Compendium of Monitoring Activities at Disposal at Sea Sites in 2006-2007

Annual Report to the Office of the London Protocol
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Environmental Protection and Operations Directorate
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Cover: A typical pile of musk-ox offal disposed of on sea ice at the Sachs Harbour, Northwest Territories disposal site.

Summary

Canada is a maritime nation whose 243,790 km of coastline is the longest of any nation in the world. The Canadian maritime environment is relatively uncontaminated, but does have some problems. One of the measures in place to protect Canada's marine environment and meet our international obligations under the *London Convention 1972* and its *1996 Protocol*, is the regulation of disposal at sea through a permit system under the *Canadian Environmental Protection Act, 1999* (CEPA).

Each year, as required by CEPA, Environment Canada conducts representative monitoring at disposal at sea sites. This National Compendium of Monitoring Activities provides a technical summary of the monitoring activities conducted in 2006 at a total of 6 disposal sites. This compendium is produced annually to meet national and international reporting obligations.

In the Atlantic Region, the Charlottetown Harbour disposal site was selected for monitoring to investigate its stability and the possible effects of dredging and disposal activities on nearby fish habitat and other uses of the sea. Bathymetric surveys indicate that very little erosion occurs at the site, and that it is a highly stable environment. Also, total suspended solids in the water column around the site do not appear to be increased significantly over natural levels as a result of dredging and disposal. Further bathymetric surveys at the site may be considered to determine long term erosion trends.

Monitoring data are presented summarizing an extensive investigation of the stability of the Sand Heads Disposal site. This site receives very large volumes of dredged material annually, and there is evidence that slope failures have occurred on several recent occasions. The site can remain open, but the timing and rate of disposal activities must be carefully managed to avoid the potential creation of tsunami-type waves. A concurrent study looked at the possibility of diverting some of the disposal activities to Robert Banks for sediment nourishment purposes. However, it appears that nourishment needs would be met in only a few years, so the site would not make a suitable long term alternative to the existing Sand Heads site.

Three disposal sites were monitored in Quebec Region in 2006. This first was disposal site GI-2 at Grosse-Ile, whose stability had been modelled in the past. A survey was conducted to confirm the predictions made by the model, and determine whether any commercially important aquatic species would be impacted in the areas that received dispersed material. Of the three species in or close to the areas affected by the dispersion, none were expected to be affected by it due to their particular ecologies. The second disposal site studied was Depot D. Bathymetric work here determined that the site is highly stable, and will be used to plan future surveys that are intended to investigate the efficacy of caps placed over fine-grained materials with elevated levels of arsenic. Third, baseline bathymetric data was collected at Depot E, which is a newly designated disposal site and the largest now open in the Quebec Region.

Permits for the disposal of musk ox offal have been issued six times in the past at the Sachs Harbour, Northwest Territories disposal site. Monitoring of the site was triggered by concerns raised in the local community. Offal disposed of on sea ice was tagged with sonic transmitters that were located on the sea floor after the ice had melted. Depth measurements under the ice were also taken. These two components of the study indicated that on-ice disposal had occurred outside of the area specified in the permit. Enforcement officers have been notified of this permit violation. Little decomposition was observed two months following disposal. Further work at this site is recommended to determine the full extent of offal dispersal and to ensure that decomposition is occurring as anticipated.

Comments

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Introduction

Canada is a maritime nation. It possesses 243,790 km of coastline, the longest of any nation in the world, and has a vital interest in preserving a healthy marine environment. Though by world standards the Canadian maritime environment is relatively uncontaminated, Canada's territorial waters do have some problems, especially in harbours, estuaries and near shore areas.

Canada regulates disposal at sea through a permit system under the Canadian Environmental Protection Act, 1999 (CEPA 1999). This is one of the measures in place to protect Canada's marine environment and meet our international obligations under the London Convention 1972 and its 1996 Protocol on preventing marine pollution.

CEPA 1999 requires Environment Canada to monitor representative disposal at sea sites each year. This is conducted in accordance with national monitoring guidelines and is dependant on available resources from the disposal fees collected. In order to respond to Canada's national and international reporting obligations, this National Compendium of Monitoring Activities, based on regional reports, is produced annually.

Role of monitoring

Disposal site monitoring allows permittees continued access to suitable disposal sites by helping to ensure that the permit conditions were met and the use of the site has not caused unacceptable or unpredicted impacts. It verifies that assumptions made during the permit review and site selection process were correct and sufficient to protect the marine environment and human health. Monitoring allows Environment Canada to gather information and take appropriate action to manage the sites in an environmentally sound manner.

Monitoring also plays a critical role in reviewing the overall adequacy of controls. Information compiled nationally and regionally, over time, provides the basis to assess whether the disposal at sea regulatory controls, guidelines and permit conditions are adequate to protect the marine environment and human health.

Experience gained from monitoring may also highlight the need for research to develop better monitoring tools, or to refine the monitoring program, to address specific environmental, health or public concerns. It is also expected that monitoring will uncover gaps in our understanding of impacts, particularly in the area of cause and effect relationships.

To increase the level of stakeholder involvement, annual meetings with clients and other interested parties are organized to gather additional comments on past monitoring and to guide Regional priorities for future assessments. The annual meetings also ensure Environment Canada’s decisions concerning monitoring activities are carried out in an open and transparent manner.

Finally, Environment Canada’s disposal site monitoring, reporting and stakeholder communication activities are critical to fulfilling its federal and international obligation to apply the Precautionary Principle while administering CEPA.

Conducting monitoring studies

Monitoring at disposal at sea sites is conducted according to national guidelines. Activities carried out in a given year are based on available resources and may involve an assessment of the physical, chemical and biological features of sites under review. Impact hypotheses are generated following permit reviews, and form the basis of this monitoring.

Physical monitoring relates to the collection of geological information that is relevant to determining the area of deposition, delineating the disposal site boundaries, studying the accumulation of dredged material within the area of deposition, and documenting evidence of sediment transport from the disposal site.

Biological and chemical assessments are undertaken concurrently in many cases, and the monitoring design for these parameters takes into account the size and dispersal characteristics of the site. Chemical monitoring is aimed at measuring the levels of chemicals in sediments and comparing them to lower action levels set by the Disposal at Sea Regulations or other national screening levels for additional parameters of concern.

CEPA Lower Action Levels.

Lower Action Levels for chemicals in sediments (*Disposal at Sea Regulations*) (mg/kg, dry weight)

Chemical	Current Level
Cadmium	0.6
Mercury	0.75
total PCBs	0.1
total PAHs	2.5

Biological monitoring is primarily centred on biological testing in the laboratory and benthic community surveys. The biological test methods currently used for sediment assessment include:

- an acute toxicity test using marine or estuarine amphipods (the endpoint is lethality);
- a fertilization assay using echinoids (the endpoint is fertilization);
- a toxicity test using a photoluminescent bacteria, the Microtox® solid-phase test (the endpoint is bioluminescence); and
- a bedded sediment bioaccumulation test using bivalves (the endpoint bioaccumulation).

Integrative assessment

If sediments are below the lower action levels or other applicable national screening levels for contaminants, and pass all biological tests, no further action is required. However, if levels of contaminants or biological test results demonstrate a cause for concern then the first step is to verify compliance with the terms of the permits issued since the site was last monitored.

The second step generally involve checking potential sources of pollutants and conducting further site characterization. After considering this information, the following hierarchy of interpretative guidance can be applied to the concurrent chemical and toxicological data:

- if sediments at the disposal site contain substances in excess of national screening levels (including lower action levels), pass the acute toxicity test, but fail one sublethal or bioaccumulation test, then consideration could be given to modifying further use of the site and investigating the long term stability of the material onsite;
- if the sediments contain substances below the national screening levels, yet fail any of the biological tests, then further investigation would be required to determine if this is the result of either a confounding factor such as laboratory anomaly, or the presence of a contaminant not included in the chemical screening; or
- if the sediments contain substances in excess of the national screening levels and either fail the acute test or fail two (or more) additional tests including the sublethal tests and the bioaccumulation test, then further monitoring, site closure or remediation could be considered.

As well, cursory benthic community surveys can be used as a general sediment quality indicator. The overall assessment of the disposal site considers all available information from physical, chemical and biological monitoring.

Intensity of monitoring

Monitoring at every disposal site is not considered necessary, as current knowledge of impacts related to disposal of dredged material from routine dredging allows for good assessments to be drawn from representative disposal sites. Representative sites are selected by attempting to ensure that the major sites (>100,000 m3 of dredged materials/year) are monitored at least once every five years. Monitoring at other sites is triggered by national monitoring guidelines criteria which are based on volume, proximity to sensitive areas, or level of concern. The number of sites monitored in a year and the parameters measured at each site depend on the available resources through the collection of fees from permittees.

Reporting

Canada’s Disposal at Sea Program is administered through regional offices which are largely responsible for the permit review process, as well as for planning, conducting and reporting on monitoring studies undertaken in their administrative areas. This compendium, based on regional detailed reports, is produced annually to respond to Canada's national and international reporting obligations. Readers may request more detailed information on any of the monitoring activities in this compendium, from the appropriate regional office.

Atlantic Region: *Charlottetown Harbour, Prince Edward Island*

Background

The Charlottetown Harbour disposal site is located on the southern margin of the Hillsborough River, just northeast of the confluence with the West and North Rivers and in close proximity to downtown Charlottetown. The disposal site has been in use since 1982 and was last used in 2006 (see Table 1). A total of approximately 131,000 m³ of dredged material has been disposed of at the site under the authority of five separate Disposal at Sea Permits.

Table 1 - Disposal Site History – Charlottetown Harbour Disposal Site

Permit Number	Year	Total Quantity Disposed (m³)
4543-2-1264	1982	40,995
4543-2-1790	1985	35,000
4543-2-5851	1996	12,167
4543-2-5974	1998	18,200
4543-2-6369	2006	24,940

The disposal site is bounded by a polygon approximately 400m long and 200m wide (see Figure 1). Water depth at the disposal site varies from approximately 0m to -10m (based on multibeam surveys) (PWGSC, 2007).

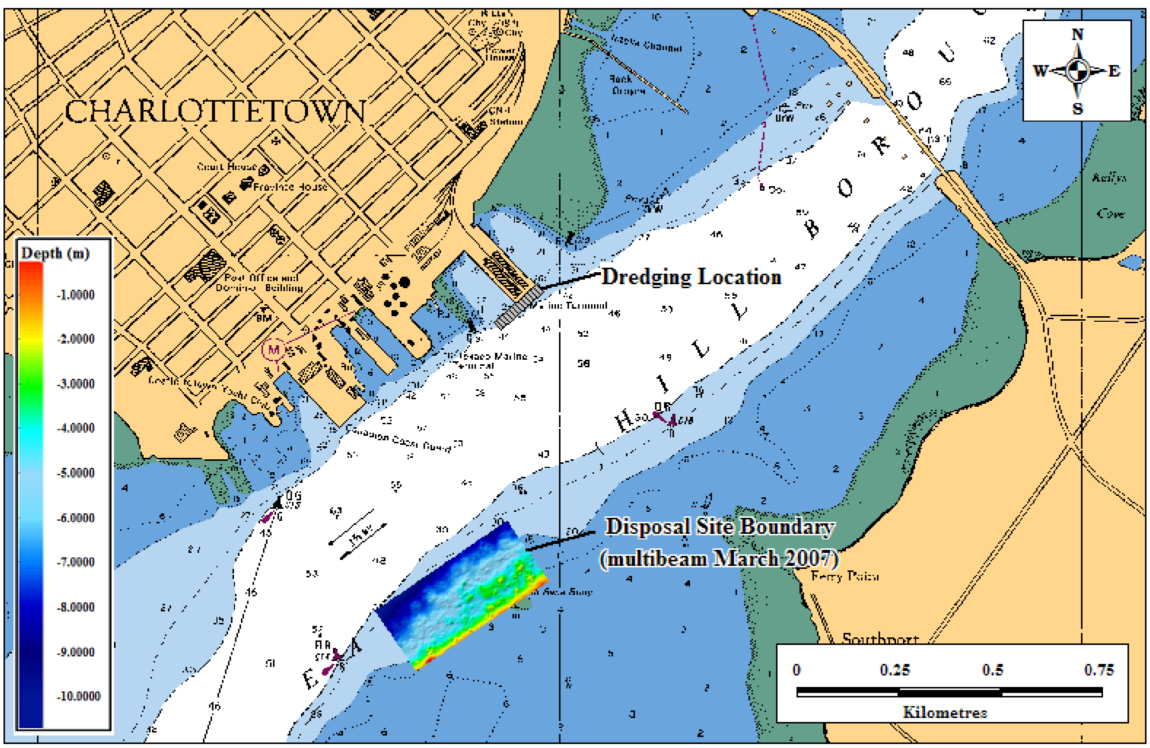

Figure 1: Multibeam survey (March 2007) of Charlottetown dredged material disposal site

The most recent use of the disposal site was in 2006 by the Charlottetown Harbour Authority Incorporated (CHAI) who was granted a Disposal at Sea Permit authorizing disposal of up to 28,000 m³ of dredged material. The material was dredged to facilitate the Phase I construction and expansion of the Charlottetown marine terminal. The fishing community in the Charlottetown area expressed significant concerns about the impact that dredging and disposal activities may have on various fisheries resources in the area. The concerns included the stability of the disposal site and the potential increase of total suspended solids (TSS) in the water column caused by the dredging and disposal operations. Some fishermen felt that the increase of sediment transport away from the disposal site and increase of TSS at the dredged and disposal sites may have direct impacts on marine organisms, nearby shellfish beds and on the lobster fishery in the Northumberland Strait.

Environment Canada's *National Guidelines for Monitoring Dredged and Excavated Material at Ocean Disposal Sites* identify criteria, concerns, and others factors relevant to the decision to monitor a site and to the design of the monitoring program. Factors which apply to the Charlottetown Harbour Disposal Site are listed in Table 2.

Table 2. Charlottetown Disposal Site - Factors Supporting the Need for a Monitoring Program

Monitoring Factors	**Relevance**
Possible effects on nearby sensitive habitats	The fishing community in Charlottetown Harbour is opposed to the use of the disposal site. Some fishermen believe that disposal activities may have direct adverse impacts on marine organisms, nearby shellfish beds and on the lobster fishery.
Potential conflicts with other nearby uses of the sea	There are approved shellfish harvesting areas within 500m of the disposal site.
	Fishermen harvest a variety of species of fish in close proximity to the disposal site

Impact Hypothesis

Based on the concerns raised with respect to the use of the disposal site, a monitoring program was designed to test the following hypotheses:

(i) *The Charlottetown Harbour disposal site is generally stable and non-dispersive, and so, the majority of the material disposed of at the site will remain in place.*
(ii) *Dredging and disposal activities in Charlottetown Harbour to not raise water column TSS levels significantly over background TSS levels.*

Monitoring Conducted

Site Stability
A series of three surveys were conducted at the disposal site to collect detailed bathymetric data that would be used to assess its physical stability and to identify potential related effects on off-site resources and activities. The surveys were conducted by PWGSC as follows:

1) In August 2006, prior to the commencement of 2006 disposal activities, a 12-channel hydrographic sweep system mounted aboard the vessel *Rampart Surveyor* was used to conduct the first survey;

2) Immediately following the cessation of disposal activities in November 2006, a Reson 7125 multibeam system was used in place of the 12-channel hydrographic sweep system to conduct the second survey. The multibeam system provided higher resolution data than the sweep system could, and also facilitated the collection of backscatter data which aided in the interpretation of the surficial substrate types. Data from the first sweep survey could not be included in comparisons with the latter two surveys because it was of lower resolution.

3) In March of 2007, a third survey was conducted using the Reson 7125 multibeam system to assess the stability of the site over winter.

In addition to the three survyes, data from two hydrographic surveys conducted in 1998 were re-processed to provide further background information about site conditions and to look at long term changes occurring at the site.

TSS Levels

Jacques Whitford Environmental Consultants Ltd., on behalf of the proponent, conducted monitoring of total suspended sediments (TSS) during dredging and dredged material disposal activities associated with the construction of the marine terminal wharf extension. TSS monitoring was a component of the Environmental Protection Plan (EPP) required under the 2006 Disposal at Sea Permit granted to the Charlottetown Harbour Authority Incorporated.

A series of monitoring stations were established to measure TSS levels in the water column (see Figure 2). Prior to the start of dredging activities, background TSS data was collected at these stations in a variety of meteorological conditions to establish baseline levels proximal to the project. A TSS monitoring program was then implemented during the dredging and disposal activities to examine any changes resulting from the project. Criteria for determining the acceptable range of TSS values were based on the guidelines outlined in the Canadian Council of Ministers of the Environment (CCME) publication entitled *Canadian Water Quality Guidelines for the Protection of Aquatic Life – Total Particulate Matter*. Maximum increases of 25 mg/L over background levels were considered to be within the acceptable range for project values (Jacques Whitford, Final Report, 2006).

A total of 260 individual samples were taken during the baseline monitoring and a further 504 samples were taken during the monitoring phase. The samples were collected over a variety of tidal conditions (rising, slack, falling) and water column depths (near-surface and near-bottom).

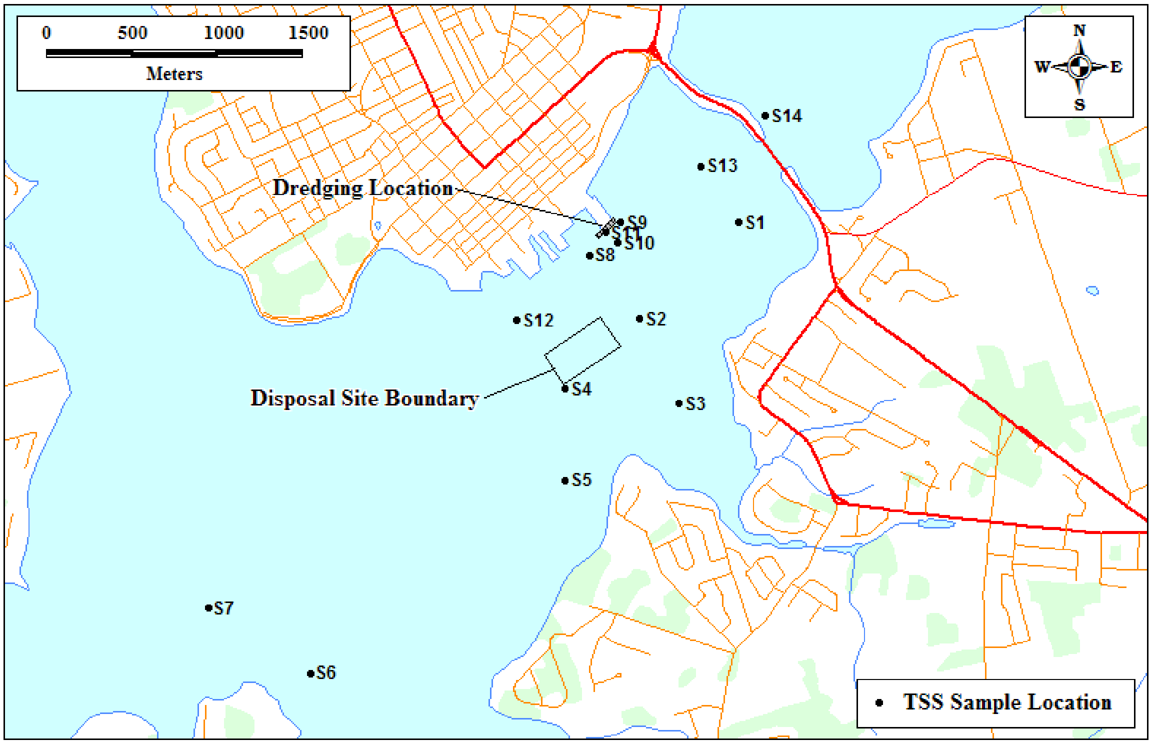

Figure 2. Charlottetown disposal site and TSS sampling stations

Results and Discussion

Site Stability

Through the use of *MapInfo Professional - Vertical Mapper* software, the multibeam bathymetric data collected in November 2006 was compared with the multibeam data collected in March 2007. This was accomplished by first converting the multibeam survey point data into grids of equal size with an equal number of cells (Figures X and Y where resolution = $1m^2$) and then subtracting the grid depth of the November 2006 survey from the depth of the March 2007 survey (see Figure 3).

The values in the resulting grid show net changes in depth ranging from +20 cm to -30 cm (see Figure 3). The histogram in Figure 4 shows that the majority of the depth differences are clustered around -5 cm. That said, it should be noted that the vertical accuracy of the multibeam equipment is limited to approximately +/- 10 cm. Given that the differences in seafloor depth are largely within the range of the vertical error, it is therefore difficult to accurately quantify the degree of erosion that has occurred, other than to note that erosion, if any, is limited.

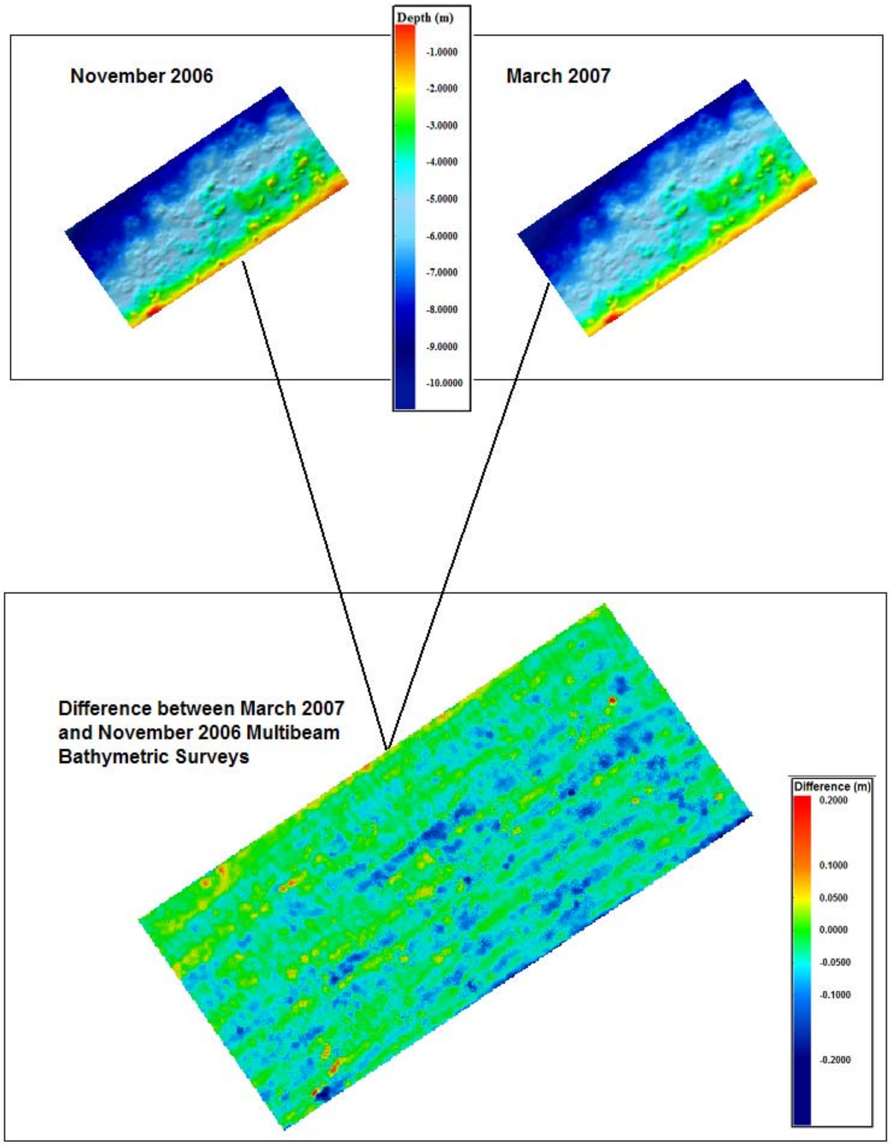

Figure 3. Net changes (m) to seafloor bathymetry at the Charlottetown Harbour disposal site during the period November 2006 to March 2007

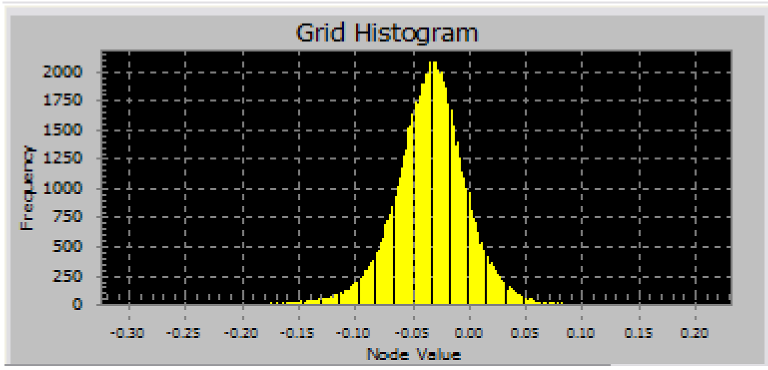

Figure 4. Histogram of the net bathymetric change at the Charlottetown Harbour disposal site during the period November 2006 to March 2007

Site Stability

At the majority of sample locations average TSS concentrations were within 5 mg/L of background levels. There were six sampling sites that were found to have average TSS concentrations above + 5mg/L as compared to baseline levels. Of these six sites, four (S8, S9, S10, S11) were located in the immediate vicinity of the dredging activity (<200 metres), one (S13) was located within the projected zone of influence (ZOI) predicted by the oceanographic modeling, and one (S7) was located outside the ZOI. Further investigation into the S7 site indicated that the elevated value occurred following a rainfall event (previous 24-hour period). Given that the S7 site is located just offshore from erosion prone cliffs (Rocky Point), and given other sample locations showed normal TSS values on this date, it is likely that this single elevated TSS reading was in part due to natural sedimentation in the harbour (Jacques Whitford, Final Report, 2006).

Both the baseline data and monitoring data were analyzed using a variety of statistical approaches (Basic Statistics, ANOVA/GLM, Correlations, and NMDS). No statistically significant differences were found between baseline TSS levels and those observed during dredging and disposal activities. A dotplot summarizing the TSS sampling program data is provided in Figure 5. Descriptive statistics for the baseline and monitoring portions of the sampling program are also provided in Table 3 and Table 4.

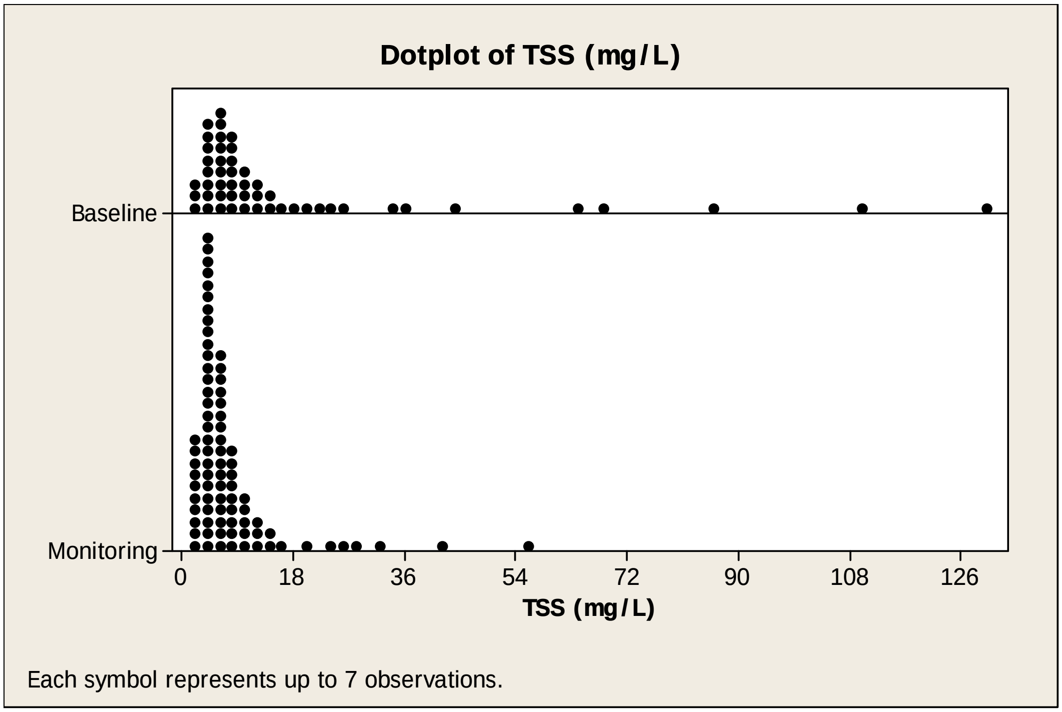

Figure 5. Dotplot showing baseline TSS (mg/L) and monitoring TSS (mg/L) for all samples

Table 3 and Table 4. Descriptive Statistics: TSS (mg/L)

Variable	**Phase**	**Count**	**N**	**N***	**Mean**	**SE Mean**	**StDev**	**Variance**
TSS (mg/L)	Baseline	260	259	1	9.347	0.817	13.152	172.964
	Monitoring	504	504	0	6.069	0.205	4.594	21.108

*Note that one Baseline TSS sample was excluded from these statistics (where TSS = 340 mg/L) due to concerns that the water sampler may have struck bottom.

Variable	**Phase**	**Minimum**	**Q1**	**Median**	**Q3**	**Maximum**
TSS (mg/L)	Baseline	1.000	4.000	6.000	10.000	130.000
	Monitoring	1.100	3.600	4.900	7.100	56.000

Conclusions

An analysis of the multibeam data indicates that the dredged material disposed of at the Charlottetown Harbour disposal site has remained relatively stable. Future multibeam bathymetric surveys may be conducted in order to examine long-term stability of the Charlottetown dredged material disposal site.

The TSS measurements taken during the 2006 dredging and disposal activities indicate that some sample locations exhibited average TSS values that were higher than baseline levels; however, when examined over the duration of the project, the increased TSS levels measured during dredging and disposal activities were not found to be statistically significant compared with background conditions. While dredging and disposal operations may have temporarily increased the sediment load in Charlottetown Harbour, these increases were largely within the natural range of TSS concentrations found in the harbour. No further management action is needed at this time.

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Pacific and Yukon Region: *Sand Heads, British Columbia*

Background

The Sand Heads Ocean Disposal Site (Figure 6) was first used in 1974 and has since received over 12 million cubic metres of sand. In 2001, over 784,000 cubic metres of sand was approved for disposal at the site. Since that time, concerns have been raised about the stability of the sediments disposed of at the site. These concerns have prompted Environment Canada, in partnership with the Geological Survey of Canada, to investigate the management of dredge spoils at the Sand Heads Disposal Site. The study considered the stability of the Sand Heads site, and looked at the sediment transport conditions and potential for sediment remobilization at an alternative disposal site located on the adjacent tidal flats of the Fraser River Delta. This alternative site, was first proposed by McLaren and Ren (1995).

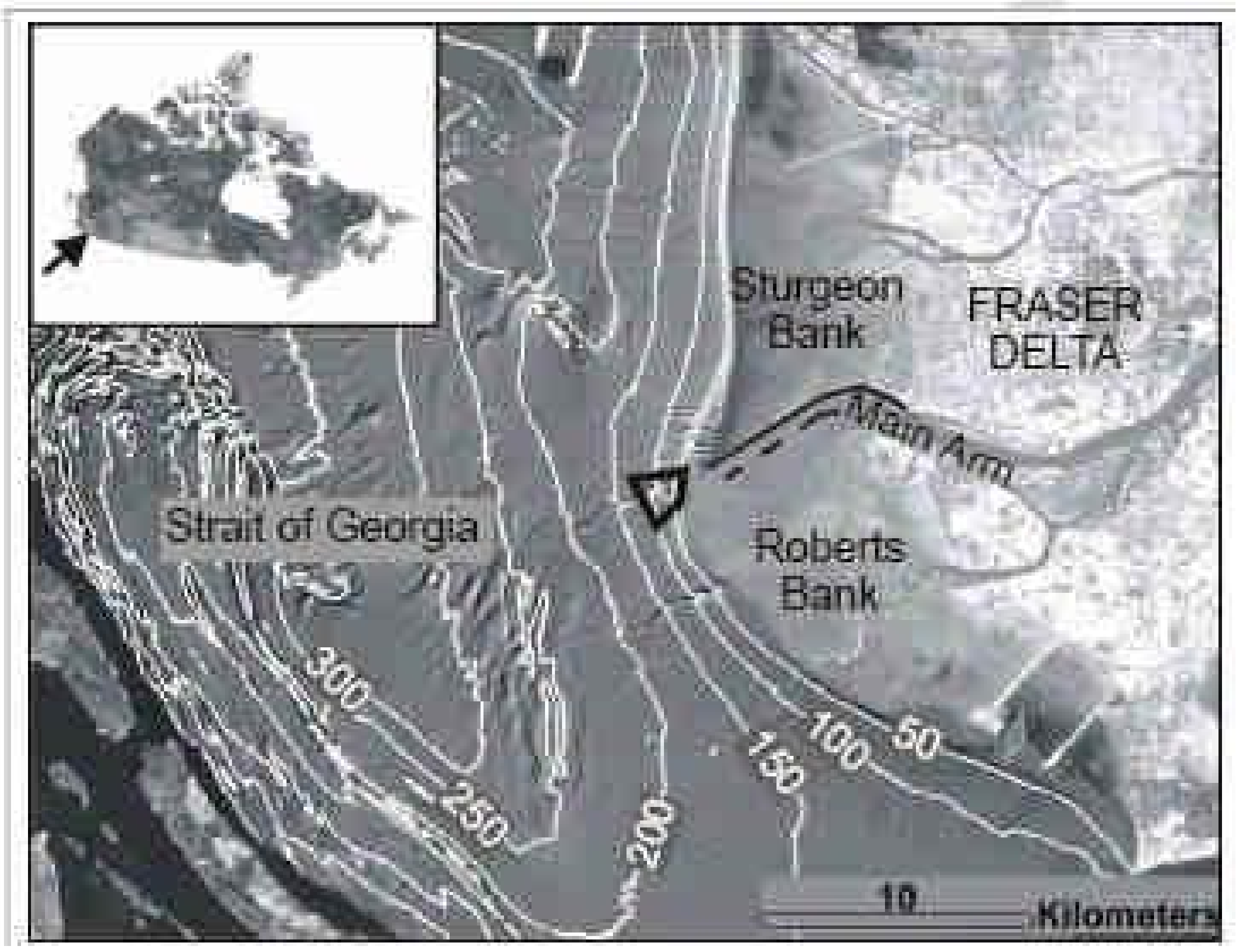


Figure 6. Map showing the limits of the Sand Heads, British Columbia disposal site, and the main morphological features of the study area.

Impact Hypotheses

- (i) *Instability at the Sand Heads Ocean Disposal Site may be sufficient to trigger significant slope failures, and tsunami-type waves.*
- (ii) *Roberts Banks may be a suitable alternative disposal site, depending on current and expected sediment transport trends at this site.*

Monitoring Conducted

Assessment of the Sand Heads Disposal Site

Prior to the commencement of surveying the Sand Heads Disposal Site, a literature review was conducted to identify the main morphological features and major sediment transport patterns at the site. Two important features were identified. First, the upper slope area of the river mouth was identified as an area of instability; five slope failures occurred in this area between 1970 and 1985, the largest and most recent involving at least one million cubic metres of sediment. High sedimentation rates in this area result in loosely packed sediment, and the creation of gas pockets within the piles of spoil. The second notable feature is an area of irregular, slope parallel ridges located just south of the main channel. The possible causes of this feature were investigated.

The Sand Heads Sea Valley was mapped using an EM100 multibeam system mounted on a DOLPHIN semi-submersible ROV (Currie and Mosher, 1996). This data was included in the results of the current study. In 2000 and 2001, a systematic multibeam survey of the Sand Heads Disposal Site was conducted using a Kongsberg Simrad EM3000 system between five and 100 metres of water depth. An EM1002 system was used in deeper waters. All surveys were conducted with differential GPS positioning and motion compensation. Data were cleaned and corrected for tidal variations using measured tides from the regional tide gauge network. Sound velocity variability in the Sand Heads area is naturally high due to variations in the position and thickness of the buoyant freshwater plume from the Fraser River. Sound velocity profiles were taken frequently with a moving vessel profiler and the data corrected for sound velocity changes. The processed EM 100 data were gridded at 10 m intervals, the EM 1002 data at 5 m intervals, while the EM3000 data were gridded at 2 m intervals. Backscatter amplitude data were extracted from the raw multibeam signal and processed using software developed at the Geological Survey of Canada.

The EM3000 surveys were repeated in 2002 and 2003, and the differences between the various gridded data sets were calculated using ArcGIS software.

Assessment of Alternative Disposal Site

The results of earlier sediment transport studies at the alternative disposal sites were reviewed in detail to determine the biological and sediment zones present at Roberts Banks in the vicinity of the proposed disposal site. Then, two field studies were conducted. The first took place between December 23, 2003 and February 22, 2004, during which time wave height measurements were taken at four locations on a shore-normal transect. The second study was conducted during March and April of 2003 to investigate the mechanisms controlling sediment entrainment and transport on the upper sand flats of Roberts Banks (Figure 7).

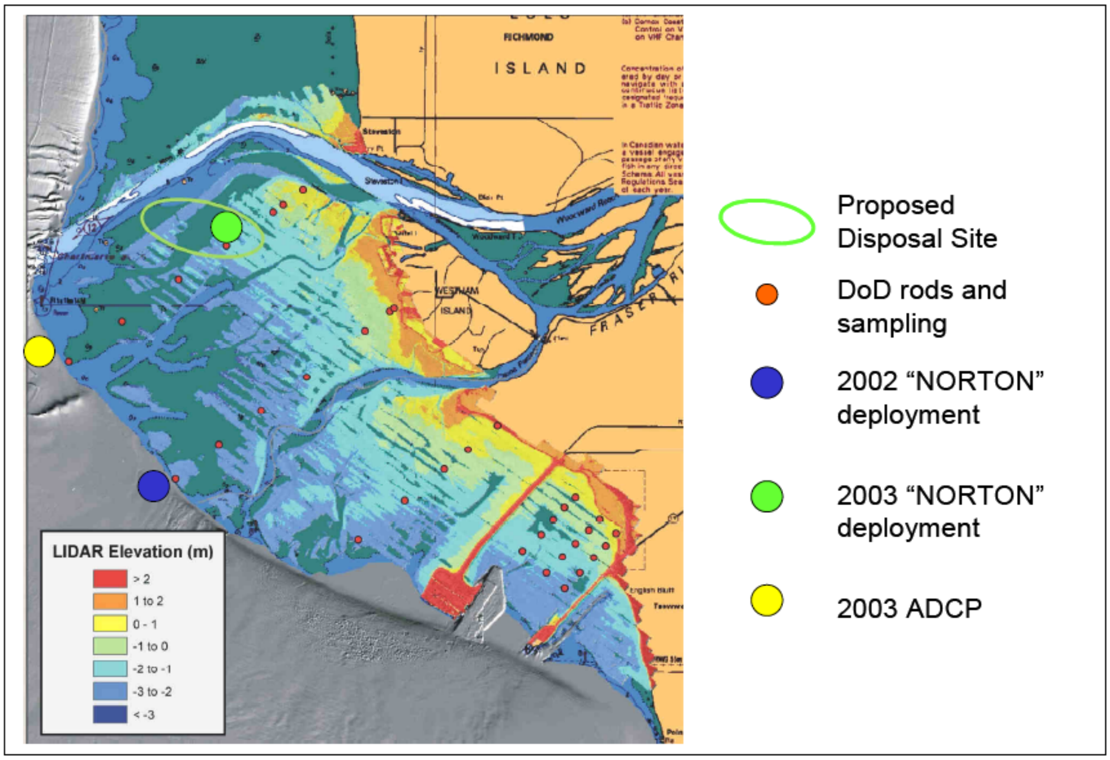


Figure 7. Map of wave and current stations for measurements made in March –April 2003. "Norton" is an instrumented tripod containing wave, current and suspended sediment measuring devices used for sediment transport investigations.

Results and Discussion

Stability of the Sand Heads Disposal Site

Rendering of the 2001 multibeam bathymetry grid provided detailed imagery of the upper slope channels, which have been described in detail in regional reports (Figure 8). There are numerous channels dissecting the upper slope, several of which converge to form the main submarine channel (or Sand Heads Sea Valley). The remainder form five separate gully systems, to both the north and south of the main channel. Most of the tributary channels and smaller gullies show fresh, scalloped morphology that incises into the delta platform, indicating headward erosion.

The approximately 6 km^2 area of the slope just to the south of the submarine channel is characterized by a distinctive morphology of discontinuous, contour-parallel ridges and trenches with spacings of 50 to 140 m and ridge-to-trench relief of 1 to 3 m (Figure 9). The area extends from approximately 30 to 185 m depth.

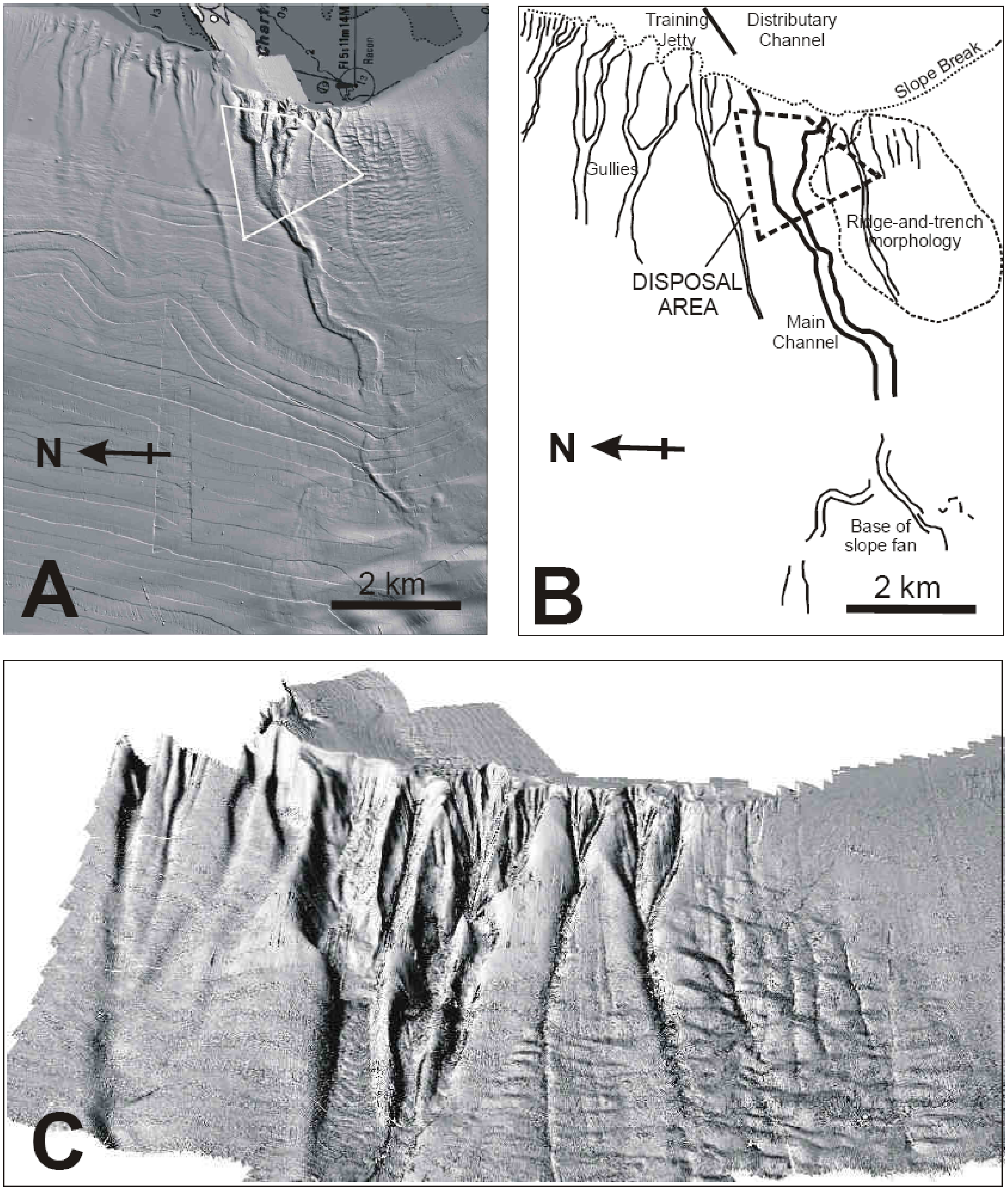
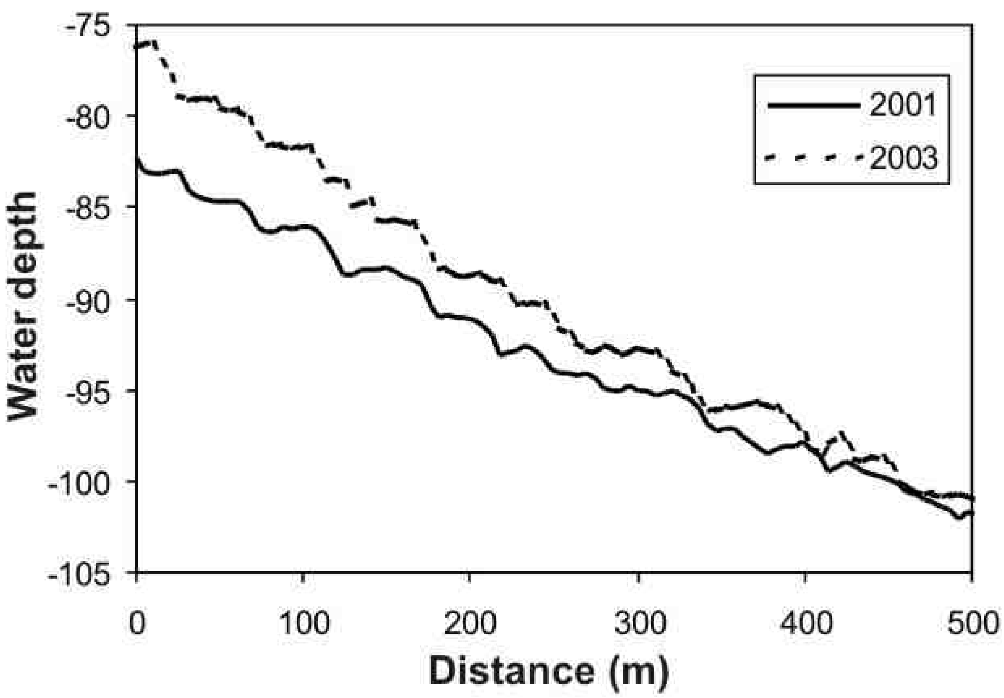


Figure 8 . (A) Shaded relief image of multibeam bathymetry showing detailed morphology of the disposal area; (B) line sketch of main morphological features; (C) 3-D rendering showing details of head area.

Figure 9. Bathymetric profiles along axis of channel showing relief of bedforms.



Difference maps generated from the bathymetric grids are presented in Figure 10. In the seven-year interval between the 1994 and 2001 surveys, there was a net accumulation of sediment over the entire area (Figure 10a). The thickness of accumulation decreased away from the river mouth but several meters of accumulation was registered as much as 1 km offshore. Greater than 10 m of accumulation occurred in areas of maximum relief such as tributary canyon heads and the northernmost tributary channel, related to the 1985 slope failure. There were no significant areas of net erosion over this time period.

Over the one-year periods from 2001 to 2002 and 2002 to 2003, the depositional pattern is very similar with accumulations as high as 15 m in one scalloped tributary channel head (Figure 10b, c). In 2003, the linear escarpment observed at the slope break in the 2001 image, is completely in-filled by sedimentation. Between 2002 and 2003, there were significant erosional differences, both in the river channel and in the head of two scalloped tributary channel heads.   During this time period, two canyon head areas show significant erosion, with more than 6 m of sediment being removed. Very fresh scalloped escarpments are visible in both regions indicating slope failure. Volumes of sediment displaced in each case are in the order of 2 to 5 x 10^5 cubic metres.

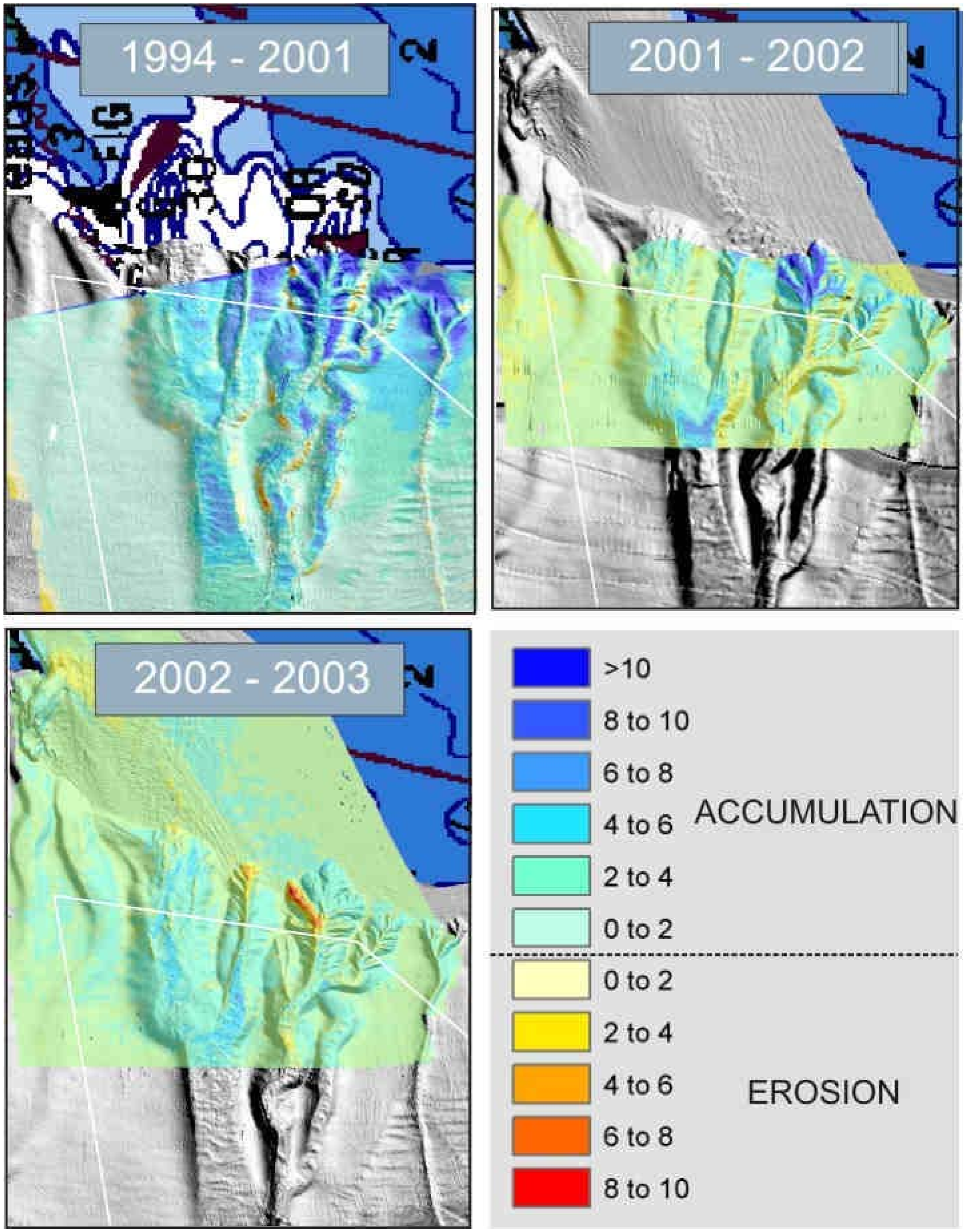


Figure 10. Difference maps: (a) 1994-2001; (b) 2001-2002; (c) 2002-2003.

The detailed imagery of the main submarine channel shows that the disposal site covers an area that includes the head of an active tributary-channel-fan system and part of the ridge-and-trench morphology. In contrast to other disposal sites in the region and elsewhere, the dredge spoil is not visible on multibeam backscatter imagery except possibly for patchy areas of the backscatter on the north side of the site. There are several possible reasons for this. First the material being deposited is probably similar in grain size and backscatter intensity to sediments of the receiving area. Second, dredge spoil may be rapidly overlain by sediment deposition at the river mouth. Finally, sediment deposited in the channel system may be re-mobilized and transported by gravity flows.

In the main submarine channel, there is a history of sediment instability and the new data presented here show further evidence for slope failure between 2002 and 2003, in the form of fresh, scalloped morphology and bathymetric changes of greater than 10 m between surveys. The focus of this instability is in the tributary canyon heads, upslope of the disposal site. The 2002-2003 slide volumes are an order of magnitude smaller (10^5 vs. 10^6 cubic metres) than the 1985 event, and similar to the volumes of dredge spoil deposited at the disposal site each year. Any spoil deposited in the upper part of the submarine channel system would likely be re-mobilized by gravity flows originating in this area. The submarine channel morphology strongly suggests that the flow slides are transformed into turbidity currents that flow down the channel. There is also evidence that the recent channel-floor deposits may incorporate dredge spoil material derived from the disposal area but risk being re-mobilized by more ignitive turbidity currents.

The results of this study provide a clear indication that the delta slope in the river mouth area, particularly in the vicinity of tributary channel heads, is susceptible to slope failure. Triggering mechanisms, while uncertain in their detail, are closely related to rapid loading by natural sediment deposition, resulting in high water contents, loose packing and elevated pore pressures. Dredge disposal at Sand Heads involves single drop volumes close to 3000 m^3, which represent considerable, near instantaneous loading events. Given the data collected, disposal activities have the potential to trigger slope failures; whether they do or not depends on both the location and the timing of disposal in relation to the evolving condition of the slope sediments. In terms of location, the highest risk area is the upper slope location characterized by the highest sedimentation rates and annual accumulations of several metres of uncompacted sand. It is likely that dredging of the channel itself influences the position of this high-risk area. In terms of timing, sedimentation at the channel mouth is likely to be maximum at the peak of snowmelt discharge typically between late May and early June. Where this coincides with spring tides, the probability of triggering a failure by the tidal drawdown mechanism is greatest. Dredge disposal at this time has a higher probability of triggering slope failure.

The Sand Heads disposal site is located in an area of rapid sedimentation and observed slope instability. Dredge spoil deposited in the area is likely to be incorporated into debris flows and turbidity currents generated by transformation of liquefaction-induced submarine slides and transported downslope in the submarine channel system. Finer fractions of this material may be deposited on channel levees and adjacent slope areas by overspill of turbidity currents. Coarser material may be deposited within the channel itself or transported to the base of slope, where a broad depositional fan, characterized by shallow ephemeral channels, is forming. Dredge spoil deposited on the adjacent section of slope, characterized by ridges and troughs, may be rapidly buried and slowly transported down slope by a creep failure mechanism or possibly reworked by turbidity currents that are generated by mixing induced convection of sediment from the buoyant river plume. Dredge disposal has the potential to trigger submarine slides on the upper slope, but such slides are likely to be small in scale and unlikely to generate significant tsunami waves. However, continued steepening of the delta front due to the stabilization of the river channel may be conditioning the slope for a larger-scale tsunami-generating slide.

There remain many uncertainties related to the scale and mechanisms of slope failure on the Fraser Delta slope particularly the migration and dynamics of pore fluids, including methane gas. Future work should focus on in situ observations of pore fluids and their response to forces that might result in large slope failures.

Suitability of Alternative Disposal Site

A 1995 study (GeoSea) suggested a long term pattern of sediment transport for the delta front as shown in Figure 11. The principal elements of this pattern are: a generally northward transport of sediment along the delta slope; generally shoreward transport across Sturgeon and a relatively complex circulatory transport pattern on Roberts Bank. Several areas of net erosion were identified from the sediment transport trends on both banks. The study proposed that dredge spoil deposited on the northern end of Roberts Bank would supply sediment to one of these erosional areas and thus provide a beneficial nourishment of the bank.

Since 1995, several other studies of sediment transport processes have been conducted in the vicinity of Roberts Bank. The results generally indicate that wave and current conditions differ according to water depth, storm conditions, tidal elevation, and during ebb and flow tides; also, waves act non-uniformly along the shoreface of the tidal flat.

The study presented here on the potential for beneficial disposal on Roberts Bank was conducted concurrently with a study of the impacts of sea level rise on the Roberts Bank tidal flats (Hill et al. 2004) funded by the Climate Change Impacts and Adaptation Program. This complementary study included detailed studies of the sedimentary processes and morphodynamics of Roberts Bank. The findings related to sediment transport patterns are presented here without discriminating between the two sources of funding.

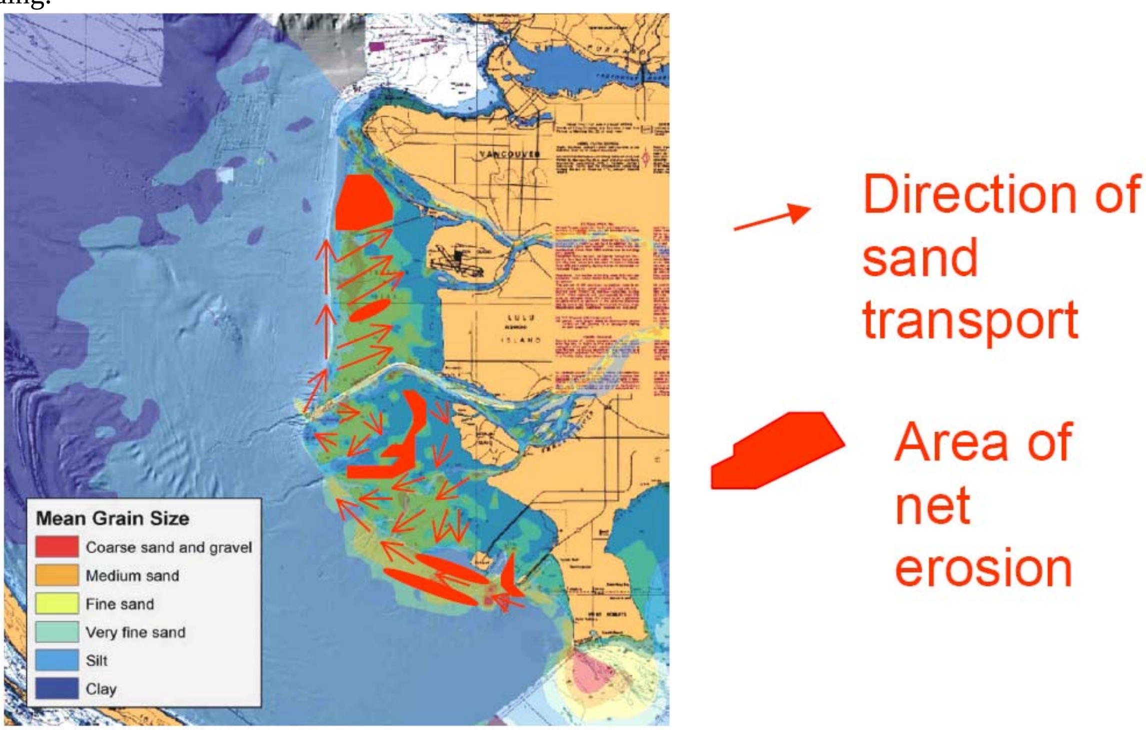


Figure 11. Summary of sediment pathways identified by GeoSea (1995).

For the majority of Roberts Bank there is a succession of biosedimentological zones starting at the dyked landward edge moving seaward across-shore. There is a grain size-coarsening trend from muddy silt in the marshes to fine sorted sand at the outer reaches of the sandflats. Vegetative diversity is greatest in the upper marsh areas, particularly the high brackish marsh, and decreases seaward.

There is a transition from mud-dominated sediment and salt or brackish marsh at the landward margin to sand-dominated sediment along the more energetic seaward margin. These sand flats provide a natural barrier to storm waves through a combination of wave breaking and frictional dissipation. Wave height measurements from four locations along a shore-normal transect from a two-month deployment from December 23, 2003 to February 22, 2004 indicate that wave height and energy are dissipated exponentially over the intertidal flat (Figure 12). The attenuation varies with the relative wave height ratio (ratio of significant wave height, Hs, to water depth, h) of the incident waves, such that dissipation increases as water depths decrease and/or incident wave heights increase. The wave energy available for resuspending sediment therefore decreases in the landward direction. Over the period of the measurements, only 5% of the recorded wave conditions were capable of entraining sediment at the outer flat whereas this proportion was reduced to 0.5% by the transition zone to the mudflat. Significant morphological change on the sand flat and the mudflat is therefore likely to be restricted to extreme storm events.

The cross-shore reduction in wave height also likely contributes to ecological stability through the establishment of biofilms and vegetation, which in turn contributes to morphological stability. This creates a strong non-linear dependency of the mudflat and marsh environments on the morphodynamics of the fronting sand flat**.**

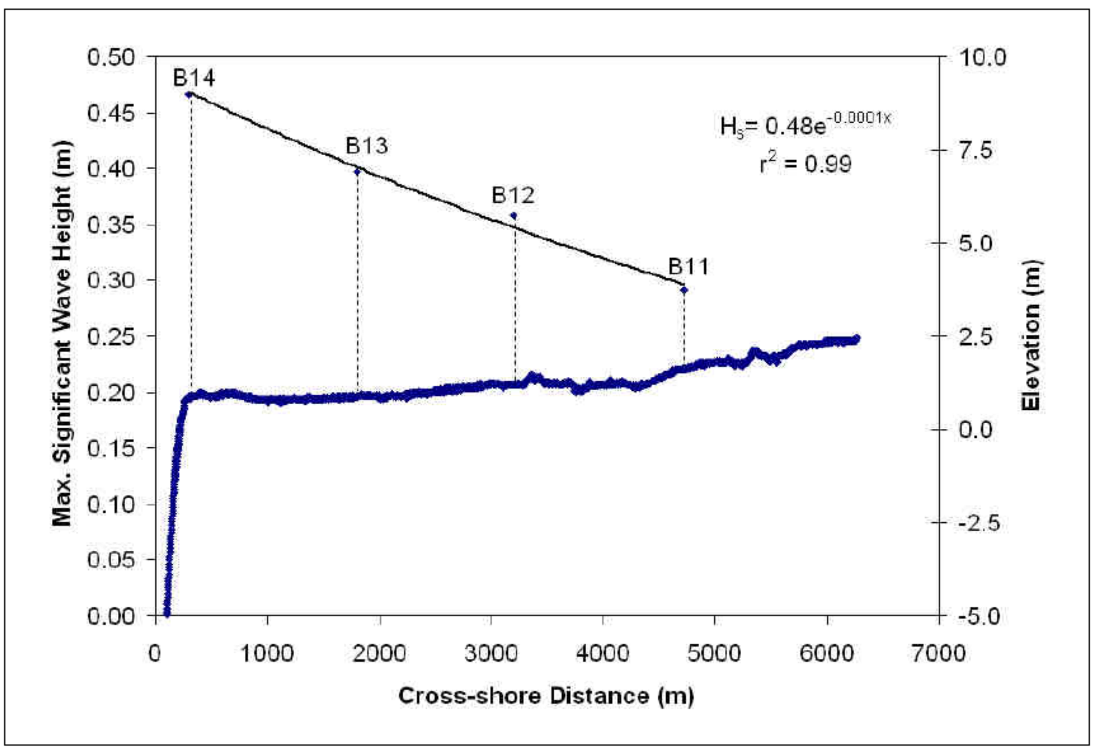


Figure 12. Exponential attenuation of wave energy across the tidal flat. In this case the data represent the maximum wave heights during a moderate storm event. Similar exponential decreases in wave height and energy are found for most wave conditions.

The transport of sediment by currents was observed to increase dramatically in the presence of waves. In general, currents (both tide and wind-generated) were not of sufficient strength alone to initiate transport, but had a significant impact on the direction of transport. Under calm conditions, the direction of net sediment transport is controlled by the tidal current asymmetry (relative strength of flood versus ebb current). However, during storms, wind-generated currents develop, and these currents provide an additional component to the sediment transport direction. Since wind-generated currents are typically associated with storm waves capable of entraining sediment, these currents have a disproportionately large impact on the direction of net transport over the long term. Over a sufficiently long time period the difference in the amount of sediment transport by the flood and ebb currents becomes small relative to the asymmetries of the mean current (Lee et al., 2004). It is reasonable to expect that the greater frequency and higher magnitude of storm winds from offshore would preferentially favour current asymmetry in the landward direction (to the SE, 1450) and force a net transport in that direction. This is consistent with the findings of GeoSea (1995) whose grain-size trends suggested that sediment at the Norton site would be transported to the southeast (135o). Given the tenuousness of the link between the small-scale observations of this study and the larger-scale transport pathways identified from grain size trends, this result is encouraging and gives further confidence to the sediment transport pattern suggested by GeoSea.

Conclusions

Sand Heads Disposal Site

The Sand Heads disposal site shows clear signs of slope instability and the potential for the creation of conditions that could lead to significant slope failures. Disposal activities at the site must be carefully managed to ensure that their rate and timing do not contribute to this instability. Also, the search for an alternative disposal site should continue.

Alternative Roberts Banks Disposal Site

The results of the sediment transport studies conducted paint a picture of tidal flats that, while obviously influenced on a daily basis by tidal currents, show very low rates of sediment transport and accretion except during major storms. Under storm conditions, wave motions enhance the tidal currents to create conditions under which sediment re-suspension and transport can occur. It is clear that the Roberts Bank tidal flats represent a low energy wave environment compared to beaches around the world where re-nourishment projects have been undertaken. Re-dispersal of emplaced sediment would therefore be slow and the initial emplacement morphology would likely be sustained for many years.

Emplacements of sand are unlikely to be remobilized rapidly and re-distributed by natural conditions, so in order to be effective emplacement would have to be distributed across the bank. Detailed calculations of a nourishment plan would have to be made to evaluate the required volumes. Early estimates suggest that it would take only a few years (of 2002-2003 dredged volumes) to cover the proposed disposal site with 0.5 to 1 m of sediment. Given that the projected sea level rise resulting from global climate change over the next century is generally considered to be less than 1 metre, this is likely to be the maximum requirement. Given the low rates of sediment re-dispersal, the requirement for dredge spoil material on Roberts Bank does not appear to be much larger than a few years worth of the typical dredged volume. However, a smaller program dispersing a few centimeters of re-nourishment per year and using a small percentage of the total dredge spoil available could be sustainable.

A second issue is that even subtle morphological changes to the tidal flat surface can trigger ponding of flood tidal waters on the inner tidal flat and initiate tidal creek erosion. The morphology of tidal channel networks depends on the volume of water passing through the channels. The Roberts Bank sea level study results suggest that the channel density in Roberts Bank decreased by about 30% between

the early 1960’s and 1980’s. Placement of re-nourishment material on the outer and middle tidal flats would potentially reverse this situation by pooling water on the inner tidal flat and delaying the flow of water during the ebb tide. This would effectively increase the volume of water to be evacuated on the ebb tide, potentially requiring a more extensive tidal creek network.
Tidal creek erosion has been an ongoing problem in the inter-causeway area, and the tidal creek system has still not stabilized. It is beyond the scope of this study to evaluate this issue in more detail.

Quebec Region: *Grosse-Île , Disposal Site GI-2*

Background

Figure 13. Location of the study area

Dredged material disposal site GI-2 is located 1.5 km northeast of Grosse-Île harbour in the Magdalen Islands at coordinates 47°37.85' N, 61°29.60' W, beneath 7 m of water (NAD 83) in a primarily sandy location. This location is shown in Figure 13. Since its designation as a disposal site in 1994, it has received dredged material from the Grosse-Île harbour only. A total of 35,775 m^3 of sediment were disposed of at the site from 1994 to 2006, inclusively, and these sediments are comprised of sand with traces of silt, clay and colloids. Previous chemical analysis of the sediments at the site indicate that contaminants are below detection limits, or under Canadian Council of Ministers of the Environment guidelines. The site remains open at this time.

In 2002, a study to assess the stability of this disposal site was conducted (Marceau and Ropars, 2004). Based on the results of this study, it was concluded that this site should be regarded as highly dispersive, with only 5% of the sediments deposited following dredging activities remaining at the site. Materials placed at the site from 1994 to 2004 were likely to have dispersed over a distance of 1.2 km in a predominantly southeast direction (Figure 14).

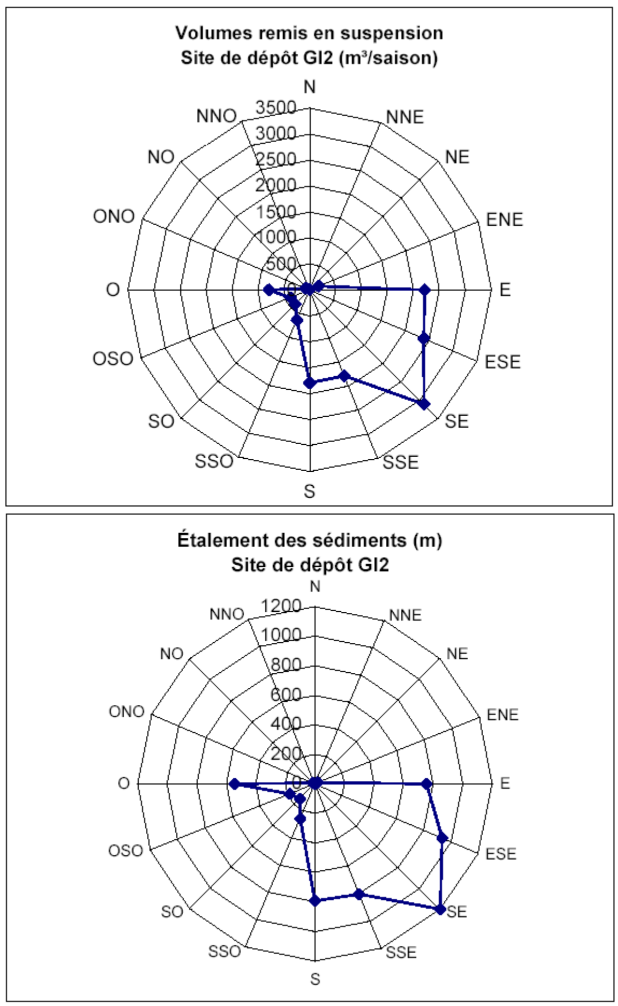


Figure 14. Volume of sediment put into suspension and direction of spread at disposal site GI-2

Impact Hypothesis

Disposal site sediments that disperse into surrounding areas are not negatively impacting fish habitat nor fishing activities in those areas.

Monitoring Conducted

The hydrodynamics of the disposal site were investigated to verify the model of dispersion created in previous monitoring cycles.

The disposal site was also surveyed to determine the types of fish habitat and fishing activities present. This information was analyzed in the context of the sediment dispersal patterns revealed by the site hydrodynamics, and by the predictions made in the last round of monitoring to identify any impacts on fish and fishing as a result of sediment dispersal.

Results and Discussion

Site Hydrodynamics

The tidal currents around the Magdalen Islands vary significantly in velocity and direction. At site GI-2, the direction of the current observed is essentially southeast, because the flood current splits at Cap du Dauphin and the shoals off the cape, shifting the current to the southwest towards Île aux Loup, and southeast towards Pointe de l'Est.

These currents have a direct impact on natural sedimentation at site GI-2, and contribute to the annual accumulation of sand in the access channel to Grosse-Île harbour and in the harbour itself. It is not uncommon for sand banks to form in these channels, and necessitate the removal of additional volumes of sediment. Because the extent of sand transport by littoral drift is unknown, it is difficult to quantify the actual contribution from site GI-2 relative to the natural contribution. Nonetheless, based on the models generated to date, it is reasonable to believe that this contribution will be minimal. In the worst-case scenario, there may be a slight, gradual rising of the ocean floor by several centimeters over twelve years that covers an area of approximately 70 ha.

Due to the large sediment grain size, the volume of suspended material expected in the water column as sediment moves off the disposal site is likely minimal. Also, being comprised primarily of sand, the disposal site sediments are very similar in composition to the naturally occurring seafloor around the site, and are not expected to cause physical or chemical impacts that differ greatly from those caused by the natural sediments in the area.

Fish Habitat and Fishing Activities in the Area

Because the sediments around the disposal site are similar in composition to the material disposed of at the disposal site, the aquatic resources present in the receiving environment should be similar to those present at site GI-2 itself. Although a large quantity of sediment was transported off of site GI-2 between 1994 and 2006, the location of the Magdalen Islands in the middle of the Gulf of St. Lawrence and the sandy composition of the islands, create a sector that is characterized by complex and primarily erosive sedimentary dynamics. In this area, it is unlikely that the complete and significant destruction of sandy habitat, or even a distinctive modification of that habitat will be observed.

Monitoring results suggest that only three species use the sector affected by sand transport from site GI-2 over an area of approximately 70 ha to the southeast of the site. In this sector, herring are fished in spring, summer and fall at the disposal site itself. The entire sector north of Grosse-Île is designated as an Atlantic mackerel breeding ground and a potential spawning ground. And, American lobster stocks occur and are harvested via spring traps at the northern limit of the study area. These resource distributions are shown in Figure 15 and 16).

It is not expected that any of the three species of interest in this study are affected by the dispersal of sediments from the disposal site. Herring is harvested for use as bait by several fishers in the area, but is not fished commercially. The gradual southeast movement of sand on the floor is not likely to disrupt this activity. The herring spawning area is located south of Grosse-Île in the lagoon and the eggs of this species are pelagic. The potential mackerel spawning habitat in the study area is also unlikely to be impacted by the accumulation of sediments on the seafloor since it deposits its eggs near the surface, and its larvae are also pelagic. Lobster larvae also stay near the surface, while juveniles seek substrates near rocky bottoms.

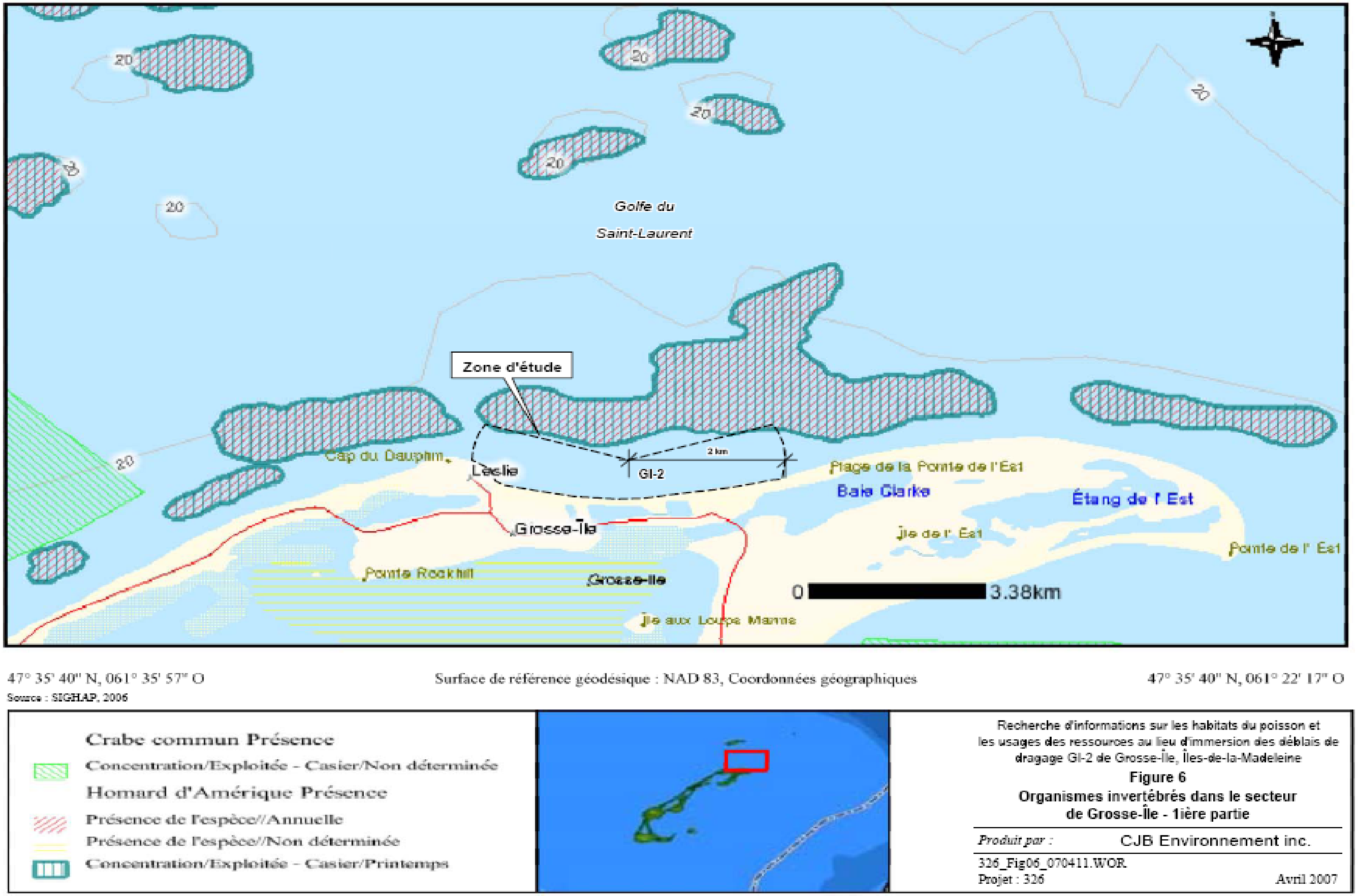


Figure 15. Distribution of rock crab and American lobster near disposal site GI-2

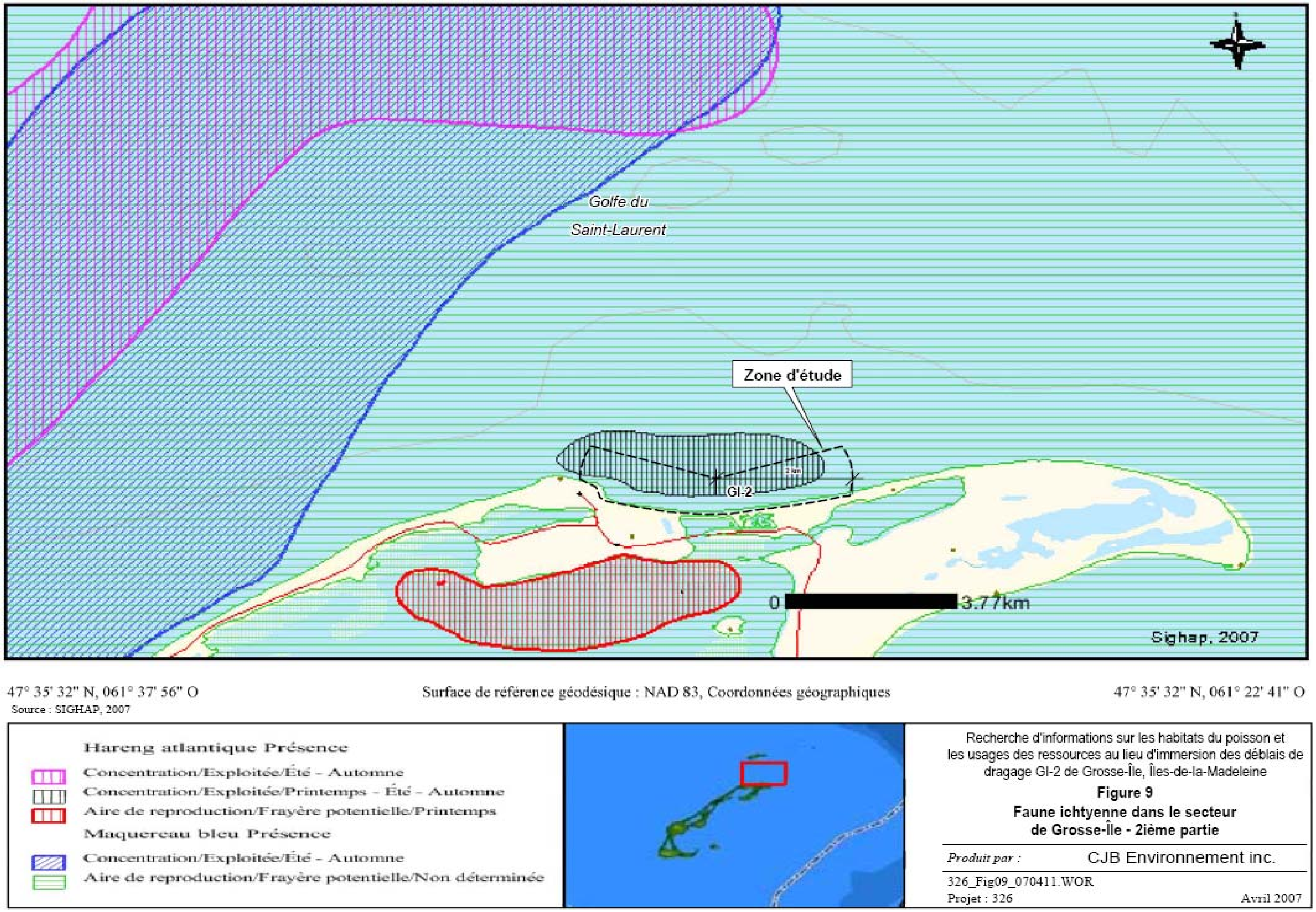


Figure 16. Distribution of Atlantic herring and Atlantic mackerel near disposal site GI-2

Conclusions

Although the phenomenon of sanding is relatively pronounced due to the large volume of sediments (32,653 m^3) that may have moved off site GI-2 between 1994 and 2006, the resulting accumulation is very gradual and corresponds, in the worst-case scenario, to a small rise of the seafloor over a period of several years.

None of the species identified in the study area or its immediate vicinity are at risk of being affected by the gradual southeasterly transport of sand from the disposal site.

As a result of the gradual encroachment, in the worst-case scenario, benthic colonization of new substrates off site GI-2 is occurring continuously and very quickly. Given that the physical and chemical properties of the study area are, in all likelihood, similar to those of the material being transported, the impact on habitat is negligible. The risk of a gradual decline in the quality and quantity of habitat of the benthic species that occur in the study area is therefore virtually non-existent. This study has demonstrated that given the preferred direction of sediment resuspension and spread, in the worst-case scenario, there is little risk that the encroachment of habitats will cause harmful effects on fish habitat, sensitive adjacent areas, or resource users located near disposal site GI-2.

Quebec Region: *Magdalen Islands – Depot D*

Background

Dredged material disposal site Depot D is located approximately 4 km to the south-southeast of the Grande Entrée channel, in the Magdalen Islands. This disposal site zone is delineated by the following coordinates: 47°31.55' N and 61°36.03' W; 47°31.04' N and 61°35.82' W; 47°31.37' N and 61°35.55' W; 47°31.20' N and 61°36.32' W (NAD 83). The site lies in 13 m of water, and a total of 1,670,000 m^3 of sediments have been disposed of there.

During maintenance dredging projects conducted in the Grande Entrée channel in 1992, 1997 and 2002, and in anticipation of a 2008 maintenance project, the permittee characterized the load site sediments. The characterizations revealed that sediments in the sectors of the basin and curve contained levels of arsenic that were slightly in excess of the CCME criteria. To manage the disposal of these fine, enriched sediments, the proponent capped them with coarser, non-enriched material from other dredging areas. The quantity of unenriched sediments to be dredged largely exceeded the quantity of fine sediments. The projects conducted in 1992, 1997 and 2002 created four separate mound-shaped zones at the disposal site.

The general objectives of the environmental monitoring activities planned for the site include an assessment of the method used to cap the fine enriched sediments with coarse, clean material; an assessment of the effectiveness and safety of containment in the marine environment; and a determination of whether the capping method could be improved.

Impact Hypothesis

> *Sediments at Depot D are relatively stable, and so bathymetric surveys of the area will help to properly position core drilling stations during future monitoring studies.*

Monitoring Conducted

The Canadian Hydrographic Service conducted bathymetric surveys at Depot D during November of 2006.

Results and Discussion

The bathymetric surveys enabled the accurate location of the disposal mounds at Depot D (see Figure 17).

Also, the survey results were compared to surveys conducted in 2002. This comparison revealed that during this four year interval, very little sediment movement occurred (see Figure 18).

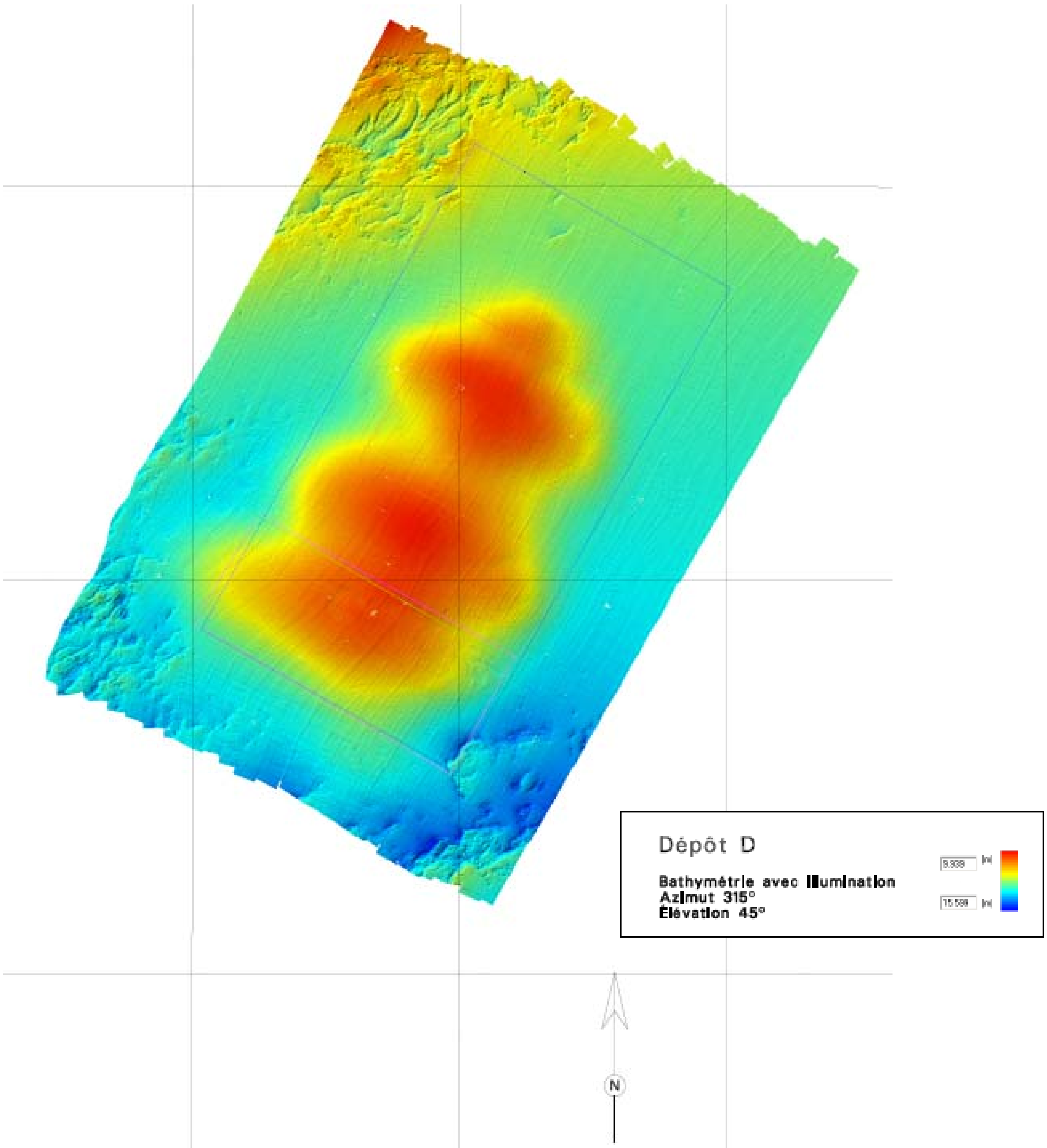


Figure 17. Bathymetric survey of Depot D with illumination, depth of 9 to 15 m

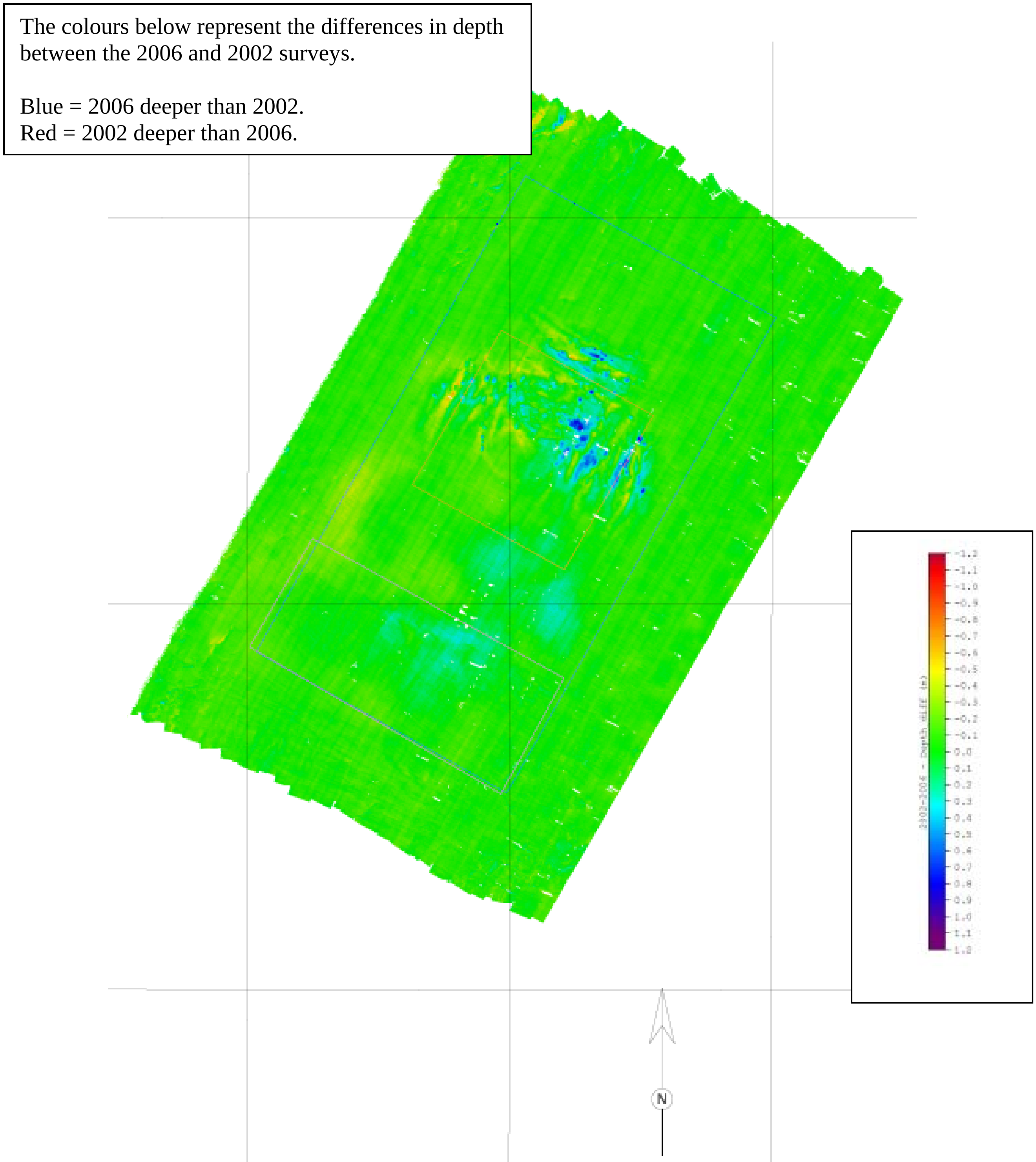


Figure 18. Differences in bathymetry data of Depot D between the 2002 and 2006 surveys

Conclusions

The Depot D disposal site is characterized by very high stability. The survey information collected will be used to plan the positioning of stations for the core drilling that will be carried out in 2008 to meet the longer term monitoring objectives outlined above.

Quebec Region: *Magdalen Islands – Depot E*

Background

Depot E is a newly designated disposal site located 6 km south of the Grande Entrée channel, in the Magdalen Islands. It is the largest disposal site in Quebec Region. This area is defined by the following coordinates: 47°37.85' N, 61°29.60' W (NAD 83). The site is intended to replace Depot D for future maintenance dredging projects in the Grande Entrée channel, and no materials have been deposited there to date.

The majority of the material deposited at Depot D was disposed of by a single permittee during maintenance dredging conducted in the Grande Entrée channel. In the next ten years, this permittee will need to dispose of a volume of material that exceeds the remaining capacity of Depot D. For this reason, the permittee will be authorized to dispose of future dredged materials at the newly designated Depot E. This decision will take effect in 2008, and the new site should be able to accommodate the materials that the permittee needs to dredged in the next decade.

Impact Hypothesis

Depot E is a stable, non-dispersive disposal site.

Monitoring Conducted

The Canadian Hydrographic Service conducted bathymetric surveys at Depot E during November of 2006. This survey data will provide an image of baseline conditions at the site, and will enable the identification of sediment dispersal in later years.

Results and Discussion

The bathymetric surveys have demonstrated that Depot E is extremely homogeneous and is located in an area where the depth does not vary by more than 1.5 m over 2 km (see Figure 19). These initial data from the future Depot E disposal site will enable a determination of any bathymetric changes that occur following disposal activities, and a determination of the stability of the site.

Conclusions

Follow up work to determine the suitability of the new Depot E disposal site is recommended following the commencement of disposal activities there in 2008.

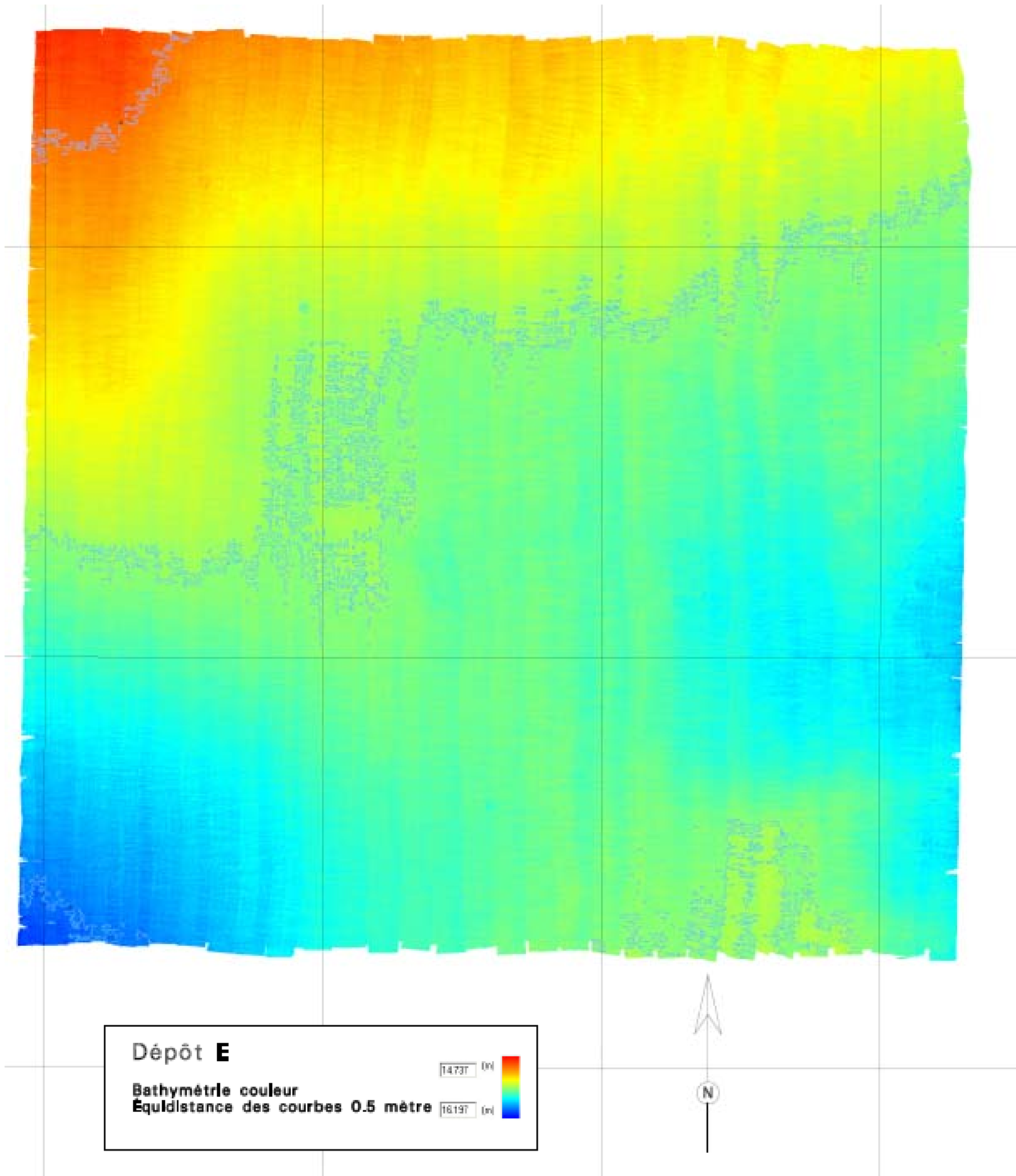


Figure 19. Bathymetric survey of the future disposal site E, depth of 14.7 to 16.2 m

Prairie and Northern Region: *Sachs Harbour, Northwest Territories*

Background

The ocean disposal of offal consisting of the heads, bones and intestines of muskox slaughtered in the commercial hunt is carried out under permit. Permits for this activity were also issued in 1998, 2000, and 2002 through 2006. During to the review for the most recent permit issuance, residents of Sachs Harbour expressed concern that muskox skulls had been found on the shore after breakup. The residents wanted to find out if the material was coming from the disposal operation The community also voiced concerns regarding potential links between the disposal and declines in local fish populations (specifically Arctic Char) and increased invertebrate 'sea lice' (amphipod) populations. To address these concerns, a two-phase follow-up monitoring plan was established. The first phase was conducted in May 2006, shortly after the permittee put the offal on the sea ice. The second phase was completed in July 2006 when the harbour was free of sea ice.

Impact Hypothesis

> *After initial deposition on the sea ice, Muskox offal are being deposited on the sea floor at the designated disposal site, where they are decomposing in the marine environment.*

Monitoring Conducted

To test this hypothesis, monitoring activities were conducted to determine 1) the location of muskox offal deposited on the ice and on the sea bed after melting, 2) the water depth at the disposal site, and 3) the level of decomposition of the offal.

Location of offal deposits

The offal was disposed of in eleven circles within the disposal area. Each circle was made up of six to ten piles of offal. The location of each circle was determined using a Garmin GPSMAP 76 CS unit while standing in the center of each circle.

To track the movement and ultimate disposal location of the musk ox offal, five sonic transmitter tags were tightly secured to the skeletal parts of the remains using metal wire (see Figure 20 and 21) on the north-western portions of the piles. The signals emitted by the tags in saltwater were detected using a hydrophone and receiver. The manufacturer's specifications suggested that detection was possible in water up to 400 metres deep and up to one kilometre away, depending on water chemistry and the quantity of suspended particles. The location of each tag on the ice was recorded using the Garmin GPS unit.

In July 2006, a boat equipped with a hydrophonic receiver was used to try to locate the tags placed on the offal piles in May. The boat transversed the areas where the muskox offal was expected to be.

Disposal site depth

Four measurements of water depth were made throughout the disposal area using a personal dive sonar, PDS-2. At each of four locations, three measurements were taken, and recorded with the PDS-2, and the Garmin 76 CS was used to determine the location of the depth measurement.

Figure 20. Tag secured to a portion of ribcage.

Figure 21. Tag secured to horn.

Degree of offal decomposition
At locations where a tag was found, a remotely operated vehicle (ROV) was deployed to visually determine the level of decomposition of the muskox offal.

Results & Discussion

Location of offal deposits

Figure 22 and 23, and Table 5, illustrate the position and number of disposal sites found on the sea ice. There were 11 disposal sites, with each disposal site consisting of six to eleven piles of offal, placed in a circle. Table 1 denotes the locations of the centre of each disposal sites. The material was not placed in the correct position on the ice, and was therefore disposed of in violation of a permit condition. Offal could not be removed from the ice at the time this error was discovered, since it had frozen in place and the necessary machinery could not be brought in due to a lack of ice roads. The permit stipulated that offal should be deposited further offshore than location D in Figure 1; location D marks the inner edge of the disposal area.

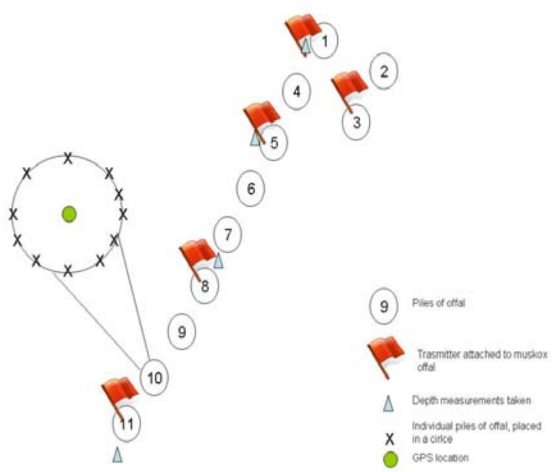


Figure 22. Position of muskox offal disposal sites on sea ice, location of tags and depth measurements, May 10, 2006.

Offal Disposal ID	North	West
Loading Area	N 71^0 59.079'	W 125^0 18.665'
O1	N 71^0 58.288'	W 125^0 21.353'
O2	N 71^0 58.239'	W 125^0 21.196'
O3	N 71^0 58.211'	W 125^0 21.373'
O4	N 71^0 58.251'	W 125^0 21.481'
O5	N 71^0 58.212'	W 125^0 21.612'
O6	N 71^0 58.167'	W 125^0 21.758'
O7	N 71^0 58.121'	W 125^0 21.909'
O8	N 71^0 58. 029'	W 125^0 22.219'
O9	N 71^0 57. 988'	W 125^0 22.357'
O10	N 71^0 57. 947'	W 125^0 22.488'
O11	N 71^0 57. 901'	W 125^0 22.637'

Table 5. Locations of offal disposal sites, as found May 10, 2006.

Table 6 indicates the location of each tag. The tags were secured to skeletal remains, in circles 1, 3, 5, 8, and 11, with circle 1 the closest to shore (approximately 2 km) and circle 11 being the farthest from shore (approximately 3 km). Tags were attached to the ribcage (circles 1, 3, 5), horn (circle 8) and femur (circle 11).

Table 6. Location of activated sonic transmitters, attached to skeletal remains of muskox

Tag #	Circle #	Location	Secured by
1	O1	N 71^0 58.301', W 125^0 21.367'	Ribcage
2	O5	N 71^0 58.223', W 125^0 21.611'	Ribcage
3	O8	N 71^0 58.039', W 125^0 22.206'	Horn
4	O11	N 71^0 57.910', W 125^0 22.645'	Femur
5	O5	N 71^0 58.219', W 125^0 21.352'	Ribcage

One tag was found 450 metres south of the May 2006 installation location. The search for the other four tags was hindered by shifting sea ice. Scattered offal was observed when the ROV was piloted southward from the transmitter location.

Figure 23. Circles of offal disposed of on the sea ice in a north/south direction.

Disposal site depth

Depth measurements were taken in the centre of circles 1 and 5, between circles 7 and 8, immediately south of circle 11. Table 7 indicates the locations of the holes used and the water depths recorded. Three depth readings were recorded at each site, with the exception of hole B, where two recordings were made. Depths were generally less than the 10-20m anticipated; this was due to the incorrect placement of the offal on the ice. Depth readings at location D were greater than 10m, which suggests that water depth at the correct disposal site would have been sufficient to meet permit assumptions.

Table 7. Location and values of depth measurements

Hole ID	Location	Depth (ft)	Depth (m)	Average Depth (m)
A	N 71^0 58.291', W 125^0 21.359'	17.5	5.3	5.3
		17.5	5.3	
		17.5	5.3	
B	N 71^0 58.213', W 125^0 21.608'	20.0	6.1	6.1
		20.0	6.1	
		-		
C	N 71^0 58.076', W 125^0 22.057'	26.0	7.9	7.9
		26.0	7.9	
		26.0	7.9	
D	N 71^0 57.891', W 125^0 22.666'	34.0	10.4	10.5
		35.0	10.7	
		34.0	10.4	

Degree of offal decomposition

ROV observations of offal on the sea bed suggested that minimal tissue decomposition had occurred in the two months that had elapsed since disposal was completed.

Conclusions:

The material was not deposited at the designated disposal site. The permittee has been informed that disposal did not take place at the site designated in the permit and that the water depth over the final resting place of the material did not meet the permit criteria of 10 m. Environment Canada Enforcement has been informed and is following up.

The method of tagging and locating offal was effective for determining the disposal location of offal on the sea floor.

Because the density of the material observed around the located tag was low, it is hypothesized that the majority of the offal was dispersed over a wider area than could be surveyed in 2006. A follow-up program will be required to assess the extent of dispersal and to determine the limits of the offal disposal site. Ice conditions were found to restrict the area that could be searched for tags. Future searches should be carried out when the ice pack has receded far enough to permit a larger search area.

Further monitoring work to confirm the water depth at the designated disposal site would be beneficial to verify that the assumptions made when the permit was issued are correct.

Decomposition rates could not be assessed because the follow-up program took place shortly after disposal operations. A follow-up survey at the same location would allow a confirmation of the adequate decomposition of the offal. Ultimately it may not be possible to determine decomposition rates as ice and wave action may bury or disperse the offal.

Annex 1. Monitoring Expenditures

In March 1999, pursuant to Treasury Board policy on cost recovery, Environment Canada introduced a monitoring fee of $470 per 1000m^3 of dredged or excavated material. This fee is known as a "right or privilege" fee and is meant to provide Canadians with a fair return for use of public resources. Proceeds from this fee are used to cover the cost of disposal site monitoring, thus allowing environmentally sound management and allowing users continued access to their disposal sites.

Part of Environment Canada's commitment was to provide an annual summary of revenues and expenditures related to disposal site monitoring. The figures below represent the seventh year of cost recovery. In the 2006-2007 fiscal year, Environment Canada collected slightly more than in the previous fiscal year, with revenues amounting to just over $1.2 million. The total net cost to the federal government was $122,212.

Monitoring Expenditures 2006-2007	
Atlantic Region	$191,444.34
Quebec Region	$60,671.34
Prairie and Northern Region	$18,194.11
Pacific and Yukon Region	$384,274.97
Headquarters	$28,248.50
Environment Canada indirect costs	$285,424.30
Sub total costs for Environment Canada	$968,257.56
In-kind support from other federal departments	$358,650.00
Total cost for federal government	$1,326,907.56
Resources Recovered 2005-2006	
Monitoring Fees	$1,204,695.00
Net costs 2005-2006	
Resources collected over federal government costs	-$122,212.56
Net Environment Canada costs	$236,437.44

Annex 2. Offices for the Disposal at Sea Program

The Disposal at Sea Program Offices are located in the following Environment Canada offices.

Atlantic Region-Maritimes
Disposal at Sea Program
Environmental Protection Branch
Environment Canada
45 Alderney Drive, 4th Floor
Dartmouth, Nova Scotia
B2Y 2N6

Atlantic Region-Newfoundland and Labrador
Disposal at Sea Program
Environmental Protection Branch
Environment Canada
6 Bruce Street, Mount Pearl
Newfoundland and Labrador
A1N 4T3

Quebec Region
Disposal at Sea Program
Environmental Protection Branch
Environment Canada
105 McGill Street, 4th Floor
Montreal, Quebec
H2Y 2E7

Prairie and Northern Region
Disposal at Sea Program
Environmental Protection Branch
Environment Canada
5204 - 50th Avenue, Suite 301
Yellowknife, Northwest Territories
X1A 1E2

Pacific and Yukon Region
Disposal at Sea Program
Environmental Protection Branch
Environment Canada
201 - 401 Burrard Street
Vancouver, British Columbia
V6C 3S5

National Capital Region
Disposal at Sea Program
Environmental Protection Service
Environment Canada
351 St. Joseph Boulevard, 7th Floor
Hull, Quebec
K1A 0H3

Further details may be found on-line at the Program's web site www.ec.gc.ca/seadisposal/