the MV Arctic to abandon early winter voyages to the Polaris and Nanisivik mines in December of 1986 and 1989 (Gorman 1987, 1990).

The old ice concentrations typically occur in the 4/10 to 7/10 range in Zone C during the winter months. This old ice field creates a zone of ice pressure and ridging in the developing first year ice field around it, as evident on the RADARSAT image of Figure 2. The reason for this are two fold. Firstly, the greater thickness of the old ice (and some of these floes exceed 5 metres in thickness as they are sourced from the area of the Arctic Ocean with the oldest and thickest multi-year ice floes) cause the floes to move at a slightly different rate in response to winds and current than do the thinner first year ice floes around them. Secondly, the track of mid-winter storms into Baffin Bay in winter tend to bring north-easterly winds that cause heavier ridging on the central and western side of Baffin Bay.

The flow of old ice through Nares Strait stops with the formation of shore-fast ice in Smith Sound at the southern exit of Nares Strait, usually by mid-February. As the remainder of the winter progresses the old ice field gradually drifts southward. However, old ice is always found in central Baffin Bay in winter and spring.

Zone D – East Baffin Shear Zone

A prominent feature of the ice regime of Baffin Bay in the winter and spring is a shear zone of ice along the east coast of Baffin Island as delineated as Zone D on Figure 2. Each fall shore fast ice forms along the coastline of Baffin Island. In the region along the north and east coast of Baffin Island as well as Bylot Island, a shear develops between the mobile ice of Lancaster Sound and Baffin Bay and the shore fast ice. Under stormy conditions, particularly when winter low pressure cells bring north-east winds into Baffin Bay, the mobile pack ice is driven against the shore fast zone and gets "sheared" by the Canadian Current as the mobile ice is carried southward. This creates a large shear ridge at the boundary of the fast ice zone that can accumulate to over 20 metres in thickness. This zone is also an area of very high ice pressure when stormy conditions exist.

Fortunately, there is a break in the shearing process at the eastern entrance to Pond Inlet as diverging currents limit the formation of a shear ridge. However, there is still an offshore pressure zone in this area.

Zone E – Level Fast Ice of Pond and Milne Inlets

Relatively level fast ice forms each fall in the channels of Pond and Milne Inlets. This ice achieves an average thickness of 1.6 metres with extremes approaching 2.0 metres. The Canadian Ice Service ran an ice thickness measurement station at Pond Inlet for a number of years. Data from this station provides an accurate measurement of the level ice and snow thickness for this ice regime. Data for the monthly analysis in the 1990's presented in Attachment B used the weekly data from the CIS records.

Figure 6 is the average ice thickness curve for Pond Inlet as calculated by the Canada Ice Service ice thickness data. There is a total of 125 nautical miles of shore fast ice leading to the Milne Inlet port site.

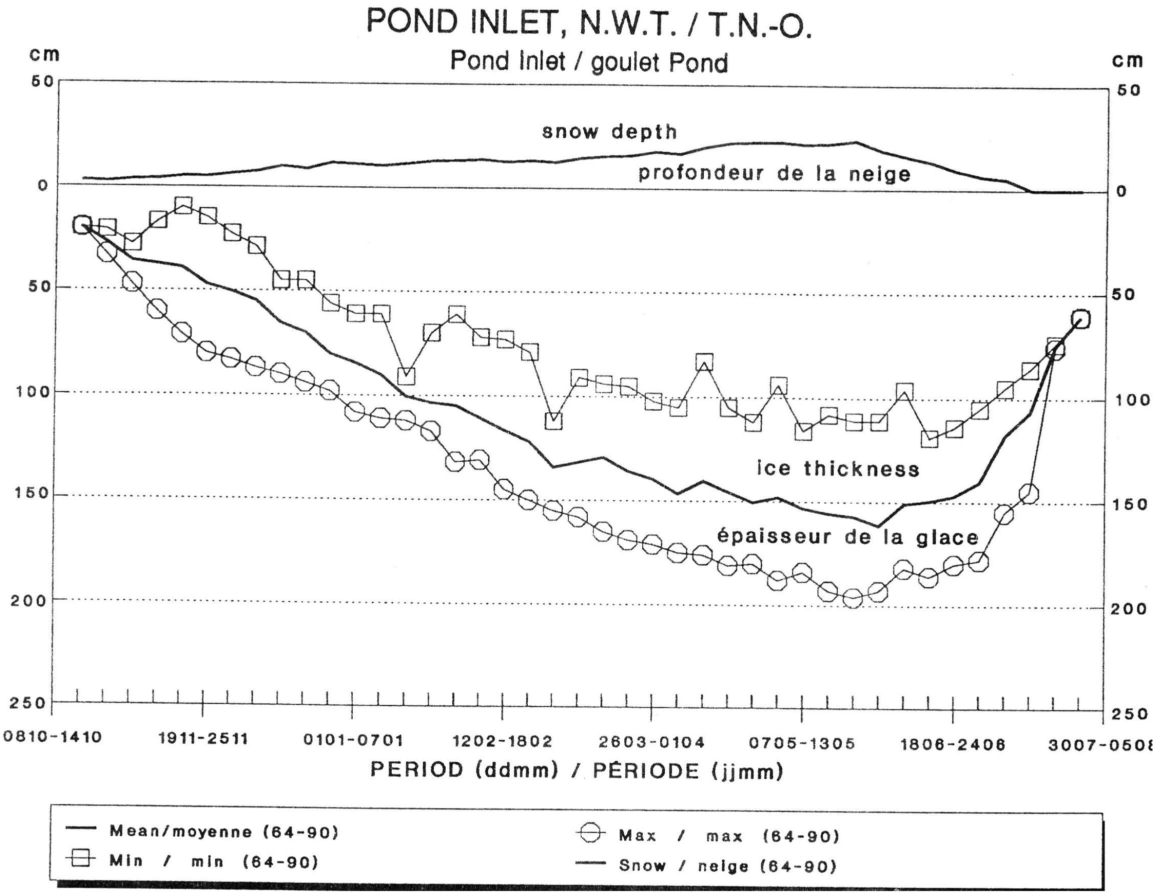

Figure 6: Ice Thickness data from Pond Inlet (IC 1992).

Zone F – Fast Ice of Eclipse Sound

The fast ice of Eclipse Sound (Zone F) takes on a different character than that found in Pond and Milne Inlets. Although the fast ice achieves a similar thickness, the fact that Eclipse Sound is exposed to Navy Board Inlet to the north means that the ice cover is susceptible to more ridging during formation due to the greater fetch in the sound. In addition, quantities of old ice frequently drift south from Lancaster Sound through Navy Board Inlet into Eclipse Sound during freeze-up often leaving 3/10 to 6/10 concentrations of old ice in the winter fast ice of the sound. The quantity of old ice each winter is highly variable from none in some years to high concentrations in others. An additional factor is the frequent transit of the fast ice in Eclipse Sound will require the selection of additional paths as the track builds up ice rubble in the winter. The choice of alternate routes could be problematic when high old ice concentrations occur in the fast ice in Eclipse Sound.

Zone G – Lancaster Sound

The conditions within Lancaster Sound will be very dynamic. In mid-winter pressure ridges will form in several locations and will be influenced by the pressure in Zone C.

Although technically mobile, the ice in the region will effectively consolidate and loosen several times throughout the winter.

Zone H – Admiralty Inlet

The final 50 miles of the journey will be through Admiralty Inlet and area of relatively consistent shorefast ice the thickness of which will rarely exceed two metres. Figure 7 is the average ice thickness curve for Arctic Bay as calculated by the Canada Ice Service ice thickness data.

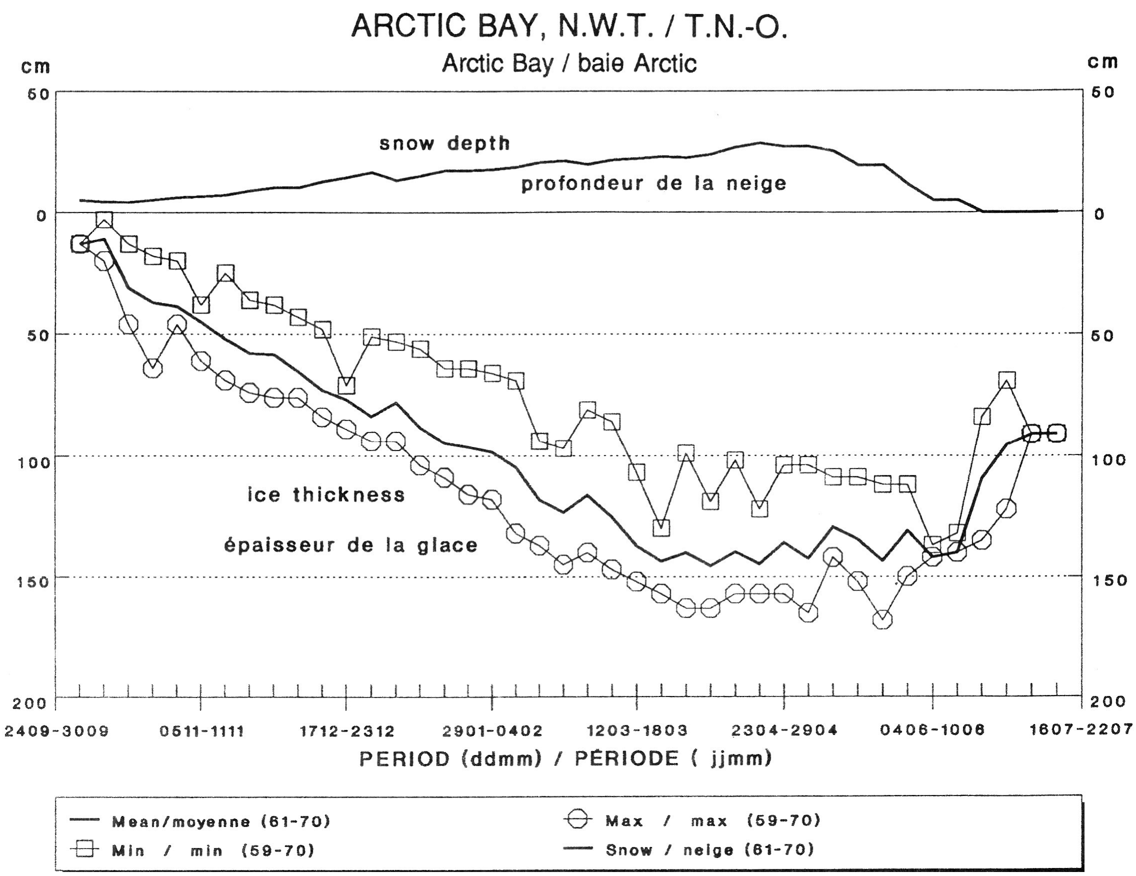

Figure 7: Ice Thickness data from Arctic Bay (IC 1992).

1.2.1.1 Ice Season along the Shipping Routes to North Baffin Sites

The first signs of the spring break-up in the region occur in April as the West Greenland Lead and North Water Polynya expand, as illustrated in Figure 8.

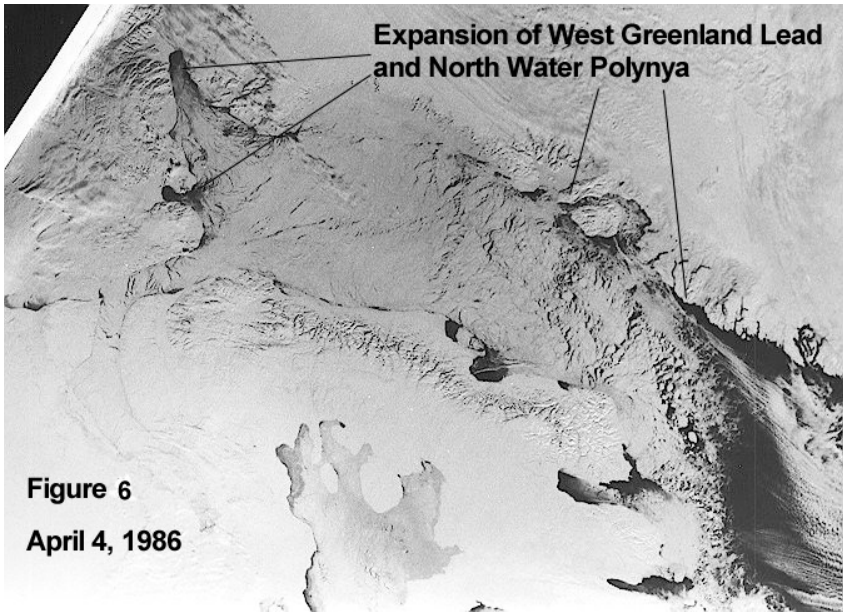

Figure 8: NOAA Satellite Image April 4, 1986

The expansion of the leads continues through May to August as the ice cover of Baffin Bay reduces, as illustrated in Figure 9.

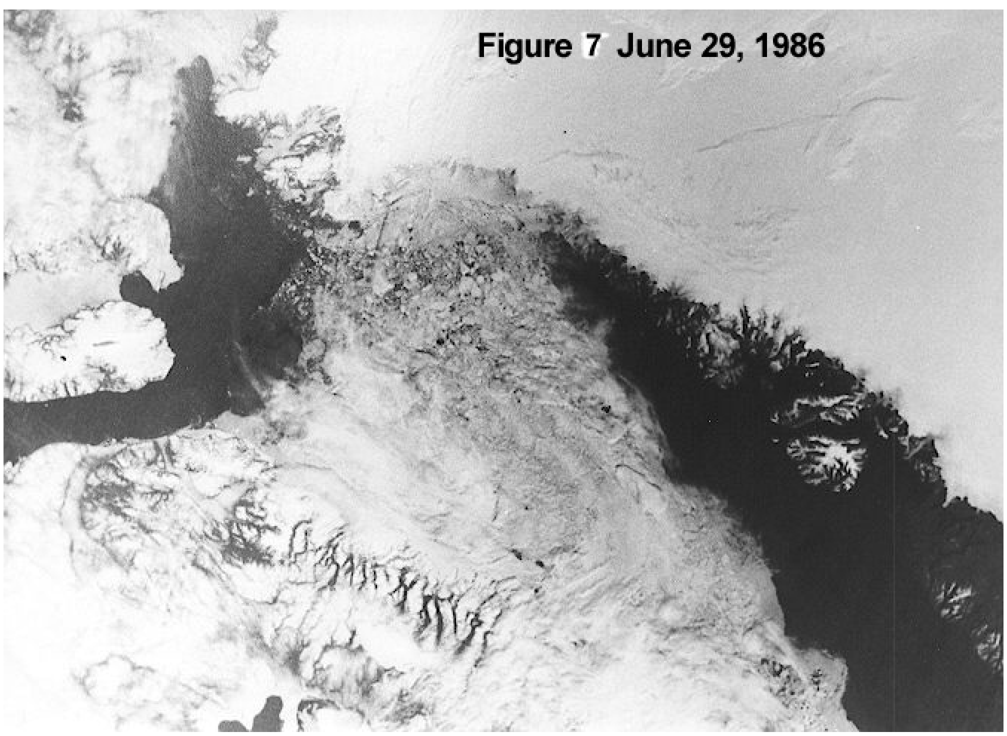

Figure 9: NOAA Satellite Image June 29, 1986

The melting of the fast ice in Milne Inlet occurs in late June with the fracture and clearing of Eclipse Sound and Pond Inlet occurring during the month of July as illustrated in Figure 10 and Figure 11. Note the clearing of Lancaster Sound is well underway, while

Pond Inlet and Admiralty Inlet remain fast. Remnants of the Baffin pack remain firmly in place on the Baffin coast.

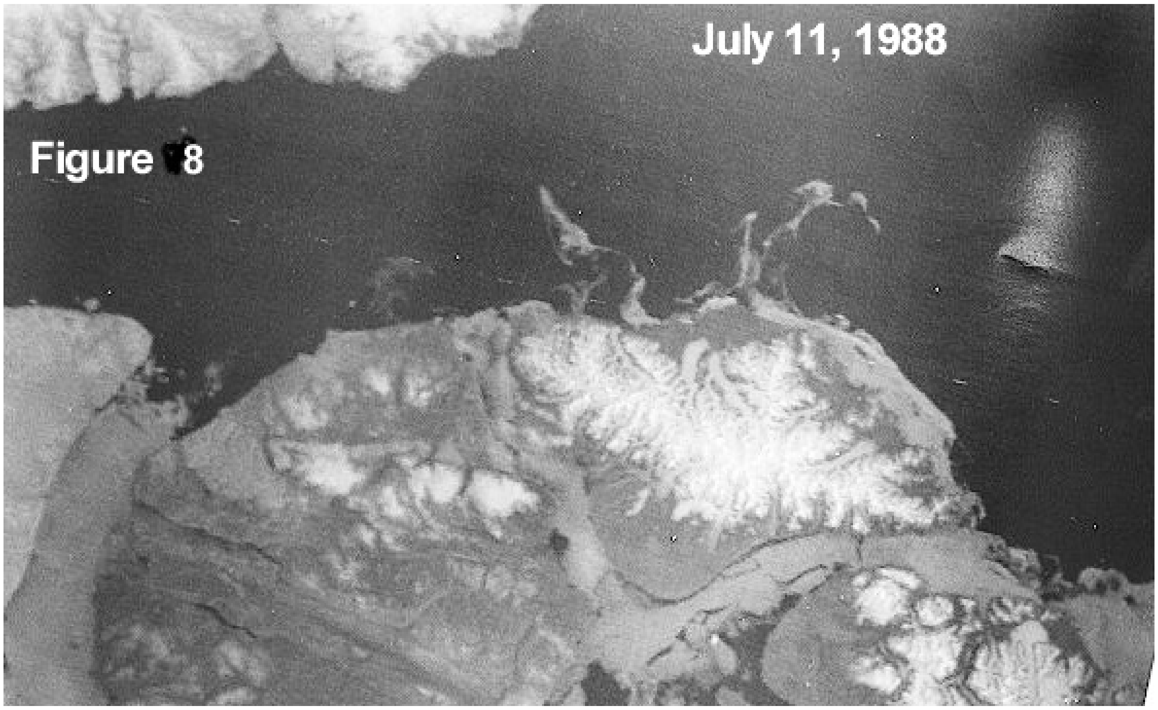

Figure 10: NOAA Satellite Image July 11, 1988

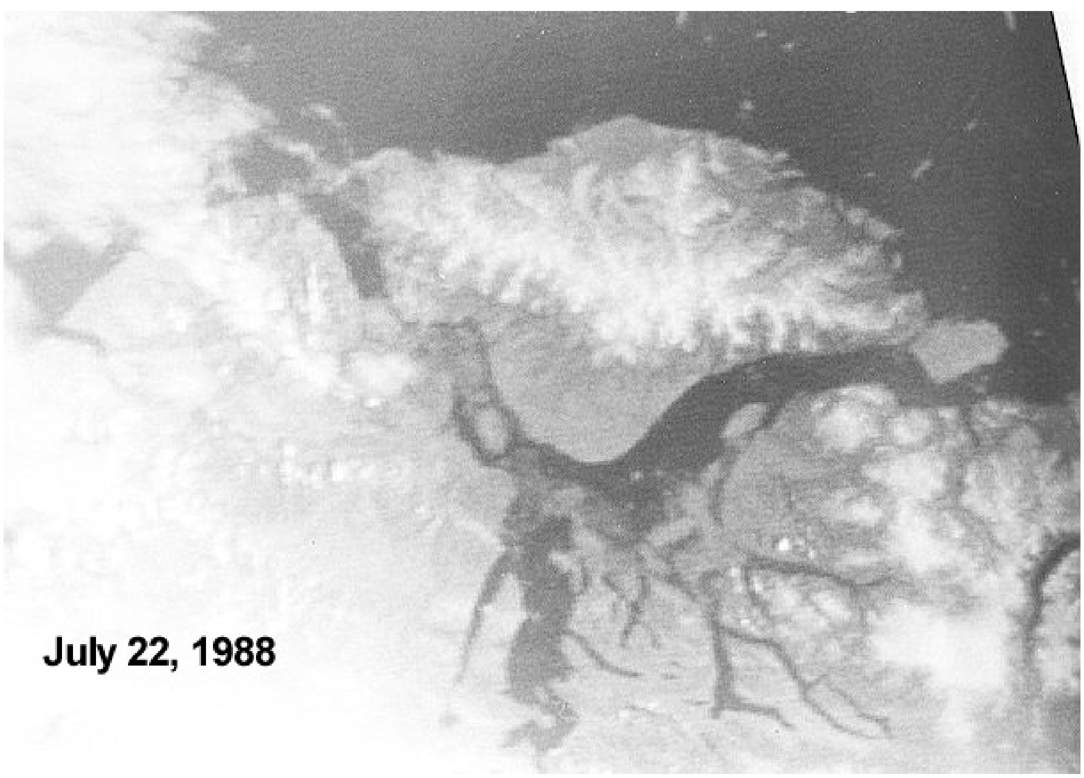

Figure 11: NOAA Satellite Image July 22, 1988. Pond Inlet clearing well, but Admiralty Inlet remains consolidated

However, a cool summer may delay the fracture of the fast ice in Eclipse Sound into mid-August as illustrated in Figure 12 below.

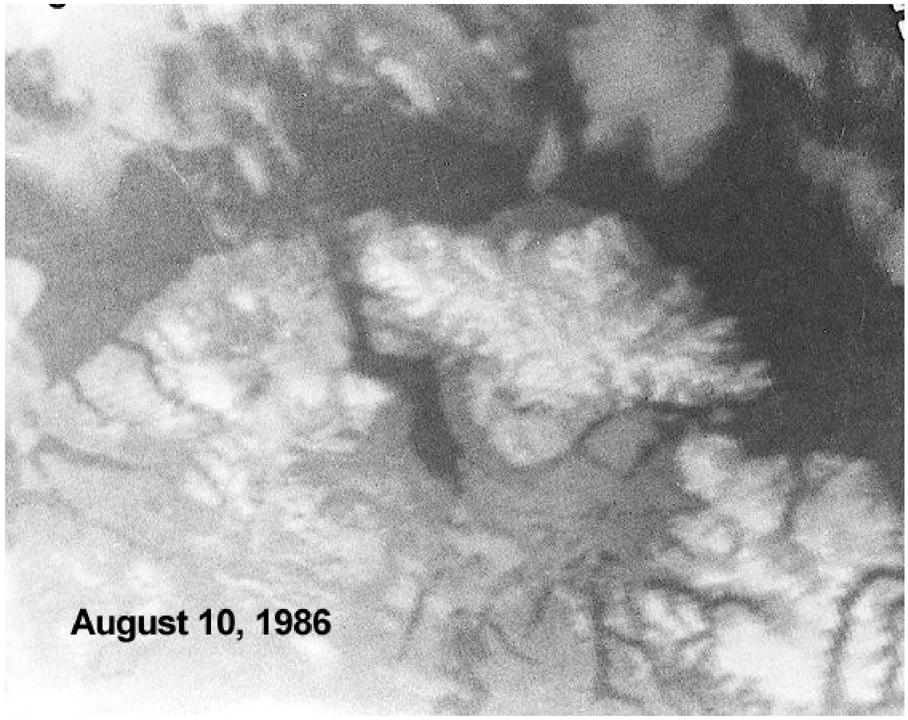

Figure 12: NOAA Satellite Image August 10, 1986

Freeze-up occurs rapidly in the access channels to Milne Inlet in early October as new/young ice spreads south-eastward from Lancaster Sound and northern Baffin Bay. Of particular note is the advance of Arctic Ocean old ice from Nares Strait into northern Baffin Bay across the entrance to Lancaster Sound affecting traffic to potential port site in Nanisivik. This old ice covers the eastern entrance to Pond Inlet by early November. The advance of freeze-up (and the old ice from Nares Strait) is illustrated in Figure 13 below.

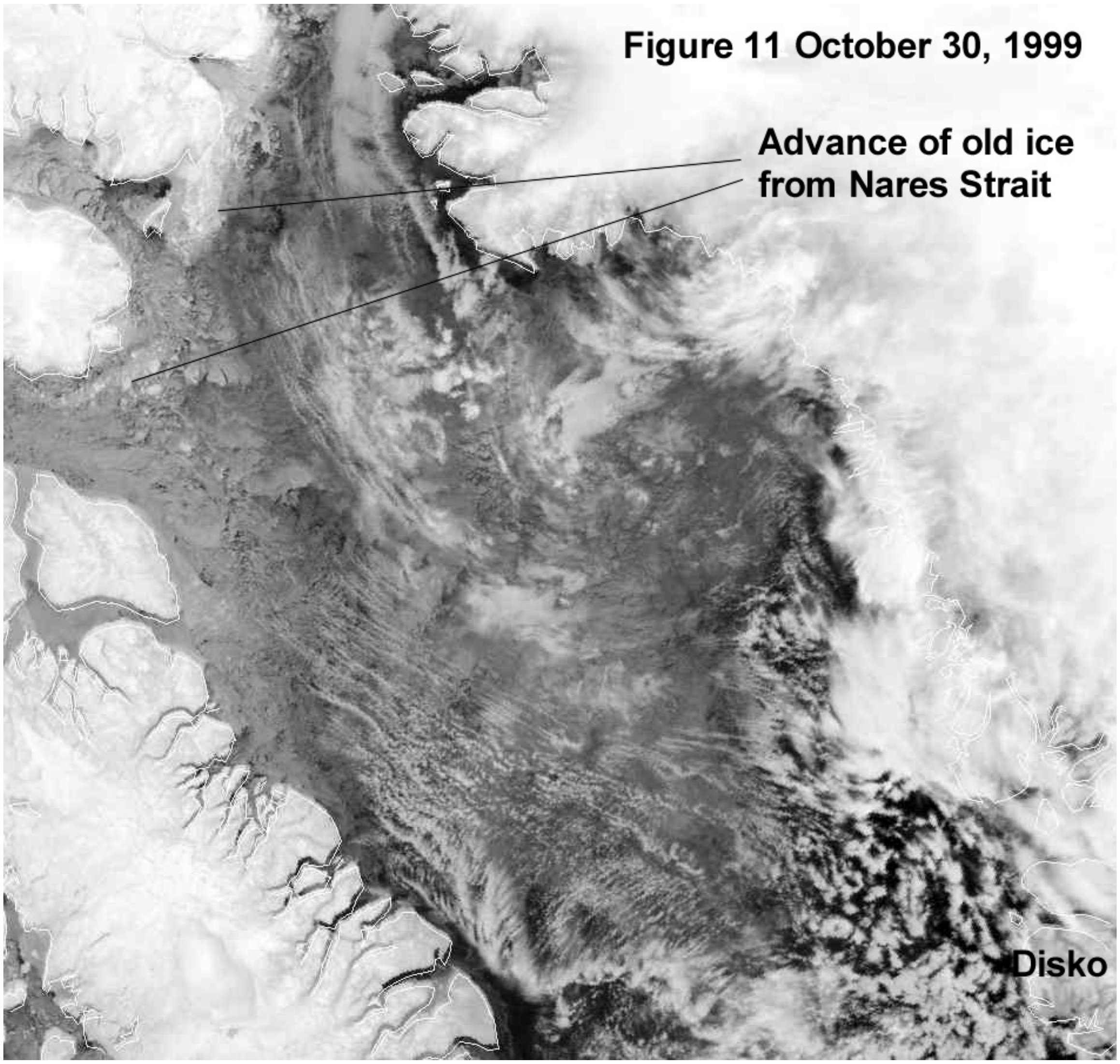

Figure 13: NOAA Satellite Image October 30, 1999

The development of the typical winter conditions for the access to Milne Inlet as shown in Figure 2 above occurs by early December. Though the conditions across Lancaster Sound appear to be looser, embedded in that ice will be old ice. Likewise pressure ridges can begin to form along the Baffin Coast at this time.

1.2.2 Steensby Inlet Access

The tabulation of monthly ice statistics for the route to Steensby Inlet used a list of waypoints following the nominal route into the Inlet as defined by Enfotec and are shown in Figure 14. This represents a new routing analysis to Steensby Inlet.

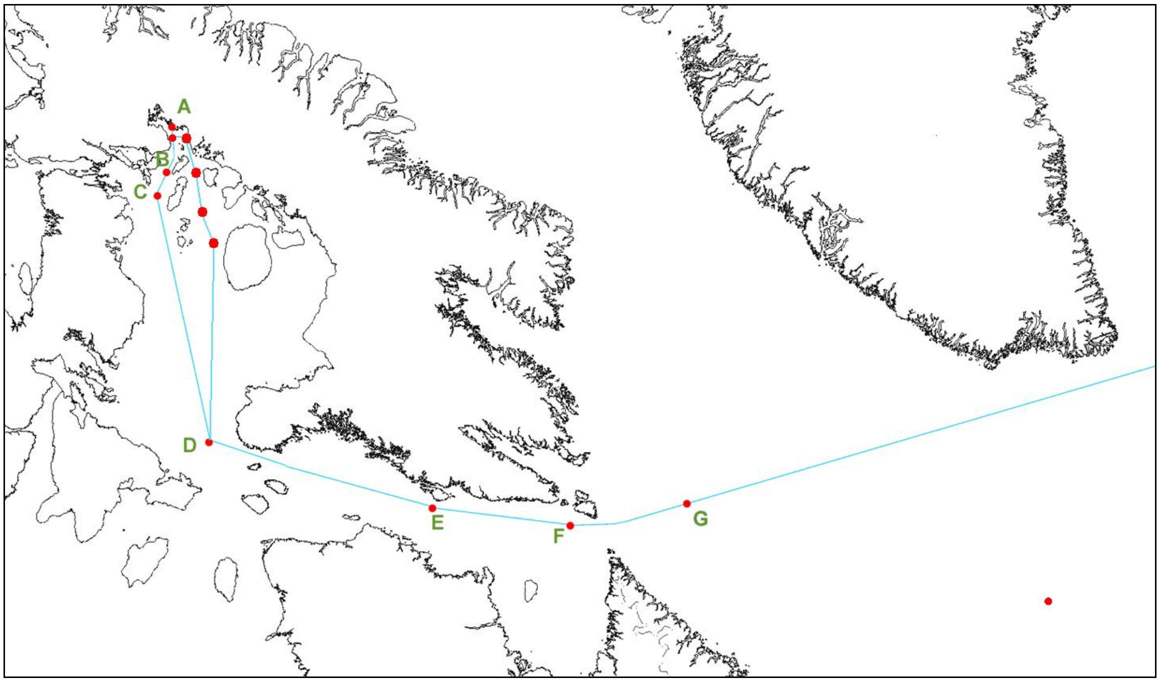

Figure 14: Route waypoints used for the Steensby Routing Analysis

The results of the detailed month-by-month analysis of the ice conditions leading to Steensby Inlet are provided in Attachment C. A summary of the mid-winter ice conditions that occur along the shipping corridors to Steensby Inlet is provided in Figure 15 below. The image used for Figure 15 is the RADARSAT Ice Atlas mosaic of the eastern Canadian Arctic from February 1, 1999, produced by the Canadian Ice Service (CIS 1999) and is representative of the typical mid-winter ice conditions leading to Steensby Inlet. Five ice regime zones of similar ice conditions have been defined by Enfotec based on the analysis of this study. The zones are marked A to E on Figure 15.

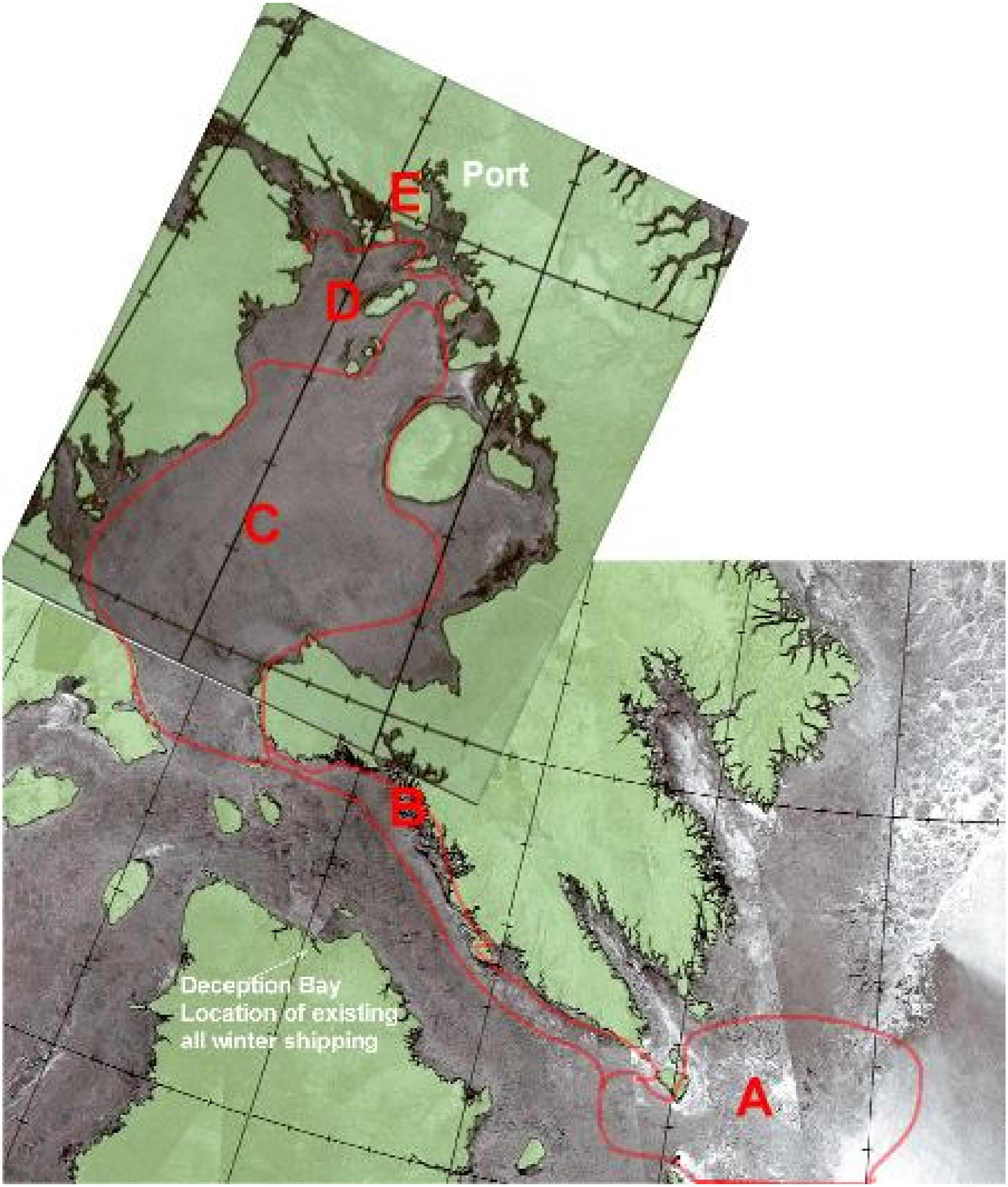

Figure 15: Ice Zones in the shipping channels leading to Steensby Inlet

Zone A – Labrador Sea

Zone A covers the eastern entrance to Hudson Strait in the Labrador Sea. A typical ice chart of the mid-winter condition of Hudson Strait is displayed as Figure 16. The ice of this zone is a composite of the following source areas for sea ice:

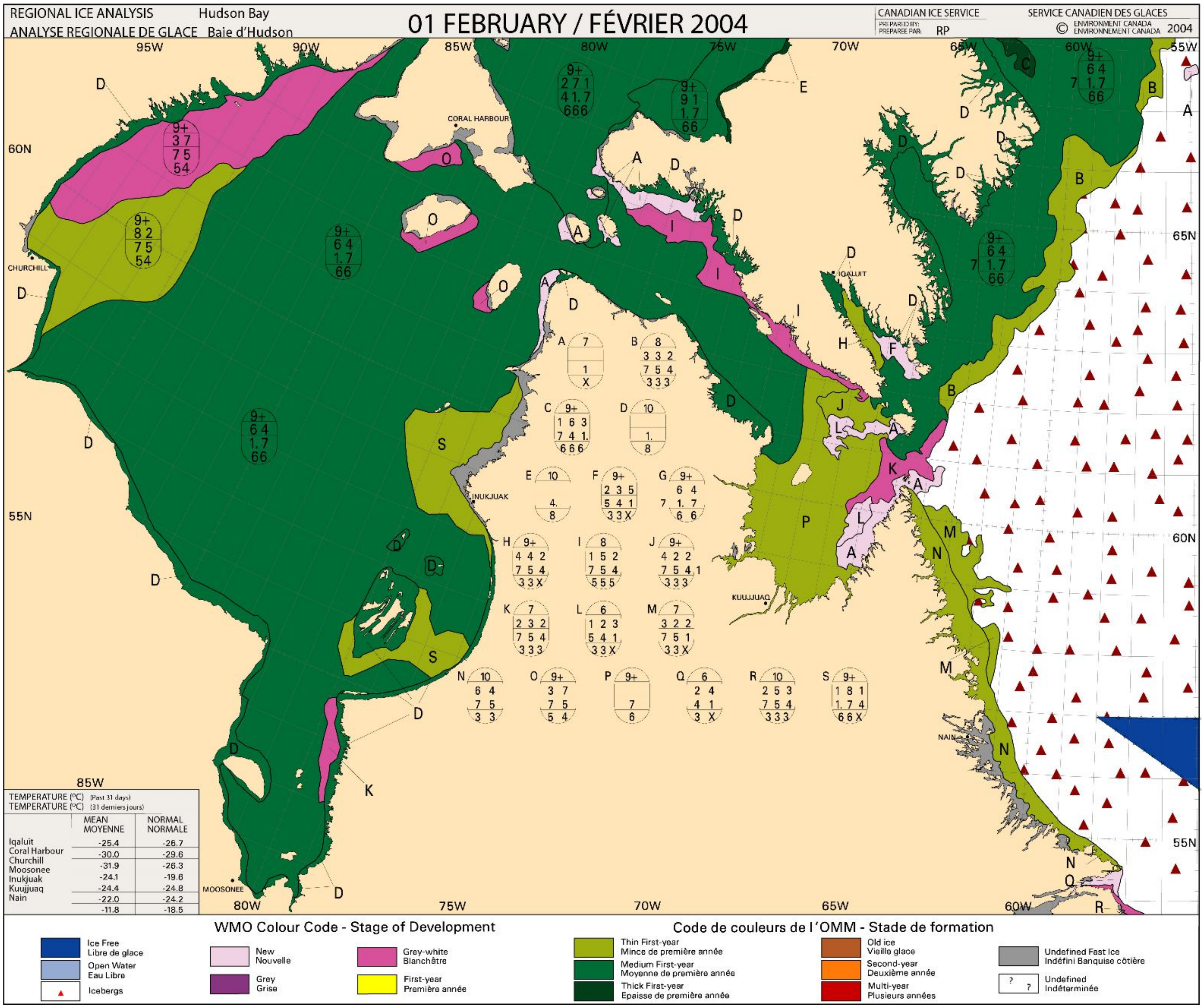

Figure 16: Typical Ice Condition during mid-winter time in Hudson Strait. Note the relative absence of Thick First Year Ice compared to Baffin Bay (as seen in Figure 3).

First year and old ice drifting south from Baffin Bay through Davis Strait. This ice tends to occur on the eastern edge of the pack ice of the zone. This is due to the fact that the ice of Baffin Bay is deflected to the east as it drifts south past

Cape Dyer to enter Davis Strait. The Baffin Bay ice tends to contain the thickest first year ice floes in the zone as well as the old ice that drifts south through Baffin Bay over the winter. The old ice tends to occur along the eastern third of the zone from mid-March to early June in concentrations that rarely exceed 2/10. The reason old ice concentration in the zone is lower than that typically found in Baffin Bay to the north is due to the fact that the old ice concentration is dispersed as it passes Cape Dyer.

Locally grown first year ice in Davis Strait as well as from Cumberland Sound and Frobisher Bay. The sea ice found in the central and western portion of Zone A is ice that formed near the coast of Baffin Island in Davis Strait. This ice tends to be thinner than the first year and old ice that enters the region from Baffin Bay.

Sea ice from Hudson Strait. The sea ice drifting eastward from Hudson Strait exits Hudson Strait into Zone A at the south side of the zone north of Cape Chidley Labrador. This ice trends to be heavily ridged by the tidal currents in Hudson Strait and of similar thickness to the ice from Baffin Bay.

The eastward limit of the ice edge in the Labrador Sea can be highly variable, depending on the severity of winter temperatures as well as prevailing winds at any given time. Westerly winds and colder than average temperatures can push the eastern ice edge east of 57W and strong easterly winds can press the ice edge westward as close as Resolution Island. Moderate ice pressure can be experienced in the Zone during easterly wind conditions when the pack ice is compressed westward. The analysis of ice conditions for this study has noticed a tendency for more extensive ice in Zone A in the early 1990's compared to recent years this century.

It should be noted that ships will occasionally encounter pressured ice in the area of Resolution Island that may result in delays in transit times. However, with the vessels envisioned these delays will be relatively short and likely coincide with easterly winds and larger tides.

Zone B – South Baffin Lead

The prevailing north-westerly winds over the region results in the creation of numerous leads along south-facing coastlines in Hudson Strait and at the northern reaches of the Foxe Basin. The most prominent of these leads is the lead found along the south coast of Baffin Island, defined as Zone B on Figure 15. Figure 17 is a satellite image showing the typical extent of the lead along the south coast of Baffin Island.

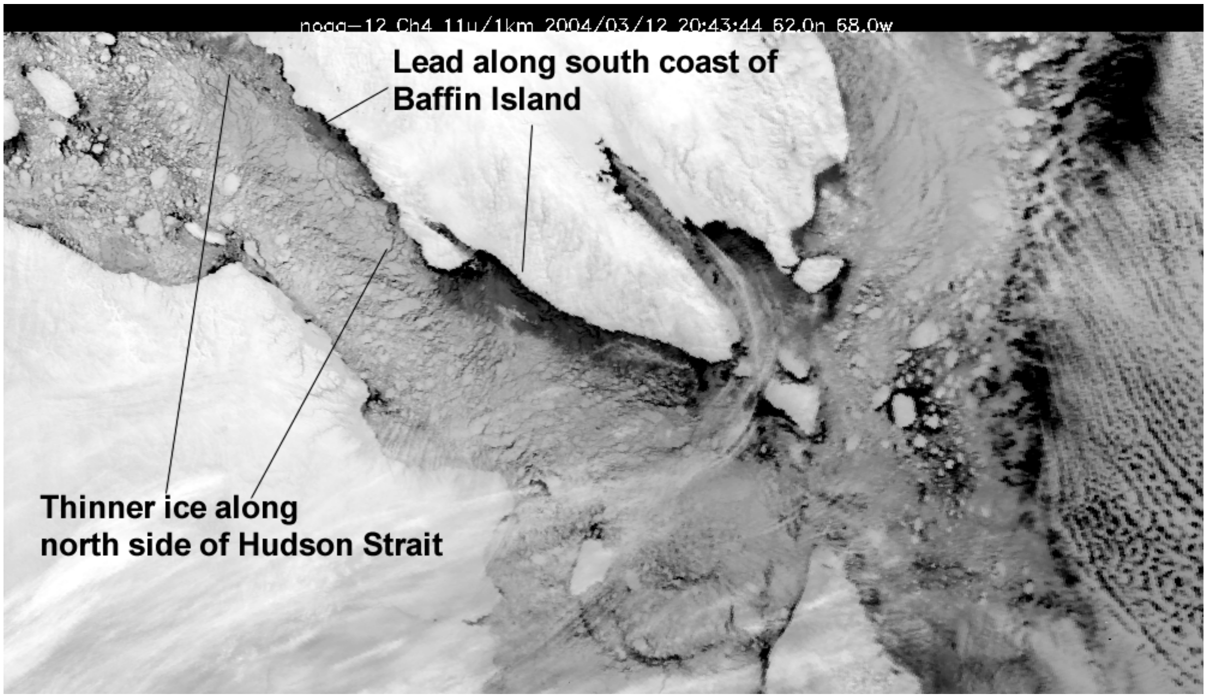

Figure 17: Satellite image from March 12, 2004, showing the lead found along the south coast of Baffin Island.

The lead is most prominent between Resolution Island and Big Island becoming narrower west of Big Island. The lead is present most of the winter and early spring closing only occasionally under southerly wind conditions for brief periods. The general north-west to south-east forcing of the ice that creates the lead also creates a zone a thinner first year ice in the area. Although termed a “lead” the cold temperatures in the region in mid-winter results in the “open water” areas always containing a thin new or young ice layer.

Another feature of Zone A is the presence of icebergs in the area west to Big Island. The ocean current pattern in Hudson Strait is such that icebergs drifting south through Davis Strait are carried westward along the south coast of Baffin Island before being carried south then eastward once again. Figure 18 illustrates the current pattern in Hudson Bay. The diverging currents away for the Baffin Island coast west to Big Island is also a factor in helping to maintain the large lead that is present in this area in the winter.

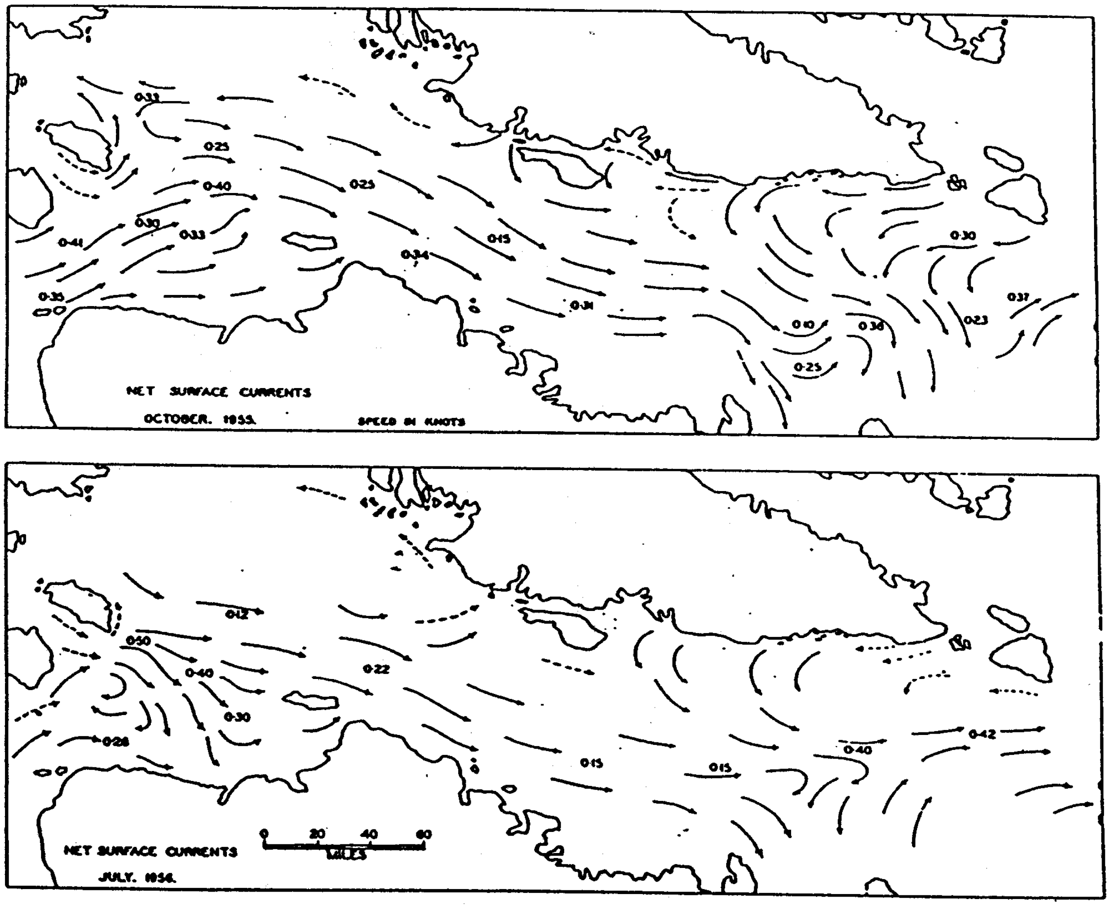

Figure 18: Ocean current patterns in Hudson Strait (Campbell 1958).

<u>Zone C – Foxe Basin Pack Ice</u>

Zone C defines the southern and central regions of the Foxe Basin. This area contains 9+/10 first year pack ice throughout the winter. Radar imagery of this pack ice taken in the mid winter indicates that ridging is common in this zone, likely caused by the pulsing of the Atlantic tide into the basin in winter. This ridging is evident by the mottled appearance of the pack ice in this zone in Figure 15. In addition, the persistent north-westerly winds in mid winter compress the pack ice southward toward Hudson Strait.

Zone C is the region where ice pressure will be most likely encountered on a regular basis for winter ship transits to Steensby Inlet. The causes of ice pressure in the pack ice are twofold. The most common cause is the daily ebb and flow of the tide in Foxe Basin that will give episodic pressure events as the tide waxes and wanes during the day. Tidal-induced ice pressure is commonly experienced now by the MV Arctic while crossing Hudson Strait during winter transits to the Port of Deception Bay. It is likely that these pressure events will also be experienced in the Foxe Basin but to a somewhat lesser extent as the tidal current is likely lower in this area. It is unlikely that the ore carriers will experience the ice pressure events in the transit of Hudson Strait (in Zone B) as they will be staying on the north side of the strait where the ice is thinner and pressure is less of an issue. The second source of ice pressure for Zone C will be wind-induced. Since the Foxe Basin is a relatively enclosed basin, it is highly susceptible to wind-induced ice pressure, regardless of the direction the wind blows from. The wind blows almost continuously in this region in winter making ice pressure a common event.

It should be noted on the issue of ridging that this may not, in fact, pose a serious impediment to the ore carriers. The experience of the MV Arctic in transiting the heavily ridged ice of Hudson Strait is that the ice is so rubbled by winds and tides that the vessel actually moves through the ice easily when the pressure is not on the ice field.

Small amounts of old ice in concentrations of 1/10 to 2/10 occasionally occur in the pack ice of Zone C, usually along the western edge of Foxe Basin. There are two source areas for this old ice. One source of old ice occurs in summers when cooler than normal temperatures prevail over the region such that not all the first year ice in Hudson Strait melts. This will occasionally leave a small amount of second year ice in the Foxe Basin that slowly drifts south in the fall and early winter to exit through Hudson Strait. This is a relatively rare occurrence, usually about once every six to ten years and becoming somewhat less frequent recently. The second source of old ice is the drift of small amounts of old ice spilling through Fury and Hecla Strait at the north-west entrance to the Foxe Basin from Committee Bay at the south end of the Gulf of Boothia. This was once a fairly common source of old ice for the Foxe Basin but there has been a reduction in the concentration of old ice in the source area of Committee Bay such that this has not been recorded to have occurred in the past 10 years.

Zone D – Northern Foxe Basin

Like the south coast of Baffin Island, the northern Foxe Basin develops thin first year ice and open water leads throughout the winter as the prevailing north-westerly winds push the Foxe Basin pack ice south away from the Baffin Island Coast. Figure 19 is a satellite image from February 28, 2003 showing the thinner ice leads across the northern section of the Foxe Basin.

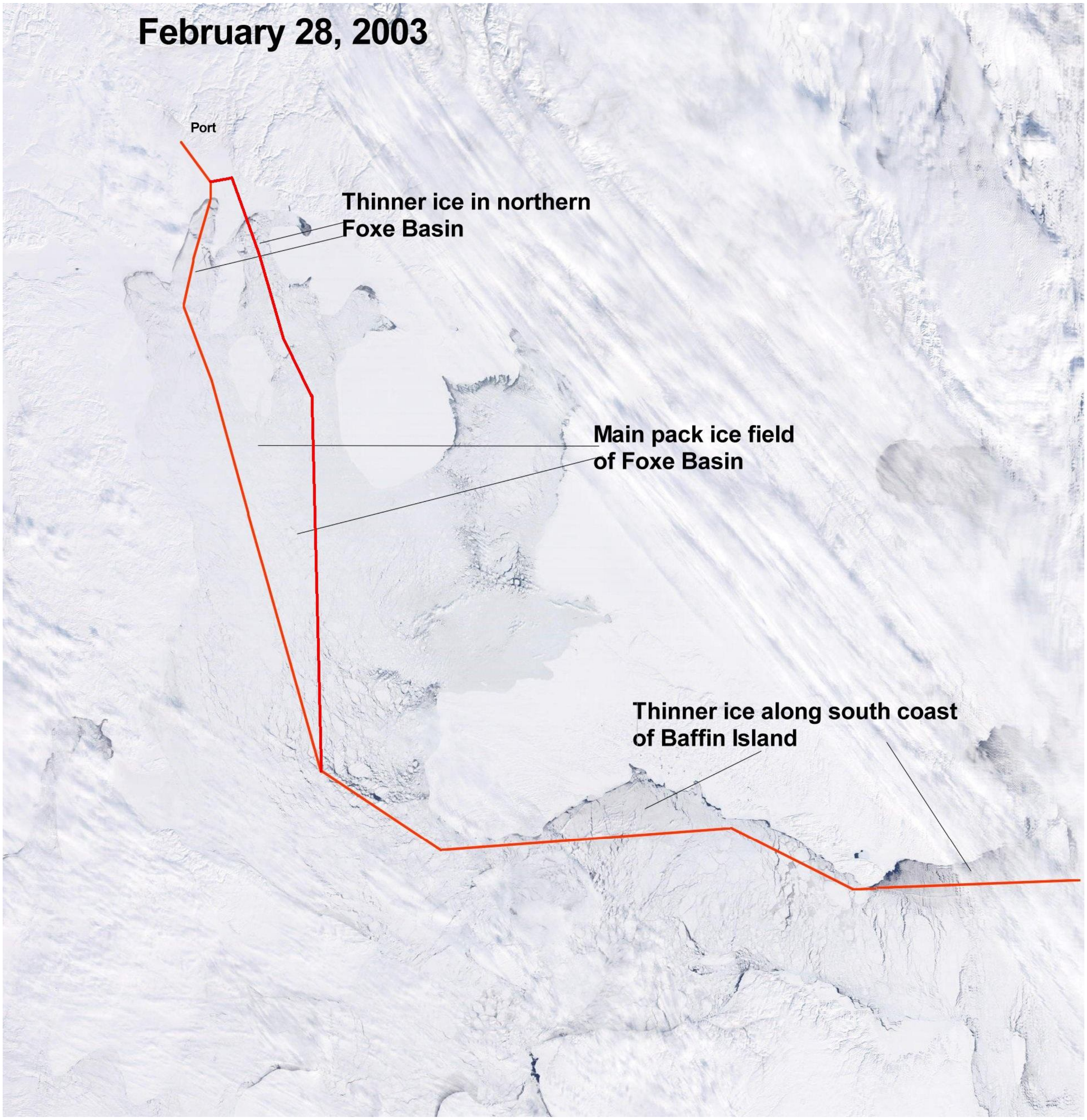

Figure 19: Satellite image of the ice features of the Foxe Basin in winter. The nominal shipping route to Steensby Inlet is shown in red.

Inclusions of old ice can be seen in Northern Foxe Basin during late summer and early fall in very small concentrations (Figures 20, 21, 22 and 24). Multi-year or old ice is sometimes, but not systematically each year, seen in 1/10 concentration or in traces coming from Fury and Hecla Strait and drifting along the coast of Hall Beach. In any event, this ice will not present a hazard to ships using the proposed route to Steensby Inlet on the western side of Foxe Basin.

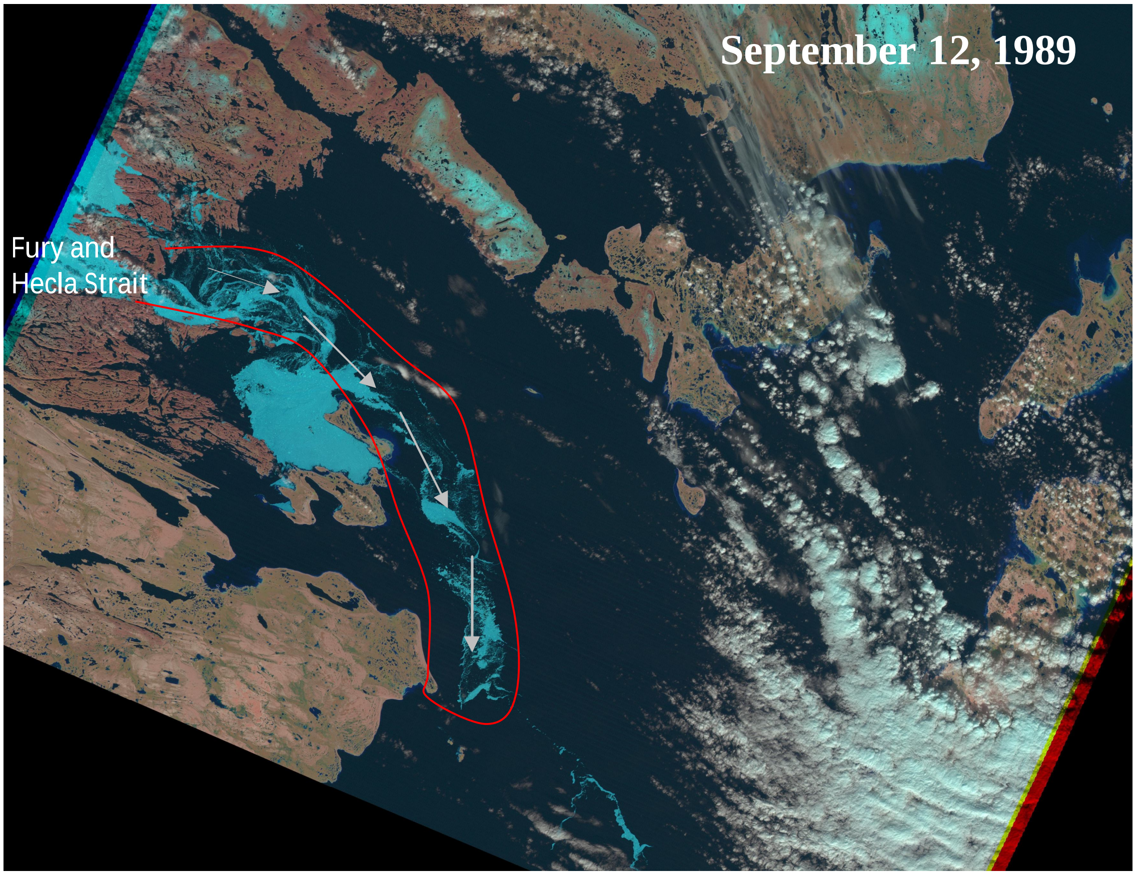

Figure 20: Satellite image showing a typical pattern of ice flowing from Fury and Hecla Strait on the western side of Foxe Basin in late summer or early fall.

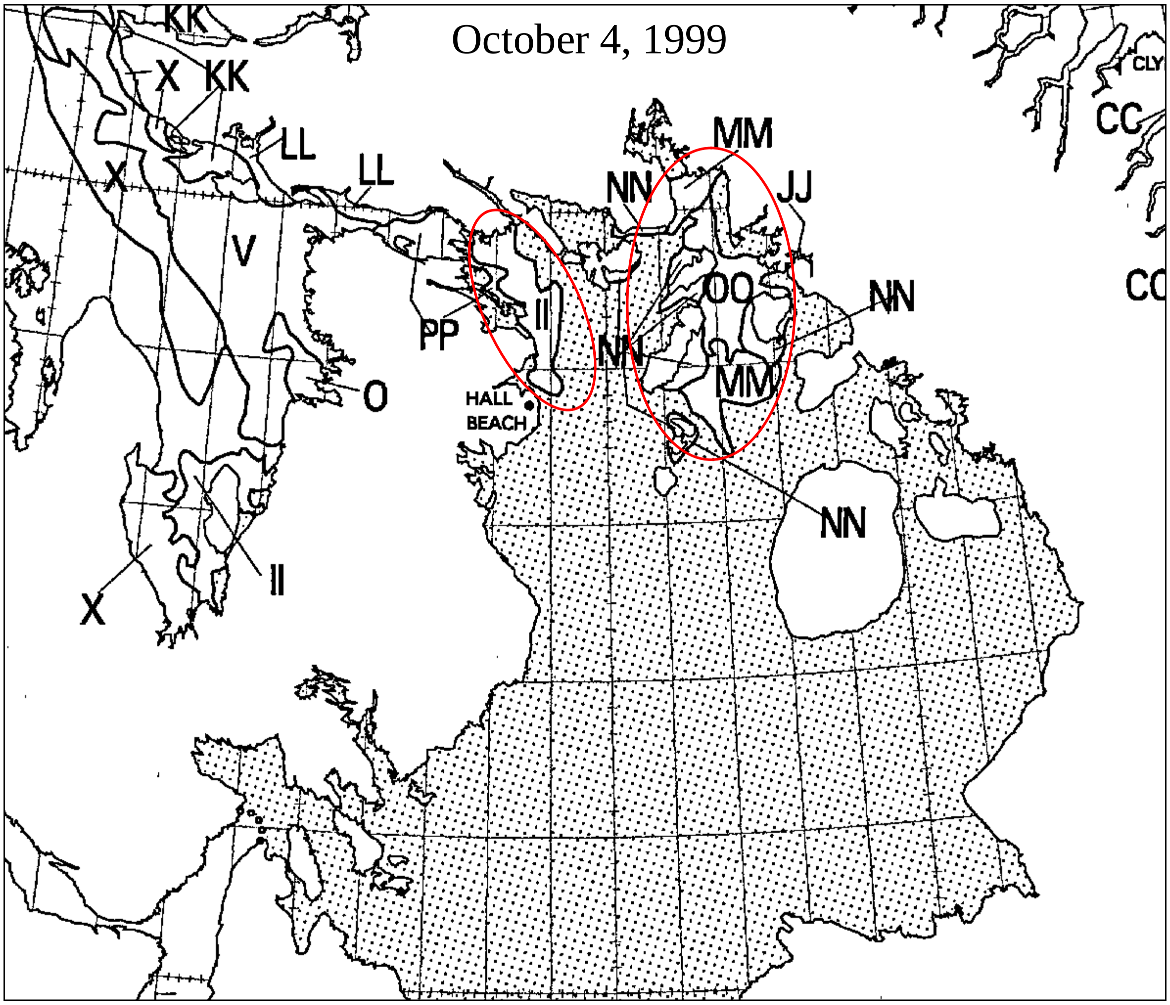

Figure 21: Example of old ice inclusions in Foxe Basin (CIS archive).

The pack coming from Fury and Hecla Strait shows an ice concentration of 5/10, within which 1/10 of multi-year ice in strips and patches can be observed. As for the ice packs in the Steensby Inlet area, inclusions of second-year ice (which is most likely first-year ice having just turned as second-year ice due to the ice anniversary on October 1st) are seen within new ice in open packs.

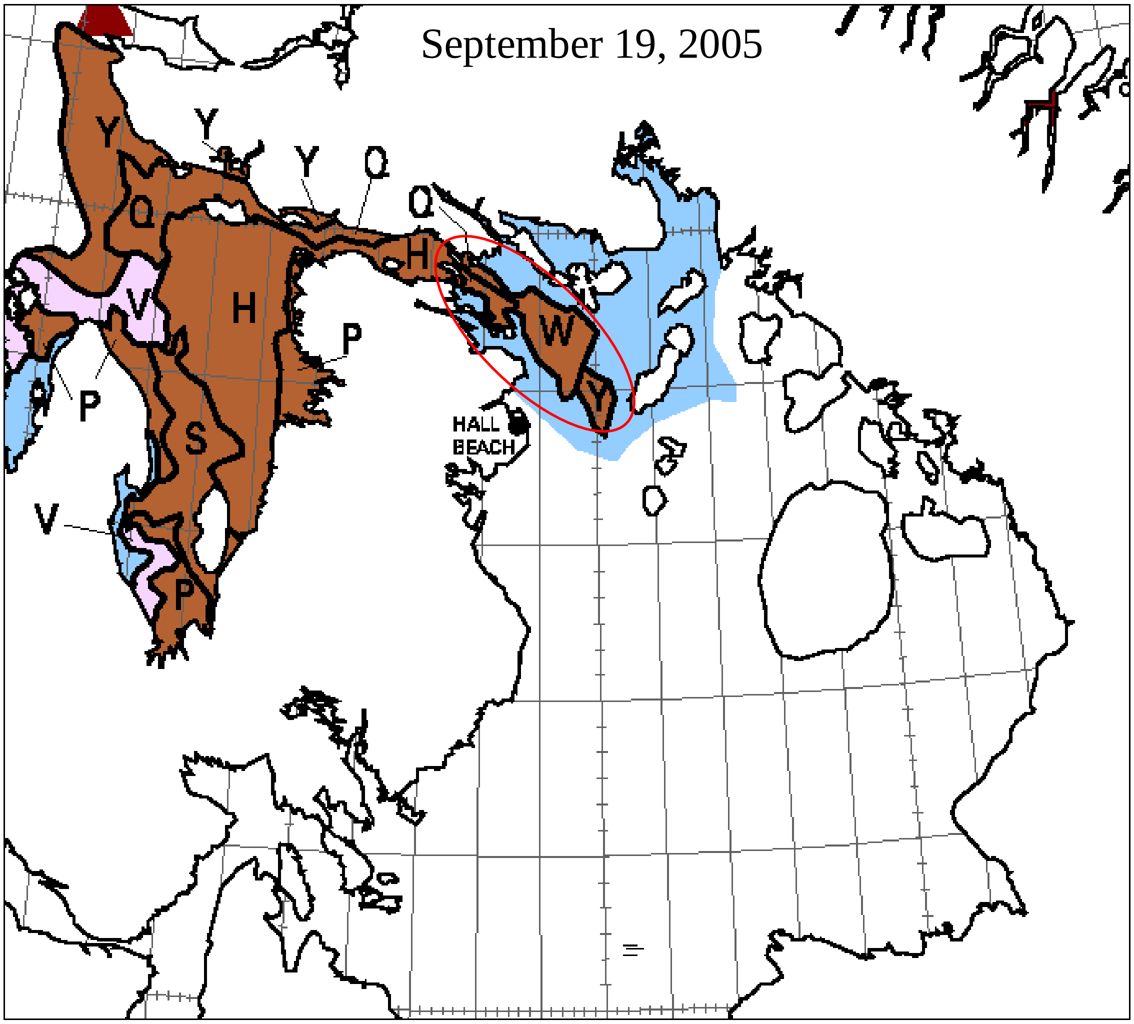

Figure 22: Example of old ice inclusions coming from Fury and Hecla Strait in late summer (CIS archive).

The ice pack coming from Fury and Hecla Strait follows surface currents (see Figure 23) and flows southward along the coast near Hall Beach. Ice is formed as open packs in concentrations up to 4/10, within which 1 to 3/10 of old ice in strips and patches can be observed.

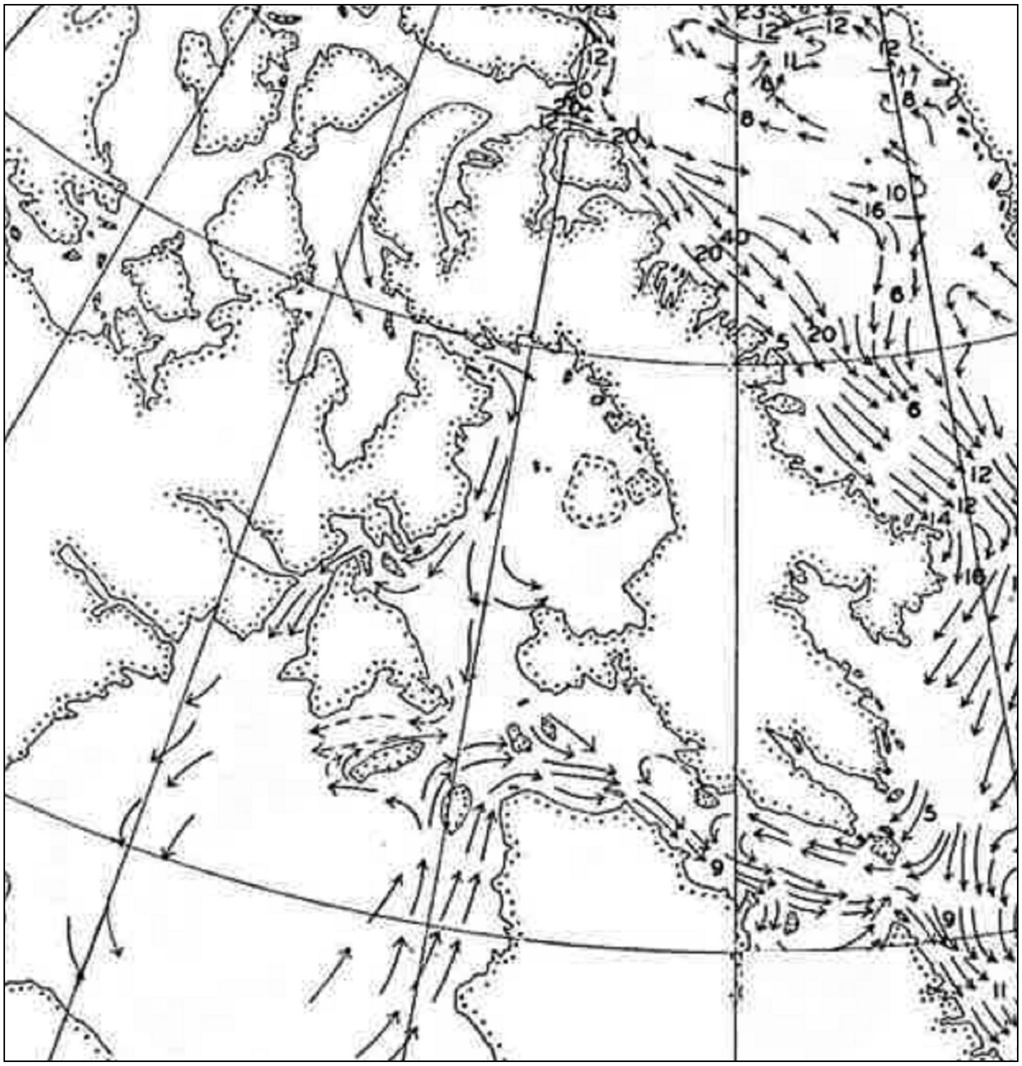

Figure 23: Surface currents in the Eastern Arctic (CHS / DFO, 1994).

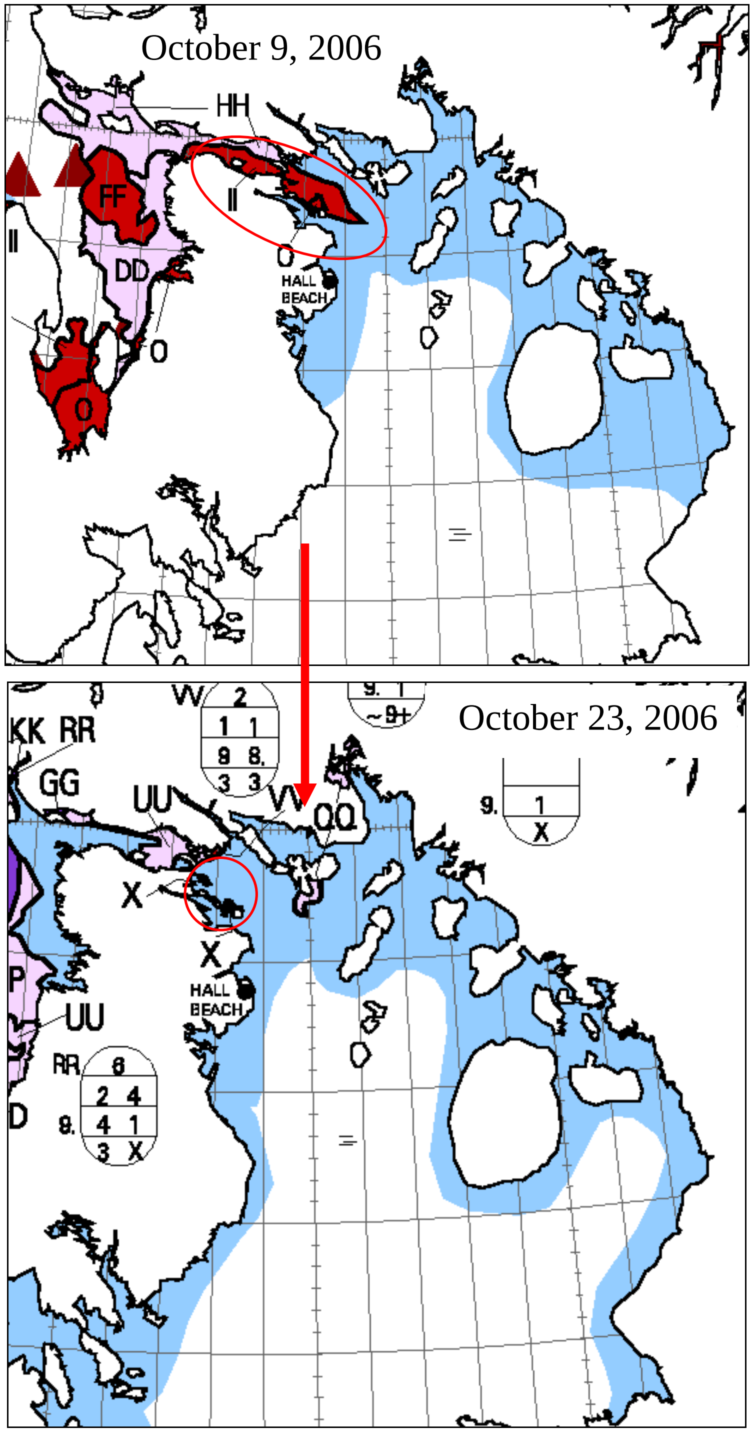

Figure 24: Example of ice evolution in fall (CIS archive).

The open ice pack coming from Fury and Hecla Strait on October 9 contained 3/10 of multi-year ice in strips and patches. Less than two weeks later, most of the young ice had melted, but a small pack of multi-year ice in 7/10 concentration remained close to the mouth of Fury and Hecla Strait.

Zone E – Steensby Inlet

The waterways in the access to the proposed port site in Steensby Inlet develop shore fast ice each winter along both of the routes. The southern anchor of the shore fast ice reaches Koch Island. The boundary between the shore fast ice and the mobile pack ice of the northern Foxe Basin represents a diverging ice edge over the winter with the result that an open water lead is usually always present off the fast ice edge. The additional benefit of this diverging condition is that no shear ridge occurs along the fast ice edge in winter. There is an average of 65 nautical miles of shore fast ice leading to the Steensby Port site which appears very level with few ridges or leads. Unlike in the case of Eclipse Sound, there is only a small possibility that old ice can become entrained in the ice cover.

There are only recent measurements of the shorefast ice in the Steensby area. Those measurements taken in 2008 support the notion that maximum thicknesses will reach about 2 metres. Although some areas were measured in excess of that, the vast majority of readings were closer to the 2-metre mark. Figure 25 shows the site location and its ice thickness measurements (in metres) for Steensby Inlet; the measurements were taken in May and June 2008.

The closest ice thickness measurement station in the region which has historical data is located at Hall Beach to the southwest of Steensby Inlet, where ice thickness has been recorded since 1959. An average ice thickness of 192 cm is observed at the end of the winter's growth (around April 15), with a standard deviation of 30 cm and extremes reaching up to 250 cm. Figure 26 shows median ice thickness through the year (October to July) for each decade since 1959. These thicknesses average 5% to 10% more than those recorded at Pond Inlet.

It should be noted that the MV Arctic presently trades all winter to the port of Deception Bay on the north coast of Quebec. The ice conditions the MV Arctic traverses to the port of Deception Bay are similar to those that are to be transited to reach Steensby Inlet. The vessel is able to contend with the shorefast ice with varying degrees of difficulty however the main impediment is always in the pressure ridges or shear zone. Vessels trading to Steensby will not have to contend with that type of condition.

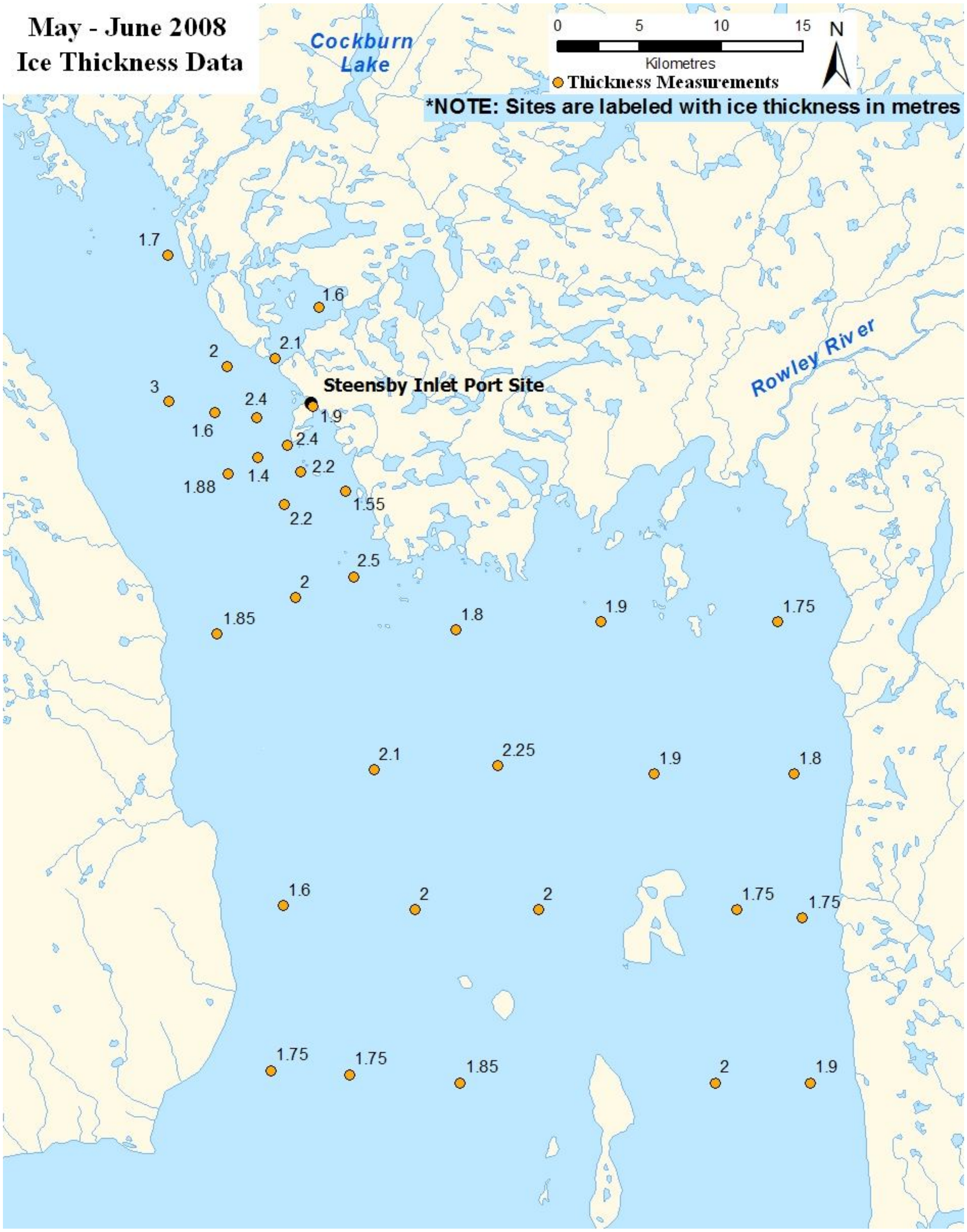

Figure 25: Ice Thickness Measurement Data of Steensby Inlet in May and June 2008.

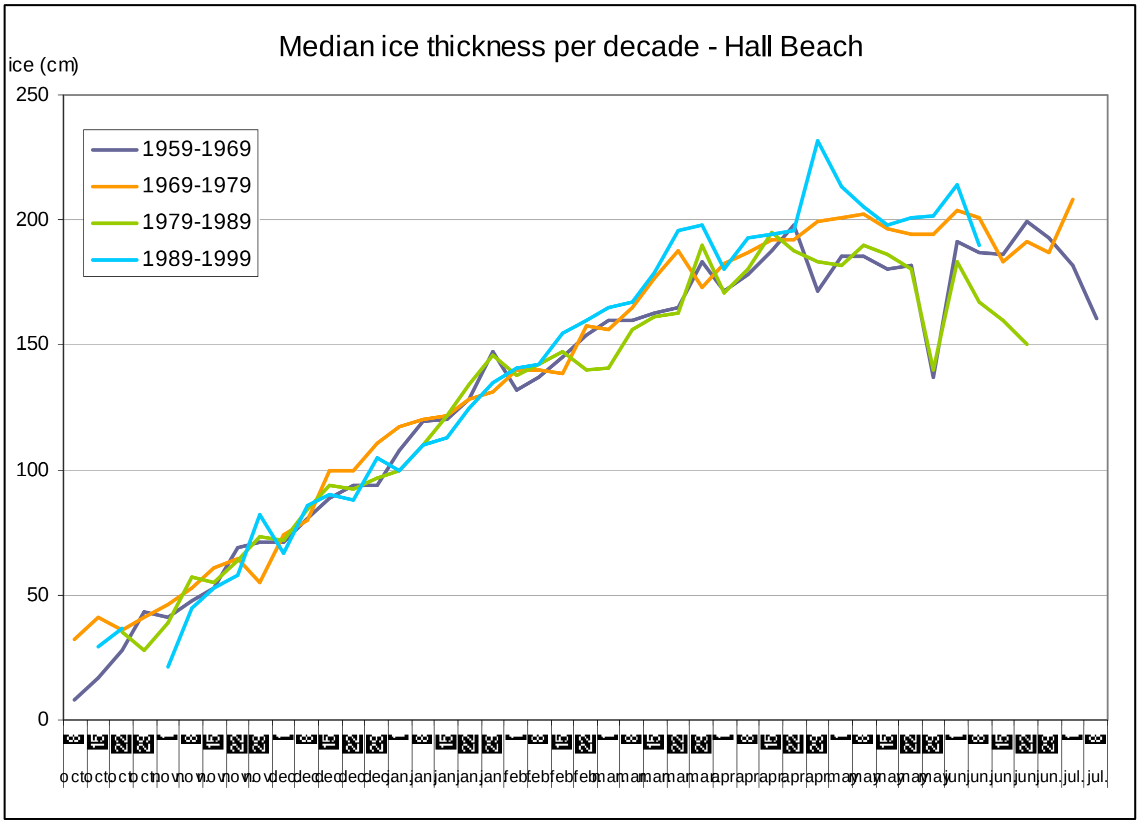

Figure 26: Ice thickness data from Hall Beach.[1] (Data: CIS)

1.2.3 Ice Season in the Accesses Channels to Steensby Inlet

The first sign of the spring break-up is the widening of the leads found in northern Foxe Basin and along the south coast of Baffin Island during the month of April and May as solar radiation increases in the region. Figure 27 is a satellite image from May 2, 2003 showing the expansion of the leads in the region.

[1] Note: Ice thickness data between 2000 and 2010 is too sparse to allow the calculation of a median that would be representative of that decade.

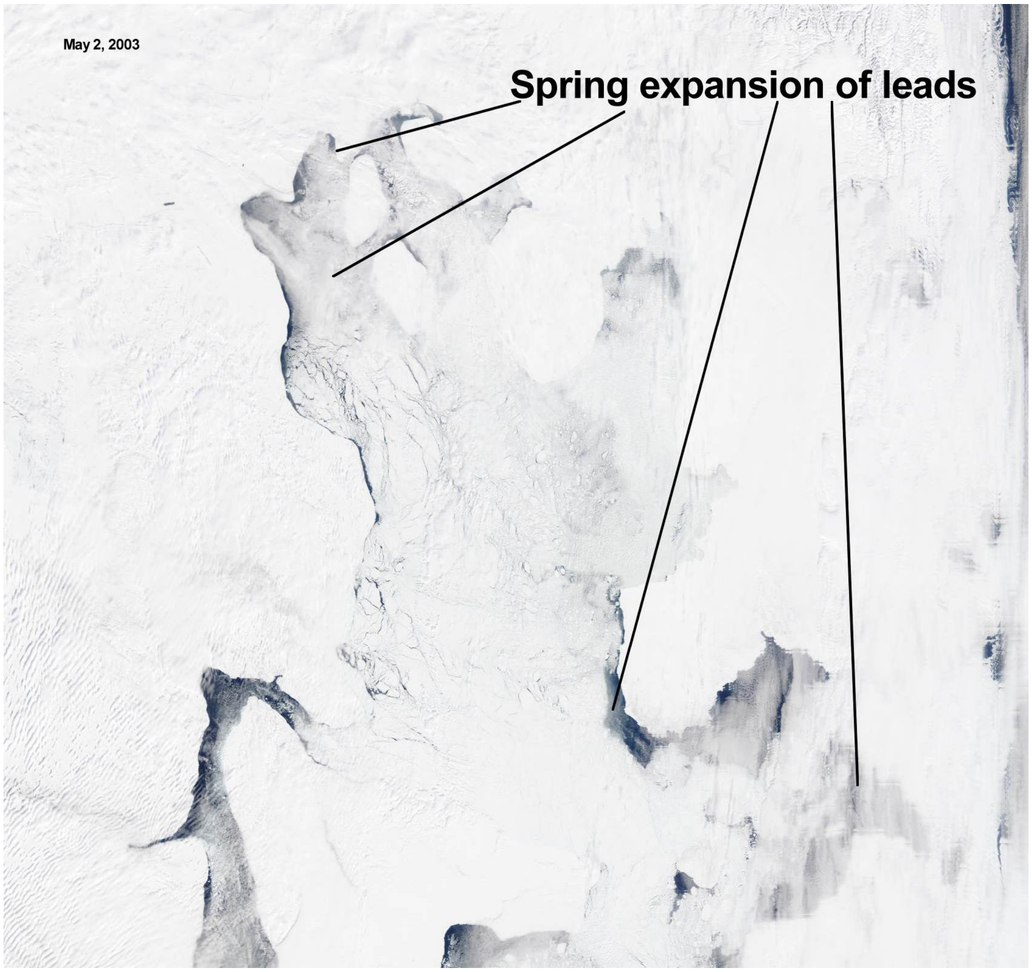

Figure 27: Satellite image of the spring expansion of leads in the access to Steensby May 2, 2003.

Ice reduction is slow and gradual during the months of June and July as Hudson Strait clears of sea ice and the ice edge in the Foxe Basin retreats northward. Figure 28**Erreur ! Source du renvoi introuvable.** is a satellite image from July 6, 2003 showing the typical ice conditions for the Foxe Basin in the early summer.

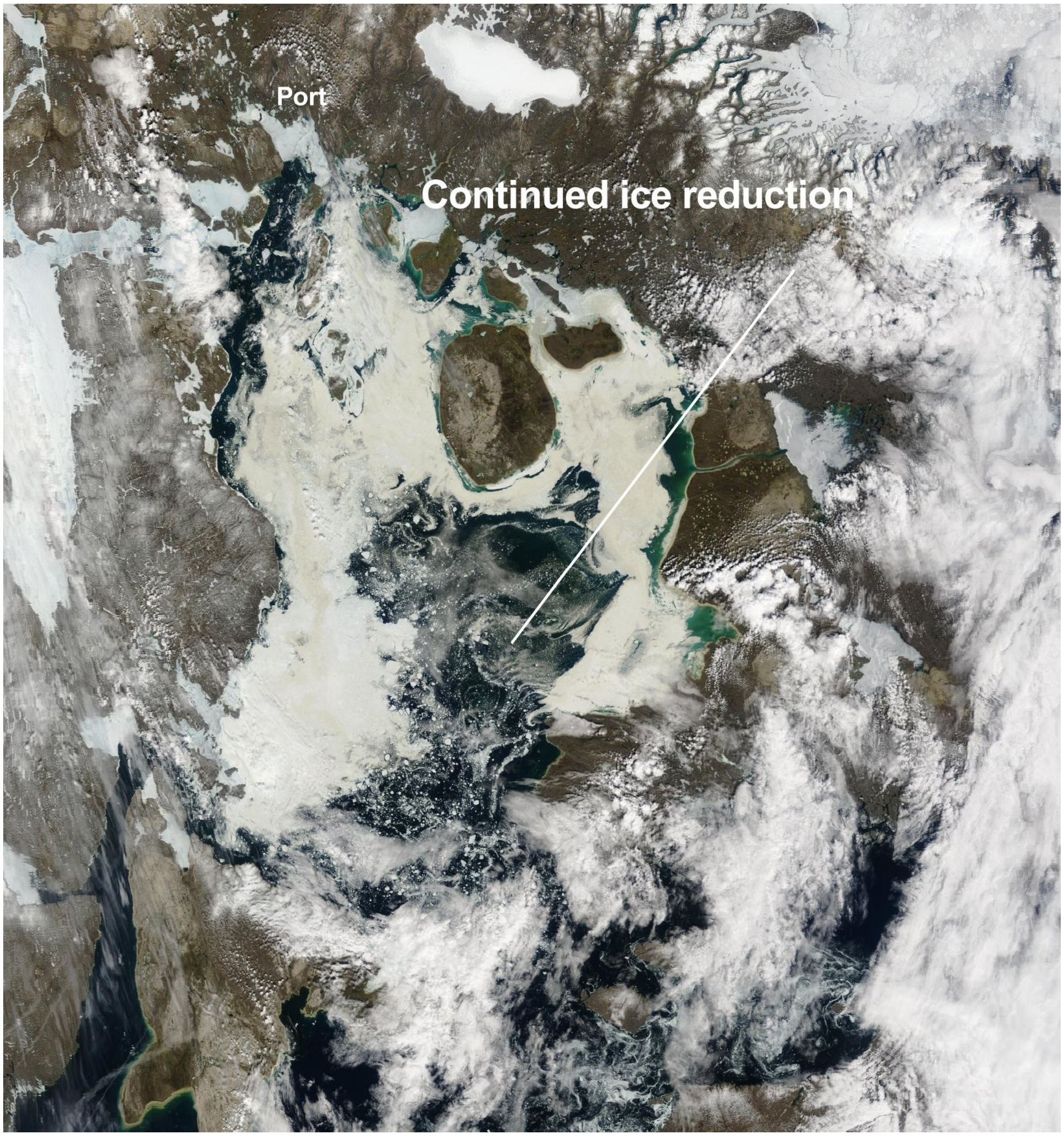

Figure 28: Satellite image showing the continued reduction in sea ice in the access to Steensby by the early summer July 6, 2003.

The fast ice of Steensby Inlet fractures during the second and third week of July. The fracture begins with the fracture of the lower portion of the fast ice in late June and this is followed by the complete fracture of the Inlet by the fourth week of July. The satellite images of Figure 29 illustrate the typical fracture sequence of the fast ice of Steensby Inlet.

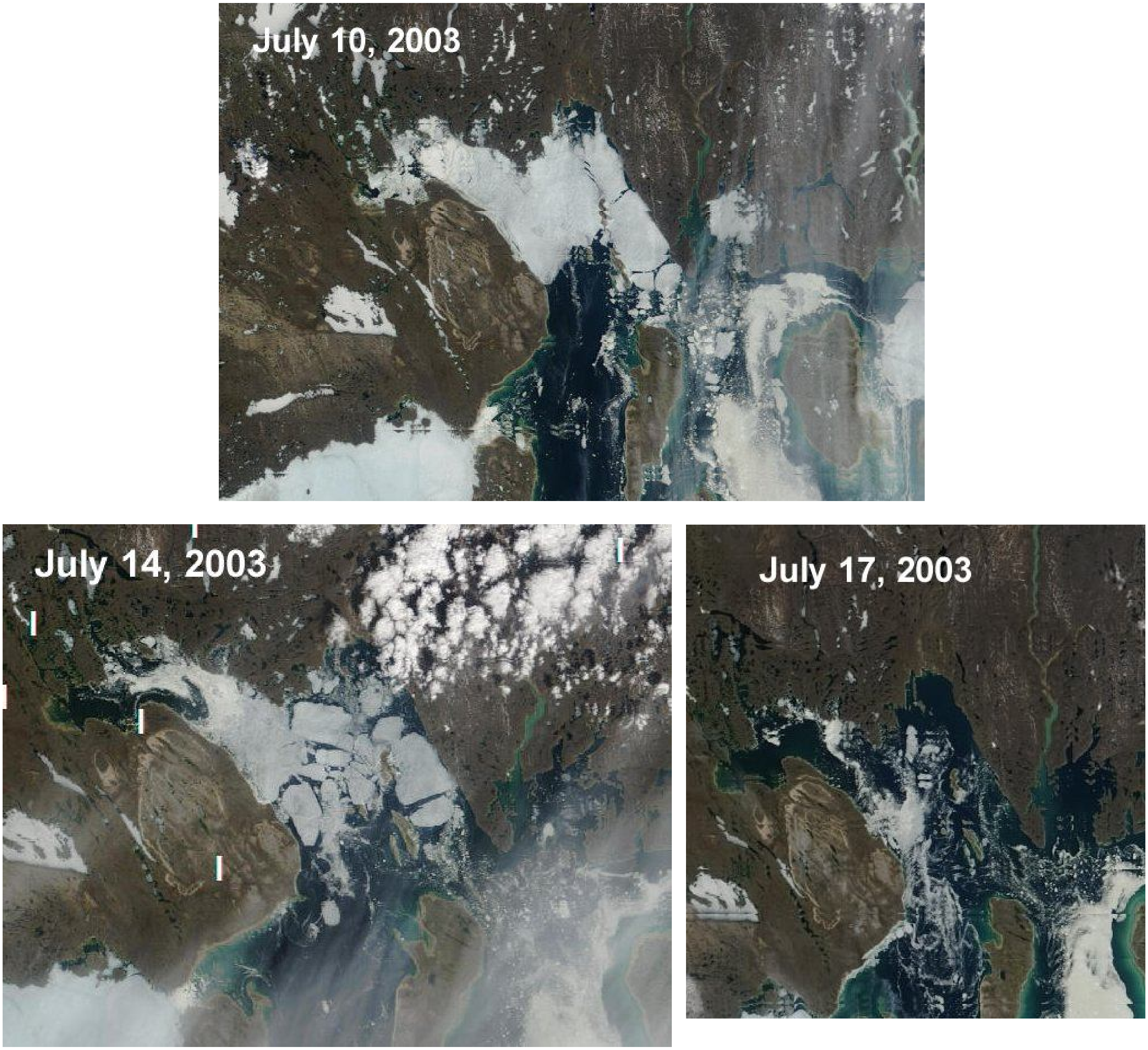

Figure 29: Typical fast ice fracture sequence for Steensby Inlet July 10 - 17, 2003

The pack ice of the Foxe Basin continues to reduce during the months of August and September as strips and patches of ice in the basin gradually melt, as illustrated in the satellite image of Figure 30 below. In rare cool summers some of this remnant pack ice will remain in the Foxe Basin to become second year ice by October 1. The concentration of this ice rarely exceeds 2/10 second year ice.

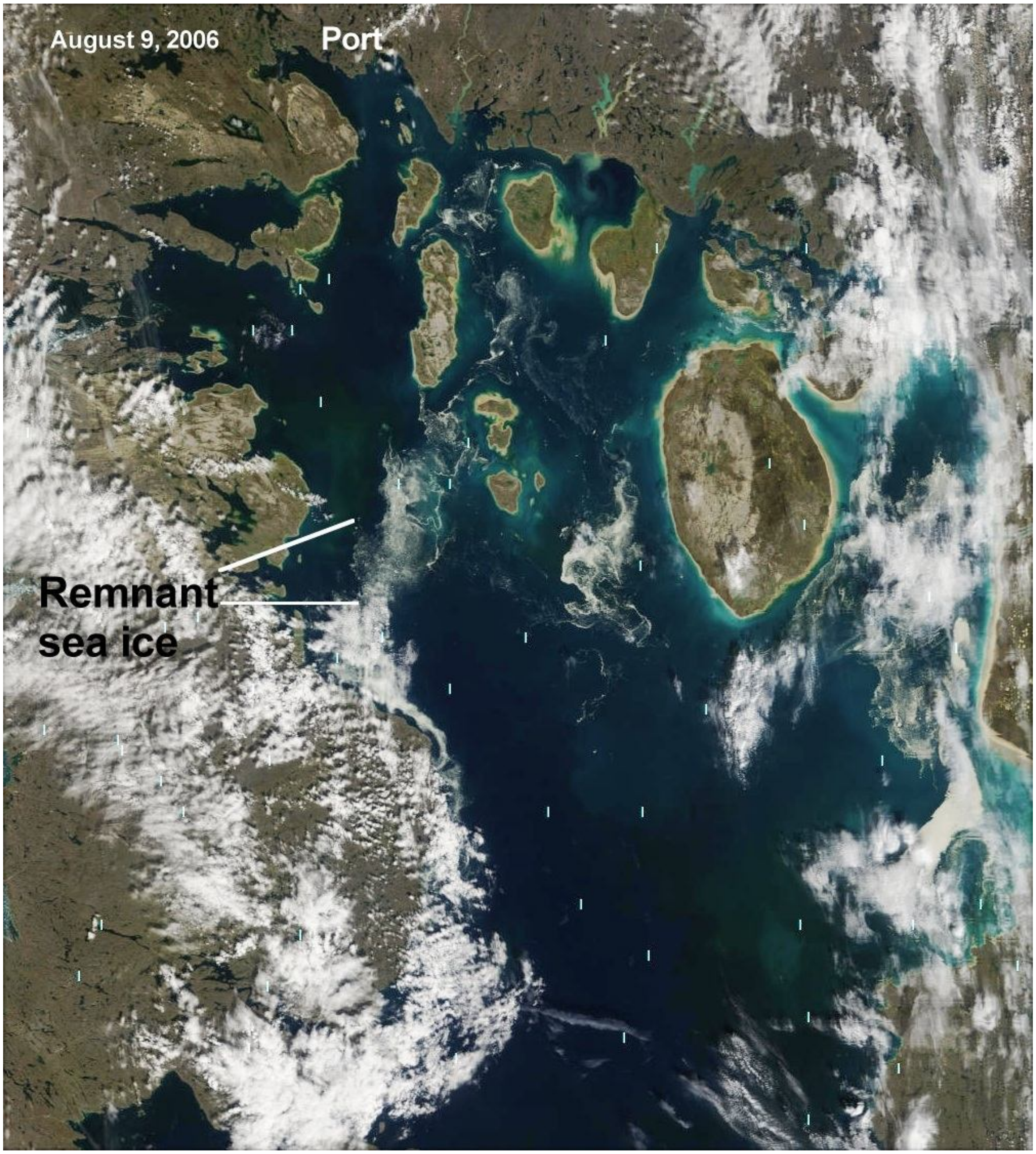

Figure 30: Satellite image of remnant decaying first year ice in the northern Foxe Basin August 9, 2006.

Sea ice can commonly occur in the access channels into the month of September before clearing, as indicated in the satellite image of Figure 31 from September 1, 2003. The incidence of first year ice surviving the summer's melt has reduced in recent years and now only occurs approximately in 10% of summers. The occurrence of remnant ice in the Foxe Basin does not preclude the use of market vessels during the late summer period for the project although some measures as using an owner familiar with navigation in sea ice and experienced Ice Navigators would provide mitigation.

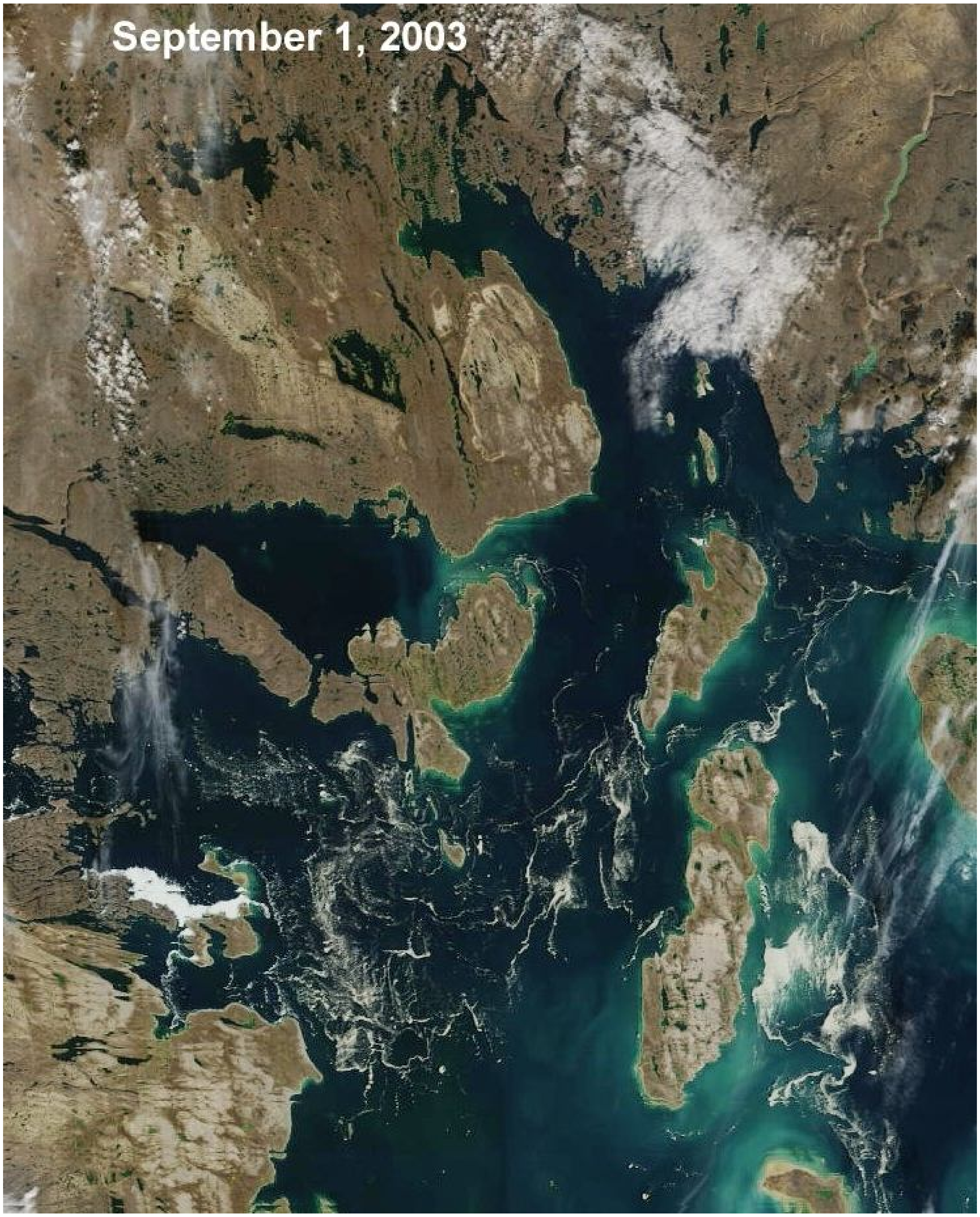

Figure 31: Satellite image showing remnant first year ice persisting into September along the shipping route to Steensby Inlet September 1, 2003.

Freeze-up starts in late October with new/young ice expanding southward from northern Foxe Basin and extending eastward through Hudson Strait in December. Figure 32 is a satellite image showing the expansion of ice formation in the northern Foxe Basin while Figure 33 shows the advancement of ice through Hudson Strait in December.

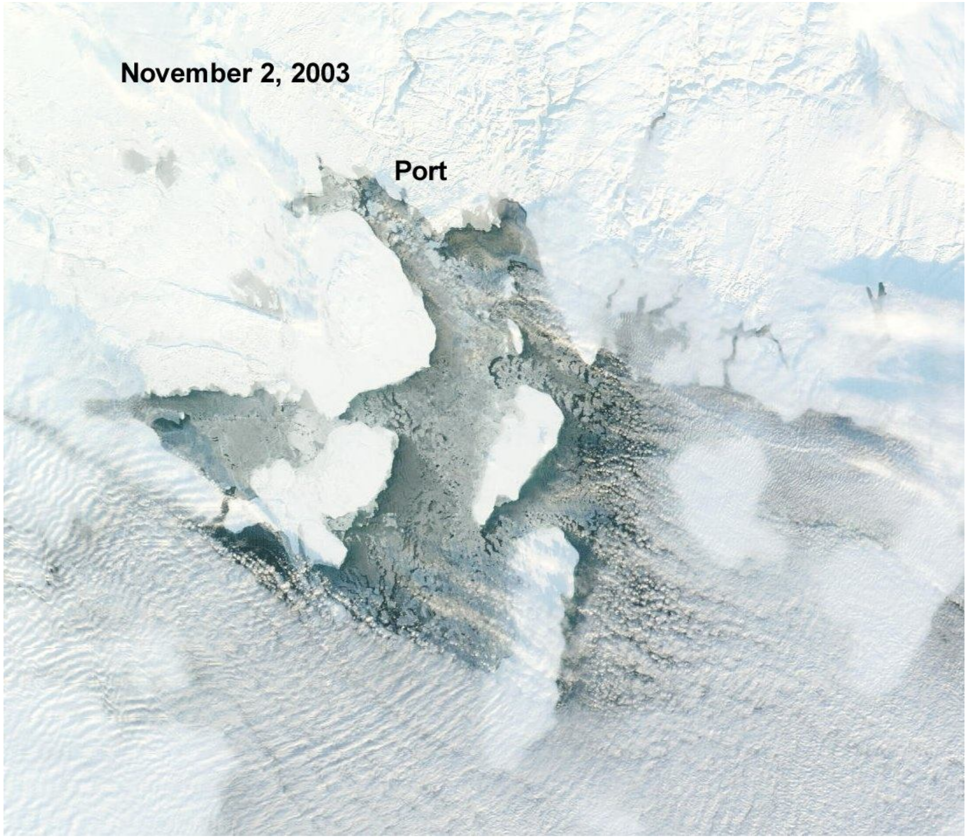

Figure 32: Satellite image showing the advancement of new/young ice in the northern Foxe Basin during freeze-up on November 2, 2003.

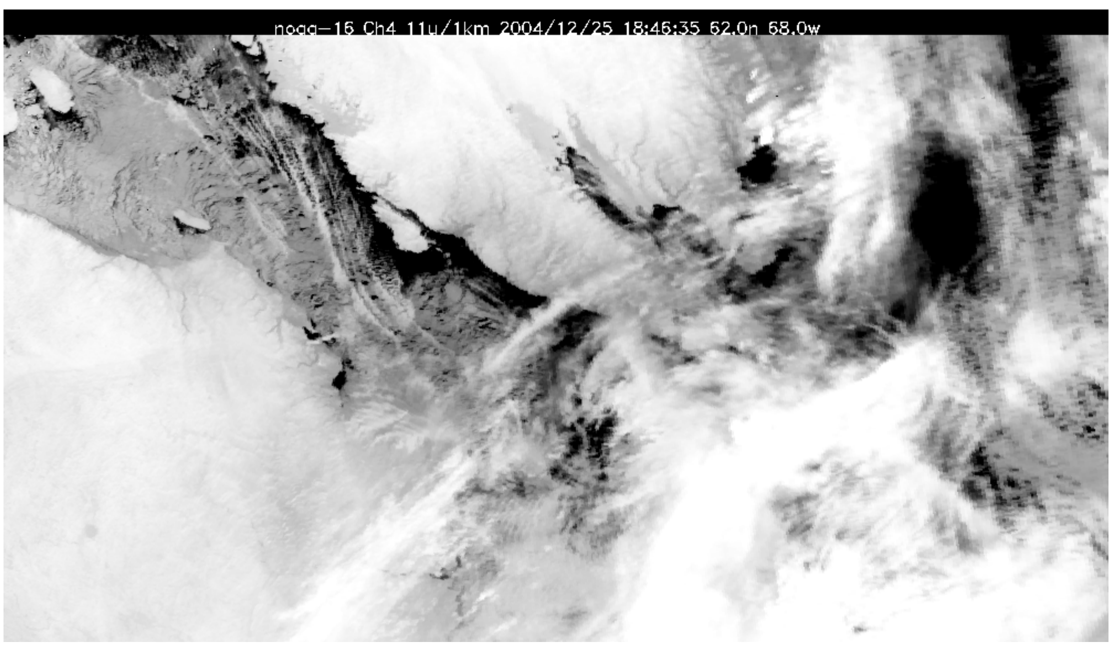

Figure 33: Satellite image showing the ice advance through Hudson Strait on December 25, 2004.

2 Vessel Access to North Baffin Sites and Steensby Inlets by Ice Class

Enfotec used the results of the review of the ice conditions presented in Section 2.0 to determine the accessibility of each port option by vessel ice class. The ability of a ship to transit ice covered waters is determined by the vessel's ice class, a notation applied to the vessel's class certificate based on the amount of ice strengthening. Each classification society that is part of the International Association of Classification Societies (IACS), as well as the governments of Canada and Russia, has a set of rules they use to classify ships based on the amount of ice strengthening contained in the vessel. There is general agreement amongst the various players on the rules that govern vessel designed for use in the Baltic and these are often called the Finnish-Swedish Baltic Ice Classes. However, the rules defined by IACS members as well from Canada and Russia that applied to polar vessels were highly variable with little agreement amongst the groups.

In August of 2006, after many years of study, IACS adopted the unified requirements for polar vessels to overcome this discrepancy. The IACS Unified Requirements for Polar Vessels will now be the standard by which all IACS members will classify Polar Vessels built after July 1, 2007. It should be noted that there are now two sets of ice class rules in existence: the Finnish-Swedish Baltic Ice Classes (the familiar Ice Class 1A, 1B, 1C etc) as well as the new Polar Classes, intended for vessels that navigate in polar ice conditions. The general operating profile of the various Polar Classes (denoted PC) are described in Table 1 below.

Table 1: IACS Polar Class Descriptions.

Polar Class	Ice Description
PC 1	Year-round operation in all Polar waters
PC 2	Year-round operation in moderate multi-year ice conditions
PC 3	Year-round operation in second-year ice with old ice inclusions
PC 4	Year-round operation in thick first-year ice with old ice inclusions
PC 5	Year-round operation in medium first-year ice with old ice inclusions
PC 6	Summer/Autumn operation in medium first-year ice with old ice inclusions
PC 7	Summer/Autumn operation in thin first-year ice with old ice inclusions

The inevitable question arises as to how these new Polar Classes compare to the previous ice classes to which existing vessels have been built. Table 2 is an estimate of equivalency that Enfotec has developed based on a combination of the operational profiles and construction standards of the various classes. There is an overlap between the top two Finnish-Swedish classes and the bottom two Polar Classes with the PC 6 being generally equivalent to the 1A/1A Super and the PC 7 being equivalent to 1B. **The equivalencies noted below are Enfotec's estimates only as there are no officially recognized equivalencies accepted by government agencies or IACS for the Polar Classes!**

Table 2: Enfotec's Table of Nominal Polar Ice Class Equivalencies.

Polar Class	CAC	ASPPR	DNV	RMRS
PC-1	CAC 1	AC 10	POLAR-30	LU-9
PC-2	CAC 2	AC 8	POLAR-25	LU-9
PC-3	CAC 3	AC 6	POLAR-20	LU-8
PC-4	CAC 3	AC 4	POLAR-15	LU-7
PC-5	CAC 4	AC 3	POLAR-10	LU-6
PC-6		AC 2	Ice-10 Ice 1A*	LU-5
PC-7		Type B	Ice-05 Ice-1A	LU-4

Using the guidelines of the new Polar Classes Enfotec has analyzed the potential access windows of ships by ice class to each of Milne and Steensby Inlet. This work used the parameters of the Arctic Shipping Pollution Prevention Regulations (ASPPR) and the Arctic Ice Regimes Shipping System (AIRSS) to determine estimated access dates by ice class.

There are two aspects to the shipping control provisions of the ASPPR: the Zone/Date system of the original 1972 regulations and the Arctic Ice Regime Shipping System (AIRSS) of the 1996 amendment to the regulations (Transport Canada 1996). The Zone/Date system dates from the original 1972 enactment and divides the waterways of the Canadian Arctic north of 60°N into16 Shipping Safety Control Zones, as illustrated in Figure 34. Access to each zone is controlled by a table of entry and exit dates based on the ice classification of the vessel under the regulations as described in Table 3. The existing range of entry and exit dates only applies to vessels classed as "Arctic Class" or "Type" (the Type vessels follow the equivalency to the Finnish-Swedish Baltic rules) from the original 1972 regulations.

The Zone/Date system was the mainstay of the shipping control of ASPPR for many years. However, with experience it became apparent that the ice conditions found in the Canadian Arctic were far more variable than what could be described in a rigid zone/date system (CAC 1993). There were many examples of vessels encountering severe ice conditions within the allowable access windows and other examples where vessels were denied access to areas of light ice conditions. Under Clause 6 (3) of the original ASPPR regulations, ships were allowed to proceed into a zone before the opening date or after the closing date if the Master could demonstrate that the ice conditions to be found in the intended zone of entry were no worse than those to be found in a zone the vessel would otherwise be allowed to enter on that date. For example, if a high concentration of multi-year ice was to be encountered by a vessel along its intended route and the operator could find a similar ice condition in a zone for which the vessel was allowed entry, then permission was granted to enter the zone outside of the published zone date for the vessel. Interpretation was difficult at the best of times or, alternatively, the ship owner could apply for an exemption based on predicted ice conditions no less than one year in advance.

Table 3: Allowable Entry Dates by Ice Class and Zone Date.

	Col. I	Col. II	Col. III	Col. IV	Col. V	Col. VI	Col. VII	Col. VIII	Col. IX	Col. X	Col. XI	Col. XII	Col. XIII	Col. XIV	Col. XV	Col. XVI	Col. XVII
Item	Category	Zone 1	Zone 2	Zone 3	Zone 4	Zone 5	Zone 6	Zone 7	Zone 8	Zone 9	Zone 10	Zone 11	Zone 12	Zone 13	Zone 14	Zone 15	Zone 16
1.	Arctic Class 10	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year
2.	Arctic Class 8	July 1 to Oct. 15	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year
3.	Arctic Class 7	Aug. 1 to Sept. 30	Aug. 1 to Nov. 30	July 1 to Dec. 31	July 1 to Dec. 15	July 1 to Dec. 15	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year	All Year
4.	Arctic Class 6	Aug. 15 to Sept. 15	Aug. 1 to Oct. 31	July 15 to Nov. 30	July 15 to Nov. 30	Aug. 1 to Oct. 15	July 15 to Feb. 28	July 1 to Mar. 31	July 1 to Mar. 31	All Year	All Year	July 1 to Mar. 31	All Year	All Year	All Year	All Year	All Year
5.	Arctic Class 4	Aug. 15 to Sept. 15	Aug. 15 to Oct. 15	July 15 to Oct. 31	July 15 to Nov. 15	Aug. 15 to Sept. 30	July 20 to Dec. 31	July 15 to Jan. 15	July 15 to Jan. 15	July 10 to Mar. 31	July 10 to Feb. 28	July 5 to Jan. 15	June 1 to Jan. 31	June 1 to Feb. 15	June 15 to Feb. 15	June 15 to Mar. 15	June 1 to Feb. 15
6.	Arctic Class 3	Aug. 20 to Sept. 15	Aug. 20 to Sept. 30	July 25 to Oct. 15	July 20 to Nov. 5	Aug. 20 to Sept. 25	Aug. 1 to Nov. 30	July 20 to Dec. 15	July 20 to Dec. 31	July 20 to Jan. 20	July 15 to Jan. 25	July 5 to Dec. 15	June 10 to Dec. 31	June 10 to Dec. 31	June 20 to Jan. 10	June 20 to Jan. 31	June 5 to Jan. 10
7.	Arctic Class 2	No Entry	No Entry	Aug. 15 to Sept. 30	Aug. 1 to Oct. 31	No Entry	Aug. 15 to Nov. 20	Aug. 1 to Nov. 20	Aug. 1 to Nov. 30	Aug. 1 to Dec. 20	July 25 to Dec. 20	July 10 to Nov. 20	June 15 to Dec. 5	June 25 to Nov. 22	June 25 to Dec. 10	June 25 to Dec. 20	June 10 to Dec. 10
8.	Arctic Class 1A	No Entry	No Entry	Aug. 20 to Sept. 15	Aug. 20 to Sept. 30	No Entry	Aug. 25 to Oct. 31	Aug. 10 to Nov. 5	Aug. 10 to Nov. 20	Aug. 10 to Dec. 10	Aug. 1 to Dec. 10	July 15 to Nov. 10	July 1 to Nov. 10	July 15 to Oct. 31	July 1 to Nov. 30	July 1 to Dec. 10	June 20 to Nov. 30
9.	Arctic Class 1	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 25 to Sept. 30	Aug. 10 to Oct. 15	Aug. 10 to Oct. 31	Aug. 10 to Oct. 31	Aug. 1 to Oct. 31	July 15 to Oct. 20	July 1 to Oct. 31	July 15 to Oct. 15	July 1 to Nov. 30	July 1 to Nov. 30	June 20 to Nov. 15
10.	Type A	No Entry	No Entry	Aug. 20 to Sept. 10	Aug. 20 to Sept. 20	No Entry	Aug. 15 to Oct. 15	Aug. 1 to Oct. 25	Aug. 1 to Nov. 10	Aug. 1 to Nov. 20	July 25 to Nov. 20	July 10 to Oct. 31	June 15 to Nov. 10	June 25 to Oct. 22	June 25 to Nov. 30	June 25 to Dec. 5	June 20 to Nov. 20
11.	Type B	No Entry	No Entry	Aug. 20 to Sept. 5	Aug. 20 to Sept. 15	No Entry	Aug. 25 to Sept. 30	Aug. 10 to Oct. 15	Aug. 10 to Oct. 31	Aug. 10 to Oct. 31	Aug. 1 to Oct. 31	July 15 to Oct. 20	July 1 to Oct. 25	July 15 to Oct. 15	July 1 to Nov. 30	July 1 to Nov. 30	June 20 to Nov. 10
12.	Type C	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 25 to Sept. 25	Aug. 10 to Oct. 10	Aug. 10 to Oct. 25	Aug. 10 to Oct. 25	Aug. 1 to Oct. 25	July 15 to Oct. 15	July 1 to Oct. 25	July 15 to Oct. 10	July 1 to Nov. 25	July 1 to Nov. 25	June 20 to Nov. 10
13.	Type D	No Entry	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 10 to Oct. 5	Aug. 15 to Oct. 20	Aug. 15 to Oct. 20	Aug. 5 to Oct. 20	July 15 to Oct. 10	July 1 to Oct. 20	July 30 to Sept. 30	July 10 to Nov. 10	July 5 to Nov. 10	July 1 to Oct. 31
14.	Type E	No Entry	No Entry	No Entry	No Entry	No Entry	No Entry	Aug. 10 to Sept. 30	Aug. 20 to Oct. 20	Aug. 20 to Oct. 15	Aug. 10 to Oct. 20	July 15 to Sept. 30	July 1 to Oct. 20	Aug. 15 to Sept. 20	July 20 to Oct. 31	July 20 to Nov. 5	July 1 to Oct. 31

It came clear that the practical application of the Zone/Date system resulted in vessels accessing areas regardless of the actual safety of the prevailing ice conditions in the area. To counter this problem, Transport Canada proposed the introduction of the Ice Regime Shipping Control System (IRSCS) as part of ASPPR (Transport Canada, 1989). In this new system, an "Ice Regime" is defined as a region of generally consistent ice conditions based on a simple arithmetic calculation that produces an "Ice Numeral" that combines the ice regime with the vessel's ability to navigate in the region.

SHIPPING SAFETY CONTROL ZONES

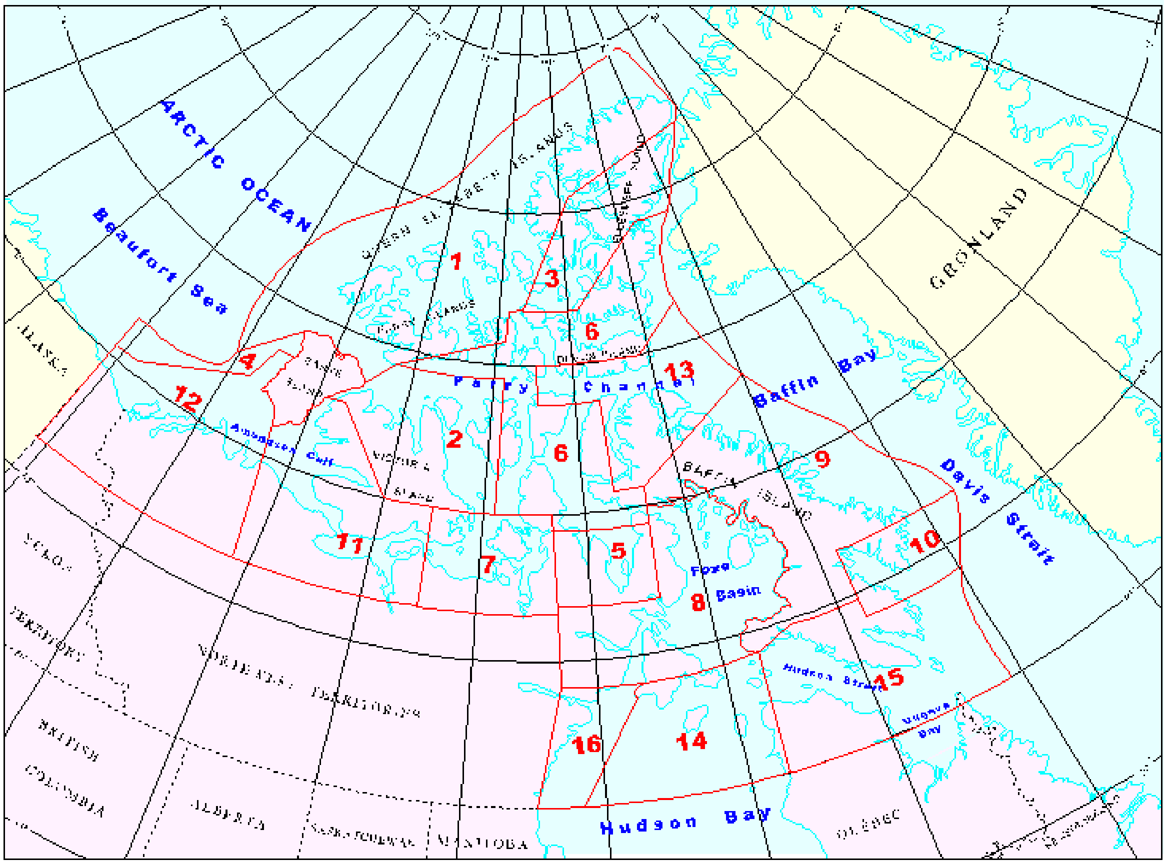

Figure 34: Arctic Shipping Safety Control Zones.

Every ice type (including open water) has a numerical value that is dependent on the ice category of the vessel. This number is called an Ice Multiplier. The value of the Ice Multiplier reflects the level of risk or operational constraint that the particular ice type poses to each category of vessel. Table 4 displays the ice multipliers for each type of ice and vessel ice class as contained in the AIRSS regulations.

Table 4: AIRSS Ice Multiplier Table

I	II	III	IV	V	VI	VII	VIII	IX	X	XI
SHIP CATEGORY	ICE TYPE	OPEN WATER	GREY ICE	GREY WHITE ICE	THIN FIRST YEAR 1st STAGE	THIN FIRST YEAR 2nd STAGE	MEDIUM FIRST YEAR	THICK FIRST YEAR	SECOND YEAR	MULTI YEAR
	ICE TYPE SYMBOL	OW	G	GW	FY	FY	MFY	TFY	SY	MY
CAC 3		2	2	2	2	2	2	2	1	-1
CAC 4		2	2	2	2	2	2	1	-2	-3
Type A		2	2	2	2	2	1	-1	-3	-4
Type B		2	2	1	1	1	-1	-2	-4	-4
Type C		2	2	1	1	-1	-2	-3	-4	-4
Type D		2	2	1	-1	-1	-2	-3	-4	-4
Type E		2	1	-1	-1	-1	-2	-3	-4	-4

For any ice regime, an Ice Numeral is calculated by taking the sum of the products of the concentration of the ice types present (in tenths) in the region and their ice multipliers in the following equation:

IN = (Ca IMa) + (Cb IMb) + ...

Where: IN- Ice Numeral Ca- concentration in tenths of ice type "a" IMa- Ice Multiplier for ice type “a” (see Table 4). The term on the right hand side of the equation (a, b, c, etc.) is repeated for as many ice types as may be present, including open water. The Ice Numeral is therefore unique to the particular ice regime and the ice class of ship operating within its boundaries. A Master would acquire ice information along the intended route and would not navigate into an area that contained a negative numeral for the vessel.

Using the general equivalencies of Table 2 with the numerals of Table 4, we have applied the AIRSS calculations to the data tabulations completed for Milne and Steensby Inlet options. The results of this analysis are tables of access dates by vessel ice class for each route option. These results are discussed in the following subsections for each route option.

2.1 *Vessel Access by Ice Class – North Baffin Sites*

Table 5 presents the access by ice class for North Baffin Sites, as determined in this study.

Table 5: Vessel Access to North Baffin Sites by Ice Class

Ship Category		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PC 1	ASPPR Zones	NA											
	AIRSS	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••
PC 2	ASPPR Zones	NA											
	AIRSS	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••
PC 3	ASPPR Zones	NA											
	AIRSS	▪▪▪	▪▪▪	▪▪▪ •••	•••	•••	•••	•••	•••	•••	•••	•••	▪▪▪
PC 4	ASPPR Zones	NA											
	AIRSS				1 •••	•••	•••	•••	•••	•••	•••	••• 10	
PC 5	ASPPR Zones	NA											
	AIRSS						20 •••	•••	•••	•••	•••	••• 10	
PC 6 Type A	ASPPR Zones						25 •••	•••	•••	•••	••• 22		
	AIRSS								1 •••	•••	••• 20		
PC 7 Type B	ASPPR Zones							15 •••	•••	•••	••• 15		
	AIRSS								1 •••	•••	••• 15		
Type C	ASPPR Zones							15 •••	•••	•••	••• 10		
	AIRSS								1 •••	•••	••• 10		
Type D	ASPPR Zones							30 •••	•••	••• 30			
	AIRSS								1 •••	••• 30			
Type E	ASPPR Zones								15 •••	••• 20			
	AIRSS								1 •••	••• 30			

▪▪▪▪▪▪▪▪▪▪ Period when old ice could impede vessel.

Access to North Baffin Sites is via only one zone, that of Zone 13 although the routes utilized for this study also included options through Zone 9 (see Figure 34). The ASPPR zone dates listed in Table 5 above only considered the Zone 13 dates. The numbers listed on either side of the lines denotes the dates within the month when shipping could start or stop for that class of vessel. Zone dates do not exist for the PC 5 to PC 1 classes in the ASPPR.

For the Type or "Baltic Class" vessels, the limiting ice type is the first ice type where a negative numeral is encountered for that class, as listed in Table 4. What is readily apparent from this graph is that there is little to be gained by using Baltic ice class vessels in the Canadian Arctic. This is because the transition from thick first year ice to open water is abrupt in the summer and the fall freeze-up is so rapid that the ice transitions through the young ice stages are so rapid that the window closes on all of the Baltic ice classes at nearly the same time.

In most cases the Zone date system provides access into ice conditions that are beyond the capabilities of these vessels. In the case of the access to Milne Inlet, the limiting factor is when the thick first year shore fast ice clears in Pond Inlet and Eclipse Sound. This usually does not occur until the end of July. For the fall freeze-up, the limitation is when first year ice growth occurs during the month of October.

For the Polar Classes of PC 1 to PC 5, the limiting factor is the concentration of old ice found in North Baffin Waters in the winter. Based on our analysis of the ice conditions in the access routes, we have identified that the minimum ice class required for year-round access to North Baffin is PC 3. However, we have highlighted the period from late November to late March in red where special care would be required for a PC 3 vessel navigating in the region. This is because the limiting old ice concentration to maintain a positive numeral for a PC 3 vessel is 6/10 concentration. Old ice concentrations above 6/10 occur regularly in central Baffin Bay in winter so careful route selection by this vessel would be required to avoid these areas. Our analysis of the ice conditions for this study indicated that this would be possible given the right technology on the vessel. However, a vessel of PC 2 construction would have less concern for this situation.

2.2 Vessel Access by Ice Class – Steensby Inlet

Table 6 presents the access by ice class for Steensby Inlet, as determined in this study. The ASPPR Zones that are transited to reach Steensby Inlet are Zones 15 and 8. The limiting zone is Zone 8 so these are the dates shown in Table 6. The ice limitation for access by the "Type" or "Baltic" ice classes for Steensby Inlet is the timing of clearing of the first year ice in the Foxe Basin, which usually does not completely clear in most years until mid August. In addition, ice decay and melt out is slower in the Foxe Basin such that remnant strips and patches of ice can persist through the "open water" period, although these would not limit access by the Baltic ice classes. As with the Milne Inlet access, the limitation in the fall is the rapid development of first year ice in late October in the northern reaches of the Foxe Basin. Clearing occurs about two weeks later in the access to Steensby Inlet than for the access for Milne but the freeze-up tends to be about two to three weeks later as well.

For the Polar Class vessels, the limitation is the amount of old ice present in eastern Hudson Strait as well as in the Foxe Basin in the late fall and winter months. These old ice concentrations rarely exceed 2/10 concentration in these areas and the lowest PC class vessel to maintain a positive numeral in 2/10 old ice (when thick first year ice makes up the remainder of the matrix) is PC 5. However, there are patches of old ice that can exceed 2/10 concentration along the route to Steensby Inlet that will require special route selection by a PC 5 vessel. There period in the winter where this is most likely is marked as red on Table 6. A vessel constructed to PC 4 would have less concern for this issue.

Table 6: Vessel Access to Steensby Inlet by Ice Class

Ship Category		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
PC 1	ASPPR Zones	NA											
	AIRSS	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••
PC 2	ASPPR Zones	NA											
	AIRSS	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••
PC 3	ASPPR Zones	NA											
	AIRSS	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••
PC 4	ASPPR Zones	NA											
	AIRSS	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••	•••
PC 5	ASPPR Zones	NA											
	AIRSS	•••	▪▪▪	▪▪▪	▪▪▪	▪▪▪	•••	•••	•••	•••	•••	•••	•••
PC 6 Type A	ASPPR Zones								1 •••	•••	•••	••• 10	
	AIRSS									1 •••	•••	••• 10	
PC 7 Type B	ASPPR Zones								10 •••	•••	••• 31		
	AIRSS								10 •••	•••	••• 31		
Type C	ASPPR Zones								10 •••	•••	••• 25		
	AIRSS								10 •••	•••	••• 25		
Type D	ASPPR Zones								15 •••	•••	••• 20		
	AIRSS									20 •••	••• 25		
Type E	ASPPR Zones									20 •••	••• 20		
	AIRSS									20 •••	••• 25		

▪▪▪▪▪▪▪▪▪▪ Period when old ice could impede vessel

3 Potential Effect of Climate Change on Different Port Sites Options

In recent years, diminishing ice cover in the Canadian arctic has occurred and is directly tied to climate change. While there have been some exceptions, ice is generally forming later and clearing earlier than seen before. It is generally accepted that this trend will continue. Therefore, the project will need to ensure decisions taken today consider the long-term affects of possible and or likely changes to the ice conditions along the different routes and port sites.

While global temperatures may continue to rise, in the Arctic, the current pattern of ice growth will remain relatively unchanged. Except for a few years showing ice conditions outside the normal trend, ice thickness at Hall Beach (closest measurement station from Steensby Inlet) shows a regular evolution trend from October to July between 1959 and 1999 (see Appendix 1). Although freeze-up and break-up occur earlier in the season, the overall ice growth pattern reaches similar thicknesses at the end of winter (more or less 200 cm by the end of April).

Freezing degree days in Hall Beach are recorded since 1969. Figure 35 shows a small variation in monthly cumulative value of freezing degree days between 1969 and 2010; this can relate to a recent known trend of warmer temperatures in the Arctic and globally. As well, the yearly total number of freezing degree days since 1981 displayed in Figure 36 shows a very slow decreasing trend.

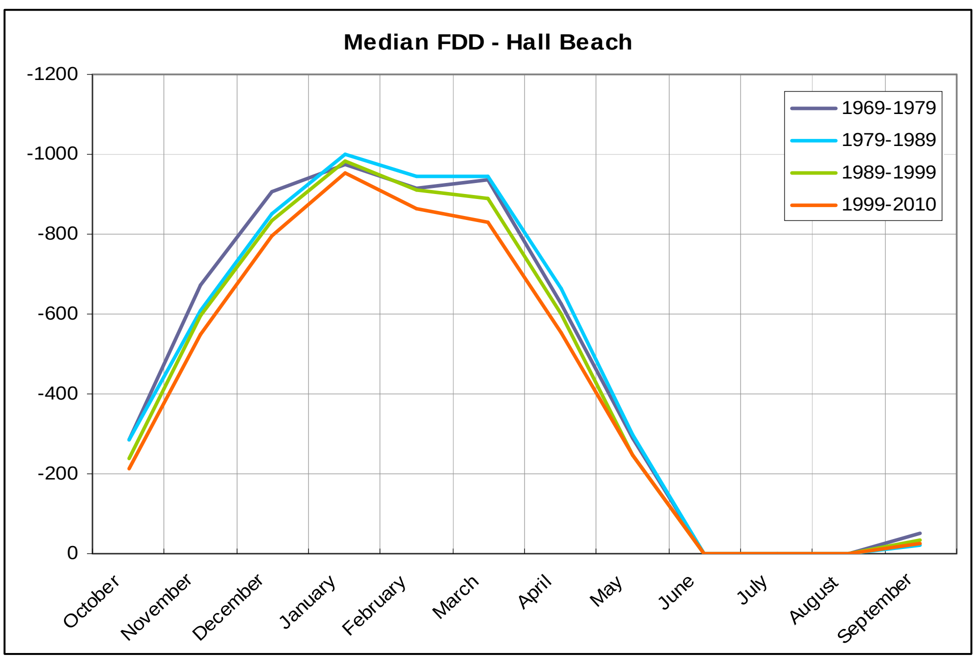

Figure 35: Median of monthly freezing degree-days in Hall Beach from 1969 to 2010 (data: CIS).

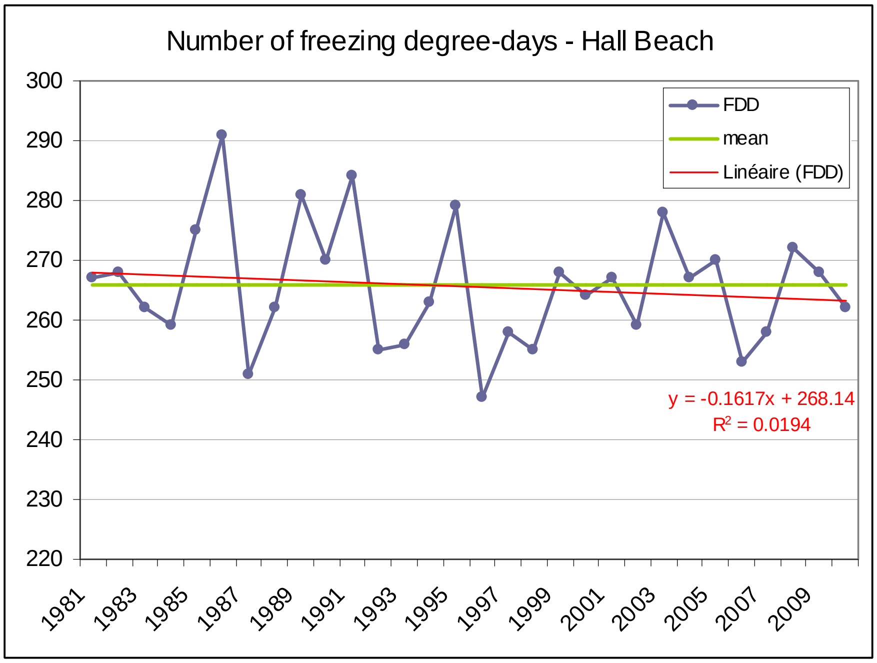

Figure 36: Variation in yearly total freezing degree-days in Hall Beach between 1981 and 2010 (data: CIS).

Even though temperatures are known to be warmer than before, freezing degree days in the Arctic are such that ice growth, while potentially diminished will continue to follow historical patterns. As a result, conditions will continue to ensure ice growth as per these patterns, but small variations in ice thickness can be expected.

Simply put, winter ice will remain a challenge to navigation for all but the most capable vessels. The potential for an increase in the amount of old ice presents a greater tactical challenge to navigation. Navigators will necessarily be warier of the increased presence of old ice. Old ice embedded in ice floes and in the pack ice in general is often difficult to identify, especially when there is a significant snow cover. This leads to an increased risk of unanticipated contact with multi-year ice. While the presence of multi-year ice in Foxe Basin is not unheard of, the concentration will always be higher in North Baffin: climate change will not bring conditions in Foxe Basin to a harsher level than those in North Baffin.

Depending on the progression of climate change, the amount of multi-year or older ice will certainly change and those affects will be most relevant to the North Baffin Sites. At worst, the pattern of migration of old ice will become less predictable and it will be more widespread. It is not likely that concentrations will increase to the point where a higher ice-class is required, although the risks to navigation will be elevated for North Baffin Sites.

Ocean currents and prevailing predominant wind patterns will likely remain unchanged. The effect will be that while ice conditions in the eastern arctic may change, the relative differences between areas will remain the same. For example, as defined earlier, vessels transiting the Baffin pack will contend with pressured, thick first year ice. In Foxe Basin, at the same time, conditions will be medium first year ice. We expect that the relative differences between these areas will remain, supporting into the future the choice of a site in Foxe Basin as being least intrusive.

4 Conclusions

This study provides a description of the ice conditions that occur along the access route to two potential port sites for the Mary's River iron ore project. This project was completed by Enfotec Technical Services for Baffinland Iron Mines Corporation. The following conclusions are made on ship access to each route option.

4.1 North Baffin Option

The conclusions for the North Baffin option are as follows:

Conclusion # 1

Due to the presence of high concentrations of old ice in Baffin Bay, Lancaster Sound and Eclipse Sound, a vessel of minimum ice class PC 3 is required for year-round access to Milne Inlet. However, special care would be required in route selection for this vessel and a PC 2 vessel may be more suitable.

Conclusion # 2

The shipping season for vessels of Baltic ice class design spans from August 1 to the end of September. Higher Baltic ice classes of Type C to A can extend the navigation season into the first 10 days of October. Due to the nature of the sea ice in the Canadian Arctic, there is little to be gained by using higher Baltic ice classes. **If a site were to be selected within Zone 9, the shipping season for Baltic Class vessels would be further reduced by about three weeks.**

Conclusion # 3

The 125 nautical miles of shore fast ice to be transited includes a 30 nautical mile section in Eclipse Sound that does contain, on occasion, concentrations of old ice that could make multiple track selections difficult in the mid-winter. Likewise, vessels entering Lancaster Sound will contend with old ice and the associated problem of maintaining a single track.

Conclusion # 4

The heavy ridging that can be expected at the entrance to and within Lancaster Sound has the potential to add significant delays to winter transits. This ridging, which has been known to be 20 m in depth, may at times be virtually impenetrable for periods of time while the ice remains under pressure. This may be narrowly viewed as a commercial consideration; however consequent long delays in vessel access to the port would almost certainly lead to congestion with several ships potentially affected. The Project would need to consider this possibility in determining winter shipping schedules.

4.2 Steensby Inlet Option

Conclusion # 5

Due to the presence of lower concentrations of old ice in eastern Hudson Strait in the mid-winter and in central Foxe Basin in the late fall and winter, a vessel of minimum ice class PC 5 is required for year-round access to Steensby Inlet. However, patches of old ice could exceed 2/10 concentration so special routing care would be required. A PC 4 vessel may be a more suitable vessel.

Conclusion # 6

The shipping season for vessels of Baltic ice class design spans from August 10 to the third week of October. As is the case with Milne Inlet, there is little to be gained by using higher Baltic ice classes.

4.3 Comparison of North Baffin and Steensby Port Options

A number of conclusions can be drawn by comparing the two port options as follows:

Conclusion # 7

The port option to Steensby Inlet would require a vessel two ice classes lower (PC 4/5) compared to Milne Inlet (PC 2/3). This is owing to the much lower concentrations of old ice found along the route to Steensby Inlet than is the case for Milne Inlet. It should be noted that the MV Arctic attempted early winter voyages into the eastern Canadian Arctic in early December in both 1986 and 1989 and had to abandon the voyages because of the heavy old ice concentrations and pressure in Baffin Bay just north of the entrance to Pond Inlet (the Canadian Coast Guard vessel CCGS Louis St. Laurent was with the MV Arctic in 1986 and the CCGS Sir John A MacDonald in 1989 and they both were also unable to contend with the ice conditions). However, the same MV Arctic now trades all winter to Deception Bay on the south side of Hudson Strait independently without any icebreaker escort through essentially similar ice conditions as those that lead to Steensby Inlet. This is an operational example of the difference between the ice conditions to these two port options.

Conclusion # 8

Although a preference has been stated by the project to use the eastern route in Foxe Basin, this route will require more manoeuvring. The effect of this may be increased rubble in the vessel track in the area of turns and course alterations. Transit times in the periods of heaviest ice conditions may be adversely affected due to the additional manoeuvring. Although the planned vessels will no doubt be able to contend with conditions along either route, from a planning point of view, it is always preferable not to restrict the navigators' options.

Conclusion # 9

The season for Baltic ice class vessels starts later for the Steensby Inlet option (August 10 as opposed to August 1 for Milne) but also extends later in the season to near the end of October which is almost a month later than for Milne Inlet. This provides Steensby an average of a three week longer "open water" shipping season than Milne Inlet. However, remnant drift ice in scattered ice floes remains longer in the access channels to Steensby Inlet than to Milne Inlet during the "open water" period. Nonetheless, there is a longer season of access by conventional vessels to Steensby Inlet than Milne Inlet.

Conclusion # 10

The access to Milne Inlet contains 125 nautical miles of shore fast ice while the access to the port in Steensby Inlet is through about 60 nautical miles of fast ice, giving Milne 65 nautical miles more fast ice in which the vessels will have to manage multi ship transits in winter. In addition, the Steensby Inlet fast ice appears level with no shear ridge at the entrance and only rare inclusions of old ice. The shore fast ice of Eclipse Sound is subject to ridging during freeze-up and often contains old ice inclusions. For these reasons Steensby Inlet has much more favourable fast ice conditions for winter navigation than the fast ice leading to North Baffin Sites.

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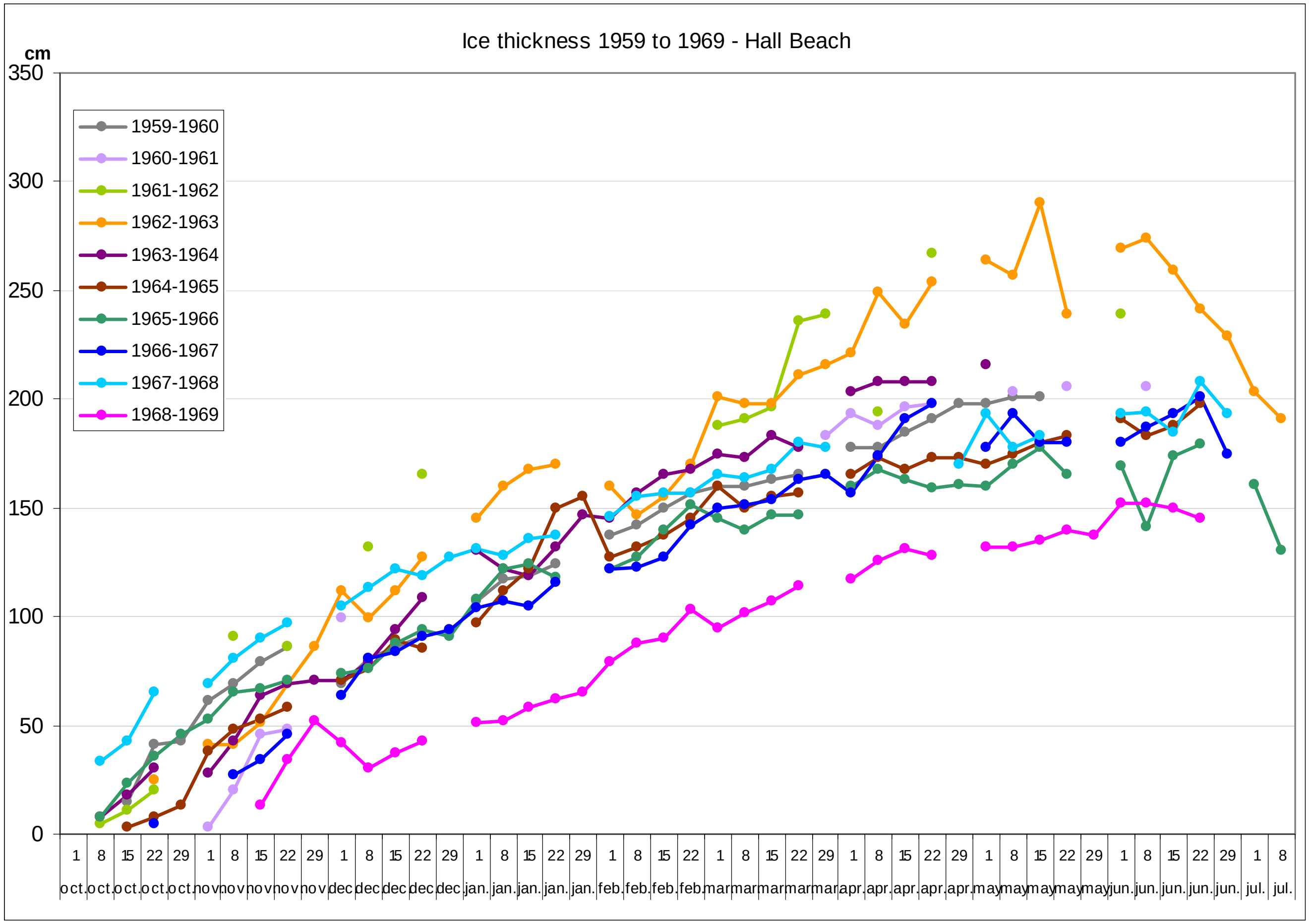
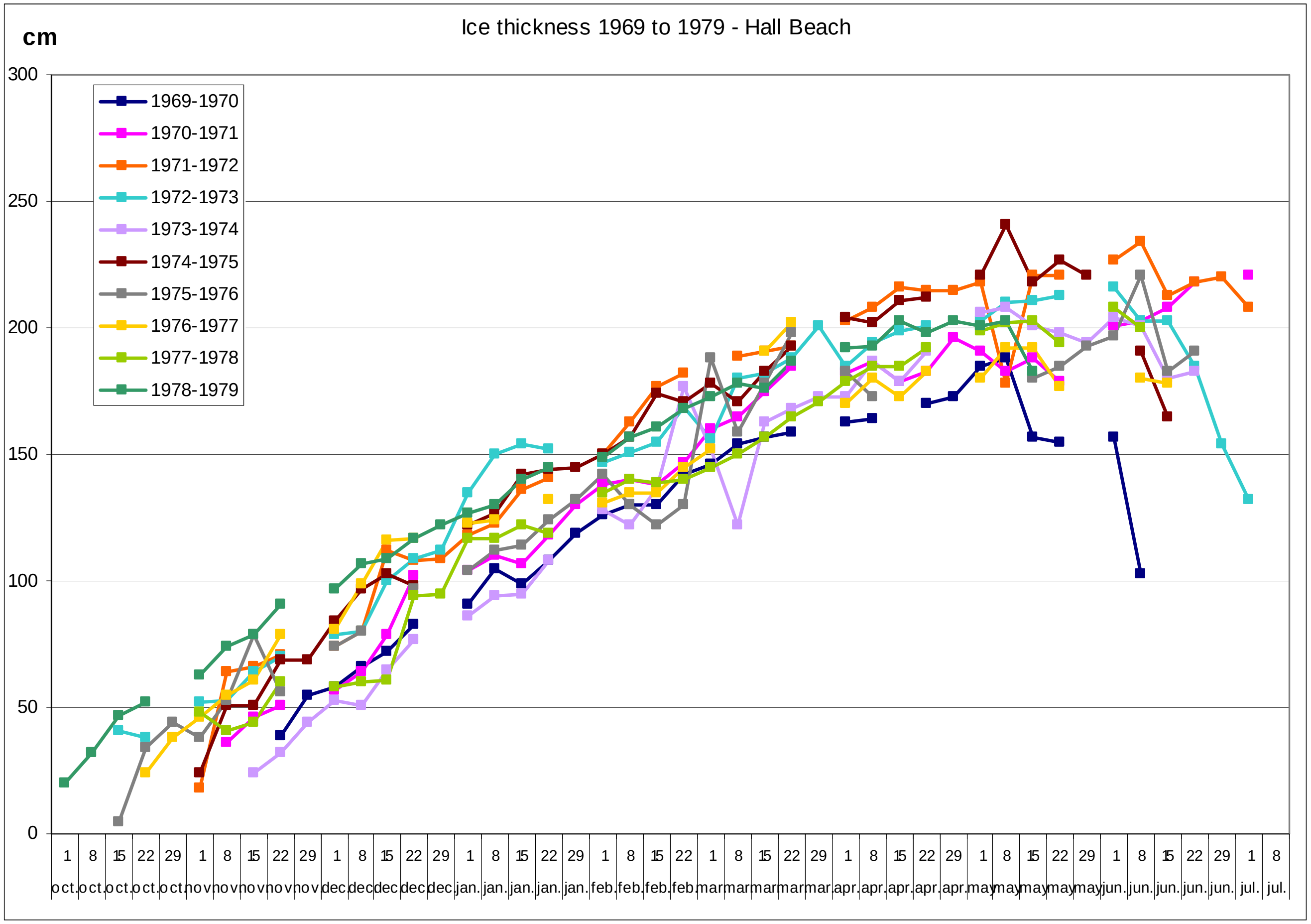
Special thanks to Mr Claude Dicaire, from the Canadian Ice Service, for Hall Beach historical data.

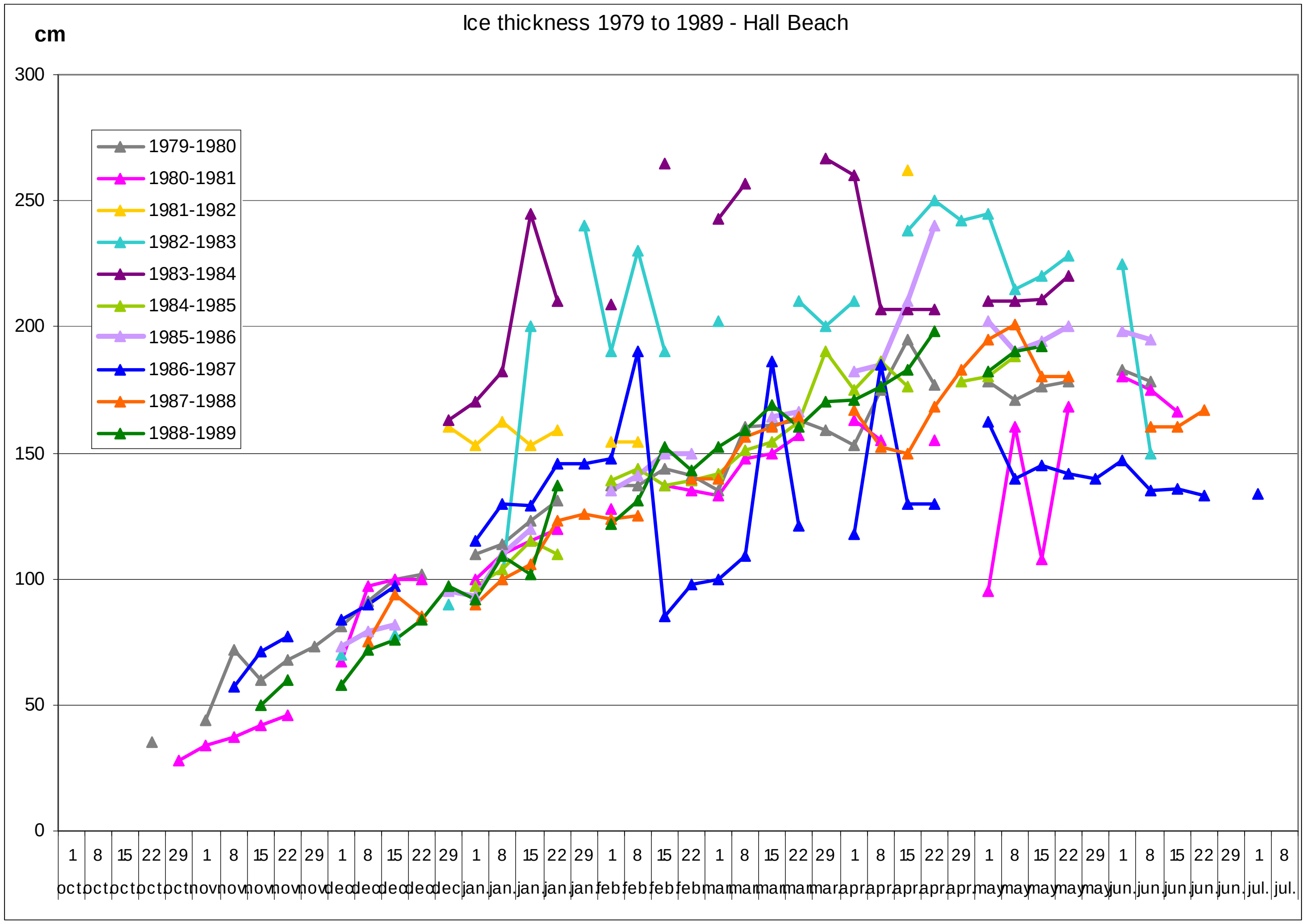
6

7 Appendix

Appendix 1: Ice thickness at Hall Beach from 1959 to 1999 (data: CIS).




Ice thickness 1969 to 1979 - Hall Beach
cm
300
250
200
150
100
50
0
1969-1970
1970-1971
1971-1972
1972-1973
1973-1974
1974-1975
1975-1976
1976-1977
1977-1978
1978-1979
1 oct. 8 oct. 15 oct. 22 oct. 29 oct
1 nov 8 nov 15 nov 22 nov 29 nov
1 dec 8 dec 15 dec 22 dec 29 dec
1 jan. 8 jan. 15 jan. 22 jan. 29 jan.
1 feb. 8 feb. 15 feb. 22 feb
1 mar 8 mar 15 mar 22 mar 29 mar
1 apr. 8 apr. 15 apr. 22 apr. 29 apr.
1 may 8 may 15 may 22 may 29 may
1 jun. 8 jun. 15 jun. 22 jun. 29 jun.
1 jul. 8 jul.


Ice thickness 1979 to 1989 - Hall Beach
cm
300
250
200
150
100
50
0
1979-1980
1980-1981
1981-1982
1982-1983
1983-1984
1984-1985
1985-1986
1986-1987
1987-1988
1988-1989
1 oct
8 oct
15 oct
22 oct
29 oct
1 nov
8 nov
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22 nov
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1 dec
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1 jan.
8 jan.
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1 feb
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1 mar
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1 apr
8 apr
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22 apr
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29 may
1 jun.
8 jun.
15 jun.
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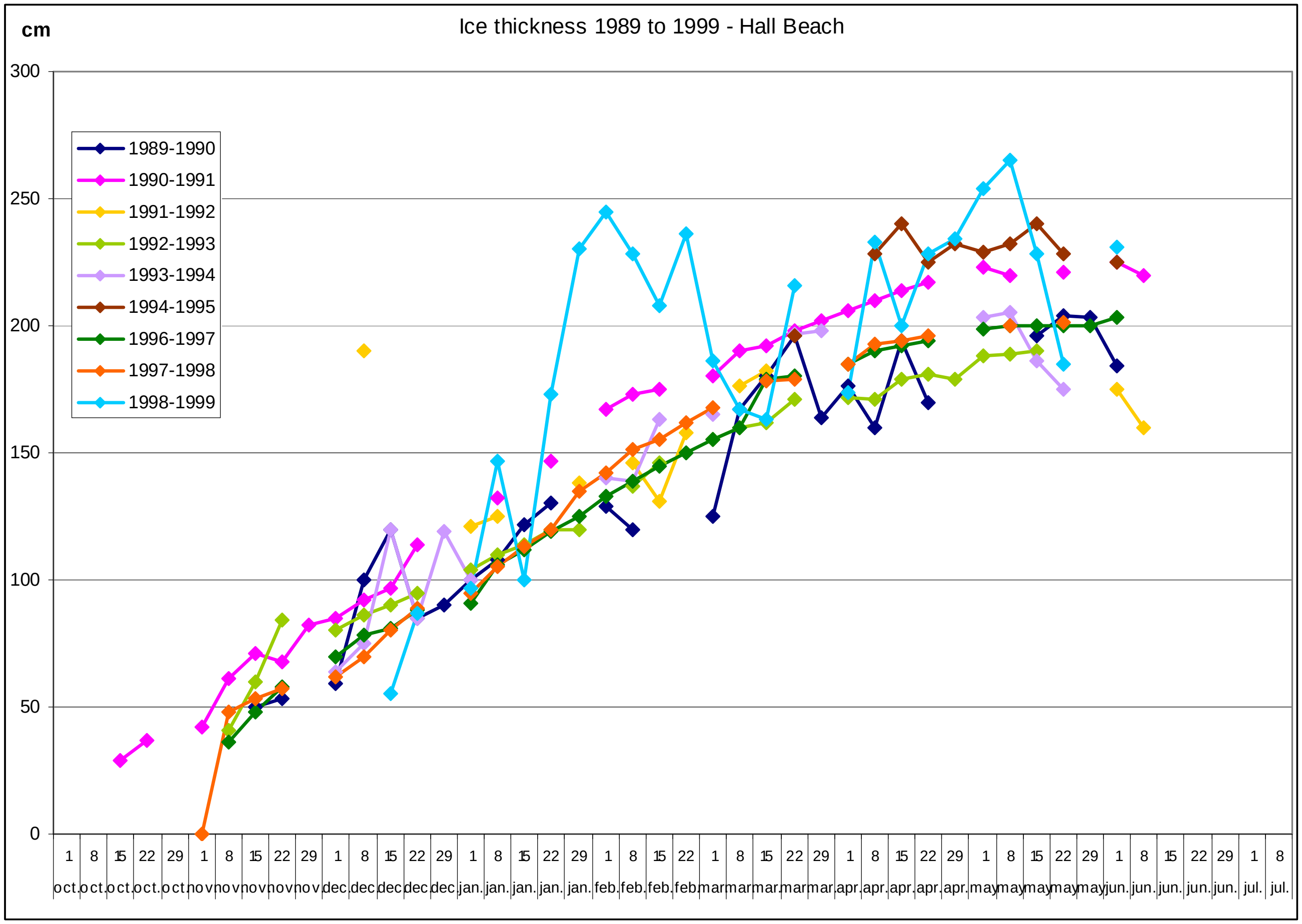
29 jun.
1 jul.
8 jul.



cm
Ice thickness 1989 to 1999 - Hall Beach
300
250
200
150
100
50
0
1989-1990
1990-1991
1991-1992
1992-1993
1993-1994
1994-1995
1996-1997
1997-1998
1998-1999