# APPENDIX 8A

# MARINE BASELINE DESCRIPTION

# APPENDIX 8A-1

# OCEANOGRAPHY BASELINE

# MARY RIVER PROJECT

Environmental Field Studies

## MARINE BASELINE SYNTHESIS
## PHYSICAL, CHEMICAL, AND BIOLOGICAL OCEANOGRAPHY

## 2010

Prepared for Baffinland Iron Mines Corporation

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# EXECUTIVE SUMMARY

The Mary River Project (“the Project”) is a proposed iron ore mine and associated facilities that will be located on North Baffin Island, in the Qikiqtani Region of Nunavut. The Project involves the construction, operation, closure, and reclamation of a 21 million tonne-per-annum (Mt/a) open pit mine that will operate for 21 years. The high-grade iron ore to be mined is suitable for international shipment after only crushing and screening with no chemical processing facilities. Three Mt/a of iron ore will be transported via an upgraded existing road to Milne Inlet where it will be stockpiled for shipment during the open water season. A railway system will transport an additional 18 Mt/a of the ore from the mine area to an all-season deep-water port and ship loading facility at Steensby Port where the ore will be loaded into ore carriers for overseas shipment through Foxe Basin. A dedicated fleet of cape-sized ice-breaking ore carriers, and some non-icebreaking ore carriers and conventional ships, will be used during the open water season to ship the iron ore to markets.

This environmental baseline report synthesizes existing literature, Inuit traditional knowledge collected during Inuit Qaujimajatuqangit studies, and results from Project-specific studies to provide an environmental description of the marine environment in the vicinity of the proposed Milne and Steensby Ports. This information will be used to support an Environmental Impact Statement (EIS) for the Project, to be submitted by the Baffinland Iron Mines Corporation (“Baffinland”) to the Nunavut Impact Review Board (NIRB). Marine baseline studies were developed using an ecosystem-based approach and were designed to collect information on specific aquatic ecosystem components including the following:

- Physical oceanography;
- Water quality;
- Sediment quality;
- Coastal and seabed habitat;
- Lower trophic levels (phytoplankton, zooplankton, macro-invertebrate communities);
- Fish communities;
- Metal residues in fish tissues;
- Seabirds; and,
- Marine mammals.

The Project-specific studies detailed in this baseline report were conducted between 2007 and 2010. Study areas included Milne Inlet on the northern side of Baffin Island, and Steensby Inlet to the south.

**Milne Inlet**

***Physical Environment***

Milne Inlet is a long narrow fjord with steep sidewall slopes and depths reaching more than 100 m within a few hundred metres of the coastline. The head of Milne Inlet near the proposed port development site is a complex of coarse-grained deltas with steep pro-delta areas prograding into the deep fjord. Nearshore areas on the delta are characterized by abundant ice push features. The shoreline of Milne Inlet is generally composed of coarse sediment beaches with numerous sections of raised beach ridges.

The wind climate at Milne Inlet is dominated by winds from the northeast and southeast sectors. Mean wind speeds are typically around 4.6 m/s (9 knots). The maximum wind speed recorded at Milne Inlet between 2006 and 2008 was 38.2 m/s (74 knots). Strongest monthly mean winds occur in August.

Milne Inlet is dominated by a “fast-ice” regime, although icebergs are also present. Ice ride-up features are common in intertidal and nearshore areas. Maximum tidal amplitudes in Milne Inlet are typically about 2.0 m. Initial measurements indicate that tidal currents are very weak near the head of the Inlet. Maximum fetch is limited to about 10 km and wave heights are unlikely to exceed 1 m, even in the most severe wind conditions. CTD data from Milne Inlet collected in 2008 and 2010 during the open-water season generally showed a very warm surface layer (about 8-10 m thick) underlain by a thin (~ 20 m), cold, saline water mass beneath which was a largely homogeneous warmer water mass extending to depths in excess of 100 m.

***Chemical Environment***

The water quality of Milne Inlet was circumneutral, hard, and clear with moderate amounts of nutrients. Nutrient concentrations tended to be higher in deep waters than they were near the surface, and a distinct upper layer of water was observed. Nutrients are generally higher during the ice-cover season than during the open-water season. Overall, nutrient concentrations are generally within range of those found in previous studies conducted in nearby arctic waters.

The major elements in water samples collected from Milne Inlet reflect those typical of marine waters (e.g., chloride, sodium, sulphate, magnesium, etc.). Several metals (including cadmium and iron) are present in such low concentrations that they are generally below the analytical level of detection. Mercury concentration exceeded the CCME guideline for the protection of marine aquatic life in two samples collected from Milne Inlet. No other exceedences were observed; however, the CCME guideline was regularly less than the DL for cadmium, arsenic, and occasionally mercury. Thus, comparisons to these guidelines could not be properly assessed.

Though sediments in shallower areas of Steensby Inlet tended to have a higher amount of coarse material than those in deeper areas, this was not observed for Milne Inlet sediments. Metal concentrations are higher in sediments with a higher proportion of fines and are similar to concentrations reported in literature. Petroleum compounds measured in Milne Inlet were low, also reflective of the literature. Concentrations of arsenic, cadmium, chromium, copper, lead, mercury, and zinc are always below the respective Probable Effects Levels and Interim Sediment Quality Guidelines.

***Biological Environment***

Observations made with underwater video imagery formed the basis of the nearshore seabed habitat mapping at the Milne Inlet Port Site. Vegetation cover was the dominant biotic feature in nearly all observations, with bladed kelps and filamentous red algae being the dominant flora. Overall, the nearshore subtidal vegetation cover is somewhat less in the Milne Inlet survey area than observed at Steensby Inlet. Associated fauna at Milne Inlet is depth stratified, generally sparse, and was most often observed in places where algal cover was low. Brittle stars, sea urchins and bivalve siphons are all commonly observed in Milne Inlet.

Surveys conducted in 2007 revealed that the coastal habitats of Milne Inlet are typical of periglacial coastal environments where most of the shoreline is dominated by either rock or coarse sediment beaches comprised of poorly sorted boulder, cobble, pebble and sand. Limited open-water seasons and the coarse nature of the shorelines results in complex, poorly organized shoreline morphology. In some locations, glacial rebound has created prominent raised beach complexes. The presence of sea ice limits the development of intertidal biota, although rockweed was commonly observed along the shore (45-55% of the shoreline). Milne Inlet has considerable evidence of human use, with hundreds of tent rings, dozens of active hunting camps, and several large and abandoned construction camps; human debris is common along the shoreline.

Chlorophyll *a* concentrations measured in Milne Inlet were within range of those measured in the literature for Arctic marine waters. The observed trend of higher chlorophyll *a* in deep water in Milne Inlet is consistent with the literature and indicates that maximum concentrations typically occur near the bottom of the mixing zone. Contrary to the literature, chlorophyll *a* was higher during the ice-cover season than during the open-water season. However, chlorophyll *a* in the water column is known to increase as the ice begins to melt and ice-associated algae are released. This phenomenon may explain the high chlorophyll *a* concentrations that were observed under ice-cover, as sampling occurred near the end of the ice-cover season (i.e., May and June) when melting may have been underway.

Abundances in the nearshore algal community were estimated from analysis of the georeferenced underwater video imagery collected at Milne Inlet. The shallowest depth category (< 3 m) had the lowest average algal cover in Milne Inlet. The 3 m to 15 m depth category had the highest algal cover, which primarily consisted of benthic bladed kelps (BKS; 38% mean coverage). Foliose red algae averaged 4% cover, while the filamentous red algae were only observed as trace amounts. Vegetation cover decreased in depths over 15 m, though community composition remained similar to that of the 3 m to 15 m depth range.

Twenty-three invertebrate taxa were collected from vertical zooplankton tows carried out in Milne Inlet during 2008 and 2010. The cyclopoid copepod *Oithona similis* dominated the Milne Inlet zooplankton community in both years, followed by *Calanus finmarichus/glacialis* in 2008 and calanoid copepodites in 2010. *C. finmarichus*, *Pseudocalanus. minutus*, *O. similis*, Harpacticoida, *Sagitta elegans*, and *Fritillaria. borealis* were present in 100% of samples in 2008 and 2010. Zooplankton samples were collected from water depths that ranged up to 150 m, and the dominant species were similar to those identified within that depth range in Lancaster Sound in 1979.

Drop camera videography conducted from the shoreline out to a depth of 25 m provided imformation on epifauna within Milne Inet; clams (Bivalvia), brittle stars, and sea urchins were most frequently observed. Brittle stars collected in benthic infauna samples suggest that the density of these echinoderms increases with depth.

Benthic infauna sampling in Milne Inlet was conducted in 2010, with samples collected along transects from shallow subtidal (<3 m) to deep-water (> 60 m) sites. A total of 146 benthic infauna species were identified from Milne Inlet. Polychaetes and ostracods were the most abundant taxa in Milne Inlet, although copepods, amphipods and several species of bivalves were also common. As reported in previous studies of the Canadian Arctic, the abundance and community composition of benthic infauna in Milne Inlet varies with depth. Copepods were more prevalent at shallower sites and clams dominated at deeper sites. The highest density of organisms occurred between 15 m and 25 m, and there was a small decrease in density with increasing depth.

The nearshore marine fish community in the vicinity of the Milne Port is characterized by low species diversity and abundance. Arctic char, fourhorn sculpin, shorthorn sculpin, Arctic staghorn sculpin, and Greenland cod were captured during the experimental gillnetting program, with sculpin species accounting for 80% of the catch. Muscle samples collected from the Arctic char catch contained an average mercury concentration below the Health Canada commercial export limit of 0.5 ug/g. Although few Arctic char were captured at the Milne Port site, the nearby Tugaat and Robertson Rivers support anadromous char populations.

## Steensby Inlet

### *Physical Environment*

Foxe Basin is a broad, shallow, enclosed basin in the Canadian Shield with water depths typically less than 100 m. Most of the shipping route into Steensby Inlet is in excess of 40 m deep, but it also contains numerous shallow shoals. Southern Steensby Inlet is marked by two north-south longitudinal troughs reaching maximum depths of about 145 m, shoaling to a depth of 40-60 m near the proposed port area.

During the ice-cover period, winds in northern Foxe Basin and Hudson Strait are predominantly from the west (Hudson Strait only) or northwest. Directionality is more variable during the open-water season, but winds are predominantly southerly or southeasterly. Wind data near the proposed port reveal a mean annual hourly speed of 17.1 km/h, a mean maximum wind speed of 22.5 km/h, and occasional maximum speeds in excess of 90 km/h.

Steensby Inlet is dominated by a fast-ice regime. Field observations indicated relatively featureless ice with very little pressure ridging evident, and observations along the shoreline showed no evidence of pressure ridging or ice push features on shore. Satellite observations indicated that ice melt generally begins in June, with fracturing of the fast-ice in early- to mid-July, and clearing at the beginning of August. Time-lapse photography collected in 2008 supports this characterization of breakup with ice melt pools observed in late June, fracturing of the ice during the first week of July, and gradual clearing of ice through the remainder of July. Multi-year ice stranded along the shore in September of 2008 and 2010 may have originated from Fury and Hecla Strait. Freeze-up begins in late October at the north end of Steensby Inlet and by early December is reaching into northern Foxe Basin.

Tides are mainly semidiurnal in Steensby Inlet, and have a pronounced fortnightly cycle that alters currents in the region. The maximum observed tidal range is approximately 4 m during spring tides and 1.5 m to 2 m during neap tides. Near the proposed port area, maximum currents were between 62 cm/s and 75 cm/s in September and October. Under-ice measurements off the port area revealed currents of less than 50 cm/s. After surface ice fracturing in early July, maximum current velocities increase to 75 cm/s. Currents are tidally driven during ice-covered conditions. Surface drifters (drogues) released near the proposed port area during the open-water season generally sustained a net northward or northwestward movement through the inlet, resulting primarily because winds were from the southeast. Mean wave heights are in the range of 0.3 m during the open-water season, and maximum wave heights measured near the proposed port facility are 0.9 m. Wave climate is controlled by locally generated waves.

Under-ice CTD profiles measured in June showed a thin (< 8 m), warmer (2$^{o}$C to -1$^{o}$C), fresher (salinity 3 to 33 psu) surface layer with a sharp interface below which waters were approximately -1.7$^{o}$C and salinities were between 33 psu and 34 psu. CTD profiles measured during open-water conditions were characterized by surface temperatures of 3.0$^{o}$C to 3.5$^{o}$C and bottom water temperatures of less than 0.6$^{o}$C. Surface salinities were generally between 25.2 psu and 25.6 psu with bottom water salinities of 27.0 psu to 27.7 psu. The step-like character of many profiles in both ice-cover and open-water conditions suggests a complex suite of water masses present in the inlet.

***Chemical Environment***

The water quality of Steensby Inlet is circumneutral, hard, and clear with moderate amounts of nutrients. Nutrient concentrations tend to be higher in deep waters than they were near the surface, and nutrients are generally higher during the ice-cover season than during the open-water season. Overall, nutrient concentrations in Steensby Inlet are within range of those found by previous studies conducted in nearby arctic waters.

The major elements in water samples collected from Steensby Inlet are typical of those from marine waters (e.g., chloride, sodium, sulphate, magnesium, etc.). Several metals (including cadmium and iron) were present in such low concentrations that they were generally below the analytical level of detection. The CCME guideline was regularly less than the detection limit for cadmium, arsenic, and occasionally mercury. Thus, comparisons to these guidelines could not be properly assessed.

Sediments in shallower areas of Steensby Inlet tend to have a higher amount of coarse material than those in deeper areas, consistent with results reported in other studies. Metal concentrations are higher in sediments with higher proportions of fines, similar to trends observed in previous studies of the region. Concentrations of arsenic, cadmium, chromium, copper, lead, mercury, and zinc are always below the Probable Effects Levels and most were below the Interim Sediment Quality Guidelines (ISQG). However, arsenic, chromium, and mercury exceeded their respective ISQG at a few sites in Steensby Inlet.

***Biological Environment***

Shoreline surveys conducted in 2007 revealed that the coastal habitats of Steensby Inlet are typical of periglacial coastal environments where most of the shoreline is dominated by either rock or coarse sediment beaches comprised of poorly sorted boulder, cobble, pebble and sand. Limited open-water seasons and the coarse nature of the shorelines result in complex, poorly organized shoreline morphology. In some locations, glacial rebound has created prominent raised beach complexes, and though ice ride-up features occur, they are less common than in Milne Inlet. The presence of sea ice limits the development of an epibiotic community in shallow areas, although rockweed was commonly observed along the shore (45% to 55% of the shoreline), and salt marshes are found along about 13% of the coast in Steensby Inlet. Intertidal kelps are rare but shallow nearshore kelp is observed throughout the inlet and is very common offshore, in water depths greater than 10 m. The shoreline of Steensby Inlet has little evidence of anthropogenic disturbances – a few active camps were noted and a number of older archaeological sites were observed.

Four depth-stratified seabed habitat classes were described from bathymetry and geo-referenced underwater digital videography collected in the Steensby Port area. Each class was defined by the dominant substrate and assemblage of benthic algae and epifauna. High resolution bathymetry and side-scan sonar images were combined with the mapped habitat classes to extrapolate areas of habitat classes across the nearshore. Ice scour ridges, troughs and wallow depressions were commonly observed, in particular at depths less than 9 m. Substrates are generally coarse sediment in the nearshore, tending towards muddy gravelly sands in the deeper areas. Vegetation cover is the dominant biotic feature in nearly all observations, with the bladed kelps and foliose red algae being the most abundant flora. Associated fauna was depth stratified, generally sparse, and is most often observed in places where algal cover was low.

Chlorophyll *a* concentrations measured in Steensby Inlet were within range of those measured in the literature for Arctic marine waters. Concentrations were higher during the ice-cover season than during the open-water season.

Algal community information was collected using underwater videography in Steensby Inlet in 2007 and 2008. Sample collection in Steensby Inlet in 2008 was used to supplement the videography data. The shallowest depth category (< 3 m) has the lowest average algal cover. The 3 m to 15 m depth category has the highest algal cover and primarily consists of benthic bladed kelps (BKS), which averaged 34% cover. Foliose red algae averaged 8% cover, and filamentous red algae averaged 14% cover. Vegetation cover decreases at depths greater than 15 m, although community composition remains similar to that of the 3 m to 15 m depth range.

Thirty invertebrate taxa were identified from vertical zooplankton tows conducted in Steensby Inlet in the fall of 2008 and fall 2010. Calanoida had the highest average density in 2008, followed by the chordate Larvacea, and Thoracica. In 2010, Thoracica had the highest average density followed by Calanoida and Larvacea. Species dominance and richness were similar between the two years. The species *P. minutus* and *Balanus sp*. (nauplius or cypris) were present in 100% of samples in both years, while *F. borealis, C. finmarichus*, and unidentified polychaete larvae were absent from only one site in either 2008 or 2010. In 2010, Harpaticoida and unidentified calanoid copepodites were also present in 100% of samples. The dominance of copepods within Steensby Inlet samples appears to be typical for the region, as reported in the literature.

In 2007 and 2008, distribution and abundance of epifauna were classified from underwater towed videography. Samples were collected opportunistically during Steensby Inlet algal sampling in the same years. Like the infauna samples (see below), epifauna species are stratified by depth. Although barnacles and bacterial mats were commonly at shallow depths and feather stars are common in deeper waters, anemones are the most abundant taxa at all depths.

Benthic infauna sampling in Steensby Inlet was conducted along transects from shallow subtidal (<3 m) to deep-water (> 60 m) sites. Polychaetes, usually followed by either Malacostraca or ostracods, were the most abundant taxa of the 202 benthic infauna species identified from the Steensby Inlet samples. Benthic invertebrate community composition and densities changed with depth. The highest benthic infauna densities occurred between 10 m and 45 m, and the lowest occurred at 3 m (likely due to disruption of habitat due to ice scour).

In general, the marine fish community near the Steensby Port documented during Project-specific studies was characterized by low species diversity and abundance. Arctic char, fourhorn sculpin, shorthorn sculpin, and Atlantic lumpfish were captured during experimental gillnetting programs. Arctic cod and larval sculpin (most likely ribbed sculpin) were commonly consumed by Arctic char. Arctic char were by far the most common species observed, comprising 90.6% of the total catch between 2007 and 2010. The average concentration of mercury within muscle tissue samples collected from the Arctic char catch was below the Health Canada commercial export limit of 0.5 ug/g.

Arctic char are distributed throughout coastal areas in the vicinity of the port site, but were captured in much greater abundance in Ikpikitturjuaq Bay (a large bay just to the north of the Steensby Port site). The Ikpikitturjuaq River enters into Ikpikitturjuaq Bay and has long been known to support a population of anadromous (sea run) Arctic char that was sufficient in size to support a commercial fishery. Scientific literature and IQ contend that most anadromous char populations display strong fidelity to their natal stream, and remaining in close proximity to the outlet. Thus, it is thought that most of the char captured in the vicinity of the Steensby Port were members of the Ikpikitturjuaq River population. Numerous other rivers within Steensby Inlet support anadromous populations of Arctic char. Some, such as the Cockburn River or the Rowley River, occur within close proximity (10-15 km) to the Steensby Port.

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# 1.0 INTRODUCTION

The Mary River Project ("the Project") is a proposed iron ore mine and associated facilities located on North Baffin Island, in the Qikiqtani Region of Nunavut (Figure 1.1-1). The Project involves the construction, operation, closure, and reclamation of a 21 million tonne-per-annum (Mt/a) open pit mine that will operate for 21 years. The high-grade iron ore to be mined is suitable for international shipment after only crushing and screening with no chemical processing facilities. Three Mt/a of iron ore will be transported via an upgraded existing road to Milne Inlet where it will be stockpiled for shipment during the open water season. A railway system will transport an additional 18 Mt/a of the ore from the mine area to an all-season deep-water port and ship loading facility at Steensby Port where the ore will be loaded into ore carriers for overseas shipment through Foxe Basin. A dedicated fleet of cape-sized ice-breaking ore carriers and some non-icebreaking ore carriers and conventional ships will be used during the open water season to ship the iron ore to markets.

This environmental baseline study report has been prepared in support of an Environmental Impact Statement (EIS) for the Project, to be submitted by the Baffinland Iron Mines Corporation ("Baffinland") to the Nunavut Impact Review Board (NIRB).

Marine aquatic studies were developed using an ecosystem-based approach to provide information to help assess potential environmental effects resulting from development of the Project. Marine environmental studies were designed to collect baseline information on specific aquatic ecosystem components including:

- Physical oceanography;
- Water quality;
- Sediment quality;
- Marine aquatic habitat;
- Lower trophic levels (phytoplankton, zooplankton, benthic invertebrate communities);
- Fish communities;
- Metal residues in fish tissues;
- Seabirds; and,
- Marine mammals.

This baseline report presents a synthesis of information related to the marine environment including physical oceanographic information, water and sediment quality, marine habitat, and biotic communities excluding seabirds and marine mammals. Seabirds and marine mammals are presented in separate baseline reports.

## 1.1 STUDY AREAS

Project interaction with the marine environment will occur through the proposed development and operation of ports at Milne and Steensby inlets, and through shipping activities. The majority of field studies synthesized here were focused in the immediate vicinities of the proposed port sites in Milne and Steensby inlets. A small number of physical oceanographic programs such as the collection of bathymetric data along proposed shipping lanes were conducted farther from the port sites.

**Milne Inlet**

The proposed Milne Port lies on the northern side of Baffin Island, at the southern terminus of Milne Inlet (Figures 1.1-1 and 1.1-2). Ships using the Milne Port would access Lancaster Sound from the north Atlantic via Davis Strait and Baffin Bay. From Lancaster Sound, access to Milne Inlet is through Pond Inlet into Eclipse Sound, or perhaps via Navy Board Inlet and south through Eclipse Sound and Milne Inlet.

The Milne Port area is a narrow fjord, characterized by deep waters and high surrounding head lands. All marine waters inland of Lancaster Sound are covered by fast ice through much of the year. Port operation and shipping activity at the Milne Port would occur from approximately August through October. Marine mammal field investigations related to development of the Milne Port were focused on Eclipse Sound and Milne Inlet.

**Steensby Inlet**

The propsed Steensby Port lies within Steensby Inlet, located on the south side of Baffin Island and at the northern end of Foxe Basin (figures 1.1-1 and 1.1-3). Ships would access the Steensby Port from the north Atlantic via Hudson Strait and Foxe Basin.

Steensby Inlet is a wide bay, characterized by shallow waters and gentle terrestrial relief around most of its perimeter. Shipping from Steensby Port would occur year-round. The shipping route from the north Atlantic to Steensby Inlet is covered with pack ice through much of the year, and Steensby Inlet is covered by fast ice from December through July.

## 1.2 OVERVIEW OF BASELINE STUDIES

Marine baseline field studies were conducted from 2007 through 2010. Several companies participated in the various field programs, including (in alphabetical order):

- AMEC Earth and Environmental (AMEC);
- Archipelago Marine Research Ltd (AMR);
- Coastal and Ocean Resources Inc. (CORI);
- Fugro Jacques GeoSurveys Inc. (Fugro);
- Kivalliq Marine;
- MacGregor GeoScience Limited;
- North/South Consultants Inc.(NSC); and,
- Terra Remote Sensing Inc.

The majority of marine field investigations were focused on the environments in the immediate vicinity of the port sites. Field investigations conducted farther afield in Steensby Inlet and Foxe Basin included the collection of bathymetric data along the proposed shipping route through northern Foxe Basin (conducted by Kivalliq Marine, MacGregor Geoscience, and Fugro), and the collection of physical oceanographic data (water column characteristics, tide data, and ocean current information) throughout Steensby Inlet (Kivalliq Marine, MacGregor Geoscience, AMEC, CORI, NSC). Table 1.1-1 provides an overview of timing of marine environment data collections for each major environmental component.

## 1.3 OVERVIEW OF REPORT

This report provides:

- a review of available scientific information specific to each environmental component (emphasis is placed on information specific to Milne and Steensby inlets where possible);
- a summary of Inuit traditional knowledge collected during the Inuit Qaujimajatuqangit (IQ) conducted for the Project, as well as through other IQ initiatives; and,
- an overview of methods and results of marine field investigations conducted for the Project during 2007-2010.

This report is structured into four main sections:

Section 2: Physical Oceanography - This section describes existing information and Project-specific studies regarding components of the physical environment in Milne and Steensby inlets including seafloor morphology and bathymetry, climate and wind, tides and currents, wave conditions, water temperature and salinity conditions, and sea ice conditions;

Section 3: Chemical Oceanography - This section describes existing information and Project-specific studies describing water and sediment quality conditions in Milne and Steensby inlets; and,

Section 4: Biological Oceanography - This section describes existing information and Project-specific studies describing marine seabed and coastal habitat, lower trophic levels (phytoplankton, zooplankton, benthic invertebrate communities), fish communities, metal residues in fish tissues.

# 2.0 PHYSICAL ENVIRONMENT

## 2.1 SEAFLOOR MORPHOLOGY AND BATHYMETRY

### 2.1.1 Literature Review and IQ

**Milne Inlet**

Milne Inlet is a deep, north-south trending fjord system at the western end of Eclipse Sound (Figure 2.1-1). The inlet system includes two minor arms, Tremblay Sound to the west (depths to 260 m) and Eskimo Inlet to the east (depths to 285 m) adjacent to the main portion of Milne Inlet. Bathymetry within Milne Inlet is complex with several deep basins (up to 841 m) and mid-channel islands (Canadian Hydrographic Service (CHS) 1966, CHS 1985). The southern-most basin adjacent to Koluktoo Bay is up to 318 m deep. Robertson River, the largest river draining into Milne Inlet, has created a wide delta along the western shore of Koluktoo Bay. The proposed port is located at the southern end of Milne Inlet (Figure 1.1-2). This portion of the inlet has a U-shaped cross-sectional profile characteristic of fjords and a maximum water depth of approximately 150 m. Phillips Creek and a smaller creek to the east discharge into the inlet and have created a sand, fjord-head deltaic complex along the southern shore with small estuaries.

**Northern Foxe Basin and Steensby Inlet**

Hudson Strait is a steep-sided U-shaped trough which is generally between 200 and 400 m deep. North of Ungava Bay, the trough becomes a very deep (1000 m) isolated basin lying just west of the entrance to Hudson Strait. A sill at less than 400 m depth separates Hudson Strait from the Labrador Sea.

Foxe Basin is a broad shallow depression north of Hudson Bay, bordered on its eastern and northern sides by Baffin Island and on the west by the Melville Peninsula and Southampton Island; it is an enclosed basin within the Canadian Shield. Most of Foxe Basin is characterized by water depths of much less than 100 m, particularly in the northern and eastern areas of the basin (Prinsenberg 1986). Within Foxe Basin, tidal flats account for approximately 10 percent of the total area and can reach up to 15-25 km in width in the southeastern part of the basin (Figure 2.1-2).

A long, narrow trough extends northward along the Melville Peninsula from north of Southampton Island, with maximum water depths off Hall Beach of about 80 m (Prinsenberg 1986, Jakobsson et al. 2008). The seafloor morphology in the vicinity of this trough is highly complex. This trough deepens progressively southward to more than 100 m before plunging abruptly into a deep (~350 m) northwest-southeast trending trough along the north side of Southampton Island (Foxe Channel).

Northeast of Hall Beach, the seafloor deepens into a broad, complex trough reaching more than 100 m in depth at the entrance to Steensby Inlet (Prinsenberg 1986, Jakobsson et al. 2008). Near the islands in northeastern Foxe Basin the seafloor is marked by a complex of basins (60-80 m deep) and shoal areas (< 40 m).

### 2.1.2 Project-Specific Field Surveys

A series of bathymetric and side-scan sonar data collections were undertaken at Milne and Steensby inlets during 2007, 2008, and 2010 to provide detailed bathymetry, seabed morphology and substrate information in the immediate vicinities of the proposed port sites. Additionally, offshore ship-based bathymetric data collections were undertaken in 2007 and 2008 in northern Foxe Basin to survey potential shipping lanes into Steensby Inlet.

#### 2.1.2.1 Methods

**Milne Inlet**

In 2008, multi-beam and single beam bathymetric data were acquired in Milne Inlet near the proposed port location. These data were supplemented by additional single-beam bathymetric data collected in 2010. Side-scan sonar data collected from the proposed port area in Milne Inlet in 2008 were used to characterize seabed morphology and substrates. All Milne Inlet data were tide-corrected to a tidal datum of -1.3 m relative to msl. Detailed survey methodology is provided in CORI (2008a).

**Northern Foxe Basin**

Bathymetric surveys were undertaken through several corridors in northern Foxe Basin to delineate a feasible shipping route for ore carriers to access the Steensby Port. These surveys were conducted by Kivalliq Marine and MacGregor Geoscience in 2007, and Kivalliq Marine and Fugro in 2008. Ship-based multi- and single-beam sonar systems were used to collect bathymetric data in both years. Additional detail on sampling methodology is provided in Fugro (2009). General survey areas are illustrated in Figure 2.1-3.

**Steensby Inlet**

Multi- and single-beam bathymetric data were acquired in Steensby Inlet in the nearshore areas in the immediate vicinity of the proposed port facilities in 2007 and 2008. Survey effort was directed at five discrete loactions in the area, and was conducted at a level of effort such that 100% coversge was obtained ineach area. Seabed morphology and substrates in the proposed Steensby Inlet port area were characterized using side-scan sonar data obtained in 2007. All Steensby Inlet data were tide-corrected to tidal datum of -2.27 m relative to msl. Detailed survey methodology is provided in CORI (2008a).

#### 2.1.2.2 Results

**Milne Inlet**

The general nearshore bathymetry in the vicinity of the Milne Port is shown in Figure 2.1-4. The southern end of Milne Inlet is characterized by (a) steep side-wall slopes, typical of a fjord carved into bedrock; (b) a subaqueous delta front with seaward-dipping slopes up to 10°; and, (c) a relatively flat seabed in the central portion of the inlet (slopes <4°). The intertidal zone width varies significantly from less than 10 m in some places to over 200 m.

A mosaic of side-scan sonar imagery of the delta front at Milne Inlet is shown in Figure 2.1-5, and illustrates the seabed morphology of the delta near the proposed port facility. The image suggests that seabed sediment is primarily sand on the delta front. The most prominent features are ice gouging and ice impact features on the seabed (figures 2.1-5 and 2.1-7). The hummocky topography that is apparent in some of the sonar imagery (Figure 2.1-7) likely reflects older ice gouge features that have been covered with a drape of sediment. Ice gouging is less common in water depths less than 10m.

The ice gouges are significant and indicate that icebergs are likely frequently grounded on the delta front near the proposed Milne port. Gouges to 40 m water depths suggest significant size. Many of the gouges end abruptly, indicating that the iceberg deteriorated after grounding and calving reduced buoyancy, with the keel lifting off the seabed.

**Northern Foxe Basin**

The 2007 northern Foxe Basin survey suggested that navigation into Steensby Inlet from northern Foxe Basin was feasible on both sides of Rowley and Koch Islands (see Figure 2.1-3 for surveyed area) but noted that additional survey work would be required to fully assess the feasibility of the two routes. Additional survey work conducted in 2008 focused on the eastern side of Rowley Island and provided full seabed coverage for a four nautical mile wide corridor extending south from Steensby Inlet for approximately 108 nautical miles (Fugro 2009). Data collected in 2007 and 2008 have yet to be integrated to provide an overall bathymetric map of the shipping routes.

A depth of 25 m has been identified as a minimum acceptable water depth for the shipping route. Water depth was in excess of 40 m over most of the area surveyed in 2008, but Fugro (2009) indicated that careful consideration must be given when finalizing the route in central Steensby Inlet and along the east side of Steensby Inlet, as numerous shoals occur in those areas. Fugro (2009) further indicated that the surveyed area near Koch and Rowley (see Figure 2.1-3) may present some navigational challenges related to corridor width.

**Steensby Inlet**

Detailed bathymetric and geophysical studies were carried out in the nearshore areas in the immediate vicinity of the proposed port area (Figure 2.1-8). Steep offshore gradients to more than 60 m occur in the vicinity of the proposed ore dock. Between the larger islands and the mainland, water depths do not typically exceed 10 m (small local depressions reach about 13 m) and the topography is complex; similarly the area south of the proposed ore dock (off the southern end of the island) is a broad complex of shoals and small islets with water depths less than 10 m.

Side-scan sonar results reveal that the seafloor in the immediate area is generally covered by scattered cobbles and boulders on a sandy gravel seafloor. Ice-related features are common in nearshore areas (CORI 2008a). These include:

i) elongate, shore-parallel linear ridges and depressions (Figure 2.1-9); and,

ii) nearly circular shallow depressions (5-15 m in diameter) floored by finer sediments usually devoid of cobbles and boulders (“ice wallows”) (Figure 2.1-10).

While present in most areas, the shore-parallel ridges and depressions are particularly well developed along the shoreline north of the proposed port. Ice wallows can be highly concentrated (in some cases overlapping), yielding a patchwork of circular zones of fine sediments with intervening cobble/boulder zones. These are believed to originate from the grounding of multi-year ice.

In some areas (e.g., to the north of the proposed port site; Figure 2.1-11) gravelly shore-normal ridges were observed. These are generally of low relief (< 1-2 m) although some of the largest are up to 7 m above the surrounding seafloor and in some cases continuous for more than 150 m into water depths of at least 35 m. These ridges are 10-20 m wide.

## 2.2 METEOROLOGICAL CONDITIONS

### 2.2.1 Literature Review and IQ

**Milne Inlet**

In-depth studies of Milne Inlet climate and wind patterns have not been previously conducted.

**Northern Foxe Basin and Steensby Inlet**

The following summarizes meteorological conditions (temperature, winds and precipitation) in Foxe Basin and Hudson Strait (Maxwell 1986):

***Temperature -*** Mean daily temperatures in northern Foxe Basin are -26 to -30$^{o}$C in January; increase to -15 to -21$^{o}$C by April, are as high as 5 to 6$^{o}$C in July and then decrease to -7.5 to -11$^{o}$C by October. In Hudson Strait, mean daily temperatures range from - 18$^{o}$ to -25$^{o}$C in January; warm up to -11 to -16$^{o}$C in April; and 5 to 6$^{o}$C in July; and fall to -2.5 to -5$^{o}$C by October.

***Winds -*** Dominant winds in northern Foxe Basin in January are from the northwest. In Hudson Strait, they are from the northwest and west in January. Winds in both areas are much more variable in July, although with a slight dominance of winds from the northwest exists in eastern Hudson Strait. Mean wind speeds at Hall Beach (Foxe Basin) are similar throughout the year (18-21 km/h) except for October when they reach up to 25 km/h. Maximum wind speeds are 106 km/h in October and range from 70 to 100 km/h throughout the rest of the year. At Cape Hopes Advance (Hudson Strait) mean wind speeds are more variable throughout the year (23-33 km/h). Maximum wind speeds there occur in October, December and February (97-106 km/h).

***Precipitation -*** Annual rainfall at Hall Beach mainly occurs in August (39.1 mm) out of an annual total of 99.5 mm. Snowfall is highest (21.5 cm) in October out of an annual total of 121.3 cm. At Cape Hopes Advance (Hudson Strait), rainfall is again highest in August (45.7 mm) of an annual total of 146.2 mm. Snowfall is highest in December (25.1 cm) of a total of 151.9 cm.

***Freshwater Inputs*** - River discharge into Foxe Basin, Hudson Strait, Ungava Bay and Hudson Bay is of primary importance for the hydrology of the system (Saucier et al*.* 2004). The annual discharge of rivers into the basin are among the most significant contributors of freshwater (Déri and Wood 2004; Déri et al. 2005). The river discharge of all rivers into this basin represents approximately 18% of the total river discharge to waters north of the Arctic Circle, more than any other large river basin in Eurasia and North America (Carmack 2000; Shiklomanov et al. 2000). River discharge in the Hudson Bay/Foxe Basin complex has a prominent seasonal periodicity with maximum discharge normally observed in June and July (Saucier et al. 2004).

***Climate*** - The climate of Hudson Strait and Ungava Bay is dominated by air masses that originate over the Arctic Islands to the north (Bryson and Hare 1974). In winter, the air mass is cold, relatively dry, and considered continental in nature (Maxwell 1980, 1986). In spring and summer this continental Arctic air mass retreats northward to be replaced by a warmer, moister air mass known as ‘maritime Arctic’. The mean atmospheric pressure field is dominated throughout the entire year by an intense low pressure area centered over eastern Davis Strait (Maxwell 1982, 1986). The associated cyclonic motion produces north and northwesterly winds over Hudson Strait bringing cold continental Arctic air to the region.

### 2.2.2 Project-Specific Field Surveys

#### 2.2.2.1 Methods

Methods used to collect meteorological data at both Milne and Steensby Inlets are described in RWDI (2008).

#### 2.2.2.2 Results

A complete meteorological assessment of climate for the north Baffin region (which includes Steensby and Milne inlets) is provided by RWDI (2008). Only key elements of the meteorological conditions as they relate to oceanography are summarized here.

***Temperature*** - Mean temperatures in this region of the Arctic Ocean are approximately -15 C, with minimum monthly temperatures occurring in February (-34 C) and maximum monthly temperatures occurring in July (+8 C) (RWDI 2008, Table 13). The seasonal variation in temperature is the driving force behind annual sea ice formation and variations in water column stratification.

***Winds*** - Wind regimes are extremely important as they cause surface currents or storm surges, create waves and can be important for ice movement. Milne Inlet monthly average wind speeds are in the range of 4-6 m/s (8 to 12 knots) with August being the windiest month and January being the calmest month (RWDI 2008, Table 15). Figure 2.2-1 summarizes the wind directional occurrence for Milne Inlet and shows two dominant nodes: winds from the northeast and winds from the southeast.

Average wind speeds for Steensby Inlet are in the range of 4-6 m/s (8 to 12 knots) (RWDI 2008, Table 15). The maximum measured wind velocities to date have been approximately 27-29 m/s (52 - 56 knots). October is the windiest month of the year and December is the least windy month of the year.

Figure 2.2-2 summarizes the directions and speeds of wind for Steensby Inlet. The dominant wind direction in Steensby Inlet is from the northwest, with secondary directions from the east and southeast; stronger winds are more likely to be from the southeast.

## 2.3 TIDES AND CURRENTS

### 2.3.1 Literature Review and IQ

**Milne Inlet**

Canadian Hydrographic Service tidal data show that tides within Milne Inlet are semi-diurnal, and that maximum tidal amplitudes at the head of Milne Inlet are approximately 2.3 m (Canadian Hydrographic Service; http://www.tides.gc.ca/; Tide Station 5791).

Measurements of currents at Cape Hatt, near the entrance to Milne Inlet, show that tidal currents were generally small (<0.05 m/s), but jets of higher currents occur near coastal promontories with maximum current velocities in the range of 0.15 m/s to 0.3 m/s (Buckley et al. 1987). Currents in Milne Inlet will be largely dominated by the tides, especially in winter. Wind-driven circulation may be a secondary factor during the open-water season, though there are no data on the overall circulation in Milne Inlet. Estuarine flow will be least important in determining current velocities and motions in Milne Inlet. Buckley et al. (1987) suggest that internal waves may occur in Milne Inlet during early summer periods when the pycnocline is strong.

**Steensby Inlet**

Tidal amplitudes vary widely as the tide progresses up Hudson Strait from the Labrador Sea and into Foxe Basin. Reported tidal amplitudes are 4.5 m in the southeast corner of the basin (near Foxe Peninsula) but decrease to 0.5 m off Hall Beach (Melville Peninsula) where they are affected by the tide entering Foxe Basin through Fury and Hecla Strait (Prinsenberg 1986). Limited tidal measurements made in Foxe Basin indicate that:

i. Tides in most of the region are strong, being responsible for > 95% of the entire energy of sea level variations; in some areas of Foxe Basin (southeast) the tidal range exceeds 8.5 m;

ii. Tides are the major factor determining hydrologic and dynamic characteristics, including water structure and ice motions;

iii. Tides in this region are mainly semidiurnal; and,

iv. Due to complicated topography and bathymetry, tides are spatially highly variable; tidal heights at nearby locations can differ by a factor of two to three.

Tidal currents dominate in the Canadian Arctic Archipelago (CAA). Results from two current meters deployed in the northwestern part of Foxe Basin (Greisman 1984) clearly indicated that the observed currents were mainly semidiurnal tidal currents. Tidal models (diurnal and semidiurnal) constructed for this region by Kowalik and Proshutinsky (1994) and Lyard (1997) indicate that tidal currents in the CAA are generally between 0.2 and 0.4 m/s, but in some areas can exceed 1.5 m/s. These high tidal current speeds appear necessary to keep areas such as the Hall Beach polynya ice free throughout the winter (Prinsenberg 1986).

The mean circulation of Foxe Basin (summarized in Figure 2.3-1) shows a net southerly directed mean flow from Fury and Hecla Strait along the western shore of the basin. Mean circulation within Hudson

Strait (summarized in Figure 2.3-2) shows that mean currents in Hudson Strait follow a well-defined westward-flowing pattern along the north side of the Strait and eastward-flowing pattern along the southern shore of the Strait.

### 2.3.2 Project-Specific Field Surveys

#### 2.3.2.1 Methods

**Milne Inlet**

No tidal studies were undertaken in Milne Inlet because the Canadian Hydrographic Service has previously deployed tide gauges at Koluktoo Bay and in Milne Inlet. Current velocity information was collected in 2010 near the proposed Milne Port site. A small number of Acoustic Doppler Current profiles (ADCP) were obtained in August 2010 from a surface vessel, and two bottom-mounted ADCP current meters were deployed near the proposed port facility in September 2010.

**Steensby Inlet**

Tide gauges were installed near the proposed port area in Steensby Inlet (1) between 1 September 2007 and 18 April 2008 (231 days) and (2) between September 4 and October 7, 2008 (33 days) to determine the complete suite of tidal constituents, thus permitting prediction of local tidal conditions into the future. Additionally, pressure sensors on current profilers installed near the port area and at the entrance to Steensby Inlet enabled a more precise characterization of the tides throughout the region.

Current meter profiles through the water column were obtained in Steensby Inlet at five sites: two located near the proposed port site and three at the entrance to Steensby Inlet near Koch Island (Figure 2.3-3). The instruments were deployed from September 5 until October 13, 2008 (AMEC 2009). Under-ice measurements were made using ADCPs at two locations (20 m and 60 m water depth) near the proposed port area in Steensby Inlet; the shallower instrument was removed on June 7, 2088 while the deeper instrument remained deployed until October 7, 2010. In September 2008, GPS-tracked surface drogues were deployed to investigate wind-driven and tidally driven circulation patterns near the proposed port area.

#### 2.3.2.2 Results

**Milne Inlet**

Current profiles obtained in August 2010 indicated that current speeds are very low near the proposed port. Data collected by bottom-mounted ADCPs in fall 2010 showed that surface currents reach maximum velocities of 0.32 m/s near the proposed port facility, while near-bottom velocities were 0.08 m/s in 27 m of water.

**Steensby Inlet**

Water levels in the southern part of the inlet were studied using: a tide gauge that was deployed for 33 days near the proposed port site; an eight-month deployment of an ADCP with a pressure sensor in the same area; and a five-month record from the pressure sensor in a bottom-mounted Acoustic Doppler

Current Profiler (ADCP). These long deployments permitted the examination of water level differences between open water and ice-cover conditions. The studies allowed for the determination of 44 different tidal constituents, and the prediction of water levels due to tides into the future. Salient results include:

- Chart datum for Steensby Inlet has been established as -0.227 m relative to msl.
- Tides are mainly semidiurnal and have a pronounced fortnightly cycle. The maximum observed tidal range was approximately 4 m during spring tides and 1.5 to 2 m during neap tides.
- The residual time series (obtained by subtracting the predicted tide from the original data) is small. Tides account for 99.3% of the energy in the sea level fluctuations, indicating relatively little residual energy from atmospheric forcing effects and other secondary factors.
- Long-term water level records indicate intense and abrupt variations associated with atmospheric activity in Steensby Inlet (Foxe Basin) in the winter ice-covered season. Strong set-downs of up to -0.93 m and strong set-ups of up to +0.77 m in the residual sea level occurred several times during the observational period.
- Shore profiles in the Steensby port area showed that the average lower limit of terrestrial vegetation is 5.2 m above tidal datum (2.21 m amsl), suggesting that this is effectively the “marine limit” for the port area (CORI 2008b).

Ice cover slightly attenuates tidal sea level variations by about 5-6%. In contrast, tidal phases are consistent among all instrument records, indicating that the ice suppresses tidal oscillations but does not slow the propagation of tidal waves.

Under-ice current measurements taken near the proposed ore dock in May and June 2008 show that currents are invariably less than 0.5 m/s (1 knot) until the end of June. After surface ice fracturing in early July, current velocities increase rapidly and can reach more than 0.75 m/s (1.5 knots) by mid- to late July. As expected, currents are tidally driven during ice-covered conditions.

In late August, a very strong tidal dominance with maximum current speeds of about 0.9 m/s (1.75 knots) was measured at a depth of 8 m near the proposed ore dock, (ASL 2008). Maximum velocities were much less (<~ 0.6 m/s; 1.2 knots) at greater depths. Current data collected in September 2008 (Table 2.3-1) show that maximum current velocities near the surface are approximately 0.6 m/s (1.2 knots) and were slightly lower at depth (0.46 m/s = 0.9 knots). Under-ice velocities had maximum velocities of 0.30-0.35 m/s (0.6 knots) which were similar throughout the water column (ASL 2008).

Currents in the channel between the ore dock island and Baffin Island (Table 2.3-2) were relatively uniform with depth, with maximum velocities of 0.5 to 0.6 m/s (1.1 knots). Current meter profiles (AMEC 2009) from September between Koch Island and Cape Jensen (72 m depth) show that maximum velocity occurs in surface waters and velocities of up to 0.81 m/s (1.6 knots) were achieved. Seafloor velocities were a maximum of 0.4 m/s (0.8 knots). In October, velocities were similar reaching maximum values of 0.84 m/s (1.7 knots) in surface waters and 0.41 m/s (0.8 knots) near the bottom. Mean velocities were also similar in September and October at this site from approximately 0.2 m/s (0.4 knots) at the surface diminishing to 0.14 m/s (0.3 knots) at the seafloor.

Between Koch Island and Cape Thalbitzer (96 m depth), maximum velocities of 0.9 m/s (1.75 knots) were measured in surface waters during September (Table 2.3-3), while maximum bottom water velocities were 0.6 m/s (1.2 knots). In October, maximum surface velocities were 0.87 m/s (1.7 knots) with maximum velocities of 0.65 m/s (1.3 knots) at the seafloor. Mean velocities were similar in both months and measured 0.26 m/s (0.5 knots) at the surface and .23 m/s (0.45 knots) at the seafloor.

Surface drifters (drogues) were released in the vicinity of the proposed dock facilities in Steensby Inlet from 8 to 28 September, 2008. Thirty-seven drifter runs were carried out (Figure 2.3-4). Results showed that the vast majority of the drifters sustained a net northward or northwestward movement through the inlet, though with perturbations in their trajectory which were clearly tidal in nature. The pattern occurred as a result of dominant southeast winds in the area during this time period. A few drifters moved southwestward into Steensby Inlet and a very few moved southward and into the bays south of the proposed port area.

## 2.4 WAVE CLIMATE

### 2.4.1 Literature Review and IQ

There is no information available on previous wave climate studies conducted in either Milne Inlet or Steensby Inlet.

### 2.4.2 Project-Specific Field Surveys

Field programs to document the wave climates in Milne Inlet in 2010 and Steensby Inlet in 2008.

#### 2.4.2.1 Methods

**Milne Inlet**

A wave gauge was deployed at Milne Inlet during the month of September 2010 (AMEC 2010). The wave height detection limit for the instrument was set at 0.05 m.

**Steensby Inlet**

Wave sensors were deployed at two locations within Steensby Inlet in 2008, although the sensor deployed at the mouth of Steensby Inlet between Koch Island and Cape Thalbitzer (Site 2) was lost (Figure 2.3-3). The recovered wave sensor provided data for a location near the proposed ore loading facility (AMEC 2009).

#### 2.4.2.2 Results

**Milne Inlet**

Wave heights exceeded the 0.05 m detection limit 45% of the time, exceeded 0.3 m 10% of the time and exceeded 0.5 m 2% of the time. The highest significant wave measured was 0.57 m with a wave period of approximately 3 seconds. This wave height was measured during a 2-day, early September storm event (7-8 September 2010).

The dominant wave approach direction during the storm event was from the northeast, which is coincident with the maximum fetch direction.

The wave data confirm that the Milne Inlet port area is a comparatively low wave-energy site. Waves are locally-generated and highest waves originate from the northeast. Assessment of wave fetch (~ 10 km) and maximum winds of 15 m/s (30 knots) suggest that significant waves of 1.3 m and wave periods of 3.8 sec could be generated near the port site. Such wave conditions would only be generated during the strongest winds during open-water months.

**Steensby Inlet**

Wave sensors were deployed at two locations within Steensby Inlet in 2008, although the sensor deployed at the mouth of Steensby Inlet between Koch Island and Cape Thalbitzer was lost. The recovered wave sensor provided data for a location near the proposed ore loading facility (AMEC 2009).

Measurements show that the mean wave height is 0.3 m and mean period is about 2.3 s (Table 2.4-1), which indicates that waves at the loading facility are primarily locally generated waves under typical wind conditions. During strong wind events, maximum wave heights of 0.9 m with periods of 5.4 seconds were generated, consistent with locally generated waves within the Inlet. The most common wave approach direction at the proposed loading site is from the south.

## 2.5 TEMPERATURE AND SALINITY

### 2.5.1 Literature Review and IQ

**Milne Inlet**

Oceanographically, Milne Inlet behaves like other inlets in the region. In winter, the inlet is covered by ice and there is no freshwater input. Consequently, salinity and temperature are controlled by cooling at the surface and ice formation. During the ice-cover season, profiles show that temperature and salinity are relatively uniform with depth at -1.5°C and 32 practical salinity units (psu), respectively (Buckley et al. 1987). These values are typical of an under-ice water column subject to cooling near the surface and convective overturn. In the open water season, the inlets behave more like traditional estuaries, as they receive a significant input of fresh water at the surface, and remain highly stratified, with a strong pycnocline typically at a depth of 5 to 10 m (Fissel et al. 1981; Buckley et al. 1987). Surface water temperatures of 4.5°C have been measured in the summer, decreasing to -1.5°C at a depth of 45 m (Buckley et al. 1987). Salinities of 23 psu at the surface were typical of open water conditions. The largest river flowing into Milne Inlet is the Robertson River, which empties into Koluktoo Bay near the head of Milne Inlet.

**Steensby Inlet**

Foxe Basin, Hudson Bay and Hudson Strait make up a large Canadian inland sea system. There is a net transport of sea-water through the system from the Arctic Ocean through Fury and Hecla Strait and Foxe Basin to the Labrador Sea and Atlantic Ocean (Sadler 1982). In addition, there is a considerable contribution from river runoff. The freshwater input (runoff plus precipitation minus evaporation) into Hudson Bay is 20 times larger than which runs into Foxe Basin. Sea-ice meltwater is a much more significant source of freshwater in Foxe Basin (Jones and Anderson 1994). Therefore, three water types enter this system: river runoff, seawater from the Arctic Ocean, and seawater from the Labrador Sea (Jones and Anderson 1994). In addition, sea-ice production and melting together with physical mixing produce a range of water masses.

High salinity waters occur in the eastern part of Hudson Strait where Labrador Sea water is encountered. This water mass is characterized by warm temperatures (> -0.1°C) and is cooled and diluted by overlying water as it moves toward Foxe Basin. In Hudson Strait, the water below 180 m is warmer than the water above it. A sill separating Hudson Bay and Foxe Channel prevents the intrusion of the deep (> 185 m) saltier and colder water of Foxe Channel into Hudson Bay (Campbell 1964; Prinsenberg 1986). The most spectacular feature of the horizontal distribution of sea surface temperatures (SST) and sea surface salinities (SSS) in Hudson Strait is a marked across-channel gradient over the entire length of the strait, with lower salinities and higher temperatures to the south (Drinkwater 1986).

The small amount of Arctic water flowing southward through Fury and Hecla Strait significantly influences the circulation, and temperature and salinity fields in Foxe Basin (Prinsenberg 1986; Ingram and Prinsenberg 1988). Due to intense tidal mixing in Fury and Hecla Strait, the Arctic water entering Foxe Basin is vertically homogeneous. In late winter, the water temperature is -1.7°C and the salinity is between 32.0 and 32.1 psu, while in summer the water temperature ranges from 0.5 to 0.75°C, with a salinity of 31.0 to 32.0 psu.

Melting of ice floes during summer causes large surface variations in the salinity and temperature distributions of Foxe Basin which obscure the spatial variations caused by cyclonic circulation (Campbell 1964). The range of surface water temperatures is typically between -1.7°C and 3.1°C, with warmer surface temperatures occurring in Foxe Channel (Prinsenberg 1986). The range of surface salinity is large, due to both local dilutions by meltwater from ice floes and river runoff.

In the shallow eastern part of the basin, very large tides (8 m) cause complete mixing. Fresher and warmer water occurs on the western side of Foxe Basin where surface water flows southward along the Melville Peninsula. The highest tidal ranges and strongest currents (250 cm/s) occur in the southeastern corner of Foxe Basin, causing intense turbulence in that area (Campbell 1964).

The cold saline bottom water of Foxe Basin is produced by salt rejection during ice growth over its extensive tidal flats (Campbell 1964). While the water column is weakly stratified in the summer, intense tidal mixing it to becomes homogeneous by the end of November.

### 2.5.2 Project-Specific Field Surveys

Temperature and salinity measurements were taken through the water column in open water and ice-cover conditions in 2007, 2008, and 2010 to describe water mass characteristics within Milne and Steensby inlets during periods of open water and ice-cover.

#### 2.5.2.1 Methods

**Milne Inlet**

Water mass physical characteristics were studied by lowering a RBR Ltd. (Ottawa, Canada; www.rbr-global.com) model TD-410 submersible CTD (conductivity/temperature/depth) meter through the water column at sampling sites. *In situ* vertical temperature and conductivity at depth profiles were collected at a limited number of CTD stations in Milne Inlet in June and September of 2008, and in August 2010 (Figure 2.5-1). A more detailed description of sampling methods is available in NSC 2010a.

**Steensby Inlet**

Temperature and salinity profiles were collected at Steensby Inlet using the same methods as at Milne Inlet. Measurements were collected along a grid north and south of the proposed port area (Figure 2.5-2). In September 2007 and 2008, profiles were collected in east-west transects within approximately 5 km north and south of the proposed port area. In June 2008, CTD profiles were collected over a much larger area, extending southward to the entrance of Steensby Inlet. In August 2010, select sites within the grid were sampled one additional time.

#### 2.5.2.2 Results

**Milne Inlet**

*In situ* profiles collected from Milne Inlet in September 2008 and August 2010 showed that a comparatively warm (0°C to 8°C), brackish (23 psu to 30 psu) surface layer about 8 m to 10 m thick, was present over a cold (-1°C), saline (32 psu) water mass that extended to depths in excess of 100 m (Figures 2.5-3 and 2.5-4).

**Steensby Inlet**

September 2007 CTD profiles in deep water areas (i.e., > 50 m) were generally characterized by surface temperatures of 3.0°C to 3.5°C and bottom temperatures of less than 0.6°C; in some instances bottom temperatures were less than 0.0°C. Surface salinities at these deep sites were generally between 25.2 psu and 25.6 psu, with bottom water salinities of 27.0 psu to 27.7 psu. A surface water mass of warmer and fresher water ranged from 5 m to 22 m in thickness, though not always with a clearly defined pycnocline. The step-like character of some of the profiles suggests that a complex suite of water masses was present in the inlet.

June 2008 profiles under the ice showed a thin (less than 8 m thick) warmer surface layer (2°C to -1°C) of fresher water (salinity 3 psu to 33 psu) with a sharp interface below which water was typically at about 1.7°C with salinities between 33 psu and 34 psu (Figure 2.5-5). Step-like profiles, particularly of temperature, were often observed.

September 2008 profiles differed from the same time period in 2007 in that the surface warm and fresh water mass was generally less than 5 m to 8 m thick, with a more abrupt transition to underlying colder and saltier waters. Again, step-like profiles, occasionally with reversals in gradient, were observed in many cases, suggesting a complex system of water masses (Figures 2.5-6).

CTD profiles collected in the open-water season of 2010 showed very little freshwater within Steensby Inlet. Salinity varied little with depth and was about 32 psu in all the profiles (Figure 2.5-7). Temperature varied from +1°C to 5°C in the surface layer and was typically -1°C in the bottom layer. Generally, the surface layer was about 10 m to 20 m thick (NSC 2010a). A few stations showed an intermediate, transitional water mass extending to 40 m depths, suggesting that the inlet was spatially variable and water mass mixing events occurred over relatively small spatial scales within Steensby Inlet.

## 2.6 SEA ICE

### 2.6.1 Literature Review and IQ

**Milne Inlet**

In Milne Inlet freeze-up typically occurs in early October and results in level fast ice (Enfotec 2010). Eclipse Sound also becomes covered with fast ice, but due to ice pressures from Lancaster Sound, it may contain anywhere from 3/10 to 6/10 old ice. Ice in Eclipse Sound is likely to show more ice shear ridges than ice in Milne Inlet to the south. Mean ice thickness in Milne Inlet and Eclipse Sound reaches approximately 1.6 m in most years, with maximum ice thickness occurring in May. In some years, ice as thick as 2 m has been measured (Figure 2.6-1). Ice melt occurs in June, with fracturing and clearing in July. In cold years, fracturing and breakup within Milne Inlet and Eclipse Sound may be delayed as late as mid-August.

**Steensby Inlet**

For most of the year, Foxe Basin is blocked by ice floes. During that time, landfast ice dominates in the north, while pack ice prevails toward the south. Foxe Basin itself is rarely ice-free until September; open pack ice is common throughout the summer. Vigorous tidal currents and strong winds keep the ice pack in constant motion and contribute to numerous polynyas and shore leads which are found throughout the region. This same motion, combined with high sediment content of the water makes the sea ice of Foxe Basin dark and rough, and easily distinguishable from other ice found in other parts of the Canadian Arctic (Campbell and Collin 1958). Another peculiarity of the ice cover in Foxe Basin is its hummocky topography. Not only is the offshore pack ice formed under stormy autumn conditions, but it is also in constant motion throughout much of the ice-cover season in response to tidal currents and wind.

At the time of maximum ice coverage, land-fast ice is found around the major islands, in the eastern shallows and in the large bays located along the western shore (Markham 1981; Prinsenberg 1986; Enfotec 2010). Changes in the extent of ice cover are minimal during late May and June but include the disappearance of land-fast ice along the shores and growth of the Hall Beach Polynya in a southerly direction.

Mean ice thickness in Foxe Basin has been recorded for almost 40 years. However, almost all of these measurements have been made close to shore in level land-fast ice. The mean measured maximum thickness of ice, ranging from 175 cm in the south to 200 cm in the north, is likley underestimated for the offshore regions, where pressure ridges and rafting occur (Prinsenberg 1986). The ice cover in Foxe Basin is almost entirely made up of first year ice, with only the area around Igloolik likely to exhibit multi-year year ice brought from the north through Fury and Hecla Strait.

Northwesterly winds cause further growth of open water areas north of Southampton Island and the Hall Beach Polynya (Figure 2.6-2; Stirling et al. 1981). Ice concentrations decrease rapidly in August as both Hudson Bay and Hudson Strait become ice free (Markham 1981; Prinsenberg 1986; Enfotec 2010). At this time, ice floes move into the area north of Southampton Island which is ice free earlier in the season. Melting and transport of ice out of the basin continue throughout September, and complete clearing normally occurs before the end of the month. Ice from Fury and Hecla Strait starts to enter Foxe Basin in the mid-August and continues throughout the summer.

Freeze-up usually begins by mid-October in the northwestern corner of Foxe Basin and extends south to Prince Charles Island (Markham 1981). The northern half of Foxe Basin is 90% covered by ice by the end of October, with only small ice-free areas remaining in Foxe Channel. A large recurring polynya in the northwestern part of the basin, known as the Hall Beach Polynya, is surrounded by a large area with less than 9/10 ice concentration (Figure 2.6-2). Other smaller, recurring polynyas and leads occur in the northern part of the basin; open leads and polynyas may also develop south and southeast of the islands due to predominantly northwesterly winds (Markham 1981; Prinsenberg 1986).

### 2.6.2 Project-Specific Field Surveys

Only limited field investigations were conducted to document ice conditions in Milne and Steensby inlets.

#### 2.6.2.1 Methods

**<u>Milne Inlet</u>**

Ice thickness was measured at six water quality sampling sites in Minle Inlet in June 2008.

**<u>Steensby Inlet</u>**

In addition to broader studies of ice conditions related to shipping throughout the entire region (Enfotec 2010), two 2008 field studies were conducted to assess ice conditions in the Steensby port area:

i) georeferenced aerial imagery was collected during marine mammal overflights to document ice conditions prior to breakup; and,

ii) time-lapse cameras were set up to document breakup conditions.

Aerial overflight imagery was collected by fixing a camera to shoot time-stamped photos from the window of a Twin Otter and by simultaneously collecting GPS fix data to georeference the photographs (Table 2.6-1). Following the survey, photos were georeferenced by matching GPS time stamp to the photo time stamp and were viewed for significant features.

Time lapse cameras were setup in several locations near the proposed facilities at the Steensby port area. The cameras were programmed to collect hourly images throughout the break-up and freeze-up periods. Camera locations were adjusted throughout the summer (one system was swept away by waves).

#### 2.6.2.2 Results

**Milne Inlet**

Ice-thickness at the southern end of Milne Inlet ranged from 1.5 m to 1.6 m in June 2008 (Figure 2.6-3).

Ice bergs are also frequently noted within Milne Inlet and Eclipse Sound, and abundant ice push features along the shore of Milne Inlet provide evidence of ice rideup (CORI 2008c).

**Steensby Inlet**

Steensby Inlet is covered by fast ice approximately 9 months of the year (Enfotec 2010). Ice within Steensby Inlet had virtually no ridging in the winter of 2007-2008 (Figure 2.6-4; CORI 2008b). The southern extent of land fast ice is Koch Island (Enfotec 2010). South of the landfast ice zone is the northern Foxe Basin; although there is considerable ice movement within northern Foxe Basin, there is rarely a shear ridge along the fast ice edge and open water is common throughout the winter. Fast ice measurements taken from the Canadian Ice Service data show a very consistent ice edge position (Figure 2.6-5; Environment Canada 2002).

Ice measurements made in Steensby Inlet during 2008 show that fast ice thickness reaches an average of 2 m, with a few measurements up to 3 m (Figure 2.6-5). These measurements are consistent with those made at Hall Beach from 1961 to 1990.

Ice melt in Steensby Inlet begins in June, but the timing of breakup is largely controlled by Foxe Basin ice-clearing events. Ice fracturing within Steensby Inlet generally occurs in mid to late July (Enfotec 2010). In 2008, the ice fractured at Steensby Camp between 4-7 July but did not completely clear until late July (as documented by time lapse cameras; CORI 2008b). Freeze-up begins in late October at the north end of Steensby Inlet and by early December is reaching into northern Foxe Basin. In 2008, large blocks of multiyear ice (~4-5 m in thickness) were stranded along the shore throughout Steensby Inlet (Figure 2.6-6), indicating some ice persists throughout the Inlet. In addition, ice wallow pits caused by stranded ice in the nearshore were observed in 5-7 m water depths, suggesting that stranding of multiyear ice may be common (CORI 2008a); Enfotec (2010) estimates that second-year ice rarely exceeds 2/10 ice cover.

Northern Foxe Basin has a significantly more dynamic ice regime than Steensby Inlet. There is considerable winter ice movement and open-water along the margin with the Steensby Inlet fast ice. While leads open in late April and May, the clearing of ice is relatively slow and controlled by the clearing of ice from Hudson Strait. Most of northern Fox Basin is clear by early July, although ice may linger within marginal channels. Freeze up is delayed within northern Foxe Basin, as fast ice advances southwards from Steensby Inlet. As mentioned previously, some first year ice remains throughout the summer to become second year ice (estimated to be less than 2/10 coverage) (Enfotec 2010).

## 2.7 SUMMARY

**Milne Inlet**

*Seabed Morphology.* Milne Inlet is a long narrow fjord with steep sidewall slopes reaching more than 100 m depth within a few hundred metres of the coastline. The head of Milne Inlet near the proposed port development site is a complex of coarse-grained deltas with steep pro-delta areas prograding into the deep fjord. Nearshore areas on the delta are characterized by abundant ice push features. The shoreline is generally coarse sediment beaches with numerous sections of raised beach ridges.

*Inlet Winds.* The wind climate at Milne Inlet is dominated by winds from the northeast and southeast sectors. Mean wind speeds are typically around 4.6 m/s (9 knots). Maximum wind speed recorded at Milne Inlet between 2006 and 2008 was 38.2 m/s (74 knots). Strongest monthly mean winds occurred in August.

*Tides and Currents.* Maximum tidal amplitudes in Milne Inlet are typically about 2.0 m. Initial measurements indicate that tidal currents are very weak near the head of the Inlet. Data collected by bottom-mounted ADCPs in 2010 showed that near the proposed port facility surface currents reach maximum velocities of 0.32 m/s; near-bottom velocities were 0.08 m/s in 27 m water depth (AMEC 2010).

*Wave Climate.* No wave measurements have been made but maximum fetch is limited to about 10 km and wave heights are unlikely to exceed 1 m, even in the most severe wind conditions.

*Temperature and Salinity.* CTD data from Milne Inlet collected in 2008 and 2010 during open water commonly show a very warm surface layer about 8-10 m thick underlain by a thin (~ 20 m), cold, saline water mass beneath which is a largely homogeneous warmer water mass extending to depths in excess of 100 m.

*Sea Ice.* Milne Inlet is dominated by a “fast-ice” regime,” although icebergs are also present. Ice push features are common in intertidal and nearshore areas, likely a result of steep offshore gradients.

**Steensby Inlet**

*Seabed Morphology*. Foxe Basin is a broad, shallow, enclosed basin within the Canadian Shield, characterized by water depths generally much less than 100 m. Most of the survey shipping route into Steensby Inlet is in excess of 40 m deep, although the inlet itself contains a number of shoals. Southern Steensby Inlet is marked by two north-south longitudinal troughs reaching maximum depths of approximately 145 m, and then it shoals to a depth of 40 m to 60 m near the proposed port area to the north. Ice features such as ridges, troughs and “wallow marks” are common in the nearshore areas near the proposed port area.

*Inlet Winds*. In January, dominant winds in Steensby Inlet are from the northwest, while in Hudson Strait they are from the northwest and west. In July, winds in both areas are much more variable. Wind near the proposed dock facilities achived a mean annual hourly speed of 17.1 km/h, a mean maximum wind speed of 22.5 km/h and occasional maximum speeds in excess of 90 km/h. Winds throughout the winter ice-covered period are generally from the north; in summer and early fall southerly and southeasterly winds are more prevalent.

*Tides and Currents*. Tides in Steensby Inlet are semidiurnal and have a pronounced fortnightly cycle. The maximum observed tidal range is approximately 4 m during spring tides and 1.5 to 2 m during neap tides. Near the proposed port area (12 m depth), maximum currents in September and October were between 62 and 75 cm/s. Under-ice current measurements off the port area revealed currents of less than 50 cm/s. After surface ice fracturing in early July, maximum current velocities increase to 75 cm/s. Currents are tidally driven during ice-cover conditions. Surface drifters released near the proposed port area during open water generally sustained a net northward or northwestward movement through the inlet.

*Wave Climate.* Mean wave heights are in the range of 0.3 m during open water season. Maximum wave heights measured near the proposed port facility are 0.9 m. Waves in Steensby Inlet do not appear to be generated outside the inlet; i.e., wave climate is controlled by locally generated waves.

*Temperature and Salinity*. Under-ice CTD profiles in June show a thin (< 8 m) warmer surface layer (2 to -1 $^{o}$C) of fresher water (salinity 3 to 33 psu) with a sharp interface below which water is typically at about -1.7 $^{o}$C and salinities are between 33 and 34 psu. During open water conditions, surface temperatures are 3.0 and 3.5 $^{o}$C, and bottom water temperatures are less than 0.6 $^{o}$C. Surface salinities are generally between 25.2 psu and 25.6 psu, with bottom water salinities of 27.0 psu to 27.7 psu. The step-like character of many profiles in both ice-covered and open conditions suggests a complex suite of water masses present in the inlet.

*Sea Ice.* Steensby Inlet is dominated by a “fast-ice” ice regime. Field observations indicated relatively featureless ice with very little pressure ridging evident. Observations along the shoreline showed no evidence of shore pressure ridging or ice push features on the shore. Satellite observations indicated that ice melt begins in June, with fracturing of the fast ice in early to mid- July and clearing at the beginning of August (Enfotec 2010). Time lapse photography collected in 2008 supports this characterization of breakup with ice melt pools observed in late June, fracturing of the ice during the first week of July and gradual clearing of ice through the remainder of July. Multi-year ice stranded along the shore in September of 2008 and 2010 may have originated from Fury and Hecla Strait.

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# 3.0 CHEMICAL ENVIRONMENT

## 3.1 WATER QUALITY

### 3.1.1 Literature Review and IQ

No previous studies of water quality have been conducted in Milne or Steensby inlets, and few have documented nutrient or metal concentrations in nearby waters. Further, nutrient concentrations in the Pacific Ocean are higher than in the Atlantic Ocean, and the signature of Pacific waters can be traced as far as Lancaster Sound (Michel et al. 2006); therefore, the current literature review is limited to studies from Lancaster Sound, Foxe Basin, and occasionally Baffin Bay.

Nitrogen, phosphorus, carbon, and silica are macronutrients that are essential for growth of marine plants. Additionally, many other elements (e.g., iron and copper) are micronutrients that are required in smaller amounts (literature summarized in LGL Limited 1983). The inorganic forms of these elements (i.e., nitrate, ammonia, and orthophosphate) are more available to primary producers than the elemental forms (i.e., N and P). Silica (i.e., silicate, $SiO_x$) is essential particularly for specific algae that have siliceous shells (i.e., diatoms and silicoflagellates).

Within the eastern Canadian Arctic Archipelago, open-water concentrations of nitrate and silicate are typically low in the euphotic zone because of rapid assimilation by phytoplankton and aquatic plants; however, concentrations in deeper waters can be much higher (Table 3.1-1; LGL 1983; Mose Jensen et al. 1999; Michel et al. 2006). Historically, nitrate was thought to be the predominant nitrogen source to primary producers in marine environments. However, recent work has shown that wind-induced upwelling of ammonia from deep waters can contribute up to half the nitrogen assimilated by phytoplankton (Kuzyk et al. 2010). Phosphate concentrations have not increased with depth in all studies (Table 3.1-1; Mose Jensen et al. 1999; Michel et al. 2006). Carbon concentrations exhibit a high amount of spatial variation in the region and are strongly influenced by riverine inputs (Kuzyk et al. 2009). For example, dissolved organic carbon concentrations decreased from greater than 7 mg/L to 0.48 mg/L along a transect offshore from the Nelson River Estuary in southwestern Hudson Bay (Baker et al. 1993 *in* Kuzyk et al. 2009). Overall, nutrient concentrations tend to increase during the ice-covered season because of lower photosynthetic and nutrient assimilation rates. Additionally, spatial differences can occur, particularly in spring as primary production and nutrient assimilation rates rapidly increase (Cross 1982; LGL Limited 1983). No literature was located documenting values of other routine parameters (such as alkalinity, pH, or turbidity) in the eastern Canadian Arctic.

Few studies of metal concentrations in water have been reported for eastern Arctic waters. Cadmium and iron concentrations measured in waters of Baffin Bay were 0.00003 mg/L to 0.00006 mg/L, and 0.0003 mg/L to 0.0008 mg/L, respectively (Campbell and Years 1982 *in* Thomas et al. 1983); Thomas et al. (1983) also reported that lead and zinc concentrations in surface waters near the Nanisivik lead-zinc mining operation increased subsequent to development. A study of mercury concentrations in Foxe Basin and Hudson Bay showed that mean aqueous concentrations were 0.00048 ± 0.00007 mg/L and 0.00082±0.36 mg/L, respectively (Hare et al. 2008). Mercury in Foxe Basin did not increase with depth; however, depth stratification was reported for Hudson Bay (Hare et al. 2008). The authors noted that 83% to 87% of total mercury was present in the dissolved form and that particulates comprised a small fraction of the mercury content in the area (Hare et al. 2008).

### 3.1.2 Project-Specific Field Surveys

Water and sediment quality sampling programs were conducted at Milne and Steensby inlets during 2007-2010.

#### 3.1.2.1 Methods

**Sample Locations and Dates**

The water chemistry of Steensby and Milne inlets were assessed during 2007-2010. Sampling periods occurred during the open-water season, in August and September, and under ice-cover in May and June. Not all sites were sampled during all sampling periods. Samples were collected from locations with ranging water depths distances from shore to characterize the overall conditions within each inlet. Details on sampling locations and dates are provided in Table 3.1-2 and Figure 3.1-1 for Milne Inlet, and in Table 3.1-3 and Figures 3.1-2 for Steensby Inlet.

**Field and Laboratory Methods**

Samples were collected using a van Dorn or Kemmerer water sampler from one meter below the water surface, and either at 1 m above the sediment or at 30 m depth (the maximum depth the van Dorn would sample to). The water samplers were pre-cleaned prior to initiation of sampling and were also rinsed with water from the site prior to sample collection. Laboratory supplied sample bottles were filled and processed according to instructions provided by the laboratories. Samples were then stored on ice and in the dark until receipt by the laboratories. Samples for dissolved metals were filtered in the field at the time of collection using Acrodisc® 32 mm Syringe Filters with 0.45 µm Supor® membrane filter, then preserved.

All samples were submitted to Exova Accutest Inc. in Ottawa, ON (Exova Accutest) within 48 hrs of being collected. Analysis of routine parameters and nutrients were conducted at Exova Accutest. Analysis of total and dissolved metals were subcontracted to ALS Environmental (ALS) in Vancouver, BC. Both laboratories are certified with the Canadian Association of Laboratory Accreditation (CALA). Parameters measured and analytical methods used by the laboratories are provided in NSC (2010a).

**Data Analysis**

Means were calculated for parameters where replicate samples were collected and the resulting mean was used to represent the site conditions during that particular sampling event. Measurements reported by the laboratory that were below the analytical detection limit (DL) were assigned a value of one half the DL for all calculations and are presented at half the DL in all figures. Summary statistics, including mean, standard deviation (SD), minimum, and maximum, were then calculated from the data collected during each season. Data were compared to the Canadian Council of Ministers of the Environment (CCME) water quality guidelines for the protection of marine aquatic life (1999, updated to 2010). Guidelines for marine environments exist for pH, nitrate, arsenic, cadmium, and mercury.

#### 3.1.2.2 Results

**Milne Inlet**

The surface waters of Milne Inlet were circumneutral (pH: 7.33 to 7.98), hard (total hardness: 1620 mg/L to 5990 mg/L) and clear (turbidity: 0.3 NTU to 0.6 NTU) with moderate amounts of nutrients (Table 3.1-4). Total nitrogen (TN) ranged from 0.55 mg/L to 3.10 mg/L, total phospohorus (TP) ranged from 0.011 mg/L to 0.54 mg/L, total organic carbon (TOC) ranged from less than 0.5 mg/L to 0.6 mg/L, and reactive silica concentrations ranged from 0.07 mg/L to 2.43 mg/L. Alkalinity, ammonia, TP, reactive silica, total dissolved solids (TDS), and conductivity measured at sites in Milne Inlet were generally higher in deep waters than they were at the surface, particularly during the open-water season. There was some indication that the inlet can stratify during the open-water season (e.g., before and during August) but that it mixes in the fall as surface waters cool (e.g., in September). With the exceptions of ammonia and reactive silica, there was little spatial variability in routine parameters measured in Milne Inlet. As expected, there were some differences in the water quality of the inlet between the ice-cover and open-water seasons. The ranges of alkalinity, ammonia, TDS, and conductivity measured in the surface waters of Milne Inlet were all lower during the open-water season than the ice-cover season, and the range of concentrations of reactive silica in deep waters of the inlet was lower during the open-water season than the ice-covered season (Table 3.1-4). Results for all sites, seasons, and depths were within the CCME guidelines for the protection of marine aquatic life for pH and nitrate.

The major elemental constituents of the waters within Milne Inlet (in order of decreasing importance) were chloride, sodium, sulfate, magnesium, calcium, and potassium (Table 3.1-5) Total and dissolved metal concentrations were often similar, illustrating that metals were present in the water column in the dissolved form and were not typically associated with particulates. Water concentrations were less than or near detection for total and dissolved forms of several metals and contaminants, including: aluminum; antimony; arsenic; beryllium; bismuth; cadmium; chromium; cobalt; copper; iron; lead; lithium; nickel; selenium; silicon; silver; thallium; tin; titanium; vanadium; zinc; and, phenols. When detected, concentrations of most metals in Milne Inlet were higher at depth than they were near the surface, particularly during the open-water season (Figure 3.1-3). Specifically, the range of concentrations of the boron, bromide, calcium, chloride, magnesium, molybdenum, potassium, sodium, strontium, sulphate, uranium, and hardness (Table 3.1-4) measured in deep waters was higher than the range measured for surface waters during the open-water season. During the ice-cover season, this trend was only present for hardness, calcium, magnesium, and sodium.

Overall, metals in the surface waters of Milne Inlet were more dilute in August 2010 than in September 2008, and during the open-water compared to the ice-cover season. Near the surface, the ranges of hardness, boron, bromide, calcium, chloride, magnesium, molybdenum, potassium, sodium, strontium, and sulphate were all lower in August 2010 than in September 2008 and the range in concentration of these metals were also lower during the open-water season compared to the ice-cover season (Figure 3.1-4). Conversely, metal concentrations in the deep waters of Milne Inlet varied less between seasons and years than they did in surface waters. With the exception of bromide, which was lower at depth during the open-water season, metal concentrations at depth were similar between open-water and ice-cover (Figure 3.1-5).

Results for mercury exceeded the CCME guideline for protection of marine aquatic life at two locations (MWQ-02 and -03) in June 2008, but not at any other site or sampling period. The DL exceeded the CCME guideline for arsenic during all periods and for cadmium in June and September 2008; therefore, exceedences of the CCME guidelines could not be assessed in these instances. Results for cadmium were below the CCME guideline in August 2010.

**Steensby Inlet**

The surface waters of Steensby Inlet were circumneutral (pH: 7.54 to 7.96), hard (total hardness: 3760 mg/L to 6680 mg/L), and clear (turbidity: 0.1 NTU to 1.3 NTU), with a moderate amount of nutrients (Table 3.1-4). TN concentrations ranged from less than 0.10 mg/L to 4.56 mg/L, TP concentrations ranged from less than 0.02 mg/L to 0.63 mg/L, TOC concentrations ranged from less than 0.50 mg/L to 1.4 mg/L, and reactive silica concentrations ranged from 0.08 mg/L to 1.41 mg/L. During both the open-water and ice-cover seasons, most routine parameters were fairly consistent across depth, indicating that the inlet was generally well-mixed within the upper 30 m (Table 3.1-6). The exceptions to this trend were conductivity, alkalinity, and ammonia measured during the open-water season, which were generally higher at depth than at the surface. Some variability in routine water chemistry was observed between years and sampling sites, particularly during the open-water season. Water chemistry also varied between seasons such that alkalinity, TP, reactive silica, total dissolved solids (TDS), and conductivity were higher under ice than during the open-water season. Turbidity was slightly lower during the ice-cover season than it was during the open-water season (Table 3.1-4).

Results for all sites, seasons, and depths were within the Canadian Council for Ministers of the Environment (CCME) guidelines for the protection of marine aquatic life for pH (7.0 to 8.7) and nitrate (3.6 mg N/L). No guidelines exist for the other routine parameters measured.

The major elements in water samples collected from Steensby Inlet were those that would be expected to occur in marine waters (i.e., chloride, sodium, sulphate, magnesium, calcium, potassium, and bromide; Table 3.1-7). Total and dissolved metal concentrations were often similar, illustrating that metals were present in the water column in the dissolved form and were not typically associated with particulates. Water concentrations were less than or near the DL for: total and dissolved forms of several elements and contaminants, including: antimony; arsenic; beryllium; bismuth; cadmium; chromium; cobalt; iron; lead; lithium; mercury; nickel; selenium; silicon; silver; thallium; tin; titanium; vanadium; zinc; and, phenols.

Overall, metal concentrations at depth were similar to those near the surface; however, some metals were generally higher in deep waters than in surface waters during the open-water season. These included: calcium, magnesium, sodium, and strontium (Figure 3.1-6). Most metals (that were detected) were present at higher concentrations during the ice-cover season than during the open-water season. In particular, concentrations of boron, calcium, chloride, and strontium were all higher under ice-cover than during the open-water season (Figure 3.1-7).

Mercury concentrations were below the CCME guideline for protection of marine aquatic life (0.000016 mg/L) during the ice-cover and open-water seasons of 2008. The DL exceeded the CCME guidelines for the protection of marine aquatic life for mercury in September 2007, and all sampling periods for arsenic

(0.0125 mg/L) and cadmium (0.00012 mg/L). Consequently, exceedences of these guidelines could not be assessed (Table 3.1-7). No guidelines exist for the other metals or contaminants.

### 3.1.3 Summary

The water quality of Steensby and Milne inlets was similar to each other in that both inlets were circumneutral, hard, and clear with moderate amounts of nutrients. Similar to trends noted in the literature (LGL 1983, Mose Jensen et al. 1999; Michel et al. 2006), nutrient concentrations tended to be higher in deep waters than they were near the surface. This is particularly true of Milne Inlet where a distinct upper layer of water was observed. Nutrients were generally higher during the ice-cover season than during the open-water season. Overall, nutrient concentrations in Steensby and Milne inlets were generally within range of those found by previous studies conducted in nearby arctic waters (Table 3.1-1).

The major elements in water samples collected from Steensby and Milne inlets were those that would be expected to occur in marine waters (e.g., chloride, sodium, sulphate, magnesium, etc.). Several metals (including cadmium and iron) were present in such low concentrations that they were generally below the analytical level of detection. Mercury concentration exceeded the CCME guideline for the protection of marine aquatic life in two samples collected from Milne Inlet. No other exceedences were observed. However, the CCME guideline was regularly less than the DL for cadmium, arsenic, and occasionally mercury. Consequently, comparisons to these guidelines can not be properly assessed.

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## 3.2 SEDIMENT QUALITY

### 3.2.1 Literature Review and IQ

As a result of fast ice, ice scour, and tidal influence, arctic shorelines are generally composed of cobble and pebbles, with finer particles (i.e., silt and clay) being transported to and deposited in deeper areas (Thomson 1982). In one study, sand content of sediments from Hudson Bay decreased from 26% at the shallowest site (34 m) to 0% offshore (150 m; Kuzyk et al. 2009). Grain size and the corresponding depth association also explain the nutrient content of sediments (Thomson 1982). For example, carbon content of substrates in Lancaster Sound were lower in shallow waters [e.g., 0.7 ± 0.5% at 5 m to 10 m depth (n=13)] than in deep waters [1.6 +/- 0.9% at 52 m to 250 m depth (n=57); Thomson 1982]. However in another study, total nitrogen (0.04% to 0.21%) and organic carbon (0.40% to 1.55%) contents of surface sediments from Hudson Bay did not vary with depth (34 m to 430 m water depth; Kuzyk et al. 2010).

Sedimentary cadmium, lead, and zinc concentrations were measured in Strathcona Sound (in Admiralty Inlet) prior to development of the Nanisivik Lead-Zinc Mine (Thomas et al. 1983). Pre-development concentrations of these metals (SFC layer, <0.2 µm size fraction) were 2.05 ± 0.74 µg/g, 43.1 ± 19.7 µg/g, and 0.11 ± 0.02 µg/g, respectively, and the authors noted that natural sources contributed to the elevated concentrations (Bornhold 1975 *in* Thomas et al. 1983). Sedimentary concentrations of cadmium, lead, and zinc increased subsequent to initiation of the mine operation (Schneider-Vieira 1996).

A study of the concentration of petroleum residues in surface sediments in southern Foxe Basin, Hudson Bay, Hudson Strait, and Baffin Bay in 1982 and 1983 reported that the mean concentration for Foxe Basin was 1.78 µg/g (n = 8), with an overall mean of 2.29 µg/g for the region (n = 131; Levy 1986). Petroleum residues were higher in finer substrates, and therefore concentrations of these substances increased with water depth. The author noted that these concentrations were typical of the area and were below the levels known to cause adverse effects in biota.

### 3.2.2 Project-Specific Field Surveys

#### 3.2.2.1 Methods

**<u>Sample Location and Dates</u>**

Sediment chemistry of Milne Inlet was examined during the open-water seasons of 2008 and 2010 (Tables 3.2-1). Studies in Steensby Inlet were conducted during the open-water seasons of 2007, 2008, and 2010 (Table 3.2-2). Sampling sites were located at various locations within each inlet to characterize the overall conditions of the inlet while also examining specific sites with historic and potential future impacts (Figures 3.2-1 and 3.2-2).

**Field and Laboratory Methods**

Sediment samples were collected from nearshore (i.e., sites located in the inter-tidal zone with water depths from 0 m to 4 m) and offshore (i.e., sites with depths > 10 m) areas. In nearshore areas, sediments were sampled along the beach at low tide (in approximately 30 cm of water) by collecting surface sediments directly into sample containers. Offshore samples were collected with a Petite Ponar grab sampler. If necessary, sediments from several grabs were combined in order to provide sufficient sample for analysis. When this occurred, sediments were pooled in a steel or glass container then thoroughly mixed prior to being placed into sample containers. As well, the grabs were separated spatially, but as close together as feasible to ensure that sampling disturbances from one grab did not affect another. With both methods, only the upper 5 cm of sediments were collected to facilitate comparison to CCME sediment quality guidelines and because this fraction is more likely to detect an effect after the Project than a sample comprised of a deeper layer of sediments.. All samples were retained in containers provided by the analytical laboratory then stored in the dark and kept cool until receipt at Exova Accutest (Ottawa, ON; CALA accredited). Parameters and laboratory methods for sediment quality analyses are provided in NSC (2010a).

**Data Analysis**

Means were calculated for parameters where replicate samples were collected and the resulting mean was used to represent the site conditions. For the purposes of statistical analysis, measurements reported to be below the DL were assigned a value of one half the DL for all calculations and are presented at half the DL in all figures. All results were compared to the CCME interim sediment quality guidelines (ISQG) for the protection of marine aquatic life (1999, updated to 2010). Mann-Whitney U-tests and linear regressions were performed using XLSTAT Version 2007.4 by Addinsoft.

#### 3.2.2.2 Results

**Milne Inlet**

In Milne Inlet, the inter-tidal region extends to a depth of approximately two meters, and out of the twelve sites sampled for sediment quality, only two of them (MSQ-1 and -02) fell within this region (Table 3.2-1). As a result of the small "nearshore" sample size for Milne Inlet, the nearshore versus offshore classification was not used, and all sites were considered to be representative of the sediment quality in Milne Inlet as a whole.

The composition of sediment in Milne Inlet varied spatially but was dominated by either sand or sand and silt (Figure 3.2-3). Nutrients levels in the sediments of Milne Inlet were low, though some variation was observed (Table 3.2-3).

Sediment metal concentrations varied spatially in Milne Inlet and were related to silt content. Aluminum, arsenic, calcium, chromium cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, strontium and vanadium were higher at sites with a greater proportion of silt in the sediment (Table 3.2-4).

Antimony, beryllium, cadmium, mercury, selenium, silver and thallium were below detection at all sites in Milne Inlet (Table 3.2-3).

Since shipping has occurred periodically in Milne Inlet over the past 45 years, sediment from three sites were analyzed for hydrocarbons, with MSQ-12 selected as a reference site and sites MSQ-04 and MSQ-08 as potential impact sites. No hydrocarbons were detected in the sediments of the reference site, but some were detected in low levels at sites MSQ-04 and/or -08, including: oil and grease; naphthalene; hydrocarbons C10-16, and C16-C34; and, toluene (Table 3.2-5). Naphthalene was the only PAH detected.

Sediment concentrations were always below the CCME guidelines for protection of marine aquatic life for arsenic, cadmium, chromium, copper, lead, zinc; and, where measured, PAHs (Tables 3.2-3 and 3.2-5; CCME 1999 updated to 2010). No guidelines exist for nutrients or the other metals or hydrocarbons.

**Steensby Inlet**

In Steensby Inlet, nearshore sediments had a higher proportion of coarse material and lower amounts of nutrients and metals than offshore sediments. However, regardless of location, the sediments within the inlet were composed predominantly of sand and had low levels of nutrients (Table 3.2-6). Metals and major ions adsorb to silt and clay more readily than to sand; as a result, offshore sediments had a higher concentration of most metals including aluminum, arsenic, barium, boron, cadmium, calcium, chromium, iron, lead, magnesium, manganese, nickel, potassium, sodium, vanadium, and zinc than nearshore sediments (Table 3.2-6). However, regardless of location, some metals were always near or below the DL throughout Steensby Inlet, including: antimony, beryllium, cadmium, mercury, selenium, silver, and thallium.

CCME sediment quality guidelines for the protection of marine aquatic life exist for arsenic, cadmium, chromium, copper, lead, mercury, and zinc (CCME 1999 updated to 2010). No sites in Steensby Inlet had sediment metal concentrations in excess of the respective probable effect level, and concentrations of cadmium, copper, lead, and zinc were also always below the respective CCME interim sediment quality guideline (ISQG, Table 3.2-6). However, arsenic, chromium and mercury exceeded their respective ISQG at no less than one site (Figure 3.2-4); these exceedences were as follows: arsenic at site SSQ-07; chromium at sites SSQ-07, -08, -09, -10, -15, -24, -29 and -35; and, mercury at sites SSQ-07, and -18.

### 3.2.3 Summary

Consistent with the literature, sediments in shallower areas of Steensby Inlet tend to have a higher amount of coarse material than those in deeper areas (Thomson 1982, Kuzuk et al. 2010). Additionally, metal concentrations in the current study were higher in sediments with higher proportion of fines. Similar trends have been observed for nutrients in previous studies in the region (Thomson 1982). Petroleum compounds measured in Milne Inlet in this study and in another study conducted in the region were low (Levy 1986).

CCME interim sediment quality guidelines for the protection of marine aquatic life exist for arsenic, cadmium, chromium, copper, lead, mercury, and zinc (CCME 1999 updated to 2010). Concentrations of these metals recorded in Milne and Steensby inlets were always below the PEL and most were generally below the ISQG. However, arsenic, chromium and mercury exceeded their respective ISQG at a few sites in Steensby Inlet.

### 3.2.4 References

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# 4.0 BIOLOGICAL ENVIRONMENT

## 4.1 MARINE AQUATIC HABITAT

Fish habitat is defined in the federal *Fisheries Act* as “Spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes”. Because fish habitat is defined by its capability to support fish life processes (including food production), the term aquatic habitat is used in this section to describe the structure of the environment within which fish, and the aquatic biota on which they feed, live. Aquatic habitat, whether freshwater or marine, is typically described on the basis of water depth, water or current velocity, water temperature and other physical characteristics such as salinity, substrate type, and cover. These characteristics determine whether individuals, communities, and populations of fish and other aquatic biota may find the biophysical features they require for life, such as suitable areas for reproduction, feeding sites, resting sites, cover from predators and adverse environmental conditions, movement corridors, and overwintering. The biophysical characteristics of the habitat play a large role in determining the species composition and biomass of the biotic community that can be sustained.

### 4.1.1 Literature Review and IQ

There are few direct studies of marine habitat in Milne Inlet, Steensby Inlet, or Foxe Basin. However, several projects have included some description of biophysical data for the nearshore. For example, the Baffin Island Oil Spill Project (BIOS) was carried out in close proximity to Milne Inlet and provides one of the few surveys within the region where habitats were documented. The four BIOS study bays had substrate characteristics similar to that observed near the proposed Milne port site (see Section 4.1.2.2). The beaches and intertidal zones were mainly gravel/cobble pavement overlying sand (Cross et al*.* 1984). From the nearshore subtidal to 7 m depth, the substrate was a mix of silt, sand, gravel and larger boulders. In deeper waters, an unconsolidated silt veneer is present overlying the substrate, which becomes more predominant with increasing depth. Results from the floral and faunal surveys included in the BIOS program are described in sections 4.2.2.1 and 4.4.1.1, respectively. Epibenthic community assemblages were sampled and described as part of the BIOS research on effects of oil on nearshore macrobenthos.

Thomson (1982) sampled benthic fauna communities at a number of locations in the eastern Arctic and related his findings to various types of benthic habitats in the Lancaster Sound-northwest Baffin Bay area. The author described substrates and the distribution of standing crops of faunal species, and related the community structures observed to depth, currents, and geographic locations. Further descriptions of the faunal communities reported by Thomson (1982) are presented in Section 4.4.2.1.

### 4.1.2 Project-specific Field Surveys

#### 4.1.2.1 Methods

**<u>Seabed Habitat Mapping</u>**

**Milne Inlet**

Seabed habitat along the southern end of Milne Inlet was mapped using drop camera video imagery collected in September 2008, and additional imagery was collected in August 2010 (Figure 4.1-1). The video imagery provides information on the distribution and occurrence of epibenthic biota, as well as substrate. Drop camera imagery was collected by drifting or slowly trolling along transects approximately perpendicular to the shoreline and spaced a few hundred metres apart. Each transect was surveyed from the shore (depth approximately 2 to 3 m) to approximately 25 metres depth. Detailed bathymetric survey information for the area was collected in 2008, and those data were used together with the video tracklines to assign depth intervals to the biological features classified from the imagery.

The classification of the video imagery provides spatial data describing concentration and distribution of epibenthic faunal and floral constituents as well as for substrate types. Substrates observed in the video imagery were mapped with respect to:

- Substrate (sediment, rock, vegetation);
- Sediment class (e.g., gravel, sandy gravel, sand, sandy mud, etc.);
- Percent boulders;
- Percent cobbles;
- Percent pebbles; and,
- Percent total gravel.

Biotic habitat features were classified from the video in terms of vegetation types and percent cover, and by visible fauna and their distribution. Further description of the features and methodologies used for the classification of imagery are provided in CORI (2008a) and Archipelago (AMR 2010). Seabed habitat classes were then defined within Milne Inlet by linking the drop camera videography images to bathymetric data that had been collected separately. Based on depth intervals and the biota they contained, three different classes were identified.

**Steensby Inlet**

Extensive seabed habitat mapping was conducted near the proposed port in Steensby Inlet. Work conducted in September 2007 included the collection of towed underwater video (Seabed Imaging and Mapping System – SIMS; CORI 2008a) and georeferenced high-resolution side-scan sonar survey data (including bathymetry measurements), which provided almost 100% coverage of seafloor substrate in surveyed areas. Four areas were surveyed using both the SIMS video and side-scan sonar techniques, while a larger area was surveyed using side-scan sonar alone. The SIMS surveys followed a gridded trackline path with an approximate 100 m grid size and covered areas from the upper intertidal zone to approximately 45 m water depth. Towed survey speed was 0.5 m/s, and depth measurements were collected during the survey. In early September 2008, additional video drop camera data were collected from bays adjacent to the 2007 survey region (Figure 4.1-2). Steensby Inlet drop camera surveys followed the same protocol used at Milne Inlet.

The resultant interpretations of substrate types were imported into ArcGIS for presentation as trackline plots of the classified imagery (substrate types along the vessel track). For the Steensby Port area, these plots were then overlaid on the side-scan sonar mosaics where they provided the ground-truth required for the creation of polygon maps of habitat types.

During the biological classification of the seabed imagery, depth stratification of biota was observed, particularly in the types and abundances of attached algae. When these spatial data were examined by depth recorded during the image collection, and from tracklines overlaid on bathymetry, four nearshore ‘Habitat Classes’ were defined by depth interval and described by dominant biota and substrate characteristics. These classes were later extrapolated to parts of the Steensby Port area for which detailed bathymetric data had been collected, but that were outside of video survey lines (CORI 2008a).

**Coastal Habitat Surveys**

**Milne and Steensby Inlets**

Surveys were conducted to image and map coastal habitat in Milne or Steensby inlets. The aerial survey methodology followed the ShoreZone program (Harney et al. 2008) where low-altitude, low-tide georeferenced video and photographic imagery of the shorelines was acquired. The coastal imaging surveys were conducted during a period of spring low tides (31 August to 2 September 2007; CORI 2008c). The extent of the aerial surveys conducted in Milne Inlet is shown in Figure 4.1-3 and the extent of surveys for Steensby Inlet is shown in Figure 4.1-4. A more detailed summary of the methodology and flight details is provided in CORI 2008c.

Approximately 13 hr of georeferenced, high definition video imagery and over 11,000 georeferenced photos collected at low tide provided the basis for a coastal habitat classification in the project areas. Photos were reviewed by a geomorphologist and by an ecologist to classify the coastal habitat (CORI 2008c). The Milne Inlet shoreline (Figure 4.1-5) was subdivided into 10 km segments for classification into six repeatable classes (Table 4.1-1).The shorelines of Steensby Inlet were similarly subdivided into 10 km shoreline segments for the purpose of classification (Figure 4.1-6), and the coastal habitats within each 10 km segment were characterized in terms of seven repeatable classes of morphology (Table 4.1-2). Biotic features mapped in both Steensby and Milne Inlets included: salt marsh types; rockweed (*Fucus* sp.) types; and filamentous algae and benthic kelps (CORI 2008c). The occurrence of each coastal class and each biotic feature was estimated from review of the aerial imagery and then mapped. Other features such as unusual ice push features, archaeological sites, cabins or camps were also systematically cataloged (CORI 2008c).

Ground verification surveys were conducted in the Steensby Port area in 2008 (CORI 2008b) to document intertidal slopes, elevation levels of salt marshes, and the marine limit (e.g., lowest elevation of terrestrial vegetation).

#### 4.1.2.2 Results

**Seabed Habitat Mapping**

**Milne Inlet**

Seabed habitat associations at Milne Inlet were observed in drop camera imagery collected during 2008 and 2010. The habitat classes identified from the 2008 survey data are summarized in Table 4.1-3. These classes were then assigned to seabed habitat in the vicinity of the proposed port site, and bathymetric data were used to extrapolate the habitat classification into surrounding areas (Figure 4.1-7). Details from the benthic seabed habitat surveys are presented in CORI (2010a).

Substrate described from the drop camera classification showed that the shallow depths (< 3 m) are gravelly sand and sandy gravels. In the two deeper classes (3-15 m and > 15 m), the dominate substrates are similar, with slightly finer materials (muddy sand) observed (Figure 4.1-10). Almost half of the substrate type in this interval was supported a dense cover of benthic kelps.

Seabed algae distribution in the shallow community in Milne Inlet is dominated by filamentous brown algae and rockweed, while the 3-15 m and > 15 m classes were dominated by bladed kelps and filamentous red algae, respectively (Table 4.1-3). Encrusting coralline algae is relatively common, especially on boulders in the deepest regions along survey lines. The benthic flora is further described in Section 4.2.2.2.

While fauna were more abundant in deep community areas, a tunicate (most likely *Molgula* sp) was observed multiple times on the sandy substrate in shallow community areas (Table 4.1-3 and Figure 4.1-9). Imagery from deeper sites frequently contained brittle stars, sea urchins (likely *Strongylocentrotus droebachiensis*), free swimming scallops and other bivalves (including numerous clam siphons) (Figure 4.1.10).

**Steensby Inlet**

Seabed habitat in the immediate vicinity of the proposed port in Steensby Inlet was classified and mapped from imagery collected in 2007 and 2008 (CORI 2008a and AMR 2010). Classification revealed that the very nearshore (0-3 m) substrate consists of boulder/cobble materials with small amounts of sand. In water deeper than a few metres, substrates become finer, with sandy gravels followed by gravely sand and muddy gravely sand with increasing depth. Scattered gravel (e.g. ice-dropped pebbles and cobbles) occurs throughout the entire area surveyed. Ice-related features are abundant in water depths less than 9 m and consist of 1) ice wallows, which are shallow circular depressions several metres in diameter, rimmed with course materials, and 2) linear ridges and troughs that run parallel to sub-parallel to the shoreline and extend many tens of metres.

Vegetation dominated the biota at all depths surveyed, and significant algal cover was observed even at the maximum depths examined in the surveys (~50m). Epibenthic invertebrates were less commonly observed in the imagery, likely due to fauna being obscured under the high cover of benthic kelps. Species assemblages observed in the vegetation were used to describe four depth-stratified habitat classes (Table 4.1.4). Habitat classes were then extrapolated based on bathymetry data into areas outside of the video imagery (Figure 4.1-15). A more detailed presentation of the seabed habitat mapping program in Steensby Inlet is available in CORI (2008a).

**<u>Coastal Habitat Surveys</u>**

**Milne Inlet**

Approximately 373 km of shorelines were classified in Milne Inlet, which is part of a large fjord system off the western portion of Eclipse Sound. The most prominent coastal characteristic is the steep coastal relief that creates dramatic backdrops for the comparatively small and inconspicuous shore zone. Steep rock cliffs plunge into the inlet at many locations. In other areas, talus slopes of hundreds of metres in height overlay narrow coarse sediment beaches. Bedrock controls much of the coastal orientation and morphology along the Milne Inlet shores, with accretional beach deposits sandwiched between rock headlands. Extensive coastal rebound following deglaciation has created large areas of raised beach deposits 100 m or more above the present sea level. The raised beaches are unvegetated and form prominent coast-parallel lineations throughout the inlet.

The major anomaly in the fjord-like topography of the Inlet is the 13 km long Eskimo Inlet on the east side of Milne Inlet. Eskimo Inlet has little bedrock shoreline and only moderate coastal relief. The backshore is mostly vegetated alluvium interrupted by alluvial streams and deltas; sand and gravel beaches of moderate width front these alluvial deposits. The head of Eskimo Inlet is a wide intertidal flat and salt marsh complex.

Shore types within Milne Inlet are summarized in Figure 4.1-16. Approximately 30% of the coast is rock-dominated (rock cliffs and rock cliff with beaches). Alluvial fan shorelines are the most common shore type, where talus slope from the steep cliffs dominate the shoreline morphology. As a result of recent deglaciation, raised beach ridges are common (23%) and prominent. Delta complexes and lagoons are rare within Milne Inlet.

The short open-water season in Milne Inlet leads to a coastal geomorphology that is storm dominated, where coastal features are created by single storm events. Raised beaches, which are very common in Milne Inlet, also appear to be created primarily during infrequent, yet episodic, high-energy storm events. The presence of sea ice causes numerous ice rideup features both within the intertidal zone as well as in the backshore and subtidal areas.

Salt marshes are rare in Milne Inlet (Figure 4.1-17), although a small number were noted in delta complexes. No measurements of tidal elevation were made of salt marshes in Milne Inlet but they appear to be confined to the upper intertidal zone. Lagoons are also rare in Milne Inlet and no brine pools or *Beggiatoa* mats were noted. Rockweed was comparatively widespread within the inlet and was mapped along 55% of the shoreline (Figure 4.1-18). The filamentous and benthic kelps were much rarer – observed on 1% and 6% of the shoreline, respectively.

There is much evidence of human activities within Milne Inlet: several dozen, occupied, active hunting camps were noted during the survey and as many as one hundred tent ring sites. Drift plywood and steel drums were common in storm swash lines (hundreds of each seen along the surveyed coast). Several larger, abandoned camps were noted along both the east and west shores of the inlet.

**Steensby Inlet**

Approximately 710 km of shoreline habitat were classified within Steensby Inlet. There is considerable diversity of shore types within Steensby Inlet (Figure 4.1-19) with rock cliffs and beaches, alluvial fans, wide flats and lagoon complexes accounting for over 90% of the shore morphologies. Beaches are comprised of poorly sorted boulder, cobble, pebble and sand.

There is strong regional variation in coastal morphologies within Steensby Inlet (CORI 2008c). The western shore of Steensby Inlet is comprised of sedimentary bedrock and the dominant shore type is Wide Flats (Table 4.1-2). Intertidal flats on this shore type can be nearly a kilometer in width in some areas and the low relief extends into the backshore. Backshore areas are typically mantled by raised beach ridges. The northern portion of Steensby Inlet is dominated by the lagoon complex shore type. These are extremely low relief areas and freshwater runoff from the northern regions complicates the location of marine versus freshwater dominated lagoons. The eastern shore of Steensby Inlet is the most diverse in terms of shore morphology. Resistant granitic bedrock has resulted in comparatively high coastal relief and a considerable bedrock shoreline (approximately 40% is bedrock controlled bedrock or bedrock with beaches shore types).The alluvial fan shore type (an additional 41% of the coast) is related to the higher coastal relief caused by the resistant bedrock.

Salt marshes within Steensby Inlet occurred on about 13% of the coastline (Figure 4.1-20) and appeared to be an important feeding habitat for snow geese, as many are heavily grazed. Most of the marshes were in 'fall colours' of golden brown during the survey, and were a low turf of salt-tolerant herbs and grasses. All salt marsh features are found in the uppermost intertidal and splash zone, and would be inundated only at the very highest tides. Surveys in 2008 (CORI 2008b) measured the average lower limit of salt marsh as 3.5 m above tidal datum (1.2 m amsl) and the upper limit as 4.6m above tidal datum (2.3 m amsl).

Intertidal and shallow subtidal algae were also mapped from aerial imagery in Steensby Inlet (Figure 4.1-21). Rockweed occurs both in the intertidal and in the shallow subtidal regions (this mapping data summarizes intertidal rockweed observations only). It was very commonly observed (45% of shoreline) in all regions of the Steensby Inlet (Figure 4.1-21). Rockweed that had been detached from it holdfasts formed prominent drift lines at the high water line. The filamentous algae type was rarer and occurred on about 12% of the coast. Benthic kelps are common in the subtidal region and are easily seen on and mapped from the aerial imagery. Nearshore kelps occur along 27% of the shoreline in Steensby Inlet and are most common along the western shore where the low-gradient nearshore shallows provide wide, shallow subtidal habitat.

Two other unusual features were noted in Steensby Inlet: (1) shallow water brine pools, and (2) shallow subtidal patches of white bacterial mat, *Beggiatoa spp* (seen as brilliant white mats on the shallow seabed). Brine pools and *Beggiatoa* patches were essentially 'point features' with limited along-shore extent. Brine pools were always associated with ponded, shallow standing water and very low wave energy conditions. The subtidal *Beggiatoa* patches were also seen in low energy bays, and seemed to be associated with concentrations of decomposing algal drift, which had accumulated in subtidal depressions.

### 4.1.3 Summary

**<u>Seabed Habitats</u>**

**Milne Inlet**

Three nearshore habitat classes were described in Milne Inlet based on observations from drop camera imagery. Substrates are gravelly sands which become finer with depth. Bladed kelps are abundant and provide dense cover between 3 m and 15 m, while shallower water tends to be mostly bare of attached biota. Epifauna are the most abundant biota present at depths > 15 m, with dominant species including brittle stars, scallops and sea urchins. Similar species assemblages and substrate descriptions were documented during the BIOS project at Cape Hatt, at the mouth of Milne Inlet (Cross et al. 1984).

**Steensby Inlet**

Classification from observations made with underwater video imagery was the basis of nearshore seabed habitat mapping in Steensby Port Site. Four georeferenced, depth-stratified habitat classes were described. Substrates were generally coarse sediment in the nearshore, tending towards muddy gravely sands in the deeper areas surveyed. Vegetation cover was the dominant biotic feature in nearly all observations, with rockweed the most common in shallow water, and the bladed kelps and foliose red algae types being very abundant in the three deeper habitat classes. The most common epifauna across all surveyed depths are anemones, sea stars and sea urchins. Numerous feather star crinoids were seen in > 15 m habitats.

**<u>Coastal Habitats</u>**

**Milne Inlet**

The fjord system coastal habitats in Milne Inlet are typical periglacial coastal environments where most of the shoreline is dominated by either steep rock or coarse sediment beaches. Limited open water seasons and the coarse nature of the shorelines result in complex, poorly organized shoreline morphology. In some locations, glacial rebound has created prominent raised beach complexes, and ice rideup features are particularly common in Milne Inlet. The presence of sea ice limits the development of an epibiotic community, although rockweed is common in moderate density along the shore. Salt marshes and benthic kelps are uncommon on Milne Inlet shorelines. Evidence of human use was seen throughout Milne Inlet, with hundreds of tent rings and many active camps.

**Steensby Inlet**

The periglacial coastal habitats in Steensby Inlet are a diverse mix of low-gradient flats, wide lagoon complexes and bedrock cliffs. Raised beach ridges are prominent, in particular along the low-gradient sediment-dominated shorelines on the west side of the inlet. Rockweed and benthic kelps are common in Steensby Inlet, and salt marshes were observed along about 13% of the coast. The shoreline of Steensby Inlet has little evidence of anthropogenic disturbances; a few active camps were noted and a number of older archaeological sites were observed.

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## 4.2 PRIMARY PRODUCERS

Primary producers are organisms that create biomass from inorganic compounds; in most cases this is achieved through photosynthesis. There are typically three primary groups of photosynthetic organisms present in the marine aquatic environment: microscopic algae (phytoplankton) that live suspended in the water column; ice algae that grow on the bottom of the ice; and larger, rooted algae (kelp) that grow from shallow to deep waters where substrate and light availability are suitable. The majority of primary production in Arctic marine waters is by phytoplankton; kelp and ice algae contribute only small fractions of overall primary production (Welsh et al. 1992). Many aquatic organisms, including invertebrates and fish, rely on phytoplankton and algae either directly or indirectly as a food source. As a result, changes in algal abundance or composition can directly or indirectly affect those animals. Information regarding phytoplankton and kelp was collected from Milne and Steensby inlets.

### 4.2.1 Phytoplankton

Phytoplankton are primary producers that are small aquatic plant-like organisms (i.e., algae) that are most often found suspended or entrained in the water column. Chlorophyll *a* and pheophytin *a* are two types of photosynthetic pigments that are commonly used as indicators of phytoplankton biomass. Plankton biomass, and thus pigment concentrations, is typically related to the concentrations of nutrients, notably nitrogen and phosphorus, in water.

#### 4.2.1.1 Literature Review and IQ

Chlorophyll *a* concentrations in Lancaster Sound and Baffin Bay have been documented since 1977 as a means of estimating primary productivity and phytoplankton biomass. Maximum chlorophyll *a* concentrations typically occur near the bottom of the mixing zone (which generally occurs close to the bottom of euphotic zone) and open-water concentrations rarely exceed 10 $mg/m^3$ (Table 4.2-1, and references therein). Chlorophyll *a* concentrations measured during the ice-covered period are generally less than 0.5 mg/m$^3$ (Conover et al. 1999 *in* Michel et al. 2006), although concentrations tend to increase as the ice melts and releases ice-associated algae into the water column (Cross 1982).

#### 4.2.1.2 Project-Specific Field Surveys

**Methods**

Phytoplankton biomass and productivity in Milne and Steensby inlets was estimated by collecting water samples to meaure the concentrations of chlorophyll *a* and pheophytin *a.* Sampling was conducted concurrently with water quality sampling (see Section 3.1) and occurred during open-water conditions in August and September and under ice-cover in May and June. Note that not all sites were sampled during all sampling periods. Samples were collected from locations with ranging water depths distances from shore to characterize the overall conditions within each inlet. Details on sampling locations and dates are provided in Table 3.1-2 and Figure 3.1-1 for Milne Inlet, and in Table 3.1-3 and Figure 3.1-2 for Steensby Inlet. Details on field and laboratory methods used are provided in Section 3.1.2.1.

Means concntrations were calculated where replicate samples were collected. The resulting mean was used to represent the site conditions during that particular sampling event. Summary statistics, including mean, standard deviation (SD), minimum, and maximum, were then calculated from the data collected during each season.

**Results**

**Milne Inlet**

As in Steensby Inlet, primary productivity by phytoplankton (as indicated by chlorophyll *a*) in Milne Inlet was low (Table 4.2.2). Surface water concentrations of chlorophyll *a* ranged from <0.2 µg/L to 1.7 µg/L and <0.2 µg/L to 2.1 µg/L during the open-water and ice-cover seasons, respectively. Deep water concentrations were similarly low during the open-water season (<0.2 µg/L to 2.0 µg/L), but higher concentrations were observed at depth during the ice-covered season (1.1 µg/L to 5.2 µg/L). A more detailed presentation of results is presented in NSC (2010a).

**Steensby Inlet**

Primary productivity by phytoplankton (as indicated by chlorophyll *a*) in Steensby Inlet was generally low (Table 4.2.2); however, a somewhat greater range in concentrations was observed during the ice-cover season. Chlorophyll *a* concentrations measured during the open-water season ranged from <0.2 µg/L to 2.7 µg/L at the surface, and from <0.2 mg/m$^3$ to 1.9 mg/m$^3$ at depth, while concentrations under ice ranged from <0.2 mg/m$^3$ to 7.3 mg/m$^3$ near the surface and <0.2 mg/m$^3$ to 4.9 mg/m$^3$ in deep waters. A more detailed presentation of results is presented in NSC (2010a).

#### 4.2.1.3 Summary

Chlorophyll *a* concentrations measured in both Milne and Steensby inlets were within range of those previously reported for Arctic marine waters. The observed trend of higher chlorophyll *a* in deep water in Milne Inlet is consistent with the literature, indicating that the maximum concentrations typically occur near the bottom of the mixing zone. Contrary to the literature, which indicates that concentrations during the ice-cover season are generally low, chlorophyll *a* in both inlets was higher during the ice-cover season than during the open-water season. However, the literature indicates that chlorophyll *a* in the water column will increase as the ice begins to melt and ice-associated algae are released. Most sampling during ice-cover conditions took place in June, when ice ablation may have been underway, possibly explaining the high chlorophyll *a* concentrations observed under ice-cover.

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### 4.2.2 Marine Flora

Marine plants include vascular macrophytes that mostly occur in shallow, inter-tidal areas, but attached macroalgae growing in subtidal areas comprise the majority of marine plant life. Algae are primary producers lacking seeds, flowers, leaves, and true roots that create biomass from inorganic compounds generally through photosynthesis. Common groups of marine algae (i.e., kelp) include foliose and filamentous red, brown and green algae, and rockweed. Besides contributing to primary production in marine waters, macroalgae provide food and an important habitat features for invertebrates and small fish. The distribution of macrophytes depends upon environmental factors such as water depth and light penetration, substrate, and current velocity.

#### 4.2.2.1 Literature Review and IQ

A study conducted by Dunton and Sechell (1987) on the dependence of consumers on kelp-derived carbon in the Arctic showed that kelp plays an important role in the arctic food chain. Macroalgal herbivores (such as gastropods and chitons), an ascidian, a predatory gastropod, and a mysid showed the greatest assimilation of kelp-derived carbon. The importance of this food source also continues into the pelagic food chain, as these lower trophic organisms are prey items for birds, fish, and marine mammals.

The majority of marine flora in the Canadian Arctic are species common to the Atlantic Ocean (Lee 1973). A representative intertidal algal community between Baffin Bay to Hudson Strait includes the green algal genera *Enteromorpha*, *Blidingia, Ulothrix, Urospora, Rhizoclonium* and *Codium*; the brown algae genera *Fucus, Ralfsia, Pseudolithoderma, Petroderma, Lithosiphon, Sphacelaria,* and *Pilayella;* and the red alga genus *Rhodochorton* (Lee 1973). In a summary of Arctic subtidal macrophytes, Wilce (1997) also noted that the Arctic supports a subset of temperate North Atlantic marine flora, and includes those species which are well adapted to low light conditions, a short growing season, and constant low water temperatures. Most Arctic sublittoral macrophytes are perennials, and several species including the brown algae *Agarum clathratum*, *Laminaria solidungula*, and *Alaria esculenta,* and a variety of red and brown crustose forms, may live longer than one or two decades (Wilce 1997).

Wilce (1997) describes five zones of depth-stratified algal communities for Arctic nearshore seaweed habitats. The shallow subtidal zone (described as extreme low water to 3 m depth) is subject to disturbance from ice scour and very low salinities during the ice-free season, and tends to be mostly barren. However, in sheltered areas, rockweed (*Fucus* sp*.)* may form dense populations, where it is responsible for the highest biomass in this zone. Other taxa which occur in this zone are the filamentous brown algae *Pilayella, Dictyosiphon,* and *Desmarestia*. In the zone that extends from 3 to 6 m, several benthic kelps including *Saccharina latissima*, *S. longicruius*, *Alaria esculenta* and *Agarum clathratum* form a conspicuous benthic canopy. Leafy red algae, such as *Phycodrys rubens*, *Phyllophora truncata*, *Turnerella pennyi*, the wiry green alga, *Chaetomorpha melagonium*, and other filamentous genera such as *Desmarestia* are all predictably common under the kelp canopy. The lower part of this zone is described as having "the greatest diversity and biomass [of seaweed]" in the Arctic sublittoral (Wilce 1997). In the zone from 7 to 20 m, benthic kelps *Laminaria solidungula* and *Agarum* dominate the vegetation. Understory smaller algae, including the species that grow between 3 and 6 m, as well as the red algae species *Polysiphonia arctica*, *Callophyllis cristata,* and *Ptilota serrata* are observed. Between about 25 to 30 m[1], *L. solidungula* and *Agarum* occur, however kelp vegetation is sparser. *Agarum* is the last of the larger macrophytes to disappear with increasing depth. At depths greater than 30 m, only a number of calcareous and fleshy crustose forms are observed, including the brown alga *Pseudolithoderma* and the coralline red algae *Lithothamnion* (Wilce 1997).

The Baffin Island Oil Spill Project (BIOS) recorded 60 species of benthic algae at Cape Hatt (located near the Milne Inlet study area) (Cross et al. 1984). Samples were collected along transects at depths of 3 and 7 m, but only algae from the 3 m depth transects were sorted and weighed. Several species of small filamentous brown algae (*Stictyosiphon tortilis, Pilayella littoralis* and *Dictyosiphon foeniculaceus)* dominated the understory and accounted for 76% of algal biomass. Other species of understory algae, including *Sphacelaria* and *Chaetomorpha,* together comprised another 8% of total algal biomass. The dominant larger species at 3 m were *Neodilsea integra* (red alga), *Fucus*, *Laminaria* spp. and *Chorda* spp. (which together made up 13% of macroalgal biomass). Total algal biomass estimates based on the 3 m samples ranged from 74.7 g/m$^2$ to 1032.6 g/m$^2$. As these samples were comprised primarily of plant fragments, samples collected from the Laminaria kelp zone between 3 to 5 m depth (dominated by

[1] The author did not present information on the algal community between 20 m and 25 m.

*Saccharina lattisima* and also included *Laminaria solidungula, S. longicruris, Alaria* and *Agarum*) would have resulted in much higher estimates of kelp biomass.

Marine macrophytes identified by local resource users from Igloolik included hollow stemmed kelp, edible kelp, and bladder wrack (NCRI 2008). Hollow stemmed kelp is found in Murray Maxwell Bay, areas near Jens Munk Island, and off the southeastern shore of Igloolik Island, but are most abundant in the narrow stretch of water joining Murray Maxwell Bay with Fury and Hecla Strait. Edible kelp is found primarily off the southwestern and northern shores of Jens Munk Island and at the mouth of Foster Bay (NCRI 2008). Bladder wrack can be found in a large area east of Igloolik Island and along the eastern shore of Steensby Inlet (NCRI 2008).

#### 4.2.2.2 Project-Specific Field Surveys

<u>**Methods**</u>

**Milne Inlet**

The distribution of benthic algae at Milne Inlet was investigated using drop camera videography in 2008 and 2010. However, detailed depth-referencing data were only available for the 2008 footage (Figure 4.1-1). As a result, the 2010 data were included in the percent occurrence calculations but were excluded from the depth-stratified percent cover calculations. More information about the nearshore habitat mapping of Milne Inlet is presented in Section 4.1.2 and CORI (2008a).

Vegetation observed in the video imagery was classified into vegetation categories (Table 4.2-3), and then the proportion of observations that included each vegetation category was calculated for each depth zone (<3 m, 3-15 m and >15 m). Depth zones corresponded to the habitat classes defined in Section 4.1.2, with the deeper classes (habitat classes 3 and 4) combined. The percent contribution of each vegetation category to the total cover in each depth zone was then calculated.

**Steensby Inlet**

A towed underwater video survey (SIMS) (CORI 2008a) was completed in Steensby Inlet in 2007 to classify nearshore habitat features including the distribution of benthic algae. Additional seabed habitat information was collected with video drop camera in Steensby Inlet in 2008, although limited bathymetric data prevented these images from being accurately depth-referenced. As a result, the 2008 data were included in the percent occurrence calculations but were excluded from the depth-stratified percent cover calculations. The contribution of each vegetation category to the total cover within each depth interval in Steensby Inlet was calculated using the same approach as in Milne Inlet.

Field collections of macroalgae were conducted at Steensby Inlet in 2008 to identify species associated with each habitat class (CORI 2008b). A minimum of two sites were sampled within each habitat class (Figure 4.2-1) using a custom-designed grapple hook assembly. Additional algal samples were also collected opportunistically during the drop camera survey in 2008. Algal samples were pressed and dried as preserved herbarium specimens, and identifications were confirmed by a phycological taxonomic specialist.

## Results

### Milne Inlet

Algal community composition in Milne Inlet, as calculated based on underwater imagery collected in 2008 and 2010, is presented in Table 4.2-4. Vegetation categories classified from the 2008 survey in Milne Inlet are listed in Table 4.2-3 and the total contribution of each vegetation category per depth zone is shown in Figure 4.2-2. Vegetation assemblages and density differed between depth zones, but bladed kelps (BKS) were the most abundant algal component in the inlet. While BKS were absent in waters shallower than 3 m, they were the most abundant vegetation category between 3 m and 15 m, where they accounted for 38% of the total cover. In deeper waters, the density of BKS decreased to 6%, but it was still the dominant vegetation category. Foliose (FOR) and filamentous (FIR) red algae were also absent from the shallow waters in Milne Inlet (< 3 m), but they exhibited the second and third highest percent cover values, respectively, of all vegetation categories between 3 m and 15 m. At depths greater than 15 m, the percent cover made up of FOR decreased slightly while it increased slightly for FIR. Filamentous brown algae (FIB) occurred only in shallow waters (< 3 m) and was absent in deeper waters, while encrusting and foliose coralline red algae (COR) was only present at water depths greater than 15 m.

### Steensby Inlet

Algal community composition in Steensby Inlet, as calculated based on underwater imagery collected in 2007 and 2008, is presented in Table 4.2-4. The vegetation categories classified from the towed underwater survey in Steensby Inlet in 2007 are shown in Table 4.2-3 and the total contribution of each vegetation category per depth zone is shown in Figure 4.2-2. As in Milne Inlet, BKS were the most abundant algal component in the inlet. BKS were sparse (7% cover) in waters shallower than 3 m and were most abundant at water depths between 3 m and 15 m (34% of cover). In deeper waters, the density of BKS decreased to 7%. Rockweed (FUC) makes up 26% of the cover at depths shallower than 3 m, is sparse between 3 and 15 m (6% cover), and is absent at depths below 15 m. FIR and FOR were sparse in waters less than 3 m deep, more abundant in water between 3 m and 15 m deep, and abundance decreased slightly at depths greater than 15 m. FIB was present in shallow waters (< 3 m) but was absent from deeper waters, while sieve kelp (AGR) was only present at water depths greater than 15 m.

Marine algae were sampled at the Steensby port site (CORI 2008b) to provide species-level identifications of biotic assemblages observed in the nearshore video imagery surveys (CORI 2008a). The most common algal species collected at Steensby Inlet are listed in Table. 4.2-5; a complete list of species identified is available in NSC 2010a. Overall, the dominant species in the BKS group were the benthic laminarians: *Saccharina longicruris, S. latissima,* and *Laminaria solidungula*. The green alga *Chaetomorpha* spp. was common in the collections but was not readily visible in the video imagery because it was covered in silt and mixed with the large filamentous brown alga *Desmarestia*. The most commonly collected foliose red algae (FOR) were *Phyllophora truncata* and *Odonthalia dentata*.

#### 4.2.2.3 Summary

**Milne Inlet**

As observed in other studies, the lowest abundance of macroalgae observed in Milne Inlet at depths shallower than 3 m while the greatest abundance was noted for the 3 m to 15 m depth category (Cross et al. 1984; Wilce 1997). Bladed kelps were the most abundant algae in Milne Inlet as well as being the most abundant group in the 3 m to 15 m depth class, and the taxa identified (e.g., *Saccharina*, *Agarum* and *Laminaria*) were similar to those commonly identified between 3 m and 20 m in other studies. Foliose and filamentous red algae were also present in Milne Inlet in at depths >3 m, although they were present in less than 5% of images. Vegetation cover in Milne Inlet decreased in > 15 m depths compared to shallower depths, but the algae present were similar to those identified in the more densely vegetated 3 m to 15 m depth range.

**Steensby Inlet**

As in Milne Inlet and previous Arctic studies, algal abundance in Steensby Inlet was lowest at water depths shallower than 3 m and greatest between 3 m and 15 m (Cross et al. 1984; Wilce 1997). As in the literature, rockweed (*Fucus)* was the dominant algae in shallow waters of Steensby Inlet, while bladed kelps dominated at 3 m to 15 m depths. Red algae (filamentous and foliose) were commonly identified in deeper waters (> 3 m). Vegetation cover in Steensby Inlet decreased at depths > 15 m, but the algae present were similar to those identified in the more densely vegetated 3 m to 15 m depth range, except for Agarum which was only observed at depths > 15 m.

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## 4.3 ZOOPLANKTON

Zooplankton are small animals living within the water column and are comprised of many different groups of animals including herbivorus invertebrates that graze of phytoplankton and microalgae, predatory invertebrates that prey on herbivorus, and the larvae of many fish species, among others. Herbivorus zooplankton account for much of the secondary production in arctic marine waters.

### 4.3.1 Literature Review and IQ

Bradstreet and Cross (1982) identified the presence of key lower trophic levels within food webs along ice flow edges in the high Arctic. Diatomaceous algae on the ice subsurface formed the base of the food chain, and these algae, along with dinoflagellates and ciliates, were the most abundant groups of phytoplankton in waters just south of Igloolik (Bursa 1961). Diatoms are an important food source for zooplankton (e.g., calanoid copepods and hyperiid amphipods) and ice-associated amphipods (e.g., *Onisimus glacialis, Apherusa glacialis, and Gammarus wilkitzkii*). Together with ice-associated harpacticoid and calanoid copepods (*Calanus hyperboreus*, *C. glacialis, Pseudocalanus minutus, Metridia longa*, and *Euchaeta*). Similar invertebrate species were recorded along ice edges in Foxe Basin (Grainger 1959, 1962; Atkinson and Wacasey 1989).

Grainger (1959) found that zooplankton density near Igloolik in 1955 and 1956 was lowest in mid-April (late winter) and highest prior to ice formation in late September. These trends correlated with algal growth. The author reported that the most abundant zooplankton near Igloolik were several species of copepods (*P. minutus*, *Calanus finmarchicus*, *C. hyperboreus*, and *Oithona similis*), though chaetognaths (arrow worms; *Parasagitta elegans*), cirriped larvae, hydrozoan cnidarians (*Halitholus cirratus*), and pelagic tunicates (*Fritillaria borealis*) were also common.

During a bowhead whale feeding study in northern Foxe Basin, Thomas (1999) found that zooplankton density (dominated by copepods) decreased with increasing distance from the floe edge and increased as the summer progressed.

Grainger (1962) identified 48 zooplankton species in a comprehensive survey of 100 sites in Foxe Basin. Copepods (*P. minutus*, *C. glacialis*, and *C. hyperboreus*) dominated the catch, though hydrozoan cnidarians *Aglantha digitale* and *H. cirratus*, chaetognaths *P. elegans,* and the amphipod *Themisto libellula* were also abundant. Zooplankton biomass and abundance were higher in Foxe Channel (where Foxe Basin and Hudson Strait waters mix) and in the northwest section of the basin (Fury and Hecla Strait, Igloolik area, and west of Tangle Island) than in central and eastern Foxe Basin. Copepods, chaetognaths, and hydrozoans were the most abundant and widespread taxa. Variations in ice cover duration throughout the basin partially attributed to differences in annual zooplankton development, but community composition was also strongly influenced by local hydrodynamic features on surface water temperature, salinity, stratification, and mixing conditions (Stewart and Lockhart 2005).

The zooplankton community within Milne Inlet has not been studied previously, but considerable research has been done on zooplankton within Lancaster Sound. Grainger (1965 *in* LGL Limited 1982) compiled a list of zooplankton species commonly found in the waters of the northwestern Canadian Arctic, and divided species into three groups based on their preferred habitat: i) species common in the upper 200-300 m of the water column, ii) species common in nearshore shallow water, and iii) species common in deep water. Organisms belonging to group i dominate within the waters of the Canadian Arctic Archipelago between the Beaufort Sea and Davis Strait, an area which includes Milne Inlet. This group includes eight species of copepods (*C. hyperboreus*, *C. glacialis*, *P. minutus*, *Microcalanus pygmaeus*, *Pareuchaeta glacialis*, *M. longa*, *O. similis*, and *Oncaea borealis*), one species of chaetognatha (*P. elegans*), two species of chordates (*Oikopleura vanhoeffeni* and *F. borealis*), two species of pteropod (*Limacina helicina* and *Clione limacine*), and two species of medusa (*A. digitale* and *Aeginopsis laurenti*).

In 1976 and 1978, two detailed zooplankton studies were conducted in eastern Lancaster Sound and western Baffin Bay. Observed species composition of those samples was similar to results in Grainger (1965) (Sekerak et al. 1976; 1979 *in* LGL Limited 1983). In both studies, the maximum zooplankton biomass was found within the top 50 m of the water column. Copepods were the dominant taxon (comprising 79% and 84% of the organisms in the 1976 and 1978 samples, respectively), while gastropods, amphipods, chaetognaths, larvacea, and hydrozoa and ctenophores were also common (LGL Limited 1983). In 1978, the most abundant copepod species 50 m depths to surface waters were *P. minutus* (~165 individuals/m$^3$), *O. similis* (~135 individuals/m$^3$) and *C. glacialis* (~ 62 individuals/m$^3$), while *M. longa* (~25 individuals/m$^3$) was the most abundant copepod in samples taken from depths between 150 m and 50 m (Sekerak et al. 1979 *in* LGL Limited 1983).

### 4.3.2 Project-Specific Field Surveys

#### 4.3.2.1 Methods

Vertical zooplankton tows were conducted at three locations in Milne Inlet in September 2008, and ten in August 2010 (Figure 4.3-1). Eight locations were sampled in the vicinity of the Steensby Inlet port site in September 2008 and again in August 2010 (Figure 4.3-2). Geographic location, water depth, and time were recorded from a handheld GPS unit at each sampling site. Vertical tows were conducted using a 1.0 m long, 63 µm mesh size conical net attached to a single 0.25 m diameter steel hoop frame. Samples were fixed in 10% formalin. Where a sufficient number of individuals were collected (>100 individuals) in a single tow, only one tow was required per site. At other sites, two tows were required. For more details on zooplankton sampling methods, see NSC and AMS (2010).

Samples were submitted to an aquatic invertebrate taxonomist for analysis. Zooplankton were identified to species and enumerated. Scientific names were updated in accordance with the Integrated Taxonomic Information System (ITIS 2010).

Taxon abundance was estimated by calculating the number of individuals per cubic metre of water (individuals/m$^3$). Volume of water filtered for vertical tows was estimated by multiplying the net mouth area (0.049 m$^2$) by the water depth at the sample location.

#### 4.3.2.2 Results

**Milne Inlet**

Twenty-three taxa were identified from the zooplankton communities in Milne Inlet during fall 2008 and 2010 (NSC and AMS 2010). The cyclopoid copepod *O. similis* dominated the Milne zooplankton community of the inlet in both years, followed by *C. finmarchicus/glacialis* in 2008 and Calanoida copepodites in 2010 (Table 4.3-1). *C. finmarchicus*, *P. minutus*, *O. similis*, Harpacticoida, *P. elegans*, and *F. borealis* were present in 100% of samples in 2008 and 2010. *Aglantha* sp., *A. laurenti*, unidentified Calanoida copepodites, and *C. hyperboreus* were also present in 100% of the samples collected in 2010 (NSC and AMS 2010). It should be noted that that *C. finmarchicus* and *C. glacialis* were not differentiated in laboratory results from 2008.

Densities of the seven most common taxa in Milne Inlet are listed in Table 4.3-2. In both 2008 and 2010, Cyclopoida had the highest average density (1053 individuals/m³ and 343 individuals/m³, respectively) in the inlet, followed by Calanoida (251 individuals/m³ and 157 individuals/m³, respectively) and Harpacticoida (200 individuals/m³ and 21 individuals/ m³, respectively). Mean taxa richness was higher in 2010 (23) than 2008 (12) (Table 4.3-1).

**Steensby Inlet**

Thirty invertebrate taxa were identified from zooplankton communities in Steensby Inlet in fall 2008 and 2010 (NSC and AMS 2010). The calanoid copepod *P. minutus* represented the most dominant species overall at Steensby Inlet in 2008, followed by the chordate *F. borealis* (Table 4.3-3). In 2010, the dominant species in Steensby Inlet was *Balanus* sp. (nauplii or cypris stages; Order Thoracica), followed by *P. minutus* (Table 4.3-3). *P. minutus*, *F. borealis, Balanus sp*. (nauplius or cypris), *C. finmarchicus*, *F. borealis,* and unidentified polychaete larva were present in 100% of the samples from Steensby Inlet in 2008 and 2010. However, *F. borealis, C. finmarchicus*, and unidentified polychaete larvae were each absent from one site in either 2008 or 2010 (NSC and AMS 2010). Harpaticoida and unidentified Calanoida copepodites were also present in 100% of samples from Steensby Inlet in 2010.

Densities of the seven most common taxa in Steensby Inlet are listed in Table 4.3-4. Calanoida had the highest average density in Steensby Inlet samples in 2008 (1162 individuals/m³), followed by the chordate Larvacea (384 individuals/m³) and Thoracica (284 individuals/m³). Thoracica had the highest average density in 2010 (1080 individuals/m³), followed by Calanoida (409 individuals/m³) and Larvacea (264 individuals/m³). Overall taxa richness was the same in both years (23 individuals/m³; Table 4.4-3).

#### 4.3.2.3 Summary

**Milne Inlet**

The community composition of zooplankton in Milne Inlet is comparable, over a similar range of sample depths (surface – 150 m), to that in nearby Lancaster Sound (Sekerak et al. 1976; 1979 in LGL 1983). In both regions, communities are dominated by cyclopoid (*O.similis*) and calanoid (*C. finmarchicus*/*glacialis*), *P. minutus*) copepods. The only significant difference between the two communities is the absence of *M. longa* (abundant in Lancaster Sound in the late 1970's), from the 2008 and 2010 Milne Inlet samples. In addition, of the 23 taxa comprising the zooplankton community of Milne Inlet in 2008 and 2010, Harpacticoids, tunicates (*P. sagitta*), and chaetognaths (*P. elegans*), though not overly abundant, were ubiquitous throughout the sampled area.

**Steensby Inlet**

Similarities in taxa dominance and richness between survey years in Steensby Inlet suggests stability in zooplankton community composition. The Steensby Inlet zooplankton community also shares some characteristics with those observed in nearby Foxe Basin (Grainger 1959; 1962). In particular, calanoid copepods (*P. minutus*, *C. finmarchicus*) are one of the three dominant taxa (along with Larvacea and Thoracica) in Steensby Inlet and are equally abundant in historical Foxe Basin catches. However, the cyclopoid copepod *O. similis* and calanoid copepod *C. hyperboreas*, historically abundant in Foxe Basin, were rare or absent from Steensby Inlet samples. Differences between the two communities are likely explained by geographic location and/or temporal differences between samples.

#### 4.3.2.4 References

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## 4.4 BENTHIC INVERTEBRATES

Benthic invertebrate communities are comprised of two main groups: those living on the surface of the seabed substrate (epibenthic invertebrates) and those living in the seabed sediments (benthic infauna). Benthic invertebrates are an important component in marine food webs, comprising some portion of the diet of many marine animals, including fish, seabirds, and marine mammals.

### 4.4.1 Epiphytic and Epibenthic Invertebrates

#### 4.4.1.1 Literature Review and IQ

Arctic macrofauna is dominated by polychaetes, bivalve molluscs, and crustaceans, particularly amphipods (LGL 1982; LGL 1983; Stewart and Lockhart 2005; Bluhm and Gradinger 2008). Arctic epibenthic communities are characterized by taxa with long life spans (several years to decades) and often slow growth rates, such as echinoderms, crabs, and demersal fishes (Bluhm and Gradinger 2008). These communities account for over 25 per cent of the overall benthic community respiration and, due to their often large size, contribute significantly to overall benthic biomass despite their patchy occurrence. At most surveyed locations, ophiuroids dominate the epibenthic megafauna, with several hundred individuals per square metre. Other conspicuous epibenthic fauna in varying abundances include sea urchins, sponges, sea cucumbers, sea stars, crabs, and bryozoans (Bluhm and Gradinger 2008).

In 1980, field studies sponsored by the Baffin Island Oil Spill (BIOS) Project resulted in the collection and enumeration of motile members of the epibenthic community, including crustaceans and echinoderms (sea stars and sea urchins), during shallow nearshore sampling (Cross and Thomson 1982). The abundance of crustaceans at 3 and 7 m depth transects were 473 individuals/m$^2$ and 2,733 individuals/m$^2$, respectively. Density of the sea urchin *Strongylocentrotus droebachiensis* was up to 10 individuals/m$^2$ along the 7 m transect, while the sea star *Leptasterias polaris* occurred at up to 5 individuals/m$^2$ (Cross and Thomson 1982).

Epifaunal surveys by Sekerak et al. (1976 *in* LGL 1983) found that the barnacle *Balanus crenatus*, the limpet *Acmaea rubella*, the chiton *Tonicella* sp., and bryozoans were common epibenthic fauna along the south coast of Cornwallis Island. No quantitative studies have been conducted in the region.

Though little local knowledge of macroinvertebrate distribution exists for Milne Inlet, some is available for northern Foxe Basin (NCRI 2008). According to hunters from Igloolik, amphipods are abundant around the southern edge of Igloolik Island and clams are common on the north shore of Murray Maxwell Bay and near the mouth of Gifford Fjord. Other areas of clam occupation include coastal regions off Igloolik Island and several regions in northeastern Foxe Basin at the south end of Steensby Inlet. Whelk and polar sea stars have been identified primarily from the southern edge of Igloolik Island, though they have also been reported from Gifford Fjord and the western shore of Steensby Inlet. Mussels were found along the eastern shore of Igloolik Island, the Melville Peninsula shoreline south towards Hall Beach, and the southern shore of Jens Munk Island. Sea urchins, cucumbers, and anemones (presumably various species) have also been identified from the waters around Igloolik Island. Other species such as the naked sea butterfly (*Clione* sp.), northern shrimp (*Pandalus borealis*), and mud star (*Ctenodiscus* sp.) have also been observed by local hunters in the vicinity of Igloolik Island and other areas of northwestern Foxe Basin.

#### 4.4.1.2 Project-Specific Field Surveys

**Methods**

**Milne Inlet**

Drop camera videography conducted in 2008 and 2010 provided information on the epifaunal communities present in Milne Inlet. The 2008 data were then combined with detailed bathymetry collected from the vicinity of the proposed Milne Inlet port site, and habitat classes were delineated. Observations of fauna categories per second of video imagery were mapped in a spatial dataset. The proportion of occurrence of each type of fauna was calculated from the count of observations of each faunal category within each habitat class. Up to three faunal categories were classified for each observation in order to document co-occurrences of species. More detailed drop cam videography and habitat class designation methods are described in Section 4.1.2.1.

**Steensby Inlet**

Epiphytic and epibenthic macroinvertebrates were collected opportunistically during the 2007 and 2008 field programs in Steensby Inlet (Figure 4.4-1). Invertebrates attached to algal samples (2008) and those entangled in experimental gill net sets (2007) were preserved in 10% buffered formalin and retained for identification. Date, time, water depth, and geographic location were recorded for each sample. See NSC and AMS (2010) for further details about the benthic invertebrate sampling.

Faunal assemblages were also observed in 2007 and 2008 during the SIMS video survey of seabed habitat and from video drop camera footage, respectively; however, detailed depth-referencing data were only available for the 2007 footage (see Section 4.1.2.1 for details) (Figure 4.1-2; CORI 2008a; CORI 2010a; CORI 2010b). As a result, the 2008 data were included in the determination of overall community composition but were excluded from the depth-stratified density calculations. In many areas, epifauna were underestimated because they were obscured by the overstory of benthic kelps. The presence of larger fauna, such as clams or tubeworms, was indicated by the presence of clam siphons or holes in the substrate. In some cases, identification was determined to genus; however, in most cases, a higher level taxonomic group was determined (e.g., unidentified sea star). Further explanation of the methodology used to estimate faunal density by habitat class and species assemblage is available in CORI (2010b) and NSC and AMS (2010).

**Results**

**Milne Inlet**

The most common taxa identified in drop camera footage from Milne Inlet in 2008 and 2010 were: clams (Bivalvia), brittle stars, and sea urchins (tables 4.4-1 to 4.4-3). Brittle stars were also collected in benthic infauna samples; analysis of a subset of samples collected from Milne Inlet in 2010 suggests that these echinoderms are more abundant at deep sites than at shallow ones (Table 4.4-4).

**Steensby Inlet**

Descriptions of the fauna observed during the video imagery surveys conducted in 2007 and 2008 are provided in Table 4.4.2 (CORI 2008b; CORI 2010b); these observations illustrate relative abundance of sessile epifauna (Table 4.4-3). Similar to seabed vegetation, the observed fauna were depth stratified. Anemones were the most commonly observed taxa and were found at all depths. In the shallowest areas surveyed (approximately < 3 m depth), barnacles and bacterial mats were dominant, while feather stars were commonly seen in the deeper areas. Benthic kelp assemblages dominated the seabed between 3 m to 15 m depths, and as a result, the fewest number of epifauna were observed in this depth interval. Overall community composition estimated from the 2007 and 2008 underwater videography indicated that fauna coverage was generally sparse but that anemones dominated the community (tables 4.4-1 and 4.4-3).

Various epiphytic and epibenthic invertebrate taxa were captured opportunistically during the 2007 fish and 2008 algal sampling, including: polychaetes (*Harmothoe, Pholoe,* and *Pectinaria)*, gastropods (*Margarites*); bivalves (*Astarte, Crenella* and *Musculus*); amphipods (*Stenothoe, Metopella* and others); bryozoans (*Celleporella*; Asteroidea [*Leptasterias* and *Pisaster*]; and Ophiuroidea [*Amphiura* and *Ophiocantha*]). Additional taxa were also collected during the 2007, 2008, and 2010 benthic infauna sampling (Table 4.4-5).

**Summary**

**Milne Inlet**

Although few historical studies of the epiphytic and epibenthic invertebrate community of Milne Inlet have been conducted, there appears to be some similarities between surveys. Sea urchins and sea stars were common in both the current study and in the survey conducted by Cross and Thompson (1982), suggesting that these species are ubiquitous in shallow water environments along Baffin Island. Increasing brittle star density with depth indicates that some stratification of benthic community composition may occur.

**Steensby Inlet**

The epifaunal community of Steensby Inlet is depth stratified, and contains taxa similar to those observed in the area by Igloolik residents (NCRI 2008). Anemones are abundant across all depths, though barnacles and bacterial mats, common in the shallow intertidal zone, are replaced by bivalves, brittle stars, crabs, and tubeworms at moderate subtidal depths, and feather stars in the deep (> 15 m) subtidal zone. Several other taxa are present in Steensby Inlet, but at low concentrations.

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#### 4.4.2 Benthic Infauna

##### 4.4.2.1 Literature Review and IQ

Most benthic species assemblages in the Arctic occur at specific depth ranges, and some occur mainly in one or two geographic areas or substrates (Thomson 1982). Depth and geographic location appear to be the most significant predictors of community composition in the eastern Canadian Arctic, with depth having the greatest influence. For example, Thomson (1982) identified 24 assemblages of benthic infauna within Lancaster Sound, Eclipse Sound, and northwest Baffin Bay, all of which occurred at discrete depth ranges and most of which were limited by geographic location. In each case investigated, depth alone accounted for over half of the variance explained. These two factors were shown to be more effective than depth plus substrate as predictors of species composition (Thomson 1982). LGL (1982) concurred, suggesting that bivalve composition varies primarily with depth and geographical location; however, substrate type and local conditions were also considered to be important in community composition. Stewart and Lockhart (2005) found that additional factors were important, determining that distribution of benthic organisms was positively correlated with salinity gradient and the quantity of organic matter in sediments; the dominant species of each group are able to adapt to different sediment types. Current strength is another possible factor in determining the species composition of benthic communities and affecting standing crops (LGL 1983).

Benthic invertebrate abundance generally increases with increasing depth to approximately 100 m (LGL 1982). Thomson (1982) collected infaunal samples from depths of 5 to > 1000 m in Lancaster Sound, Eclipse Sound, and northern Baffin Bay, finding that standing crop was highest between 15 and 105 m. Biomass in the richest survey area, Lancaster Sound, was > 500 g/m$^2$. Amphipods were the most important taxon in terms of biomass at 5 m depths, and accounted for approximately 76% of the total biomass (Thomson 1982). Bivalves were dominant between 10 and 100 m, accounting for approximately 52 to 78% of biomass (Thomson 1982). LGL (1982; 1983) found similar results, with density of benthic animals highest at depths less than 25 m within Eclipse Sound (5384 individuals/m$^2$) and southwest Baffin Bay (6193 individuals/m$^2$), and depths to 100 m in Lancaster Sound (4564 individuals/m$^2$) and northwest Baffin Bay (5502 individuals/m$^2$). Over all depths, the Lancaster Sound area was found to support a significantly higher biomass of infauna than in northwest Baffin Bay or Eclipse Sound (Thomson 1982). Additionally, Ellis (1960) found a mean biomass of 200 to 438 g/m$^2$ for benthic infauna along the northern coast of Baffin Island between 5 and 50 m.

LGL (1982 1983) determined that the amphipods *Gammarus setosus* and *Onisimus litoralis* were the only common inhabitants of shallow waters along high Arctic coastlines, with *G. setosus* preferring large rocky substrates and *O. litoralis* preferring sand and pebble substrates (Thomson and Cross 1980 in LGL 1983). These and other amphipod species, in addition to mysids, decapods, isopods, sea urchins, barnacles, and periwinkles were reported in shallow waters of the Baffin Bay region.

In their study of benthic invertebrates from Lancaster Sound, Welch et al. (1992) found that the bivalve *Hiatella arctica* was a major benthic component. The large bivalve *Serripes groenlandicus* averaged only 1.7 individuals/m$^2$ throughout Barrow Strait, but maintained high biomass in some areas. The bivalve *Macoma calcarea* was the most abundant clam in Resolute Bay. Abundance of the bivalve *Mya truncata* peaked at 15 m depths in Barrow Strait (Welch et al*.* 1992). Sea urchins were also abundant and brittle stars were particularly important numerically in deep water. Other notable benthos included pycnogonids, sea cucumbers, terebellid polychaetes and anemones (Welch et al. 1992). Thomson and Cross (1980 in LGL 1983) and LGL (1982) found that the tunicate *Rhizomolgula globularis* was consistently found along shorelines of the Canadian Arctic Islands, suggesting that this species may be ubiquitous or maintain a wide geographical range throughout Arctic marine shorelines.

The 1981 Baffin Island Oil Spill Project (BIOS) was one of the most extensive infaunal surveys carried out in the north Baffin region, conducted at Cape Hatt near Milne Inlet. This study found that polychaetes were dominant at 3 m depths and bivalves dominated at 7 m (Cross and Thomson 1982). These 2 groups made up 80 to 90 per cent of the sampled infauna. The most common taxa, measured by percent of total infauna numbers were: *Pholoe minuta* (15.62%), *Nereimyra punctata* (9.40%), *Euchone analis* (8.97%), *Gingula castanea* (7.18%), *Myriotrochus rinkii* (6.25%), *M. truncata* (4.14%), *Spio* spp. (3.92%), Thyasiridae spp. (3.37%), *Astarte borealis* (3.21%), and *Eteone longa* (3.07%) at 3 m depths. At 7 m depths, the 10 most dominant taxa were *P. minuta* (14.00%), Thyasiridae spp. (13.80%), *A. borealis* (8.77%), *A. montagui* (6.65%), *M. clacarea* (4.95%), *M. truncate* (4.11%), *Nuculana minuta* (3.07%), *Cingula castanea* (2.11%), *Trichotropis borealis* (1.81%), and *Pectinaria granulata* (1.67%).

In the Davis Strait, and presumably Hudson Strait and Foxe Basin, shallow water fauna appears to be typical of the high Arctic but for the increasing presence of Atlantic species (LGL 1982). Benthic invertebrates were collected at 81 stations in Hudson Strait and Foxe Basin from 1949 to 1970, at depths ranging from intertidal to > 100 m (Atkinson and Wacasey 1989). A total of 541 species were collected from all sites. Of four sites combined, 171 species from 24 higher taxa (classes, orders, or phyla) were identified, of which 58 were not found at nearby sites in Foxe Basin. These sites were deeper (29 to 110 m), on average, than other sites sampled in northern Foxe Basin. Nineteen nearby sites (Fury and Hecla Strait, Igloolik nearshore area, Hall Beach area) produced 265 species from 26 higher taxa, of which 153 were not found within the rest of the study area. A mixture of sampling techniques used over multiple years during the Atkinson and Wacasey (1989) survey can account for at least some of the community composition differences between study sites and others nearby. Differences in water depths may account for additional variation.

Cross and Thomson (1987) found that certain Arctic infauna species were susceptible to disturbance, particularly changes in water chemistry. For example, the density of polychaete juveniles and the species *Spio* sp., as well as the bivalve *Macoma* sp. decreased significantly in 1983, primarily attributed to increases in sediment oil concentrations after release of chemically dispersed oil into the area in 1982. However, differences in polychaete juvenile density were within the range of natural variability and may not have been the result of environmental changes (Cross and Thompson 1987). These data indicate that certain disturbances to the marine environment can have significant repercussions to benthic species and diversity.

#### 4.4.2.2 Project-Specific Field Surveys

Benthic invertebrate sampling programs were conducted in Milne and Steensby inlets during 2007, 2008, and 2010.

## Methods

### Milne and Steensby inlets

In Milne Inlet, 24 benthic infauna samples were collected in 2010 from five transects (of increasing depth) near the base of the inlet and one transect located approximately 10 km north of the port site (Figure 4.4-2). In Steensby Inlet, four samples with replicates were collected in 2007, five infauna samples were collected in 2008, and in 2010, 24 samples were collected from six areas near to the proposed port site (Figure 4.4-3). At each sampling site, water depth, geographic location, and sampling equipment were recorded.

At each station, samples were collected and combined until an adequate volume was available to obtain the infauna, grain size, and total organic carbon samples. The samples were collected using either a Petite Ponar or standard Ponar grab sampler, sieved through a 500 µm screen, and fixed in 10% buffered formalin. Sampling protocols were not designed to collect representative samples of smaller meiofauna such as nematode worms and formans (which require subsampling of larger grab samples and sieve sizes of 63 µm), and so counts of incidental specimens from those phyla are not included in the analyses.

In each year, data analyses were based on percent composition of each taxon within a given sample. Taxa were grouped at the class level for percent composition comparisons. Benthic density (individuals/$m^2$) was calculated for a subset of the 2010 samples. To evaluate spatial differences in community composition and density, each infauna sample was grouped according to the habitat classifications (i.e., < 3 m; 3 m to 15 m; 15 m to 25 m; and > 25 m) identified in Section 4.1. Infauna samples which were collected at depths of 3 m were included in the shallowest habitat class (<3 m).

Species lists from all years were compiled into a master species list, and nomenclature was standardized based on the current taxonomy used on the World Register of Marine Species (WoRMS 2010; NSC and AMS 2010).

## Results

### Milne Inlet

A total of 146 benthic infauna species were identified in Milne Inlet in 2010 (NSC and AMS 2010). While representatives of the nematode and foraminifera taxa (meiofauna) were most numerous in the samples, they were not included in the calculations of number of individuals/$m^2$ due to sampling protocols. Based on percent composition, polychaetes and ostracods dominated the benthic infauna community in Milne Inlet (Figure 4.4-4). Other common taxa in samples included copepods, amphipods (i.e. Malacostraca) and clams.

Based on a subset of samples collected quantitatively in 2010, the average density of infauna in Milne Inlet was 6,290 individuals/$m^2$, and the community composition of the subset generally coincided with that of the whole inlet (Figure 4.4-4; Table 4.4-4). In Milne Inlet, infauna species assemblages were depth-stratified and density decreased slightly with depth (NSC and AMS 2010).

As discussed in the sediment quality section (3.2), in Milne Inlet there were no significant changes in substrate particle size or nutrient content with increasing depth; however, as mentioned above, some differences in the infauna community with depth were observed. Generally, copepods formed a greater proportion of the infauna community at shallower sites, whereas the proportion of clams increased with site depth (Figure 4.4-4).

**Steensby Inlet**

A total of 202 benthic infauna species were identified in Steensby Inlet between 2007, 2008 and 2010 (NSC and AMS 2010). In contrast to Milne Inlet, foraminiferans and nematodes did not consistently outnumber organisms from all other taxa in the Steensby Inlet samples. In all years, polychaetes were the dominant taxon, usually followed by Malacostraca (including amphipods and tanaid shrimp) or ostracods (Figure 4.4-5). Based on a subset of quantifiable samples collected in 2010, the average density of infauna in Steensby Inlet was 6,124 individuals/m$^2$ (excluding foraminiferans and nematodes), and the community composition illustrated by this subset was generally representative of the overall community (Table 4.4-5). The highest densities of infauna in Steensby Inlet occurred in samples collected in water depths ranging from 10 to 45 m; the lowest density was reported at the 3 m depth site, likely because of ice scour and its associated disturbance to seabed habitat.

The substrate composition in Steensby Inlet changed with increased depth; the proportion of sand decreased while silt and clay increased (Table 3.2-6). Differences in substrate were reflected in changes to the infauna community: oligochaetes formed a greater proportion of the benthic community at shallow sites than at deeper sites, while the percent contribution of copepods and clams was greater at sites deeper than 3 m (Figure 4.4-5). Similar patterns were apparent for benthic infauna densities, which were calculated from the subset of quantifiable samples collected in 2010 (Table 4.4-5). Shallower sites were also distinguished by the fact that fewer species of infauna were present, and in 2010, only one species (a type of oligochaete) was present at sites SINF-23 and SINF-27 (2 m and 3 m deep respectively); this species was not collected at any other station in Steensby Inlet (Figure 4.4-5) (NSC and AMS 2010).

**Summary**

**<u>Milne Inlet</u>**

Of the 146 taxa identified in the 2010 Milne Inlet survey, the four most abundant (i.e., nematodes, forams, polychaetes, and ostracods) are also common at Cape Hatt (Cross and Thompson 1981), suggesting that these species are ubiquitous throughout the region. Community composition in Milne Inlet is depth stratified, with copepods more prevalent at shallower sites and clams dominating at deeper sites. Excluding nematodes and forams, the average density of benthic infauna was 6,290 individuals/m$^2$ in Milne Inlet. The highest density occurred at 15 m to 25 m, and there was a slight decrease associated with increased depth. Although spatial and temporal variation in species composition and density of benthic communities is not uncommon, the density of benthic infauna measured in Milne Inlet is substantially higher than what was found for Cape Hatt (> 1000 individuals/m$^2$ to 4000 individuals/m$^2$ between 3 m and 7 m) in 1980 and 1981 (Cross and Thomson 1987). In contrast, the density of polychaetes was higher in Cape Hatt (between 750 individuals/m$^2$ and 1000 individuals/m$^2$) than that in Milne Inlet in 2010 (up to 204 individuals/m$^2$). Different sampling techniques and depths likely contribute to the observed differences between studies.

## Steensby Inlet

Polychaetes, nematodes, amphipods, and tanaid shrimp typically are among the most abundant taxa captured in Steensby Inlet surveys. Excluding nematodes and forams, the average benthic density is 6,124 individuals/$m^2$ in Steensby Inlet, with the highest densities occurring between 10 m and 45 m, and the lowest at 3 m (likely due to disruption of habitat due to ice scour).

As in Milne Inlet, the infaunal community of Steensby Inlet is depth stratified. Benthic infauna community composition differences were identified with changes in depth. Oligochaetes comprised a greater proportion of the catch at shallow sites than at deep sites, while copepods and clams comprised a greater proportion of the catch at sites deeper than 3 m. Additionally, the oligochaete identified at two of the shallow stations in Steensby Inlet was not found at any other site although it is commonly found in intertidal and shallow marine beaches on the Atlantic coast of North America (Lasserre 1971). Though collections were not quantitative, Atkinson and Wacasey (1989) found that Foxe Basin contained a relatively high diversity of infaunal species, many of which were similar to those captured in Steensby Inlet surveys.

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## 4.5 MARINE AND ANADROMOUS FISH

Fish play a key role in ecosystem function and are generally considered important to stakeholders and regulatory agencies. Fish and fish habitat are protected by the *Fisheries Act*.

### 4.5.1 Literature Review and IQ

Only limited information was found describing the nearshore marine fish communities in the Baffin Island region, particularly on the south side of the island in Foxe Basin. In general, nearshore fish communities in the Arctic can be characterized by low species diversity and fish abundance in relation to more southerly areas (LGL 1982) (Table 4.5-1). Anadromous Arctic char occur seasonally in most areas, and benthic species such as sculpins, eelpouts, and lumpfish occur in a scattered distribution and in small numbers (LGL 1982). Arctic cod are a pelagic and ice-associated species that occur throughout most of the Arctic, and are possibly the most important prey species for other fish and many species of seabirds and marine mammals. Although their distribution appears to change between years, they frequently occur in nearshore waters in large numbers.

More information regarding offshore fish communities has been collected, largely the result of interests related to commercial fisheries or industrial development. In particular, considerable information has been collected in Baffin Bay and Davis Strait due to the importance of Greenland halibut fisheries. These surveys have provided preliminary species inventories for the western Davis Strait region (Imperial Oil Ltd. et al. 1978 cited in LGL Ltd. 1982), northern and southern Baffin Bay, and Davis and Hudson straits (Chambers and Dick 2007; Jorgensen et al. 2005; C. Chambers Unpublished data). By 2007, 145 fish species were identified in Davis Strait and Baffin Bay as a result of Greenland halibut surveys conducted by Fisheries and Oceans Canada (DFO) (Chambers and Dick 2007; Jorgensen et al. 2005). From those surveys, Jorgensen et al. (2005) were able to define seven relatively discrete fish assemblages within the Davis Strait/Baffin Bay region. For example, in the northern Baffin Bay region, one assemblage consisted of ‘shallow’ water fishes (<400 m) and was characterized by eight indicator species; mailed sculpin, hookear sculpin, Atlantic poacher, Vahl’s eelpout, Arctic skate, spotted wolffish, sea tadpole, and daubed shanny. Another, deeper assemblage (up to 2000 m) was dominated by glacial eelpout, black seasnail, threadfin seasnail and Arctic skate. Chambers and Dick (2007) found similar results, determining that community composition was dependent on (but not limited to) a combination of depth, water temperature, and latitude.

Due to its importance to local residents, the majority of information regarding species occurrence, as well as fish abundance and distribution in most nearshore areas pertains to Arctic char. Thus, a brief overview of char life history is provided here. Arctic char occur as freshwater residents or are anadromous (feed in marine water but overwinter and spawn) in freshwater. The following is pertinent to anadromous char.

Anadromous stocks of Arctic char spend a portion of their lives at sea, making annual migrations from freshwater wintering areas to feed intensely in marine waters during open water periods. This is promotes rapid growth during the open water period, and is an important aspect of the char's life history intense feeding and rapid growth (Johnson 1980; Gyselman 1984). Downstream migrations as soon as ice break-up occurs in May or June, and fish return to freshwater wintering areas prior to freeze up in fall. Char reach sexual maturity between ages 3 and 13 depending on latitude (Dempson and Green 1985; Kroeker 1986; 1987; Stewart and Bernier 1988; Richardson et al. 2001; Evans et al. 2002), and age at first migration to sea is between 3 and 8 years (Sprules 1952; Moore 1975; Johnson 1980; Richardson et al. 2001; Evans et al. 2002). Though subject to debate, it is generally accepted that most individuals do not migrate to sea in the year that they will be spawning (Griffiths et al. 1975; Moore 1975; Johnson 1980; McCart 1980). Though Arctic char fidelity along certain shoreline habitats is high, some mixing of stocks occurs within the marine environment by resting (juvenile or non-spawners) individuals (Johnson 1980; Gyselman 1994; Evans et al. 2002). Most Arctic char do not undergo extensive migrations within the marine habitat, but instead remain within a limited feeding area close to shore (Kroeker 1986; Dempson and Kristofferson 1987). In the Steensby Inlet area, char congregate in estuarine habitat before migrating upstream in mid-August to September (Kroeker 1986; 1987). Spawning occurs shortly thereafter, typically along lake shorelines (Sprules 1952; Scott and Crossman 1973; Dempson and Green 1985; Richardson et al. 2001). This species is an important component of inshore Arctic food webs, feeding opportunistically on invertebrate species such as amphipods, mysids, decapods, polychaetes, and small fish or larvae.

The majority of available information regarding nearshore fish communities within Milne Inlet pertains to Arctic char. IQ indicates that Arctic char are distributed along the coast of Milne Inlet. In the southern portion of Milne Inlet, including Koluktoo Bay, the Tugaat and Robertson rivers both support anadromous Arctic char populations (Figure 4.5-1; Moshenko 1981; Kristofferson and McGowan 1981; Read 2004). The Tugaat River is domestically harvested by residents of Pond Inlet and supported a small commercial fishery between the early 1970's and early 1990's. The fishery was closed in 1993 following population declines (Kristofferson and McGowan 1981; Read 2004). The Robertson River drains into Koluktoo Bay and supported a small commercial fishery until the mid-1970s. The commercial fishery was closed due to a noted decline in the population and to support a sports fishery established by The Pond Inlet Co-op (Moshenko 1981; Read 2004). Other species known to occur in Milne Inlet include Arctic cod, sculpins, Greenland sharks, and Greenland cod.

As at Milne Inlet, the majority of available information regarding nearshore fish communities within Steensby Inlet pertains to Arctic char, mostly because of the species' importance to Igloolik residents and their use of the area. Numerous river systems within the Inlet and surrounding areas such as Murray Maxwell Bay support populations of anadromous char that have been harvested domestically (Figure 4.5-2; also NCRI 2008). Kroeker (1986, 1987) investigated the feasibility of commercially harvesting char from many of these rivers (Figure 4.5-2), and small commercial quotas (ranging from 1,000 kg annually up to 9,100 kg annually) were established for several rivers in the area (Clarke et al. 1989; Carder 1981; Cosens et al. 1993). Other species known to occur in Steensby Inlet or nearby areas of northern Foxe Basin include Arctic cod, Arctic staghorn sculpin, capelin, and Greenland sharks (NCRI 2008). Waters in Steensby Inlet provide spawning habitat for marine benthic fish species such as sculpins, snailfish, and lumpfish as well as pelagic species such as Arctic cod.

### 4.5.2 Project-Specific Field Surveys

Fish community sampling was conducted in nearshore marine habitat in the vicinity of the Steensby and Milne Inlet port sites during 2007 and 2010. Fishing was conducted in September during 2007 and in early August in 2010. The following sections summarize fish community sampling methods and results. Additional details are provided in NSC (2010b).

#### 4.5.2.1 Methods

**Field Methods**

Fish sampling techniques used at the proposed Milne and Steensby Inlet port sites included gillnetting with standardized experimental gill nets, standardized small-mesh gill nets, and qualitative observations using towed underwater digital videography (see Section 4.1.2). The majority of information was obtained from the gill netting programs. Field methods are described in detail in NSC (2010b).

Standard experimental gillnet gangs consisted of six 22.9 m long by 1.8 m deep twisted nylon panels of 38, 51, 76, 95, 108, and 127 mm stretched mesh. Small mesh gangs were comprised of three 9.14 m long by 1.2 m deep panels of 8, 10, and 12.5 mm stretched mesh. Nets were set on the bottom and left in place for short periods of time (less than four hours) to minimize fish mortality. All fish captured during the gillnetting programs were identified to species and enumerated by location. Each fish was measured for fork or total length (± 1 mm), depending upon the structure of the caudal fin, and for round weight (± 25 g). Live fish in good condition were released back into the water. Accidental mortalities and euthanized fish were retained and examined internally to determine sex and state of sexual maturity (i.e., had never spawned, pre-spawning condition, post-spawning condition).

Stomach contents from dead fish were examined and, if possible, identified and quantified by taxonomic group (generally, class or family for invertebrates and species for fish) in the field. For many stomachs, it was not possible to identify all contents in the field and consequently, contents were preserved in 10% formalin and sent to the laboratory for subsequent analysis.

Muscle and liver tissue were collected from a length-stratified (100 mm intervals) sub-sample of Arctic char for analysis of mercury and other contaminant content. Otoliths were collected from these fish for subsequent age analysis.

**Laboratory and Data Analysis**

A detailed description of methodologies used for catch, size ageing, diet, and contaminants analysis is available in NSC (2010b). Catch-per-unit-effort (CPUE) was standardized for each net set as the number of fish caught in 100 m of net in 24 hours (#fish/100m/24hrs). Mean fork length, weight, and relative condition factor (K) was calculated for each species. Length-frequency distributions were plotted for each species where enough individuals were captured and weight-length relationships were calculated for each species using least squares regression analysis on logarithmic transformations of fork lengths and round weights. Overall mean age and age-specific mean size and condition factor were calculated and tabulated.

The frequency of occurrence of each food category was calculated for all prey species examined in Arctic char stomachs. Arctic char muscle and liver tissue samples were analyzed for trace metal and methyl mercury concentrations, and summary statistics and length-standardized mercury concentrations (to 350 mm) were calculated from the results. Length-standardization was accomplished by applying the linear regression equation derived from each data set. For detailed descriptions of analysis methods and calculations, see NSC (2010b).

#### 4.5.2.2 Results

**<u>Milne Inlet</u>**

Sixteen standard experimental gillnet gangs were set in the vicinity of the proposed Milne Inlet port during August 2010. Net locations are illustrated in Figure 4.5-3. Nets were set at depths ranging from the shoreline up to a maximum of approximately 50 m, and remained in the water for less than four hours to minimize mortality. For additional net set information, see NSC (2010b).

**Catch Results**

Five species (see Table 4.5-2 for scientific names) and a total of 75 fish were captured in experimental gill nets set in Milne Inlet in 2010 (Table 4.5-3). Shorthorn sculpin was the most abundant species in the catch (66.7%), followed by Arctic char (14.7%), fourhorn sculpin (9.3%), Greenland cod (5.3%), and Arctic staghorn sculpin (4.0%). Fish were captured in 14 of the 16 gill net sets.

The sets with the highest CPUEs were 5, 11 and 14 (NSC (2010b). These nets were set along the west shore 10 km north of the proposed port site, along the southern shore of the inlet, and along the east shore at the southern end of the inlet, respectively (Figure 4.5-3).

**Size and Age**

Arctic char captured at Milne Inlet ranged in length from 287 to 746 mm with a mean length of 485 mm (Table 4.5-4). Mean weight and condition factor for char were 1768 g and 1.13, respectively. Due to the small sample size, sex-specific size differences were not analyzed for ASrctic char. Shorthorn sculpin captured at Milne Inlet ranged in length from 189 to 420 mm with a mean length of 277 mm. Mean weight and condition factor for this species were 274 g and 1.14, respectively. Length-frequency distributions of Arctic char and shorthorn sculpin captured at Milne Inlet are presented in Figure 4.5-4 and Figure 4.5-5, respectively.

The length-weight relationships for Arctic char and shorthorn sculpin are presented in Table 4.5-5 and the relationships between length, weight, and condition factor with age are presented in Table 4.5-6. Arctic char captured at Milne Inlet in 2010 were between 11 and 26 years of age, with 64% between the ages of 11 and 13.

**Diet Analysis**

The stomach contents from four Arctic char captured at Milne Inlet in 2010 were preserved for laboratory identification. Sixteen different taxa identified from the samples, with Cottid larvae and two species of amphipod, *Mysis litoralis* and *Mysis oculata,* occurring in all stomachs (Table 4.5-7). Two different species of Cottid larvae were found in char stomachs from Milne Inlet; the most common was found in all four stomachs and was likely ribbed sculpin, whereas the second was only observed in low numbers in one stomach, and was likely that of *Icelus* sp.

**Contaminant Analysis**

Summary statistics for muscle mercury and total metals concentrations in muscle and liver from Arctic char captured at Milne Inlet in 2010 are presented in tables 4-5.-8 and 4-5.9 (results for individual fish are provided in NSC 2010b). Mercury concentrations were above the detection limit in all Arctic char muscle and liver samples (n = 11 fish). Concentrations in muscle tissue ranged from 0.0254 to 0.1050 µg/g [ww] with a mean concentration of 0.0497 µg/g [ww] (Table 4.5-8), and an average length-standardized muscle mercury concentration of 0.0326 µg/g [ww]. None of the fish sampled at Milne Inlet had muscle mercury concentrations that exceeded the Health Canada commercial export limit of 0.5 µg/g [ww] (Health Canada 2007; NSC 2010b).

Mean concentrations of trace elements in muscle and liver tissue are presented in Table 4.5-9. Arsenic, calcium, chromium, copper, iron, magnesium, manganese, phosphorus, potassium, selenium, sodium, strontium and zinc were detected in all muscle and liver samples. In addition, all liver samples contained detectable levels of cadmium, cobalt, molybdenum and thallium. In general, trace element concentrations were lower in muscle than in liver tissue. Only calcium, magnesium, and potassium were present in significantly larger concentrations in muscle than in liver. Twelve metals in muscle and ten metals in liver were rarely ($\leq$ 10% of sampled fish) or never present at concentrations above the minimum detection limit.

**<u>Steensby Inlet</u>**

Nineteen standard experimental gillnet gangs were set in the vicinity of the proposed Steensby Inlet port during early September 2007. An additional 25 standard experimental gillnet gangs and 6 small mesh gillnet gangs were set during early August 2010. The location for each gillnet gang set is provided in Figure 4.5-6. For additional net set information, see NSC (2010b).

**Catch and CPUE**

Nets were set at depths ranging from the shoreline up to a maximum of approximately 50 m, and most were left in the water less than four hours in order to minimize mortality. In 2007, two nets could not be retrieved due to inclement weather and, consequently, were left in place for approximately 48 hours.

Four species (see Table 4.5-2 for scientific names) and a combined total of 308 fish were captured in the experimental and small mesh gill nets set in Steensby Inlet in 2007 and 2010 (Table 4.5-10). Arctic char was the most abundant species captured, comprising 90.6% of the catch. Other species captured included shorthorn sculpin (4.5%), fourhorn sculpin (4.5%), and Atlantic spiny lumpsucker (0.3%). Small mesh gill nets set in 2010 captured only Arctic char (Table 4.5-5). In 2007, fish were captured in 11 of 19 experimental gillnet sets, while in 2010 they were captured in 23 of 29 experimental gillnet sets and in 3 of 6 small mesh gillnet sets.

The gillnet sets with the largest CPUEs in 2007 (sets 5, 6 and 7) were all located within Ikpikitarjuaq Bay (a large bay to the north of the port site; Figure 4.5-6; NSC 2010b). Two sets (1 and 3) located just to the south of the mouth of the same bay had the second and third highest CPUEs in 2010. Ther highest CPUE recorded in 2010 was from anet set to the east of the Steensby Port island along the shore of Baffin Island.

**Size and Age**

Mean size and condition factor of Arctic char from the 2007 and 2010 Steensby Inlet gillnetting catches are presented in Table 4.5-11. Char captured in standard experimental gillnet gangs ranged in length from 160 to 840 mm with a mean length of 455 mm in 2007 and 486 mm in 2010. Mean weight and K for char captured in standard experimental gangs in 2007 were 1168 g and 0.98, respectively, and in 2010 averaged 1297 g and 1.04, respectively. Arctic char captured in small mesh nets in 2010 had a mean fork length of 373 mm, a mean weight of 756 g, and a mean K of 1.08.

In 2007, male Arctic char captured at Steensby Inlet had a higher mean size and K than female Arctic char. In 2010, only one Arctic char was identified as male, so a similar comparison between the sexes for that year is not possible. Overall, char captured in 2007 had a modal length interval of 475 to 499 mm with more than 60% of the catch between 350 and 599 mm long (Figure 4.5-7). The 2010 had a modal length interval of 400-424 mm, with 60% of the catch between 375 and 649 mm long (Figure 4.5-8).

Weight-length relationships for the 2007 and 2010 char samples are presented in Table 4.5-12 and the relationships between length, weight, and condition factor with age are presented in tables 4.5-13 and 4.5-14. Arctic char captured at Steensby Inlet in 2007 were between six and 24 years of age, with 59% between the ages of 12 and 18 (Table 4.5-13). In 2010, Arctic char captured at Steensby Inlet were between 7 and 26 years old, with 43% between the ages of 16 and 20 (Table 4.5-14).

Mean size and condition factor of fourhorn and shorthorn sculpin from the 2007 and 2010 Steensby Inlet gillnetting catches are presented in Table 4.5-15. Low numbers of both species in gillnet catches from 2007 and 2010 prevents a comparison between years.

**Diet Analysis**

The majority of Arctic char stomach contents collected in 2007 (87%) were identified in the field. Most (79%) contained only amphipods, but two of them contained unidentified fish remains, and one contained both unidentified fish remains a sculpin. Ten stomachs contained organisms that were not easily identified in the field, and were therefore preserved for laboratory identification. In 2010, the stomah contents from an additional 11 Arctic char stomachs were preserved for laboratory identification. Eighteen taxa, as well as fish eggs, were identified from 21 stomachs (Table 4.5-16). Overall, the most frequently occurring prey taxa were amphipods, polychaetes, Arctic cod, and cottid larvae. The cottid larvae and fish eggs were likely those of ribbed sculpin (*Triglops pingelii*). The most frequently occurring taxa in char stomachs in 2007 were amphipods, Arctic cod, and ribbed sculpin. In 2010, Arctic cod and amphipods were once again the most dominant taxa, but polychaetes and cottid larvae occurred more frequently than in 2007. Overall, char stomachs from 2010 contained a greater diversity of prey items than stomachs from 2007.

**Contaminant Analysis**

Muscle tissue and liver samples were collected from Arctic char captured at Steensby Inlet in 2007 and 2010. Summary statistics for muscle mercury and total metals concentrations in muscle and liver are presented in tables 4.5-17 and 4.5-18, respectively. All Arctic char muscle and liver samples from 2007 and 2010 contained detectable levels of mercury. Arctic char sampled in 2007 (n = 29 fish) had muscle mercury concentrations ranging from 0.0220 to 0.1190 µg/g [ww], a mean concentration of 0.0475 µg/g [ww], and an average length-standardized muscle mercury concentration of 0.0307 µg/g [ww] (Table 4.5-17). Muscle mercury concentrations in arctic char samples from 2010 (n = 30 fish) ranged from 0.0126 to 0.1350 µg/g [ww], with a mean concentration of 0.0427 µg/g [ww]; when standardized to a fork length of 350 mm, the average muscle mercury concentration was 0.0268 µg/g [ww]. None of the fish sampled at Steensby Inlet in either 2007 or 2010 exceeded the Health Canada commercial export limit of 0.5 µg/g [ww] (Health Canada 2007; NSC 2010b).

Mean concentrations of trace elements in Arctic char liver and muscle tissue samples collected from Steensby Inlet are presented in Table 4.5-18. Arsenic, calcium, copper, iron, magnesium, manganese, phosphorus, potassium, selenium, sodium, strontium and zinc were detected in all muscle and liver samples in both 2007 and 2010. In addition, all liver samples contained detectable levels of cadmium, cobalt and molybdenum. In general, trace element concentrations were lower in muscle than in liver tissue. Exceptions include calcium, magnesium, and potassium which were present in larger concentrations in muscle than in liver.

In 2007 and 2010, ten different metals were never or rarely (≤ 10% of sampled fish) present in muscle tissue at concentrations above the minimum detection limit. Antimony, beryllium, bismuth, lead, lithium, tin and titanium were rarely or never detected in liver samples from 2007 and 2010. Additionally, molybdenum was rarely detected in livers sampled in 2007.

### 4.5.3 Summary

**Milne Inlet**

The nearshore marine fish community in Milne Inlet was characterized by low species diversity and abundance in 2010. Arctic char, fourhorn sculpin, shorthorn sculpin, Arctic staghorn sculpin, and Greenland cod were captured during the experimental gillnetting program. Sculpin species were most frequently captured, comprising approximately 80% of the experimental gillnetting catch. Arctic char and Greenland cod were captured in small numbers. Although the majority of previous studies in Milne Inlet have focused on Arctic char (Moshenko 1981; Kristofferson and McGowan 1981; Read 2004), the presence of sculpins, Greenland cod and Greenland shark has also been noted. Although few Arctic char and fish other than sculpins were captured at the Milne Port site, the Tugaat and Robertson Rivers, located in close proximity to the Milne Port, support anadromous char populations. Muscle samples collected from Arctic char captured at Milne Inlet had an average mercury concentration below the Health Canada commercial export limit of 0.5 ug/g.

**Steensby Inlet**

Similar to Milne Inlet, the nearshore marine fish community as observed during Project-specific studies at the Steensby Port was characterized by low species diversity and abundance. Arctic char, fourhorn sculpin, shorthorn sculpin, and Atlantic lumpfish were captured during experimental gillnetting programs. Arctic cod and larval sculpin (most likely ribbed sculpin) were commonly consumed by Arctic char indicating their prersence as well. Arctic char were by far the most common species observed, comprising 90.6% of the total catch between 2007 and 2010. Other fish species were documented in only very low numbers. Similar species assemblages are noted for other areas of caoastal Foxe Basin (NCRI 2008). The average concentration of mercury within muscle tissue samples collected from the Arctic char catch was below the Health Canada commercial export limit of 0.5 ug/g.

Arctic char were distributed throughout coastal areas in the vicinity of the port site, but were captured in much greater abundance in Ikpikitturjuaq Bay (a large bay just to the north of the Steensby Port site). The Ikpikitturjuaq River enters into Ikpikitturjuaq Bay and has long been known to support a population of anadromous (sea run) Arctic char that was sufficient in size to support a commercial fishery (Kroeker 1986, 1987). IQ and scientific literature contend that most anadromous char populations display strong fidelity to their natal stream, remaining within close proximity when feeding in the marine environment. Thus, it is thought that most of the char captured in the vicinity of the Steensby Port were members of the Ikpikitturjuaq River population. Numerous other rivers within Steensby Inlet support anadromous populations of Arctic char (Kroeker 1986, 1987). Some, such as the Cockburn River or the Rowley River, occur within close proximity (10-15 km) to the Steensby Port.

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# TABLES AND FIGURES

Table 1.1-1. Summary of marine environmental data collections in Milne and Steensby Inlets, 2007 to 2010.

| Location | Year[1] | Ice Morphology and Dynamics | Physical Oceanography | Bathymetry | Water Quality | Sediment Quality | Coastal Habitat | Seabed Habitat | Marine Flora | Benthic Invertebrates | Zooplankton | Fish Community | Metals in Fish |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Milne Inlet | 2007 | | | | | | + | | | | | | |
| | 2008 | | | + | + | + | | + | | | + | | |
| | 2010 | + | + | + | + | + | | + | | + | + | + | + |
| Steensby Inlet | 2007 | | + | + | + | + | + | + | | + | | + | + |
| | 2008 | + | + | + | + | + | | + | + | + | + | | |
| | 2010 | | | | | + | | | | + | + | + | + |

Table 2.3-1. Summary of current meter data in the vicinity of the proposed Steensby Port (see Figure 2-10 for meter location; data from AMEC 2009).

Steensby Site 5 upward-looking ADCP (RDI WH-600 # 5311)
Statistical Summary - September 2008

| Bin | Depth | Speed | | | | East Velocity | | | | North Velocity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Max | Min | Mean | Std | Max | Min | Mean | Std | Max | Min | Mean | Std |
| # | m | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s |
| 25 | 4 | 0.51 | 0.00 | 0.14 | 0.09 | 0.24 | -0.20 | 0.00 | 0.06 | 0.45 | -0.49 | -0.05 | 0.14 |
| 24 | 5 | 0.50 | 0.00 | 0.14 | 0.09 | 0.24 | -0.19 | 0.00 | 0.06 | 0.44 | -0.49 | -0.06 | 0.14 |
| 23 | 6 | 0.49 | 0.00 | 0.13 | 0.08 | 0.27 | -0.18 | 0.00 | 0.06 | 0.42 | -0.49 | -0.05 | 0.14 |
| 22 | 7 | 0.46 | 0.00 | 0.13 | 0.08 | 0.29 | -0.17 | 0.00 | 0.05 | 0.42 | -0.45 | -0.05 | 0.13 |
| 21 | 8 | 0.52 | 0.00 | 0.12 | 0.08 | 0.33 | -0.17 | 0.00 | 0.05 | 0.47 | -0.44 | -0.05 | 0.13 |
| 20 | 9 | 0.55 | 0.00 | 0.12 | 0.08 | 0.36 | -0.17 | 0.00 | 0.05 | 0.50 | -0.44 | -0.04 | 0.12 |
| 19 | 10 | 0.56 | 0.00 | 0.11 | 0.08 | 0.38 | -0.20 | 0.00 | 0.06 | 0.53 | -0.39 | -0.04 | 0.12 |
| 18 | 11 | 0.58 | 0.00 | 0.11 | 0.08 | 0.39 | -0.20 | 0.00 | 0.06 | 0.58 | -0.36 | -0.04 | 0.12 |
| 17 | 12 | 0.60 | 0.00 | 0.11 | 0.08 | 0.37 | -0.20 | 0.00 | 0.06 | 0.60 | -0.34 | -0.04 | 0.12 |
| 16 | 13 | 0.54 | 0.00 | 0.11 | 0.08 | 0.35 | -0.21 | 0.00 | 0.06 | 0.54 | -0.35 | -0.04 | 0.12 |
| 15 | 14 | 0.48 | 0.00 | 0.11 | 0.08 | 0.30 | -0.24 | 0.00 | 0.06 | 0.48 | -0.36 | -0.03 | 0.12 |
| 14 | 15 | 0.48 | 0.00 | 0.11 | 0.08 | 0.28 | -0.24 | 0.00 | 0.06 | 0.46 | -0.37 | -0.03 | 0.12 |
| 13 | 16 | 0.48 | 0.00 | 0.11 | 0.08 | 0.30 | -0.25 | 0.00 | 0.06 | 0.44 | -0.38 | -0.03 | 0.12 |
| 12 | 17 | 0.48 | 0.00 | 0.11 | 0.08 | 0.30 | -0.25 | 0.00 | 0.06 | 0.47 | -0.39 | -0.03 | 0.11 |
| 11 | 18 | 0.46 | 0.00 | 0.11 | 0.08 | 0.30 | -0.25 | 0.00 | 0.06 | 0.44 | -0.38 | -0.03 | 0.11 |
| 10 | 19 | 0.46 | 0.00 | 0.11 | 0.08 | 0.28 | -0.24 | 0.00 | 0.06 | 0.42 | -0.37 | -0.03 | 0.11 |
| 9 | 20 | 0.47 | 0.00 | 0.11 | 0.08 | 0.27 | -0.22 | 0.00 | 0.06 | 0.41 | -0.37 | -0.03 | 0.11 |
| 8 | 21 | 0.49 | 0.00 | 0.10 | 0.08 | 0.24 | -0.21 | 0.00 | 0.06 | 0.44 | -0.36 | -0.03 | 0.11 |
| 7 | 22 | 0.49 | 0.00 | 0.10 | 0.07 | 0.25 | -0.18 | 0.00 | 0.06 | 0.45 | -0.35 | -0.03 | 0.11 |
| 6 | 23 | 0.51 | 0.00 | 0.10 | 0.07 | 0.23 | -0.18 | -0.01 | 0.05 | 0.46 | -0.38 | -0.03 | 0.10 |
| 5 | 24 | 0.49 | 0.00 | 0.09 | 0.07 | 0.23 | -0.20 | -0.01 | 0.05 | 0.45 | -0.37 | -0.03 | 0.10 |
| 4 | 25 | 0.47 | 0.00 | 0.09 | 0.07 | 0.23 | -0.19 | -0.01 | 0.05 | 0.42 | -0.35 | -0.03 | 0.10 |
| 3 | 26 | 0.46 | 0.00 | 0.08 | 0.07 | 0.23 | -0.20 | -0.01 | 0.05 | 0.43 | -0.35 | -0.02 | 0.09 |
| 2 | 27 | 0.47 | 0.00 | 0.08 | 0.07 | 0.21 | -0.20 | 0.00 | 0.05 | 0.45 | -0.34 | -0.02 | 0.09 |
| 1 | 28 | 0.46 | 0.00 | 0.07 | 0.07 | 0.21 | -0.20 | 0.00 | 0.04 | 0.44 | -0.31 | -0.01 | 0.08 |

Table 2.3-2. Summary of current meter data collected in the channel near the causeway at the proposed Steensby Port (see Figure 2-10 for meter location; data from AMEC 2009).

Steensby Site 4 upward-looking ADCP (RDI WH-600 # 1027)
Statistical Summary - October 2008

| Bin | Depth | Speed | | | | East Velocity | | | | North Velocity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Max | Min | Mean | Std | Max | Min | Mean | Std | Max | Min | Mean | Std |
| # | m | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s |
| 9 | 2 | 0.62 | 0.00 | 0.27 | 0.15 | 0.19 | -0.60 | 0.00 | 0.12 | 0.46 | -0.59 | -0.11 | 0.26 |
| 8 | 3 | 0.61 | 0.01 | 0.26 | 0.15 | 0.19 | -0.10 | 0.03 | 0.06 | 0.47 | -0.59 | -0.06 | 0.28 |
| 7 | 4 | 0.62 | 0.01 | 0.26 | 0.14 | 0.19 | -0.11 | 0.03 | 0.05 | 0.47 | -0.60 | -0.05 | 0.29 |
| 6 | 5 | 0.61 | 0.00 | 0.26 | 0.14 | 0.17 | -0.10 | 0.03 | 0.05 | 0.47 | -0.59 | -0.05 | 0.29 |
| 5 | 6 | 0.60 | 0.00 | 0.26 | 0.14 | 0.15 | -0.08 | 0.03 | 0.04 | 0.47 | -0.59 | -0.05 | 0.29 |
| 4 | 7 | 0.59 | 0.01 | 0.26 | 0.14 | 0.15 | -0.06 | 0.03 | 0.04 | 0.46 | -0.58 | -0.05 | 0.28 |
| 3 | 8 | 0.59 | 0.00 | 0.25 | 0.14 | 0.14 | -0.06 | 0.02 | 0.03 | 0.45 | -0.58 | -0.05 | 0.28 |
| 2 | 9 | 0.57 | 0.00 | 0.24 | 0.13 | 0.12 | -0.06 | 0.02 | 0.03 | 0.45 | -0.56 | -0.05 | 0.26 |
| 1 | 10 | 0.53 | 0.00 | 0.22 | 0.12 | 0.11 | -0.05 | 0.01 | 0.02 | 0.41 | -0.53 | -0.05 | 0.24 |

Table 2.3-3. Summary of current meter data from the channel between Cape Thalbitzer and Koch Island (see Figure 2-10 for meter location; data from AMEC 2009).

Steensby Site 3 upward-looking ADCP (RDI WH-300 # 931)
Statistical Summary - October 2008

| Bin | Depth | Speed | | | | East Velocity | | | | North Velocity | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Max | Min | Mean | Std | Max | Min | Mean | Std | Max | Min | Mean | Std |
| # | m | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s | m/s |
| 40 | 16 | 0.87 | 0.01 | 0.25 | 0.17 | 0.40 | -0.62 | -0.05 | 0.19 | 0.40 | -0.69 | -0.09 | 0.21 |
| 39 | 18 | 0.85 | 0.00 | 0.25 | 0.16 | 0.38 | -0.58 | -0.04 | 0.19 | 0.39 | -0.64 | -0.08 | 0.21 |
| 38 | 20 | 0.80 | 0.00 | 0.24 | 0.15 | 0.36 | -0.60 | -0.04 | 0.18 | 0.40 | -0.63 | -0.07 | 0.20 |
| 37 | 22 | 0.77 | 0.00 | 0.23 | 0.15 | 0.38 | -0.58 | -0.04 | 0.18 | 0.40 | -0.61 | -0.06 | 0.20 |
| 36 | 24 | 0.72 | 0.01 | 0.22 | 0.14 | 0.35 | -0.53 | -0.04 | 0.17 | 0.41 | -0.59 | -0.05 | 0.19 |
| 35 | 26 | 0.70 | 0.01 | 0.22 | 0.14 | 0.36 | -0.52 | -0.04 | 0.17 | 0.40 | -0.60 | -0.05 | 0.19 |
| 34 | 28 | 0.66 | 0.01 | 0.22 | 0.13 | 0.36 | -0.52 | -0.04 | 0.17 | 0.42 | -0.56 | -0.05 | 0.18 |
| 33 | 30 | 0.64 | 0.00 | 0.21 | 0.13 | 0.36 | -0.53 | -0.04 | 0.17 | 0.42 | -0.53 | -0.04 | 0.18 |
| 32 | 32 | 0.65 | 0.00 | 0.21 | 0.13 | 0.38 | -0.51 | -0.04 | 0.17 | 0.42 | -0.53 | -0.04 | 0.17 |
| 31 | 34 | 0.62 | 0.00 | 0.21 | 0.13 | 0.37 | -0.51 | -0.04 | 0.17 | 0.42 | -0.50 | -0.03 | 0.17 |
| 30 | 36 | 0.61 | 0.00 | 0.20 | 0.13 | 0.37 | -0.53 | -0.04 | 0.17 | 0.43 | -0.49 | -0.03 | 0.16 |
| 29 | 38 | 0.59 | 0.01 | 0.20 | 0.12 | 0.38 | -0.52 | -0.04 | 0.17 | 0.43 | -0.47 | -0.03 | 0.16 |
| 28 | 40 | 0.58 | 0.00 | 0.20 | 0.12 | 0.38 | -0.53 | -0.04 | 0.17 | 0.44 | -0.45 | -0.02 | 0.16 |
| 27 | 42 | 0.56 | 0.00 | 0.20 | 0.12 | 0.40 | -0.51 | -0.04 | 0.17 | 0.45 | -0.45 | -0.02 | 0.15 |
| 26 | 44 | 0.56 | 0.00 | 0.20 | 0.11 | 0.40 | -0.49 | -0.03 | 0.17 | 0.45 | -0.50 | -0.02 | 0.15 |
| 25 | 46 | 0.55 | 0.00 | 0.19 | 0.11 | 0.43 | -0.46 | -0.03 | 0.16 | 0.42 | -0.50 | -0.02 | 0.14 |
| 24 | 48 | 0.53 | 0.00 | 0.19 | 0.11 | 0.41 | -0.44 | -0.03 | 0.16 | 0.43 | -0.51 | -0.02 | 0.14 |
| 23 | 50 | 0.54 | 0.01 | 0.19 | 0.10 | 0.39 | -0.41 | -0.03 | 0.16 | 0.40 | -0.52 | -0.02 | 0.14 |
| 22 | 52 | 0.53 | 0.00 | 0.19 | 0.10 | 0.37 | -0.43 | -0.03 | 0.15 | 0.39 | -0.51 | -0.02 | 0.15 |
| 21 | 54 | 0.53 | 0.01 | 0.19 | 0.10 | 0.35 | -0.41 | -0.03 | 0.15 | 0.42 | -0.52 | -0.01 | 0.15 |
| 20 | 56 | 0.56 | 0.00 | 0.19 | 0.11 | 0.36 | -0.41 | -0.04 | 0.14 | 0.44 | -0.54 | -0.01 | 0.16 |
| 19 | 58 | 0.59 | 0.00 | 0.19 | 0.11 | 0.38 | -0.42 | -0.04 | 0.14 | 0.47 | -0.53 | -0.01 | 0.17 |
| 18 | 60 | 0.61 | 0.00 | 0.20 | 0.12 | 0.37 | -0.45 | -0.04 | 0.14 | 0.52 | -0.57 | -0.01 | 0.18 |
| 17 | 62 | 0.62 | 0.01 | 0.20 | 0.13 | 0.36 | -0.46 | -0.04 | 0.14 | 0.56 | -0.57 | -0.01 | 0.19 |
| 16 | 64 | 0.63 | 0.01 | 0.21 | 0.13 | 0.36 | -0.48 | -0.05 | 0.15 | 0.59 | -0.60 | 0.00 | 0.19 |
| 15 | 66 | 0.64 | 0.01 | 0.22 | 0.14 | 0.35 | -0.48 | -0.05 | 0.15 | 0.60 | -0.62 | 0.00 | 0.20 |
| 14 | 68 | 0.64 | 0.00 | 0.22 | 0.14 | 0.33 | -0.46 | -0.05 | 0.16 | 0.61 | -0.61 | 0.00 | 0.21 |
| 13 | 70 | 0.67 | 0.01 | 0.23 | 0.14 | 0.35 | -0.44 | -0.05 | 0.16 | 0.62 | -0.65 | 0.00 | 0.21 |
| 12 | 72 | 0.70 | 0.01 | 0.23 | 0.14 | 0.36 | -0.44 | -0.05 | 0.16 | 0.66 | -0.68 | 0.00 | 0.21 |
| 11 | 74 | 0.75 | 0.00 | 0.24 | 0.14 | 0.35 | -0.43 | -0.05 | 0.16 | 0.63 | -0.72 | 0.00 | 0.22 |
| 10 | 76 | 0.72 | 0.01 | 0.23 | 0.14 | 0.32 | -0.42 | -0.05 | 0.16 | 0.63 | -0.70 | 0.00 | 0.22 |
| 9 | 78 | 0.75 | 0.01 | 0.23 | 0.14 | 0.32 | -0.40 | -0.04 | 0.15 | 0.63 | -0.72 | 0.00 | 0.22 |
| 8 | 80 | 0.76 | 0.00 | 0.23 | 0.14 | 0.32 | -0.38 | -0.04 | 0.15 | 0.61 | -0.73 | 0.00 | 0.22 |
| 7 | 82 | 0.73 | 0.00 | 0.22 | 0.14 | 0.33 | -0.37 | -0.04 | 0.14 | 0.60 | -0.70 | 0.00 | 0.22 |
| 6 | 84 | 0.72 | 0.01 | 0.22 | 0.13 | 0.26 | -0.37 | -0.04 | 0.13 | 0.61 | -0.68 | 0.01 | 0.22 |
| 5 | 86 | 0.69 | 0.00 | 0.22 | 0.13 | 0.22 | -0.39 | -0.04 | 0.12 | 0.62 | -0.65 | 0.01 | 0.22 |
| 4 | 88 | 0.68 | 0.00 | 0.22 | 0.13 | 0.22 | -0.41 | -0.04 | 0.12 | 0.61 | -0.64 | 0.01 | 0.22 |
| 3 | 90 | 0.66 | 0.00 | 0.22 | 0.13 | 0.23 | -0.40 | -0.04 | 0.11 | 0.58 | -0.63 | 0.01 | 0.22 |
| 2 | 92 | 0.68 | 0.01 | 0.22 | 0.12 | 0.23 | -0.39 | -0.04 | 0.11 | 0.55 | -0.67 | 0.01 | 0.22 |
| 1 | 94 | 0.65 | 0.01 | 0.22 | 0.11 | 0.23 | -0.38 | -0.04 | 0.10 | 0.51 | -0.64 | 0.01 | 0.22 |

Table 2.4-1. Steensby Inlet wave measurement data (from AMEC 2009).

| **Parameter** | | **Month** | | **Total** |
|---|---|---|---|---|
| | | **Sept** | **Oct** | |
| **Wave Height (m)** | Minimum | 0.1 | 0.1 | 0.1 |
| | Mean | 0.3 | 0.3 | 0.3 |
| | Maximum | 0.9 | 0.7 | 0.9 |
| | Most frequent direction | S | S | S |
| **Wave Period (sec)** | Minimum | 2.1 | 2.1 | 2.1 |
| | Mean | 2.3 | 2.4 | 2.3 |
| | Maximum | 4.5 | 5.4 | 5.4 |

Table 2.6-1. Summary of aerial overflights where ice imagery was collected from Steensby Inlet.

| Flight Window | Dates | No. Photos |
|---|---|---|
| April | 25-29 April 2008 | 180 |
| June | 6-17 June 2008 | 485 |
| September | 10 September 2008 | 61 |

Table 3.1-1. Nutrient concentrations from the literature measured in the eastern Canadian Arctic; along with those from the current study. Values in parentheses represent standard deviation; n represents sample size.

| Sampling Date(s) | Depth (m) | Nitrate (mg N/L) Mean | Nitrate Min | Nitrate Max | Nitrate n | Phosphate (mg P/L)[1] Mean | Phosphate Min | Phosphate Max | Phosphate n | Silicate (mg Si/L)[2] Mean | Silicate Min | Silicate Max | Silicate n | Source |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Pond Inlet** | | | | | | | | | | | | | | |
| May, 1979 | Surface | 0.001 | - | - | 5-18 | 0.39 | - | - | 5-18 | 4.4 | - | - | 5-18 | Cross 1982[5] |
| June, 1979 | Surface | 0.0001 | - | - | 5-18 | 0.24 | - | - | 5-18 | 1.8 | - | - | 5-18 | Cross 1982[5] |
| **Baffin Bay (off west coast of Greenland)** | | | | | | | | | | | | | | |
| July/Aug, 1993 | Surface | nd | nd | nr | - | nr | 0.003 | 0.006 | nr | nr | 0.01 | 0.03 | nr | Mose Jensen et al. 1999 |
| | Euphotic Zone | - | 0.00 (0.00)[3] | 0.03 (0.04)[3] | 81 | - | 0.003 (0.003)[3] | 0.012 (0.009)[3] | 81 | - | 0.01 (0.0)[3] | 0.05 (0.02)[3] | 81 | Mose Jensen et al. 1999 |
| | Deep Water | - | 0.12 (0.01)[4] | 0.12 (0.01)[4] | 15 | - | 0.006 (0.003)[4] | 0.0314 | 15 | - | 0.01 (0.1)[4] | 0.19 (0.04)[4] | 15 | Mose Jensen et al. 1999 |
| **Barrow Strait** | | | | | | | | | | | | | | |
| April, 1984-2003[4] | <25 | - | - | - | - | - | - | - | - | 0.55 | - | - | 30 | Michel et al. 2006 |
| | >25 | - | - | - | - | - | - | - | - | 0.69 | - | - | 26 | Michel et al. 2006 |
| May, 1984-2003[4] | <25 | - | - | - | - | - | - | - | - | 0.55 | - | - | 99 | Michel et al. 2006 |
| | >25 | - | - | - | - | - | - | - | - | 0.7 | - | - | 69 | Michel et al. 2006 |
| June, 1984-2003[4] | <25 | - | - | - | - | - | - | - | - | 0.52 | - | - | 71 | Michel et al. 2006 |
| | >25 | - | - | - | - | - | - | - | - | 0.67 | - | - | 3 | Michel et al. 2006 |
| August, 1984-2003[4] | <25 | - | - | - | - | - | - | - | - | 0.17 | - | - | 5 | Michel et al. 2006 |
| | >25 | - | - | - | - | - | - | - | - | 0.7 | - | - | 3 | Michel et al. 2006 |
| Dec/Jan, 1984-2003[4] | <25 | - | - | - | - | - | - | - | - | 0.55 | - | - | 10 | Michel et al. 2006 |
| | >25 | - | - | - | - | - | - | - | - | 0.63 | - | - | 5 | Michel et al. 2006 |
| **Steensby Inlet** | | | | | | | | | | | | | | |
| Sept 2007/2008 | Surface | <0.10 | <0.002 | <0.10 | 20 | <0.25 | <0.02 | <0.25 | 20 | 0.19 | 0.08 | 0.57 | 13 | Current Study |
| May/June 2008 | Surface | <0.10 | <0.10 | <0.10 | 27 | 0.29 | <0.25 | 0.63 | 27 | 0.63 | 0.33 | 1.41 | 26 | Current Study |
| Sept 2007/2008 | Bottom | <0.10 | 0.006 | <0.10 | 20 | <0.25 | <0.02 | <0.25 | 20 | 0.20 | 0.09 | 0.58 | 13 | Current Study |
| May/June 2008 | Bottom | <0.10 | <0.10 | 0.11 | 27 | 0.36 | <0.25 | 0.96 | 27 | 0.60 | 0.32 | 1.12 | 27 | Current Study |
| **Milne Inlet** | | | | | | | | | | | | | | |
| Sept 2008/Aug. 2010 | Surface | <2.0 | <0.1 | <2.0 | 14 | <0.25 | 0.011 | <0.25 | 14 | 0.45 | 0.07 | 1.61 | 14 | Current Study |
| June 2008 | Surface | <0.1 | <0.1 | <0.1 | 6 | 0.31 | <0.25 | 0.54 | 6 | 1.06 | 0.14 | 2.43 | 6 | Current Study |
| Sept 2008/Aug. 2010 | Bottom | <2.0 | <0.1 | <2.0 | 14 | <0.25 | 0.024 | <0.25 | 14 | 0.43 | 0.18 | 1.02 | 14 | Current Study |
| June 2008 | Bottom | 0.13 | 0.12 | 0.15 | 6 | 0.44 | <0.25 | 0.68 | 6 | 1.90 | 0.73 | 2.5 | 6 | Current Study |

nd = not detected (detection limit not specified).

nr = not reported.

[1]Current study measured total phosphorus.

[2]Silicate measured as SiO3 in Cross 1982; as SiO2 in Mose Jensen et al. 1999; as SiOH4 in Michel et al. 2006; and, as soluble reactive silica in current study.

[3] minimum/maximum of 1-6 duplicate samples collected from 16 stations.

[4]minimum/maximum of 1 individual to 3 duplicate samples collected from 16 stations.

[5]Sampling years were 1984, 1985, 1986, 1988, 2002, and 2003.

Table 3.1-2. Sampling periods for each site where water quality samples were collected from Milne Inlet, Baffin Island, 2008 and 2010.

| | Sample Date | | | | |
|---|---|---|---|---|---|
| | 2007 | 2008 | | | 2010 |
| Site ID | Sept | May | June | Sept | Aug |
| MWQ-01 | - | - | + | + | - |
| | - | - | - | - | + |
| MWQ-02 | - | - | + | + | - |
| | - | - | - | - | + |
| MWQ-03 | - | - | + | + | - |
| | - | - | - | - | + |
| MWQ-04 | - | - | + | - | - |
| | - | - | - | - | + |
| | - | - | - | - | + |
| MWQ-05 | - | - | + | + | - |
| MWQ-06 | - | - | + | - | - |
| MWQ-07 | - | - | - | - | + |
| MWQ-08 | - | - | - | - | + |
| MWQ-09 | - | - | - | - | + |
| MWQ-10 | - | - | - | - | + |
| MWQ-11 | - | - | - | - | + |

Table 3.1-3. Sampling periods for each site where water quality samples were collected from Steensby Inlet, Baffin Island, 2007-2010.

| | Sample Date | | | |
|---|---|---|---|---|
| Site ID | Sept 07 | May 08 | June 08 | Sept 08 |
| SWQ-01 | + | + | + | + |
| SWQ-02 | + | + | + | + |
| SWQ-03 | + | + | + | + |
| SWQ-04 | + | + | + | + |
| SWQ-05 | + | + | + | + |
| SWQ-06 | + | + | + | + |
| SWQ-07 | + | + | + | + |
| SWQ-08 | - | + | + | + |
| SWQ-09 | - | + | + | + |
| SWQ-10 | - | + | + | + |
| SWQ-11 | - | + | + | + |
| SWQ-12 | - | - | + | + |
| SWQ-13 | - | - | + | + |
| SWQ-14 | - | - | + | - |
| SWQ-15 | - | - | + | - |
| SWQ-16 | - | - | + | - |

Table 3.1-4. Summary statistics for water chemistry parameters measured in samples collected from Milne Inlet during the open-water seasons of 2008 and 2010 (Open); and, ice-cover season of 2008 (Ice).

| | | | Surface | | | | | | | Bottom | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Season** | **DL[1]** | **Mean** | **SD[2]** | **Min** | **Max** | **Median** | **n** | **%>DL** | **Mean** | **SD[2]** | **Min** | **Max** | **Median** | **n** | **% > DL** |
| **Routines** | | | | | | | | | | | | | | | | |
| **Alkalinity, as $CaCO_3$ (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 5 | 89 | 9.3 | 82 | 106 | 84 | 14 | 100 | 111 | 0.8 | 110 | 112 | 111 | 14 | 100 |
| | Ice | 5 | 114 | 0.5 | 113 | 114 | 114 | 6 | 100 | 114 | 0.6 | 113 | 115 | 114 | 6 | 100 |
| **pH** | | | | | | | | | | | | | | | | |
| | Open | - | 7.82 | 0.153 | 7.33 | 7.98 | 7.85 | 14 | 100 | 7.84 | 0.095 | 7.72 | 7.98 | 7.83 | 14 | 100 |
| | Ice | - | 7.97 | 0.008 | 7.96 | 7.98 | 7.97 | 6 | 100 | 7.81 | 0.010 | 7.80 | 7.83 | 7.81 | 6 | 100 |
| **Conductivity (S/cm)** | | | | | | | | | | | | | | | | |
| | Open | 5 | 29.5 | 8.00 | 14.5 | 41.2 | 27.6 | 14 | 100 | 46.4 | 1.39 | 44.8 | 48.6 | 45.9 | 14 | 100 |
| | Ice | 5 | 48.4 | 0.44 | 47.6 | 48.9 | 48.5 | 6 | 100 | 49.0 | 0.22 | 48.7 | 49.3 | 48.9 | 6 | 100 |
| **Hardness, as $CaCO_3$ (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 5 | 3496 | 876.7 | 1620 | 4737 | 3375 | 14 | 100 | 5859 | 108.2 | 5700 | 6020 | 5860 | 14 | 100 |
| | Ice | 10 | 5770 | 164.4 | 5530 | 5990 | 5780 | 6 | 100 | 6087 | 49.3 | 6030 | 6170 | 6085 | 6 | 100 |
| **Nutrients** | | | | | | | | | | | | | | | | |
| **Ammonia (mg N/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.02 | <0.02 | 0.015 | <0.02 | 0.05 | <0.02 | 14 | 21 | 0.18 | 0.083 | 0.13 | 0.46 | 0.17 | 14 | 21 |
| | Ice | 0.02 | 0.16 | 0.028 | 0.11 | 0.18 | 0.17 | 6 | 100 | 0.19 | 0.060 | 0.15 | 0.31 | 0.17 | 6 | 100 |
| **Nitrate (mg N/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.10 / 1.00 / 2.00 | <2.0 | - | <0.1 | <2.0 | <2.0 | 14 | 0 | <2.0 | - | <0.1 | <2.0 | <2.0 | 14 | 0 |
| | Ice | 0.10 / 1.00 / 2.00 | <0.1 | - | <0.1 | <0.1 | <0.1 | 6 | 0 | 0.13 | 0.014 | 0.12 | 0.15 | 0.13 | 6 | 100 |
| **Nitrite (mg N/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.005 / 0.10 | <0.005 | 0.001 | <0.005 | 0.005 | <0.005 | 14 | 7 | <0.005 | 0.002 | <0.005 | 0.007 | 0.005 | 14 | 57 |
| | Ice | 0.005 / 0.10 | <0.1 | 0.000 | <0.1 | <0.1 | <0.1 | 6 | 0 | <0.1 | 0.000 | <0.1 | <0.1 | <0.1 | 6 | 0 |
| **Nitrate/nitrite (mg N/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.10 / 1.00 / 2.00 | <2.0 | - | <0.1 | <2.0 | <2.0 | 14 | 0 | <2.0 | - | <0.1 | <2.0 | <2.0 | 14 | 0 |
| | Ice | 0.10 / 1.00 / 2.00 | <0.1 | - | <0.1 | <0.1 | <0.1 | 6 | 0 | 0.13 | 0.014 | 0.12 | 0.15 | 0.13 | 6 | 100 |
| **TKN (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.50 / 1.0 / 2.0 | <1.0 | 0.75 | <1.0 | 3.0 | <1.0 | 14 | 21 | <2.0 | 0.85 | <2.0 | 4.0 | <2.0 | 14 | 29 |
| | Ice | 0.50 / 1.0 / 2.0 | 0.73 | 0.460 | <0.50 | 1.35 | 0.68 | 6 | 67 | 0.577 | 0.402 | 0.250 | 1.100 | 0.410 | 6 | 50 |
| **Total Nitrogen (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | - | 1.64 | 0.755 | 0.55 | 3.10 | 1.50 | 14 | - | 2.12 | 0.572 | 1.50 | 4.05 | 2.00 | 14 | - |
| | Ice | - | 0.78 | 0.460 | 0.30 | 1.40 | 0.73 | 6 | - | 0.71 | 0.403 | 0.37 | 1.22 | 0.55 | 6 | - |

Table 3.1-4. Continued.

| | | | Surface | | | | | | | Bottom | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Season** | **DL[1]** | **Mean** | **SD[2]** | **Min** | **Max** | **Median** | **n** | **% > DL** | **Mean** | **SD[2]** | **Min** | **Max** | **Median** | **n** | **% > DL** |
| **Dissolved Inorganic Nitrogen (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | - | 0.72 | 0.427 | 0.06 | 1.01 | 1.01 | 14 | - | 0.87 | 0.430 | 0.18 | 1.19 | 1.16 | 14 | - |
| | Ice | - | 0.21 | 0.028 | 0.16 | 0.23 | 0.22 | 6 | - | 0.32 | 0.054 | 0.29 | 0.43 | 0.30 | 6 | - |
| **Total Phosphorus (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.003 / 0.25 | <0.25 | 0.048 | 0.011 | <0.25 | 0.016 | 14 | 71 | <0.25 | 0.041 | 0.024 | <0.25 | 0.045 | 14 | 71 |
| | Ice | 0.003 / 0.25 | 0.31 | 0.206 | <0.25 | 0.54 | 0.29 | 6 | 50 | 0.44 | 0.245 | <0.25 | 0.68 | 0.56 | 6 | 67 |
| **Total Organic Carbon (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.5 | 0.3 | 0.14 | <0.5 | 0.6 | <0.5 | 14 | 29 | <0.5 | 0.07 | <0.5 | 0.50 | <0.5 | 14 | 7 |
| | Ice | 0.5 | 0.6 | 0.05 | 0.5 | 0.6 | 0.6 | 6 | 100 | <0.5 | 0.17 | <0.5 | 0.7 | 0.5 | 6 | 67 |
| **Dissolved Organic Carbon (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.5 | <0.5 | 0.14 | <0.5 | 0.6 | <0.5 | 14 | 21 | <0.5 | - | <0.5 | <0.5 | <0.5 | 14 | 0 |
| | Ice | 0.5 | 0.5 | 0.04 | 0.5 | 0.6 | 0.5 | 6 | 100 | <0.5 | 0.14 | <0.5 | 0.6 | <0.5 | 6 | 17 |
| **Soluble Reactive Silica (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.02 | 0.45 | 0.394 | 0.07 | 1.61 | 0.38 | 14 | 100 | 0.43 | 0.237 | 0.18 | 1.02 | 0.37 | 14 | 100 |
| | Ice | 0.02 | 1.06 | 0.935 | 0.14 | 2.43 | 1.03 | 6 | 100 | 1.90 | 0.739 | 0.73 | 2.5 | 2.21 | 6 | 100 |
| **Water Clarity** | | | | | | | | | | | | | | | | |
| **Total Dissolved Solids (g/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.005 | 23.6 | 6.50 | 10.9 | 33.0 | 22.1 | 14 | 100 | 37.1 | 1.11 | 35.8 | 38.9 | 36.7 | 14 | 100 |
| | Ice | 0.005 | 38.7 | 0.34 | 38.1 | 39.1 | 38.8 | 6 | 100 | 39.2 | 0.16 | 39.0 | 39.4 | 39.1 | 6 | 100 |
| **Total Suspended Solids (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 2 / 100 | 53 | 9 | 36 | <100 | <100 | 14 | 29 | 52 | 6 | 44 | <100 | <100 | 14 | 29 |
| | Ice | 2 / 100 | 5 | 1.4 | 3 | 7 | 5 | 6 | 100 | 3 | 1.4 | <2 | 5 | 3 | 6 | 83 |
| **Turbidity (NTU)** | | | | | | | | | | | | | | | | |
| | Open | 0.1 | 0.4 | 0.09 | 0.3 | 0.6 | 0.4 | 14 | 100 | 0.3 | 0.21 | 0.1 | 0.9 | 0.3 | 14 | 100 |
| | Ice | 0.1 | 0.3 | 0.05 | 0.3 | 0.4 | 0.3 | 6 | 100 | 0.1 | 0.04 | 0.1 | 0.2 | 0.1 | 6 | 100 |

[1]Analytical detection limit.
[2]Standard deviation of the mean.

Table 3.1-5. Summary statistics for surface water concentrations (mg/L) of selected metals and major ions measured in Milne Inlet during the open-water season, 2008 and 2010.

| Parameter | DL[1] | Mean | SD | Min | Max | Median | n | % > DL | CCME PAL[2] |
|---|---|---|---|---|---|---|---|---|---|
| **Arsenic** | | | | | | | | | |
| Dissolved | 0.025/0.03/0.04/0.05/0.06/0.08 | <0.04 | - | <0.025 | <0.06 | <0.04 | 14 | 0 | - |
| Total | 0.0001/0.04/0.05/0.06/0.08 | <0.06 | - | <0.015 | <0.08 | <0.07 | 14 | 0 | 0.0125 |
| **Barium** | | | | | | | | | |
| Dissolved | 0.0025/0.005/0.01 | 0.007 | 0.0013 | 0.005 | 0.010 | 0.006 | 14 | 100 | - |
| Total | 0.00005/0.005/0.01 | 0.008 | 0.0011 | <0.01 | 0.009 | 0.008 | 14 | 93 | - |
| **Boron** | | | | | | | | | |
| Dissolved | 0.5/1.0 | 2.3 | 0.55 | 1.1 | 3.2 | 2.3 | 14 | 100 | - |
| Total | 0.01/1.0 | 2.4 | 0.54 | 1.2 | 3.2 | 2.3 | 14 | 100 | - |
| **Bromide** | | | | | | | | | |
| Dissolved | 0.25 | 42.0 | 16.51 | 18.1 | 72.1 | 36.3 | 14 | 100 | - |
| **Cadmium** | | | | | | | | | |
| Dissolved | 0.0005/0.001/0.002 | <0.0005 | - | <0.0005 | <0.002 | <0.001 | 14 | 0 | - |
| Total | 0.00001/0.001/0.002 | <0.001 | - | <0.0005 | <0.002 | <0.001 | 14 | 0 | 0.0001 |
| **Calcium** | | | | | | | | | |
| Dissolved | 0.5 | 226 | 58.3 | 115 | 317 | 221 | 14 | 100 | - |
| Total | 0.05/0.5 | 224 | 58.6 | 111 | 314 | 211 | 14 | 100 | - |
| **Chloride** | | | | | | | | | |
| Dissolved | 1 | 10350 | 2812.1 | 4610 | 14300 | 9875 | 14 | 100 | - |
| **Iron** | | | | | | | | | |
| Dissolved | 0.3/0.6 | <0.3 | - | <0.3 | <0.3 | <0.3 | 14 | 0 | - |
| Total | 0.03/0.3/0.6 | <0.3 | - | <0.2 | <0.6 | <0.3 | 14 | 0 | - |
| **Magnesium** | | | | | | | | | |
| Dissolved | 1 | 695 | 180.1 | 334 | 956 | 674 | 14 | 100 | - |
| Total | 0.1/1 | 713 | 177.7 | 326 | 960 | 692 | 14 | 100 | - |
| **Manganese** | | | | | | | | | |
| Dissolved | 0.00025/0.005/0.010 | <0.005 | - | <0.0025 | <0.005 | <0.005 | 14 | 0 | - |
| Total | 0.00005/0.005/0.010 | <0.005 | - | <0.0025 | <0.010 | <0.005 | 14 | 0 | - |
| **Mercury** | | | | | | | | | |
| Dissolved | 0.00001 | <0.00001 | - | <0.00001 | <0.00001 | <0.00001 | 14 | 0 | - |
| Total | 0.00001 | <0.00001 | - | <0.00001 | <0.00001 | <0.00001 | 14 | 0 | 0.000016 |
| **Molybdenum** | | | | | | | | | |
| Dissolved | 0.0025/0.005/0.01 | 0.008 | 0.0069 | <0.005 | 0.031 | 0.006 | 14 | 93 | - |
| Total | 0.00005/0.005/0.010 | 0.006 | 0.0023 | <0.005 | 0.011 | 0.005 | 14 | 71 | - |
| **Potassium** | | | | | | | | | |
| Dissolved | 2.5/5 | 211 | 50.1 | 99 | 288 | 206 | 14 | 100 | - |
| Total | 0.05/0.05 | 218 | 47.0 | 98 | 283 | 216 | 14 | 100 | - |
| **Sodium** | | | | | | | | | |
| Dissolved | 0.02/2.5 | 5851 | 1571.8 | 2610 | 8097 | 5605 | 14 | 100 | - |
| Total | 0.002/0.05 | 5977 | 1572.5 | 2610 | 8360 | 5610 | 14 | 100 | - |
| **Strontium** | | | | | | | | | |
| Dissolved | 0.005/0.01 | 3.94 | 0.883 | 1.86 | 5.14 | 3.84 | 14 | 100 | - |
| Total | 0.0001/0.01 | 4.15 | 0.843 | 1.87 | 5.24 | 4.17 | 14 | 100 | - |
| **Sulphate** | | | | | | | | | |
| Dissolved | 1 | 1434 | 393.3 | 609 | 1960 | 1380 | 14 | 100 | - |
| **Uranium** | | | | | | | | | |
| Dissolved | 0.0005/0.001 | 0.002 | 0.0004 | 0.002 | 0.003 | 0.002 | 14 | 100 | - |
| Total | 0.00001/0.001 | 0.002 | 0.0003 | 0.002 | 0.003 | 0.002 | 14 | 100 | - |

[1]Analytical detection limit.
[2]CCME guideline for the protection of marine aquatic life.

Table 3.1-6. Summary statistics for water chemistry parameters measured in samples collected from Steensby Inlet during the open-water seasons of 2007 and 2008 (Open); and, ice-cover season of 2008 (Ice).

| | | | Surface | | | | | | | Bottom | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Season** | **DL[1]** | **Mean** | **SD[2]** | **Min** | **Max** | **Median** | **n** | **% > DL** | **Mean** | **SD[2]** | **Min** | **Max** | **Median** | **n** | **% > DL** |
| **Routines** | | | | | | | | | | | | | | | | |
| **Alkalinity, as CaCO3 (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 5 | 103 | 3.4 | 95 | 107 | 103 | 20 | 100 | 108 | 1.2 | 105 | 110 | 109 | 20 | 100 |
| | Ice | 5 | 120 | 5.9 | 92 | 125 | 122 | 27 | 100 | 122 | 2.0 | 113 | 124 | 122 | 27 | 100 |
| **pH** | | | | | | | | | | | | | | | | |
| | Open | - | 7.86 | 0.096 | 7.54 | 7.96 | 7.87 | 20 | 100 | 7.87 | 0.046 | 7.77 | 7.94 | 7.87 | 20 | 100 |
| | Ice | - | 7.84 | 0.036 | 7.77 | 7.93 | 7.83 | 27 | 100 | 7.84 | 0.032 | 7.78 | 7.89 | 7.85 | 27 | 100 |
| **Conductivity (S/cm)** | | | | | | | | | | | | | | | | |
| | Open | 5 | 43.0 | 1.58 | 39.2 | 44.9 | 43.3 | 20 | 100 | 45.3 | 0.59 | 43.4 | 46.1 | 45.5 | 20 | 100 |
| | Ice | 5 | 50.3 | 2.27 | 39.4 | 51.5 | 50.9 | 27 | 100 | 50.9 | 0.78 | 47.4 | 51.6 | 51.0 | 27 | 100 |
| **Hardness, as $CaCO_3$ (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 5 | 5409 | 423.8 | 4660 | 6680 | 5360 | 22 | 100 | 5590 | 206.1 | 5170 | 5920 | 5630 | 17 | 100 |
| | Ice | 5 / 10 | 5952 | 529.9 | 3760 | 6240 | 6042 | 20 | 100 | 6071 | 129.9 | 5890 | 6430 | 6045 | 20 | 100 |
| **Nutrients** | | | | | | | | | | | | | | | | |
| **Ammonia (mg N/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.02 | 0.07 | 0.070 | 0.03 | 0.36 | 0.05 | 20 | 100 | 0.11 | 0.081 | 0.05 | 0.43 | 0.10 | 20 | 100 |
| | Ice | 0.02 | 0.12 | 0.171 | 0.01 | 0.75 | 0.05 | 27 | 95 | 0.10 | 0.094 | 0.01 | 0.42 | 0.06 | 27 | 95 |
| **Nitrate (mg N/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.002 / 0.1 | <0.10 | 0.021 | <0.002 | <0.10 | <0.10 | 20 | 35 | <0.10 | 0.021 | 0.006 | <0.10 | <0.10 | 20 | 35 |
| | Ice | 0.1 | <0.10 | - | <0.10 | <0.10 | <0.10 | 27 | 0 | <0.10 | 0.012 | <0.10 | 0.11 | 0.05 | 27 | 5 |
| **Nitrite (mg N/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.10 / 0.005 | <0.10 | - | <0.005 | <0.10 | 0.00 | 20 | 0 | <0.10 | - | <0.005 | <0.10 | <0.005 | 20 | 0 |
| | Ice | 0.005 / 0.1 | <0.10 | 0.019 | 0.010 | <0.10 | 0.01 | 27 | 50 | <0.10 | 0.019 | 0.010 | <0.10 | 0.013 | 27 | 50 |
| **Nitrate/nitrite (mg N/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.1 | <0.10 | 0.0 | <0.10 | <0.10 | <0.10 | 20 | 0 | <0.10 | 0.0 | <0.10 | <0.10 | <0.10 | 20 | 0 |
| | Ice | 0.1 | <0.10 | 0.0 | <0.10 | <0.10 | <0.10 | 27 | 0 | <0.10 | 0.0 | <0.10 | 0.11 | <0.10 | 27 | 5 |
| **TKN (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.1 / 1 | 0.7 | 0.38 | <0.1 | 1.6 | 0.5 | 20 | 40 | <1.0 | 0.27 | 0.4 | 1.3 | <1.0 | 20 | 55 |
| | Ice | 0.05 / 0.5 / 1 | 1.0 | 1.02 | <0.5 | 4.5 | <1.0 | 27 | 80 | <1.0 | 1.01 | <0.5 | 5.4 | <1.0 | 27 | 65 |
| **Total Nitrogen (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | - | 0.81 | 0.409 | 0.10 | 1.65 | 0.55 | 20 | 100 | 0.80 | 0.310 | 0.48 | 1.50 | 0.67 | 20 | 100 |
| | Ice | - | 1.06 | 1.024 | 0.30 | 4.56 | 0.85 | 27 | 100 | 0.98 | 1.011 | 0.30 | 5.48 | 0.81 | 27 | 100 |

Table 3.1-6. Continued.

| | | | Surface | | | | | | | Bottom | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameter | Season | DL | Mean | SD[2] | Min | Max | Median | n | % > DL | Mean | SD[2] | Min | Max | Median | n | % > DL |
| **Dissolved Inorganic Nitrogen (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | - | 0.16 | 0.146 | 0.08 | 0.55 | 0.11 | 20 | 100 | 0.21 | 0.157 | 0.10 | 0.61 | 0.15 | 20 | 100 |
| | Ice | - | 0.17 | 0.171 | 0.06 | 0.80 | 0.10 | 27 | 100 | 0.15 | 0.093 | 0.06 | 0.47 | 0.12 | 27 | 100 |
| **Total Phosphorus (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.02 / 0.25 | <0.25 | 0.057 | <0.02 | <0.25 | <0.25 | 20 | 5 | <0.25 | 0.057 | <0.02 | <0.25 | <0.25 | 20 | 5 |
| | Ice | 0.25 | 0.29 | 0.184 | <0.25 | 0.63 | 0.27 | 27 | 40 | 0.36 | 0.221 | <0.25 | 0.96 | 0.32 | 27 | 55 |
| **Total Organic Carbon (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.5 | 0.7 | 0.26 | <0.5 | 1.4 | 0.6 | 19 | 89 | 0.6 | 0.25 | <0.5 | 1.0 | 0.6 | 20 | 70 |
| | Ice | 0.5 | 0.5 | 0.17 | <0.5 | 0.8 | 0.6 | 27 | 70 | <0.5 | 0.15 | <0.5 | 0.7 | 0.5 | 27 | 65 |
| **Dissolved Organic Carbon (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.5 | 0.6 | 0.25 | <0.5 | 1.1 | 0.6 | 19 | 74 | 0.5 | 0.24 | <0.5 | 0.9 | 0.6 | 20 | 60 |
| | Ice | 0.5 | <0.5 | 0.15 | <0.5 | 0.7 | 0.5 | 27 | 75 | <0.5 | 0.17 | <0.5 | 0.7 | <0.5 | 27 | 40 |
| **Soluble Reactive Silica (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.02 | 0.19 | 0.129 | 0.08 | 0.57 | 0.14 | 13 | 100 | 0.20 | 0.127 | 0.09 | 0.58 | 0.15 | 13 | 100 |
| | Ice | 0.02 | 0.63 | 0.233 | 0.33 | 1.41 | 0.57 | 26 | 100 | 0.60 | 0.167 | 0.32 | 1.12 | 0.58 | 27 | 100 |
| **Water Clarity** | | | | | | | | | | | | | | | | |
| **Total Dissolved Solids (g/L)** | | | | | | | | | | | | | | | | |
| | Open | 0.005 | 32.0 | 2.48 | 28.5 | 35.2 | 33.0 | 20 | 100 | 33.9 | 3.25 | 29.2 | 36.9 | 36.0 | 20 | 100 |
| | Ice | 0.005 | 40.2 | 1.82 | 31.5 | 41.2 | 40.7 | 27 | 100 | 40.7 | 0.63 | 37.9 | 41.3 | 40.8 | 27 | 100 |
| **Total Suspended Solids (mg/L)** | | | | | | | | | | | | | | | | |
| | Open | 2 | 43 | 20.9 | 4 | 89 | 39 | 20 | 100 | 48 | 18.1 | 28 | 91 | 43 | 20 | 100 |
| | Ice | 3 | <100 | 24.1 | <2 | <100 | 28 | 26 | 84 | <100 | 27.5 | 1 | <100 | 17 | 26 | 89 |
| **Turbidity (NTU)** | | | | | | | | | | | | | | | | |
| | Open | 0.1 | 0.6 | 0.30 | 0.2 | 1.3 | 0.5 | 20 | 100 | 0.6 | 0.23 | 0.3 | 1.1 | 0.6 | 20 | 100 |
| | Ice | 0.1 | 0.2 | 0.21 | 0.1 | 1.1 | 0.2 | 27 | 100 | 0.2 | 0.11 | 0.1 | 0.5 | 0.2 | 27 | 100 |

[1]Analytical detection limit.
[2]Standard deviation of the mean.

Table 3.1-7. Summary statistics for surface water concentrations (mg/L) of selected metals and major ions measured in Steensby Inlet during the open-water season, 2007-2008.

| Parameter | DL[1] | Mean | SD | Min | Max | Median | n | % > DL | CCME PAL[2] |
|---|---|---|---|---|---|---|---|---|---|
| **Aluminum** | | | | | | | | | |
| Dissolved | 0.1 | 0.18 | 0.408 | <0.10 | 1.88 | 0.05 | 20 | 25 | - |
| Total | 0.1 | <0.10 | 0.069 | <0.10 | 0.37 | <0.10 | 22 | 5 | - |
| **Arsenic** | | | | | | | | | |
| Dissolved | 0.03 / 0.05 | <0.04 | - | <0.03 | <0.05 | <0.04 | 20 | 0 | - |
| Total | 0.03 / 0.06 | <0.04 | 0.006 | <0.02 | <0.05 | <0.04 | 22 | 5 | 0.013 |
| **Barium** | | | | | | | | | |
| Dissolved | 0.005 | <0.005 | 0.0009 | <0.005 | 0.006 | <0.005 | 20 | 10 | - |
| Total | 0.005 | <0.005 | 0.0007 | <0.005 | 0.005 | <0.005 | 22 | 5 | - |
| **Boron** | | | | | | | | | |
| Dissolved | 1.0 | 3.5 | 0.40 | 2.8 | 4.4 | 3.4 | 20 | 100 | - |
| Total | 1.0 | 3.4 | 0.35 | 3.0 | 4.5 | 3.4 | 22 | 100 | - |
| **Bromide** | | | | | | | | | |
| Dissolved | 0.25 | 83.6 | 28.30 | 52.4 | 123.0 | 70.8 | 22 | 100 | - |
| **Cadmium** | | | | | | | | | |
| Dissolved | 0.001 / 0.0017 | <0.001 | - | <0.001 | <0.0017 | <0.001 | 20 | 0 | - |
| Total | 0.001 / 0.0017 | <0.001 | - | <0.001 | <0.002 | <0.001 | 22 | 0 | 0.00012 |
| **Calcium** | | | | | | | | | |
| Dissolved | 0.05 | 347 | 22.4 | 315 | 382 | 345 | 20 | 100 | - |
| Total | 0.05 | 360 | 27.2 | 309 | 431 | 359 | 22 | 100 | - |
| **Chloride** | | | | | | | | | |
| Dissolved | 1 | 15745 | 1325.5 | 13500 | 20100 | 15500 | 22 | 100 | - |
| **Iron** | | | | | | | | | |
| Dissolved | 0.3 | <0.3 | - | <0.3 | <0.6 | <0.3 | 20 | 0 | - |
| Total | 0.3 | <0.3 | - | <0.3 | <0.6 | <0.3 | 22 | 0 | - |
| **Magnesium** | | | | | | | | | |
| Dissolved | 1 | 1093 | 67.8 | 982 | 1210 | 1108 | 20 | 100 | - |
| Total | 1 | 1102 | 92.9 | 944 | 1360 | 1090 | 22 | 100 | - |
| **Manganese** | | | | | | | | | |
| Dissolved | 0.005 | <0.005 | 0.0019 | <0.005 | 0.009 | <0.005 | 20 | 10 | - |
| Total | 0.005 | <0.005 | 0.0015 | <0.005 | 0.009 | <0.005 | 22 | 5 | - |
| **Mercury** | | | | | | | | | |
| Dissolved | 0.00001 / 0.00005 | <0.00005 | 0.000026 | <0.00001 | 0.00011 | <0.00005 | 20 | 5 | - |
| Total | 0.00001 / 0.00005 | <0.00005 | - | <0.00001 | <0.00005 | <0.00001 | 22 | 0 | 0.000016 |
| **Molybdenum** | | | | | | | | | |
| Dissolved | 0.005 | 0.009 | 0.0013 | 0.007 | 0.012 | 0.009 | 20 | 100 | - |
| Total | 0.005 | 0.010 | 0.0013 | 0.007 | 0.012 | 0.009 | 22 | 100 | - |
| **Potassium** | | | | | | | | | |
| Dissolved | 5 / 20 | 336 | 31.3 | 284 | 388 | 334 | 20 | 100 | - |
| Total | 5 / 20 | 332 | 37.0 | 275 | 415 | 323 | 22 | 100 | - |
| **Sodium** | | | | | | | | | |
| Dissolved | 20 | 9196 | 580.6 | 8110 | 9960 | 9350 | 20 | 100 | - |
| Total | 20 | 9290 | 765.9 | 7930 | 11800 | 9160 | 22 | 100 | - |
| **Strontium** | | | | | | | | | |
| Dissolved | 0.01 | 6.4 | 0.53 | 5.3 | 7.6 | 6.5 | 20 | 100 | - |
| Total | 0.01 | 6.3 | 0.50 | 5.2 | 7.4 | 6.4 | 22 | 100 | - |
| **Sulphate** | | | | | | | | | |
| Dissolved | 1 | 2205 | 179.1 | 1990 | 2510 | 2160 | 22 | 100 | - |
| **Uranium** | | | | | | | | | |
| Dissolved | 0.001 | 0.003 | 0.0005 | 0.002 | 0.003 | 0.003 | 20 | 100 | - |
| Total | 0.001 | 0.003 | 0.0005 | 0.002 | 0.003 | 0.003 | 22 | 100 | - |

[1]Analytical detection limit.
[2]CCME guideline for the protection of marine aquatic life.

Table 3.2-1. Site summary information for sediment sampling conducted in Milne Inlet, 2008 and 2010.

| Site ID | Site Depth (m) | Location | Sampling Year 2008 | Sampling Year 2010 | Sample Recovered & Analysed | Sample Description |
|---|---|---|---|---|---|---|
| MSQ-01 | 1.0 | Nearshore | + | - | + | silty sand/pebbles with shells |
| MSQ-02 | 2.0 | Nearshore | + | - | + | pebbly sand with shells |
| MSQ-03 | 3.0 | Offshore | + | - | + | pebbly sand |
| MSQ-04 | 7.0 | Offshore | - | + | + | mud |
| MSQ-05 | 17 | Offshore | - | + | + | mud with shells (and tubes) |
| MSQ-06 | 24 | Offshore | - | + | + | sand/pebbles with shells |
| MSQ-07 | 30 | Offshore | - | + | + | silt/sand/mud |
| MSQ-08 | 44 | Offshore | - | + | + | mud (with tubes) |
| MSQ-09 | 10 | Offshore | - | + | + | sand |
| MSQ-10 | 28 | Offshore | - | + | + | mud |
| MSQ-11 | 14.5 | Offshore | - | + | + | pebbly sand/a few pieces of cobble |
| MSQ-12 | 62 | Offshore | - | + | + | thick, heavy mud |

Table 3.2-2. Site summary information for sediment sampling conducted in Steensby Inlet, 2007-2010.

| Site ID | Site Depth (m) | Location | Sampling Year 2007 | Sampling Year 2008 | Sampling Year 2010 | Sample Recovered & Analysed | Sample Description |
|---|---|---|---|---|---|---|---|
| SSQ-01 | 1.0 | Nearshore | + | - | - | + | - |
| SSQ-02 | 1.5 | Nearshore | + | - | - | + | - |
| SSQ-03 | 1.5 | Nearshore | + | - | - | + | - |
| SSQ-04 | 2.0 | Nearshore | + | - | - | + | - |
| SSQ-05 | 2.0 | Nearshore | + | - | - | + | - |
| SSQ-06 | 2.0 | Nearshore | + | - | - | + | - |
| SSQ-07 | 68 | Offshore | - | + | - | + | mud |
| SSQ-08 | 59 | Offshore | - | + | - | + | pebbly sand/mud |
| SSQ-09 | 54 | Offshore | - | + | - | + | pebbly sand/mud |
| SSQ-10 | 76 | Offshore | - | + | - | + | pebble, cobble, mud |
| SSQ-11 | 69 | Offshore | - | + | - | + | pebbly sand/mud |
| SSQ-12 | 77 | Offshore | - | + | - | - | pebbles |
| SSQ-13 | 97 | Offshore | - | + | - | - | cobble only |
| SSQ-14 | 28 | Offshore | - | + | - | - | cobble only |
| SSQ-15 | 21 | Offshore | - | + | - | + | sandy mud |
| SSQ-16 | 54 | Offshore | - | + | - | - | sandy mud |
| SSQ-17 | 1.0 | Nearshore | - | + | - | + | pebbly sand |
| SSQ-18 | 1.0 | Nearshore | - | + | - | + | pebbly sand |
| SSQ-19 | 1.0 | Nearshore | - | + | - | + | pebbly sand |
| SSQ-20 | 1.0 | Nearshore | - | + | - | + | pebbly sand |
| SSQ-21 | 1.0 | Nearshore | - | + | - | + | sand |
| SSQ-22 | 1.0 | Nearshore | - | + | - | + | sand |
| SSQ-23 | 1.0 | Nearshore | - | + | - | + | coarse sand |
| SSQ-24 | 1.0 | Nearshore | - | + | - | + | coarse sand |
| SSQ-25 | 1.0 | Nearshore | - | + | - | + | pebbly coarse sand |
| SSQ-26 | 1.0 | Nearshore | - | + | - | + | medium sand |
| SSQ-27 | 3.0 | Nearshore | - | - | + | + | sand with shells |
| SSQ-28 | 10 | Offshore | - | - | + | + | sand with seaweed and shells |
| SSQ-29 | 21 | Offshore | - | - | + | + | mud/pebbles with shells |
| SSQ-30 | 6.0 | Offshore | - | - | + | - | pebbles/cobble |
| SSQ-31 | 31 | Offshore | - | - | + | - | cobble with shells (and tubes) |
| SSQ-32 | 50 | Offshore | - | - | + | + | mud |
| SSQ-33 | 3.0 | Nearshore | - | - | + | - | pebbles/cobble/boulder |
| SSQ-34 | 20 | Offshore | - | - | + | + | mud/pebbly sand/cobble |
| SSQ-35 | 26 | Offshore | - | - | + | + | mud/pebbly sand |
| SSQ-36 | 3.0 | Nearshore | - | - | + | + | pebbly sand |

Table 3.2-3. Summary statistics for marine sediment quality analyses at sites in Milne inlet, 2008 and 2010. Values in bold blue and red exceed the CCME sediment quality guidelines (CCME 1999 updated to 2010).

| | Milne Inlet | | | | | | CCME Guideline | |
|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Mean** | **Min** | **Max** | **SD** | **n** | **# Detects** | **ISQG[1]** | **PEL[2]** |
| Particle Size Analysis (%) | | | | | | | | |
| Sand | 64 | 39 | 95 | 20.4 | 12 | 12 | - | - |
| Silt | 32 | 5 | 51 | 16.5 | 12 | 11 | - | - |
| Clay | 7 | 4 | 12 | 2.77 | 12 | 11 | - | - |
| Nutrients | | | | | | | | |
| Nitrite (ppm) | <1 | <1 | <1 | - | 12 | 0 | - | - |
| Nitrate (ppm) | 6 | <1 | 20 | 6.2 | 12 | 10 | - | - |
| TKN (%) | 0.05 | <0.01 | 0.20 | 0.050 | 12 | 10 | - | - |
| TOC (%) | 0.57 | 0.11 | 1.55 | 0.364 | 12 | 12 | - | - |
| TP (%) | 0.05 | <0.02 | 0.08 | 0.023 | 12 | 11 | - | - |
| Total Metals and Major Ions (µg/g d.w.) | | | | | | | | |
| Aluminum (Al) | 5206 | 721 | 8950 | 2538.8 | 12 | 12 | - | - |
| Antimony (Sb) | <1 | <1 | <1 | - | 12 | 0 | - | - |
| Arsenic (As) | 3 | <1 | 4 | 1.3 | 12 | 10 | **7.24** | **41.6** |
| Barium (Ba) | 17 | 2 | 35 | 8.1 | 12 | 12 | - | - |
| Beryllium (Be) | <1 | <1 | <1 | - | 12 | 0 | - | - |
| Boron(B) | 6.4 | 0.9 | 18.0 | 4.66 | 12 | 12 | - | - |
| Cadmium (Cd) | <0.5 | <0.5 | <0.5 | - | 12 | 0 | **0.7** | **4.2** |
| Calcium (Ca) | 81293 | 9320 | 134000 | 35277.3 | 12 | 12 | - | - |
| Chromium (Cr) | 25 | 3 | 43 | 11.6 | 12 | 12 | **52.3** | **160** |
| Cobalt (Co) | 3 | <1 | 5 | 1.4 | 12 | 11 | - | - |
| Copper (Cu) | 7 | 1 | 17 | 3.9 | 12 | 12 | **18.7** | **108** |
| Iron (Fe) | 9458 | 1700 | 14250 | 4025.9 | 12 | 12 | - | - |
| Lead (Pb) | 6 | 1 | 11 | 3.2 | 10 | 10 | **30.2** | **112** |
| Magnesium (Mg) | 36289 | 3420 | 59050 | 17854.4 | 12 | 12 | - | - |
| Manganese (Mn) | 122 | 25 | 175 | 50.5 | 12 | 12 | - | - |
| Mercury (Hg) | <0.1 | <0.1 | <0.1 | - | 12 | 0 | **0.13** | **0.7** |
| Molybdenum (Mo) | <1 | <1 | 5 | 1.3 | 12 | 1 | - | - |
| Nickel (Ni) | 16 | 2 | 24 | 6.9 | 12 | 12 | - | - |
| Potassium (K) | 1848 | 250 | 3537 | 911 | 12 | 12 | - | - |
| Selenium (Se) | <1 | <1 | <1 | - | 12 | 0 | - | - |
| Silver (Ag) | <1 | <1 | <1 | - | 12 | 0 | - | - |
| Sodium (Na) | 2970 | 639 | 7567 | 1961.6 | 12 | 12 | - | - |
| Strontium (Sr) | 49 | 9 | 77 | 21.4 | 12 | 12 | - | - |
| Thallium (Tl) | <1 | <1 | <1 | - | 12 | 0 | - | - |
| Vanadium (V) | 20 | 4 | 36 | 9.7 | 12 | 12 | - | - |
| Zinc (Zn) | 16 | 4 | 39 | 9.2 | 12 | 12 | **124** | **271** |

[1]Interim sediment quality guideline.
[2]Probable effect level.

Table 3.2-4. Results of linear regression analysis between silt content and metal concentrations in sediment samples collected from Milne Inlet, 2008 and 2010.

| Parameter | $R^2$ | p-value | Significant at α = 0.01 |
|---|---|---|---|
| Aluminum (Al) | 0.652 | 0.001 | Yes |
| Antimony (Sb)[1] | - | - | - |
| Arsenic (Ar) | 0.685 | 0.001 | Yes |
| Barium (Ba) | 0.355 | 0.041 | No |
| Beryllium (Be)[1] | - | - | - |
| Boron (Bo) | 0.379 | 0.033 | No |
| Cadmium (Ca)[1] | - | - | - |
| Calcium (Ca) | 0.646 | 0.002 | Yes |
| Chromium (Cr) | 0.529 | 0.007 | Yes |
| Cobalt (Co)[2] | 0.750 | <0.001 | Yes |
| Copper (Cu) | 0.62 | 0.002 | Yes |
| Iron (Fe) | 0.741 | <0.001 | Yes |
| Lead (Pb) | 0.598 | 0.003 | Yes |
| Magnesium (Mg) | 0.758 | <0.001 | Yes |
| Manganese (Mn)[2] | 0.822 | <0.001 | Yes |
| Mercury (Hg)[1] | - | - | - |
| Molybdenum (Mo)[3] | - | - | - |
| Nickel (Ni) | 0.668 | 0.001 | Yes |
| Potassium (K) | 0.734 | <0.001 | Yes |
| Selenium (Se)[1] | - | - | - |
| Silver (Ag)[1] | - | - | - |
| Sodium (Na)[2] | 0.357 | 0.040 | No |
| Strontium (Sr) | 0.576 | 0.004 | Yes |
| Thallium (Tl)[1] | - | - | - |
| Vanadium (V) | 0.659 | 0.001 | Yes |
| Zinc (Zn) | 0.292 | 0.070 | No |

[1]Regression analysis was not run as all values were at or below the DL.
[2]Distribution was not normal based on Lilliefores test; however, the distribution was near normal so the regression analysis was performed anyways. Results should be interpreted with caution.
[3]Molybdenum was only above the DL in one sample so regression analysis was not performed.

Table 3.2-5. Hydrocarbon results for sediment samples collected in Milne Inlet in 2008 and 2010 along with relevant CCME guidelines for the protection of marine aquatic life (CCME 1999 updated to 2010). Values in blue italics are considered suspect.

| | | | Sampling Location | | | CCME Guideline | |
|---|---|---|---|---|---|---|---|
| **Parameter** | **Units** | **DL** | **MSQ-04** | **MSQ-08** | **MSQ-12** | **ISQG[1]** | **PEL[2]** |
| Site Depth | (m) | - | 7 | 44 | 62 | - | - |
| Percent Moisture | (%) | 0.1 | 49.2 | 20.3 | 35.5 | - | - |
| **Volatile Organic Compounds** | | | | | | | |
| Ethylbenzene | (µg/g) | 0.1 | <0.2 | <0.1 | <0.1 | - | - |
| Toluene | (µg/g) | 0.1 | <0.2 | 0.3 | <0.1 | - | - |
| Benzene | (µg/g) | 0.05 / 0.1 | <0.1 | <0.05 | <0.05 | - | - |
| m/p-xylene | (µg/g) | 0.2 / 0.4 | <0.4 | <0.2 | <0.2 | - | - |
| o-xylene | (µg/g) | 0.1 / 0.2 | <0.2 | <0.1 | <0.1 | - | - |
| **Total Oil & Grease** | (µg/g) | 1 / 100 | 694 | <1 | <100 | - | - |
| **CCME Petroleum Hydrocarbons** | | | | | | | |
| F1 (C6-C10) | (µg/g) | 10 | <20 | <10 | <10 | - | - |
| F1 - BTEX | (µg/g) | 10 | <10 | <10 | <10 | - | - |
| F2 (C10-C16) | (µg/g) | 10 | <10 | <10 | <10 | - | - |
| F2 - Napthalene | (µg/g) | 10 | 27 | <10 | <10 | - | - |
| F3 (C16-C34) | (µg/g) | 20 | 27 | <20 | <20 | - | - |
| F3 - PAHs | (µg/g) | 20 | <20 | <20 | <20 | - | - |
| F4 (C34-C50) | (µg/g) | 20 | <20 | <20 | <20 | - | - |
| **Polynuclear Aromatic Hydrocarbons (PAHs)** | | | | | | | |
| Acenaphthene | (µg/g) | 0.003 / 0.006 | <0.006 | <0.003 | <0.003 | 0.00671 | 0.0889 |
| Acenaphthylene | (µg/g) | 0.003 / 0.006 | <0.006 | <0.003 | <0.003 | 0.00587 | 0.0128 |
| Anthracene | (µg/g) | 0.005 / 0.01 | <0.01 | <0.005 | <0.005 | 0.0469 | 0.245 |
| Benzo(a)anthracene | (µg/g) | 0.005 / 0.01 | <0.01 | <0.005 | <0.005 | 0.0748 | 0.693 |
| Benzo(a)pyrene | (µg/g) | 0.005 / 0.01 | <0.01 | <0.005 | <0.005 | 0.0888 | 0.763 |
| Benzo(b+k)fluoranthene | (µg/g) | 0.005 / 0.01 | <0.01 | <0.005 | <0.005 | - | - |
| Benzo(g,h,i)perylene | (µg/g) | 0.005 / 0.01 | <0.01 | <0.005 | <0.005 | - | - |
| Chrysene | (µg/g) | 0.005 | <0.01 | <0.005 | <0.005 | 0.108 | 0.846 |
| Dibenzo(a,h)anthracene | (µg/g) | 0.003 / 0.006 | <0.006 | <0.003 | <0.003 | 0.00622 | 0.135 |
| Fluoranthene | (µg/g) | 0.005 / 0.01 | <0.01 | <0.005 | <0.005 | 0.113 | 1.494 |
| Fluorene | (µg/g) | 0.005 / 0.01 | <0.01 | <0.005 | <0.005 | 0.0212 | 0.144 |
| Indeno(1,2,3-c,d)pyrene | (µg/g) | 0.005 / 0.01 | <0.01 | <0.005 | <0.005 | - | - |
| Naphthalene | (µg/g) | 0.005 | 0.012 | <0.005 | <0.005 | 0.0346 | 0.391 |
| Phenanthrene | (µg/g) | 0.005 / 0.01 | <0.01 | <0.005 | <0.005 | 0.0867 | 0.544 |
| Pyrene | (µg/g) | 0.005 / 0.01 | <0.01 | <0.005 | <0.005 | 0.153 | 1.398 |

[1]Interim sediment quality guideline.
[2]Probable effect level.

Table 3.2-6. Summary statistics for nearshore and offshore sediments in Steensby Inlet based on samples collected in 2007, 2008 and 2010. Values in bold blue and red exceed the CCME sediment quality guidelines (CCME 1999 updated to 2010).

| **Parameter** | **Nearshore** | | | | | | **Offshore** | | | | | | **Significantly Different[1]** | **CCME Guideline** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Mean** | **SD** | **Min** | **Max** | **n** | **# Detects** | **Mean** | **SD** | **Min** | **Max** | **n** | **# Detects** | | **ISQG[2]** | **PEL[3]** |
| Particle Size (%) | | | | | | | | | | | | | | | |
| Sand | 96 | 2.5 | 87 | 99 | 18 | 18 | 52 | 12.2 | 30 | 64 | 11 | 11 | Yes | - | - |
| Silt | 2 | 2.6 | <1 | 11 | 18 | 9 | 36 | 9.7 | 25 | 55 | 11 | 11 | Yes | - | - |
| Clay | 2 | 1 | <1 | 4 | 18 | 17 | 12 | 5 | 7 | 23 | 11 | 11 | Yes | - | - |
| Nutrients | | | | | | | | | | | | | | | |
| Nitrite (ppm) | <1 | - | <1 | <1 | 18 | 0 | <1 | - | <1 | <1 | 11 | 0 | Yes | - | - |
| Nitrate (ppm) | 3.6 | 4.45 | <1 | 20 | 18 | 17 | 9 | 10.8 | 2 | 30 | 11 | 11 | No | - | - |
| TKN (%) | 0.01 | 0.01 | <0.01 | 0.04 | 18 | 7 | 0.13 | 0.05 | 0.04 | 0.24 | 11 | 11 | Yes | - | - |
| TOC (%) | 0.08 | 0.047 | 0.03 | 0.2 | 18 | 18 | 0.94 | 0.609 | 0.51 | 2.65 | 11 | 11 | Yes | - | - |
| TP (%) | 0.04 | 0.024 | 0.01 | 0.11 | 18 | 18 | 0.11 | 0.03 | 0.07 | 0.16 | 11 | 11 | Yes | - | - |
| Total Metals and Major Ions (µg/g d.w.) | | | | | | | | | | | | | | | |
| Aluminum (Al) | 1239 | 906 | 906 | 2470 | 18 | 18 | 7557 | 2048.9 | 4970 | 12600 | 11 | 11 | Yes | - | - |
| Antimony (Sb) | <1 | - | <1 | <1 | 18 | 0 | <1 | - | <1 | <1 | 11 | 0 | - | - | - |
| Arsenic (As) | <1.0 | 0.41 | <1.0 | 1.7 | 18 | 6 | 5 | 1.51 | 3 | **7.5** | 11 | 11 | Yes | **7.24** | **41.6** |
| Barium (Ba) | 7 | 3.7 | 4 | 16 | 18 | 18 | 115 | 97.2 | 40 | 369 | 11 | 11 | Yes | - | - |
| Beryllium (Be) | <1 | - | <1 | <1 | 18 | 0 | <1 | - | <1 | <1 | 11 | 0 | - | - | - |
| Boron(B) | 1 | 0.23 | 0.8 | 1.7 | 18 | 18 | 9.6 | 2.83 | 5.4 | 16.7 | 11 | 11 | Yes | - | - |
| Cadmium (Cd) | <0.5 | - | <0.5 | <0.5 | 18 | 0 | <0.5 | 0.13 | <0.5 | 0.6 | 11 | 2 | - | **0.7** | **4.2** |
| Calcium (Ca) | 6197 | 3922 | 2230 | 16300 | 18 | 18 | 64509 | 30213 | 24800 | 135000 | 11 | 11 | Yes | - | - |
| Chromium (Cr) | 17 | 15.7 | 3 | **53** | 17 | 17 | **64** | 30.8 | 31 | **125** | 11 | 11 | Yes | **52.3** | **160** |
| Cobalt (Co) | 2 | 1 | <1 | 4 | 18 | 14 | 5 | 0.9 | 4 | 7 | 11 | 11 | Yes | - | - |
| Copper (Cu) | 3 | 2.1 | 2 | 11 | 18 | 18 | 10 | 2.3 | 6 | 14 | 11 | 11 | Yes | **18.7** | **108** |
| Iron (Fe) | 6772 | 5908 | 1830 | 22100 | 18 | 18 | 18109 | 2825 | 14700 | 24800 | 11 | 11 | Yes | - | - |
| Lead (Pb) | 2 | 1 | <1 | 4 | 18 | 16 | 8 | 1.6 | 6 | 11 | 11 | 11 | Yes | **30.2** | **112** |
| Magnesium (Mg) | 2158 | 809 | 1260 | 4090 | 18 | 18 | 15432 | 3790 | 11200 | 21700 | 11 | 11 | Yes | - | - |
| Manganese (Mn) | 39 | 23 | 20 | 114 | 18 | 18 | 186 | 53.3 | 125 | 266 | 11 | 11 | Yes | - | - |
| Mercury (Hg) | <0.1 | 0.04 | <0.1 | **0.2** | 18 | 1 | <0.1 | 0.05 | <0.1 | **0.2** | 11 | 2 | - | **0.13** | **0.7** |
| Molybdenum (Mo) | <1 | 1.5 | <1 | 7 | 18 | 1 | 2 | 2 | <1 | 7 | 11 | 9 | No | - | - |
| Nickel (Ni) | 7 | 6.4 | 2 | 24 | 17 | 17 | 32 | 14 | 15 | 59 | 11 | 11 | Yes | - | - |
| Potassium (K) | 511 | 209 | 314 | 1080 | 18 | 18 | 3639 | 1207 | 2300 | 6830 | 11 | 11 | Yes | - | - |
| Selenium (Se) | <1 | - | <1 | <1 | 18 | 0 | <1 | - | <1 | <1 | 11 | 0 | - | - | - |
| Silver (Ag) | <0.2 | - | <0.2 | <0.42 | 18 | 0 | <0.2 | - | <0.2 | <0.2 | 11 | 0 | - | - | - |
| Sodium (Na) | 1660 | 495 | 694 | 2300 | 18 | 18 | 8588 | 7008.9 | 4540 | 29400 | 11 | 11 | Yes | - | - |
| Strontium (Sr) | 18 | 14 | 5 | 57 | 18 | 18 | 87 | 42.6 | 39 | 175 | 11 | 11 | Yes | - | - |
| Thallium (Tl) | <1 | - | <1 | <1 | 18 | 0 | <1 | - | <1 | <1 | 11 | 0 | - | - | - |
| Vanadium (V) | 15 | 12 | 5 | 49 | 18 | 18 | 42 | 7.7 | 34 | 62 | 11 | 11 | Yes | - | - |
| Zinc (Zn) | 7 | 2.7 | <1 | 14 | 18 | 17 | 41 | 12.3 | 25 | 69 | 11 | 11 | Yes | **124** | **271** |

[1]Significance is based on the results of a Mann-Whitney U-test at α=0.05.
[2]Interim sediment quality guideline.
[3]Probable effect level.

Table 4.1-1. Shoreline classifications in Milne Inlet.

| Shore Type | Physical Description | Biological Description |
|---|---|---|
| Rock cliff | Rock cliffs without beaches occur throughout Milne Inlet. Slopes range from steep (>30º) to ramped. Cliff heights may be several hundred metres. Intertidal zone widths are less than 5m. Rock cliff and ramp shores are widely distributed throughout Milne Inlet, although are rare in Eskimo Inlet. | Narrow steep intertidal and nearshore tend to be bare of attached macrobiota. |
| Rock shores with pocket beaches or narrow fronting beaches | Rock cliff or ramps interspersed with coarse sediment pocket beaches. Boulder ridges in the intertidal and subtidal are common. Intertidal widths usually less than 30m. Occur throughout Milne Inlet. | The rockweed algal assemblage was commonly associated with the boulder ridges observed in the nearshore subtidal in this shore type. |
| Alluvial fans | There are areas of till and glacial outwash that are termed Alluvial Fans. Backshore slopes are moderate and usually include a tundra vegetation cover. Associated intertidal areas are usually moderate to narrow coarse sediment beaches of boulder, cobble, pebble sand. Bounder ridging tends to be common. | Biota was generally absent from the intertidal in front of the alluvial fan, due to mobility of sediment. |
| Beach ridge complexes | Beach ridges are accretional features and typically contain well-sorted sediment (often pebble-cobble in Milne Inlet). Isostatic rebound results in these deposits being raised above sea level where they form relict beach ridge complexes. Intertidal zone widths are typically less than 30m. They are widely distributed throughout Milne Inlet and range from very localized to extensive. | Intertidal generally bare of attached macrobiota, due to sediment mobility. On boulder ridges or on bedrock outcrops, patchy algal assemblages were seen. |
| Alluvial Delta Complexes | Alluvial streams provide sediment to the shore and the deposits are reworked by wave processes primarily into swash ridges, spits and bars. These associated depositional landforms are accretionary features and usually consist of well-sorted sand-pebble-cobble. Bounders may occur within the complexes. Salt marsh may occur within the complex. | Intertidal and nearshore areas were generally bare of attached biota due to sediment mobility; however, a few areas of with an ephemeral cover of filamentous green algae were noted on deltas. Small areas of salt marsh vegetation were occasionally associated with estuary features. |
| Delta Flats | Delta flats are relatively rare within Milne Inlet but do occur near the heads of the main inlet and side inlets. The flats may include wide low-tide flats, usually comprised of sand, swash bars or spits (usually slightly coarser), lagoons, salt marshes, channels and inter distributary flats and bars. Intertidal zone widths may be hundreds of metres. | Intertidal and nearshore areas were generally bare of attached biota due to sediment mobility; however, a few areas of with an ephemeral cover of filamentous green algae were noted on deltas. Small areas of salt marsh vegetation were occasionally associated with estuary features. |

Table 4.1-2. Shoreline classifications in Steensby Inlet.

| Shore Type | Physical Description | Biological Description |
|---|---|---|
| Rock cliff | Rock cliffs without beaches. Slopes range from steep (>30) to ramped. Generally heights are moderate in Steensby Inlet. Intertidal zone widths less than 10m. Most common on the east shore from proposed port site south to Cape Jensen. | Upper intertidal mostly bare of attached macrobiota. Lower intertidal commonly had patchy rockweed type algae at boulder ridges. Scattered individual plants of floating canopy kelps were noted at a few locations. |
| Rock cliff with beach | Rock cliff or ramp backshore with poorly sorted sand-gravel beaches in the intertidal. Boulder ridges in the intertidal are common. Intertidal widths usually less than 30m. Most common on the east shore of Steensby Inlet from head of Inlet south to Cape Jensen. | Upper intertidal mostly bare of attached macrobiota. Lower intertidal commonly had rockweed type algae, in particular associated with boulder lag or at boulder ridges. Nearshore subtidal often showed narrow band of understory kelp complex. |
| Alluvial Fans | There are areas of till and glacial outwash that are termed Alluvial Fans. Backshore slopes are moderate and usually include a tundra vegetation cover. Associated intertidal areas are usually moderate to narrow coarse sediment beaches of boulder, cobble, pebble sand. Bounder ridging tends to be common. | Intertidal generally bare of attached macrobiota on mobile sediments. Some lower intertidal rockweed type algae associated with boulder ridges. |
| Eroding Cliffs | There are some locations of eroding, unconsolidated sediments that produce steep cliffs with sand and gravel beaches. Generally the shoreline of the Inlet is progradational due to isostatic rebound but at a few locations eroding cliffs are noted. Intertidal zone widths vary but are comparatively narrow (<30m). These cliffs occur at isolated locations with limited extent. | Intertidal generally bare of attached macrobiota, due to sediment mobility. |
| Wide Flats | Low gradient shorelines with flat backshores and foreshores. Raised beach ridge deposits are common in the backshore. Wide intertidal flats (unconsolidated) or rock platforms (sedimentary bedrock) occur; widths up to 1 km. Beaches typically consist of pebble-cobble and include supratidal storm berms and intertidal berms and beach faces. Common on offshore islets in Steensby Inlet and along the west shore of the inlet. | Upper intertidal typically bare of attached macrobiota with patchy rockweed type algae in lower intertidal, associated with boulder ridges. Shallow nearshore subtidal often has wide band of the understory kelp assemblage. |
| Delta Flats | Delta flats and channel complexes associated with larger streams (e.g., Rowley River). Wide intertidal flats comprised of sand are bifurcated by distributary channels. Salt marsh occurs locally. Intertidal zone widths may be up to 1 km. Delta flats are most common on the east shore of Steensby Inlet. | Wide intertidal area mostly bare of attached macrobiota, however several of the larger deltas had a pale haze of filamentous green algae. |
| Lagoon complexes | Lagoon complexes are low gradient shorelines primarily in the northern portion of Steensby Inlet. The “shoreline” is extremely complex. Coastal gradients are very low with “backshores” only a few centimetres above the intertidal zone. Coarse boulder-cobble veneers dominate the intertidal. Finer sediments may occur in the shallow subtidal, where ice-gouging was commonly noted. White subtidal mats are interpreted as *Beggiatoa* and indicate anaerobic seabed conditions occur locally. Brine pools were noted in some isolated lagoon basins. | Upper intertidal was bare of attached macrobiota, with patchy to sparse rockweed type algae at lower intertidal boulders. In some of the low wave exposure lagoons, a nearshore subtidal filamentous algae (?) complex was observed. |

Table 4.1-3. Milne Inlet habitat associations developed from drop camera surveys.

| Constituent | Dominant | Frequent | Occasional |
|---|---|---|---|
| **Seabed Habitat Class 1: Intertidal/Upper Subtidal (< 3 m depth)** | | | |
| Substrate | Gravelly sand | Sand | Slightly gravelly mud/sand |
| Vegetation | Filamentous brown algae, No vegetation observed | Rockweed | - |
| Fauna | No fauna observed | Solitary tunicate (likely *Molgula sp.)* (Figure 4.1-9) | - |
| **Seabed Habitat Class 2: Shallow Subtidal (3 m to 15 m depth)** | | | |
| Substrate | Gravelly sand | Sandy gravel | Gravel |
| Vegetation | Bladed kelps (Figure 4.1-8) | Filamentous Red Algae, Foliose Red Algae, Foliose Green Algae | Filamentous Brown Algae, Rockweed, Encrusting coralline red algae |
| Fauna | No fauna observed | Mussels (*Mytilus* sp.), Unidentified bivalves (clam siphons), Unidentified sea urchin, Brittle stars, Solitary tunicate (likely *Molgula* sp.) | Bacterial mats (*Beggiatoa*), Unidentified fish |
| **Seabed Habitat Class 3: Subtidal (> 15 m depth)** | | | |
| Substrate | Muddy sandy gravel | Gravelly mud/sand | Gravel or sandy gravel |
| Vegetation | Filamentous red algae | Bladed kelps, Encrusting coralline red algae, *Agarum* | Foliose red algae |
| Fauna | Brittle stars (Figure 4.1-10), Unidentified sea urchin | Unidentified bivalves (clam siphons), Scallops (likely *Chlamys* sp.) | Tube-dwelling anemone, Unidentified sea cucumber, Unidentified fish |

Table 4.1-4. Steensby Inlet seabed habitat class definitions, as determined from 2007 SIMS survey (after CORI 2008a).

| Constituent | Dominant | Frequent | Occasional |
|---|---|---|---|
| **Seabed Habitat Class 1: Intertidal/Upper Subtidal (< 3m depth)** | | | |
| Substrate | Sandy gravel,<br>Muddy sandy gravel | Gravelly sand,<br>Gravelly mud/sand gravel,<br>Slightly gravelly sand,<br>Slightly gravelly mud/sand | - |
| Vegetation | Rockweed,<br>Filamentous brown algae (Figure 4.1-11) | Bladed kelps,<br>Foliose red algae,<br>Filamentous red algae | *Agarum* |
| Fauna | No observed fauna | Barnacles | Anemones,<br>Flat holes,<br>*Beggiotoa* bacterial mats |
| **Seabed Habitat Class 2: Shallow Subtidal (3 m to 15m depth)** | | | |
| Substrate | Muddy sandy boulder-cobble,<br>Sandy boulder-cobble | Gravelly mud/sand,<br>Gavel,<br>Slightly gravelly mud/sand | Gravelly sand,<br>Slightly gravelly sand |
| Vegetation | Bladed kelps (Figure 4.1-12),<br>Foliose red algae | *Agarum*,<br>Rockweed,<br>Filamentous red algae,<br>Filamentous brown algae,<br>Coralline red algae | - |
| Fauna | No observed fauna | Anemones (Figure 4.1-13) | Sea stars,<br>Sea urchins,<br>Tube-dwelling anemones,<br>Unidentified bivalves (clam siphons),<br>Fish |

Table 4.1-4. Continued.

| Constituent | Dominant | Frequent | Occasional |
|---|---|---|---|
| **Seabed Habitat Class 3: Moderate Subtidal (15 m to 25m depth)** | | | |
| Substrate | Muddy sandy gravel,<br>Sandy gravel | Gravelly mud/sand | Gravel |
| Vegetation | Foliose red algae,<br>Bladed kelps,<br>Filamentous red algae,<br>*Agarum* (Figure 4.1-14) | Coralline red algae | - |
| Fauna | No observed fauna | Anemones | Sea urchins,<br>Sea stars,<br>Crinoids,<br>Corals,<br>Crabs,<br>Barnacles,<br>Sea cucumbers,<br>Fish |
| **Seabed Habitat Class 4: Deep Subtidal (>25m depth)** | | | |
| Substrate | Muddy Sandy Gravel | - | Sandy Gravel, gravelly Mud/Sand |
| Vegetation | Foliose red algae | Filamentous red algae,<br>*Agarum* (Figure 4.1-14),<br>Coralline red algae<br>Bladed kelps | - |
| Fauna | No observed fauna | Anemones,<br>Crinoids | Sea urchins,<br>Sea stars,<br>Corals,<br>Barnacles,<br>Crabs<br>Snails,<br>Sponges,<br>Fish |

Table 4.2-1. Chlorophyll *a* concentrations in Arctic waters near Steensby and Milne inlets.

| Sampling Area | Sampling Date | Depth (m) | Chlorophyll *a* ($mg/m^3$) Average | Minimum | Maximum | n | Source |
|---|---|---|---|---|---|---|---|
| **Baffin Bay (North-western area)** | | | | | | | |
| | Sept, 1977 | Surface | 0.68 | 0.08 | 4.9 | 17 | Harrison et al. 1982 |
| | | Subsurface | 1.98 | 0.28 | 6.86 | 17 | Harrison et al. 1982 |
| | Oct, 1977 | Surface | 1.01 | 0.68 | 1.99 | 16 | Harrison et al. 1982 |
| | Feb, 1977 | Surface | 0.17 | 0.09 | 0.27 | 16 | Harrison et al. 1982 |
| | Sept, 1978 | Surface | 0.57 | 0.19 | 1.4 | 12 | Harrison et al. 1982 |
| | | Subsurface | 3.55 | 0.94 | 8.3 | 12 | Harrison et al. 1982 |
| **Pond Inlet** | | | | | | | |
| | May, 1979 | Surface | 3.2 | - | - | 19-48 | Cross 1982[1] |
| | June, 1979 | Surface | 0.8 | - | - | 19-48 | Cross 1982[1] |
| **Cape Warrender** | | | | | | | |
| | August, 1980 | Surface | 2 | 0 | 4 | profile | Sameoto et al. 1986[1] |
| | | ~35 | 4 | 0 | 10 | profile | Sameoto et al. 1986[1] |
| **Lancaster Sound near Eclipse Sound** | | | | | | | |
| | Summer 1980 | 10 | - | 0.62 | - | 1 | Gallegos et al. 1983 |
| | | 20 | - | 3.22 | - | 1 | Gallegos et al. 1983 |
| | | 40 | - | 2.39 | - | 1 | Gallegos et al. 1983 |
| **Lancaster Sound near Admiralty Inlet** | | | | | | | |
| | Summer 1980 | 5 | - | 2.43 | - | 1 | Gallegos et al. 1983 |
| | | 24 | - | 9.51 | - | 1 | Gallegos et al. 1983 |
| | | 60 | - | 0.68 | - | 1 | Gallegos et al. 1983 |
| **Barrow Strait** | | | | | | | |
| | Winter 1986 | 0-15 | 0.1 | - | - | nr | Michel et al. 2006 |
| | Summer 1986 | Surface | - | 2 | 10 | nr | Michel et al. 2006 |
| | | 10-15 | - | 2 | 20 | nr | Michel et al. 2006 |
| **Baffin Bay (off west coast of Greenland)** | | | | | | | |
| | July/Aug, 1993 | Euphotic Zone[2] | - | 0.22 | 2.82 [3] | 16 | Mose Jensen et al. 1999 |

[1]Data were estimated from a graph.
[2]Depth integrated samples; euphotic zone extended to between 21 and 67 m at 16 stations
[3]One nearshore site had a concentration of 13.24 $mg/m^3$.

Table 4.2-2. Summary statistics for chlorophyll *a* and pheophytin *a* measured in water samples collected from Steensby and Milne inlets during the open-water (Open) and ice-cover (Ice) seasons, 2007-2008 and 2010.

| | | | Surface | | | | | | | Bottom | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Season** | **DL[1]** | **Mean** | **SD[2]** | **Min** | **Max** | **Median** | **n** | **% > DL** | **Mean** | **SD[2]** | **Min** | **Max** | **Median** | **n** | **% > DL** |
| **Steensby Inlet** | | | | | | | | | | | | | | | | |
| **Chlorophyll *a* (mg/m$^3$)** | | | | | | | | | | | | | | | | |
| | Open | 0.2 | 0.7 | 0.85 | 0.1 | 2.7 | 0.1 | 20 | 45 | 0.7 | 0.67 | <0.2 | 1.9 | 0.3 | 19 | 68 |
| | Ice | 0.2 | 1.1 | 2.00 | <0.2 | 7.3 | <0.2 | 25 | 37 | 0.5 | 1.05 | <0.2 | 4.9 | <0.2 | 25 | 26 |
| **Pheophytin *a* (mg/m$^3$)** | | | | | | | | | | | | | | | | |
| | Open | 0.2 | 0.8 | 1.61 | <0.2 | 7.0 | <0.2 | 25 | 16 | 1.1 | 1.44 | <0.2 | 6.5 | 0.6 | 25 | 47 |
| | Ice | 0.2 | 0.8 | 1.61 | <0.2 | 7.0 | <0.2 | 25 | 16 | 1.1 | 1.44 | <0.2 | 6.5 | 0.6 | 25 | 47 |
| **Milne Inlet** | | | | | | | | | | | | | | | | |
| **Chlorophyll *a* (mg/m$^3$)** | | | | | | | | | | | | | | | | |
| | Open | 0.2 | 0.5 | 0.63 | <0.2 | 1.7 | <0.2 | 14 | 43 | 0.5 | 0.73 | <0.2 | 2.0 | <0.2 | 14 | 21 |
| | Ice | 0.2 | 0.8 | 0.77 | <0.2 | 2.1 | 0.6 | 6 | 67 | 2.9 | 1.55 | 1.1 | 5.2 | 2.9 | 6 | 100 |
| **Pheophytin *a* (mg/m$^3$)** | | | | | | | | | | | | | | | | |
| | Open | 0.2 | 0.2 | 0.26 | <0.2 | 0.9 | <0.2 | 14 | 14 | 2.1 | 7.40 | <0.2 | 27.8 | <0.2 | 14 | 14 |
| | Ice | 0.2 | 1.0 | 1.72 | <0.2 | 4.4 | <0.2 | 6 | 17 | <0.2 | - | <0.2 | <0.2 | <0.2 | 6 | 0 |

[1]Analytical detection limit.
[2]Standard deviation of the mean.

Table 4.2.3. Floral categories classified in Steensby Inlet and Milne Inlet from nearshore video imagery.

| Algal Group | SIMS Code | Description |
|---|---|---|
| **Brown algae** | AGR | Sieve kelp (*Agarum clathratum*) |
| | BKS | Large bladed kelps (including *Saccharina longicruris, Saccharina latissima, Laminaria solidungula)* |
| | FIB | Filamentous brown algae (including *Desmarestia* and *Pylaiella*) |
| | FUC | Rockweed (*Fucus distichus subsp. edentatus*) |
| **Green algae** | FOG | Foliose green algae |
| **Red algae** | COR | Encrusting and foliose coralline red algae |
| | FIR | Filamentous red algae (*Polysiphonia arctica* was most common) |
| | FOR | Foliose red algae (*Phyllophora truncata* and *Odonthalia dentata* were the most common) |
| **Other** | NOV | No vegetation observed |

Table 4.2-4. Percent occurrence of flora categories identified in underwater imagery from Milne and Steensby inlets. Depth-referenced data collected in Milne Inlet in 2008 and in Steensby Inlet in 2007 are also categorized by depth interval in Figure 4.2.2-2.

| **Flora Categories** | **Milne Inlet 2008 and 2010** % Occurrence* | **Steensby Inlet 2007 and 2008** % Occurrence* |
|---|---|---|
| No observed vegetation | 35 | 11 |
| *Agarum* (benthic kelp) | 9 | 18 |
| Coralline red algae | 11 | 4 |
| Filamentous brown algae | 3 | 9 |
| Filamentous red algae | 30 | 35 |
| Foliose red algae | 7 | 45 |
| Foliose green algae | 4 | <0.1 |
| Rockweed | 2 | 27 |
| Bladed kelps | 32 | 55 |

*Note that '% Occurrence' was calculated from the count of occurrences of each feature in all classifiable seconds of imagery, and that each image can have up to 3 associated floral observations.

Table 4.2-5. Seaweeds identified from collections at Steensby Inlet during the nearshore survey, September 2008. Algal identifications by Dr. Sandra Lindstrom.

| Algal Group | Species Name | Notes about Occurrence in Video Imagery |
|---|---|---|
| **Brown Algae** | *Alaria esculenta*<br>*Agarum clathratum*<br>*Laminaria solidungula*<br>*Laminaria digitata*<br>*Saccharina latissima*<br>*Saccharina longicruris*<br>*Fucus distichus subsp. edentatus*<br>*Desmarestia aculeata*<br>*Desmarestia viridis*<br>*Ralfsia fungiformis*<br>*Sphacelaria plumosa*<br>*Punctaria glacialis*<br>*Pylaiella littoralis* | The most commonly noted seaweed in the video survey was the benthic bladed kelp *Saccharina longicruris*, although the filamentous *Desmarestia viridis* was also very common. *Agarum* generally occurred in the deepest parts of the survey.<br>The BKS (Bladed Kelps) category was comprised of a mixture of *S. longicruis, S. latissima,* and *Laminaria solidungula*. |
| **Green Algae** | *Chaetomorpha melagonium*<br>*Chaetomorpha cf. piquotiana* | Green algae collected were filamentous species, *Chaetomorpha,* that were mixed with the dominant filamentous brown alga species, *Desmarestia*. The green colour of *Chaetomorpha* was not visible in the underwater video imagery as the species was covered with silt and diatoms. |
| **Red algae** | *Phyllophora truncata*<br>*Phycodrys fimbriata*<br>*Odonthalia dentata*<br>*Polysiphonia arctica*<br>*Palmaria palmata*<br>*Devaleraea ramentacea*<br>*Rhodomela sibirica*<br>*Dilsea socialis*<br>*Scagelia pylaisaei*<br>*cf. Colaconema daviesii*<br>*Gracilaria tikvahiae* | *Polysiphonia arctica* was the most commonly collected filamentous red alga (FIR).<br>*Phyllophora truncata* and *Odonthalia dentate* were the most common foliose red algae (FOR).<br>Encrusting coralline algae (COR) was generally only noted deeper on boulder and cobble. |

Table 4.3-1. Summary of zooplankton taxa captured at Milne Inlet, fall 2008 and 2010.

| Sampling Year | Site ID | Zooplankton Richness | # Individuals/$m^3$ | Dominant Taxon 1 | Dominant Taxon 2 |
|---|---|---|---|---|---|
| **2008** | MZOO-1 | 9 | 1044 | *Oithona similis* | Harpacticoida |
| | MZOO-2 | 7 | 1703 | *O. similis* | *Calanus finmarichus/glacialis* |
| | MZOO-3 | 9 | 2101 | *O. similis* | *C. finmarichus/glacialis* |
| | **All Sites** | **12** | **1616**[2] | ***O. similis*** | ***C. finmarichus/glacialis*** |
| **2010** | MZOO-4 | 16 | 334 | *Oithona similis* | *Balanus* sp.[1] |
| | MZOO-5 | 15 | 293 | *O.similis* | Calanoida copepodites |
| | MZOO-6 | 16 | 735 | *O.similis* | Calanoida copepodites |
| | MZOO-7 | 16 | 550 | *O.similis* | Calanoida copepodites |
| | MZOO-8 | 16 | 513 | *O.similis* | Calanoida copepodites |
| | MZOO-9 | 14 | 652 | *O.similis* | Calanoida copepodites |
| | MZOO-10 | 15 | 399 | *O.similis* | Calanoida copepodites |
| | MZOO-11 | 15 | 624 | *O.similis* | Calanoida copepodites |
| | MZOO-12 | 18 | 742 | *O.similis* | Calanoida copepodites |
| | MZOO-13 | 14 | 639 | *O.similis* | Calanoida copepodites |
| | **All Sites** | **23** | **548**[2] | ***O.similis*** | **Calanoida copepodites** |

[1]Includes nauplii and cypris life history stages
[2]Average density across sites

Table 4.3-2. Density (individuals/m³) of the most common taxa in Milne Inlet, fall 2008 and 2010.

| Year | Site ID | Mean Sample Depth (m) | Density (# Individuals/m³) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Polychaeta | Calanoida | Cyclopoida | Harpaticoida | Thoracica | Chaetognatha | Larvacea |
| **2008** | MZOO-1 | 65 | 0.00 | 176.45 | 551.76 | 276.59 | 6.27 | 3.13 | 26.95 |
| | MZOO-2 | 54 | 0.00 | 257.10 | 1107.44 | 159.01 | 0.00 | 2.83 | 173.73 |
| | MZOO-3 | 57 | 1.79 | 320.05 | 1501.08 | 164.40 | 0.00 | 6.08 | 85.78 |
| | **Average** | **59** | **0.60** | **251.20** | **1053.43** | **200.00** | **2.09** | **4.01** | **95.49** |
| **2010** | MZOO-4 | 75 | 0.54 | 64.10 | 183.62 | 4.35 | 66.28 | 9.78 | 1.36 |
| | MZOO-5 | 101 | 0.40 | 58.09 | 213.80 | 4.84 | 6.45 | 2.82 | 0.81 |
| | MZOO-6 | 116 | 0.35 | 239.02 | 453.62 | 12.64 | 2.11 | 10.01 | 0.70 |
| | MZOO-7 | 124 | 0.00 | 142.93 | 379.34 | 9.86 | 1.97 | 4.11 | 3.94 |
| | MZOO-8 | 128 | 0.64 | 158.84 | 308.12 | 28.01 | 0.00 | 8.28 | 1.27 |
| | MZOO-9 | 165 | 0.00 | 186.31 | 426.70 | 23.71 | 0.99 | 3.58 | 1.48 |
| | MZOO-10 | 159 | 0.00 | 142.09 | 220.37 | 18.45 | 0.00 | 12.56 | 1.02 |
| | MZOO-11 | 63 | 0.00 | 171.87 | 405.50 | 23.28 | 2.59 | 10.02 | 5.17 |
| | MZOO-12 | 61 | 0.67 | 203.05 | 475.57 | 40.08 | 2.67 | 9.68 | 4.01 |
| | MZOO-13 | 44 | 0.93 | 203.72 | 362.99 | 44.45 | 0.93 | 14.35 | 7.41 |
| | **Average** | **104** | **0.35** | **157.00** | **342.96** | **20.97** | **8.40** | **8.52** | **2.72** |

Table 4.3-3. Summary of zooplankton taxa captured at Steensby Inlet, fall 2008 and 2010.

| Sampling Year | Site ID | Zooplankton Richness | # Individuals/$m^3$ | Dominant Taxon #1 | Dominant Taxon #2 |
|---|---|---|---|---|---|
| **2008** | SZOO-1 | 7 | 2404 | *Pseudocalanus minutus* | *Fritillaria borealis* |
| | SZOO-2 | 14 | 1927 | *P. minutus* | *F. borealis* . |
| | SZOO-3 | 8 | 1066 | *F. borealis* | *P. minutus* |
| | SZOO-4 | 10 | 1500 | *P. minutus* | *F. borealis* |
| | SZOO-5 | 16 | 1226 | *P. minutus* | *Balanus* sp.[1] |
| | SZOO-6 | 12 | 1853 | *P. minutus* | *F. borealis* |
| | SZOO-7 | 10 | 3693 | *P. minutus* | *F. borealis* |
| | SZOO-8 | 11 | 1219 | *P. minutus* | *F. borealis* |
| | **All Sites** | **23** | **1861**[2] | ***P. minutus*** | ***F. borealis*** |
| **2010** | SZOO-1 | 13 | 5245 | *Balanus* sp.[1] | *Fritillaria borealis* |
| | SZOO-2 | 13 | 1297 | *Balanus* sp.[1] | *Pseudocalanus minutus* |
| | SZOO-3 | 11 | 878 | *Balanus* sp.[1] | *P. minutus* |
| | SZOO-4 | 13 | 2084 | *Balanus* sp.[1] | *F. borealis* |
| | SZOO-5 | 15 | 1218 | *P. minutus* | *Balanus* sp.[1] |
| | SZOO-6 | 13 | 1902 | *Balanus* sp.[1] | *P. minutus* |
| | SZOO-7 | 11 | 1915 | *Balanus* sp.[1] | *P. minutus* |
| | SZOO-8 | 14 | 693 | *P. minutus* | *Balanus* sp.[1] |
| | **All Sites** | **23** | **1904**[2] | ***Balanus* sp.**[1] | ***P. minutus*** |

[1]Includes nauplii and cypris life history stages
[2]Average density across sites

Table 4.3-4. Density (individuals/m³) of the most common taxa in Steensby Inlet, fall 2008 and 2010.

| Year | Site ID | Mean Sample Depth (m) | Density (# Individuals/m³) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Polychaeta | Calanoida | Cyclopoida | Harpaticoida | Thoracica | Chaetognatha | Larvacea |
| **2008** | SZOO-1 | 11 | 22.22 | 1844.58 | 3.70 | 0.00 | 214.83 | 0.00 | 318.54 |
| | SZOO-2 | 55 | 44.63 | 1299.17 | 0.00 | 9.26 | 285.39 | 0.74 | 282.24 |
| | SZOO-3 | 58.5 | 8.36 | 390.02 | 0.00 | 16.72 | 236.80 | 0.00 | 412.31 |
| | SZOO-4 | 42 | 1.94 | 887.63 | 0.73 | 4.85 | 137.51 | 0.49 | 465.64 |
| | SZOO-5 | 68 | 31.76 | 740.28 | 0.00 | 3.00 | 443.69 | 0.00 | 0.60 |
| | SZOO-6 | 36.5 | 34.60 | 1098.96 | 0.00 | 11.16 | 334.88 | 0.56 | 363.34 |
| | SZOO-7 | 43 | 4.26 | 2185.00 | 4.74 | 0.00 | 492.71 | 0.00 | 1004.38 |
| | SZOO-8 | 83 | 4.91 | 852.18 | 2.45 | 0.00 | 127.63 | 2.45 | 227.28 |
| | **Average** | **50** | **19.09** | **1162.23** | **1.45** | **5.62** | **284.18** | **0.53** | **384.29** |
| **2010** | SZOO-1 | 15 | 260.76 | 233.60 | 4.07 | 86.92 | 3941.27 | 0.00 | 706.22 |
| | SZOO-2 | 56 | 58.21 | 463.82 | 0.00 | 14.55 | 567.50 | 0.36 | 190.99 |
| | SZOO-3 | 58 | 61.82 | 348.43 | 0.35 | 5.62 | 354.05 | 0.00 | 106.78 |
| | SZOO-4 | 40 | 195.57 | 409.47 | 0.00 | 12.22 | 1055.26 | 0.51 | 399.29 |
| | SZOO-5 | 69 | 160.61 | 484.20 | 1.18 | 5.90 | 413.34 | 0.59 | 146.44 |
| | SZOO-6 | 37 | 107.92 | 595.74 | 0.00 | 35.24 | 909.57 | 0.00 | 251.07 |
| | SZOO-7 | 44 | 103.71 | 401.88 | 0.00 | 3.70 | 1174.16 | 0.00 | 231.50 |
| | SZOO-8 | 79 | 46.42 | 334.20 | 0.00 | 7.22 | 224.86 | 0.00 | 78.39 |
| | **Average** | **50** | **124.38** | **408.92** | **0.70** | **21.42** | **1080.00** | **0.18** | **263.83** |

Table 4.4-1. Percent occurrence of fauna categories observed in 2008 and 2010 drop cam imagery from Milne Inlet, and 2007 SIMS and 2008 drop camera imagery from Steensby Inlet.

| **Fauna Categories** | **Milne Port Site 2008 and 2010** % Occurrence | **Steensby Port Site 2007 and 2008** % Occurrence |
|---|---|---|
| No observed fauna | 54 | 88 |
| Anemone sp. | <1 | 7 |
| Tube-dwelling anemone | 0.1 | 1 |
| Barnacles | - | <1 |
| Bacterial mat | <1 | <1 |
| Bivalve sp. | 22 | <1 |
| Brittle star sp. | 32 | <0.1 |
| Bryozoan complex | <0.1 | - |
| Crab sp. | - | <0.1 |
| Crinoid feather star | - | 1 |
| Fish sp. | <1 | <1 |
| Flatfish sp. | <0.1 | - |
| Flat holes (infauna indicator) | - | 2 |
| Mussels sp. | 2 | - |
| Scallop | 6 | - |
| Sea star sp. | - | <1 |
| Sea cucumber sp. | <1 | - |
| Sea Urchin | 30 | <1 |
| Snail sp. | - | <0.1 |
| Tube-dwelling worm | - | <0.1 |

Table 4.4-2. Taxonomic details of fauna groups observed in Steensby Inlet during the nearshore video imagery survey conducted in 2007 (after CORI 2008a).

| Faunal Group | SIMS Code | Description |
|---|---|---|
| **Anemones** | ANP | Tube-dwelling anemone (*Pachycerianthus* sp.) |
| | UAN | Unidentified anemones |
| **Barnacles** | BAR | Barnacles, all species |
| **Bacterial mats** | BEG | Colorless sulphur bacteria (*Beggiatoa* spp.) typically forming white, felty looking mats |
| **Bivalves** | BIV | Unidentified bivalve |
| **Snails** | USN | Unidentified gastropod snail |
| **Crinoid** | CRI | Crinoid feather star (*Florometra*) |
| **Brittle Stars** | BRI | Unidentified brittle star (Class Ophiuroidea) |
| **Sea Stars** | LEP | Six-armed seastar (*Leptasterias* sp.) |
| | STR | Unidentified sea star |
| **Urchins** | USU | Unidentified sea urchin |
| **Sea Cucumbers** | UCU | Unidentified sea cucumber |
| **Crabs** | CRB | Unidentified crab |
| | DEC | Unidentified decorator crab (could be one of several genera such as *Oregonia* sp. or *Chorilia* sp.) |
| | HRT | Unidentified hermit crab |
| **Corals** | UCO | Unidentified coral |
| **Sponges** | USP | Unidentified sponge |
| **Tubeworms** | UTU | Unidentified tube dwelling worm |
| **Infauna Burrows** | HLF | Unmounded (flat) worm, clam or crustacean holes. Species or species group cannot be distinguished. Presence indicates presence of infauna |
| **Hydroids** | HYD | Unidentified hydroid |
| **Fish** | FSH | Unidentified fish |
| | FTF | Unidentified flatfish |
| | SCU | Unidentified sculpin |
| **Unknown fauna** | UNK | Macrofauna visible but cannot be identified |

Table 4.4-3. Faunal density estimates determined from 2007 SIMS video imagery for Steensby Inlet, all surveyed areas and bays combined (after CORI 2010a). Note that visibility of epifauna is strongly influenced by the abundance of benthic vegetation and fauna were least often observed in Habitat Class 2, which had the highest percent cover of benthic kelps.

| **Habitat Class** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|
| **Depth Range (m)** | **< 3** | **3 to 15** | **15 to 25** | **> 25** |
| **Total Area (Ha)** | **59** | **94** | **34** | **35** |
| **Total # records (images)** | 25,200 | 31,960 | 7,270 | 13,800 |
| | | | | |
| **Faunal Group** | **Estimated Density of Individuals** | | | |
| Anemones | • | ⬤ | ⬤ | ⬤ |
| Barnacles | ⬤ | | • | • |
| Bacterial mats (*Beggiatoa*) | ● | ● | | |
| Bivalves (as indicated by the observation of siphons) | • | ● | • | |
| Snails | | | • | • |
| Crinoids (feather star *Florometra*) | | | ● | ⬤ |
| Brittle stars (Ophiuridae) | | • | • | • |
| Sea stars (includes all Asteroidea) | | • | • | ● |
| Sea urchins | | • | ● | ● |
| Sea cucumbers | | | • | • |
| Crabs (includes hermit crab, decorator crab and others) | | • | • | • |
| Corals | | | • | ● |
| Sponges | | | • | • |
| Tubeworms | | • | • | • |
| Infauna burrows and holes | ⬤ | ⬤ | | |
| Hydroids | | | | • |
| Fish (includes sculpins, flatfish and others) | • | ● | • | • |

Key to symbols:

| | |
|---|---|
| • | 1 to 10 observations per hectare |
| ● | 10 to 50 observations per hectare |
| ⬤ | more than 50 observations per hectare |

Table 4.4-4. Average density (individuals/$m^2$) of major benthic infauna taxa collected at selected stations in Milne Inlet in 2010.

| | | Habitat Classes | | | |
|---|---|---|---|---|---|
| **Depth Range** | | **3 m to 15 m** | **15 m to 25 m** | **> 25 m** | **Overall Average** |
| **Number of samples (n)** | | 2 | 2 | 5 | 9 |
| **Average Depth (m)** | | 5.5 | 17.5 | 56.2 | - |
| **Common Name** | **Scientific Name[1]** | | | | |
| Forams | P. Sarcodina | 5948.72 | 4826.92 | 2641.03 | 3861.82 |
| Roundworms | P. Nematoda | 7128.21 | 14769.23 | 5882.05 | 8133.90 |
| Unsegmented worms | P. Nemertea | 0.00 | 19.23 | 24.36 | 17.81 |
| Unsegmented Worms | P. Priapulida | 0.00 | 14.42 | 0.00 | 3.21 |
| Bristle worms | Cl. Polychaeta (Errantia) | 948.72 | 2857.37 | 755.13 | 1265.31 |
| Bristle worms | Cl. Polychaeta (Sedentaria) | 230.77 | 443.91 | 980.77 | 694.80 |
| Insects | Cl. Insecta | 0.00 | 0.00 | 30.77 | 17.09 |
| Mites | Cl. Arachnida | 1076.92 | 51.28 | 2.56 | 252.14 |
| Sea spiders | Cl. Pycnogonida | 0.00 | 0.00 | 5.13 | 2.85 |
| Copepods | Cl. Copepoda | 384.62 | 410.26 | 15.38 | 185.19 |
| Seed shrimps | Cl. Ostracoda | 1589.74 | 961.54 | 1417.95 | 1354.70 |
| Water scuds, cumaceans, sow bugs, crabs, and shrimp | Cl. Malacostraca | 1128.21 | 2211.54 | 452.56 | 993.59 |
| Snails | Cl. Gastropoda | 0.00 | 76.92 | 52.56 | 46.30 |
| Clams | Cl. Bivalvia | 1826.92 | 1370.19 | 1292.31 | 1428.42 |
| Sea urchins | Cl. Echinodea | 0.00 | 4.81 | 0.00 | 1.07 |
| Brittle Stars | Cl. Ophiuroidea | 0.00 | 0.00 | 50.00 | 27.78 |
| **Total** | | 20262.82 | 28017.63 | 13602.56 | 18285.97 |
| **Total (without Foraminifera or Nematoda)** | | 7185.90 | 8421.47 | 5079.49 | 6290.24 |

[1]P. = phylum, Cl. = class

Table 4.4-5. Density (individuals/$m^2$) of the major benthic infauna taxa collected at selected stations in Steensby Inlet in 2010.

| | | Habitat Classes | | | | |
|---|---|---|---|---|---|---|
| **Depth Range** | | **< 3 m** | **3 m to 15 m** | **15 m to 25 m** | **> 25 m** | **Overall Average** |
| **Number of samples (n)** | | 1 | 1 | 1 | 6 | 9 |
| **Average Depth (m)** | | 3 | 10 | 21 | 37.8 | - |
| **Common Name** | **Scientific Name** | | | | | |
| Forams | P. Sarcodina | 0.00 | 2695.65 | 1086.96 | 614.08 | 829.68 |
| Hydroids/Anemones/Medusae | P. Cnidaria | 0.00 | 43.48 | 0.00 | 0.00 | 4.83 |
| Roundworms | P. Nematoda | 0.00 | 1304.35 | 956.52 | 1827.85 | 1469.78 |
| Unsegmented Worms | P. Nemertea | 0.00 | 130.43 | 86.96 | 141.21 | 118.30 |
| Unsegmented Worms | P. Sipuncula | 0.00 | 0.00 | 0.00 | 4.27 | 2.85 |
| Unsegmented Worms | P. Priapulida | 0.00 | 0.00 | 0.00 | 9.66 | 6.44 |
| Worms | Cl. Oligochaeta | 0.00 | 43.48 | 0.00 | 0.00 | 4.83 |
| Bristle Worms | Cl. Polychaeta (Errantia) | 14.49 | 4043.48 | 1159.42 | 1713.88 | 1722.30 |
| Bristle Worms | Cl. Polychaeta (Sedentaria) | 101.45 | 978.26 | 1753.62 | 2806.55 | 2185.85 |
| Insects | Cl. Insecta | 14.49 | 0.00 | 0.00 | 0.00 | 1.61 |
| Copepods | Cl. Copepoda | 0.00 | 478.26 | 144.93 | 95.04 | 132.60 |
| Seed Shrimps | Cl. Ostracoda | 0.00 | 956.52 | 1159.42 | 600.24 | 635.27 |
| Barnacles | Cl. Cirripedia | 0.00 | 173.91 | 0.00 | 7.25 | 24.15 |
| Water Scuds, Cumaceans, Sow Bugs, Crabs, And Shrimp | Cl. Malacostraca | 57.97 | 1934.78 | 2231.88 | 859.16 | 1042.18 |
| Snails | Cl. Gastropoda | 0.00 | 0.00 | 43.48 | 79.11 | 57.57 |
| Clams | Cl. Bivalvia | 0.00 | 86.96 | 173.91 | 189.01 | 154.99 |
| Chitons | Cl. Polyplacophora | 0.00 | 0.00 | 0.00 | 4.55 | 3.03 |
| Sea Cucumbers | Cl. Holothuroidea | 0.00 | 0.00 | 0.00 | 2.42 | 1.61 |
| Brittle Stars | Cl. Ophiuroidea | 0.00 | 0.00 | 0.00 | 34.95 | 23.30 |
| Sea Stars | Cl. Stelleroidea | 0.00 | 21.74 | 0.00 | 0.00 | 2.42 |
| **Total** | | 188.41 | 12891.30 | 8797.10 | 8989.25 | 8423.59 |
| **Total (without Foraminifera or Nematoda)** | | 188.41 | 8891.30 | 6753.62 | 6547.31 | 6124.13 |

[1]P. = phylum, Cl. = class

Table 4.5-1. Potential fish species occurring Milne and Steensby inlets based on known distributions in waters 400 m or less[1,2].

| Family | Latin Name | Common Name |
|---|---|---|
| **Agonidae (Alligatorfish)** | *Leptagonus decagonus* | Atlantic poacher |
| **Ammodytidae (Sand Lance)** | *Ammodytes dubius* | Northern sand lance |
| **Cottidae (Scaleless Sculpin)** | *Gymnocanthus tricuspis* | Arctic staghorn sculpin |
| | *Icelus bicornis* | Twohorn sculpin |
| | *Icelus spatula* | Spatulate sculpin |
| | *Myoxocephalus quadricornis* | Fourhorn sculpin |
| | *Myoxocephalus scorpius* | Shorthorn sculpin |
| | *Reinhardtius hippoglossoides* | Greenland halibut |
| | *Triglops pingelii* | Ribbed sculpin |
| **Cyclopteridae (Lumpfish)** | *Cyclopteropsis jordani* | Smooth lumpfish |
| | *Cyclopteropsis* sp. | Lumpfish sp. |
| | *Eumicrotremus derjugini* | Leatherfin lumpsucker |
| | *Eumicrotremus spinosus* | Atlantic spiny lumpsucker |
| **Gadidae (Cod)** | *Boreogadus saida* | Arctic cod |
| | *Gadus ogac* | Greenland cod |
| | *Phycis chesteri* | Longfin hake |
| **Liparidae (Snailfish)** | *Liparis fabricii* | Gelatinous snailfish |
| | *Liparis gibbus* | Dusky snailfish |
| | *Liparis tunicatus* | Kelp snailfish |
| **Lotidae (Rocklings)** | *Gaidropsarus ensis* | Three-beard rockling |
| **Myxinidae (Hagfish)** | *Myxine* sp. | Hagfish sp. |
| **Osmeridae (Smelts)** | *Mallotus villosus* | Capelin |
| **Paralepididae (Barricudinas)** | *Arctozenus rissoi* | Ribbon barracudina |
| **Psychrolutidae (Fathead Sculpin)** | *Cottunculus microps* | Polar sculpin |
| **Rajidae (Rays and Skates)** | *Amblyraja jenseni* | Jensen's skate |
| | *Amblyraja radiata* | Thorny skate |
| **Arhynchobatidae (Softnose Skates)** | *Bathyraja spinicauda* | Spinytail skate |
| **Stichaeidae (Shannies)** | *Leptoclinus maculatus* | Daubed shanny |
| **Somniosidae (Sleeper Sharks)** | *Somniosus microcephalus* | Greenland shark |
| **Stomiidae (Dragonfish)** | *Chauliodus sloani* | Sloan's viperfish |
| **Zoarcidae (Eelpouts)** | *Gymnelis viridis* | Fish doctor |
| | *Gymnelus retrodorsalis* | Aurora pout |
| | *Lycenchelys* sp. | Wolf eel sp. |
| | *Lycodes pallidus* | Pallid eelpout |
| | *Lycodes reticulatus* | Reticulated eelpout |
| | *Lycodes* sp. | Eelpout sp. |

[1] Fish species list compiled from: Den Beste and McCart 1978; DFO 1980; Fishbase 2010; ITIS; Scott and Scott 1988.

[2]Several of these species are more abundant at depths > 400 m, but records exist for their presence in shallow water

Table 4.5-2. List of the species, common names, and abbreviations of fish captured during gillnetting surveys of Milne Inlet, fall 2010, and Steensby Inlet, fall 2007 and 2010.

| **Family**<br>Species | **Common Name** | **Milne Inlet** | **Steensby Inlet** |
|---|---|---|---|
| Salmonidae | | | |
| *Salvelinus alpinus* | Arctic char | X | X |
| Cottidae | | | |
| *Myoxocephalus quadricornis* | Fourhorn sculpin | X | X |
| *Myoxocephalus scorpius* | Shorthorn sculpin | X | X |
| *Gymnocanthus tricuspis* | Arctic staghorn sculpin | X | |
| Cyclopteridae | | | |
| *Eumicrotremus spinosus* | Atlantic spiny lumpsucker | | X |
| Gadidae | | | |
| *Gadus ogac* | Greenland cod | X | |

Table 4.5-3. The total number of fish captured (catch) and catch-per-unit-effort (CPUE; #fish/100 m/24hrs) by species across all experimental gillnetting sites at Milne Inlet, August 2010.

| **Species** | **Catch** | **CPUE** | **CPUE Range** |
|---|---|---|---|
| Arctic char | 11 | 4.54 | 0.00 – 23.96 |
| Arctic Staghorn sculpin | 3 | 1.24 | 0.00 – 8.38 |
| Fourhorn sculpin | 7 | 2.89 | 0.00 – 25.15 |
| Greenland cod | 4 | 1.65 | 0.00 – 10.75 |
| Shorthorn sculpin | 50 | 20.63 | 0.00 – 58.69 |
| **Total** | **75** | **30.95** | **0.00 – 92.23** |

Table 4.5-4. Mean length, weight, and condition factor (K), of Arctic char captured during small mesh gillnetting surveys of Milne Inlet, fall, 2010.

| Fish Species | n[1] | Length (mm) | | | Weight (g) | | | K | |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | SD[2] | Range | Mean | SD | Range | Mean | Range |
| Arctic char | 11 | 485 | 184 | 287-746 | 1768 | 1730 | 250-4250 | 1.13 | 0.96-1.33 |
| Arctic Staghorn Sculpin | 3 | 168 | 52 | 122-225 | 83 | 63 | 25-150 | 1.54 | 1.32-1.94 |
| Fourhorn Sculpin | 6 | 174 | 51 | 125-260 | 100 | 84 | 50-250 | 1.70 | 1.22-2.56 |
| Greenland Cod | 2 | 611 | 137 | 514-708 | 2750 | 2051 | 1300-4200 | 1.07 | 0.96-1.18 |
| Shorthorn Sculpin | 50 | 277 | 44 | 189-420 | 274 | 193 | 75-1000 | 1.14 | 0.72-1.58 |

[1]only includes fish for which size measurements were obtained; thus, may not equal total number of fish captured
[2]standard deviation

Table 4.5-5. Weight-length relationships for Arctic char and shorthorn sculpin captured during experimental gillnetting surveys of Milne Inlet, fall 2010.

| Site | n[1] | Weight-Length Equation | $r^2$ |
|---|---|---|---|
| Arctic char | 11 | $\log_{10}\text{Weight} = -4.81 + 2.95\ (\log_{10}\text{Length})$ | 0.99 |
| Shorthorn sculpin | 50 | $\log_{10}\text{Weight} = -6.25 + 3.53\ (\log_{10}\text{Length})$ | 0.92 |

[1]only includes fish for which size measurements were obtained; thus, may not equal total number of fish captured

Table 4.5-6. Age-specific mean size and condition factor (K) for Arctic char captured during experimental gillnetting surveys of Milne Inlet, late August, 2010.

| Age (yrs) | Length (mm) | | | | Weight (g) | | | | K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | n [1] | Mean | SD [2] | Range | n | Mean | SD | Range | n | Mean | Range |
| 11 | 1 | 315 | - | - | 1 | 350 | - | - | 1 | 1.12 | - |
| 12 | 3 | 357 | 67.6 | 287-422 | 3 | 567 | 354.7 | 250-950 | 3 | 1.13 | 1.05-1.26 |
| 13 | 3 | 366 | 27.1 | 336-388 | 3 | 583 | 125.8 | 450-700 | 3 | 1.18 | 1.03-1.33 |
| 18 | 1 | 660 | - | - | 1 | 3200 | - | - | 1 | 1.11 | - |
| 20 | 2 | 733 | 19.1 | 719-746 | 2 | 4100 | 141.4 | 4000-4200 | 2 | 1.05 | 0.96-1.13 |
| 26 | 1 | 720 | - | - | 1 | 4250 | - | - | 1 | 1.14 | - |

[1]only includes fish from which ageing structures were collected in 2010; thus, may not equal total number of fish captured
[2]standard deviation

Table 4.5-7. The frequency of occurrence of dietary items in the stomachs of Arctic char captured at Milne Inlet, 2010.

| | | |
|---|---|---|
| **# of stomachs examined in the lab:** | 4 | |
| **# of stomachs with contents:** | 4 | |
| **# of empty stomachs:** | 0 | |
| **Taxon** | **# of Occurrences** | **Frequency of Occurrence (%)** |
| Polychaeta | 1 | 25.00 |
| Arthropoda | | |
| Crustacea | | |
| Amphipoda | | |
| *Eurythenes gryllus* | 1 | 25.00 |
| *Ischyrocerus megacheir* | 1 | 25.00 |
| *Onisimus glacialis* | 2 | 50.00 |
| *Gammarus wilkitzkii* | 1 | 25.00 |
| *Themisto libellula* | 3 | 75.00 |
| Mysidacea | | |
| *Mysis litoralis* | 4 | 100.00 |
| *Mysis oculata* | 4 | 100.00 |
| *Mysis relicta* | 1 | 25.00 |
| Mysis sp. | 3 | 75.00 |
| Decapoda | | |
| Sabinea septemcarinata (Zoeal Stage) | 1 | 25.00 |
| Decapoda sp. (Zoeal Stage) | 1 | 25.00 |
| Chelicerata | | |
| Pycnogonida sp. | 2 | 50.00 |
| Mollusca | | |
| Gastropoda | | |
| Opisthobranchia | | |
| Gymnosomata sp. | 1 | 25.00 |
| Chordata | | |
| Osteichthyes (fish) | | |
| Cottidae (Larvae #1) | 4 | 100.00 |
| Cottidae (Larvae #2) | 1 | 25.00 |
| Pleuronectidae (Larvae) | 2 | 50.00 |

Table 4.5-8. Mean size, age, and muscle total mercury concentration (Hg) of Arctic char captured at Milne Inlet, 2010.

| Parameter | n | Mean | SD[1] | Range |
|---|---|---|---|---|
| Length (mm) | 11 | 485 | 184.3 | 287 - 746 |
| Weight (g) | 11 | 1768 | 1730.4 | 250 - 4250 |
| Age (years) | 11 | 15.5 | 4.82 | 11 - 26 |
| Hg (mg/Wkg) | 11 | 0.0497 | 0.02966 | 0.0254 - 0.1050 |
| Standardized Hg (µg/g [ww])[2] | 11 | 0.0326 | - | - |

1 - standard deviation

2 - “standardized" to a fork length of 350 mm; "standardized" value generated from the following regression equation: $Log_{10}(Hg) = -4.18 + 1.06 (Log_{10}(350))$; $r^2 = 0.52$

Table 4.5-9. Mean concentrations (µg/g [ww]) of trace elements in muscle tissue and livers of Arctic char captured at Milne Inlet, 2010.

| | | % Moisture | Element Concentration (µg/g [ww] for all elements) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Al | Sb | As | Ba | Be | Bi | Cd | Ca | Cr | Co | Cu |
| | MDL[1] | 0.1 | 2.0 | 0.010 | 0.010 | 0.010 | 0.10 | 0.030 | 0.0050 | 2.0 | 0.10 | 0.020 | 0.010 |
| Muscle | n[2] | 11 | 0 | 0 | 11 | 3 | 0 | 0 | 7 | 11 | 11 | 1 | 11 |
| | Mean[3] | 74.1 | <2.0 | <0.010 | 0.816 | <0.010 | <0.10 | <0.030 | 0.0057 | 122.3 | 0.59 | <0.020 | 0.848 |
| | SD[4] | 1.35 | - | - | 0.1732 | - | - | - | 0.00328 | 26.88 | 0.900 | - | 0.2690 |
| | Minimum | 72.1 | <2.0 | <0.010 | 0.542 | <0.010 | <0.10 | <0.030 | <0.0050 | 80.3 | 0.16 | <0.020 | 0.552 |
| | Maximum | 76.2 | <2.0 | <0.010 | 1.120 | 0.015 | <0.10 | <0.030 | 0.0113 | 164.0 | 3.27 | 0.022 | 1.400 |
| Liver | n[2] | 11 | 1 | 0 | 11 | 2 | 0 | 0 | 11 | 11 | 11 | 11 | 11 |
| | Mean[3] | 67.1 | <2.0 | <0.010 | 1.369 | <0.010 | <0.10 | <0.030 | 0.3079 | 71.6 | 0.91 | 0.052 | 18.719 |
| | SD[4] | 5.77 | - | - | 0.2004 | - | - | - | 0.3196 | 52.1 | 1.152 | 0.0197 | 7.8077 |
| | Minimum | 56.6 | <2.0 | <0.010 | 1.100 | <0.010 | <0.10 | <0.030 | 0.04130 | 24.6 | 0.12 | 0.030 | 7.110 |
| | Maximum | 75.1 | 2.1 | <0.010 | 1.710 | 0.021 | <0.10 | <0.030 | 1.0400 | 214.0 | 3.89 | 0.100 | 35.200 |

Table 4.5-9. Continued.

| | | Element Concentration (µg/g [ww] for all elements) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fe | Pb | Li | Mg | Mn | Hg | Mo | Ni | P | K | Se |
| | MDL[1] | 0.20-2.0 | 0.020 | 0.10 | 1.0 | 0.010 | 0.0010 | 0.010 | 0.10 | 5.0-50.0 | 20.0-200 | 0.20 |
| Muscle | n[2] | 11 | 0 | 0 | 11 | 11 | 11 | 9 | 9 | 11 | 11 | 11 |
| | Mean[3] | 9.9 | <0.020 | <0.10 | 260.6 | 0.164 | 0.0497 | 0.018 | 0.30 | 2591 | 4030 | 0.48 |
| | SD[4] | 5.03 | - | - | 22.26 | 0.0942 | 0.02966 | 0.0204 | 0.445 | 176.7 | 339.5 | 0.061 |
| | Minimum | 5.2 | <0.020 | <0.10 | 236.0 | 0.109 | 0.0254 | <0.010 | <0.10 | 2330 | 3590 | 0.40 |
| | Maximum | 20.9 | <0.020 | <0.10 | 310.0 | 0.441 | 0.1050 | 0.078 | 1.62 | 2780 | 4530 | 0.60 |
| Liver | n[2] | 11 | 0 | 0 | 11 | 11 | 11 | 11 | 9 | 11 | 11 | 11 |
| | Mean[3] | 194.2 | <0.020 | <0.10 | 170.1 | 1.412 | 0.0485 | 0.220 | 0.48 | 3294 | 2968 | 3.15 |
| | SD[4] | 65.23 | - | - | 24.20 | 0.2506 | 0.02390 | 0.0634 | 0.602 | 214.9 | 356.6 | 0.766 |
| | Minimum | 120.0 | <0.020 | <0.10 | 143.0 | 1.090 | 0.0271 | 0.130 | <0.10 | 3040 | 2180 | 2.38 |
| | Maximum | 293.0 | <0.020 | <0.10 | 223.0 | 1.930 | 0.1070 | 0.335 | 1.98 | 3730 | 3670 | 4.43 |

Table 4.5-9. Continued.

| | | Element Concentration (μg/g [ww] for all elements) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | **Na** | **Sr** | **Tl** | **Sn** | **Ti** | **U** | **V** | **Zn** |
| | **MDL[1]** | **20.0-200** | **0.01** | **0.010** | **0.050** | **1.0** | **0.0020** | **0.10** | **0.10** |
| Muscle | n[2] | 11 | 11 | 0 | 0 | 0 | 0 | 0 | 11 |
| | Mean[3] | 476 | 0.324 | <0.010 | <0.050 | <1.0 | <0.0020 | <0.10 | 6.20 |
| | SD[4] | 117.1 | 0.1222 | - | - | - | - | - | 0.802 |
| | Minimum | 316 | 0.200 | <0.010 | <0.050 | <1.0 | <0.0020 | <0.10 | 5.21 |
| | Maximum | 651 | 0.616 | <0.010 | <0.050 | <1.0 | <0.0020 | <0.10 | 8.12 |
| Liver | | | | | | | | | |
| | n[2] | 11 | 11 | 11 | 0 | 0 | 1 | 1 | 11 |
| | Mean[3] | 1502 | 0.430 | 0.019 | <0.050 | <1.0 | <0.0020 | <0.10 | 31.6 |
| | SD[4] | 389.6 | 0.7024 | 0.0045 | - | - | - | - | 6.29 |
| | Minimum | 770 | 0.071 | 0.013 | <0.050 | <1.0 | <0.0020 | <0.10 | 19.9 |
| | Maximum | 2030 | 2.53 | 0.027 | <0.050 | <1.0 | 0.0025 | 0.17 | 39.4 |

[1]MDL = minimum detection limit for trace element concentrations in the tissue; for some elements (e.g. iron [Fe]) MDL was increased due to interference encountered during analysis of some samples and, therefore, MDL ranges are presented; see NSC 2010b for details.
[2]n = the number of samples above the MDL for each trace element
[3]elements below MDLs are assumed to be half the limit for calculation of mean values; if resulting mean is below the MDL for each element (or the larger MDL for those with variable MDLs) than it is presented as less than MDL
[4]standard deviation

Table 4.5-10. The total number of fish captured (catch) and catch-per-unit-effort (CPUE; #fish/100 m/24hrs) by species across all experimental and small mesh gillnetting sites at Milne Inlet, September 2007 and August 2010.

| Year | | Catch | CPUE[1] | CPUE[2] | CPUE Range |
|---|---|---|---|---|---|
| **Standard Gillnet Gangs** | **Species** | | | | |
| **2007** | Arctic char | 134 | 17.15 | 65.73 | 0.00 - 287.32 |
| | Atlantic spiny lumpsucker | 1 | 0.13 | 0.49 | 0.00 - 8.73 |
| | Fourhorn sculpin | 2 | 0.26 | 0.98 | 0.00-5.25 |
| | Shorthorn sculpin | 5 | 0.64 | 2.45 | 0.00 - 16.32 |
| | **Total** | **142** | **18.18** | **69.65** | **0.00 – 296.44** |
| **2010** | Arctic char | 136 | 39.84 | - | 0.00 - 159.56 |
| | Fourhorn sculpin | 12 | 3.52 | - | 0.00 - 17.01 |
| | Shorthorn sculpin | 9 | 2.64 | - | 0.00 - 14.99 |
| | **Total** | **157** | **45.99** | **-** | **0.00 – 159.56** |
| **Small Mesh Gillnet Gangs** | | | | | |
| **2010** | Arctic char | 9 | 84.36 | - | 0.00 - 279.97 |

[1]includes all net sets
[2]includes all net sets EXCEPT sets 1, 18 and 19 from 2007

Table 4.5-11. Mean size and condition factor (K), by sex, of Arctic char captured during experimental gillnetting surveys of Steensby Inlet, 2007 and 2010.

| Year | Sex | Length (mm) | | | | Weight (g) | | | | K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | n [1] | Mean | SD [2] | Range | n | Mean | SD | Range | n | Mean | Range |
| **Standard Gillnet Gangs** | | | | | | | | | | | | |
| 2007 | Male | 35 | 478 | 120 | 266-801 | 35 | 1286 | 1089 | 200-5950 | 35 | 0.98 | 0.74-1.19 |
| | Female | 40 | 440 | 96 | 227-714 | 40 | 914 | 699 | 75-3875 | 40 | 0.92 | 0.60-1.56 |
| | All Fish | 129[3] | 455 | 129 | 160-840 | 128 | 1168 | 976 | 25-5950 | 128 | 0.98 | 0.60-1.56 |
| 2010 | Male | 1 | 622 | - | - | 0 | - | - | - | 0 | - | - |
| | Female | 17 | 513 | 133 | 300-706 | 17 | 1621 | 1035 | 375-3850 | 17 | 1.10 | 0.63-1.39 |
| | All Fish | 135[3] | 486 | 120 | 188-800 | 133 | 1355 | 873 | 50-4700 | 133 | 1.04 | 0.56-2.05 |
| **Small Mesh Gillnet Gangs** | | | | | | | | | | | | |
| 2010 | All Fish | 9 | 373 | 127.0 | 210-564 | 9 | 756 | 746.0 | 100-2050 | 9 | 1.08 | 0.73-1.30 |

[1]only includes fish for which size measurements were obtained; thus, may not equal total number of fish captured
[2]standard deviation
[3]includes fish that were not identified as either male or female

Table 4.5-12. Weight-length relationships for Arctic char captured during experimental gillnetting surveys at Steensby Inlet, 2007 and 2010.

| Year | n[1] | Weight-Length Equation | $r^2$ |
|---|---|---|---|
| 2007 | 128 | $Log_{10}Weight = -5.41 + 3.15 (Log_{10}Length)$ | 0.97 |
| 2010 | 133 | $Log_{10}Weight = -4.66 + 2.86 (Log_{10}Length)$ | 0.95 |

[1]only includes fish for which size measurements were obtained; thus, may not equal total number of fish captured
[2]R squared measures how successful the fit is in explaining the variation in the data (i.e. a value closer to 1.00 indicates a better fit).

Table 4.5-13. Age-specific mean size and condition factor (K) for Arctic char captured during experimental gillnetting surveys of Steensby Inlet, early September, 2007.

| Age (yrs) | Length (mm) | | | | Weight (g) | | | | K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | n [1] | Mean | SD [2] | Range | n | Mean | SD | Range | n | Mean | Range |
| 6 | 1 | 266 | - | - | 1 | 200 | - | - | 1 | 1.06 | - |
| 7 | 1 | 273 | - | - | 1 | 200 | - | - | 1 | 0.98 | - |
| 8 | 2 | 328 | 32.5 | 305-351 | 2 | 263 | 53.03 | 225-300 | 2 | 0.74 | 0.69-0.79 |
| 9 | 1 | 391 | - | - | 1 | 525 | - | - | 1 | 0.88 | - |
| 10 | 2 | 364 | 4.2 | 361-367 | 2 | 400 | 141.42 | 300-500 | 2 | 0.82 | 0.64-1.01 |
| 11 | 1 | 331 | - | - | 1 | 350 | - | - | 1 | 0.97 | - |
| 12 | 3 | 455 | 54.9 | 430-518 | 3 | 1083 | 493.29 | 750-1650 | 3 | 1.10 | 0.94-1.19 |
| 13 | 3 | 443 | 46.2 | 395-487 | 3 | 858 | 401.82 | 400-1150 | 3 | 0.93 | 0.65-1.14 |
| 14 | 1 | 347 | - | - | 1 | 650 | - | - | 1 | 1.56 | - |
| 15 | 2 | 500 | 33.2 | 476-523 | 2 | 1100 | 35.36 | 1075-1125 | 2 | 0.90 | 0.75-1.04 |
| 16 | 1 | 510 | - | - | 1 | 1200 | - | - | 1 | 0.90 | - |
| 17 | 4 | 571 | 73.8 | 526-681 | 4 | 1894 | 738.35 | 1500-3000 | 4 | 0.99 | 0.93-1.05 |
| 18 | 3 | 584 | 85.6 | 493-663 | 3 | 1783 | 490.11 | 1325-2300 | 3 | 0.90 | 0.79-1.11 |
| 19 | 1 | 557 | - | - | 1 | 1650 | - | - | 1 | 0.95 | - |
| 22 | 2 | 758 | 61.5 | 714-801 | 2 | 4913 | 1467.25 | 3875-5950 | 2 | 1.11 | 1.06-1.16 |
| 24 | 1 | 840 | - | - | 1 | 5850 | - | - | 1 | 0.99 | - |

[1] only includes fish from which ageing structures were collected in 2007; thus, may not equal total number of fish captured
[2] standard deviation

Table 4.5-14. Age-specific mean size and condition factor (K) for Arctic char captured during experimental gillnetting surveys of Steensby Inlet, early August, 2010.

| Age (yrs) | Length (mm) | | | | Weight (g) | | | | K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | n [1] | Mean | SD [2] | Range | n | Mean | SD | Range | n | Mean | Range |
| 7 | 4 | 214 | 11.9 | 203-230 | 4 | 125 | 86.6 | 50-250 | 4 | 1.21 | 0.56-2.05 |
| 8 | 1 | 360 | - | - | 1 | 450 | - | - | 1 | 0.96 | - |
| 9 | 2 | 328 | 38.9 | 300-355 | 2 | 425 | 70.7 | 375-475 | 2 | 1.23 | 1.06-1.39 |
| 10 | 1 | 388 | - | - | 1 | 750 | - | - | 1 | 1.28 | - |
| 11 | 2 | 377 | 9.9 | 370-384 | 2 | 638 | 17.7 | 625-650 | 2 | 1.19 | 1.15-1.23 |
| 13 | 1 | 376 | - | - | 1 | 700 | - | - | 1 | 1.32 | - |
| 14 | 2 | 470 | 70.0 | 420-519 | 2 | 1225 | 459.6 | 900-1550 | 2 | 1.16 | 1.11-1.21 |
| 15 | 1 | 415 | - | - | 1 | 800 | - | - | 1 | 1.12 | - |
| 16 | 2 | 487 | 29.0 | 466-507 | 2 | 1350 | 0.0 | 1350-1350 | 2 | 1.18 | 1.04-1.33 |
| 17 | 5 | 534 | 64.4 | 465-630 | 4 | 1750 | 595.8 | 1100-2450 | 4 | 1.10 | 0.98-1.21 |
| 18 | 2 | 631 | 74.2 | 578-683 | 2 | 3000 | 1202.1 | 2150-3850 | 2 | 1.16 | 1.11-1.21 |
| 19 | 2 | 559 | 96.9 | 490-627 | 2 | 1875 | 742.5 | 1350-2400 | 2 | 1.06 | 0.97-1.15 |
| 20 | 2 | 656 | 48.1 | 622-690 | 1 | 3000 | - | - | 1 | 0.91 | - |
| 24 | 2 | 642 | 90.5 | 578-706 | 2 | 1850 | 495.0 | 1500-2200 | 2 | 0.70 | 0.63-0.78 |
| 26 | 1 | 703 | - | - | 1 | 3300 | - | - | 1 | 0.95 | - |

[1]only includes fish from which ageing structures were collected in 2010; thus, may not equal total number of fish captured
[2]standard deviation

Table 4.5-15. Mean size and condition factor (K) of fish species other than char captured during experimental gillnetting surveys of Steensby Inlet, 2007 and 2010.

| Year | Species | Length (mm) | | | | Weight (g) | | | | K | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | n [1] | Mean | SD [2] | Range | n | Mean | SD | Range | n | Mean | Range |
| 2007 | Fourhorn Sculpin | 2 | 245 | 4 | 242-248 | 2 | 325 | 35 | 300-350 | 2 | 2.21 | 2.12-2.29 |
| | Shorthorn Sculpin | 5 | 326 | 48 | 278-382 | 5 | 560 | 253 | 300-850 | 5 | 1.53 | 1.40-1.61 |
| 2010 | Fourhorn Sculpin | 12 | 222 | 74 | 132-365 | 12 | 242 | 234 | 50-800 | 12 | 1.79 | 0.79-2.96 |
| | Shorthorn Sculpin | 9 | 239 | 69 | 165-335 | 9 | 219 | 197 | 50-600 | 9 | 1.52 | 0.53-3.34 |

[1]only includes fish for which size measurements were obtained; thus, may not equal total number of fish captured
[2]standard deviation

Table 4.5-16. The frequency of occurrence of dietary items in preserved stomachs from Arctic char captured at Steensby Inlet, 2007 and 2010.

| | 2007 | | 2010 | |
|---|---|---|---|---|
| **# of stomachs examined in lab:** | 10 | | 11 | |
| **# of stomachs with contents:** | 10 | | 11 | |
| **# of empty stomachs:** | 0 | | 0 | |
| **Taxon** | **# of Occurrences** | **Frequency of Occurrence (%)** | **# of Occurrences** | **Frequency of Occurrence (%)** |
| **Polychaeta** | | | 6 | 54.55 |
| **Arthropoda** | | | | |
| Crustacea | | | | |
| Amphipoda | | | | |
| *Anonyx nugax* | | | 1 | 9.09 |
| *Anonyx* sp. | | | 1 | 9.09 |
| *Apherusa glacialis* | | | 4 | 36.36 |
| *Hyperia glaba* | | | 1 | 9.09 |
| *Onisimus litoralis* | 8 | 80.00 | 2 | 18.18 |
| *Onisimus nanseni* | | | 1 | 9.09 |
| Onisimus sp. | | | 1 | 9.09 |
| *Gammarus wilkitzkii* | | | 3 | 27.27 |
| Gammaridae sp. | | | 1 | 9.09 |
| unid Amphipoda sp. | | | 2 | 18.18 |
| Mysidacea | | | | |
| *Mysis litoralis* | | | 1 | 9.09 |
| Decapoda | | | | |
| Paguridea sp. | | | 2 | 18.18 |
| **Chordata** | | | | |
| Osteichthyes (fish) | | | | |
| *Boreogadus saida* | 4 | 40.00 | 10 | 90.91 |
| Cottidae (Larvae) | 1 | 10.00 | 5 | 45.45 |
| *Eumicrotremus spinosus* | | | 1 | 9.09 |
| *Triglops pingelii* | 2 | 20.00 | 2 | 18.18 |
| Liparidae sp. | | | 1 | 9.09 |
| Fish eggs | 1 | 10.00 | | |

Table 4.5-17. Mean size, age, and muscle total mercury concentration (Hg) of Arctic char captured at Steensby Inlet during 2007 and 2010.

| Parameter | n | Mean | SD[1] | Range |
|---|---|---|---|---|
| **2007** | | | | |
| Length (mm) | 29 | 488 | 148.5 | 266 – 840 |
| Weight (g) | 29 | 1473 | 1490.5 | 200 – 5950 |
| Age (years) | 29 | 14 | 4.7 | 6 – 24 |
| Hg (mg/Wkg) | 29 | 0.0475 | 0.02495 | 0.0220 - 0.1190 |
| Standardized Hg (µg/g [ww])[2] | 29 | 0.0307 | - | - |
| **2010** | | | | |
| Length (mm) | 30 | 469 | 152.2 | 203 – 706 |
| Weight (g) | 28 | 1329 | 1015.6 | 50 – 3850 |
| Age (years) | 30 | 14 | 5.4 | 7 - 26 |
| Hg (mg/Wkg) | 30 | 0.0427 | 0.03031 | 0.0126 – 0.1350 |
| Standardized Hg (µg/g [ww])[2] | 30 | 0.0268 | - | - |

1 - standard deviation

2 - “standardized" to a fork length of 350 mm, "standardized" value generated from the following regression equation:

2007 = $Log_{10}(Hg) = -4.45 + 1.16 (Log10 (350))$; $r^2 = 0.62$

2010 = $Log_{10}(Hg) = -4.52 + 1.16 (Log_{10} (350))$; $r^2 = 0.48$

Table 4.5-18. Mean concentrations (µg/g [ww]) of trace elements in muscle tissue and liver of Arctic char captured at Steensby Inlet in September 2007 and August 2010.

| | | % Moisture | Element Concentration (µg/g [ww] for all elements) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Al | Sb | As | Ba | Be | Bi | Cd | Ca | Cr | Co | Cu |
| **Year** | **MDL[1]** | **0.1** | **2.0** | **0.010** | **0.010** | **0.010-0.030** | **0.10** | **0.030** | **0.0050** | **2.0** | **0.10** | **0.020** | **0.010** |
| Muscle | | | | | | | | | | | | | |
| 2007 | n[2] | 29 | 21 | 3 | 29 | 28 | 0 | 0 | 8 | 29 | 23 | 1 | 29 |
| | Mean[3] | 75.4 | 5.1 | < 0.010 | 0.837 | 0.035 | < 0.10 | < 0.030 | < 0.0050 | 114.0 | 0.20 | < 0.020 | 0.675 |
| | SD[4] | 2.60 | 7.04 | 0.0052 | 0.5440 | 0.0184 | - | - | 0.00290 | 67.52 | 0.157 | 0.0033 | 0.1355 |
| | Minimum | 71.2 | < 2.0 | < 0.010 | 0.317 | < 0.010 | < 0.10 | < 0.030 | < 0.0050 | 46.8 | < 0.10 | < 0.020 | 0.399 |
| | Maximum | 82.3 | 32.6 | 0.029 | 3.00 | 0.075 | < 0.10 | < 0.030 | 0.0156 | 390.0 | 0.61 | 0.028 | 0.925 |
| 2010 | n[2] | 30 | 3 | 0 | 30 | 27 | 0 | 0 | 5 | 30 | 17 | 7 | 30 |
| | Mean[3] | 75.4 | <2.0 | <0.010 | 1.415 | 0.024 | <0.10 | <0.030 | 0.0065 | 138.3 | 0.84 | <0.020 | 0.634 |
| | SD[4] | 1.42 | - | - | 1.4769 | 0.0144 | - | - | 0.01903 | 31.17 | 1.481 | 0.0097 | 0.1917 |
| | Minimum | 71.7 | <2.0 | <0.010 | 0.247 | <0.010 | <0.10 | <0.030 | <0.0050 | 90.6 | <0.10 | <0.020 | 0.336 |
| | Maximum | 78.3 | 3.6 | <0.010 | 6.57 | 0.065 | <0.10 | <0.030 | 0.1070 | 218.0 | 5.83 | 0.050 | 1.280 |
| Liver | | | | | | | | | | | | | |
| 2007 | n[2] | 29 | 21 | 0 | 29 | 24 | 0 | 0 | 29 | 29 | 25 | 29 | 29 |
| | Mean[3] | 72.6 | 4.2 | < 0.010 | 1.058 | 0.026 | < 0.10 | < 0.030 | 0.3548 | 84.1 | 0.15 | 0.091 | 31.11 |
| | SD[4] | 4.60 | 7.96 | - | 0.5351 | 0.0361 | - | - | 0.32897 | 27.74 | 0.060 | 0.0500 | 23.901 |
| | Minimum | 62.3 | < 2.0 | < 0.010 | 0.517 | < 0.010 | < 0.10 | < 0.030 | 0.0441 | 50.3 | < 0.10 | 0.038 | 9.05 |
| | Maximum | 80.4 | 44.3 | < 0.010 | 3.260 | 0.207 | < 0.10 | < 0.030 | 1.5400 | 153.0 | 0.29 | 0.245 | 96.80 |
| 2010 | n[2] | 18 | 4 | 0 | 18 | 13 | 0 | 0 | 18 | 18 | 17 | 18 | 18 |
| | Mean[3] | 72.7 | <2.0 | < 0.010 | 1.449 | 0.016 | < 0.10 | < 0.030 | 0.2336 | 50.9 | 0.70 | 0.075 | 16.19 |
| | SD[4] | 3.52 | - | - | 0.8692 | 0.0088 | - | - | 0.27328 | 16.37 | 0.723 | 0.0356 | 9.316 |
| | Minimum | 62.0 | <2.0 | < 0.010 | 0.519 | <0.010 | < 0.10 | < 0.030 | 0.0453 | 36.7 | <0.10 | 0.034 | 2.70 |
| | Maximum | 76.9 | 4.6 | < 0.010 | 3.710 | 0.030 | < 0.10 | < 0.030 | 1.0700 | 106.0 | 3.04 | 0.144 | 36.50 |

Table 4.5-18. Continued.

| | | Element Concentration (µg/g [ww] for all elements) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Fe | Pb | Li | Mg | Mn | Hg | Mo | Ni | P | K | Se |
| **Year** | **MDL[1]** | **0.20-2.0** | **0.020** | **0.10** | **1** | **0.010** | **0.0010** | **0.010** | **0.10** | **5.0-50.0** | **20.0-200** | **0.20** |
| Muscle | | | | | | | | | | | | |
| 2007 | n[2] | 29 | 1 | 1 | 29 | 29 | 29 | 9 | 8 | 29 | 29 | 29 |
| | Mean[3] | 10.76 | < 0.020 | < 0.10 | 354 | 0.161 | 0.0476 | 0.011 | < 0.10 | 2565 | 3971 | 0.39 |
| | SD[4] | 11.296 | 0.0093 | - | 46.4 | 0.1760 | 0.02495 | 0.0087 | 0.074 | 175.6 | 502.4 | 0.056 |
| | Minimum | 3.89 | < 0.020 | < 0.10 | 280 | 0.067 | 0.0220 | < 0.010 | < 0.10 | 2300 | 3380 | 0.30 |
| | Maximum | 62.30 | 0.060 | 0.14 | 502 | 1.03 | 0.119 | 0.030 | 0.30 | 2920 | 5070 | 0.52 |
| 2010 | n[2] | 30 | 0 | 0 | 30 | 30 | 30 | 15 | 17 | 30 | 30 | 30 |
| | Mean[3] | 11.40 | <0.020 | <0.10 | 282 | 0.181 | 0.0427 | 0.036 | 0.52 | 2756 | 4418 | 0.39 |
| | SD[4] | 7.268 | - | - | 33.5 | 0.1594 | 0.03031 | 0.0652 | 0.843 | 254.8 | 452.1 | 0.074 |
| | Minimum | 3.40 | <0.020 | <0.10 | 204 | 0.063 | 0.0126 | <0.010 | <0.10 | 2340 | 3410 | 0.27 |
| | Maximum | 33.30 | <0.020 | <0.10 | 342 | 0.717 | 0.135 | 0.312 | 3.65 | 3390 | 5440 | 0.60 |
| Liver | | | | | | | | | | | | |
| 2007 | n[2] | 29 | 1 | 0 | 29 | 29 | 29 | 29 | 3 | 29 | 29 | 29 |
| | Mean[3] | 287 | < 0.020 | < 0.10 | 268 | 1.40 | 0.0754 | 0.194 | < 0.10 | 3525 | 2823 | 2.38 |
| | SD[4] | 149.7 | 0.0032 | - | 39.7 | 0.2587 | 0.02887 | 0.0350 | 0.053 | 349.9 | 387.4 | 1.080 |
| | Minimum | 86 | < 0.020 | < 0.10 | 223 | 0.985 | 0.0444 | 0.136 | < 0.10 | 2910 | 2140 | 1.27 |
| | Maximum | 678 | 0.027 | < 0.10 | 369 | 2.08 | 0.167 | 0.279 | 0.32 | 4120 | 3920 | 5.90 |
| 2010 | n[2] | 18 | 0 | 0 | 18 | 18 | 18 | 18 | 14 | 18 | 18 | 18 |
| | Mean[3] | 312 | <0.020 | <0.10 | 193 | 1.26 | 0.0452 | 0.182 | 0.36 | 3576 | 3338 | 2.55 |
| | SD[4] | 209.0 | - | - | 45.1 | 0.3703 | 0.02744 | 0.0358 | 0.380 | 621.5 | 612.9 | 0.638 |
| | Minimum | 114 | <0.020 | <0.10 | 141 | 0.796 | 0.0184 | 0.133 | <0.10 | 2730 | 2340 | 1.24 |
| | Maximum | 881 | <0.020 | <0.10 | 294 | 2.20 | 0.120 | 0.257 | 1.56 | 5480 | 5360 | 3.89 |

Table 4.5-18. Continued.

| | | Element Concentration (µg/g [ww] for all elements) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Na | Sr | Tl | Sn | Ti | U | V | Zn |
| Year | MDL[1] | 20.0-200 | 0.010 | 0.010 | 0.050 | 0.10-1.0 | 0.0020 | 0.10 | 0.10 |
| Muscle | | | | | | | | | |
| 2007 | n[2] | 29 | 29 | 0 | 0 | 10 | 3 | 0 | 29 |
| | Mean[3] | 762 | 0.593 | < 0.010 | < 0.050 | 0.28 | < 0.0020 | < 0.10 | 5.33 |
| | SD[4] | 294.3 | 0.2950 | - | - | 0.616 | 0.00142 | - | 0.763 |
| | Minimum | 504 | 0.171 | < 0.010 | < 0.050 | < 0.10 | < 0.0020 | < 0.10 | 4.46 |
| | Maximum | 2050 | 1.50 | < 0.010 | < 0.050 | 3.28 | 0.0070 | < 0.10 | 8.15 |
| 2010 | n[2] | 30 | 30 | 0 | 5 | 0 | 0 | 0 | 30 |
| | Mean[3] | 723 | 0.603 | <0.010 | <0.050 | <1.0 | <0.0020 | <0.10 | 7.00 |
| | SD[4] | 153.3 | 0.1519 | - | 0.0241 | - | - | - | 0.978 |
| | Minimum | 470 | 0.371 | <0.010 | <0.050 | <1.0 | <0.0020 | <0.10 | 5.25 |
| | Maximum | 1050 | 1.02 | <0.010 | 0.122 | <1.0 | <0.0020 | <0.10 | 8.89 |
| Liver | | | | | | | | | |
| 2007 | n[2] | 29 | 29 | 12 | 0 | 1 | 10 | 7 | 29 |
| | Mean[3] | 1837 | 0.900 | 0.011 | < 0.050 | < 0.50 | 0.0020 | < 0.10 | 35.8 |
| | SD[4] | 255.1 | 0.3927 | 0.0126 | - | 0.200 | 0.00217 | 0.062 | 4.91 |
| | Minimum | 1450 | 0.277 | < 0.010 | < 0.050 | < 0.10 | < 0.0020 | < 0.10 | 26.9 |
| | Maximum | 2410 | 2.06 | 0.070 | < 0.050 | 1.10 | 0.0118 | 0.27 | 48.2 |
| 2010 | n[2] | 18 | 18 | 15 | 0 | 1 | 7 | 3 | 18 |
| | Mean[3] | 1609 | 0.271 | 0.016 | < 0.050 | <1.0 | 0.0024 | 0.11 | 29.9 |
| | SD[4] | 254.6 | 0.1073 | 0.0122 | - | 0.12 | 0.00274 | 0.226 | 5.82 |
| | Minimum | 1020 | 0.152 | <0.010 | < 0.050 | <1.0 | <0.0020 | <0.10 | 22.6 |
| | Maximum | 2020 | 0.630 | 0.060 | < 0.050 | 1.0 | 0.0121 | 1.01 | 41.9 |

[1]MDL = minimum detection limit for trace element concentrations in the tissue; for some elements (e.g. iron [Fe]) MDL was increased due to interference encountered during analysis of some samples and, therefore, MDL ranges are presented; see NSC 2010b for details.
[2]n = the number of samples above the MDL for each trace element
[3]elements below MDLs are assumed to be half the limit for calculation of mean values; if resulting mean is below the MDL for each element (or the larger MDL for those with variable MDLs) than it is presented as less than MDL
[4]standard deviation

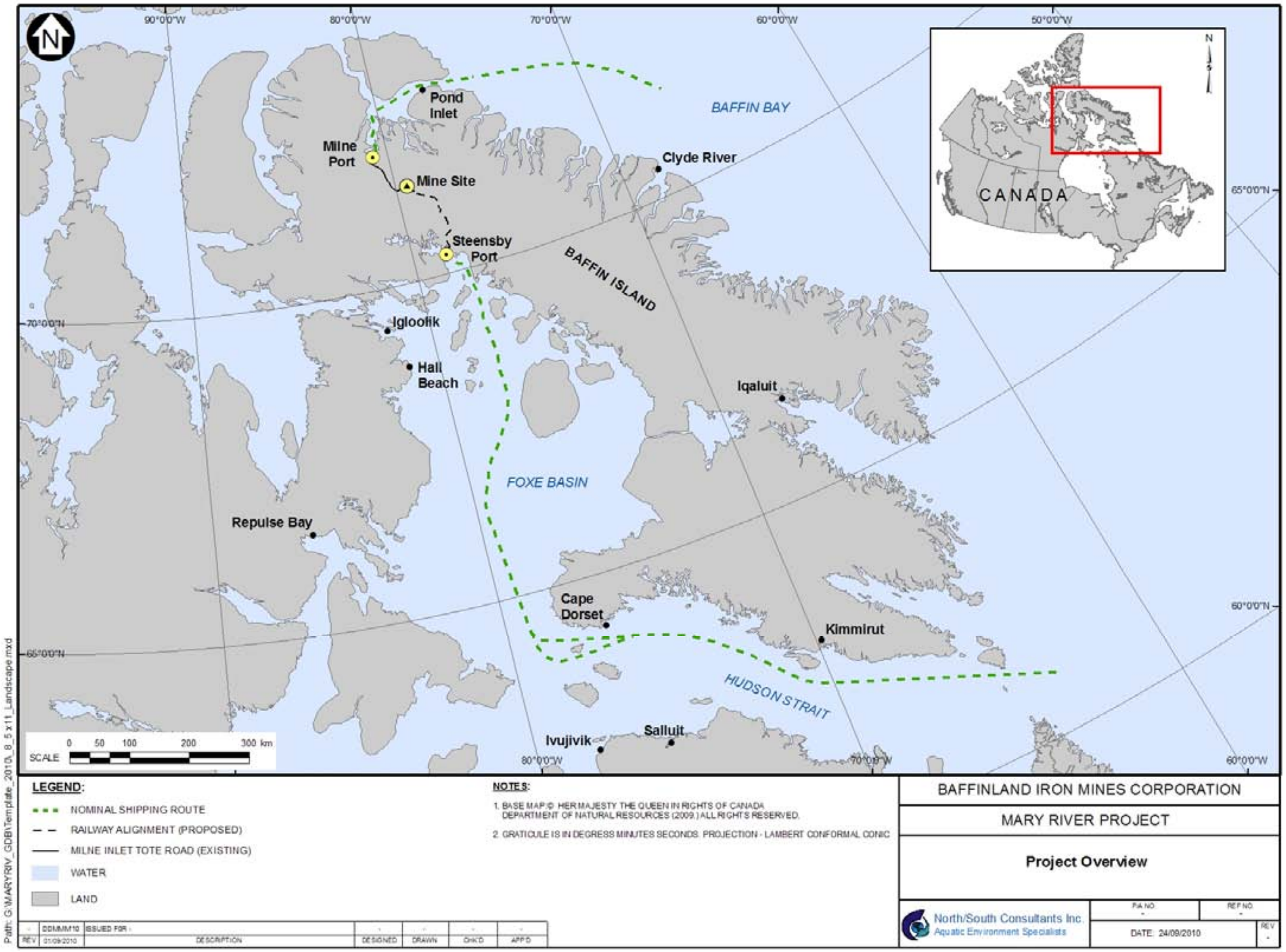


Figure 1.1-1. Location of the Mary River mine site, proposed port sites at Steensby and Milne inlets, and nominal shipping routes.

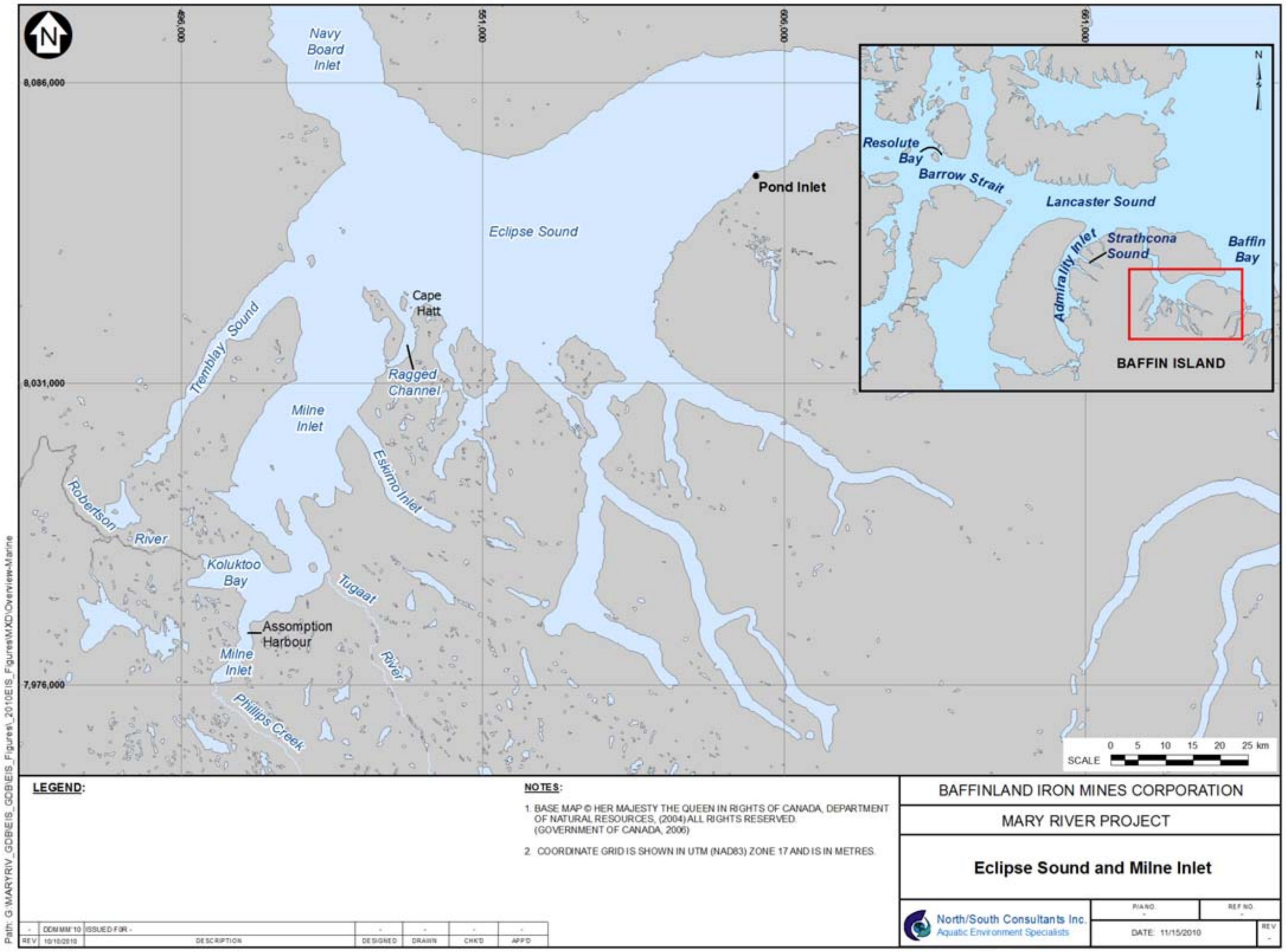


Figure 1.1-2. Place names in Eclipse Sound and Milne Inlet.

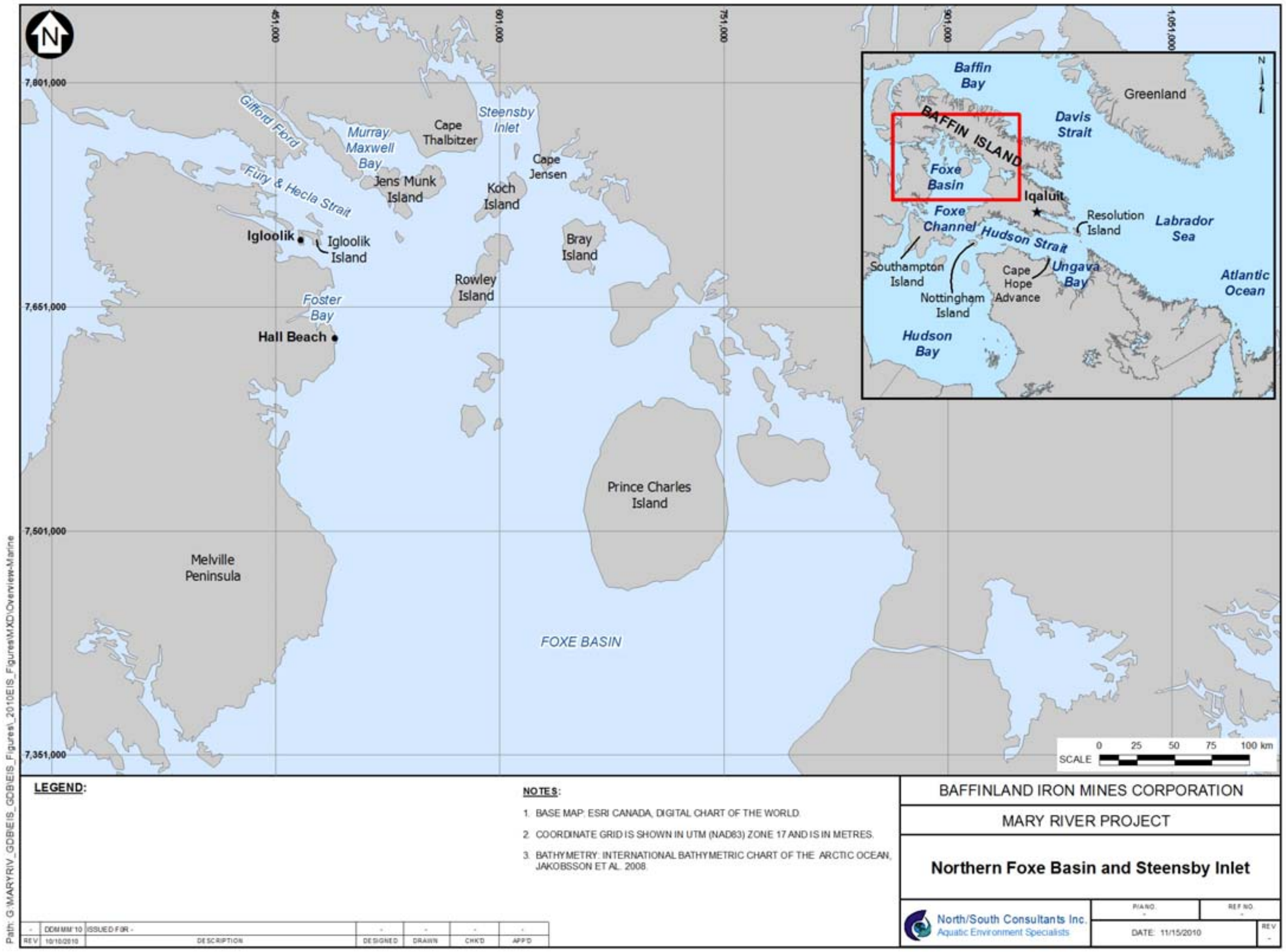


Figure 1.1-3. Place names in northern Foxe Basin and Steensby Inlet.

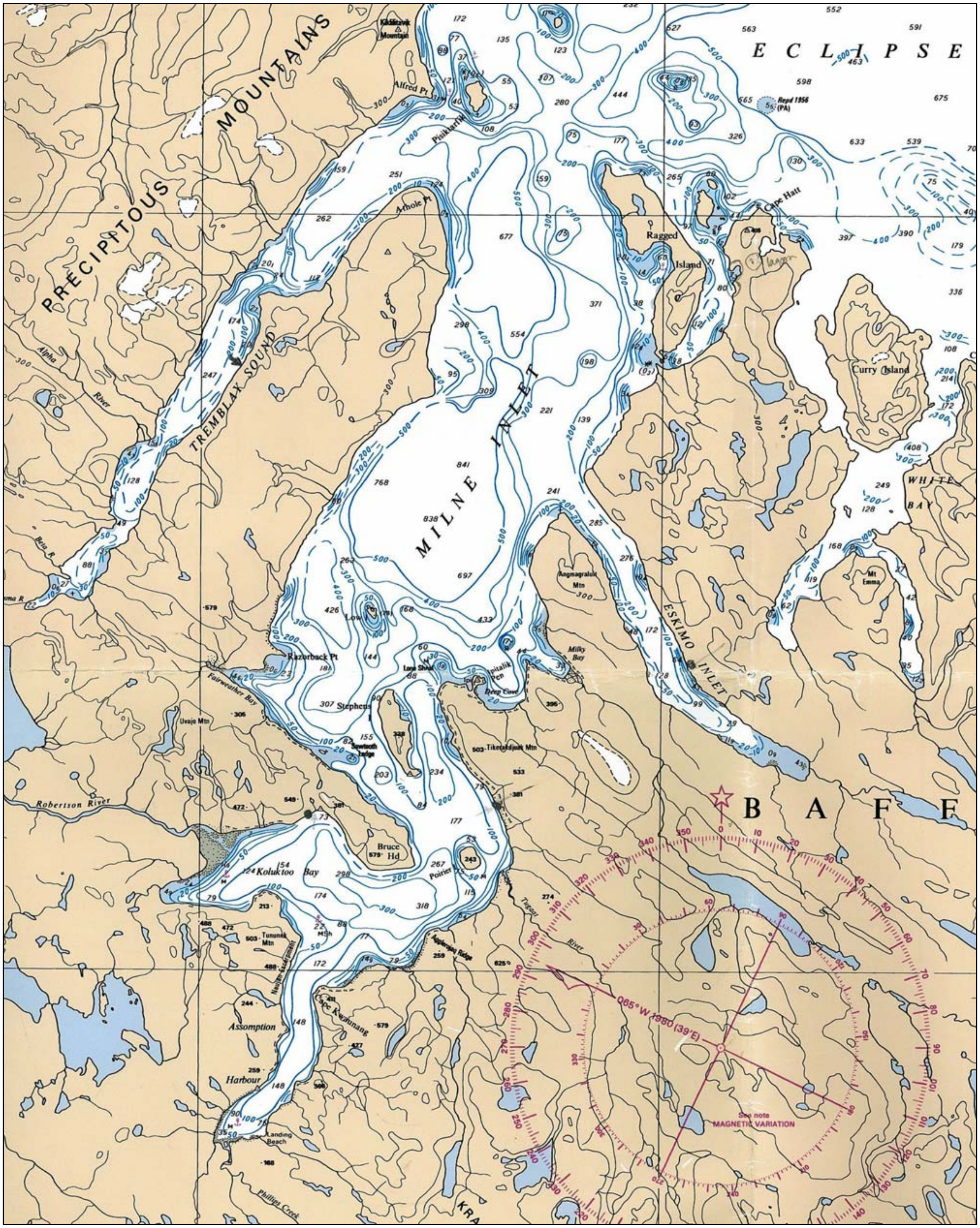

Figure 2.1-1. Scan of Canadian Hydrographic Service chart 7212 showing the general configuration and bathymetry of Milne Inlet.

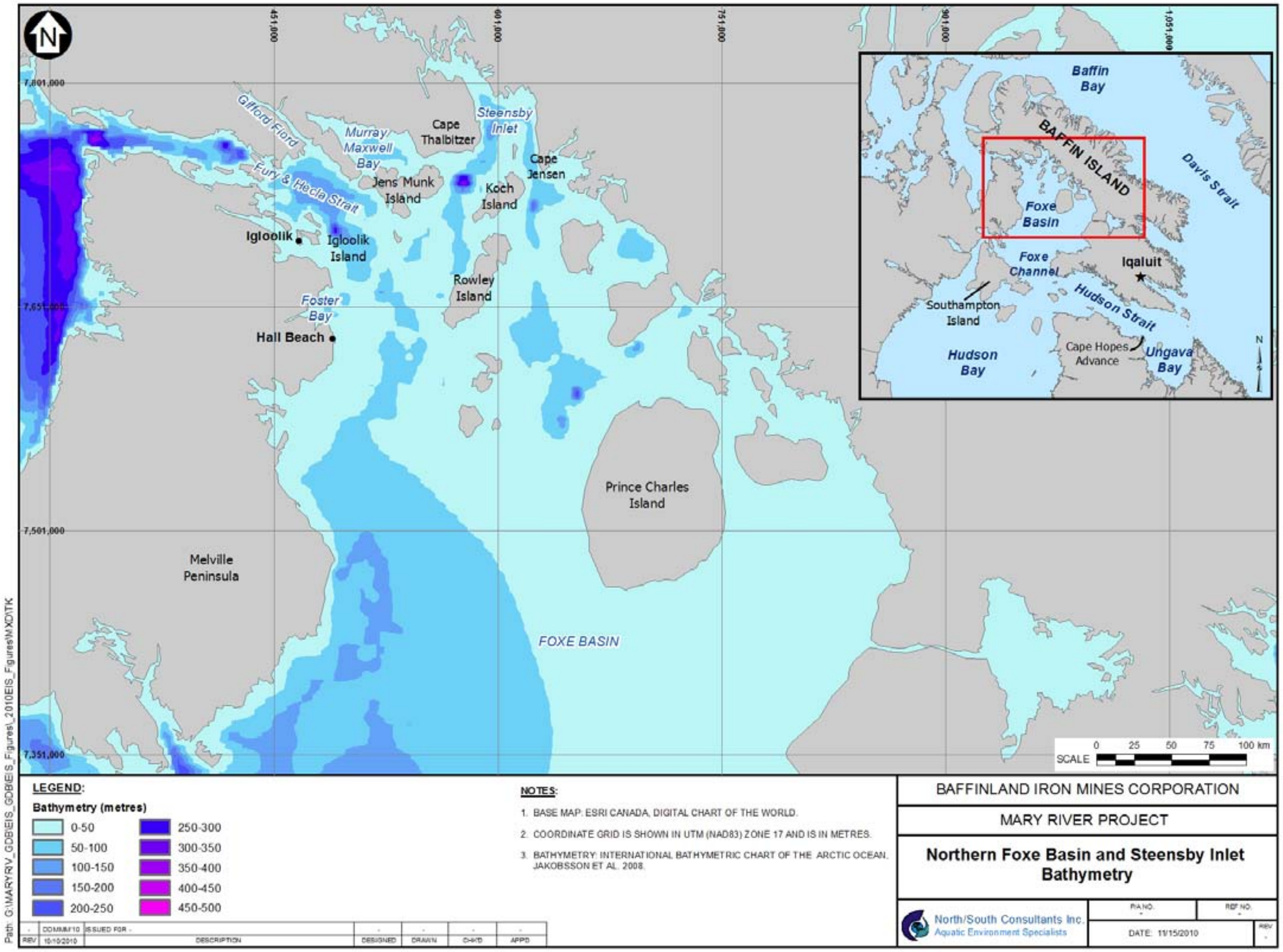


Figure 2.1-2. Bathymetry of northern Foxe Basin and Steensby Inlet (from Jakobsson et al. 2008).

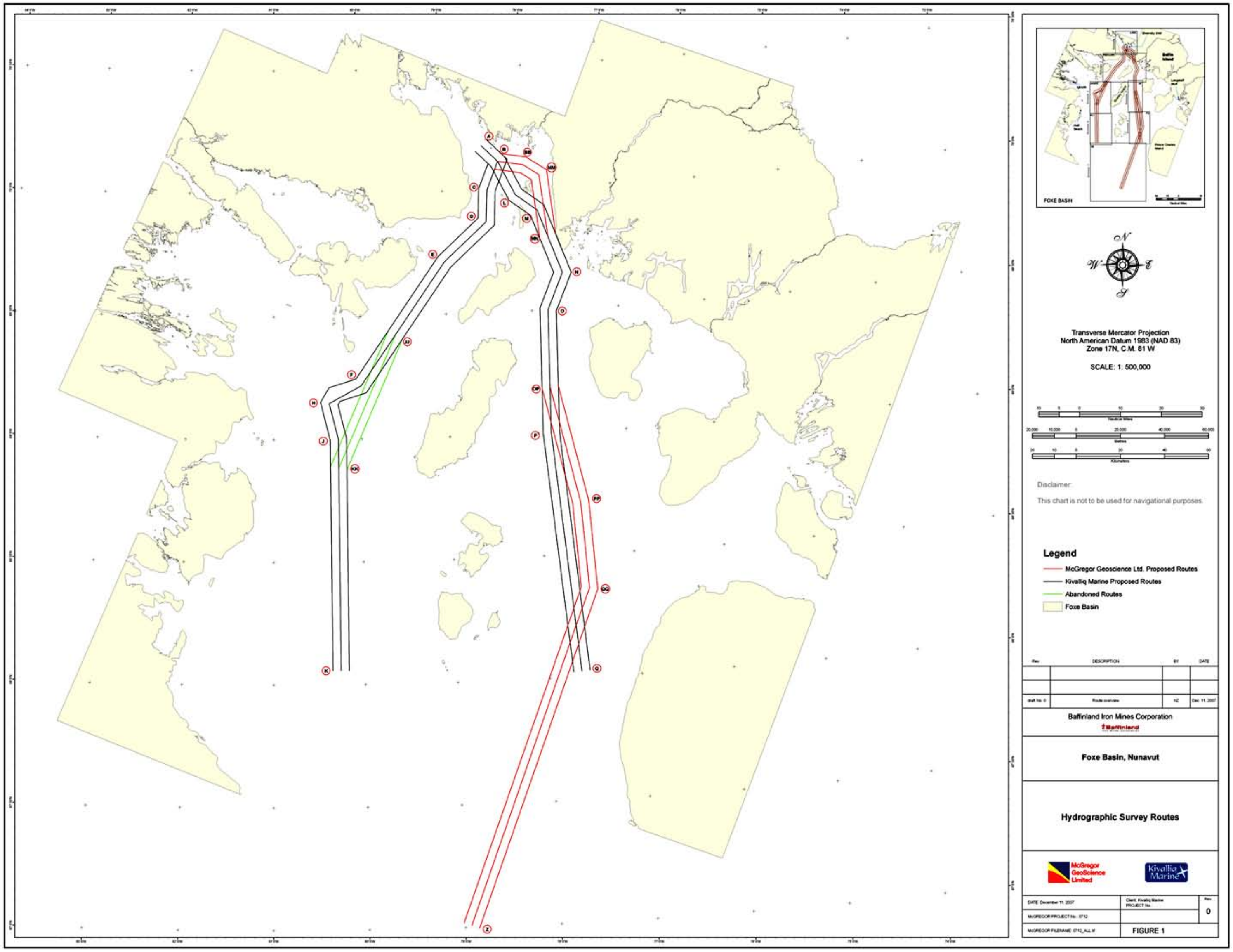


Figure 2.1-3. Offshore bathymetric coverage in northern Foxe Basin and Steensby Inlet, 2007 (condicted by Kivalliq Marine).

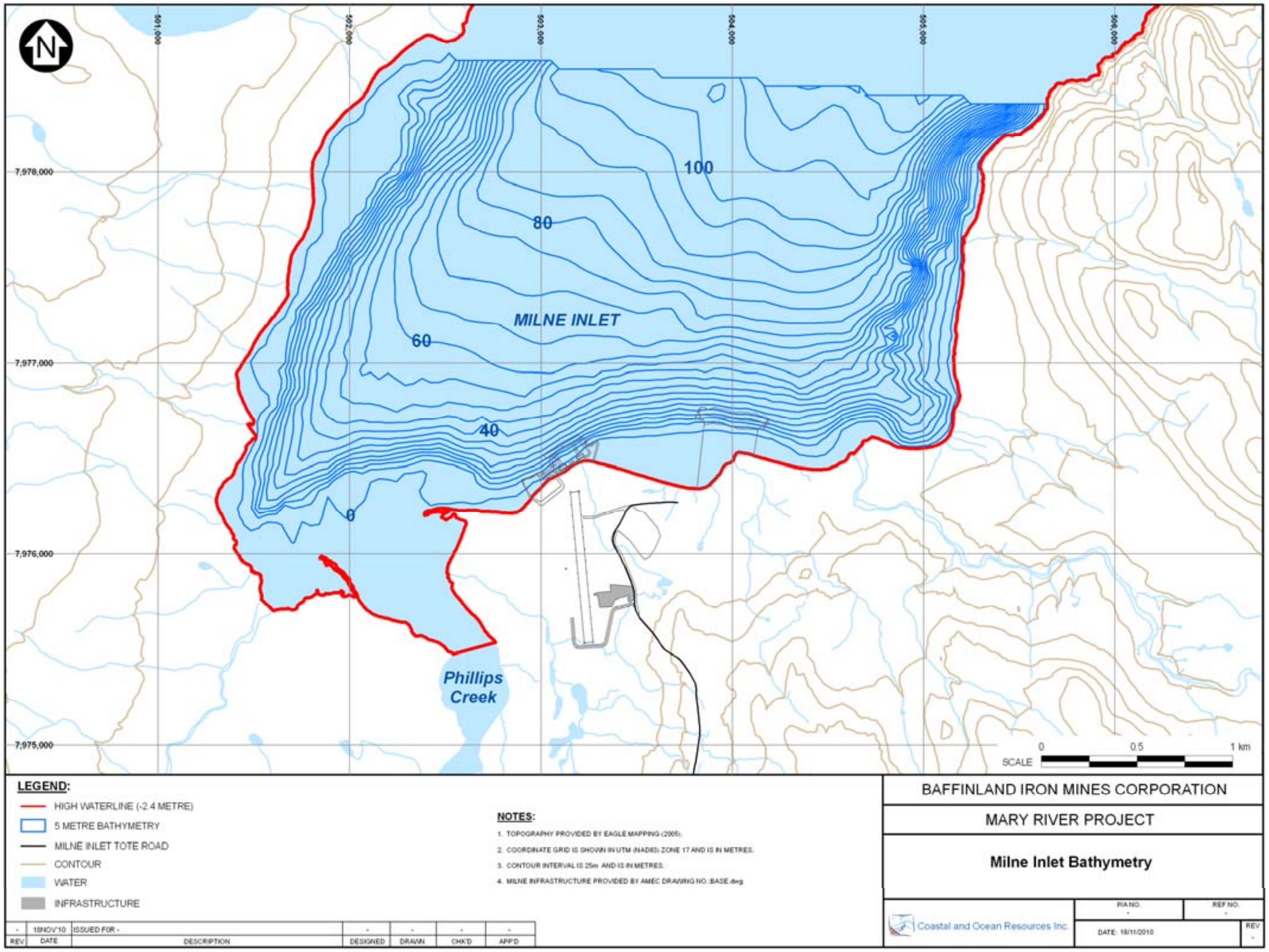


Figure 2.1-4. Bathymetry near the proposed Milne Inlet port site.

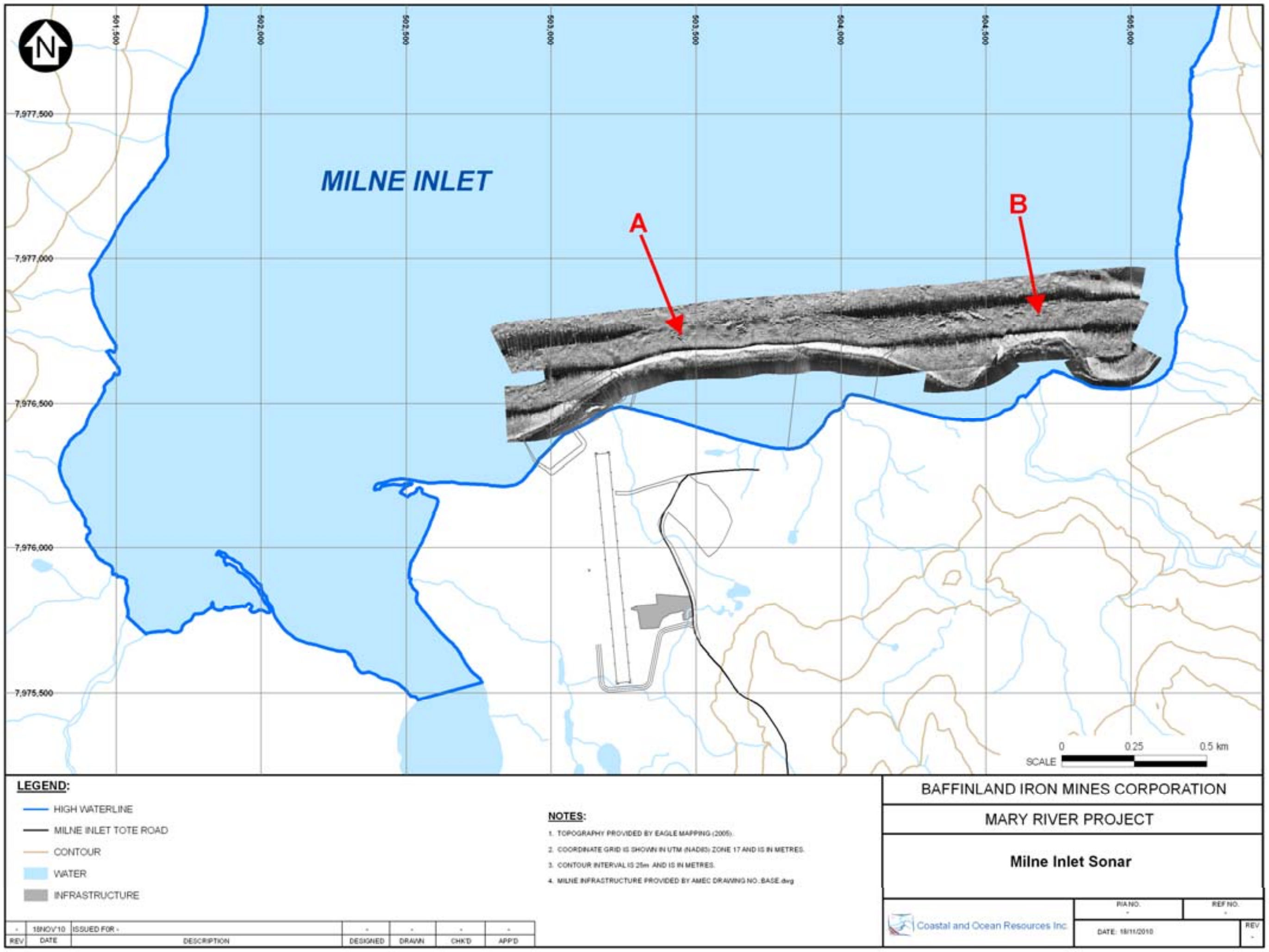


Figure 2.1-5. Sonogram mosaic of side-scan sonar imagery collected in 2008.

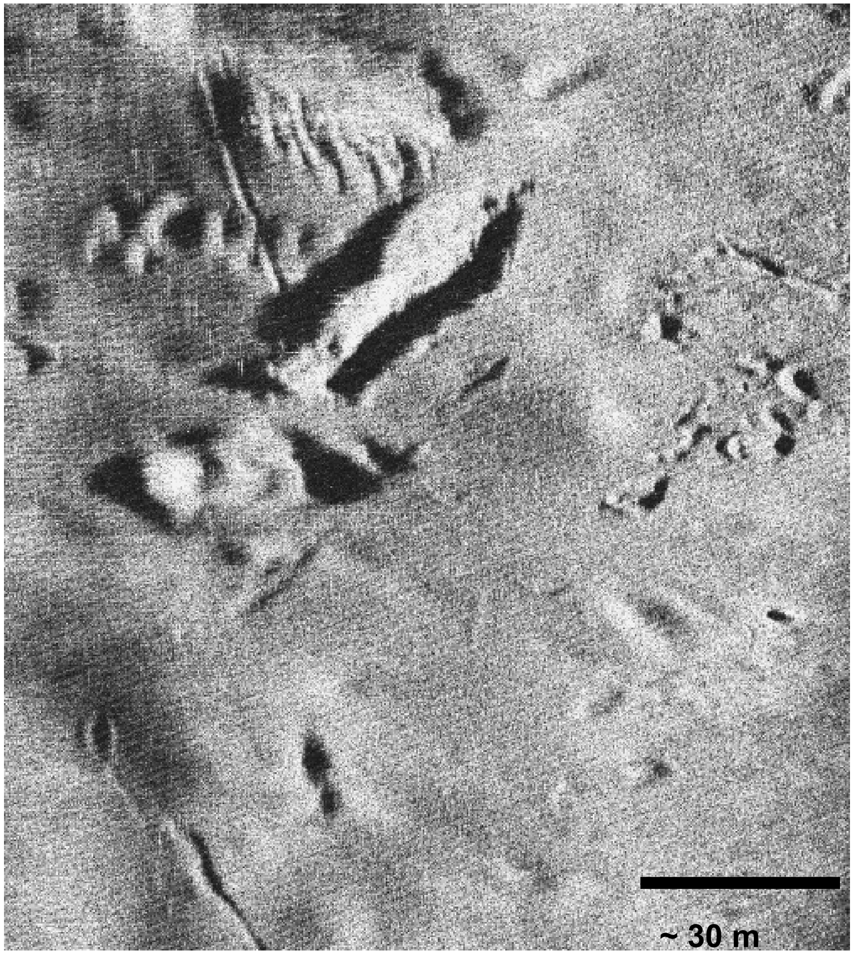


Figure 2.1-6. Expanded view of sonogram from Location A in Milne Inlet (light source from right; see Figure 2.1-5 for location), showing a deep plow mark in 22 m water depth as well as some more subtle ice gouge features. The plow mark in centre frame is likely > 2m in depth.


Figure 2.1-7. Expanded view of sonogram from Lcation B in Milne Inlet (see Figure 2.1-5; with light source from right) showing bottom ice impact features (top of image; water depth about 25 m) and a subtle hummocky disturbance pattern that probably indicates older ice gouges covered with a sediment drape.

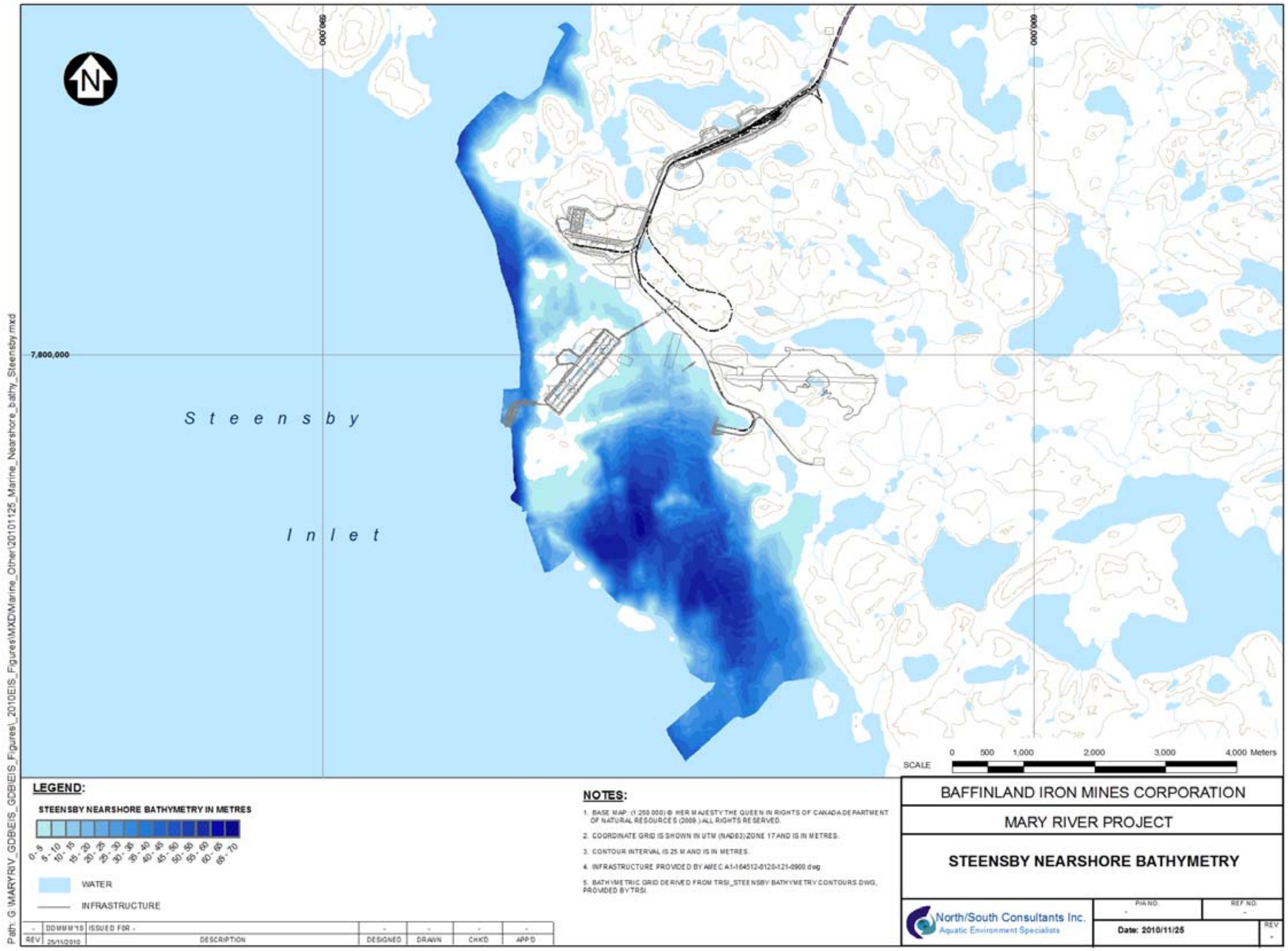


Figure 2.1-8. Results of 2007 and 2008 bathymetric surveys near the proposed port in Steensby Inlet.

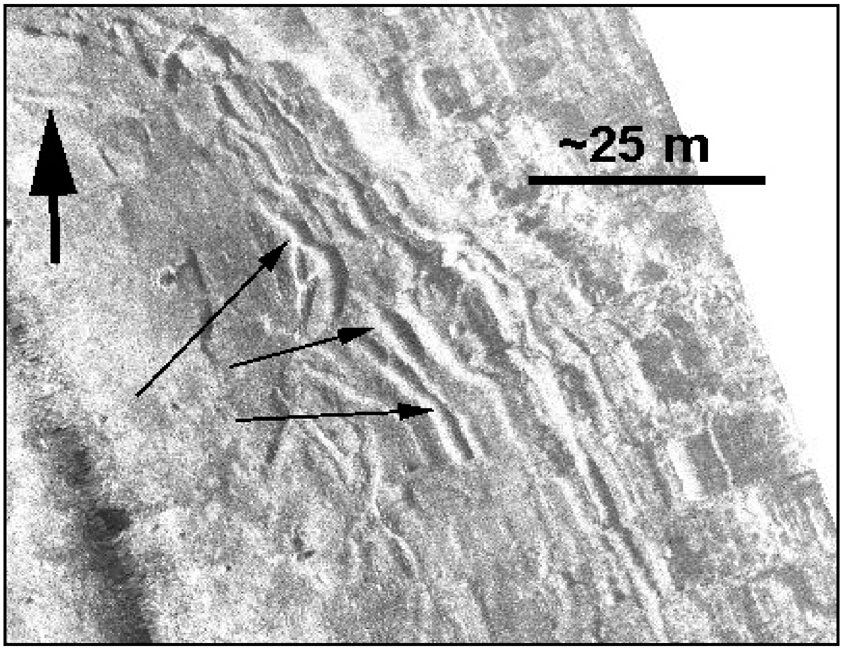


Figure 2.1-9. Ice gouges (arrows) in nearshore area near the proposed port in Steensby Inlet.

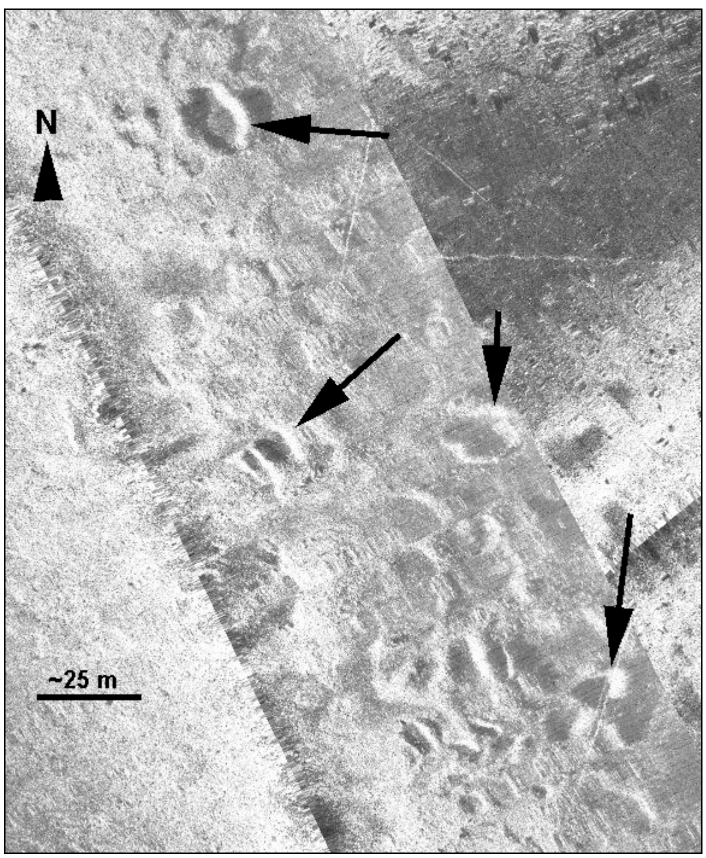


Figure 2.1-10. Ice gouges (arrows) in nearshore area near the proposed port in Steensby Inlet.

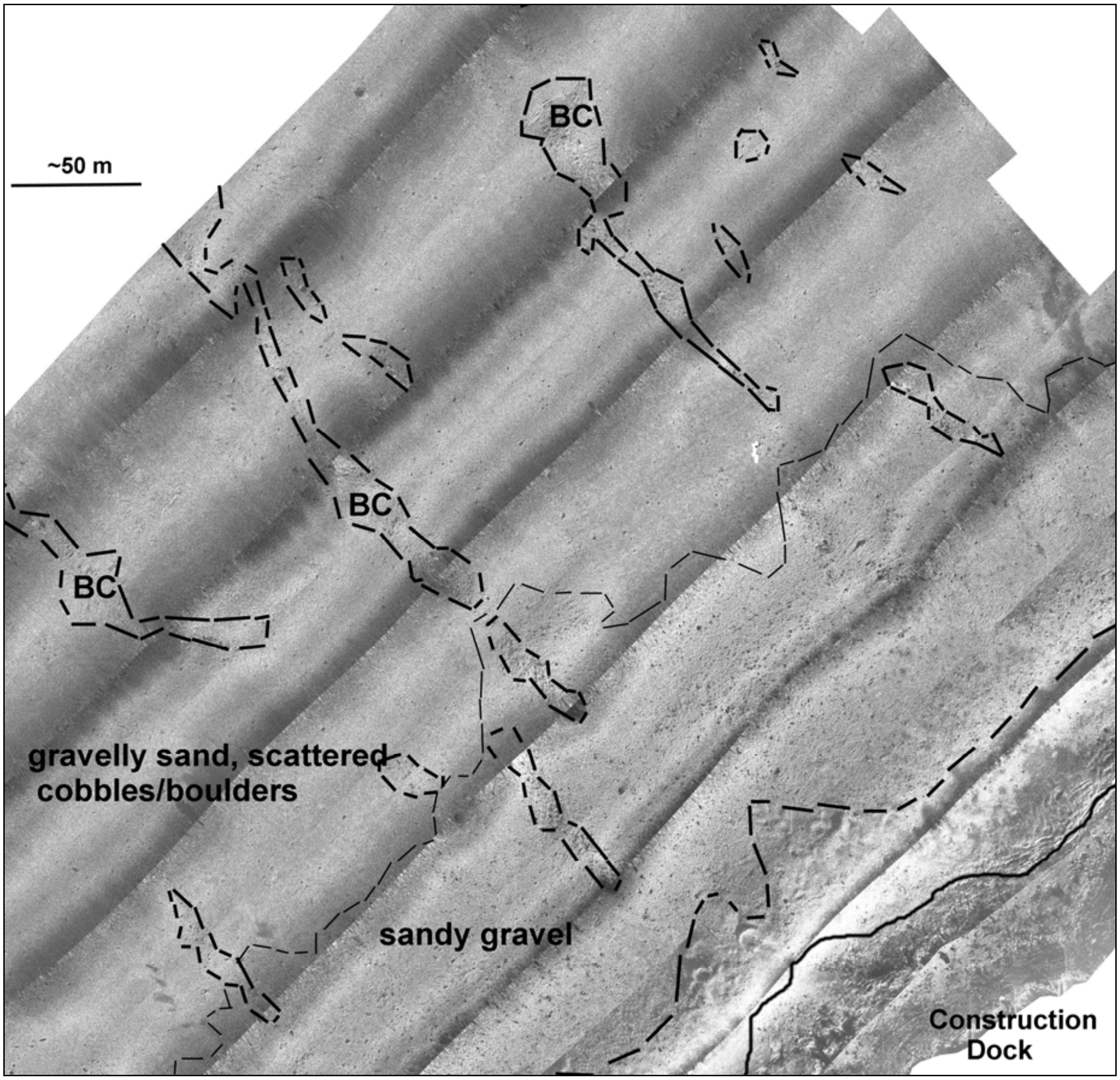


Figure 2.1-11. Boulder/cobble shore-normal ridges (De Geer moraines) near the proposed port in Steensby Inlet.

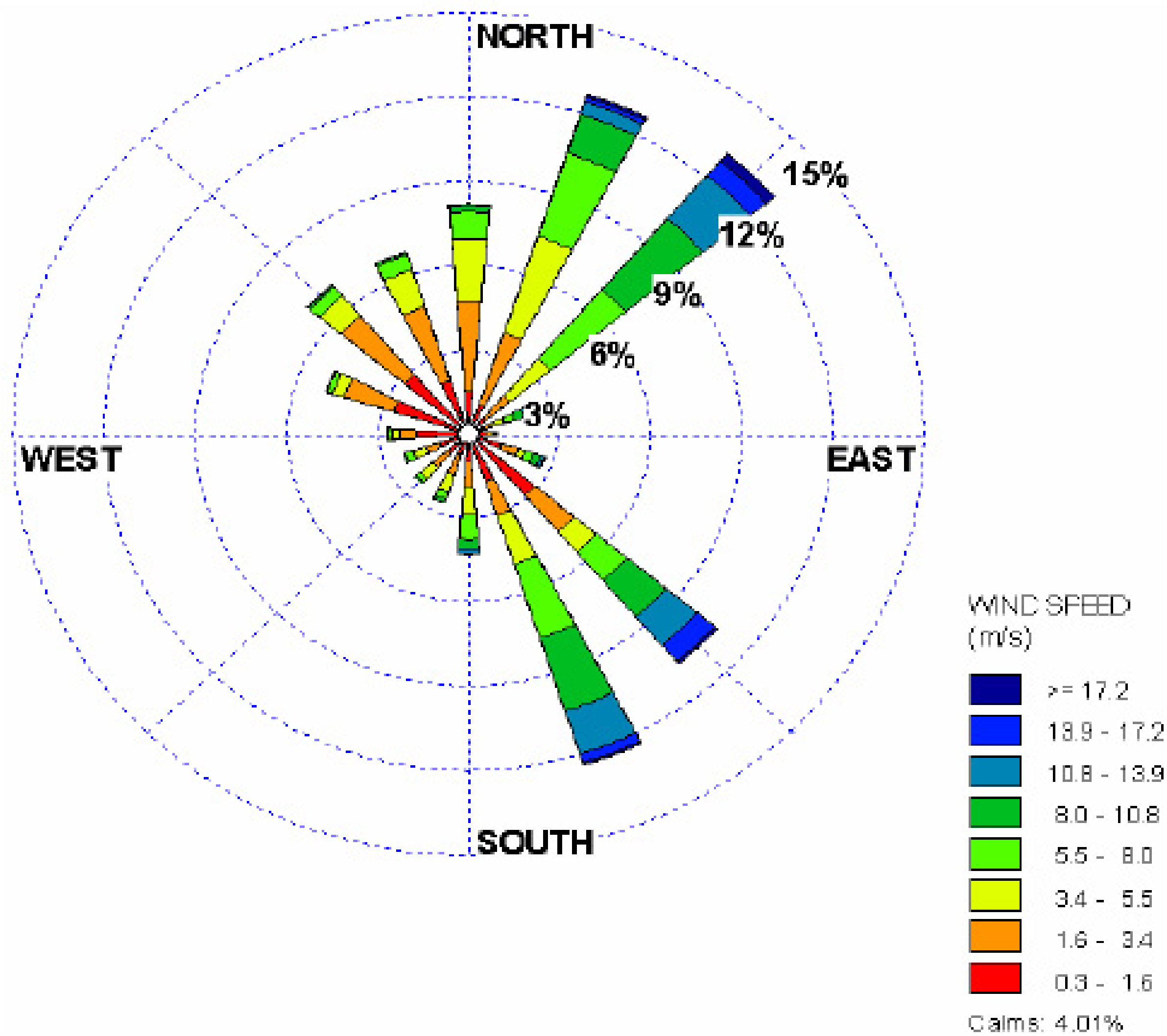


Figure 2.2-1. Wind frequency distribution for Milne Inlet (from RWDI 2008; Fig. 11).

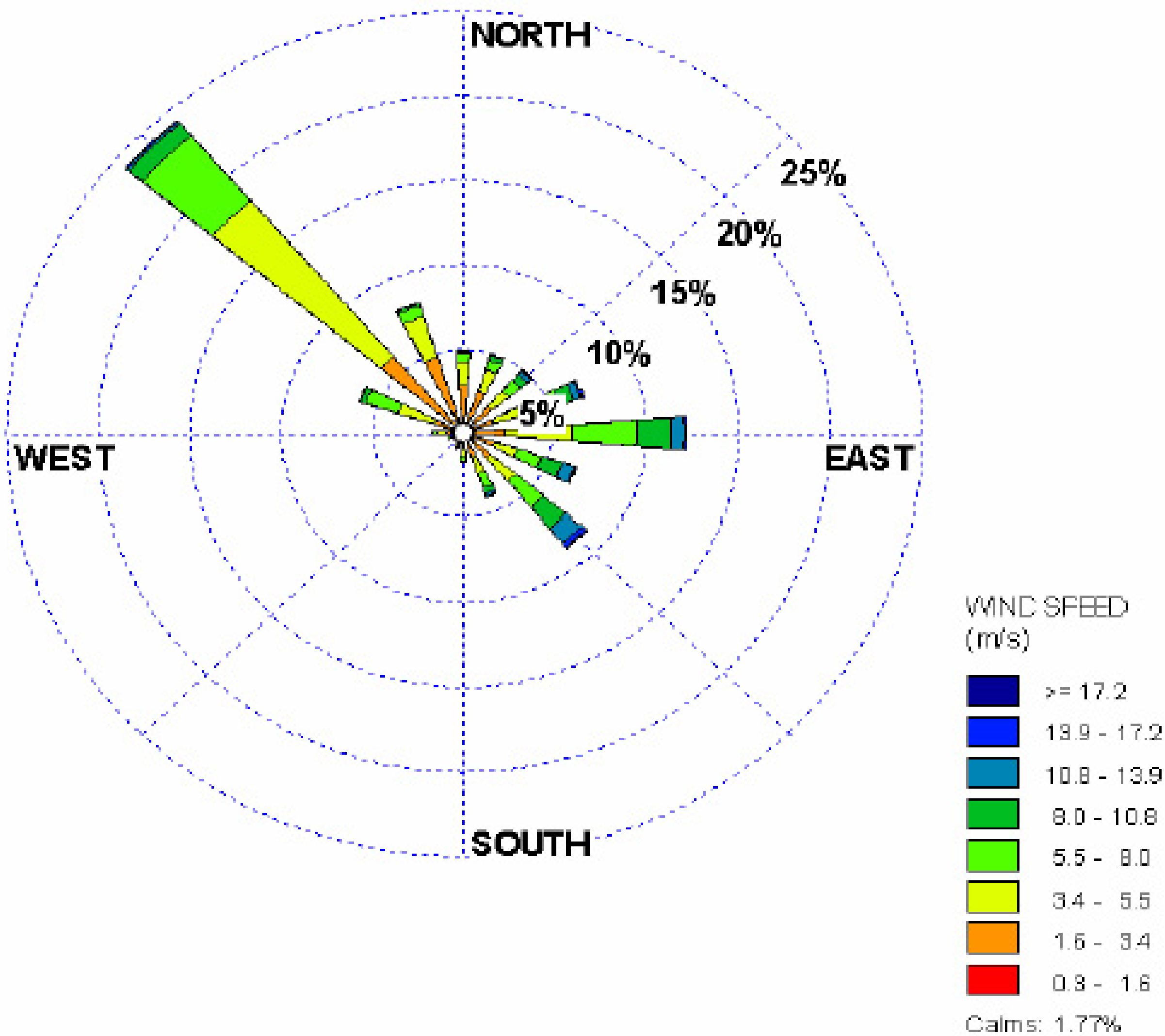


Figure 2.2-2. Wind frequency distribution for Steensby Inlet (from RWDI 2008; Fig. 13).

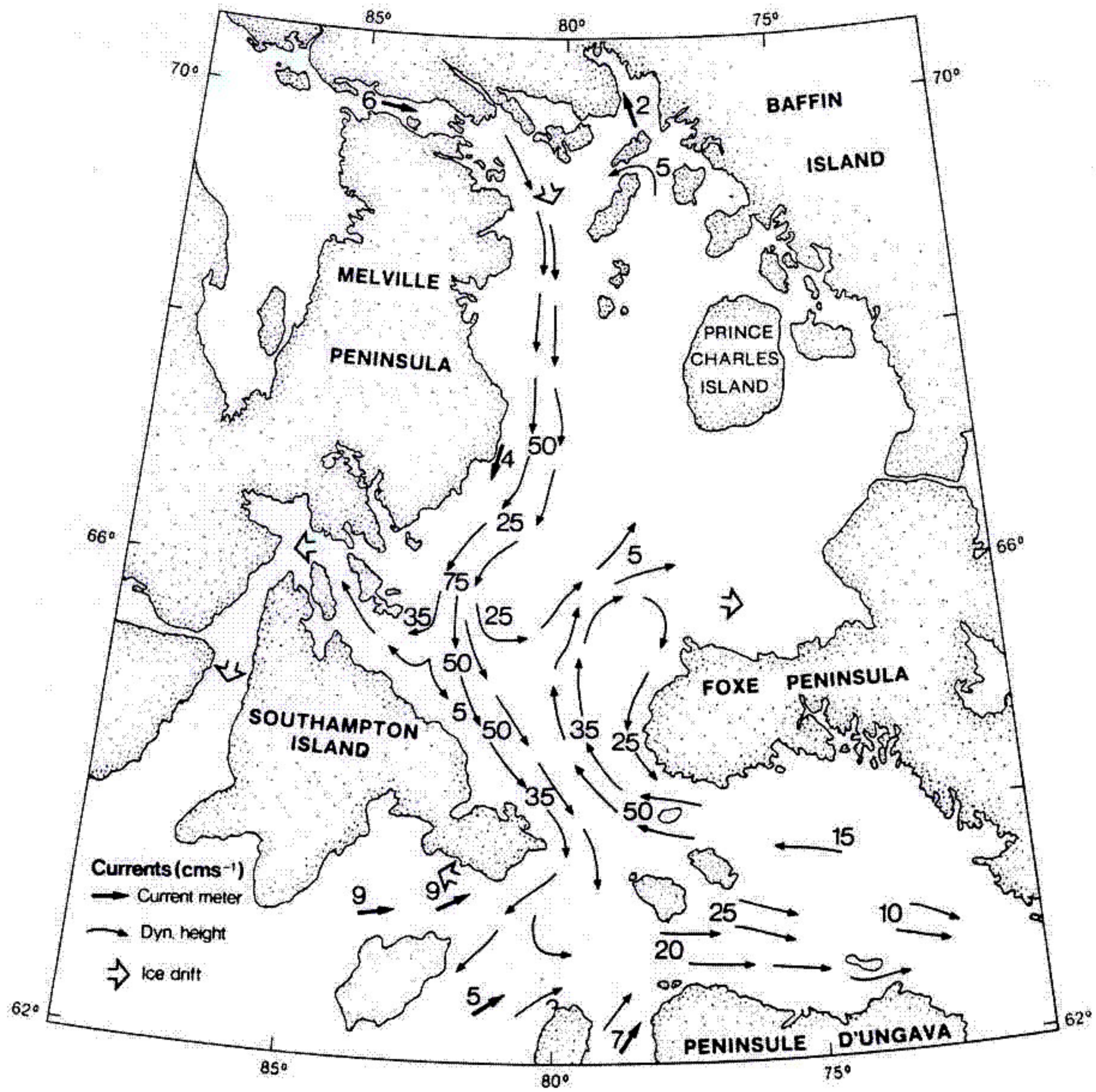


Figure 2.3-1. General oceanic circulation in Foxe Basin (from Prinsenberg 1986).

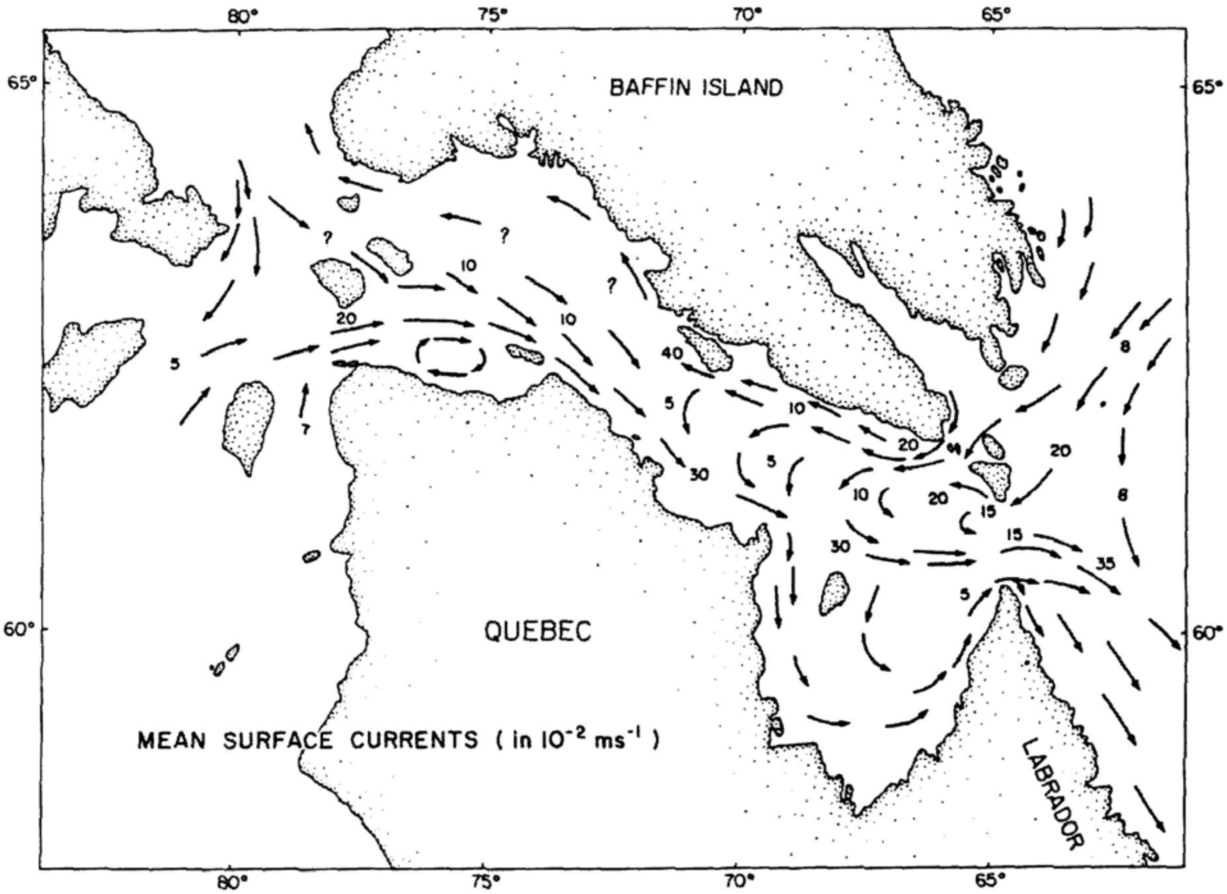


Figure 2.3-2. General oceanic circulation in Hudson Strait (from Drinkwater 1986).

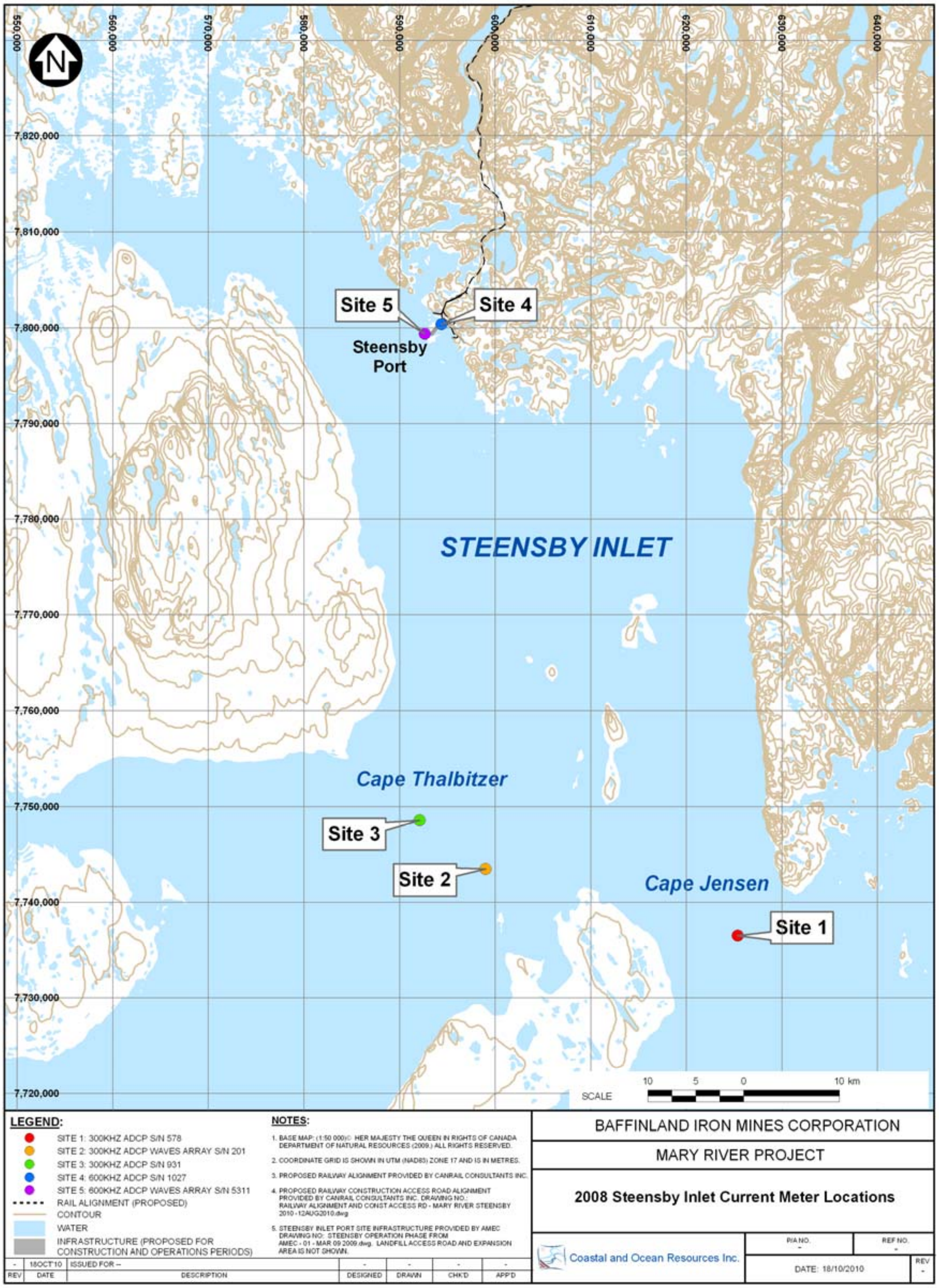


Figure 2.3-3. Current meter (ADCP) locations in Steensby Inlet, September 5 to October 13, 2008 (AMEC 2009).

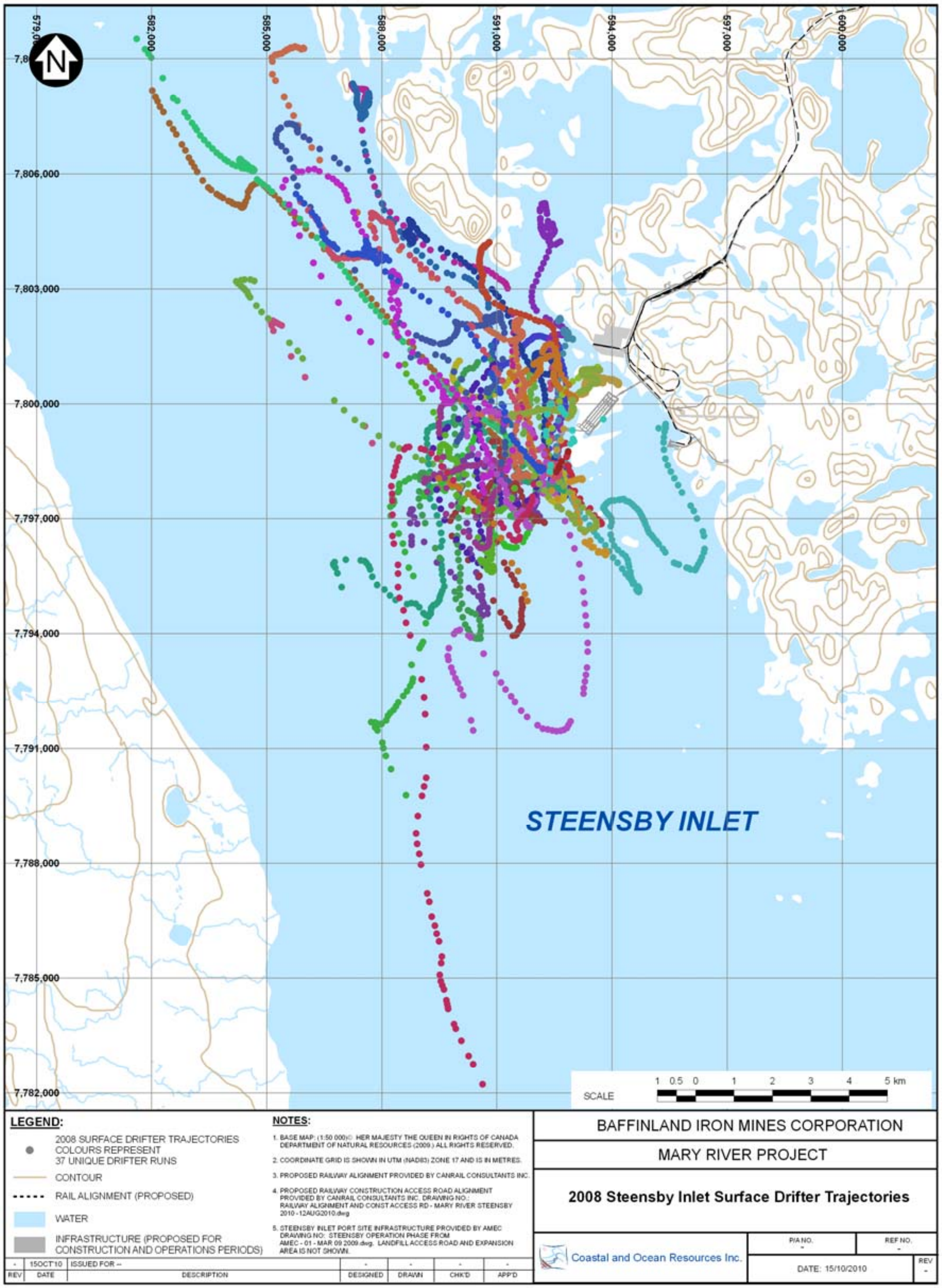


Figure 2.3-4. Surface drifter trajectories in Steensby Inlet between September 8 and 28, 2008.

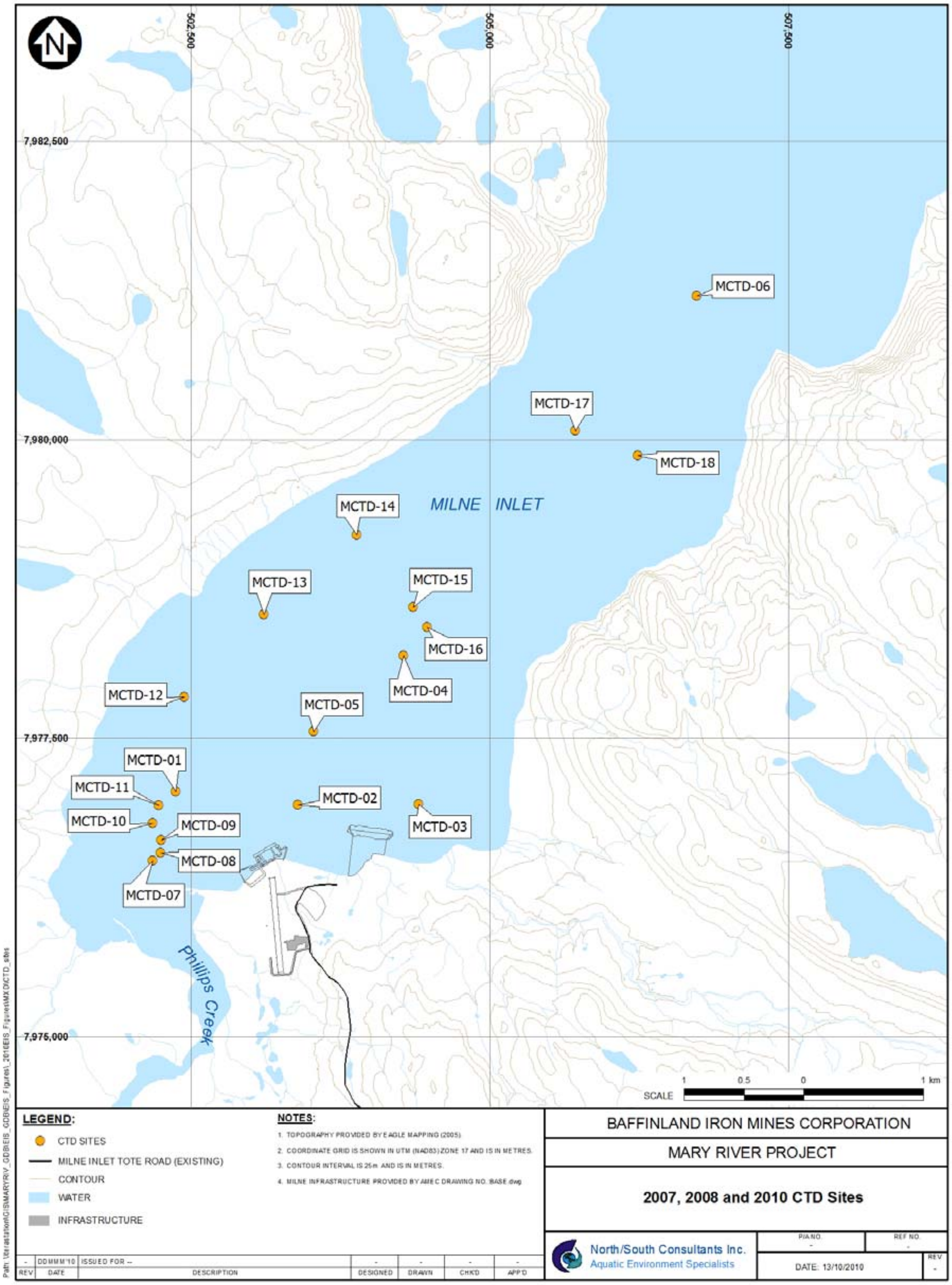


Figure 2.5-1. CTD stations monitored in Milne Inlet in 2008 and 2010.

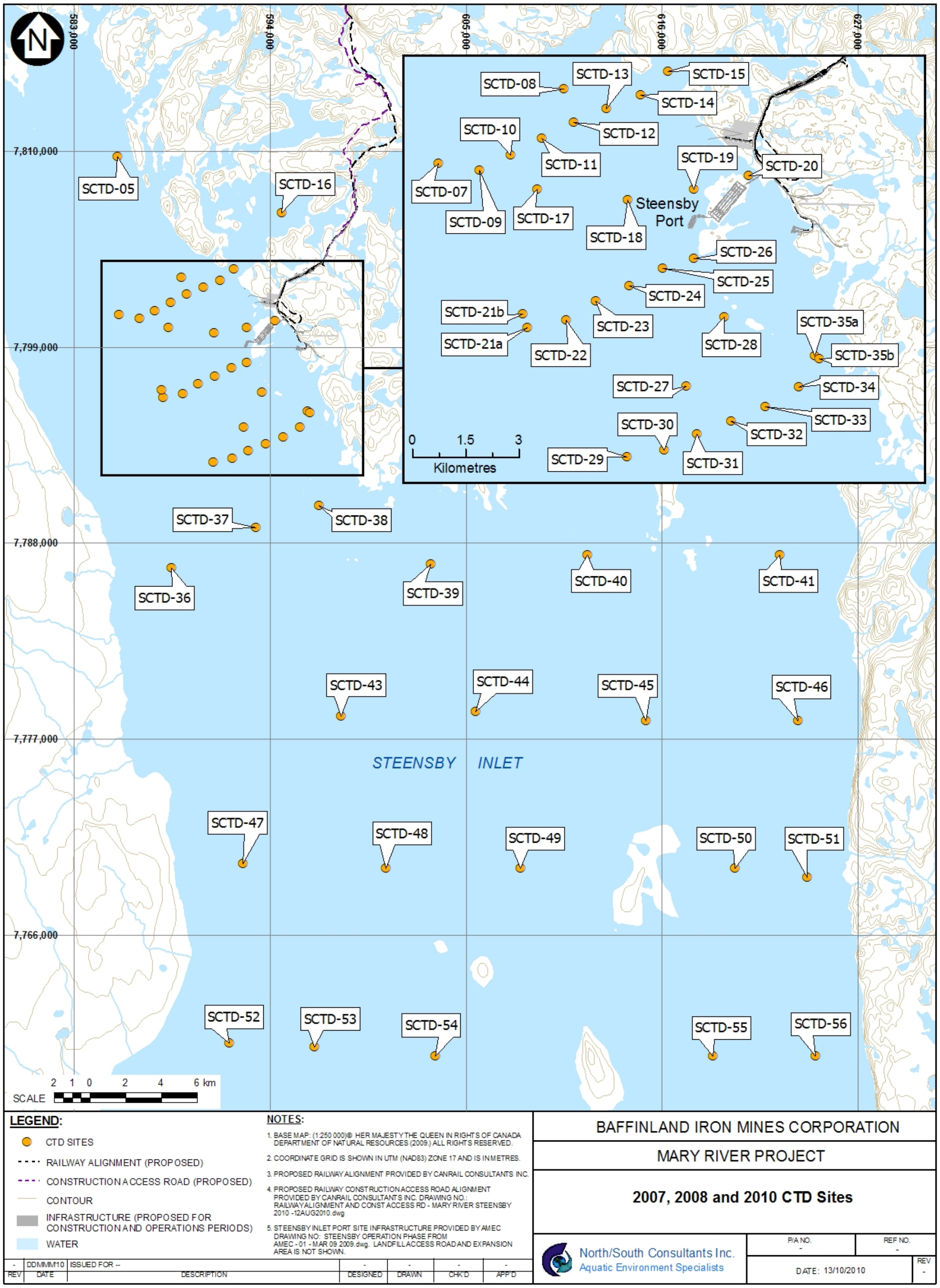


Figure 2.5-2. CTD stations monitoreed in Steensby Inlet in 2007, 2008 and 2010.

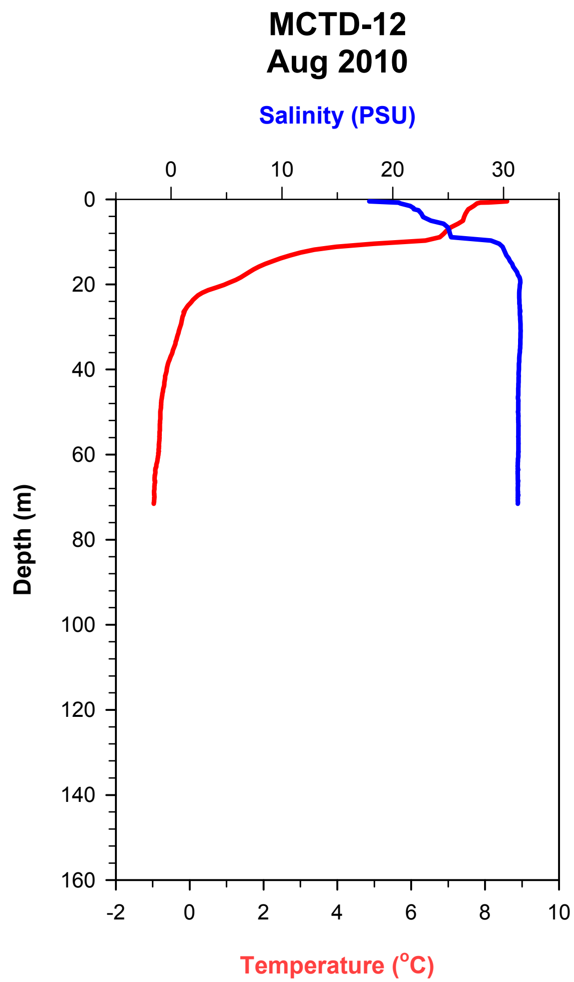


Figure 2.5-3. Shallow-water CTD cast from Milne Inlet showing strong stratification at approximately 10 m water depth (from CORI 2010).

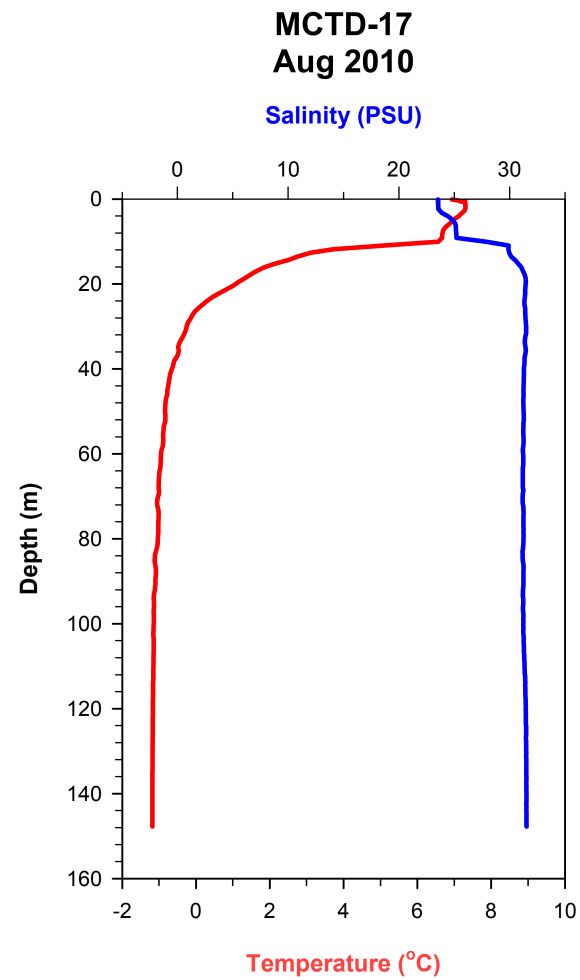


Figure 2.5-4. A deepwater-water CTD cast in Milne Inlet during 2010 showing strong stratification at approximately 10 m water depth (from CORI 2010).

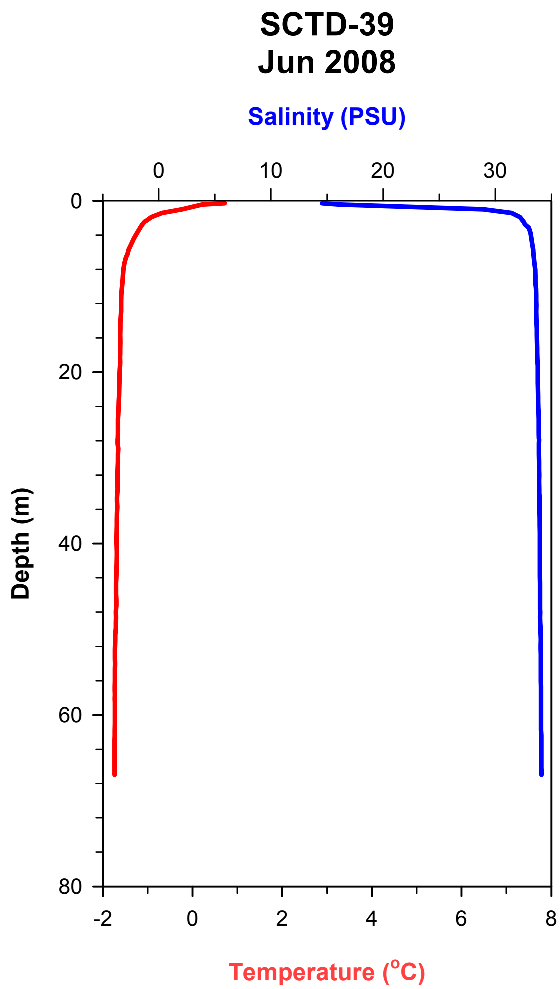


Figure 2.5-5 A CTD cast from Steensby Inlet in 2008 showing a typical CTD profile. Note that there is a thin surface layer (<5 m thick) of cool (0 to 3° C), brackish water (15-30 psu) and a well mixed colder layer below (~-1.8° C, 33 psu).

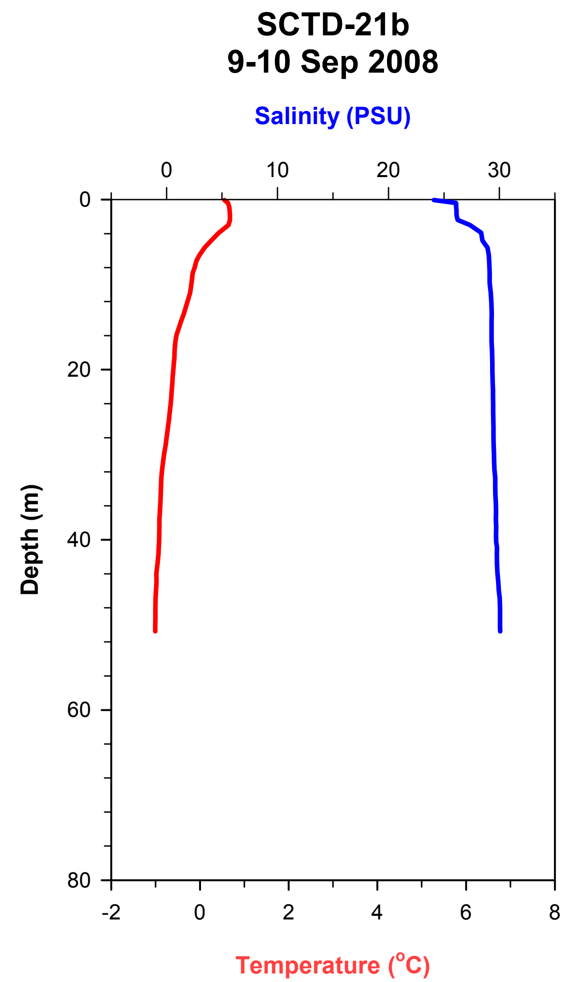


Figure 2.5-6. A shallow-water CTD cast from Steensby Inlet in 2008 showing a typical CTD profile. Note that there is a thin surface layer (~5 m thick) of cool (1° C), brackish water (28 psu) and a well mixed layer below (~-1° C, 30 psu).

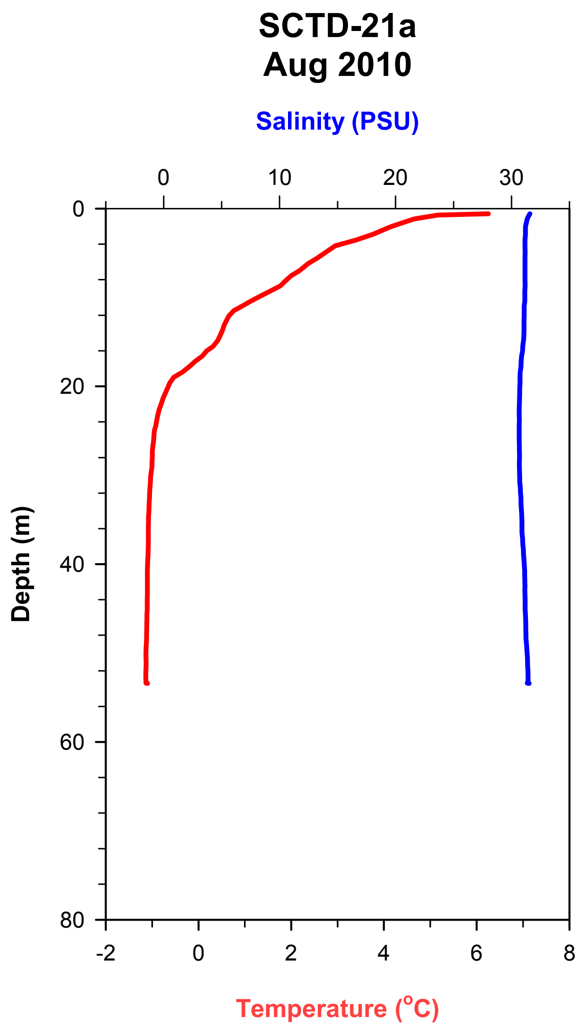


Figure 2.5-7. A shallow-water CTD cast from Steensby Inlet in 2010 showing strong stratification at approximately 20 m water depth (from CORI 2010).

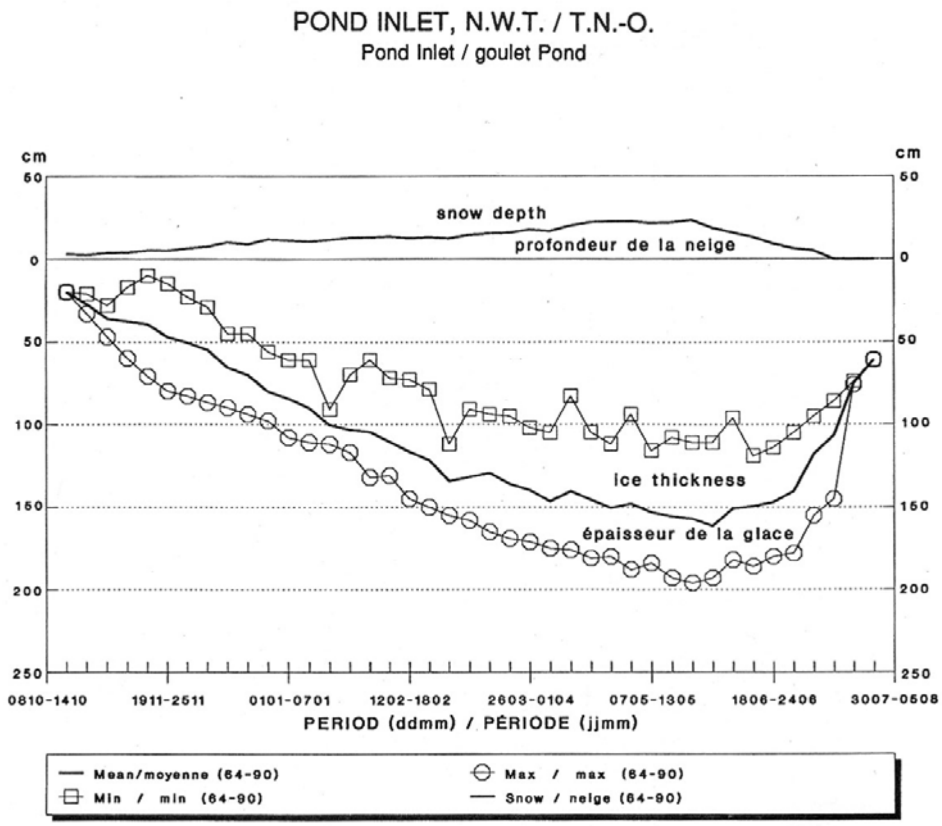


Figure 2.6-1. Ice thickness data (1964-1990) showing the typical and extreme ice thicknesses measured near Pond Inlet in fast ice (from Enfotec 2010, Fig. 6).

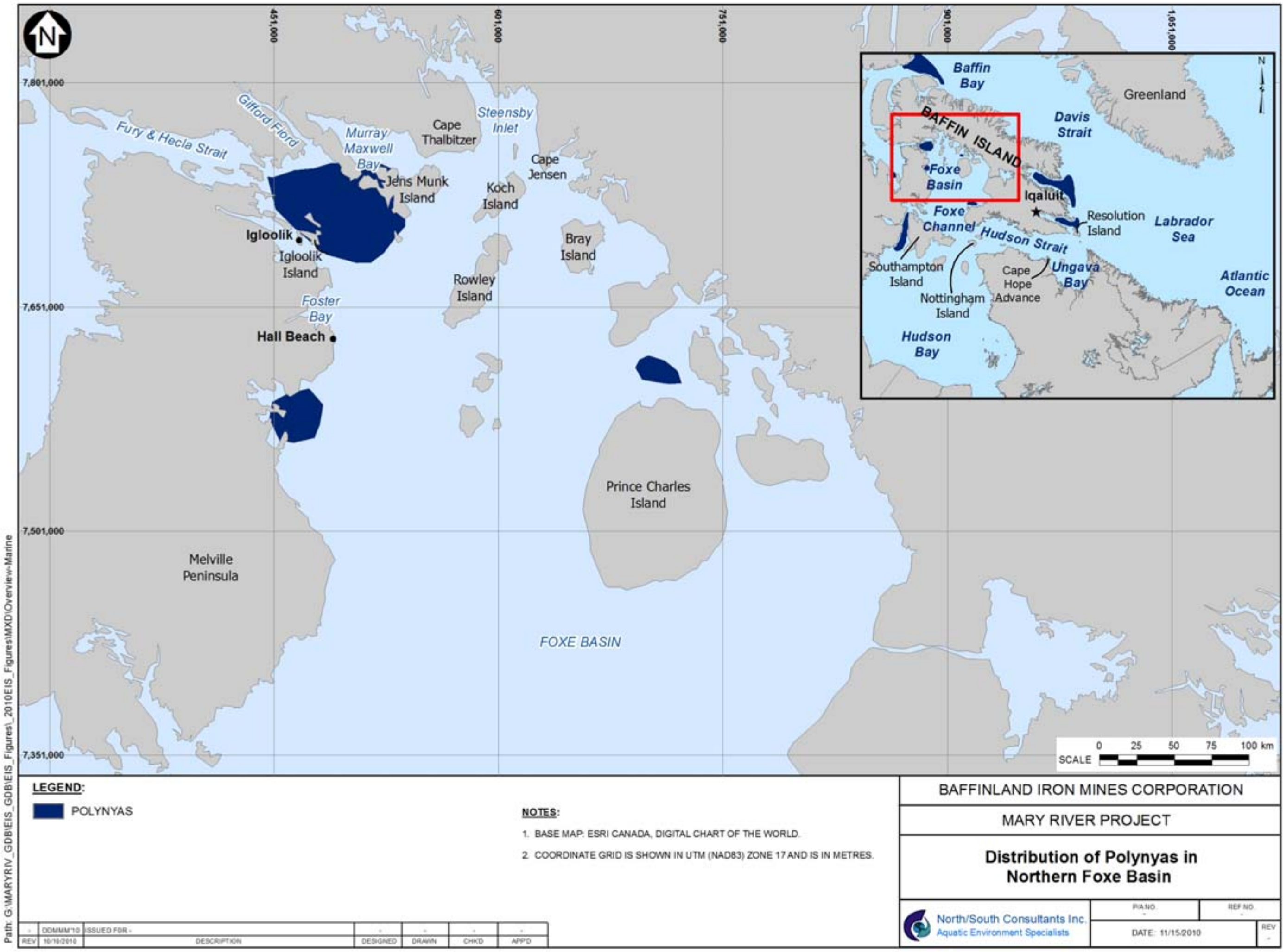


Figure 2.6-2. Polynya locations within northern Foxe Basin (from Stirling 1997).

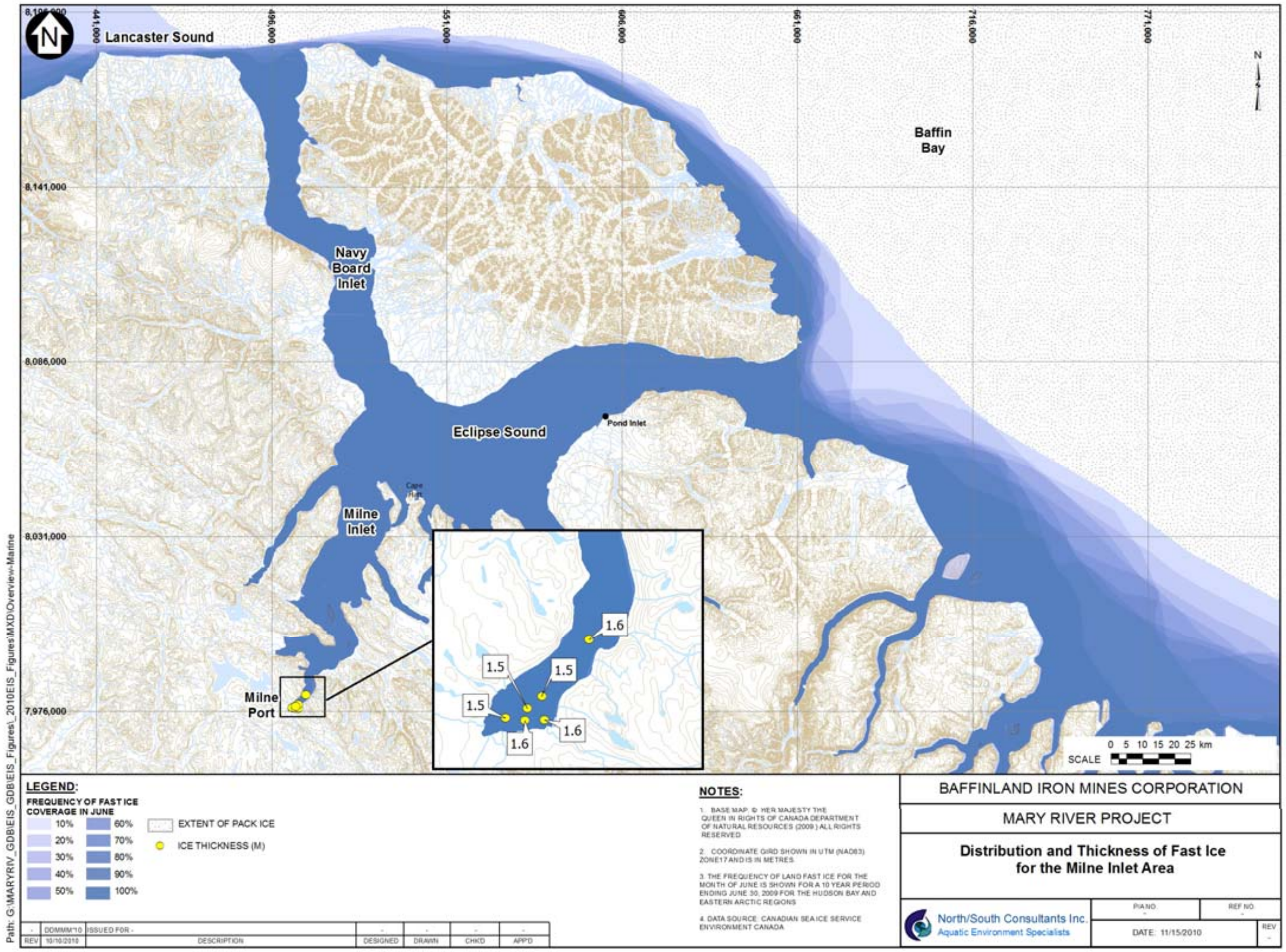


Figure 2.6-3. The distribution of fast ice in Milne Inlet and surrounding areas. Ice thickness measurements from June, 2008.

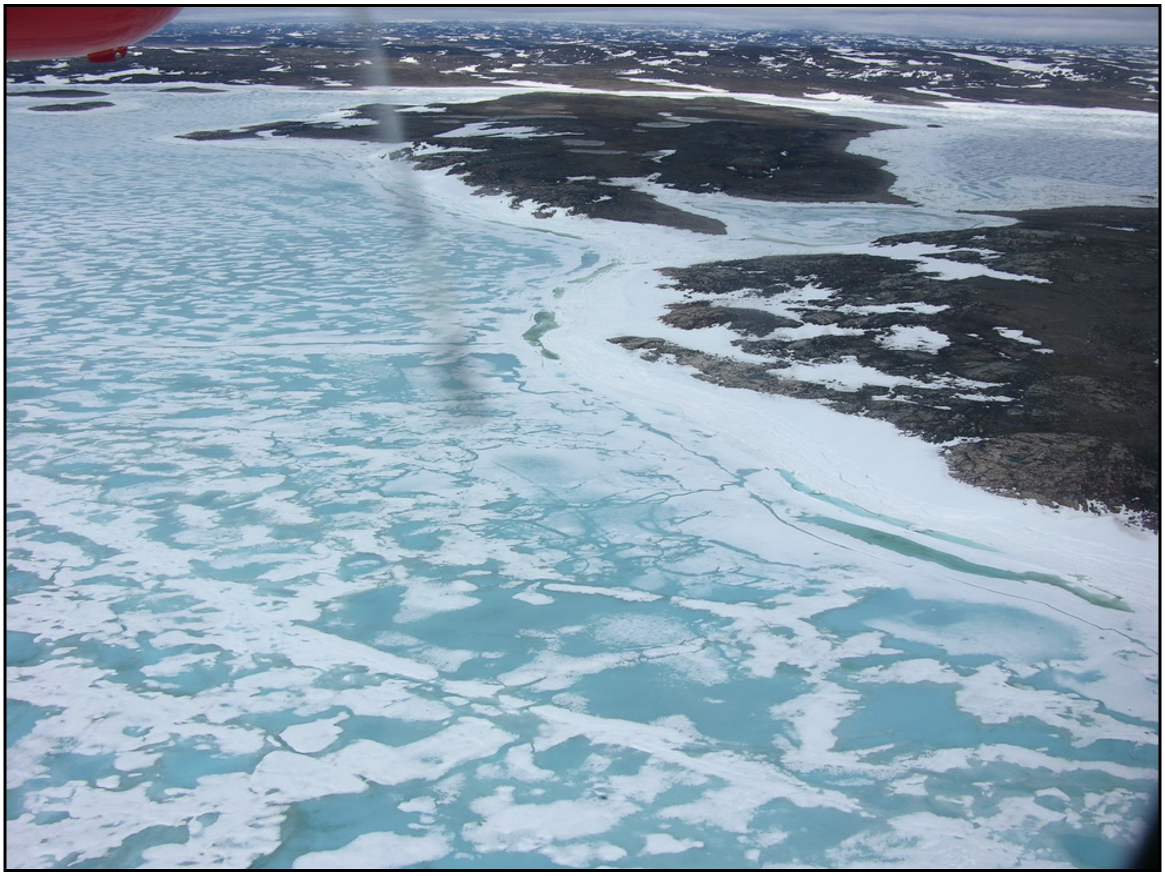

Figure 2.6-4. Sea ice near the location of proposed ore dock at Steensby Inlet. Note that (a) offshore ice is flat and featureless, (b) there is some ice melt evident in this 9 June 2008 photo, (c) a well-defined tidal hinge crack is evident near the shore and (d) there is no large-scale pressure ridging at the shore. The intertidal zone is largely covered by snow drifts.

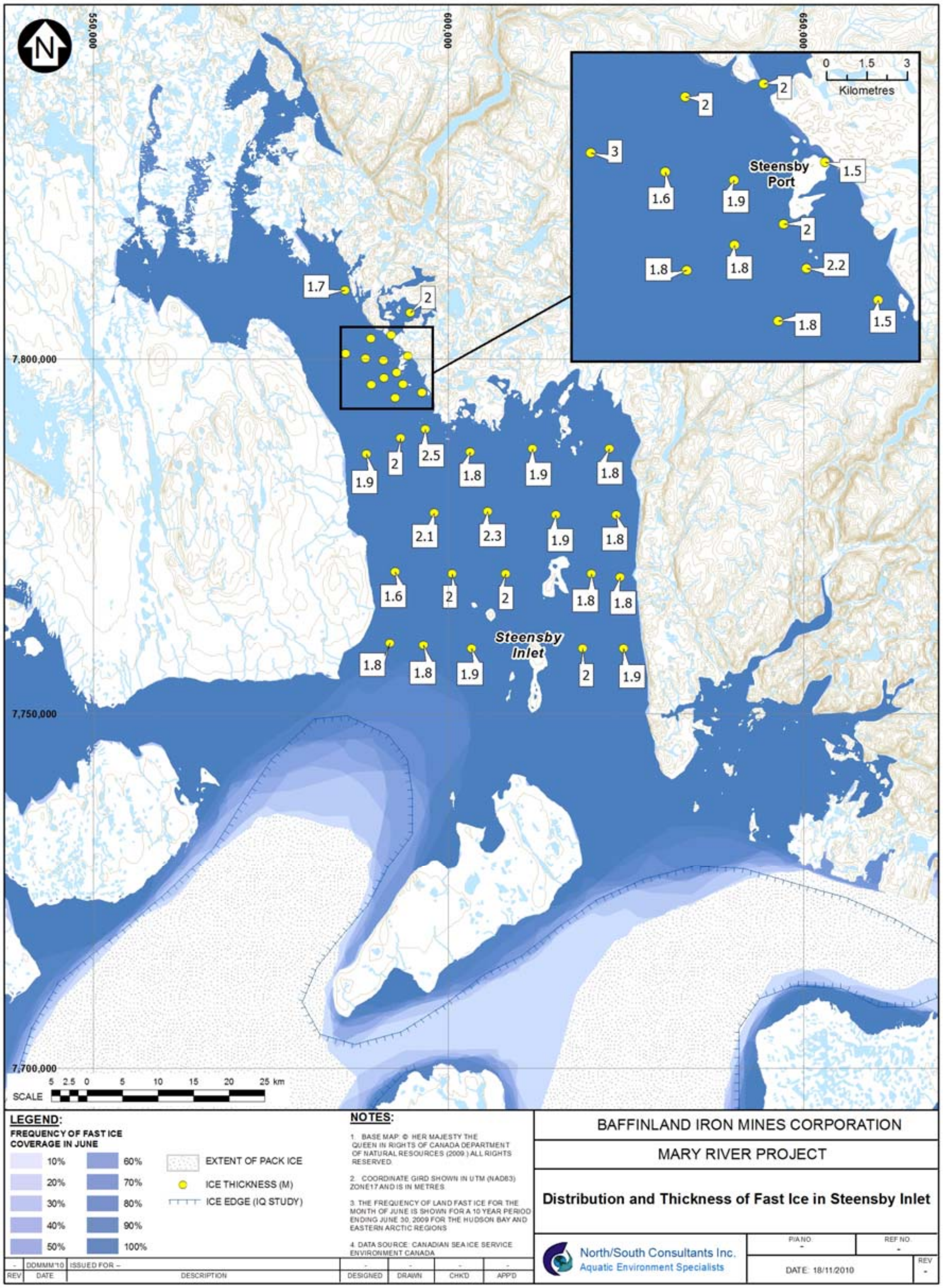


Figure 2.6-5. The distribution of fast ice in northern Foxe Basin and Steensby Inlet. Ice thickness measurements from Steensby Inlet, May and June, 2008.


Figure 2.6-6. Photographs of the proposed Steensby Port area, showing the Steensby camp and stranded multiyear ice along the shore (10 September 2008).

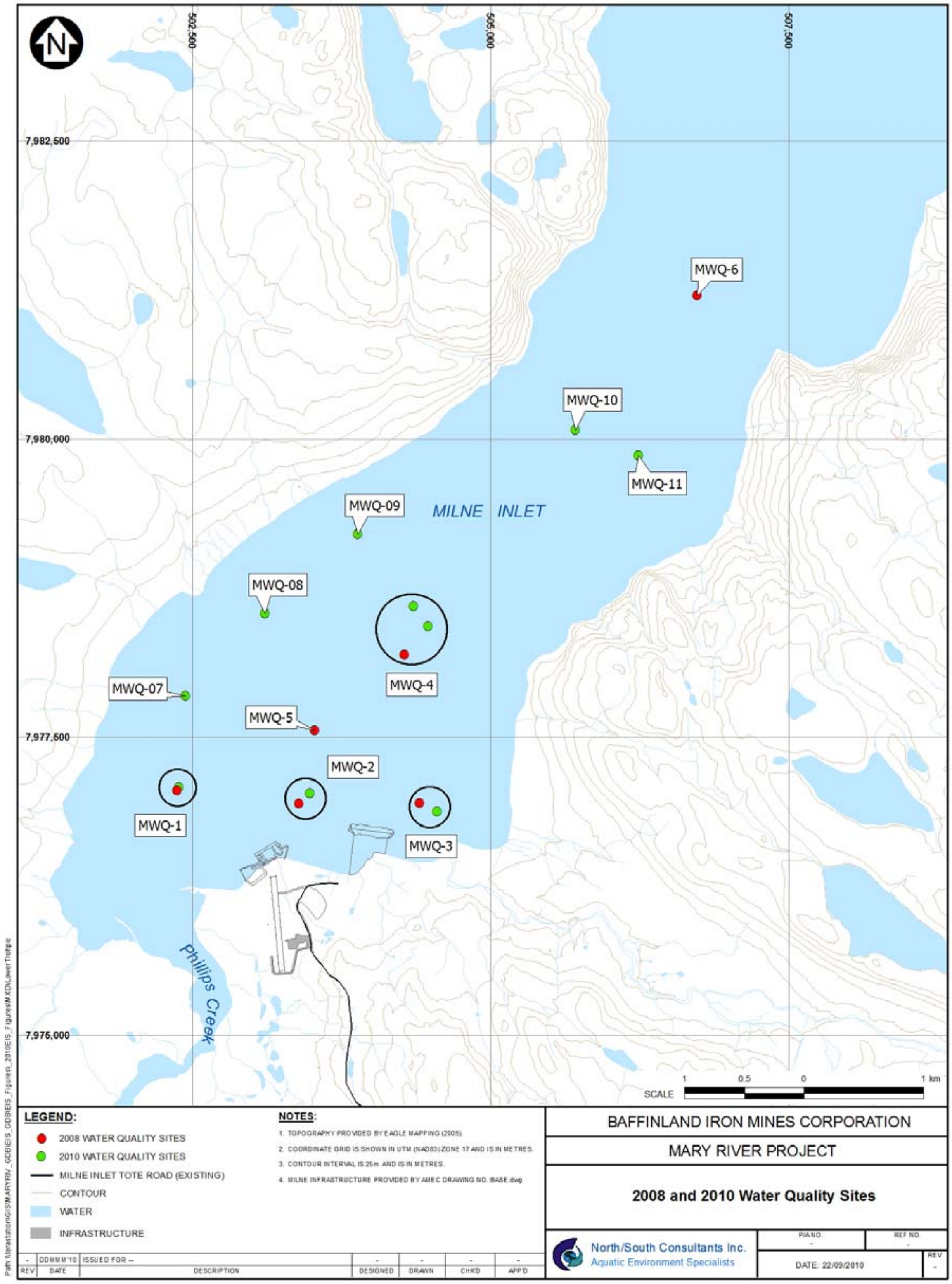


Figure 3.1-1. Water quality sampling sites in Milne Inlet, 2008 and 2010.

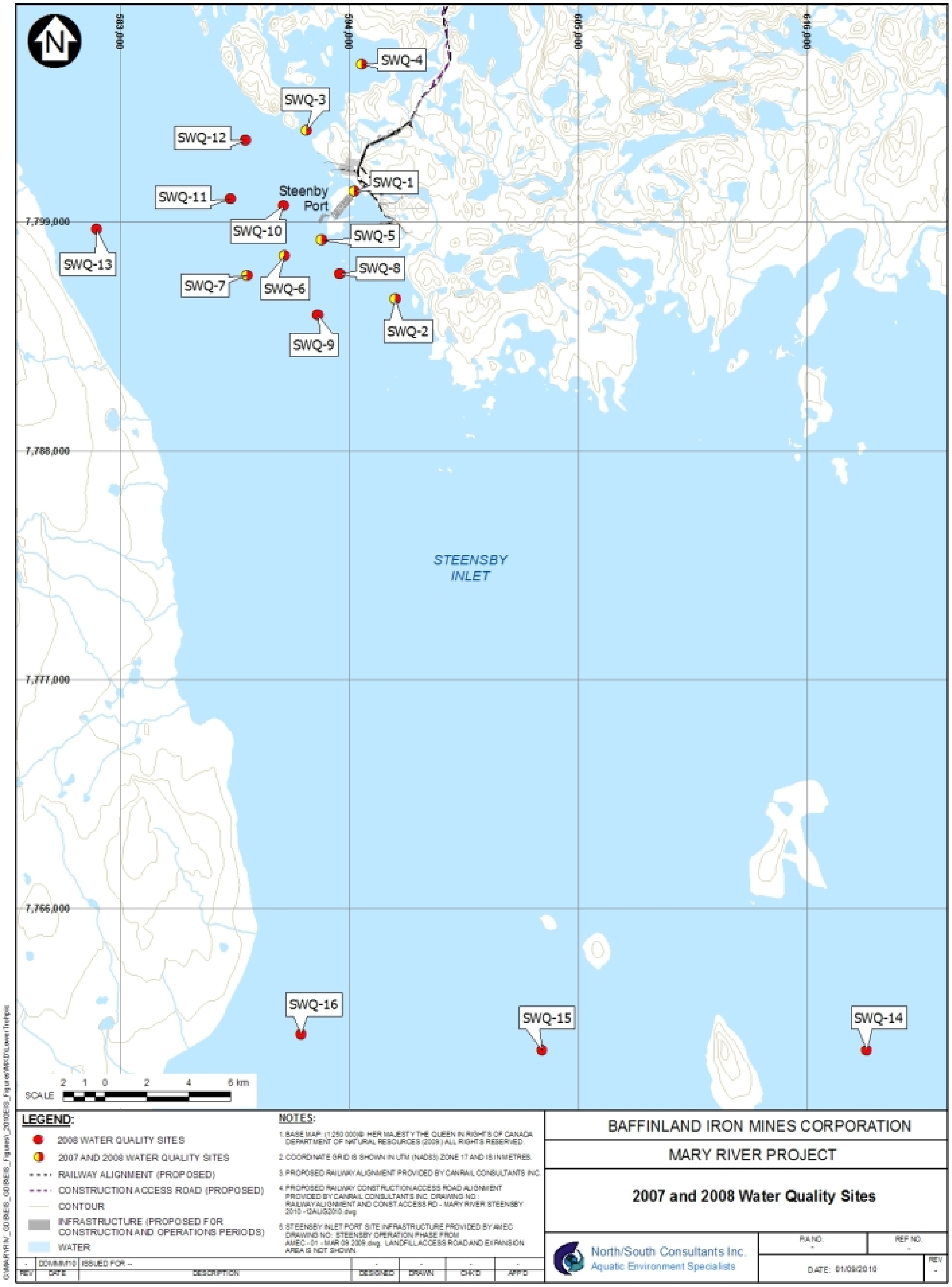


Figure 3.1-2. Water quality sampling sites in Steensby Inlet, 2007 and 2008.

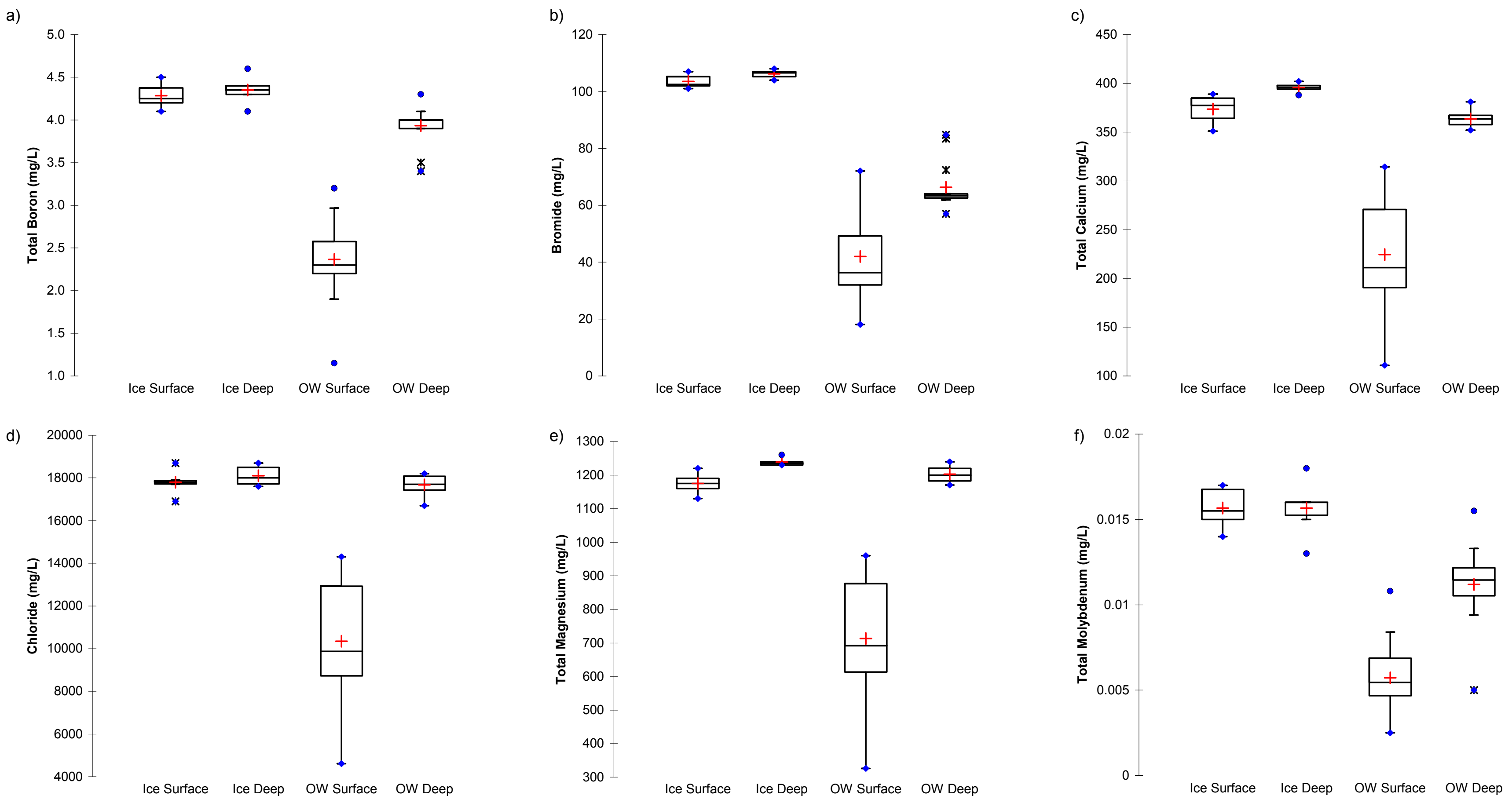


Figure 3.1-3. Boxplots for select metals measured in surface and deep water samples collected from Milne Inlet during the open-water (OW) seasons of 2008 and 2010, and the ice-cover (Ice) season of 2008.

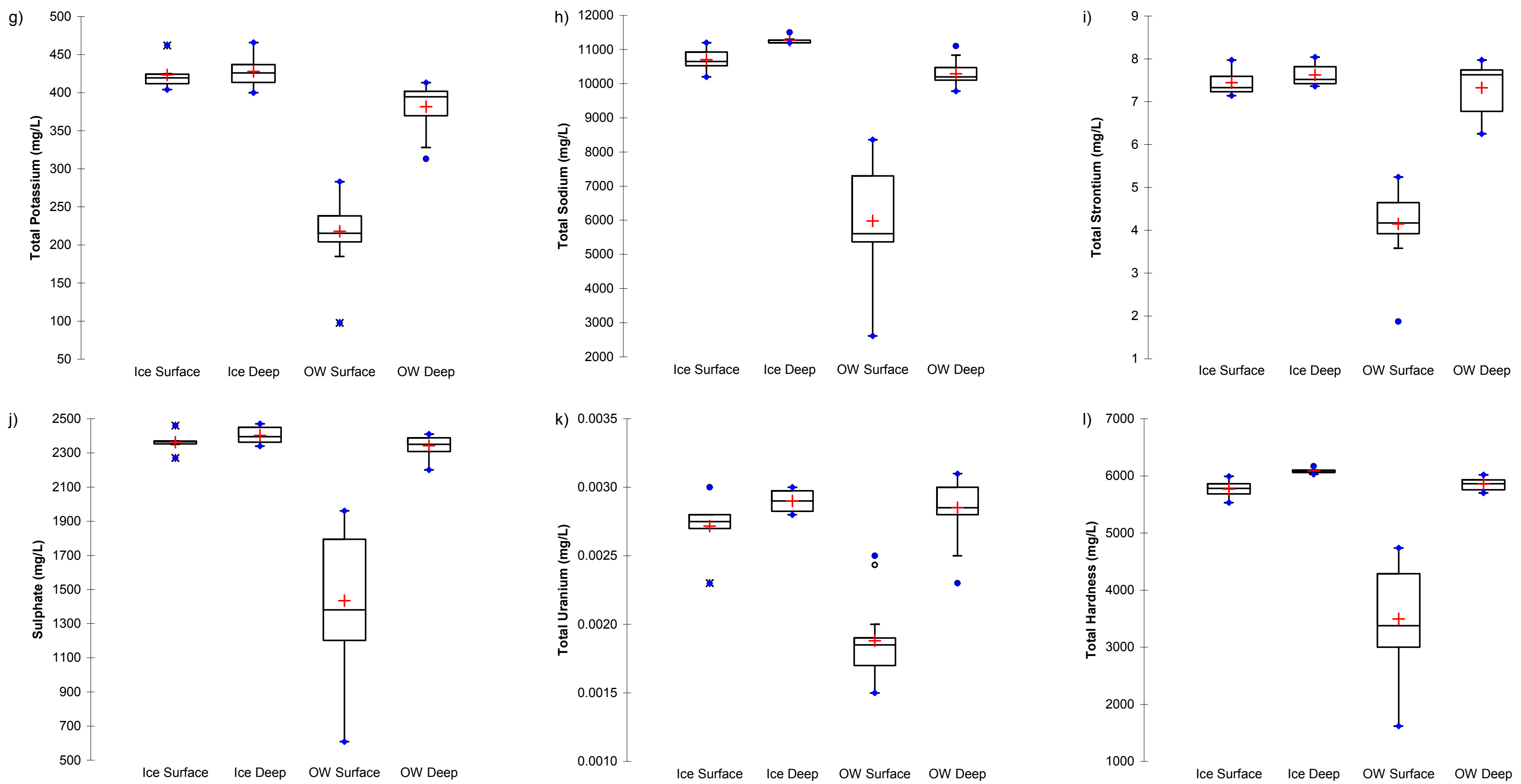


Figure 3.1-3. Continued.

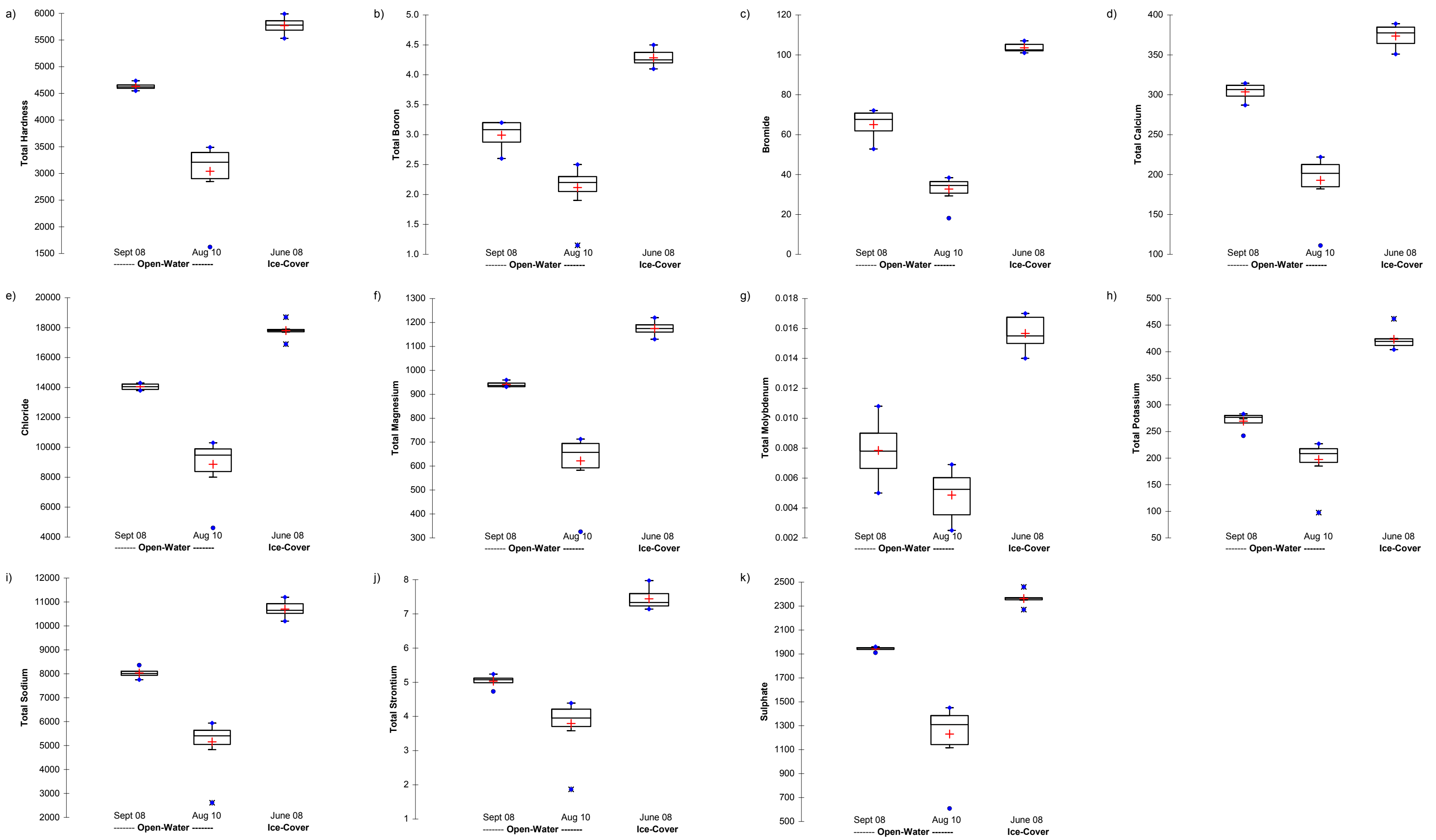


Figure 3.1-4. Boxplots for select metals (mg/L) measured in surface water samples collected from Milne Inlet during the open-water seasons of 2008 and 2010, and the ice-cover season of 2008.

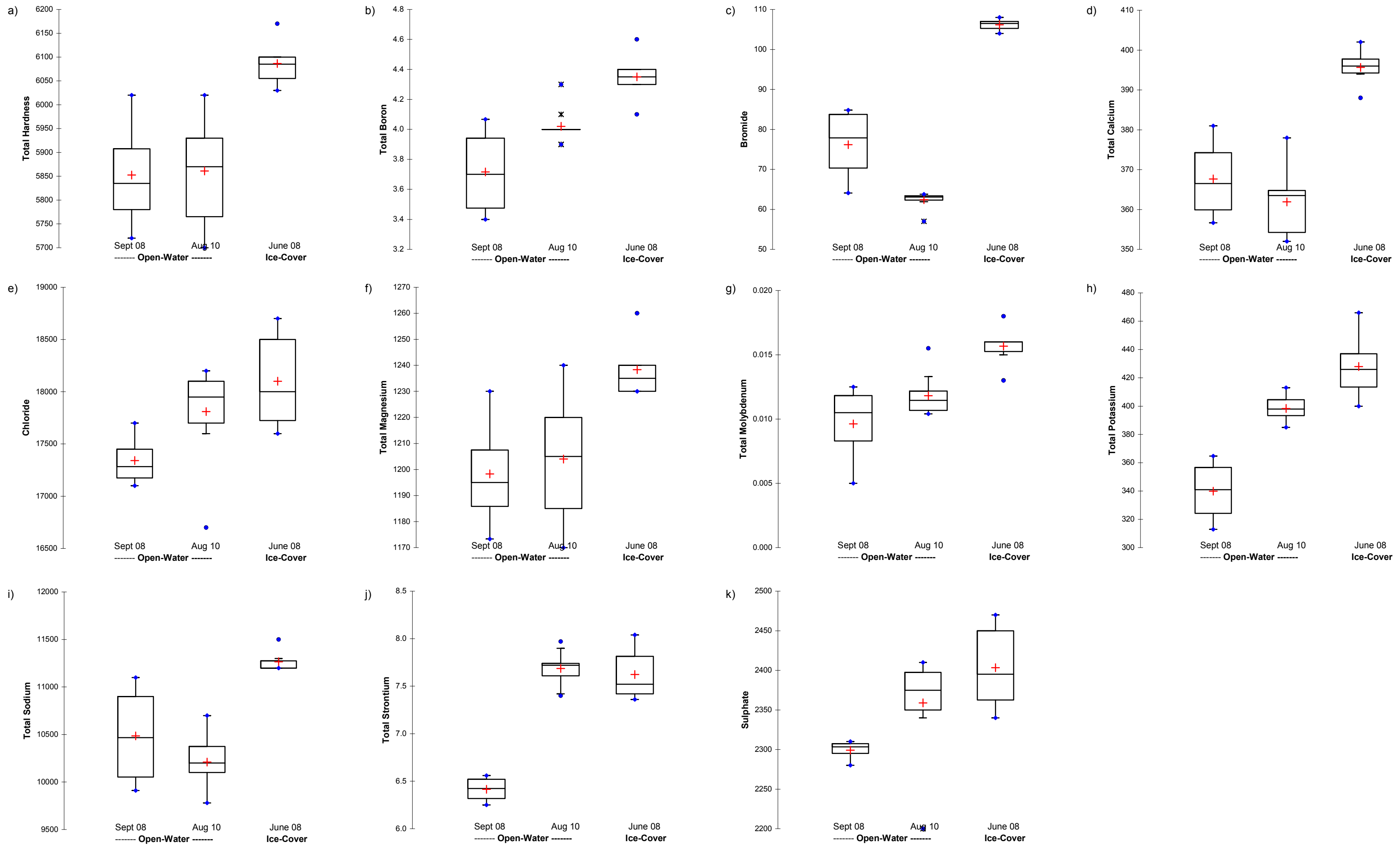


Figure 3.1-5. Boxplots for select metals (mg/L) measured in deep water samples collected from Milne Inlet during the open-water seasons of 2008 and 2010, and the ice-cover season of 2008.

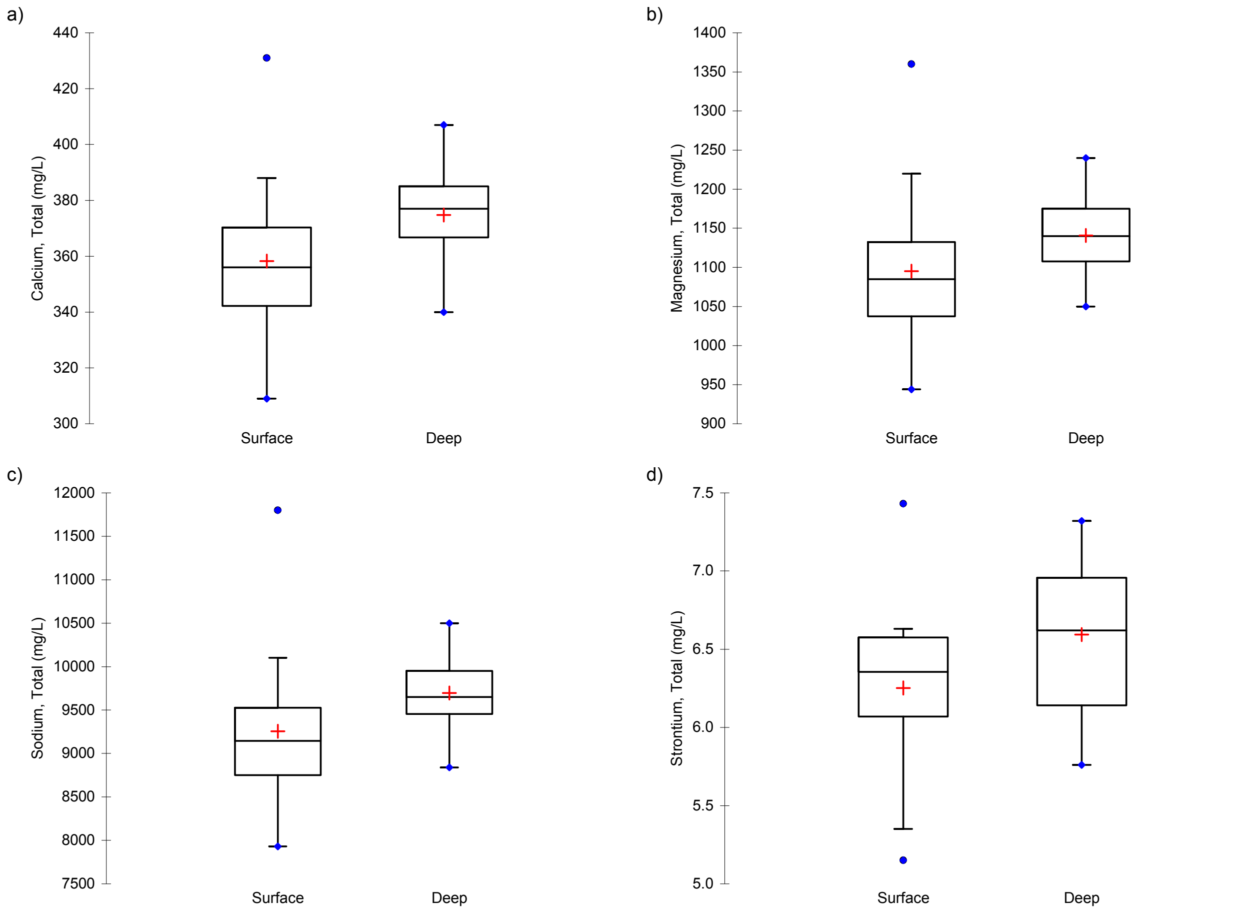


Figure 3.1-6. Boxplots for select elements measured in surface and deep water samples collected from Steensby Inlet during the open-water season, 2007-2008.

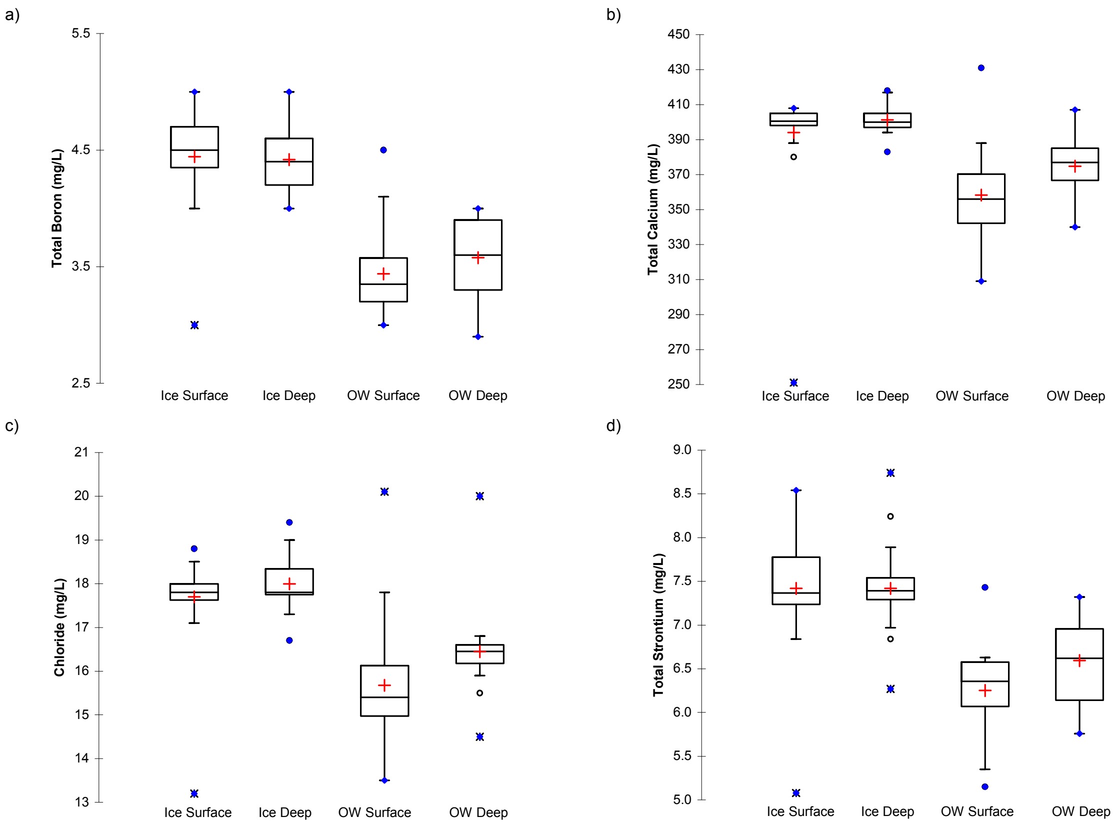


Figure 3.1-7. Boxplots for select elements measured in surface and deep water samples collected from Steensby Inlet during the open-water (OW) and ice-cover (Ice) seasons, 2007-2008.

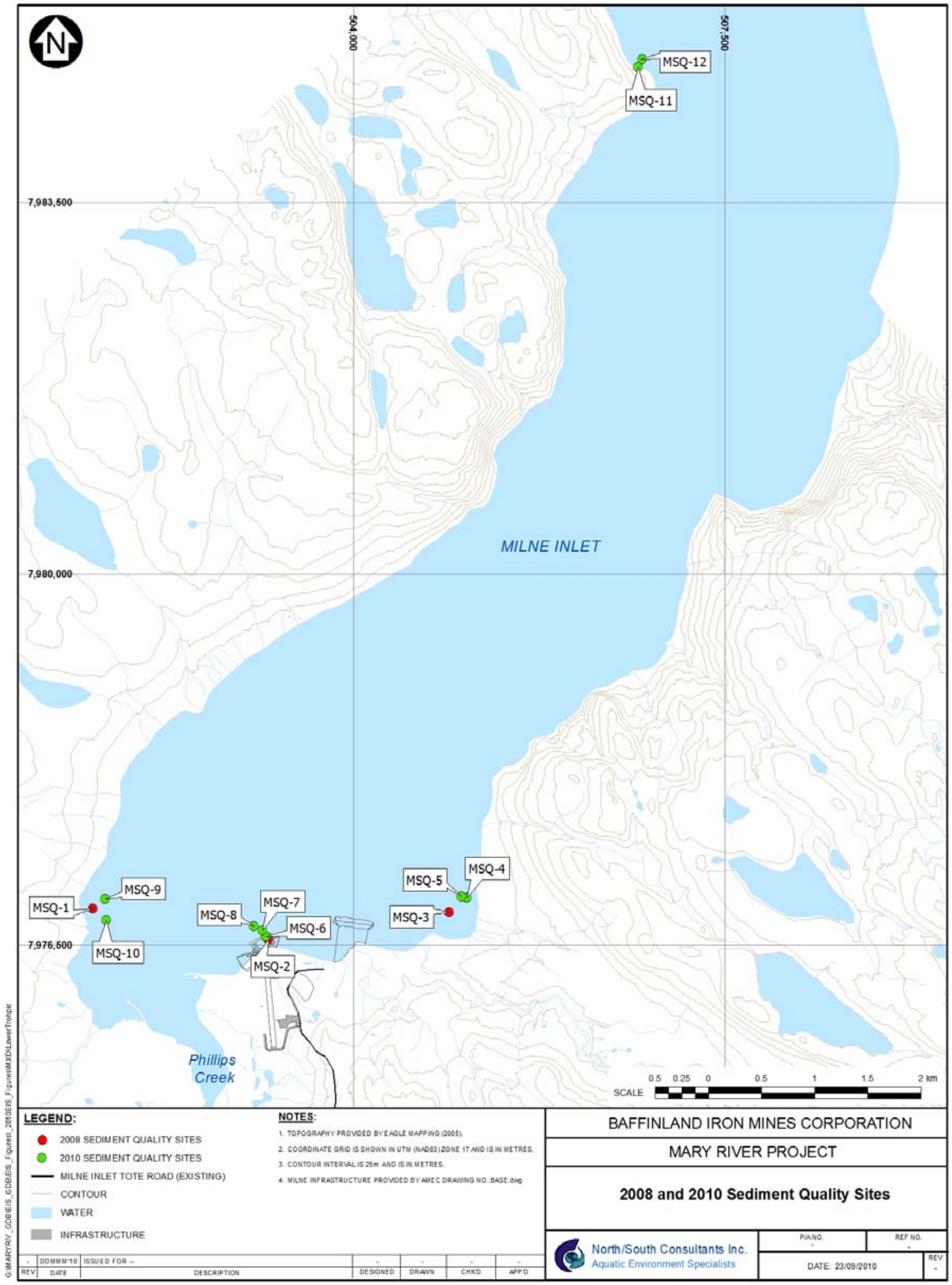


Figure 3.2-1. Sediment quality sampling sites in Milne Inlet, 2008 and 2010.

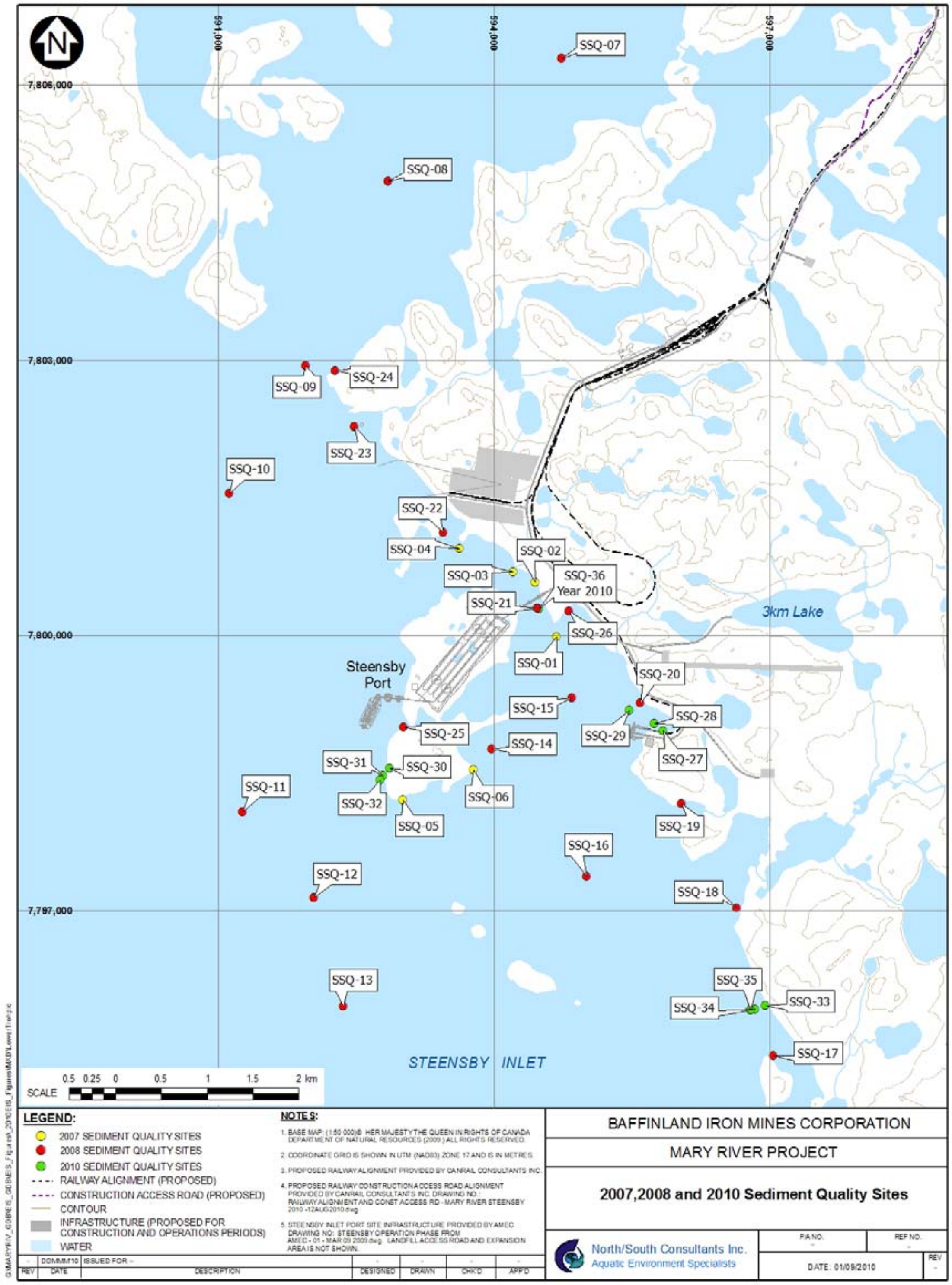


Figure 3.2-2. Sediment quality sampling sites in Steensby Inlet, 2007, 2008 and 2010.

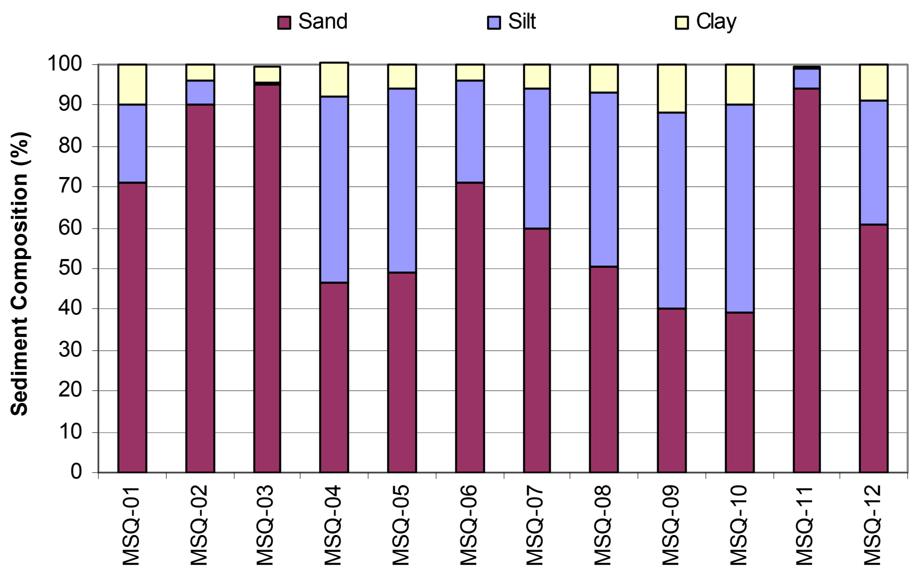


Figure 3.2-3. Sediment composition at sites sampled in Milne Inlet, 2008 and 2010.

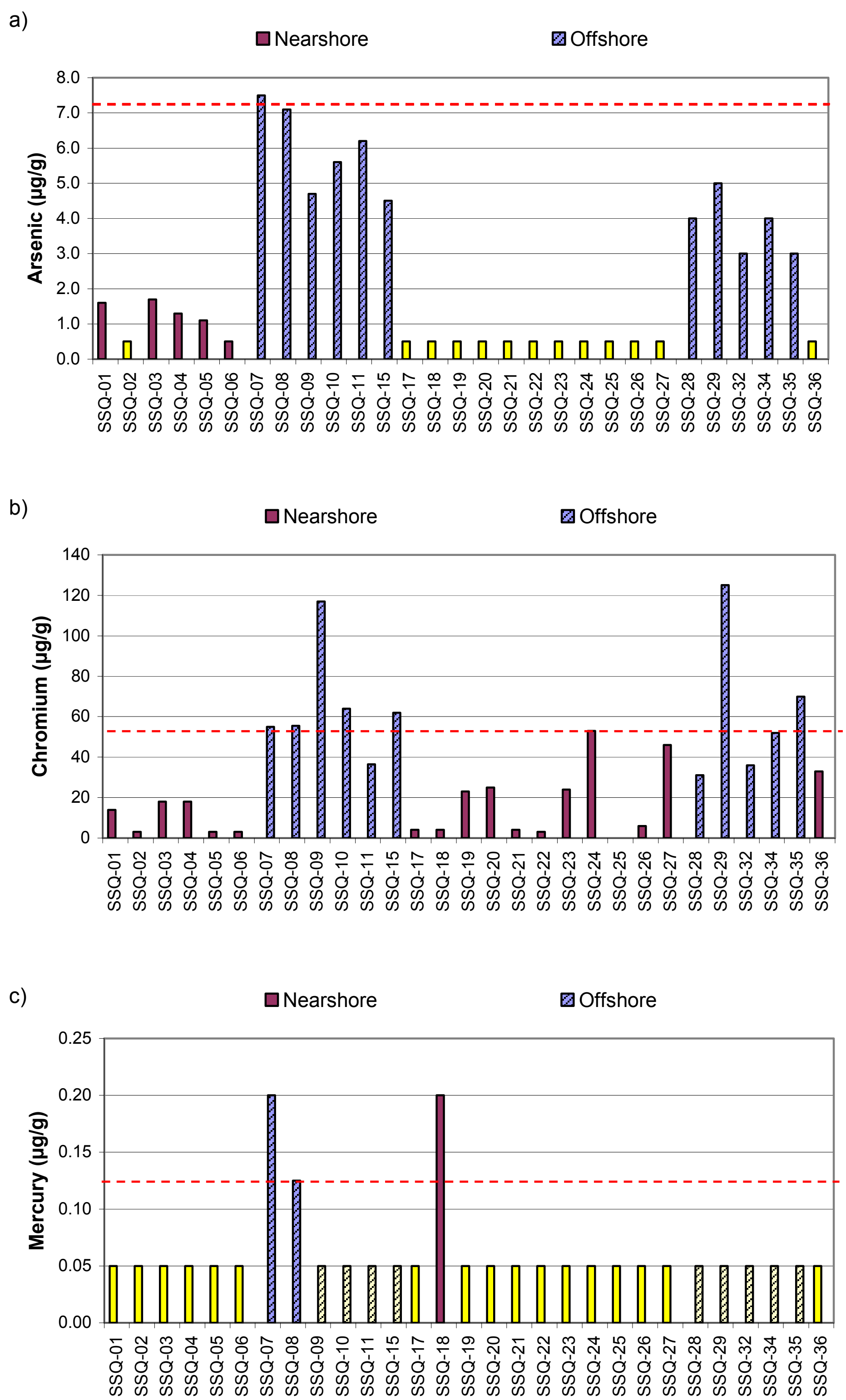


Figure 3.2-4. Sediment concentrations of a) arsenic, b) chromium, and c) mercury measured in samples collected from nearshore and offshore sites in Steensby Inlet, 2007, 2008, and 2010. Dashed lines represent the relevant CCME Interim Sediment Quality Guideline. Values below the DL were plotted at half the DL and are indicated in yellow.

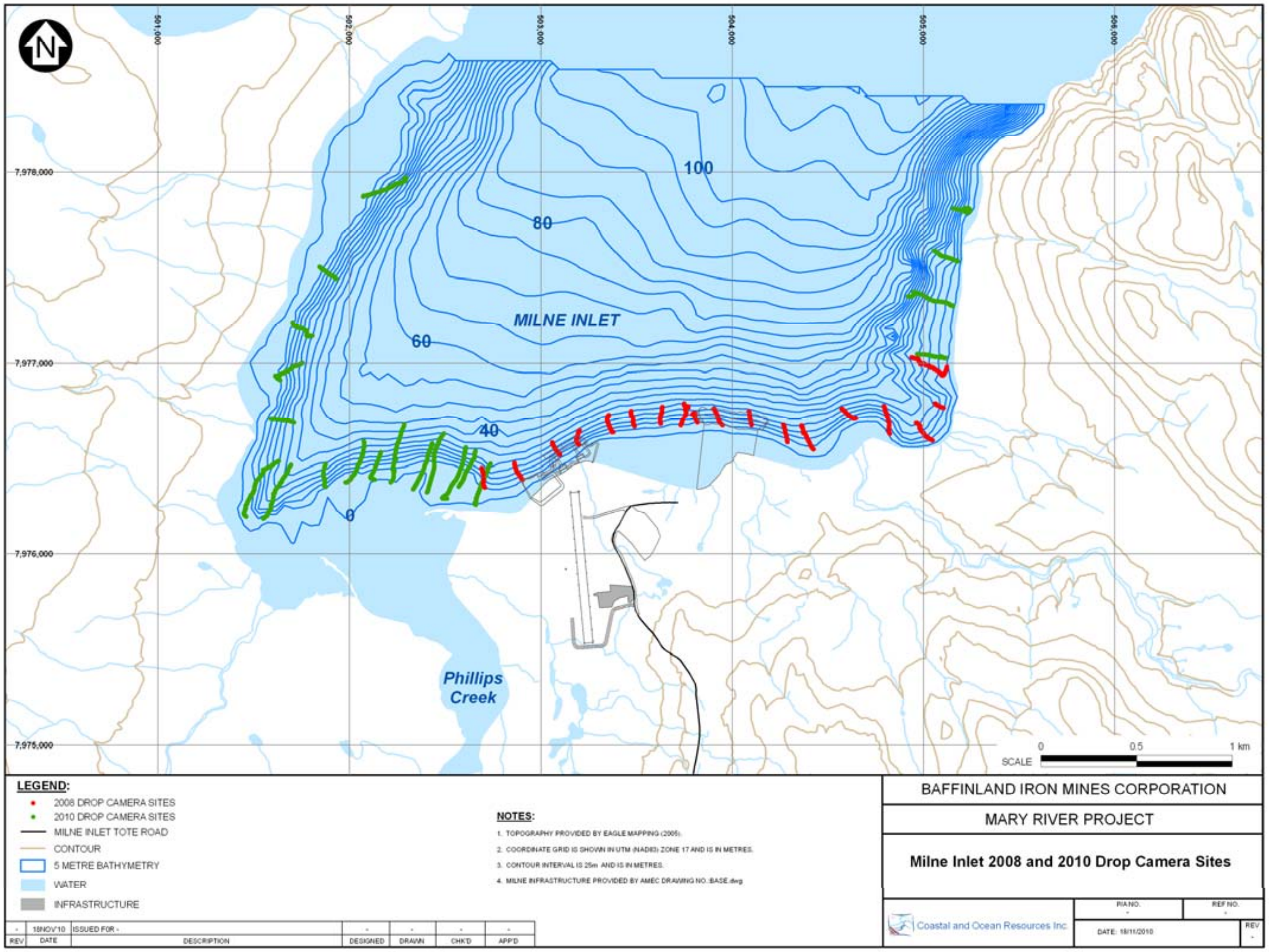


Figure 4.1-1. Video drop camera survey lines in Milne Inlet, 2008 and 2010.

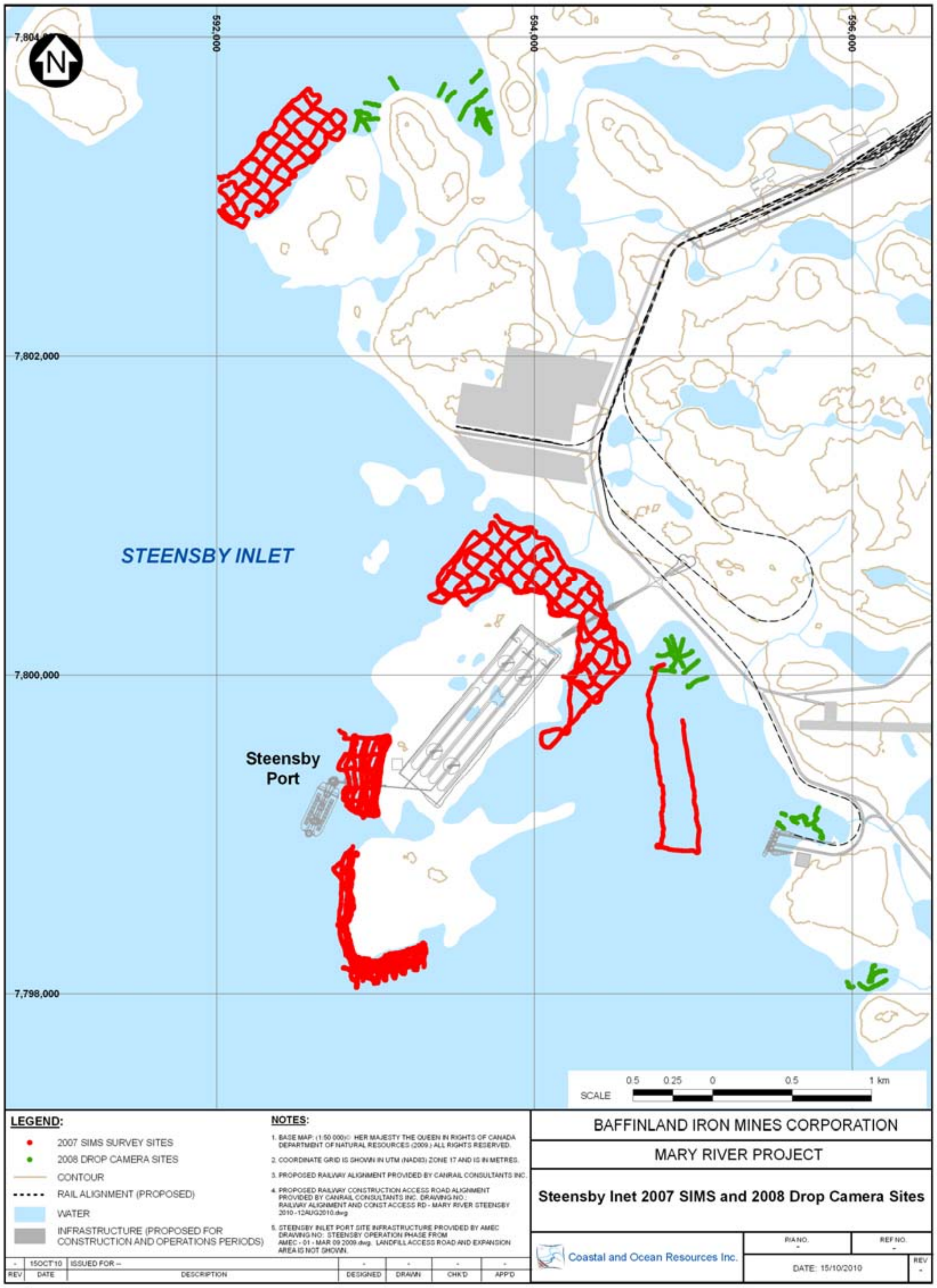


Figure 4.1-2. Nearshore imagery survey areas near the proposed port in Steensby Inlet. Note that five areas were surveyed with towed underwater video (SIMS) in 2007 and five additional bays were surveyed by drop-camera video in 2008.

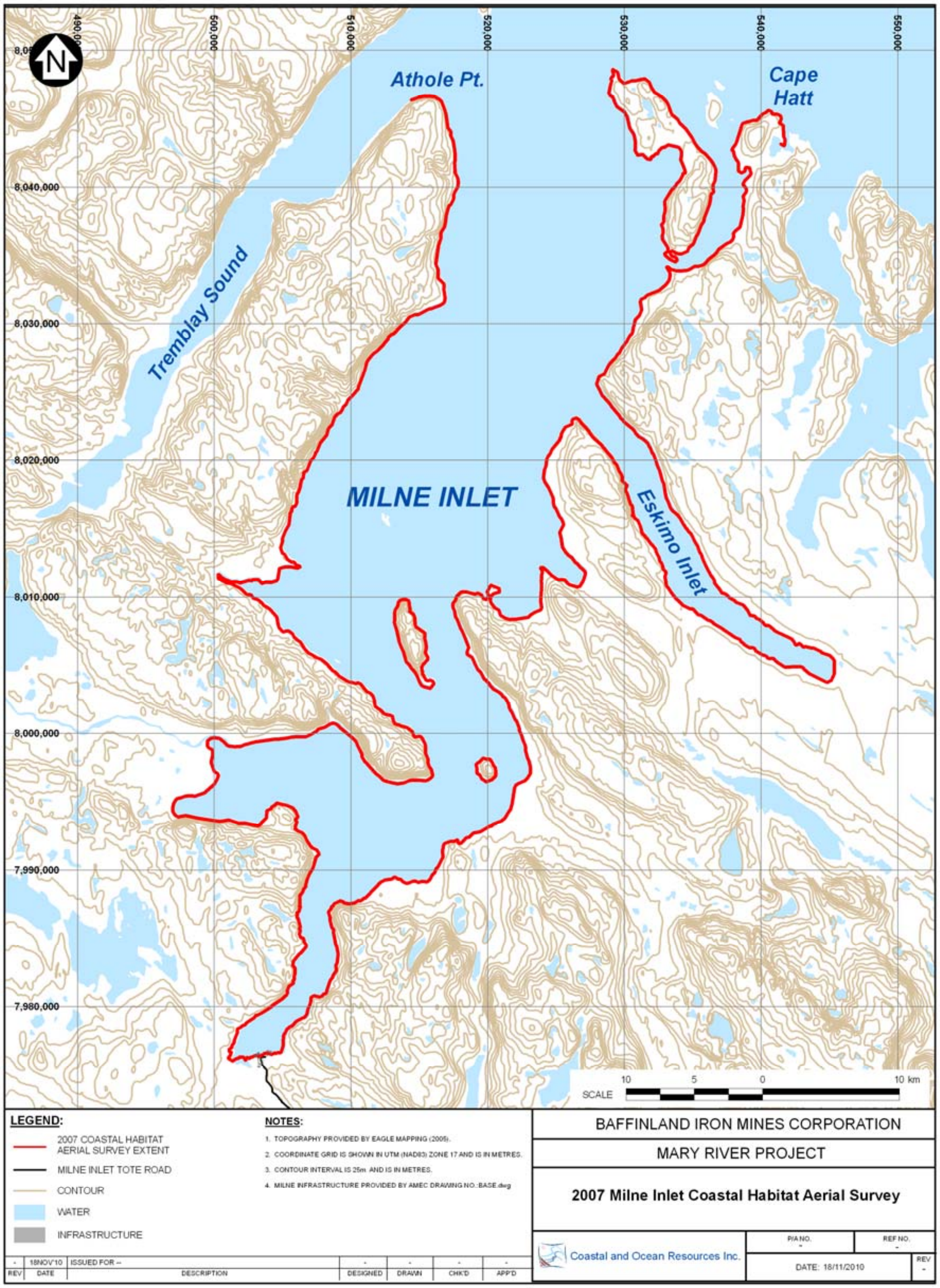


Figure 4.1-3. Extent of coastal aerial surveys in Milne Inlet (approximately 373 km surveyed).

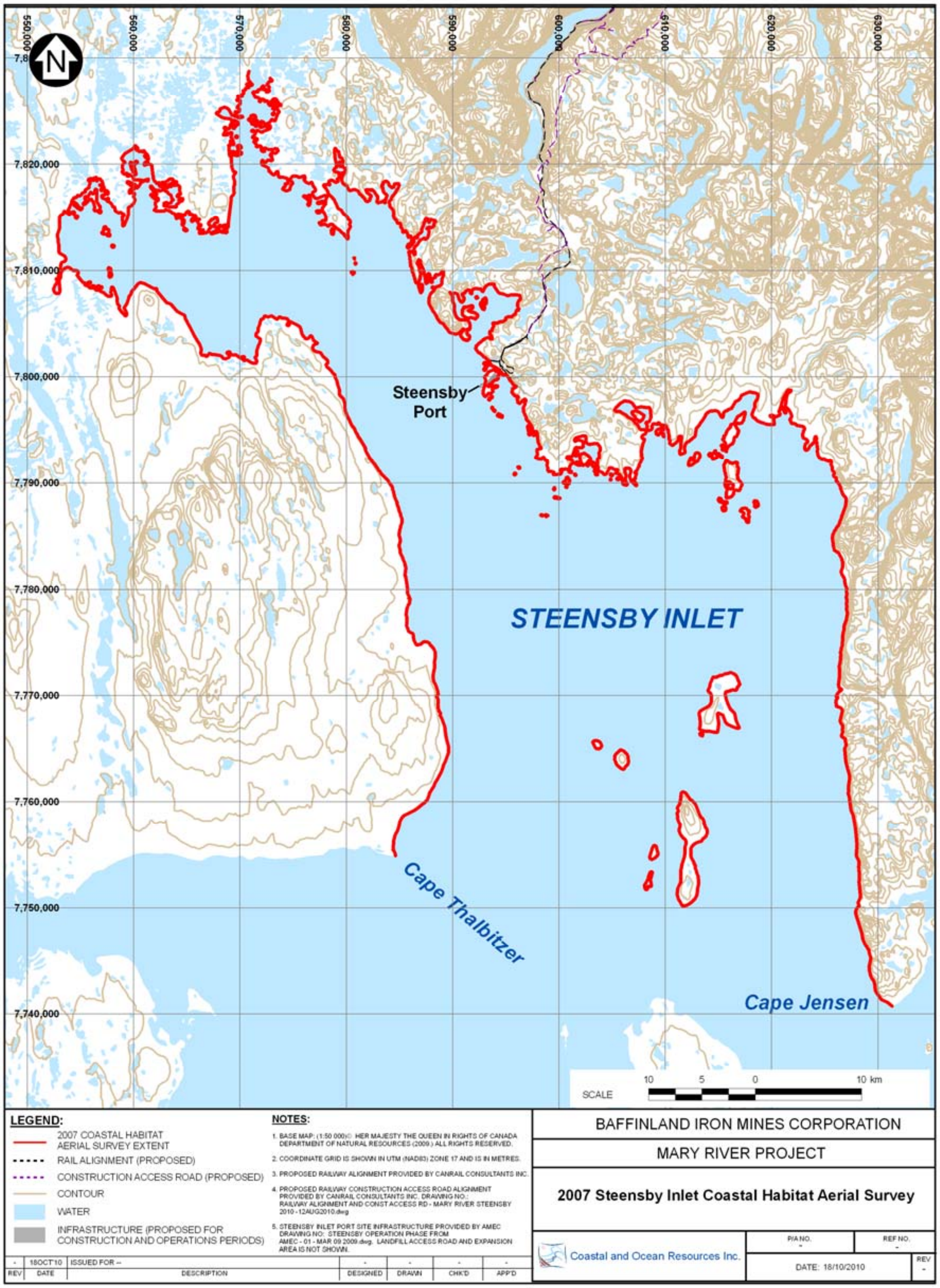


Figure 4.1-4. Extent of coastal aerial surveys in Steensby Inlet (approximately 710 km surveyed).

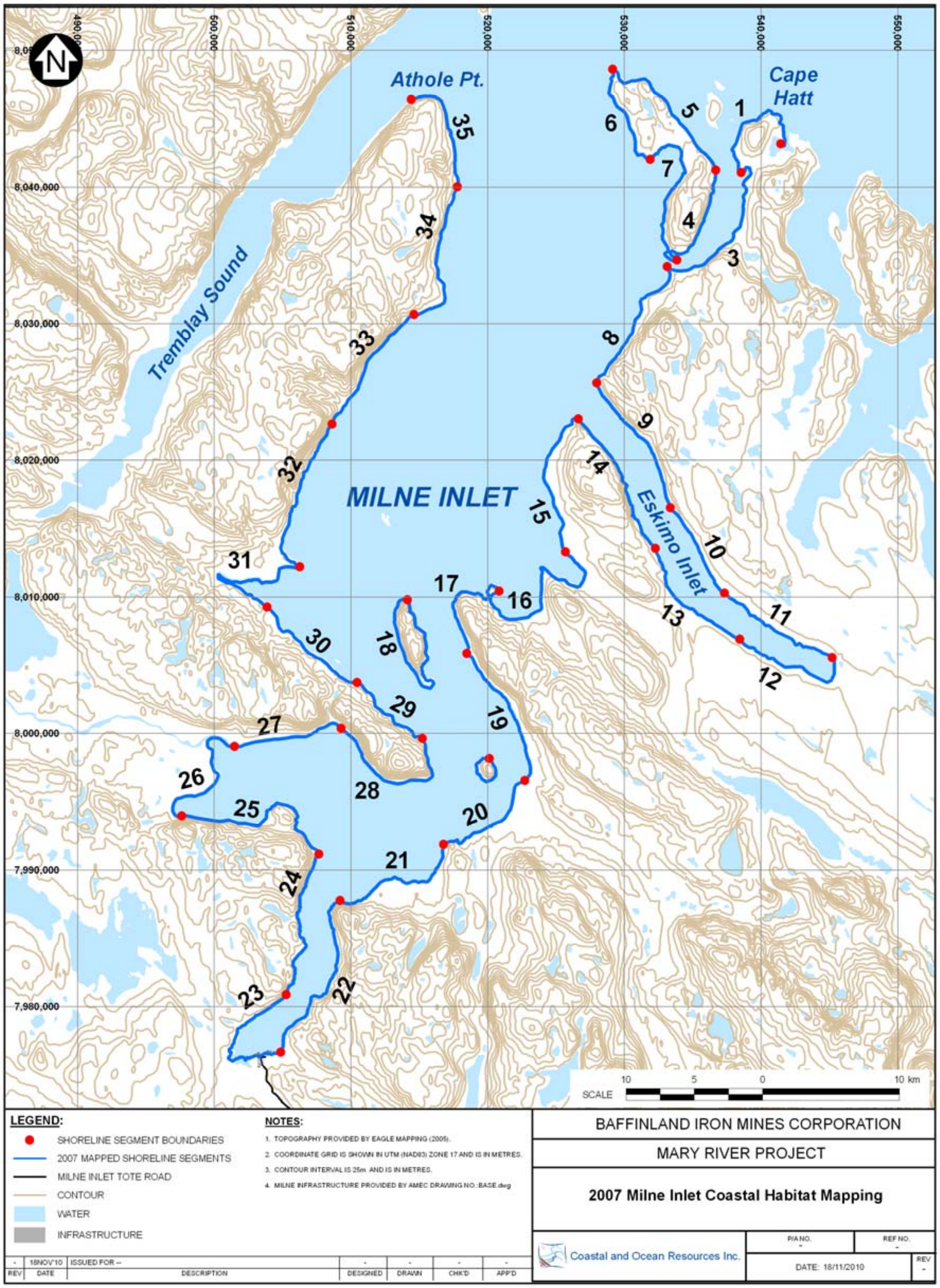


Figure 4.1-5. Segmentation used to summarize the Milne Inlet shore habitat mapping. Segment lengths are generally ~ 10 km.

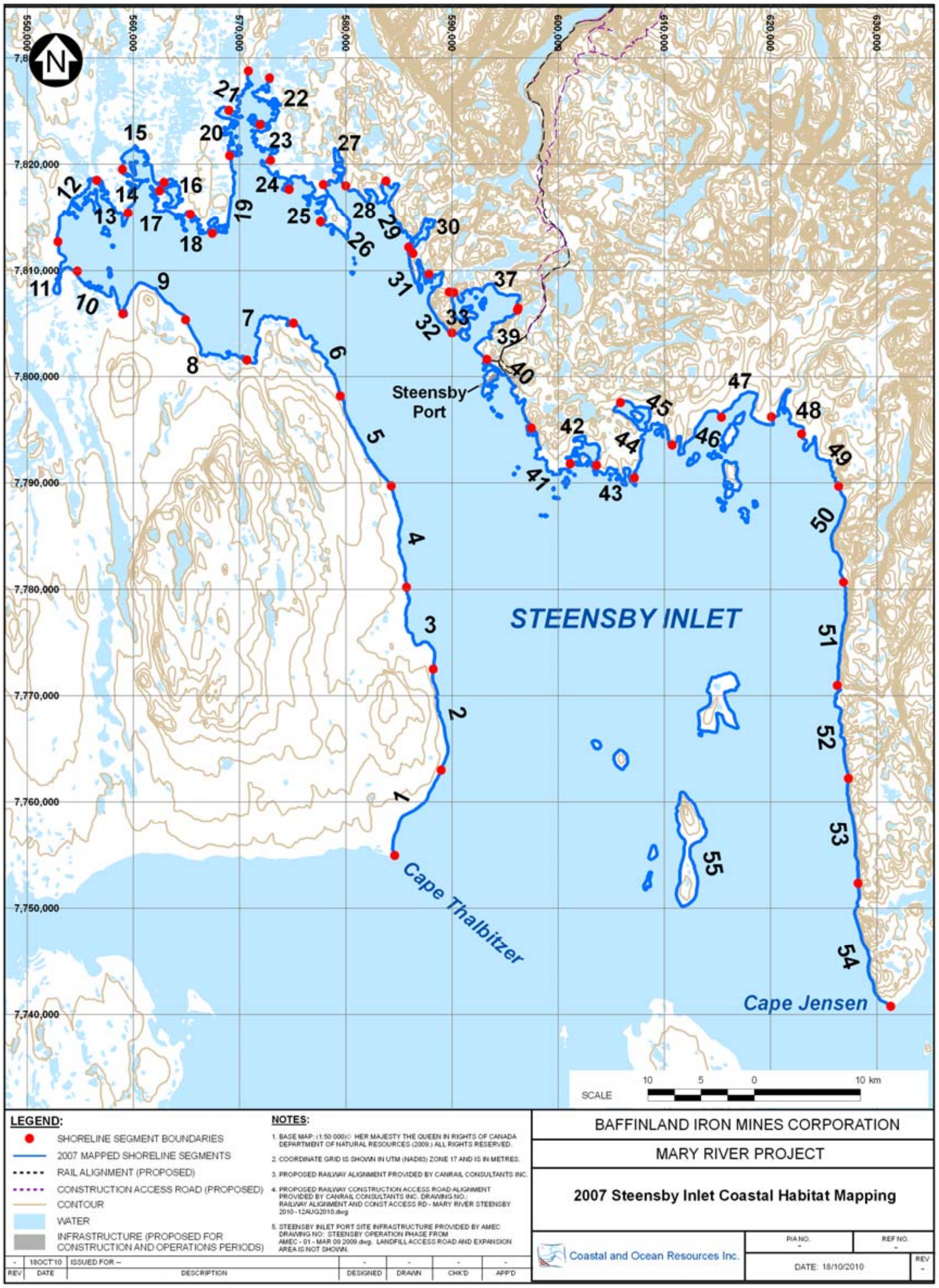


Figure 4.1-6. Segmentation used to summarize the Steensby Inlet shore habitat mapping. Segment lengths are generally ~ 10 km, although addition of offshore islands increased the shoreline length of some segments.

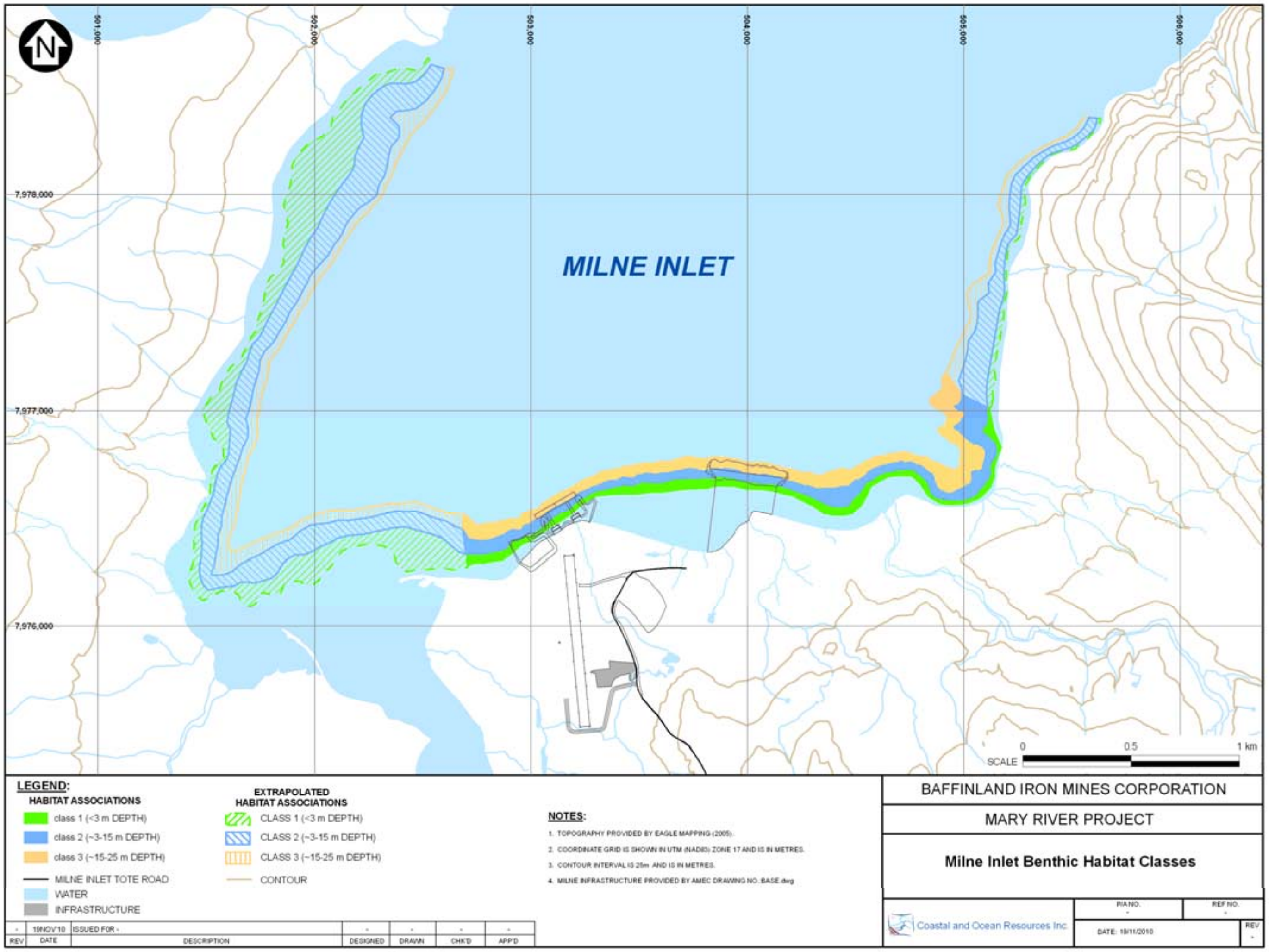


Figure 4.1-7. Milne Inlet seabed habitat classes.

Figure 4.1-8. Example of dense bladed kelps assemblage observed in Milne Inlet at > 3 m depths. Drop camera tether and weight on left of image.

Figure 4.1-9. Unidentified tunicate (likely *Molgu*la sp.) observed during a drop camera survey and photographed at shore stations in Steensby Inlet, September 2008.

Figure 4.1-10. Typical faunal assemblage in Milne Inet at depths > ~15 m showing benthos dominated by brittle stars (Ophiuroidea) and scallops, with absence of vegetation cover.


Figure 4.1-11. Typical floral assemblage in Steensby Inlet seabed habitat class 1 (Intertidal/Upper Subtidal; <3 m depth), showing *Fucus*/filamentous brown algae.


Figure 4.1-12. *Saccharina longicruris,* the common species of bladed kelp which was abundant in Steensby seabed habitat class 2 (Shallow Subtidal; 3-15 m depth).


Figure 4.1-13. Unidentified anemone, the most common epifauna observed in Steensby Inlet seabed habitat class 2 (Shallow Subtidal; 3-15 m depth).


Figure 4.1-14. *Agarum clathratum* kelp in Steensby Inlet seabed habitat class 3 (Moderate Subtidal; 15-25 m depth). *Agarum* is also commonly found in the deeper habitat class 4 (Deep Subtidal; >25 m).

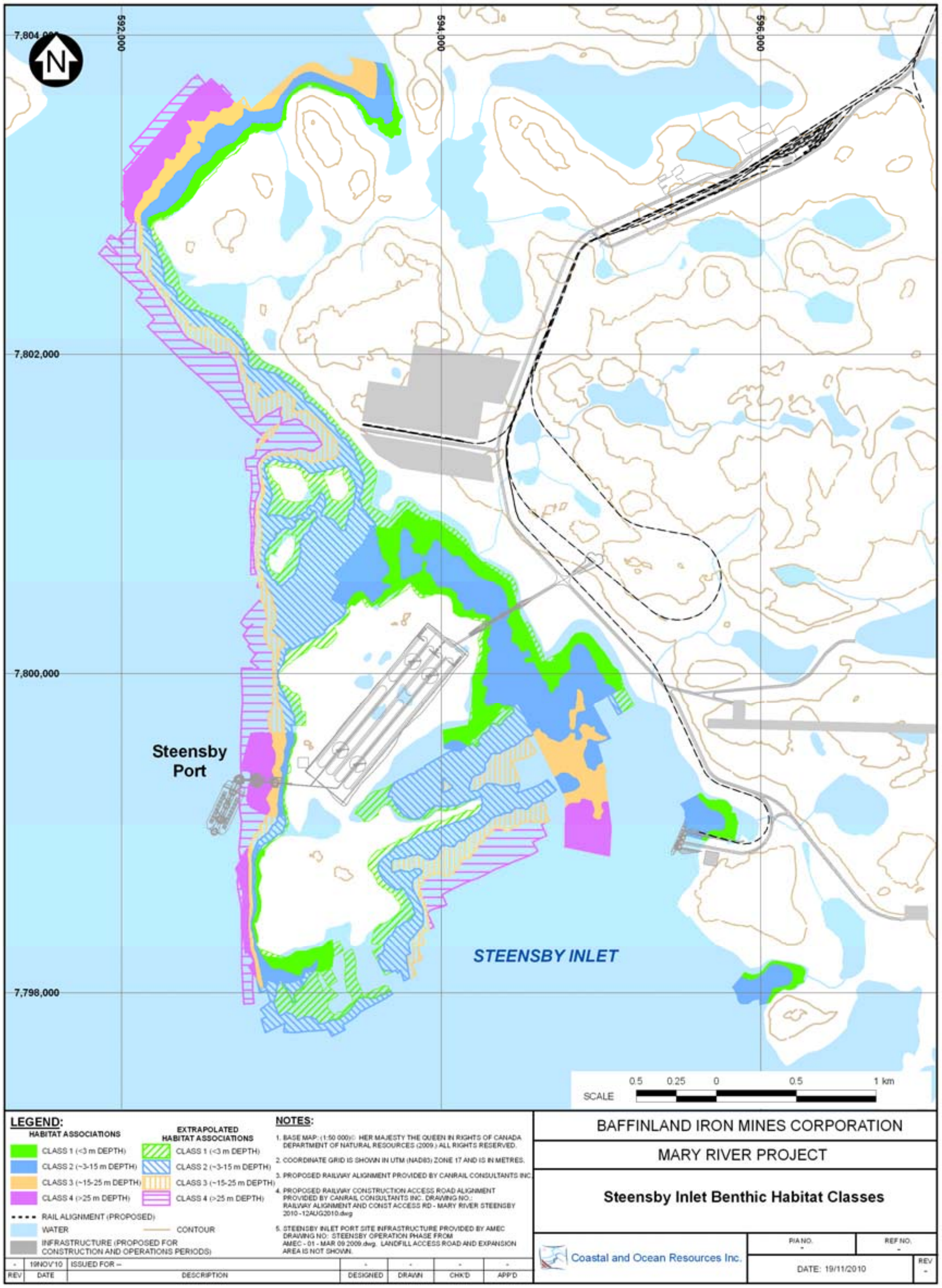


Figure 4.1-15. Steensby Inlet seabed habitat classes from underwater video classification and extrapolation by depth to adjacent areas.

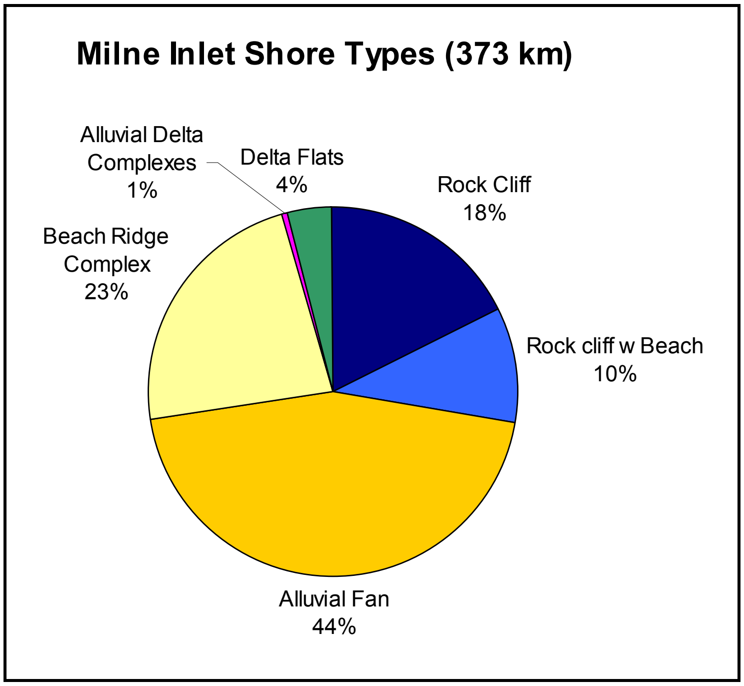


Figure 4.1-16. Summary of shore type occurrence in Milne Inlet based on the classification of 373 km of shoreline (see Figure 4.1-3 for shoreline extent).

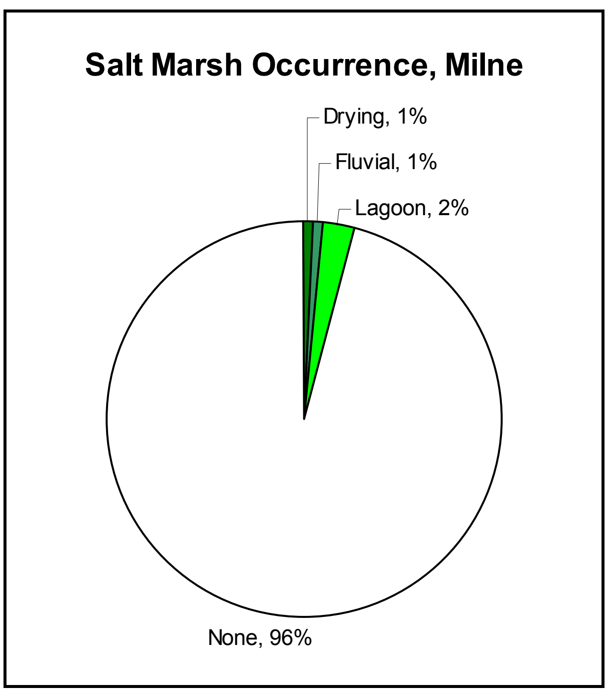


Figure 4.1-17. Occurrence of salt marsh types within Milne Inlet.

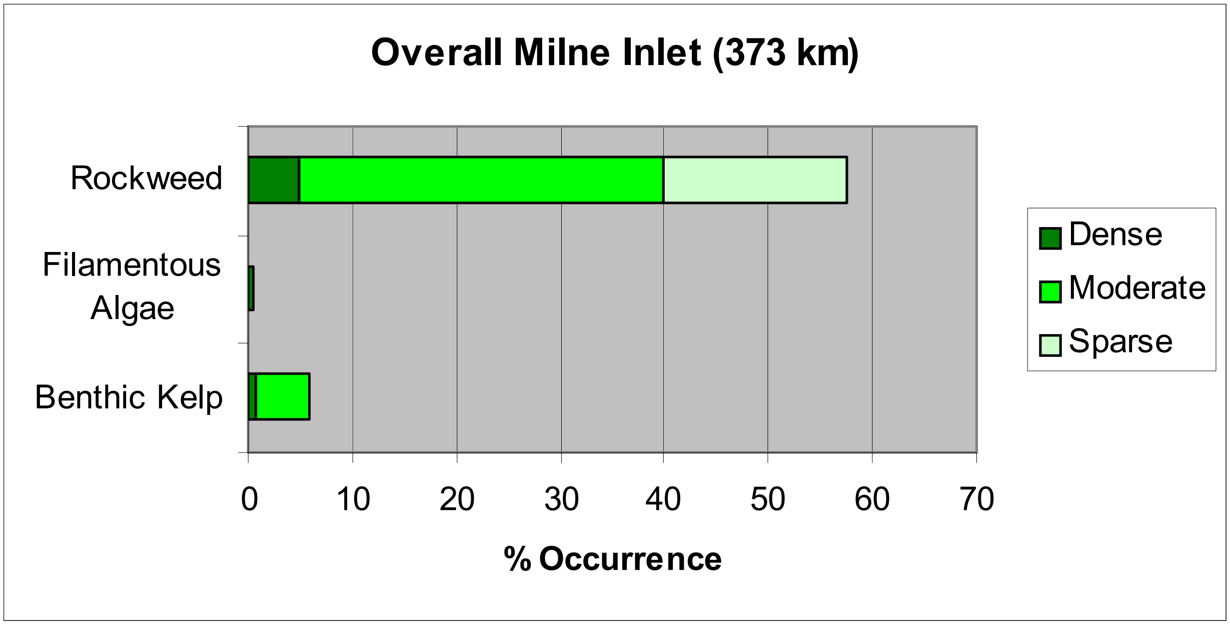


Figure 4.1-18. Occurrence of rockweed, filamentous algae and nearshore benthic kelp within Milne Inlet.

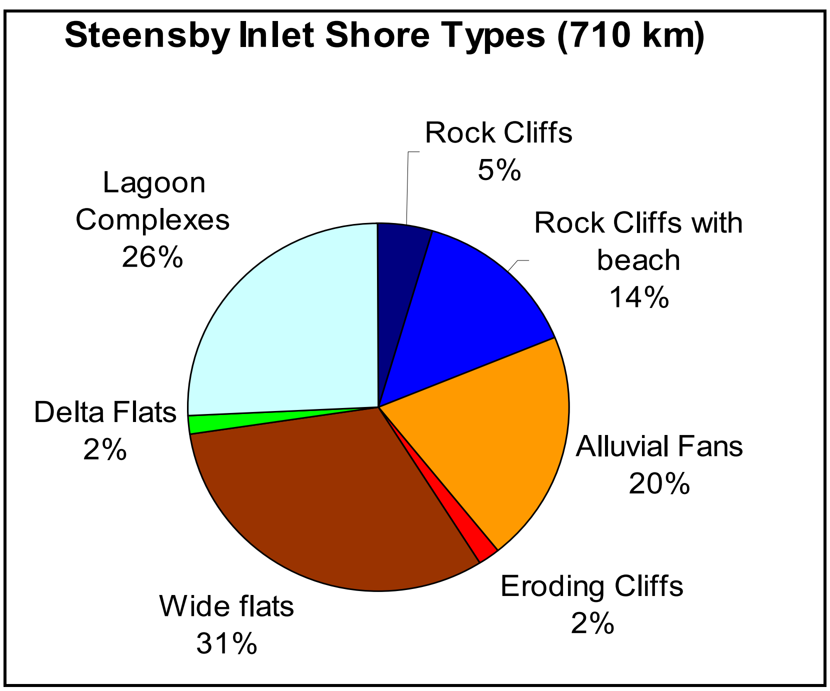


Figure 4.1-19. Occurrence of shore types in Steensby Inlet based on classification of 710 km of shoreline (see Fig. 4.1-4 for shoreline extent).

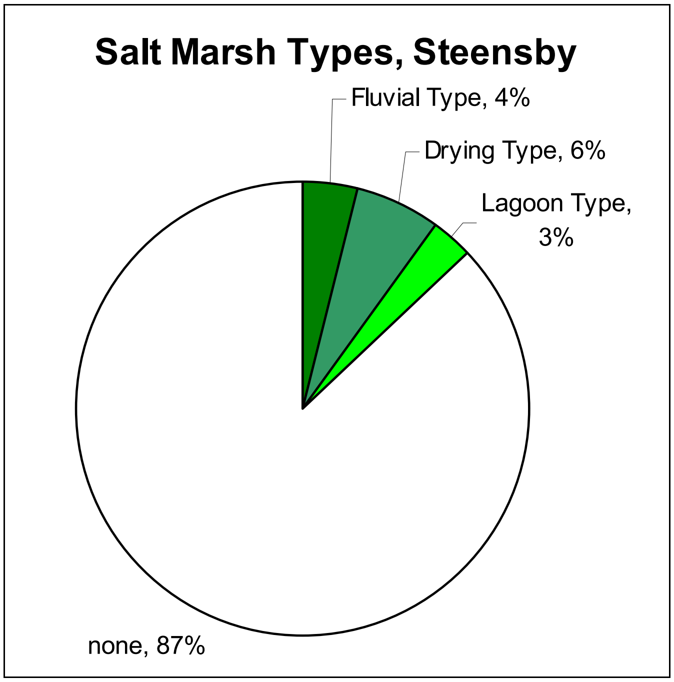


Figure 4.1-20. Occurrence of salt marsh types within Steensby Inlet.

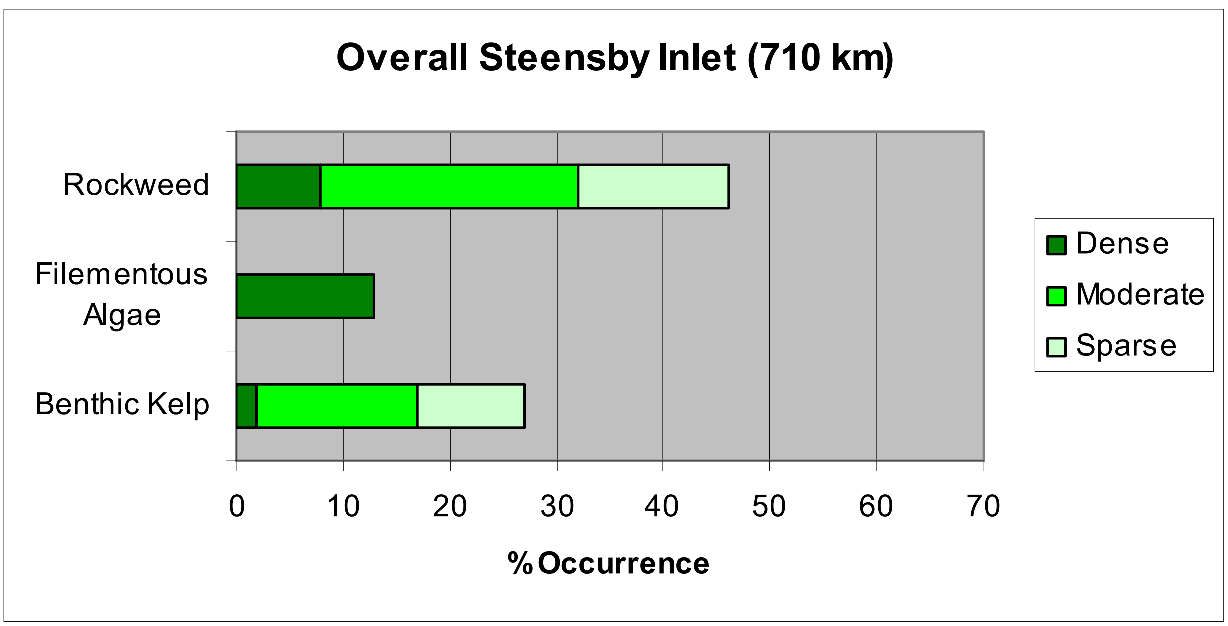


Figure 4.1-21. Occurrence of rockweed, filamentous algae and nearshore benthic kelp within Steensby Inlet.

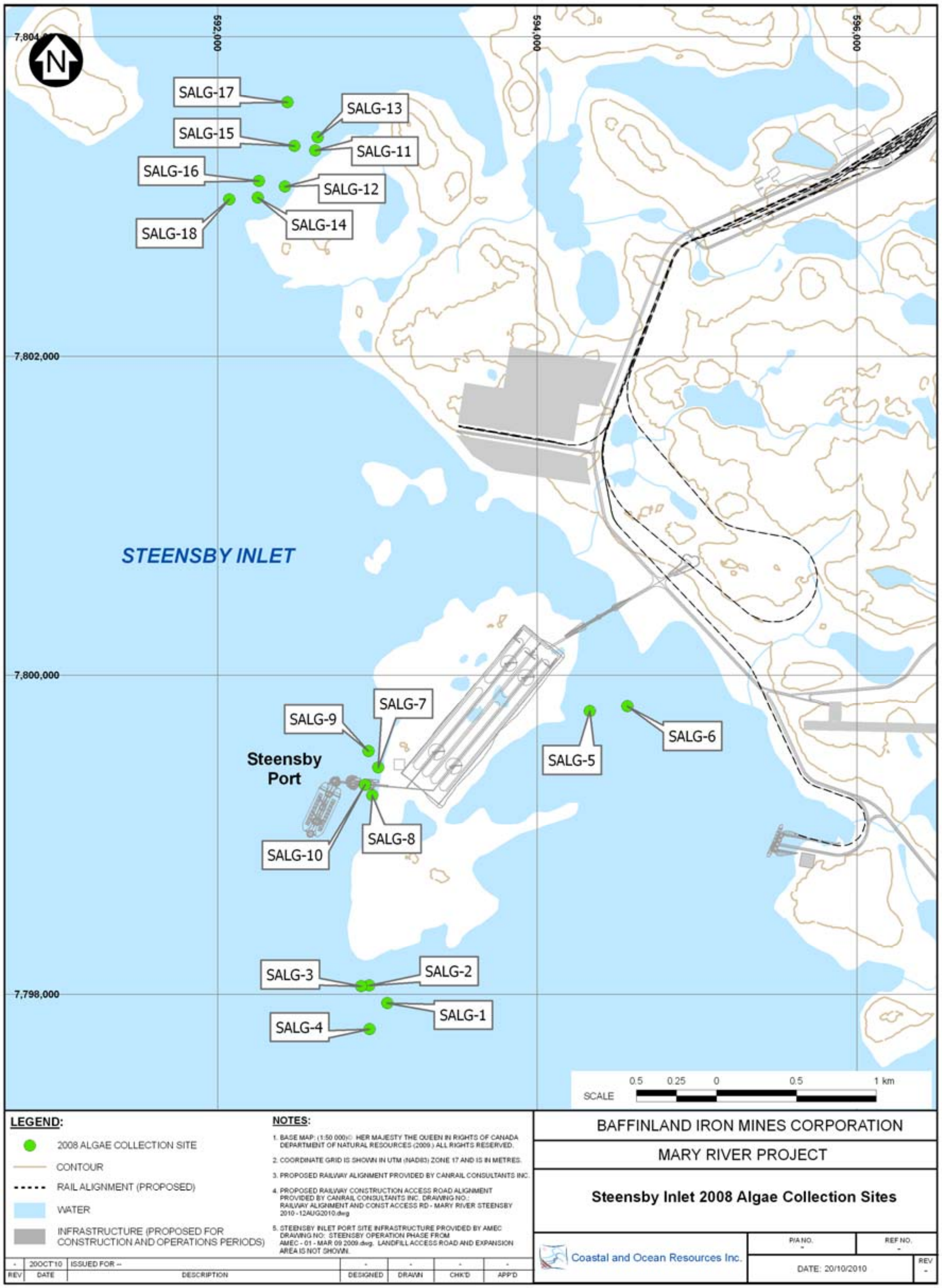


Figure 4.2-1. Locations of algal collection sites in Steensby Inlet, 2008.

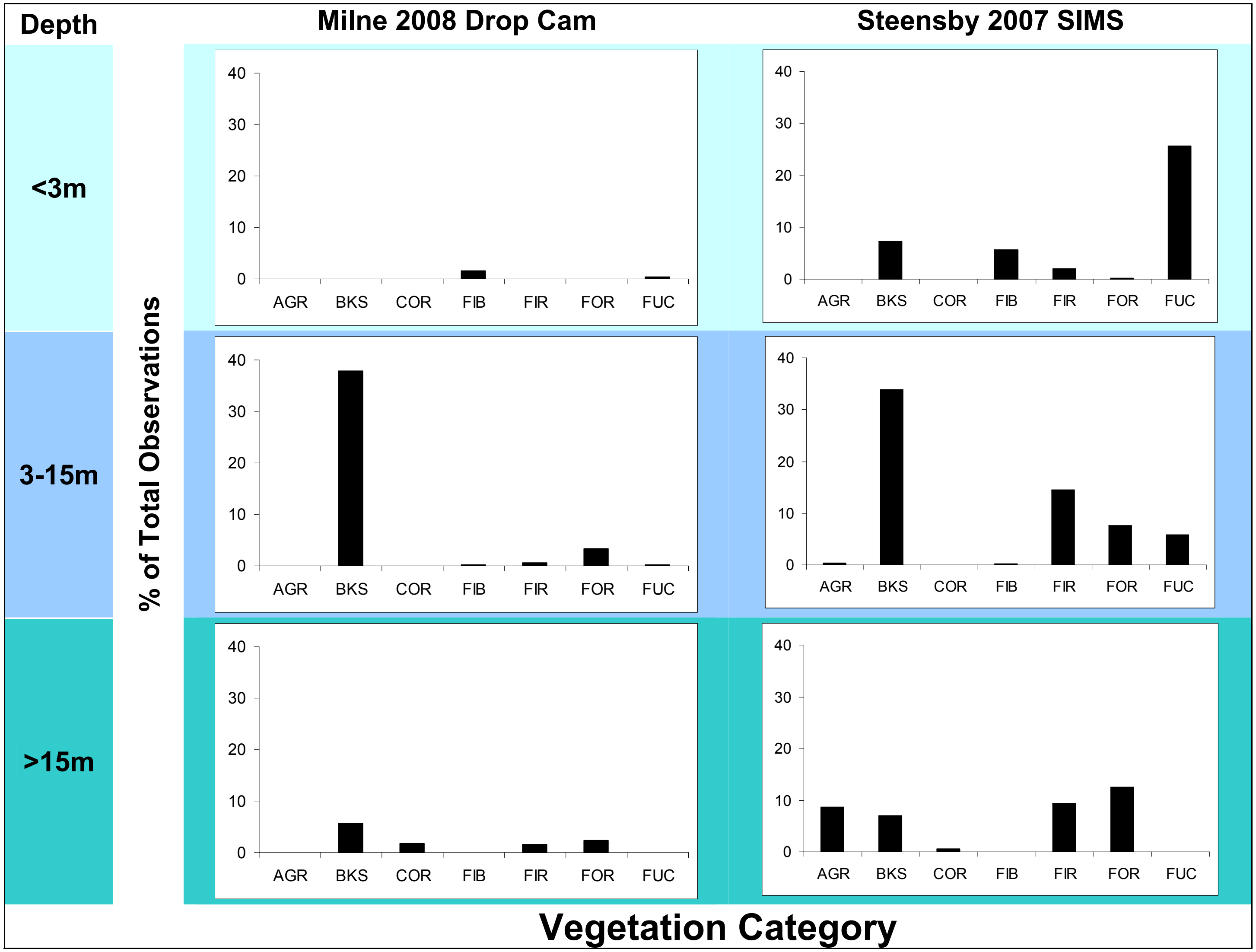


Figure 4.2-2. Estimated total percent cover of each vegetation category per depth zone. See Table 4.2-3 for key to vegetation category codes.

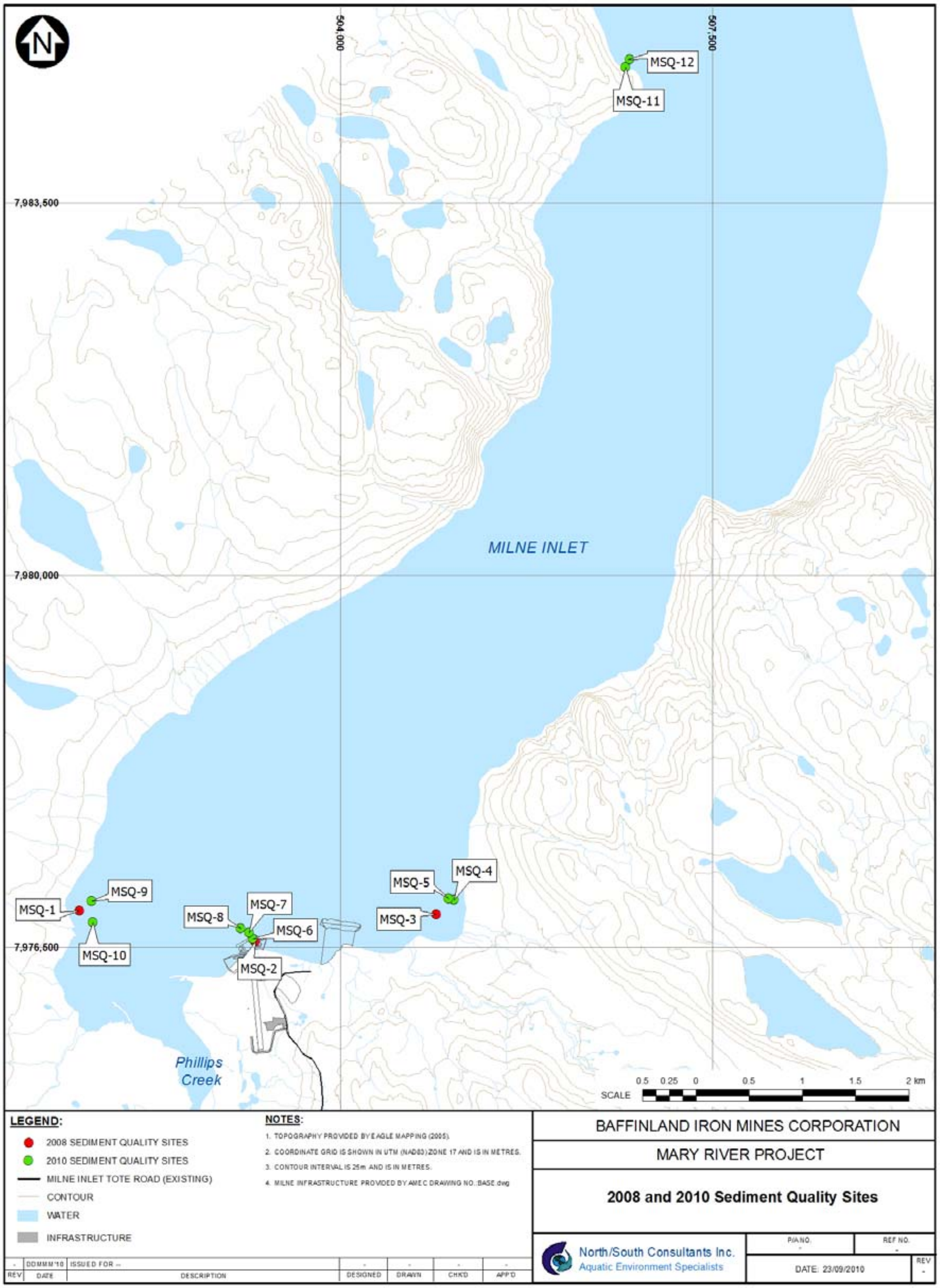


Figure 4.3-1. Zooplankton sampling sites at Milne Inlet, September 2008 and August 2010.

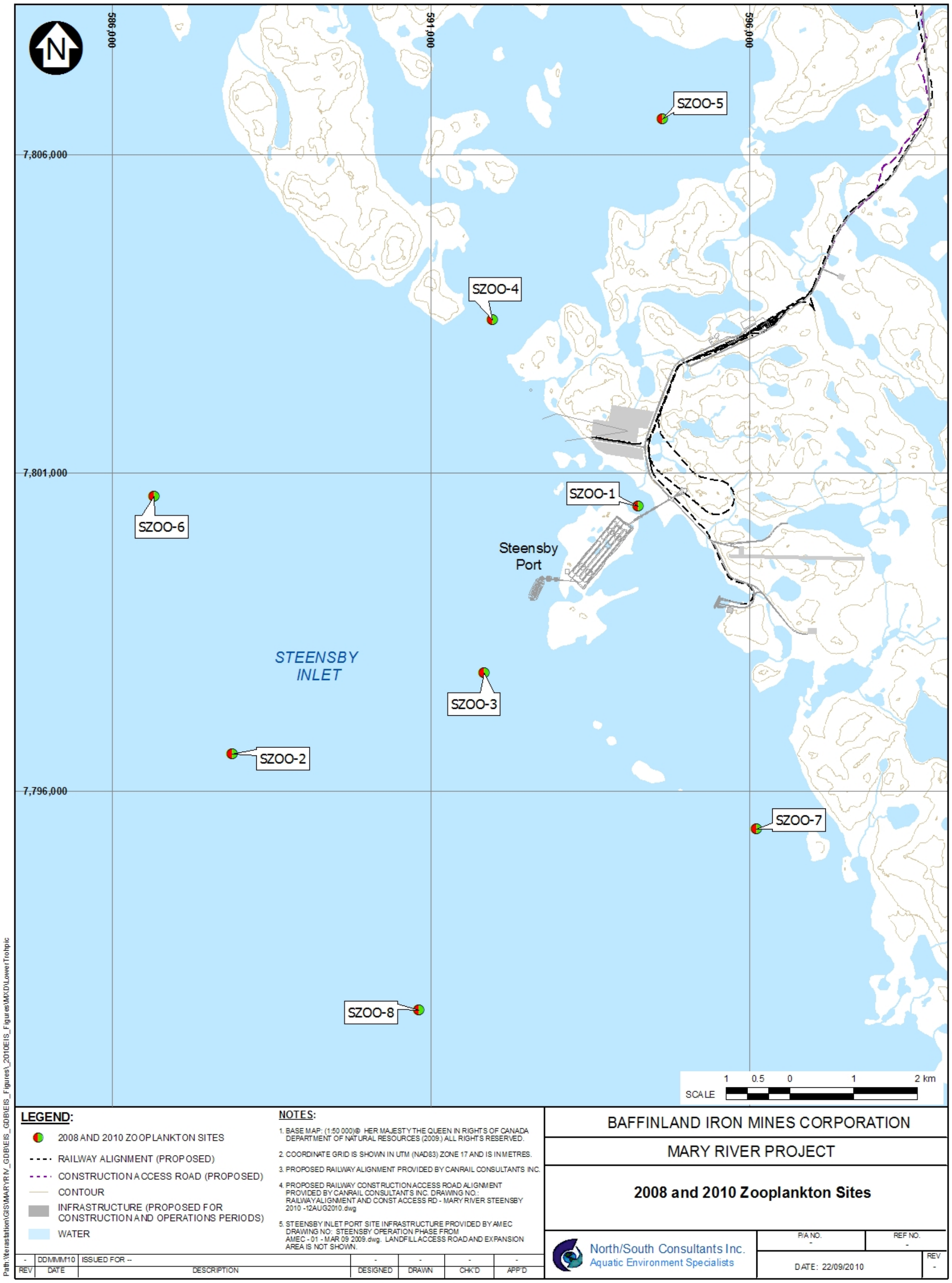


Figure 4.3-2. Zooplankton sampling sites at Steensby Inlet, September 2008 and August 2010.

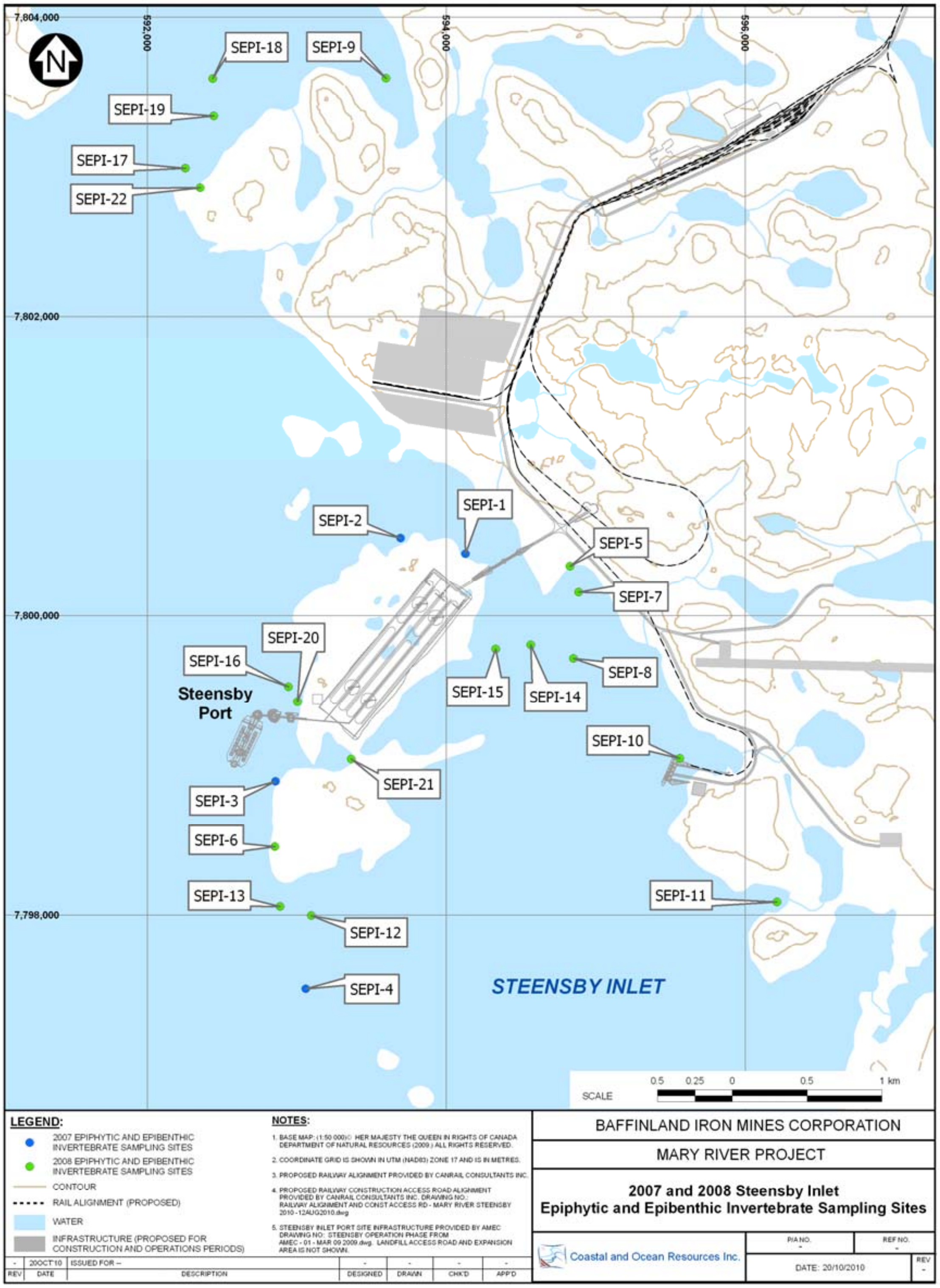


Figure 4.4-1. Location of opportunistic epiphytic and epibenthic invertebrate sample collections near the proposed port site in Steensby Inlet, 2007 and 2008.

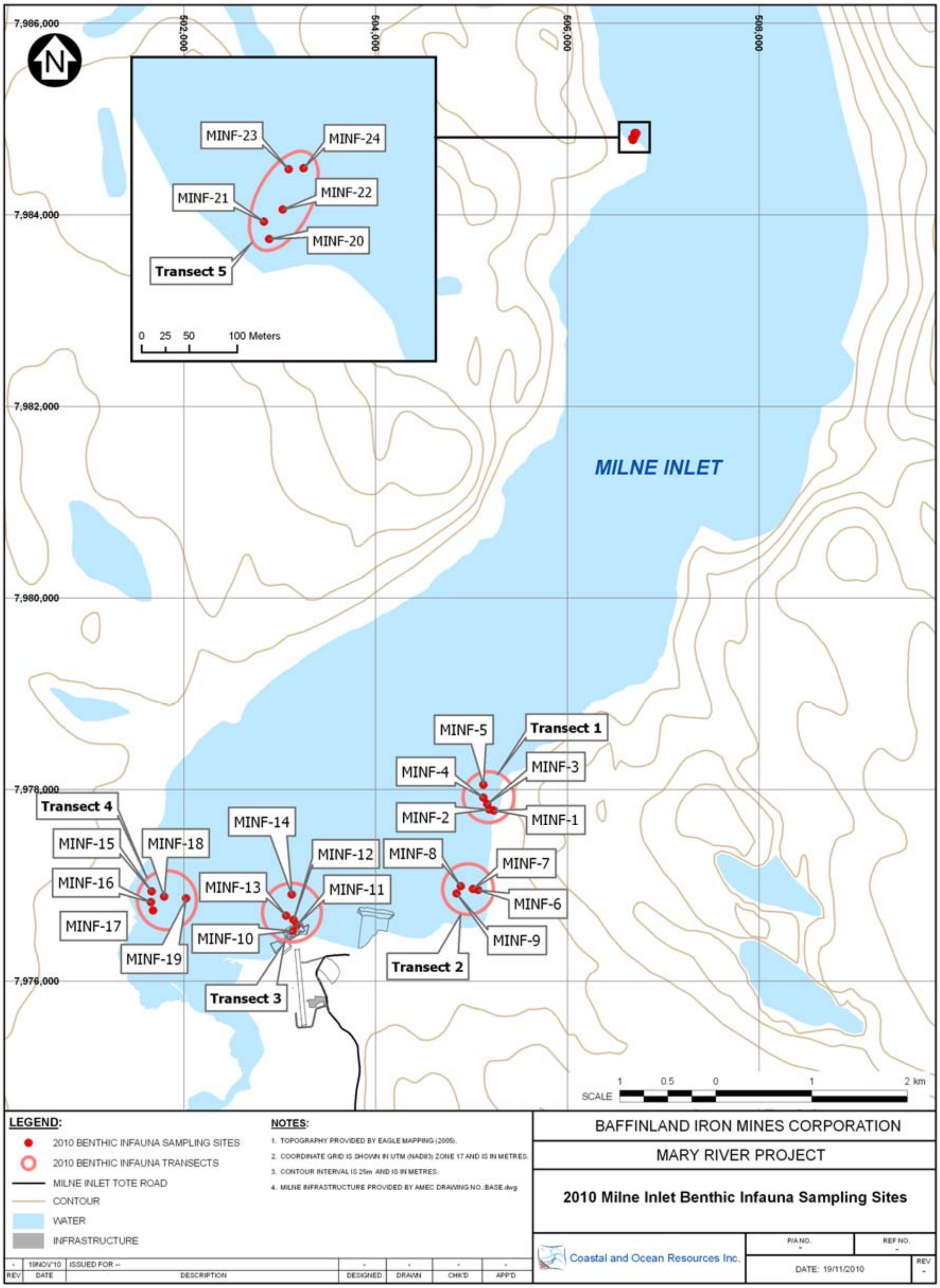


Figure 4.4-2. Location of benthic infauna sampling sites in Milne Inlet, 2010.

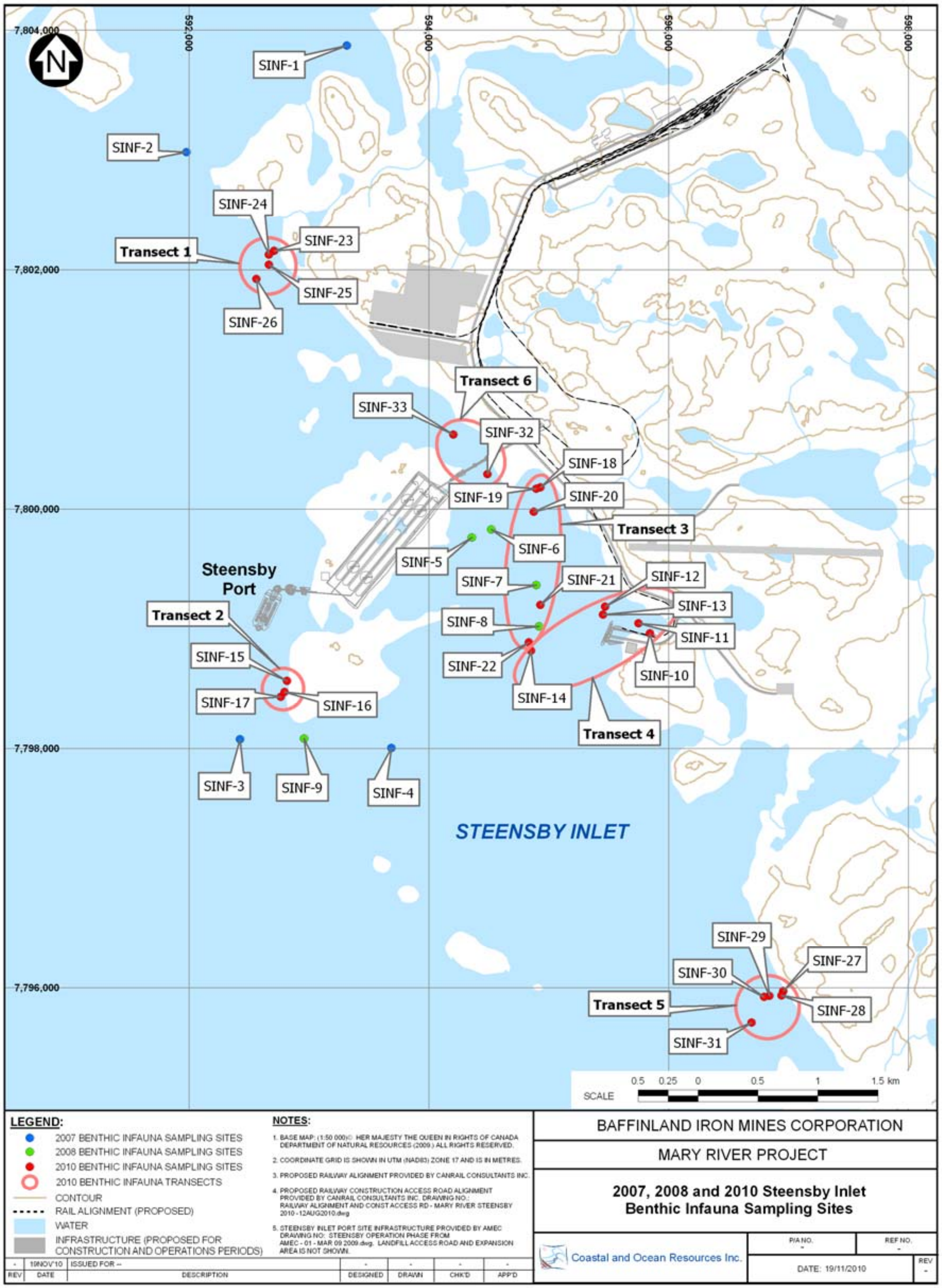


Figure 4.4-3. Location of benthic infauna sampling sites in Steensby Inlet, 2007, 2008 and 2010.

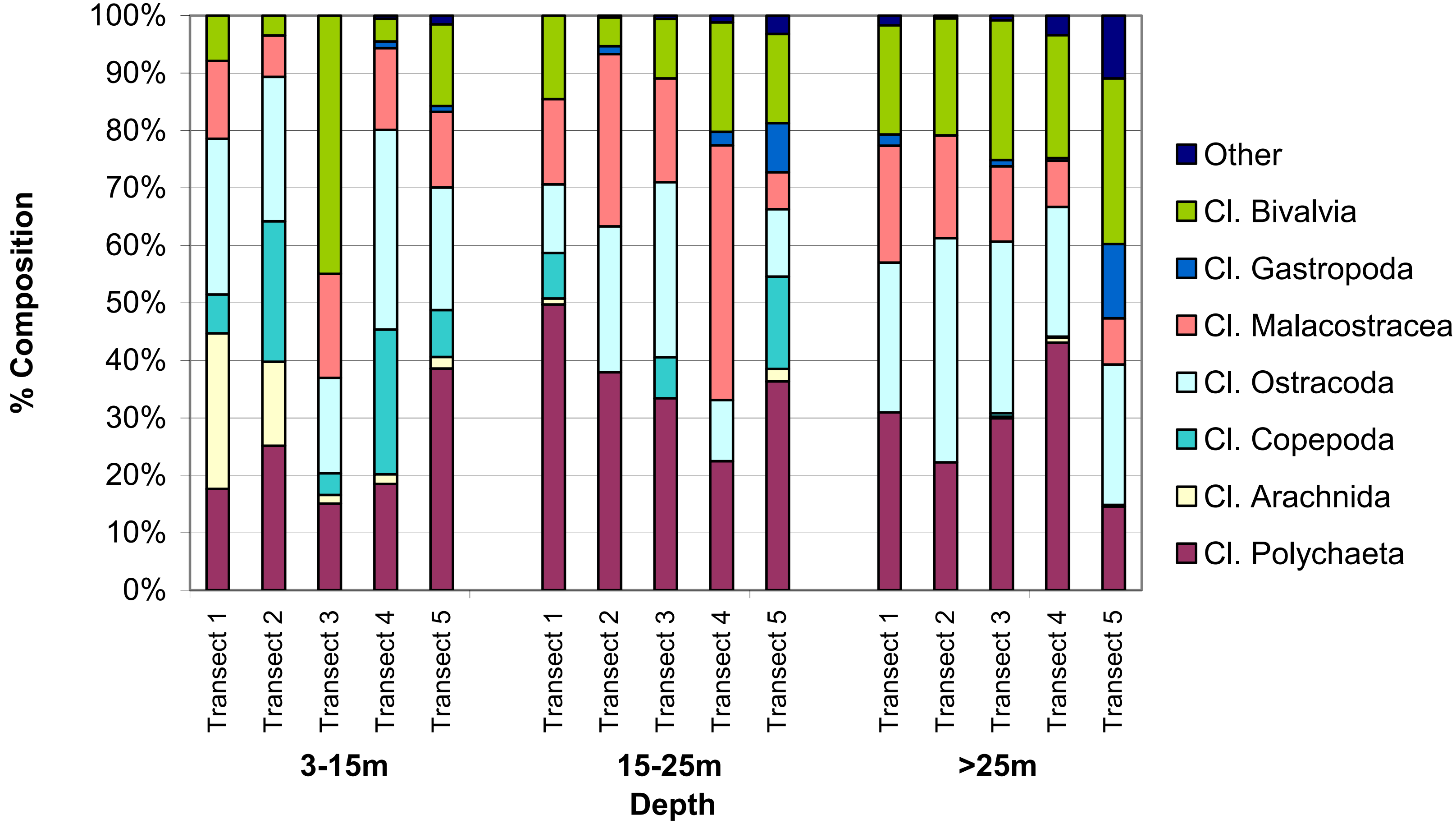


Figure 4.4-4. Percent composition of the benthic infauna community in Milne Inlet in 2010, grouped according to habitat class (i.e., depth interval). Sample size was n = 1 at depths < 25 m, and n = 2 at depths > 25 m (except for Transect 2, where n = 3).

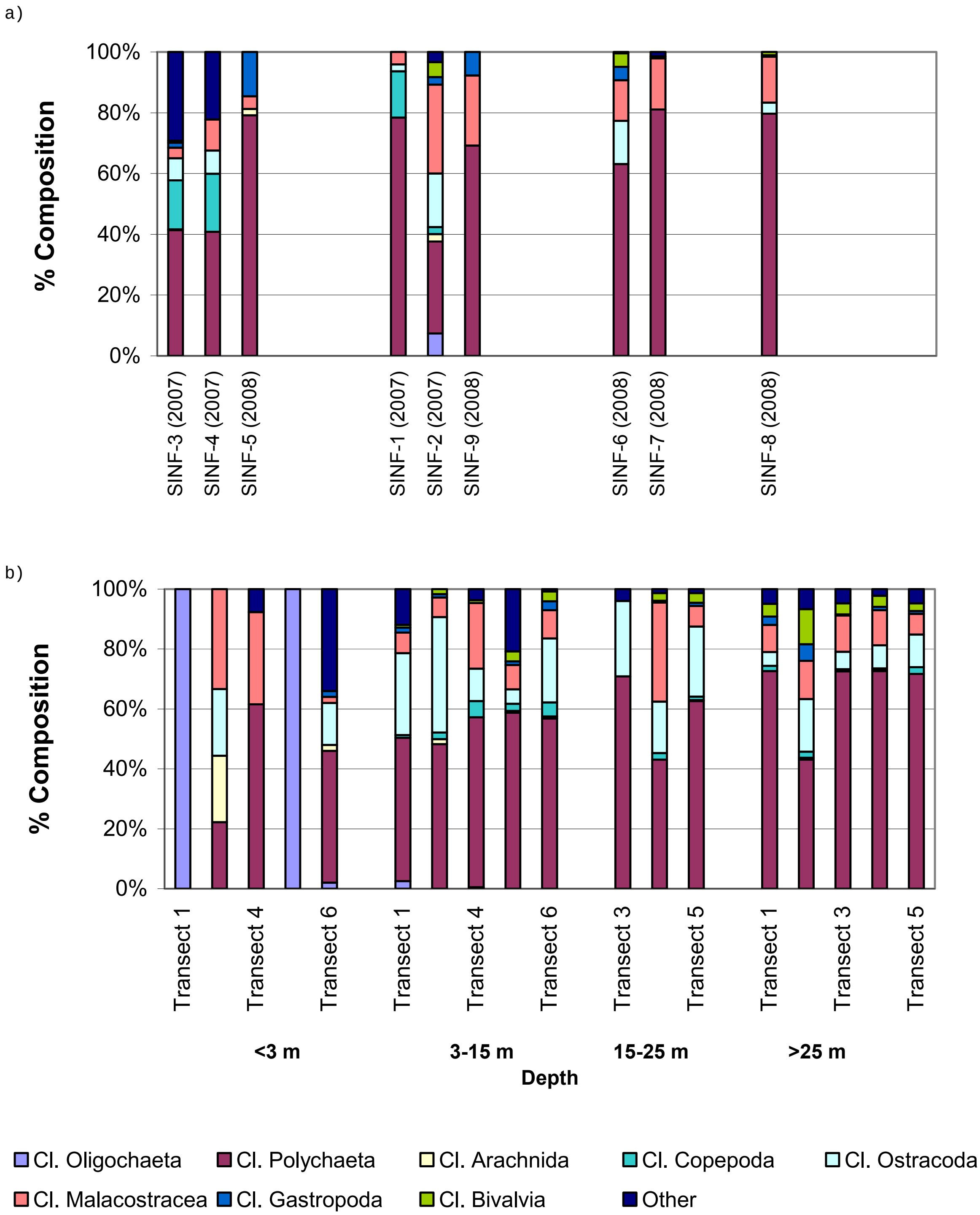


Figure 4.4-5. Percent composition of the benthic infauna community in Steensby Inlet in 2007, 2008 and 2010, grouped according to habitat class (i.e., depth interval). Sample size was n = 1 in 2007, 2008 and in 2010 at depths < 25 m, and n = 2 in 2010 at depths > 25 m.

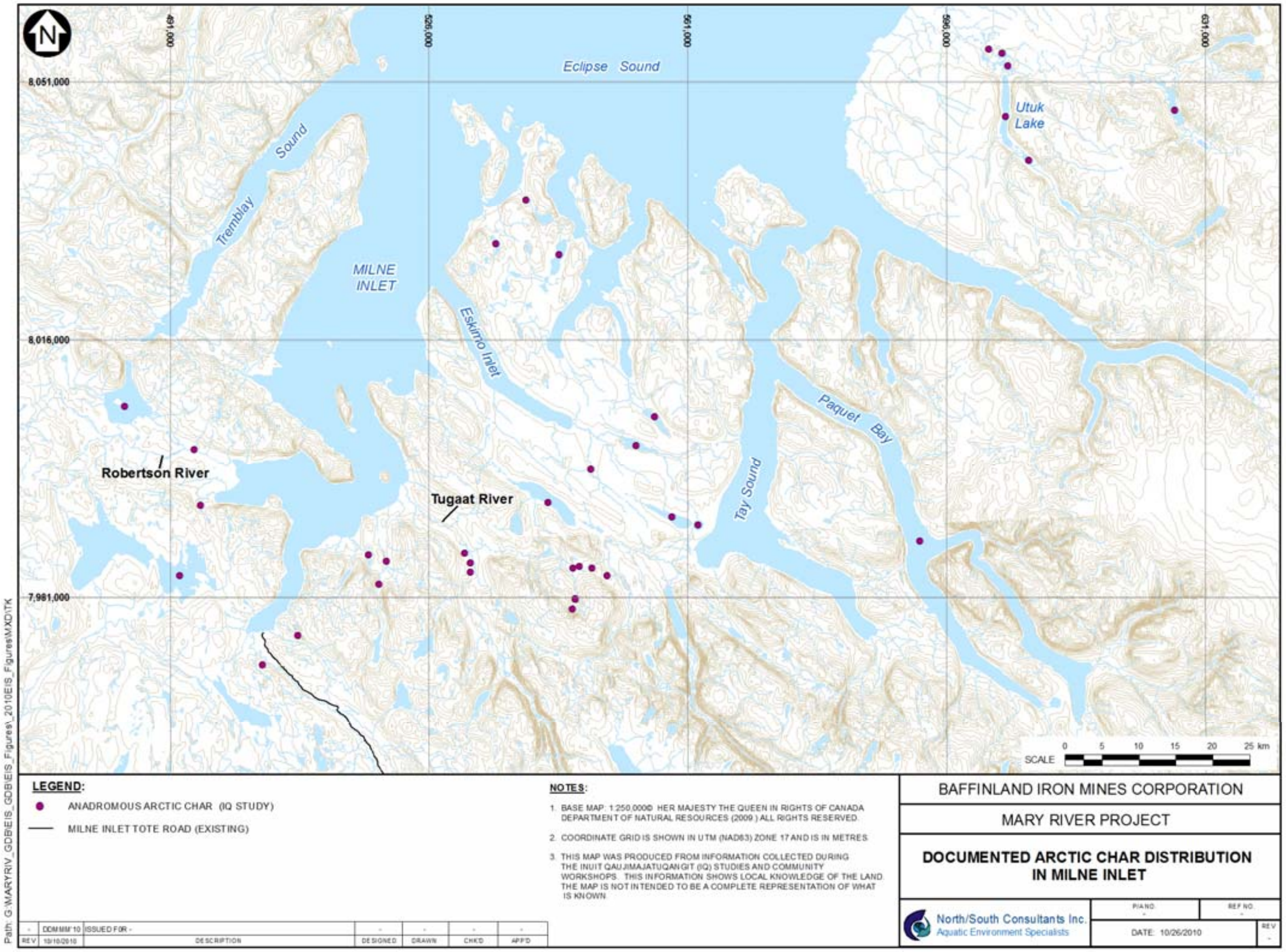


Figure 4.5-1. Distribution of Arctic char in marine and freshwater environments in the vicinity of Milne Inlet. Information from IQ interviews conducted by Knight Piésold Ltd. in Igloolik, Hall Beach, Clyde River, Pond Inlet and Arctic Bay.

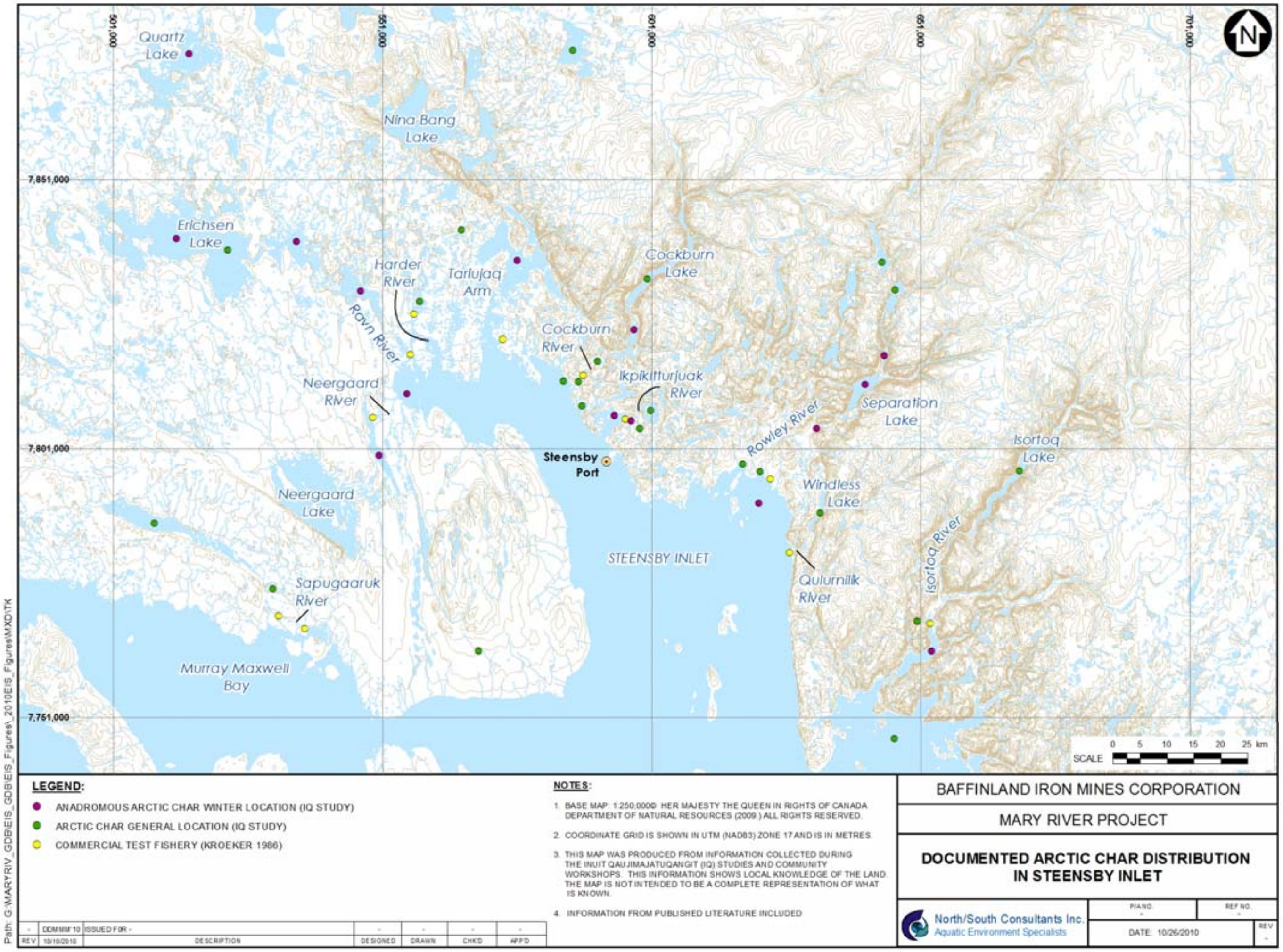


Figure 4.5-2. Distribution of Arctic char in marine and freshwater environments in the vicinity of Steensby Inlet. Information from Kroeker (1986) and IQ interviews conducted by Knight Piésold Ltd. in Igloolik, Hall Beach, Clyde River, Pond Inlet and Arctic Bay.

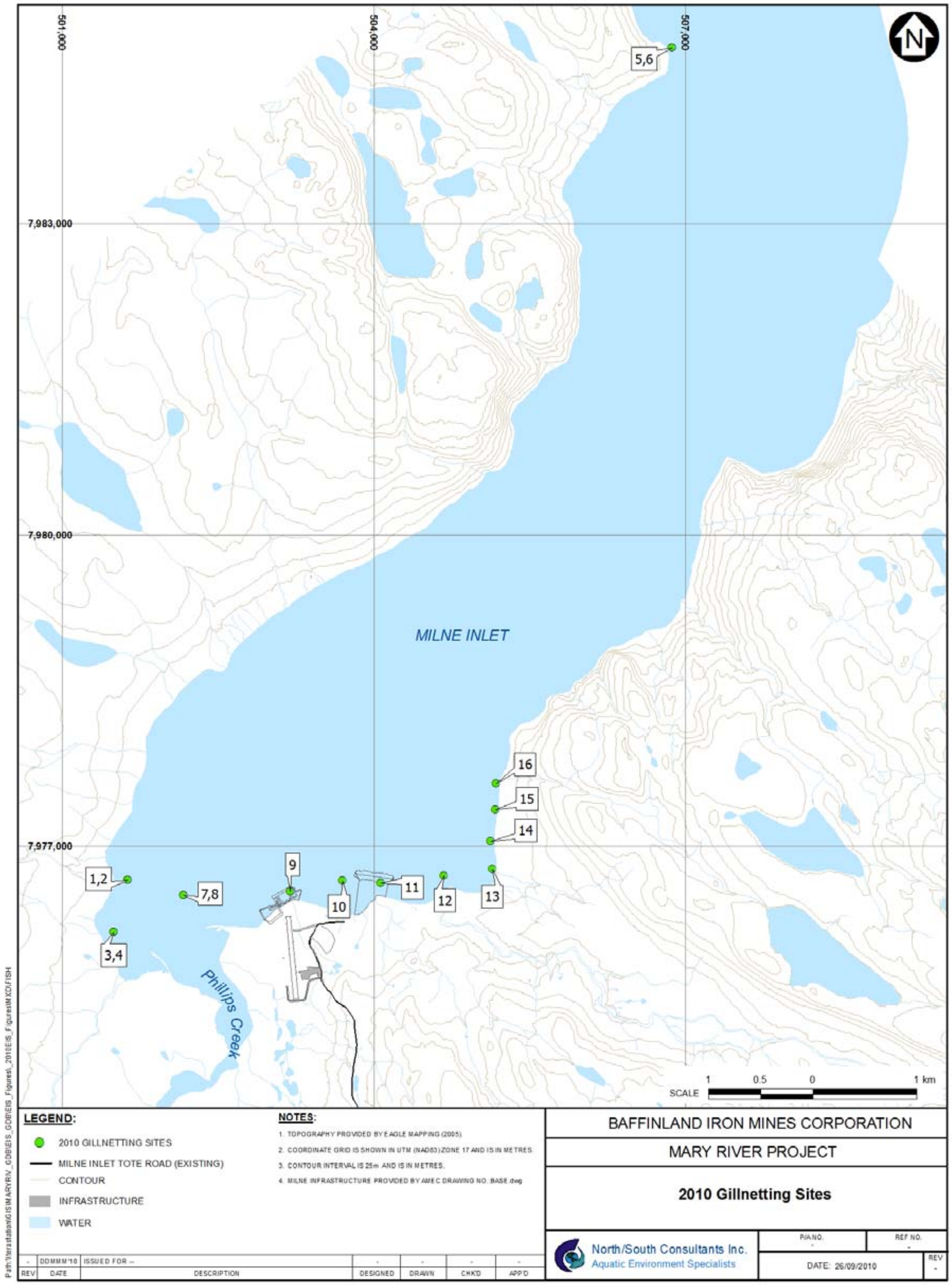


Figure 4.5-3. Location of gill net sets in Milne Inlet, 2010.

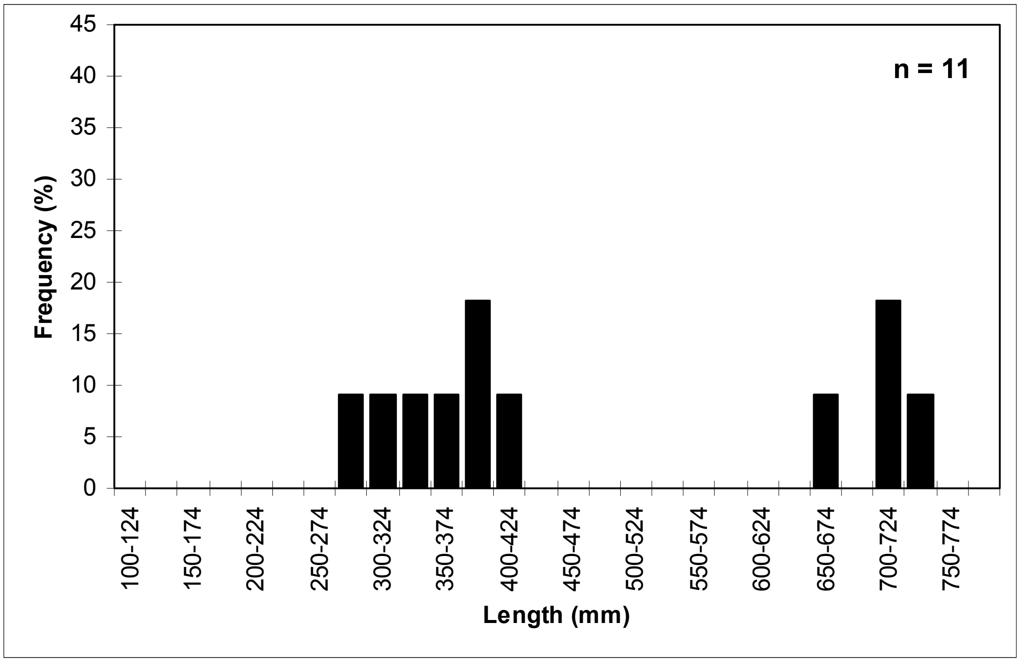


Figure 4.5-4. Length-frequency for Arctic char captured in Milne Inlet, 2010.

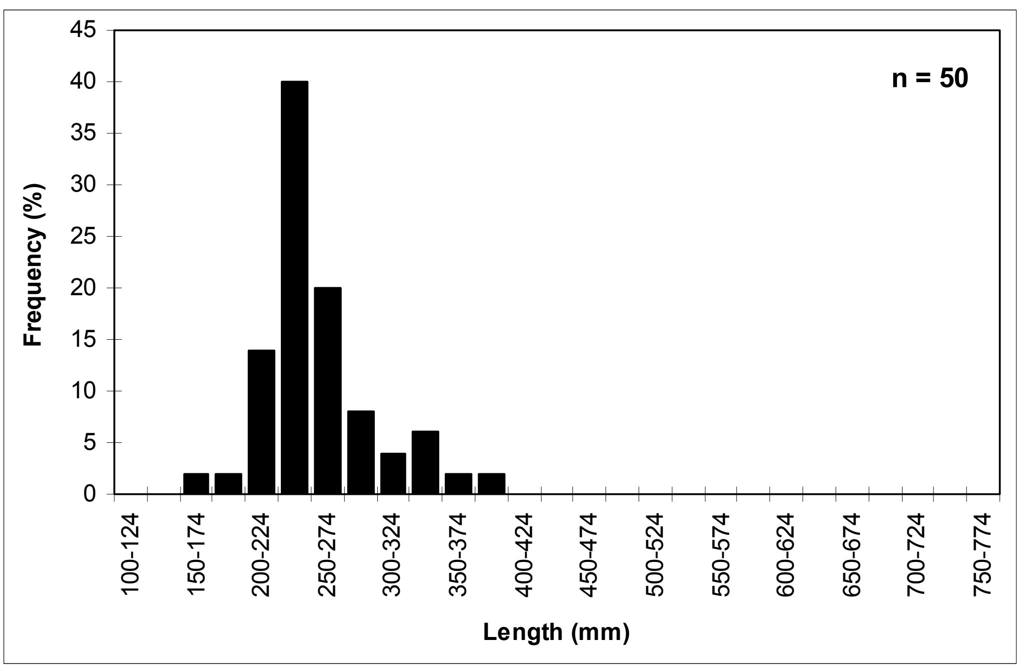


Figure 4.5-5. Length-frequency for shorthorn sculpin captured in Milne Inlet, 2010.

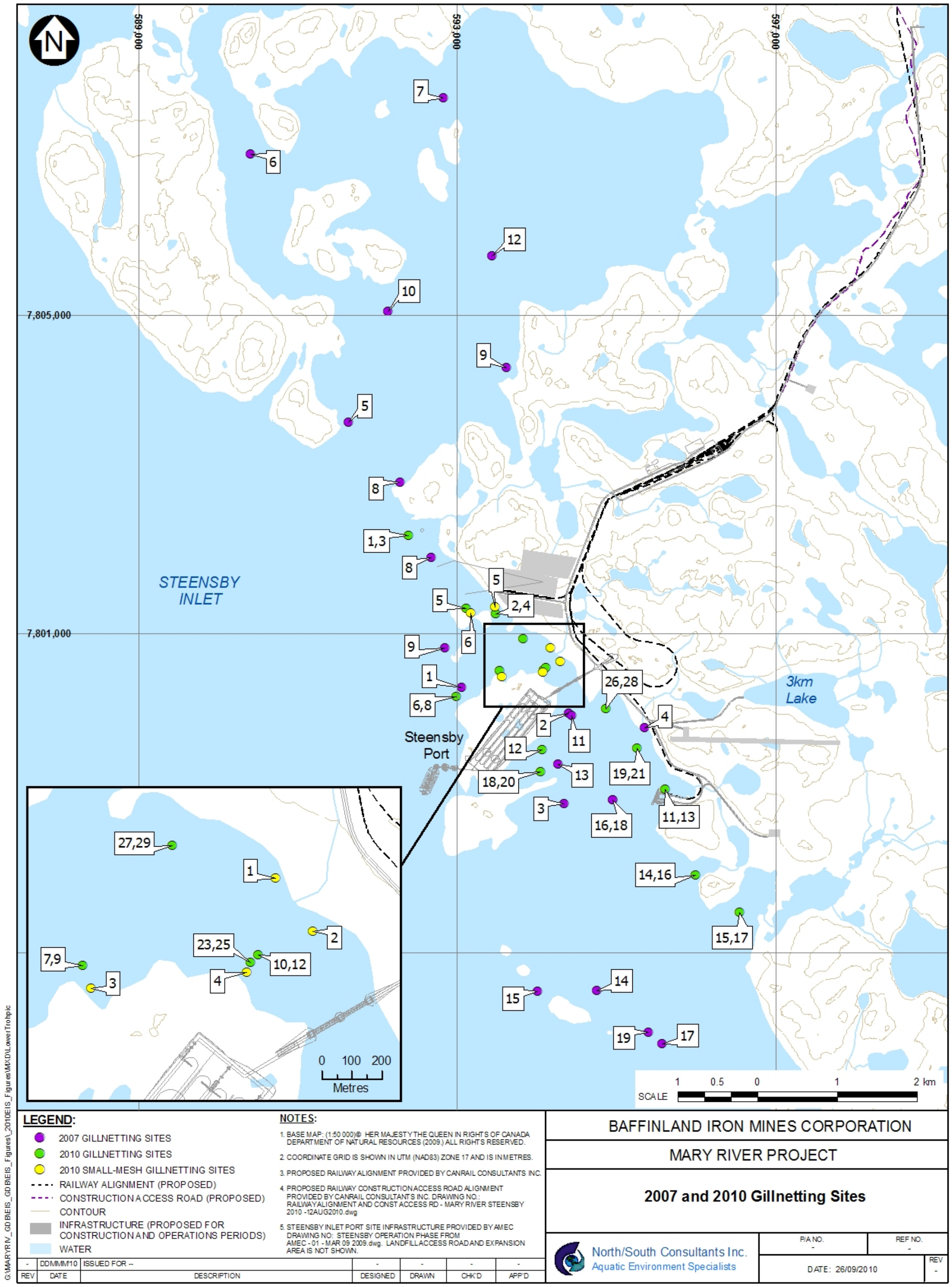


Figure 4.5-6. Location of gill net sets in Steensby Inlet, 2007 and 2010.

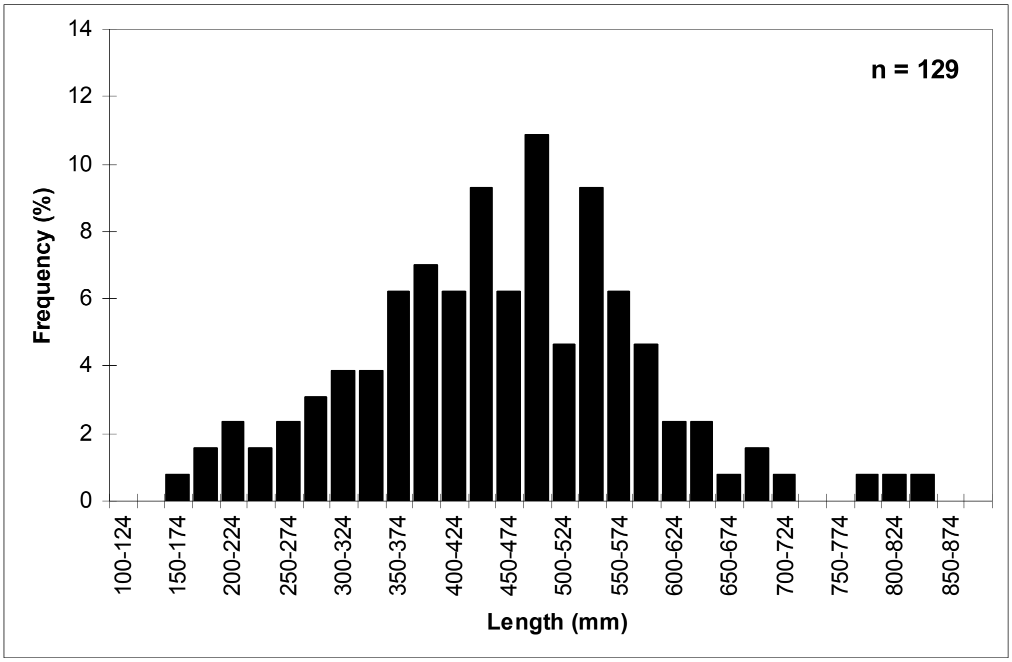


Figure 4.5-7. Length-frequency distribution for Arctic char captured in Steensby Inlet, fall 2007.

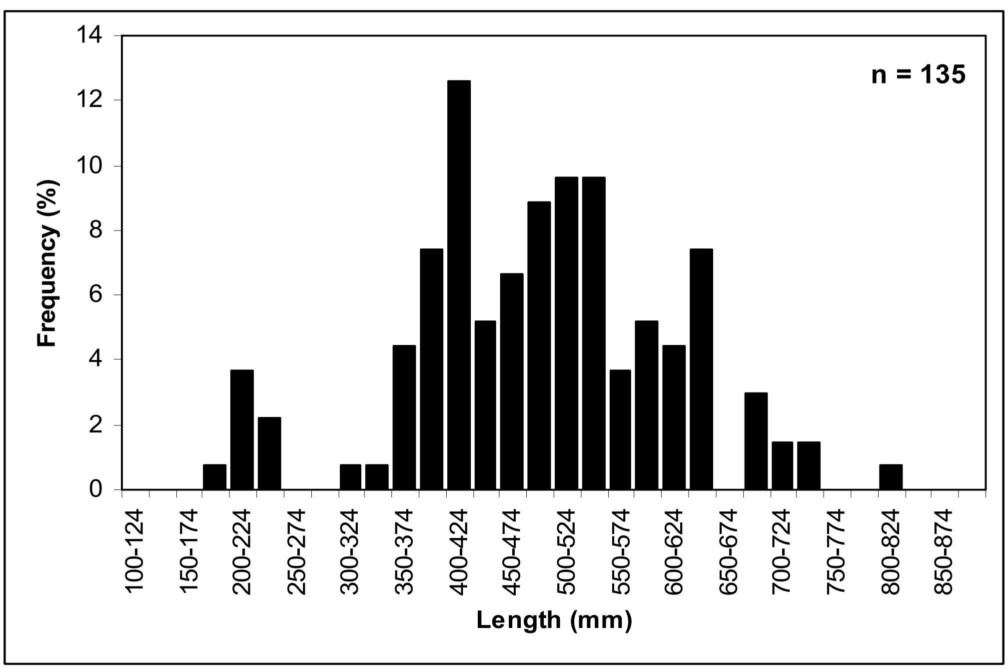


Figure 4.5-8. Length-frequency distribution for Arctic char captured in Steensby Inlet, fall 2010.