

ArcticNet: The Current and Future Vision of its Seabed Mapping Program.

Jason Bartlett: Canadian Hydrographic Service, Central and Arctic Region

Jonathan Beaudoin: Ocean Mapping Group, UNB

John Hughes Clarke: Ocean Mapping Group, UNB

Steven Brucker: Ocean Mapping Group, UNB

Steve Blasco: Geological Survey of Canada (Atlantic)

Robbie Bennett: Geological Survey of Canada (Atlantic)

Abstract

ArcticNet is a Network of Centres of Excellence of Canada that will integrate the natural, social, and human health sciences together to form a conclusion on how climate change will affect the Arctic. More specifically Project 1.6 deals with the seabed mapping of the Northwest Passage and other areas of the Arctic Archipelago. The mapping goals are to provide data and support for multi-disciplinary science, navigation, resource exploration and to aid decision making regarding security and sovereignty in the Northwest Passage.

The mapping platforms involved are the CCGS Amundsen, and starting in 2006, the CSL Heron. Since 2003, ~80 days of continuous transit-style mapping (multibeam and subbottom) have been undertaken annually and the project potentially has a 14 year lifespan. There are areas such as Pond Inlet that have been almost entirely mapped but, given the vastness of the mandated domain, the majority of the area will require much more attention in the years to come. Because of the multi-disciplinary nature of the ArcticNet program, most of the data consists of opportunistic transits with rare, focused, systematic mapping operations. Nevertheless, given the scarcity of available data in the region, it provides invaluable information for this new frontier. Particular data quality issues involve poor or non-existent vertical control, sparse sound speed information and noise due to ice-breaking. Despite all of this, the data is being used to open up new potential shipping lanes and identify potential geohazards to oil and gas development including slope instability, shallow gas venting and iceberg scouring.

Although Project 1.6 has specific goals, the mapping operations are also integrated in support of other sub-projects within ArcticNet. There is also a sharing nature between scientific disciplines that collect specific information but prove to be useful in processing of other data. One specific example is the sharing of oceanographic data. This data is collected by oceanographers with very different goals but they share this information so we, the hydrographer, can compute sound speed information for the proper processing of the multibeam data. Another example is the data sharing between organizations. As multibeam data is collected, not only will it be used by ArcticNet participants to achieve their goals, but will also be used by organizations such as CHS/GSC to meet their charting and geological mapping requirements, without having the burden of large overhead costs. Also, as part of collaborative research programs, funding from federal agencies is now being used to augment the available ship-time in the region.

Introduction

In 2003, through a joint CFI, NSERC funded program, the decommissioned 1200 class icebreaker, Sir John Franklin (now CCGS Amundsen), was brought back into service as a multidisciplinary science platform for research in the Canadian Arctic. As part of this, the ship was equipped with a variety of acoustic and supporting survey instruments to make her capable of state-of-the art seabed mapping.

ArcticNet is a Network of Centres of Excellence that will integrate expertise of scientists and managers from the natural, social, and human health sciences to help form a conclusion on the impact of climate change on the coastal Canadian Arctic. ArcticNet is broken into four main themes that have a variety of sub-projects in each one. The seabed mapping program falls under Theme 1 “Climate Change Impacts in the Canadian Arctic: A Comparative Study of the East-West Gradient of Physical and Societal Conditions”, and is managed under Project 1.6 “The Opening of the Northwest Passage: Resources, Navigation, Sovereignty and Security”. More information about ArcticNet can be found at www.arcticnet.ulaval.ca.

Project 1.6 deals with mapping the seafloor topography, surficial and underlying geological structure in the Northwest Passage and other areas of the Canadian Arctic. This data is collected as an initial step towards the management of the expected increase in international ship traffic and resource exploration due to the improving ice conditions. It will also be used to help analyze the economic, sovereignty and security implications of an ice-free passage.

There are two main survey platforms that will be used to complete the objectives of Project 1.6. These are the CCGS Amundsen and CSL Heron. These two vessels will compliment each other so as to deal with both the shallow coastal areas as well as the deeper offshore areas throughout the Canadian Arctic.

The focus of this paper will be to highlight the current and future status of the mapping program illustrating the areas that are close to completion or that need extensive examination, and a closer look at the locations that will be focused on in the coming 1-2 years. There will also be a detailed discussion on data sharing and how scientists work together to achieve their goals by effectively utilizing instrumentation maintained by other groups.

Platform(s) and Instrumentation Overview

The two vessels contain almost identical sets of instrumentation with the main difference being physical size and operating frequencies. Figure 1 highlights the difference in multibeam capability and the effective areas of operation for each. They both contain the same instrumentation for the collection of sound velocity information. This includes a surface probe to properly measure the sound speed at the transducer face and a Moving Vessel Profiler (MVP30-Heron, MVP300-Amundsen). Both vessels will be positioned

using C&C Technologies C-Nav global differential GPS system. Motion compensation on the Heron will be from the Coda Octopus F-185+, whereas the Amundsen uses an Applanix POS/MV 320. They both have Knudsen K320 3.5 KHz sub-bottom profilers with the Heron using 1 transducer element and the Amundsen using 16 transducer elements. Both vessels have an ADCP, the Heron is 600 KHz for a 1 – 30m depth range and the Amundsen is 150 KHz for a 10 – 500 m depth range. They also have multi-frequency sonar to support mid-water scattering studies. In addition, the Heron comes equipped with dual keel mounted Knudsen 200 KHz sidescan staves.

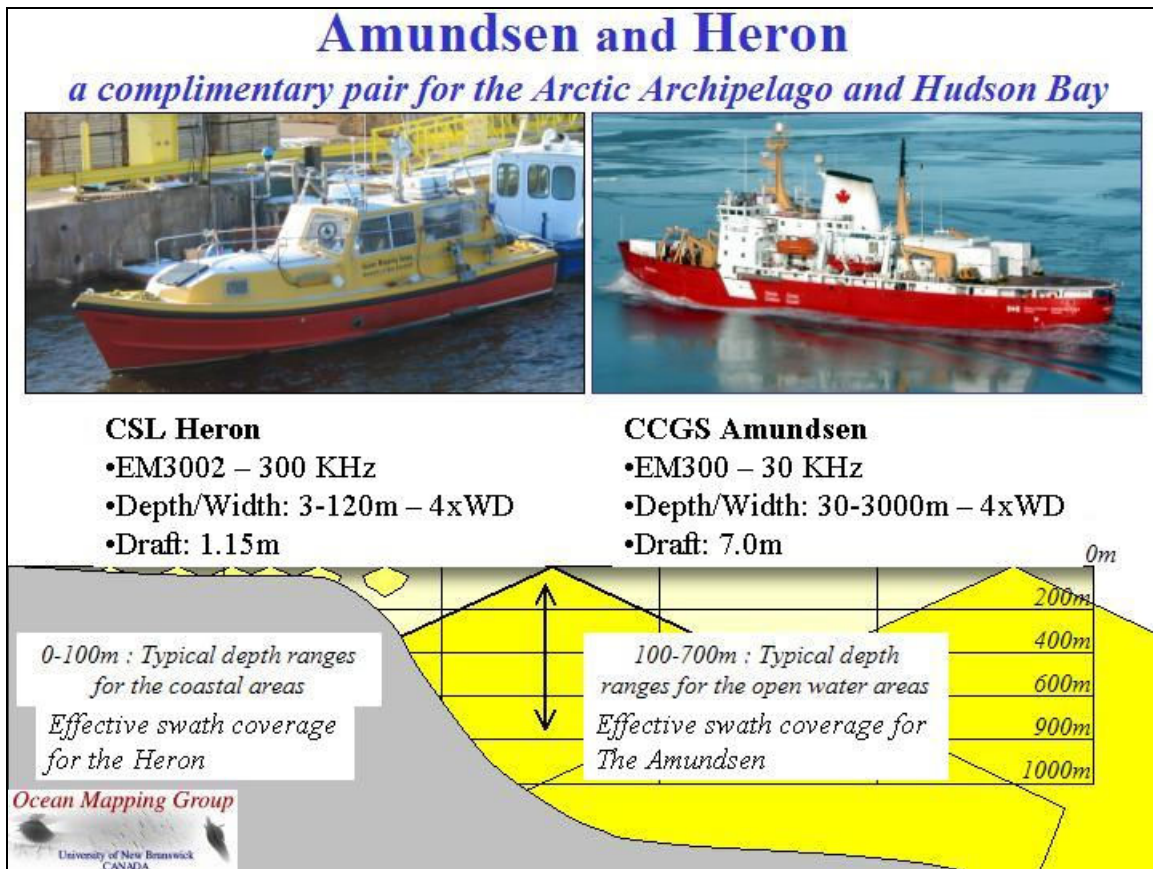


Figure 1: Comparison of multibeam technology between CSL Heron and CCGS Amundsen.

Vertical control is established by two approaches. The first and preferred approach is the use of tidal information derived from hydrodynamic models or predictions derived for a station based on constituents calculated from the permanent tide gauge network. The second approach, which is experimental, is the use of ellipsoid heights derived from the C-Nav (± 40 cm) or from PPK (post processing kinematic).

To accommodate the Heron, work was completed in the summer of 2005 onboard the Amundsen to make it a permanent fixture of the ship for the duration of the project. Figure 2 illustrates how and where the Heron fits onboard. Unfortunately, during the initial recovery of the Heron in preparation for departure there was a total failure of the davit system. The Heron fell from the deck of the Amundsen and sank into the St. Lawrence River. While there were no serious injuries, Heron operations were cancelled

for the 2005 field season. It is noteworthy to mention that the Heron has been successfully rebuilt and scheduled for a busy 2006 Arctic mapping season.



Figure 2: Heron location onboard the Amundsen

Current Status of Mapping Program

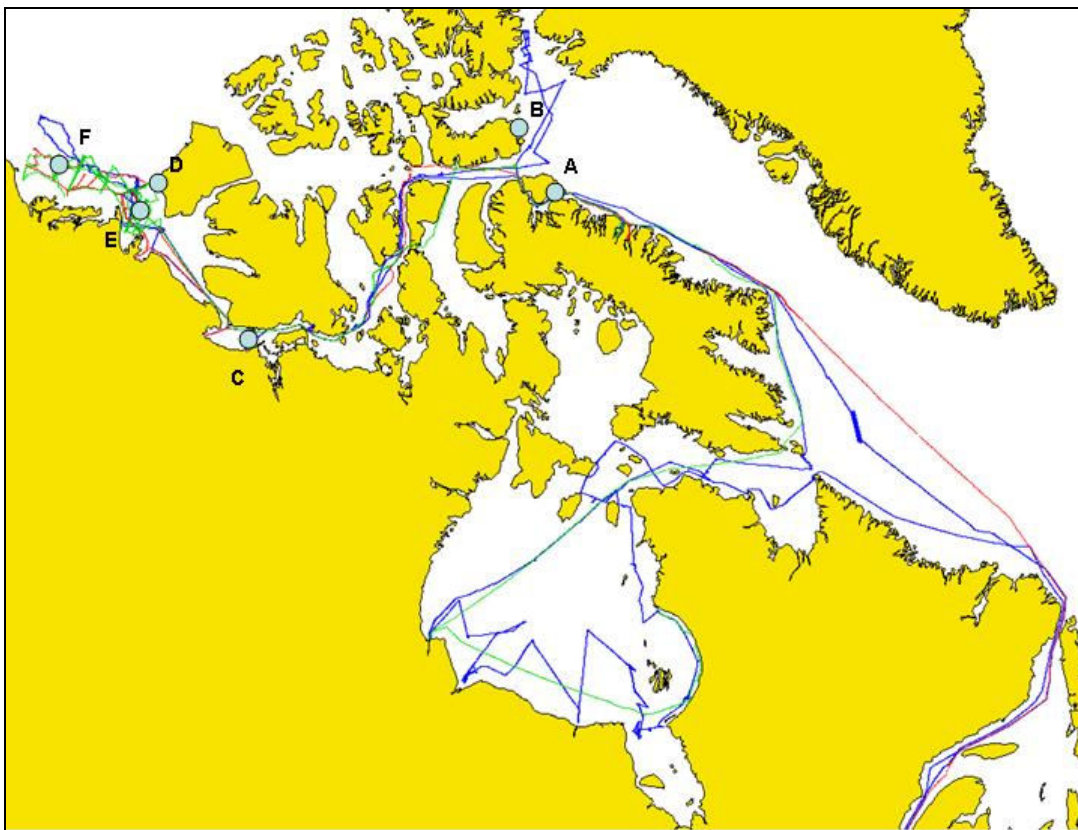


Figure 3: Points A-F represent focus areas dealt with by this paper. Also present is the track plot from the past 3 yrs; Red=2003, Green=2004, Blue=2005.

Since 2003, approximately 80 days of transit style mapping have been completed per year, which includes both multibeam and sub-bottom profiling. Figure 3 illustrates the general track data collected thus far. Given the vastness of the project area, coverage to date is still very sparse, but there are some smaller areas that have been well mapped due to being narrow and deep channels. Also, some concentrated work has been undertaken to investigate geological features and/or geohazards. There are particular data quality issues such as poor vertical control and sparse sound speed information, but the data is still providing a valuable first step towards opening new shipping lanes in certain areas of the NW Passage.

General Seafloor Mapping

Narrow, deep channels are most effectively mapped using the wide swathed width of the EM300 by allowing near shore to shore coverage using very few lines. One such mapping “success” is Pond Inlet and Navy Board Inlet, located between northern Baffin Island and Bylot Island (A: Figure 3). Generally, each year there are two transits through the area at different times, so there is an opportunity to do extra mapping. Figure 4 illustrates the coverage obtained thus far and how important this information will be for updating charts or other products that depict the seafloor topography.

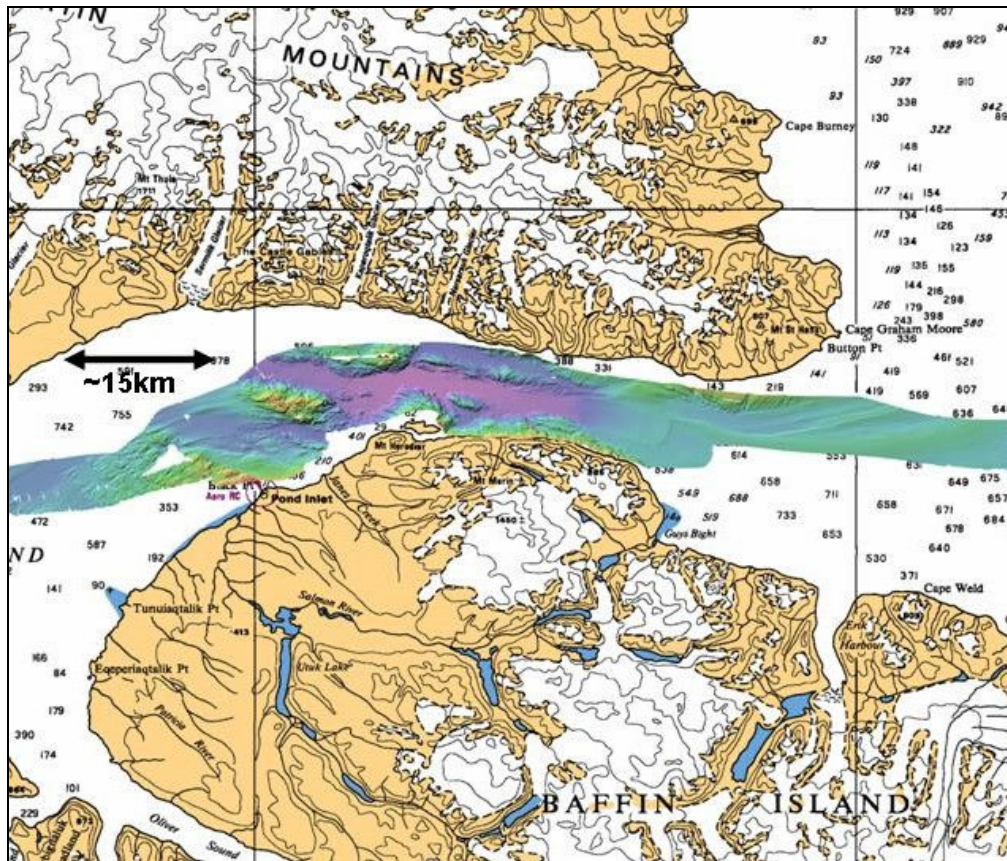


Figure 4: Multibeam Coverage in Pond Inlet

Alternate Shipping Lane Identification

The 2005 field season marked the first attempt at exploring new shipping routes. An alternate route was explored in the Coronation Gulf region (C: Figure 3). The current shipping lane travels the northern route and cuts south to arrive in the community of Kugluktuk (Coppermine). The new alternate route follows a more southerly path as indicated by Figure 5. The first transit through, which generally followed an old single beam track line, did not reveal any large areas that pose an immediate threat to navigation. There were two areas that would need extensive examination to allow the route to either shift north or south of the shoals depicted in Figure 6.

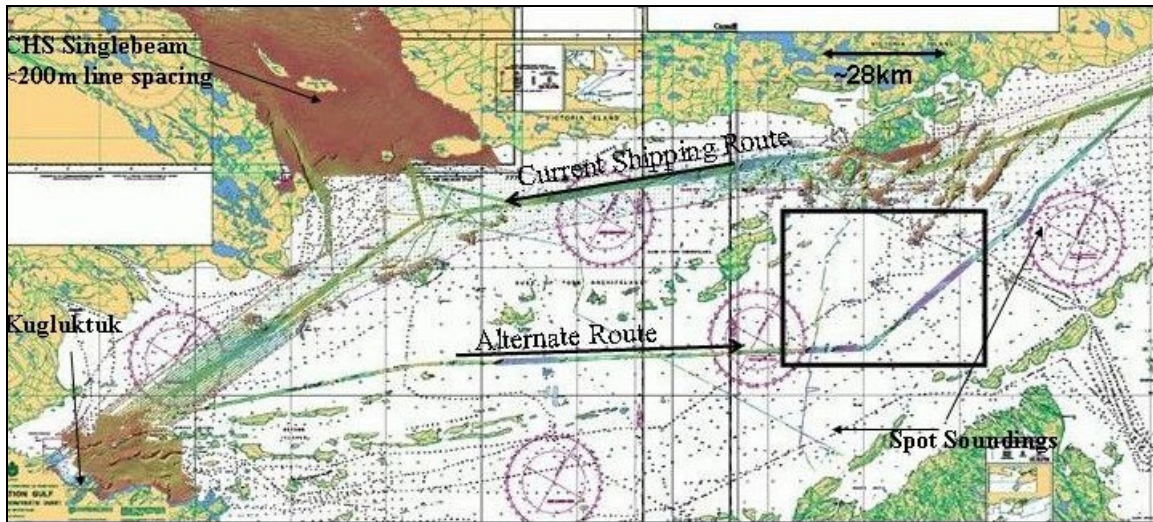


Figure 5: Current/Possible Alternate Shipping Route, Coronation Gulf.

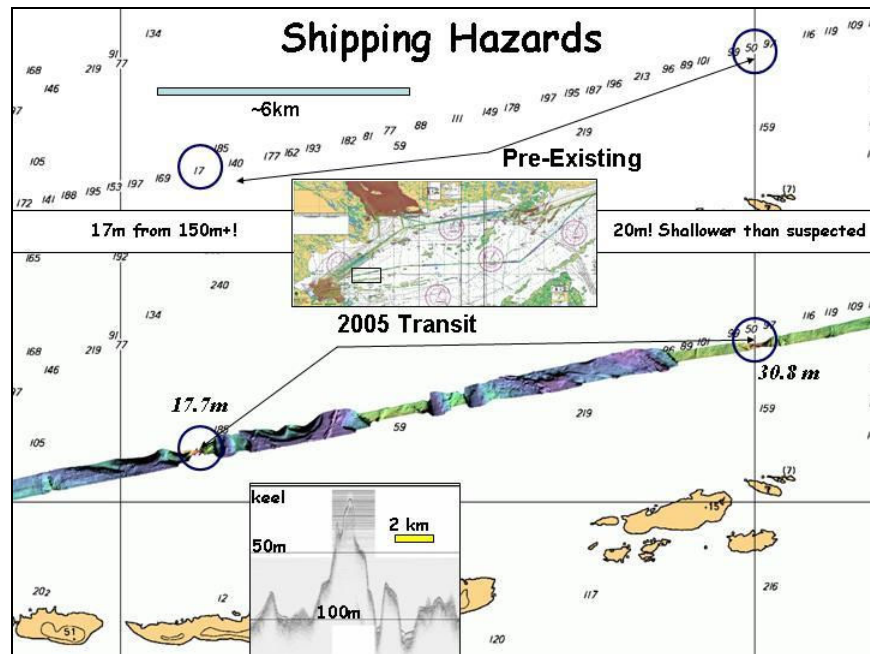


Figure 6: Two Critical Navigation Areas Located on First Transit.

As ice cover shrinks and ship traffic increases it will be important to have accurately mapped alternate routes to aid in safe shipping and to provide options in times of poor weather and/or ice conditions.

Geological Features and Geohazard Examination

In conjunction with seafloor mapping for the purposes of navigation and charting, another important element of the mapping process is to identify geological features and/or geohazards that will be of particular interest to scientific community and in some cases, private industry. This paper will focus on two locations, both situated in the western Arctic region.

The most dramatic features observed, are glacial sole marks which are situated in Amundsen Gulf (E: Figure 3) (Figure 7). These features have been observed at three different mapping sites, each located in about 400 meters of water at the western end of Amundsen Gulf; Figure 7 was the largest surveyed site. The sole marks are linear, parallel ridges and troughs that are orientated in a NW – SE direction. Each individual ridge is wider and higher above the seabed at their SE end; they decrease in size (both in width and height) to the NW. The orientation and morphology of the sole marks suggests an ice movement direction to the northwest. Similar features have been found on land on Victoria Island. It is not certain if these features originated from the movement of a large ice sheet or created by glacial melt water processes.

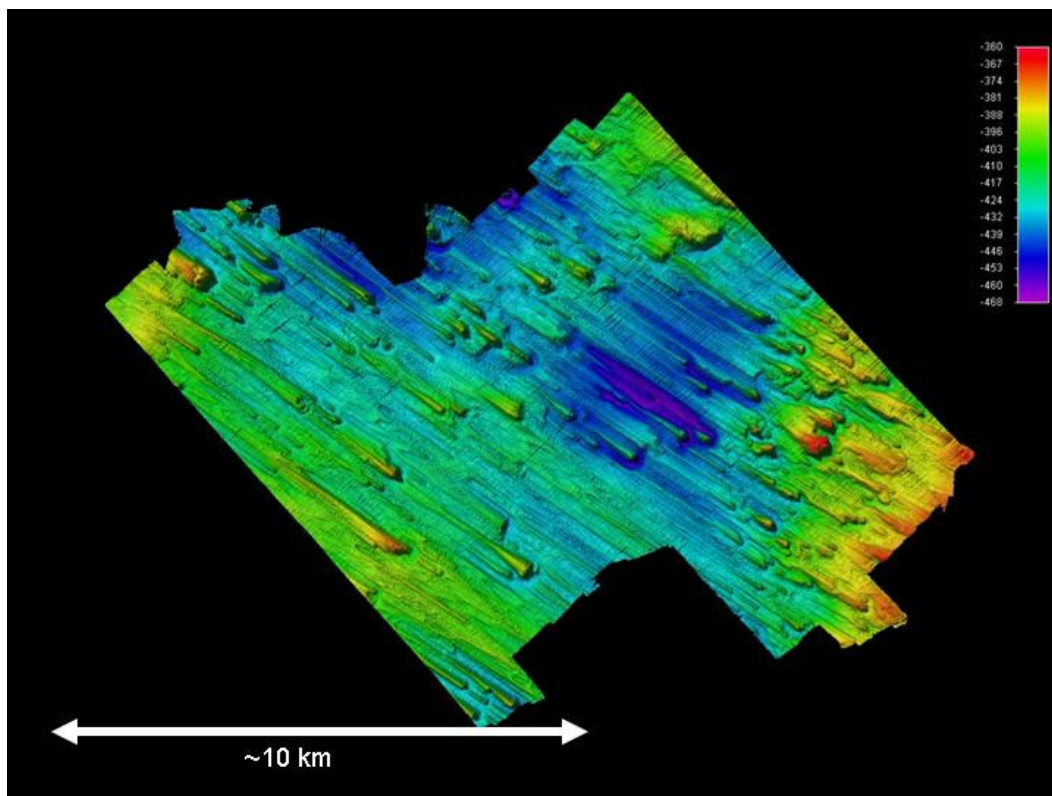


Figure 7: Glacial Sole Marks in Amundsen Gulf.

The second area of focus, a geohazard, represents a significant area of interest to the oil and gas industry. Since there is a lot of interest on the Mackenzie Shelf break (F: Figure 3) for oil and gas exploration/development, slope instability areas have to be located and examined. One such slope failure was first located in the early 1980's. In 2004, multibeam data was collected over the same site as a first step in determining the size and extent of the failure (Figure 8a). Sedimentation is not consistent across the Beaufort Shelf. The MacKenzie River sediment plume provides more sediment to the inner shelf than it does to the outer shelf and shelf break. Re-suspension and sediment transport by bottom currents and storm action can be quite dynamic, causing sediment to be swept from the shelf (Carmack and MacDonald, 2002). Therefore, high sedimentation rates may not be present in the area of the slump which could mean that the slumped sediments are pre-Holocene in age. Low sedimentation rates would also preserve the sharp morphology and "fresh" appearance of the slump (Figure 8b). Additional data is required to date the slumped material and calculate the sedimentation rate in the area of the feature.

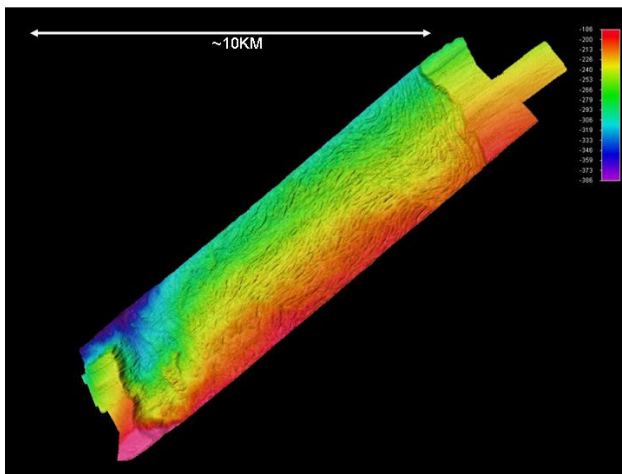


Figure 8a: Slope Failure.

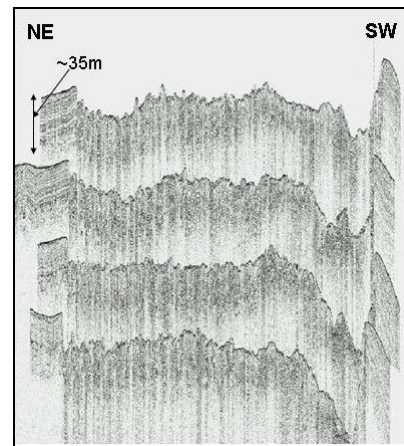


Figure 8b: Associated Seismic Profile.

Future plans for Mapping Program

To date, the current mapping program only includes data collected by the Amundsen. Starting in 2006, the CSL Heron will contribute high resolution, shallow water mapping capabilities to the program. In general, as the Amundsen is mapping the deeper, central areas of sounds and inlets, the Heron will be mapping the shallow coastal zones of these same areas. The future vision consists of building upon what has been already collected, ending with completely surveyed shipping corridors and fully examined geological features and geohazards.

General Seafloor Mapping

It was mentioned earlier that there is still a huge amount of data to be collected given the vastness of the area within the project domain. There are areas, however, that could be considered important locations of focus due to their topography and water depth. Pond Inlet and Navy Board Inlet have already been subject to significant coverage; on the other

hand, Eclipse Sound and the surrounding fjords which lie between these two areas have not been effectively covered. The community of Pond Inlet has been slated as a location for a scientific party crew change for the 2006 field season; therefore, opportunistic data collection before, during, and after the crew change will focus on these areas of sparse coverage.

Another interesting mapping project that is scheduled to take place during the 2006 field season will be the mapping of the approaches to, and the rapid retreating front of, Belcher Glacier (B: Figure 3), located on the north east corner of Devon Island. Figure 9 shows the general survey plan for both the Heron and Amundsen.

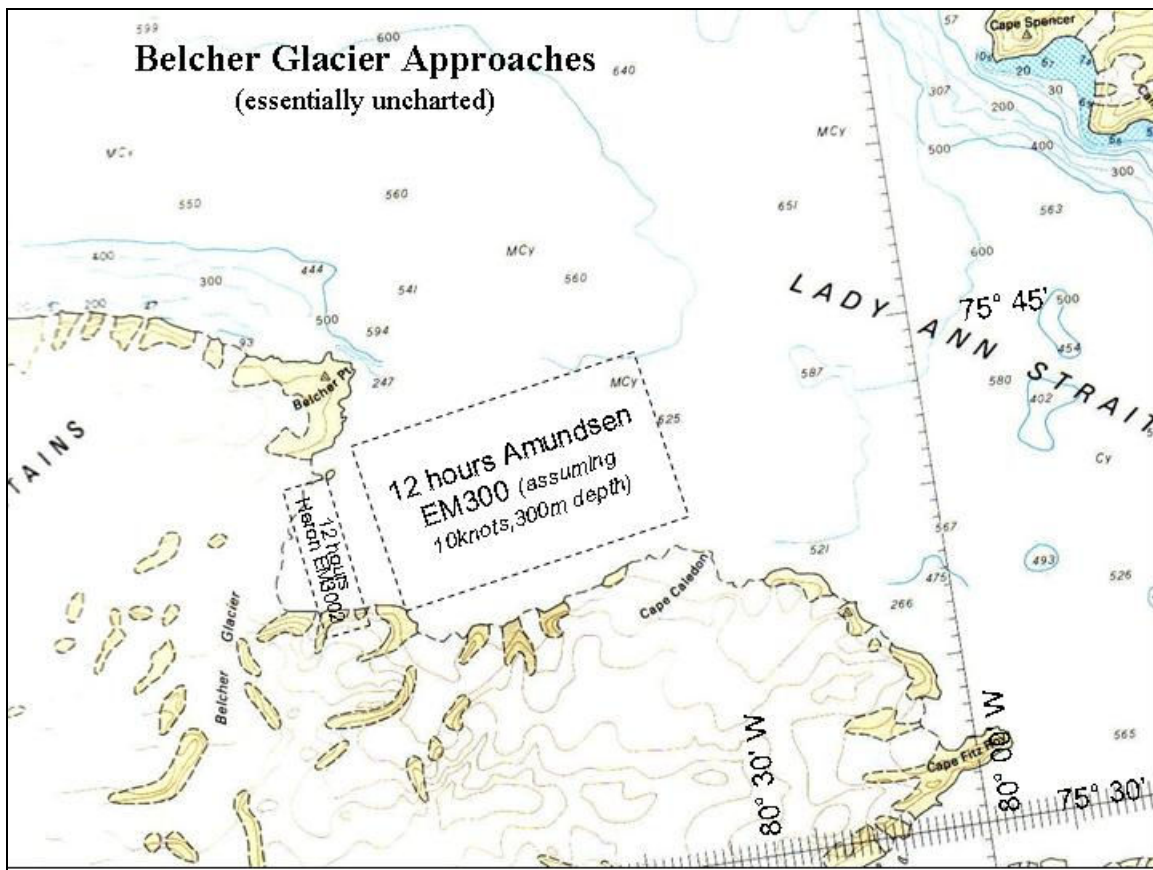


Figure 9: Belcher Glacier General Survey Plan.

The Belcher glacier mapping project, conducted under the auspices of another ArcticNet project, has multiple goals. The primary purpose is to examine the geological, and to some extent, the oceanographic processes that are taking place at the glacier-water-seabed interface. The secondary purpose is to collect seafloor information to update charts and other map products depicting the area. As it can be seen from Figure 9, there are no recorded soundings on the chart in that area. The importance of working in such areas is not simply science, but also the creation of new economic opportunities in a lower sea-ice regime. One possible opportunity could be eco-tourism. Ships that know they can enter the area could offer “up-close” tours of a very accessible glacier. Part of

the tour would include detailed explanation on its origin, age, and all the science that is happening at the glacier-water-seabed interface and surrounding area. This is a popular business in Alaska and could serve as a model for possible development in Canada.

Alternate Shipping Lane Examination

The 2006 field season will see increased time spent examining and expanding on the proposed alternate shipping route into Kugluktuk. Figure 10 illustrates the general survey plan that will be followed this coming year in the western edge of Coronation Gulf (C: Figure 3). The Amundsen will be used to expand coverage in the deeper area to make that portion of the corridor approximately 2-3 miles wide, while the Heron will be used to examine the line of shoals that are located to the northwest of the work area. As with any ArcticNet mapping, there are multiple objectives. One of the prime objectives of this project is to collect data that will accurately depict the sediment and morphological structure of the new route. This will aid in satisfying the geology requirement of Project 1.6 and provide extra information into the final suitability of the route.

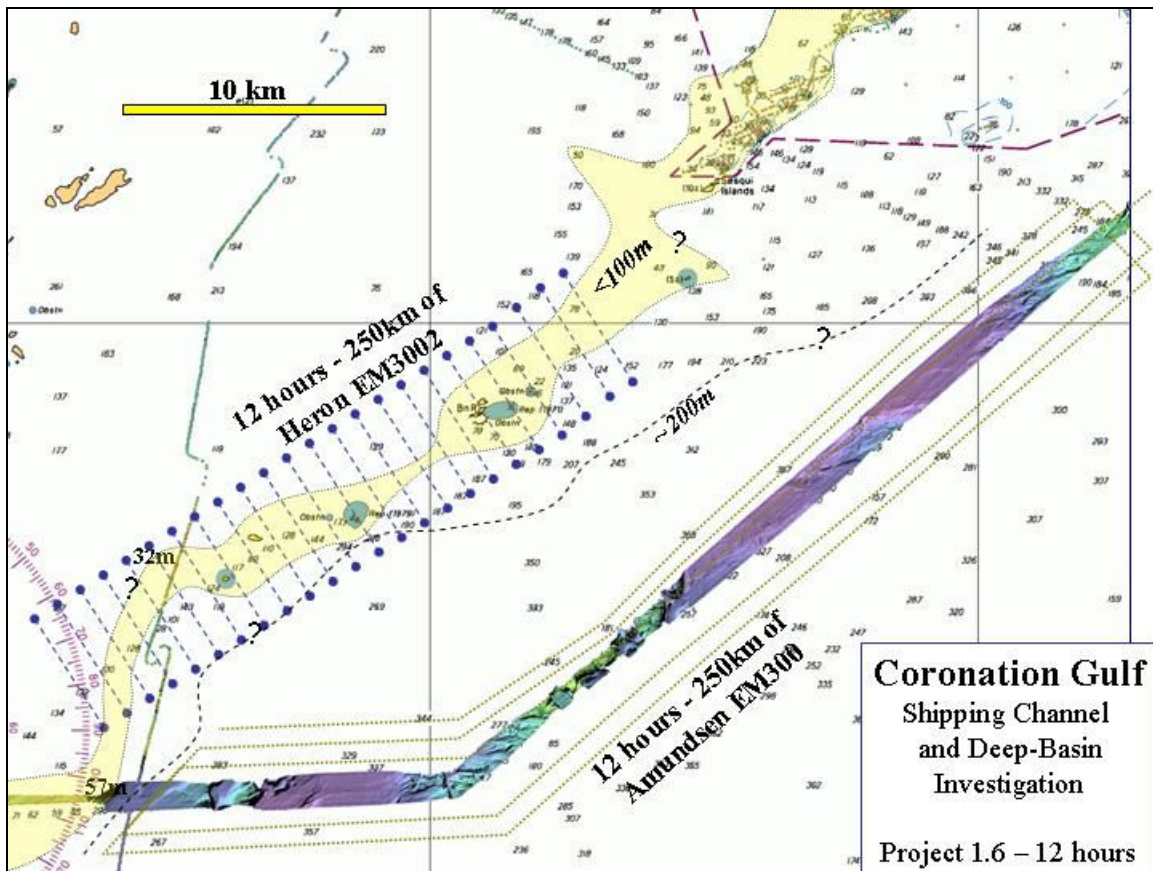


Figure 10: 2006 Survey Plan for Shipping Route Examination.

Geological Features and Geohazard Examination

There are two main geological features that will be further examined in 2006, building on what has already been collected in previous years. They are the glacial sole marks and the slope failure depicted in figure 7 & 8, respectively. Figure 11 shows the proposed work area for the glacial sole marks (E: Figure 3). It is hoped that, by extending coverage of the sole marks survey done in 2004, Project 1.6 geologists will be able to identify the cause of these features and to help form conclusions on the details of the glacial movement; for example, by locating the terminal moraine, if one exists. The importance of continued mapping of this feature is that it will help to differentiate between older relic ice scours formed by glacial icebergs and those formed by modern sea ice. This is important because a firm understanding is needed of the modern sea ice regime in order to determine how it impacts engineering parameters for seabed infrastructure (e.g. burial depths for seabed pipelines and cables).

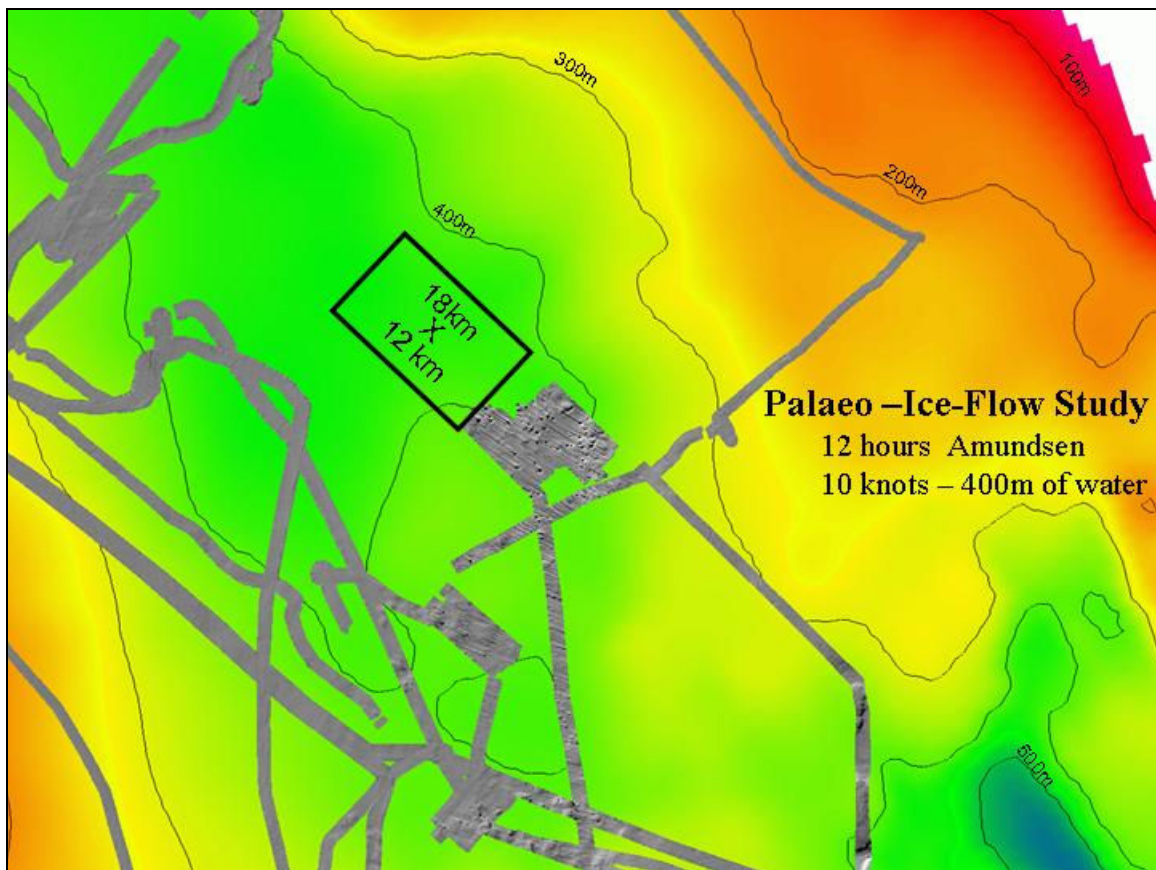


Figure 11: Proposed work on the glacial sole marks, Amundsen Gulf.

The other geological feature that will receive significant attention in the 2006 field season will be the slope failure located on Mackenzie Shelf (figure 8a, F: Figure 3). The purpose of doing extensive examination on this feature is to determine the failure mechanism, the age, and whether or not it is actively failing. Figure 12 illustrates the survey plan for this feature; note that the head and tail of this feature has yet to be located. The importance of

continued work on this feature is to understand the sediment stability on the Beaufort Slope. Determining the age is very important as it will have direct implications to seabed infrastructure (pipelines, seabed cables, and drilling platforms) as a failure of this size would cause significant damage to any structure on the seafloor in the area, not to mention the ecological impact on the fragile arctic ecosystem.

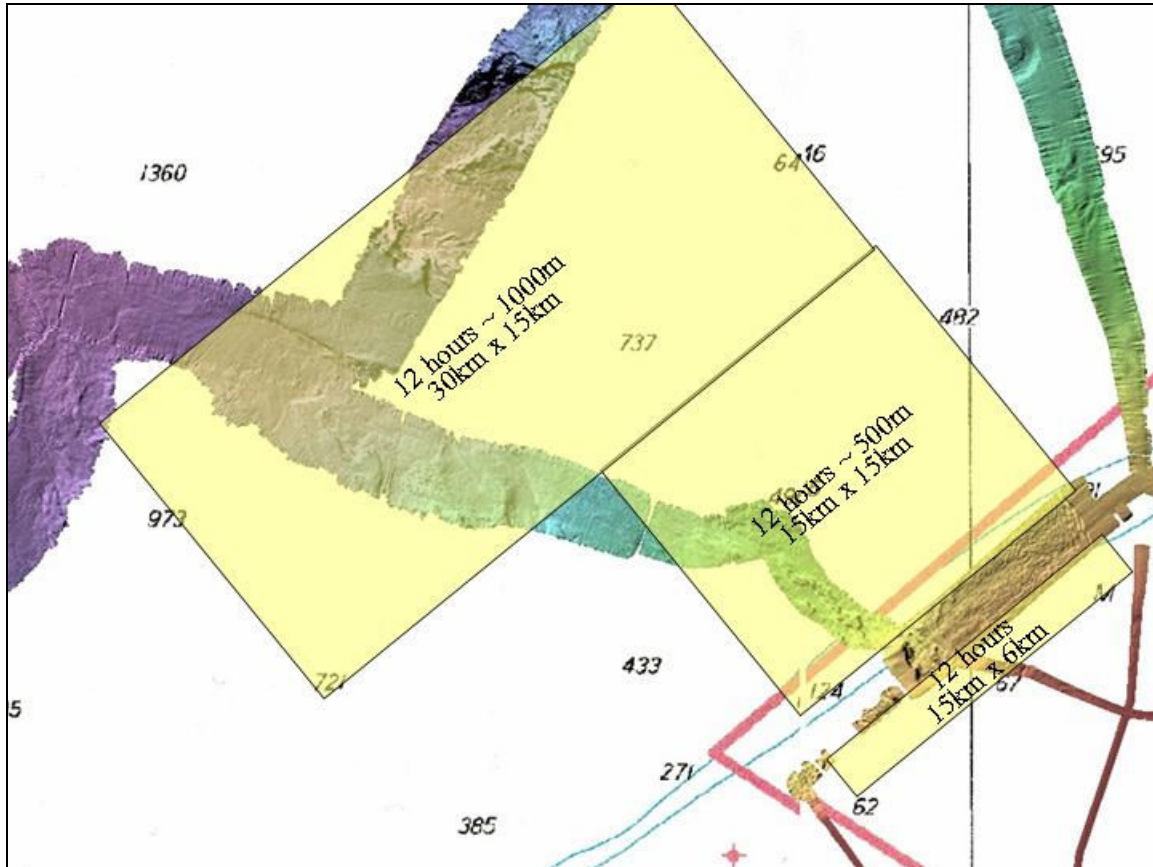


Figure 12: Slope failure survey plan 2006

Data Sharing and Project Collaboration

ArcticNet is the largest Arctic collaborative research project ever undertaken and it would require too much overhead for each group or project to be completely self-sufficient in terms of operating equipment, sailing logistics, etc. The integration or sharing of data from multiple groups allows each project to proceed effectively. The most important “partnership” exists between Project 1.6 and the group analyzing the oceanographic properties of the study area. Project 1.6 currently does not maintain instrumentation that collects sound speed information for refraction control of the multibeam, although several such pieces of instrumentation exist on board such as a MVP-300 and Seabird 911 CTD. Oceanographers are studying temperature and salinity to make conclusions on the physical properties of the sea water and we, the hydrographers, take this same information and compute sound speed to correct the multibeam data for refraction.

Similar relationships exist between most groups involved in the project, illustrating the importance of “Bridging Disciplines”.

The preceding paragraph discussed how data is shared internally among ArcticNet projects to ensure that all data can be processed to completion without each having to maintain significant overhead. Another major sharing initiative is the use of the final products by multiple groups and/or organizations to satisfy their operating requirements without having the burden of large overhead costs. The mapping data, for example, are used by Project 1.6 of ArcticNet, the Canadian Hydrographic Service (CHS), and the Geological Survey of Canada (GSC) to satisfy their mapping requirements without each organization having to separately shoulder the costs of the instrumentation and mobilization. These organizations provide funding in the form of personnel, ship-time, etc to augment the in-place funding for ArcticNet in order for multiple goals to be achieved. One such example is the cooperation between UNB’s Ocean Mapping Group and the Canadian Hydrographic Service. CHS provides funding for a sonar operator/processor, as well as logistical support, and that person is permanently stationed at the Ocean Mapping Group office to ensure effective management and operation of Project 1.6 activities.

An example of a shared initiative is a survey in Sachs Harbour (D: Figure 3), planned for the 2006 field season. The final product will be incorporated into multiple ArcticNet projects as well as used by several contributing external agencies to help complete outstanding work in the same area. Figure 13 shows the survey area/plan for Sachs Harbour.

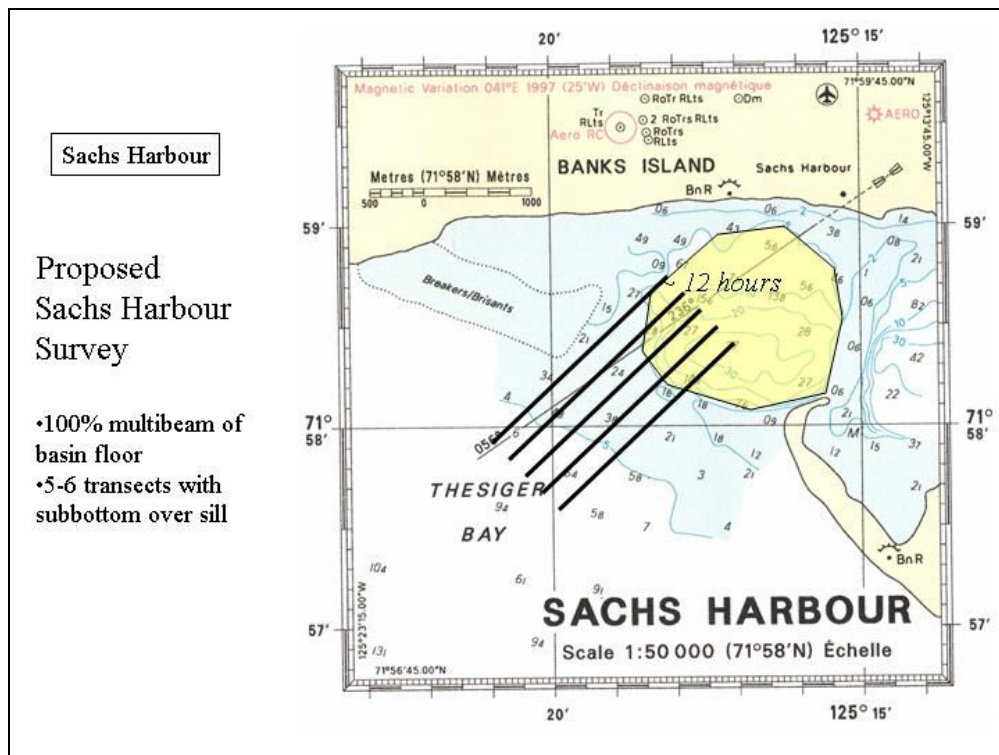


Figure 13: Survey Area for Sachs Harbour

The Sachs Harbour survey will serve as the base data for several projects within ArcticNet such as coastal vulnerability (Project 1.2), navigation purposes (Project 1.6), and possibly other projects dealing with the seafloor geology. It will also serve as important data to the CHS as the next step in completing their work in the area of interest, as it would contribute directly to completing survey coverage in Sachs Harbour.

Conclusion

ArcticNet is the largest research project ever undertaken in the Arctic; it will bridge several different scientific disciplines to form a conclusion on the impact of climate change in the Canadian Arctic. Project 1.6 has a very important role, including densifying sounding data, understanding the seafloor geology and identifying specific geohazards in support of increased ship traffic and resource exploitation. The mapping platforms, CCGS Amundsen and CSL Heron, are both very well suited to satisfy the mapping objectives. Though 1.6 deals with the Northwest Passage, mapping data is collected and maintained in Hudson Bay, Baffin Bay, the Labrador Sea, and the St. Lawrence River to augment science objectives taking place in these areas.

The current vision of the mapping program is one that shows some successes or areas that are well mapped. It also highlights that it will take significant work and time to compile the required data to complete the objectives of the project. The immediate future sees significant increase in data coverage as two transits through the NW Passage in 2006 will build upon the corridor that has been started. The 2006 field season will also give time to build upon significant geological features and geohazards such as the slope failure on the Mackenzie Shelf break.

ArcticNet is a large project with many objectives that will all contribute to a common goal. These objectives could not be met if it were not for the large inter-project cooperation and data sharing. This data sharing is important as it contributes to the understanding of each component of ArcticNet. This would not be possible if these projects were conducted independently. There is also an importance for external organizations to provide funding for personnel or ship time. This relationship allows Arctic objectives that are not contained within ArcticNet to be completed, avoiding multiple expenditures on the same data set.

ArcticNet will help direct policy creation so that Canada can plan for a changing Arctic environment, help protect and assert our sovereignty over Arctic waters, and understand the environmental and social challenges facing the warming north.

Acknowledgements

The authors are members of ArcticNet, funded in part by the Networks of Centres of Excellence Canada, the Natural Sciences and Engineering Research Council, the Canadian Institutes of Health Research and the Social Sciences and Humanities Research Council. The authors would like to thank the Canadian Hydrographic Service and the

Geological Survey of Canada for their continued support and funding for ArcticNet. The sponsors of the Chair in Ocean Mapping are also thanked for their continued support.

References

Bartlett, J., Beaudoin, J and Hughes Clarke, J.E., 2004, CCGS Amundsen: A New Mapping Platform for Canada's North: Lighthouse, Journal of the Canadian Hydrographic Association; Edition No. 65.

Beaudoin, J., Hughes Clarke, J., and Bartlett, J. Application of Surface Sound Speed Measurements in Post-Processing for Multi-Sector Multibeam Echosounders : International Hydrographic Review, v.5, no.3, p.26-31.

Blasco, Steve, J. Hughes Clarke, R. Bennett, J. Bartlett, J. Beaudoin and W. Rainey, 2004, Seafloor Features and Geological Processes as Revealed by New Multibeam Mapping Technology, Northwest Passage, *Proceedings ArcticNet 2004 Annual Scientific Meeting*.

Hughes Clarke, J.E., Dare, P., Beaudoin, J., and Bartlett, J. 2005, A Stable Vertical Reference for Bathymetric Surveying and Tidal Analysis in the High Arctic. Proceedings of the United States Hydrographic Conference 2005, San Diego, California.

Zhao, J., Hughes Clarke, J.E., and Brucker, S. 2004, Establishing a Seamless Vertical Reference along the Tidal Segment of the Saint John River: Lighthouse, Journal of the Canadian Hydrographic Association; Edition No. 66.

Carmack, E., and MacDonald, R., 2002. Oceanography of the Canadian Shelf of the Beaufort Sea: A Setting for Marine Life. *Arctic*, Vol. 55, Supp. 1, p. 29 - 45.