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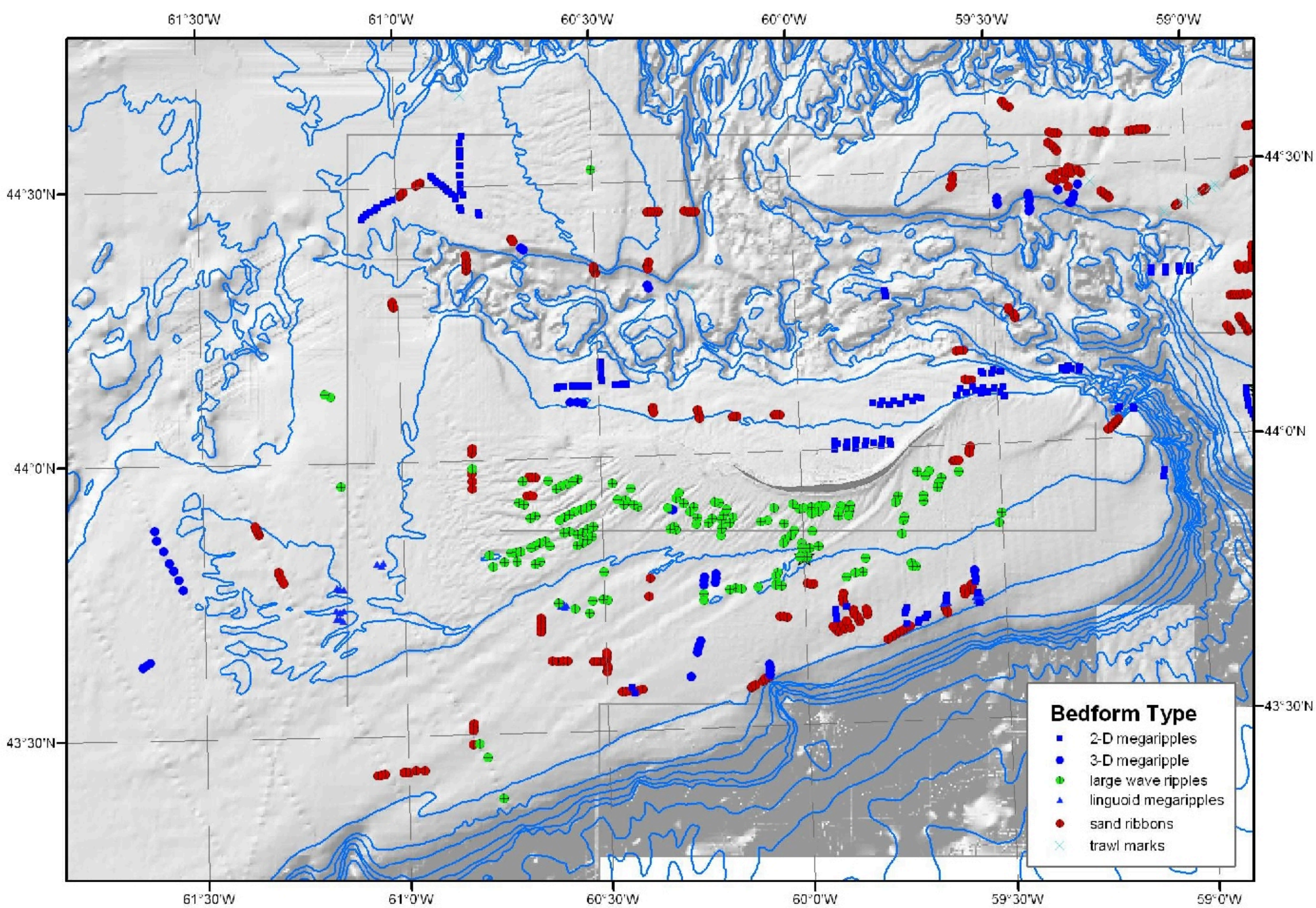
Design and Initial Development of the Sable Island Bank Seabed Stability GIS Database

Michael Z. Li and Edward L. King



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Abstract

Offshore Eastern Canada is experiencing increased offshore oil and gas development to meet North American energy demands. Sound knowledge on the nature and severity of geohazards (e.g. bedform stability, iceberg seabed scours, susceptibility of seabed to sediment failure) is an important factor in the decision to open these lands to exploration or approve new development plans. An offshore geohazard project (X-27) was established in the Geoscience for Ocean Management (GOM) program to provide regulators, federal departments and industry with a knowledge base to assess geohazard risk, set regulatory policy and evaluate development plans.

One of the components of the Offshore Geohazard project is to address the seabed stability issues on Sable Island Bank in the Scotian sub-basin. Under this activity through joint A-base and PERD funding, existing data have been and will continue to be compiled and interpreted. New data, including repeat surveys and in situ sediment dynamics measurements, were obtained. These new data and some of the compiled data were used to develop an integrated and readily accessible seabed stability GIS database that contain information on (1) surface sediment type, (2) geometry, distribution and mobility of bedforms, (3) distribution and risk potential of other surficial geohazards, and (4) location and summary of existing sediment dynamics data sets recorded by GSC seabed instruments Ralph and S4 on Sable Island Bank. It is hoped that the database will be a powerful system to store, manage, display and analyze spatial bedform mobility and geohazard data and thus a useful tool for stakeholders to effectively assess the distribution, nature, mobility and/or risk potential of bedforms and other surface geohazards on Sable Island Bank. This report serves as a phase 1 status report and intends to document the concept and theme structure of the database, describe the database development methodology, present some preliminary results from the initial population of the database, and highlight planned activities in the future phases of the database development.

Design and Initial Development of the Sable Island Bank Seabed Stability GIS Database

Michael Z. Li and Edward L. King
Geological Survey of Canada (Atlantic)

1. Introduction

Offshore Eastern Canada is experiencing increased offshore oil and gas development to meet North American energy demands. Sound knowledge on the nature and severity of geohazards (e.g. bedform stability, iceberg seabed scours, susceptibility of seabed to sediment failure) is an important factor in the decision to open these lands to exploration or approve new development plans. An offshore geohazard project (X-27) was established in the Geoscience for Ocean Management (GOM) program to provide regulators, federal departments and industry with a knowledge base to assess geohazard risk, set regulatory policy and evaluate development plans.

One of the components of the Offshore Geohazard project is to address the seabed stability issues on Sable Island Bank in the Scotian sub-basin. Sidescan, multibeam and in situ measurement data collected by the Geological Survey of Canada (GSC) in recent years have provided some new insights on the types, distribution and mobility of sandy bedforms on Sable Island Bank (e.g. Li, King et al., 2001; King, 2002a; Li et al., 2003; Smyth et al., 2003). But they have not been systematically compiled and analyzed, nor readily accessible. Under this activity through joint A-base and PERD funding, existing data have been and will continue to be compiled and interpreted. New data, including repeat surveys and in situ sediment dynamics measurements, were obtained. These new data and some of the compiled data were used to develop an integrated and readily accessible seabed stability GIS database that contain information on (1) surface sediment type, (2) geometry, distribution and mobility of bedforms, (3) distribution and risk potential of other surficial geohazards, and (4) location and summary of existing sediment dynamics data sets recorded by GSC seabed instruments Ralph and S4 on Sable Island Bank. It is hoped that the database will be a powerful system to store, manage, display and analyze spatial bedform mobility and geohazard data and thus a useful tool for stakeholders to effectively assess the distribution, nature, mobility and/or risk potential of bedforms and other surface geohazards on Sable Island Bank. The sediment and bedform mobility information in the database should also directly contribute to the Scotian Shelf Integrated Oceans Management project.

Significant portion of the results contained in this database was developed under the GOM Geology of Eastern Scotian Shelf project (X32). This project focuses on the development of a GIS based geologic framework and its relationship to benthic habitat for the eastern Scotian Shelf. Eventually the Sable bedform and surficial geohazard database will supplement this broader Scotian Shelf geological framework database.

The development of the database is a staged effort. This report serves as a phase 1 status report and intends to document the concept and theme structure of the database, describe the database development methodology, present some preliminary results from the initial population of the database, and highlight planned activities in the future phases of the database development. In the first phase (2003/04), the concept and themes of the database were developed, and the database was populated with some initial published and “legacy”data limited to the bounds of the Sable Island Bank study area (Fig. 1). The geodatabase was developed on a common access machine within the ArcMap desktop application and functioned as a prototype for organizing data into logical groupings, defining data objects and relationships, and establishing the geographic representation and attribution of features and measurements. The access to this developing database was limited to the members of the working group. In the second phase (2004/05), the database will continue to be populated with compiled existing data. New data from repetitive surveys and in situ measurements will be added. Refinements to the logical data model and theme structure will also be implemented. The refined database should move from the personal geodatabase to the GSC - Atlantic (GSCA) enterprise geodatabase under the ArcSDE/Oracle environments, making the database accessible to the staff at GSCA. In the final phase (2005/06) of the implementation, predictions from hydrodynamic and sediment transport models will be incorporated into the database. The database will be applied to data synthesis and assessing the distribution and mobility or impact of targeted bedforms and geohazards. New derivative and enhanced seabed stability maps will be produced.

Following this introduction, Section 2 presents the methodology of the database development. Section 3 discusses the designed database contents and theme structure. Some initial results are presented in Section 4 which is followed by the summary and discussions.

2. Methods

2.1 Existing Data

Existing sidescan/seismic, multibeam, and in situ measurement data have been and will continue to be compiled and incorporated in the database (a joint effort under X32 and X27). These included published journal papers, GSCA cruise and technical reports, CHS (Canadian Hydrographic Services) bathymetry charts, and the vast information in GSC Expedition Database (ED). Efforts were also made to include recent results from Department of Fisheries and Oceans (DFO) fishery habitat research areas and data from industry site surveys.

2.2 New Surveys and in situ Data

Inventory and compilation of existing data have identified areas with critical gaps. New surveys have been and will continue to be conducted to obtain information on the nature, distribution, and mobility or risk potential of bedforms and other geohazards in these areas. In particular, a back-to-back 2004 summer and 2005 spring geological/geophysical surveys have been tentatively planned to survey targeted bedforms and other geohazards to quantify their mobility or risk potential over one winter storm season.

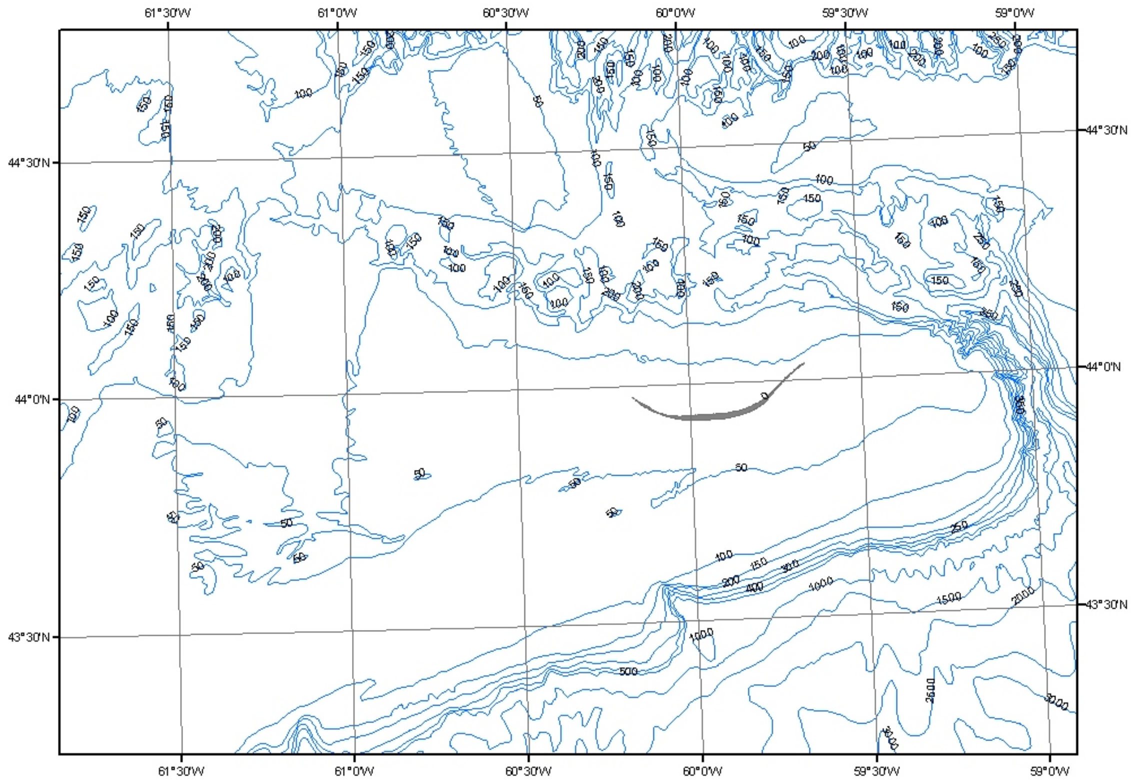


Fig. 1 The study area limits and the queryable general bathymetry contours on Sable Island Bank, Scotian Shelf.

Besides repetitive surveys, in situ hydrodynamic and sediment transport measurements are needed in order to quantify the sediment and bedform mobility and to determine the dominant fluid forces and processes that cause these mobilizations. These are accomplished through the deployments of GSCA sediment dynamics instrumentation platform RALPH (Heffler, 1996) in association with S4 wave-current meters. The planned deployments include a deployment over megaripples and large-wave ripples in a sand ridge trough at the Cohasset-Panuke (CoPan) site in 2004, and a second deployment in 2005 over megaripples and rippled scour depressions at the sediment acoustic property test site of Defence Research & Development Canada (DRDC)-Atlantic.

2.3 Storm Data and Model Predictions

Wind and wave data from offshore buoys will be analyzed in 2004/05 to derive the yearly storm statistics for a given period (e.g. 1990 to 2004) and these will be compared with the serial sidescan and multibeam coverages to quantify the mobility of targeted bedforms and the resulting mobile layer depth. Numerical wave and current models will be set up and coupled with a sediment transport model to predict the regional pattern of storm-enhanced nearbed forces, sediment and bedform mobility for the study area.

3. Database Content and Themes

The design of a GIS geodatabase is an interactive and iterative process and therefore the theme structure of the database will evolve through various development stages. The Sable Seabed Stability database completed in the first phase included the following themes (see Fig. 2): Bathymetry, Geophysical Surveys, Sediment Type and Grain Size, Bedforms, Other Geohazards, Sediment Dynamics Datasets, and Sediment and Bedform Mobility. These themes and their possible sub-themes are listed and briefly described below.

3.1 Bathymetry Theme

An understanding of the shape of the seabed (bathymetry) and the type of seabed forms (geomorphic features) is fundamental information needed for ocean planning and management. Bathymetry data and analysis of this data provide information on water depth, seabed geomorphologic features, distribution of large-scale bedforms, and regional pattern of seabed slope, all of which are required for seabed stability and geohazard assessment. Water depth and bedform types are important determinants of habitat diversity and zonation (Todd et al., 2000; Pickrill and Todd, 2003). High resolution bathymetry data is also needed for wave, current and sediment transport modelling efforts. For these reasons, the following key sub-themes were included in the Bathymetry Theme:

sub-theme 1: A general bathymetry contour map (also as background for all themes).
sub-theme 2: Surface relief map based on compiled CHS data (King unpublished).
sub-theme 3: High resolution bathymetry grid data and contour map based on combined CHS and multibeam DEM (derived under X32).
sub-theme 4: Multbeam bathymetry data.

3.2 Geophysical Survey Control Theme

Sdiescan and seismic surveys are conventional data collected in all geological and geophysical expeditions. They provide key baseline information on sediment type, distribution and characteristics of bedforms and other geohazards, and subsurface stratigraphic structures for understanding regional geological framework. The Geophysical Survey Control theme included the following sub-themes:

sub-theme 1: GSCA geophysical survey lines
sub-theme 2: Non-GSCA geophysical survey lines

3.3 Sediment Type and Grain Size Theme

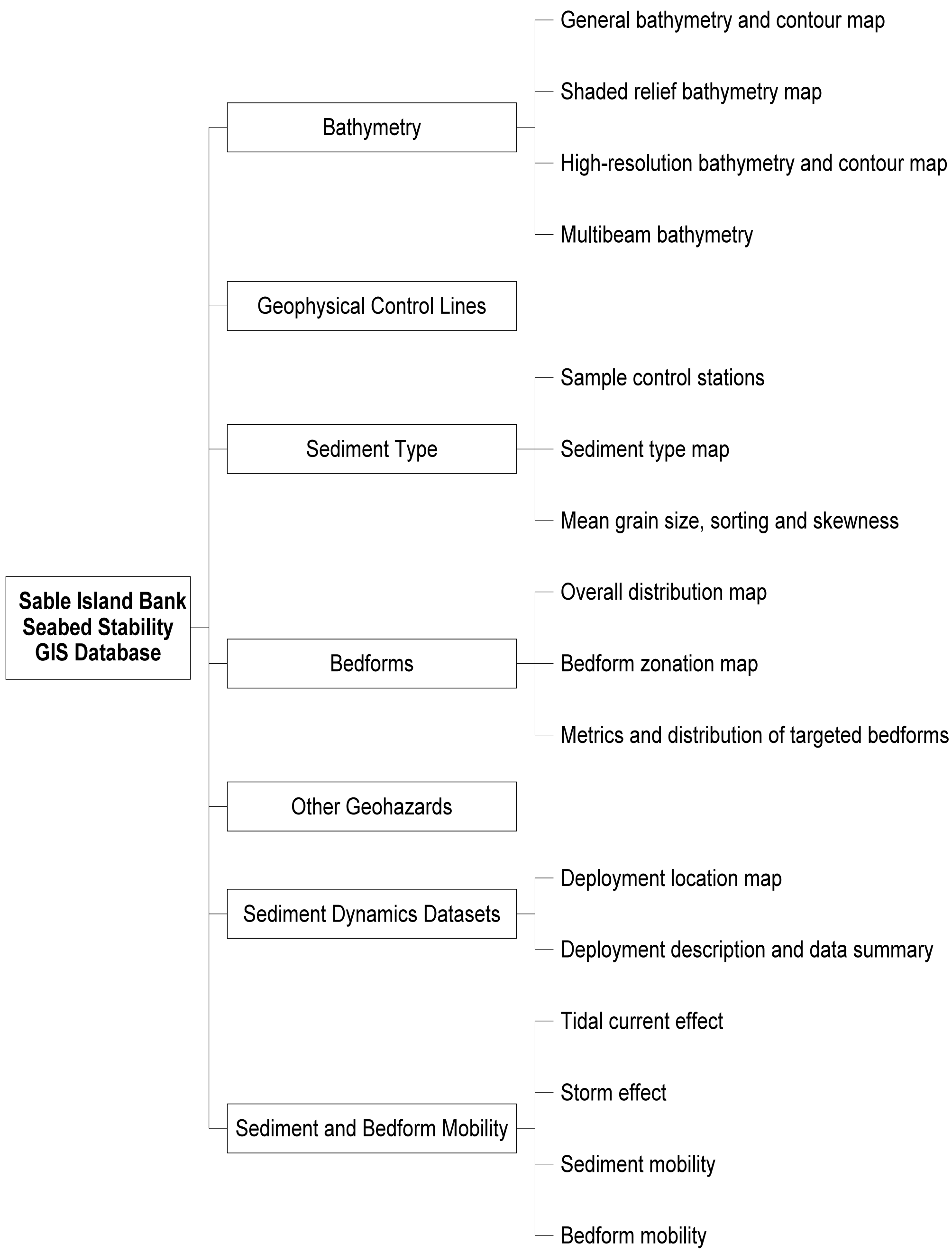


Fig. 2 The theme structure of the Sable Seabed Stability database.

Sediment type (mud, silt, sand, gravel, bed rocks etc) and grain size distribution are baseline data required for initial assessment of foundation conditions, benthic habitat classification, and modelling exercises. Key sub-themes in this layer are:

sub-theme 1: Control map of seabed sediment sample stations
sub-theme 2: Core and borehole stations
sub-theme 3: Sediment type map
sub-theme 4: Contour maps of mean grain size, sorting and skewness

3.4 Bedforms Theme

The metrics, distribution, and mobility of bedforms (covered in this and Sediment and Bedform Mobility theme) are critical information for assessing sediment/bedform stability and the depths and dynamics of sediment mobile layer, and hence impact the decision of the siting/routing and engineering design of offshore installations. Sediment and bedform mobility knowledge is also needed in habitat classification and understanding the control of geosience on habitat diversity and distribution (Todd et al., 2000; Pickrill and Todd, 2003). The Bedforms theme in the Sable database contains the following sub-themes:

sub-theme 1: Overall distribution map of various bedforms
sub-theme 2: Upgraded bedform zonation map of Amos and Nadeau (1988)
sub-theme 3: Metrics and distribution of targeted bedforms, including the distribution and metrics (height, wavelength, symmetry, crest orientation) of sand ridges, sand waves, sand ribbons, gutters, megaripples, large wave ripples (LWR), and scour depressions.

3.5 Other Geohazards Theme

Besides unstable sediment types and mobile bedforms, there is a variety of other offshore geohazards, e.g., shallow gas, shoreface pits, sediment failures, etc. The nature and distribution of some of these geohazards will be incorporated into this database.

3.6 Sediment Dynamics Datasets Theme

Nearbed hydrodynamics and sediment transport measurements using seabed instruments are an important part of seabed stability research. These in situ data provide direct information on the nearbed wave and current forcing, and the frequency and magnitude of seabed scouring, sediment transport, and bedform mobilization. Field sediment dynamics data also serve as critical ground truth for calibrating various wave, current and sediment mobility models.

GSC sediment transport instrumentation platforms have been deployed more than 20 times on Scotian Shelf since the early 1990s. These produced one of the most extensive continental shelf sediment dynamics datasets. Up to present, these complex datasets are only listed and described in tabular forms. As part of this project, these datasets have been inventoried, systematically processed, and incorporated into the Sable Seabed Stability database so that they are now better stored, displayed and used for seabed stability assessment. The deployment location and standard summaries of these datasets were included as sub-themes in the database.

Sub-theme 1: Deployment location map
sub-theme 2: Deployment description and data summary

3.7 Sediment and Bedform Mobility Theme

The significance of sediment and bedform mobility is given in section 3.3. The quantification of mobility is achieved through serial surveys, storm data analysis and model predictions. In the last phase (2005/06) of the database development, tidal and wave models will be set up for the Sable area and calibrated using seabed instrumentation data. The current and wave models will be integrated and interfaced with the GSC sediment transport model SEDTRANS to predict the tidal current effect, storm effect and sediment and bedform mobility on Sable Island Bank. Analysis of seabed instrumentation data and the comparison between storm statistics and repeat survey data will augment the assessment of bedform mobility.

Sub-themes:
sub-theme 1: Tidal current effects (tidal current velocity and current shear stress)
sub-theme 2: Storm effects (nearbed wave orbital velocity, wave shear stress and storm-enhanced combined shear stress for storms of selected return intervals; relative effect of tide and waves)
sub-theme 3: Mobility and transport mode based on grain size
sub-theme 4: Bedform mobility and mobile layer depth

4. Initial Results

4.1 Bathymetry

Query-able general bathymetry data was included as one of the sub-themes in the bathymetry theme. The contour map based on this general bathymetry data is shown in Fig. 1. This bathymetry data provides an outline of the geomorphology of Sable Island Bank and surrounding basins and canyons, and is also used as the common background for other maps. A more detailed bathymetry contour map is given in Fig. 3 which better delineates the shoals and the northeast-southwest trending sand ridges on the southern and western Sable Island Bank. Efforts are near complete to combine the CHS data with all multibeam data to generate a DEM which provides the highest resolution bathymetry information (with variable spatial resolution) presently available.

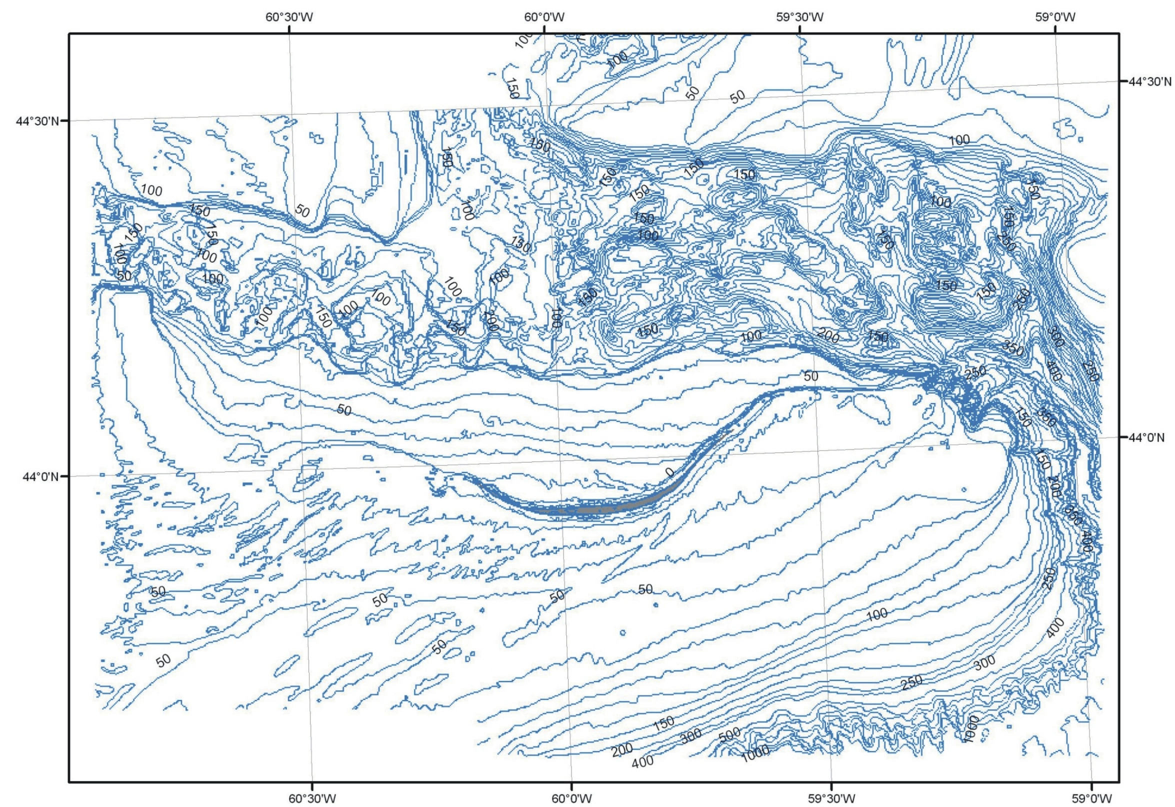


Fig. 3 A more detailed bathymetry contour map for better delineation of shoals and sand ridges on Sable Island Bank.

Using primarily CHS bathymetry data with 400 m or better spacing, a shaded relief image has been generated for the Sable bank area (Fig. 4; King unpublished map). The sun illumination in Fig. 4 helps to better depict the bank edge and the highs and lows in the adjacent basin, but more importantly better shows the orientation, scales and boundaries of the sand ridges on the entire bank.

Multibeam bathymetric mapping technology provides 100% bathymetric coverage of the seabed at the highest available vertical resolution (e.g., Courtney and Fader, 1994). Through collaboration with Exxon-Mobil Canada (formerly Sable Offshore Energy Inc.), GSCA collected serial multibeam surveys at several selected sites to study the morphodynamics of sand ridges and associated bedforms on Sable Island Bank (Li et al., 2003). These surveys provide the bathymetry data with the highest resolution for the selected sites and more accurate information on the metrics, distribution and superimposing relation of a wide range of bedforms and seabed instability features. Comparison of serial surveys, in combination with in situ hydrodynamics and

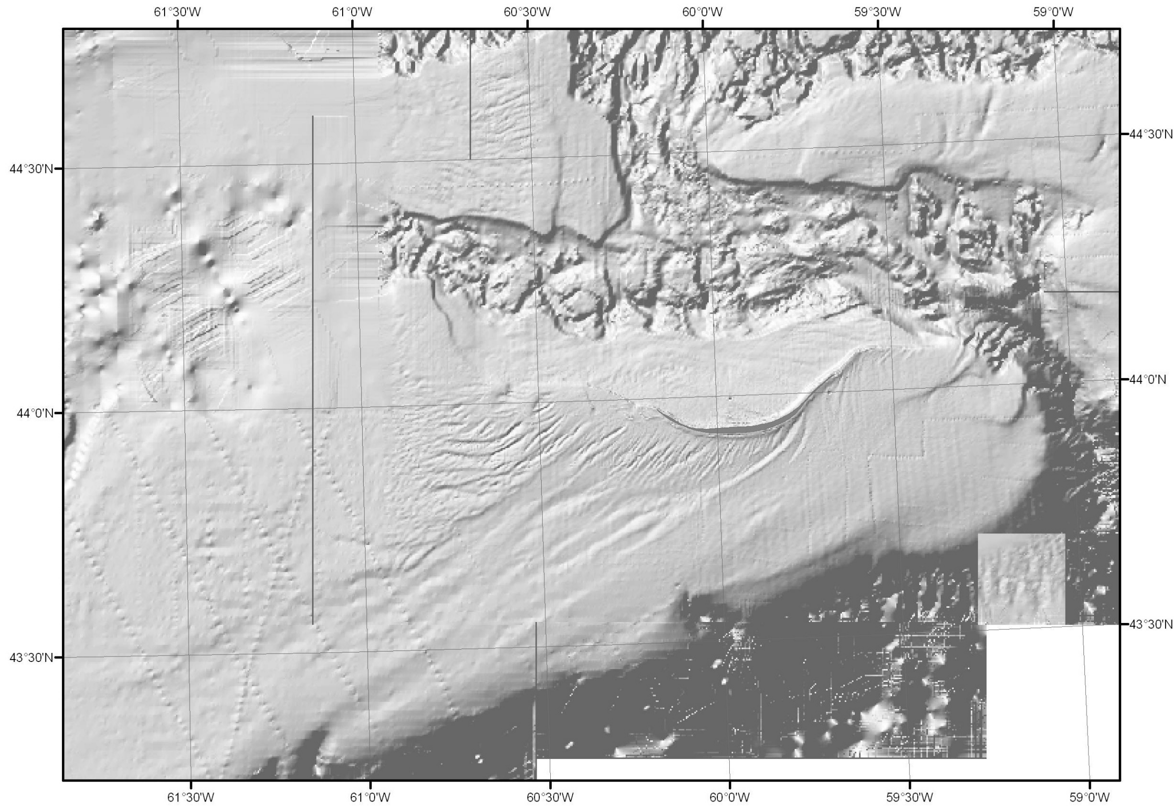


Fig. 4 A shaded relief image of the Sable Island Bank area.

sediment transport measurements, can also lead to quantification of bedform migration rate and direction.

The images of multibeam data collected from 1996 to 2001 at several sites on Sable, as shown in Fig. 5, were included in the Sable database. Polygon layers have been generated in the database to effectively display the years and areas of the serial surveys (Fig. 6). The serial surveys were mainly obtained at the CoPan (repeat surveys in 1996, 97, 98 and 2000) and South Sable (repeat surveys in 1997, 98 and 2000) sites, although surveys were also conducted for the South Venture, West Bar, East Bar and Canyon 49 areas (Fig. 6). Users can select the multibeam data for each survey site shown in Fig. 5 to query water depth and determine the occurrence and distribution of bedforms and other geohazards (see further discussion in Bedform section).

4.2 Geophysical Survey Control

Sidescan and seismic surveys are one of the main sources for deriving information on sediment type and distribution and characteristics of bedforms and other geohazards. Both GSCA

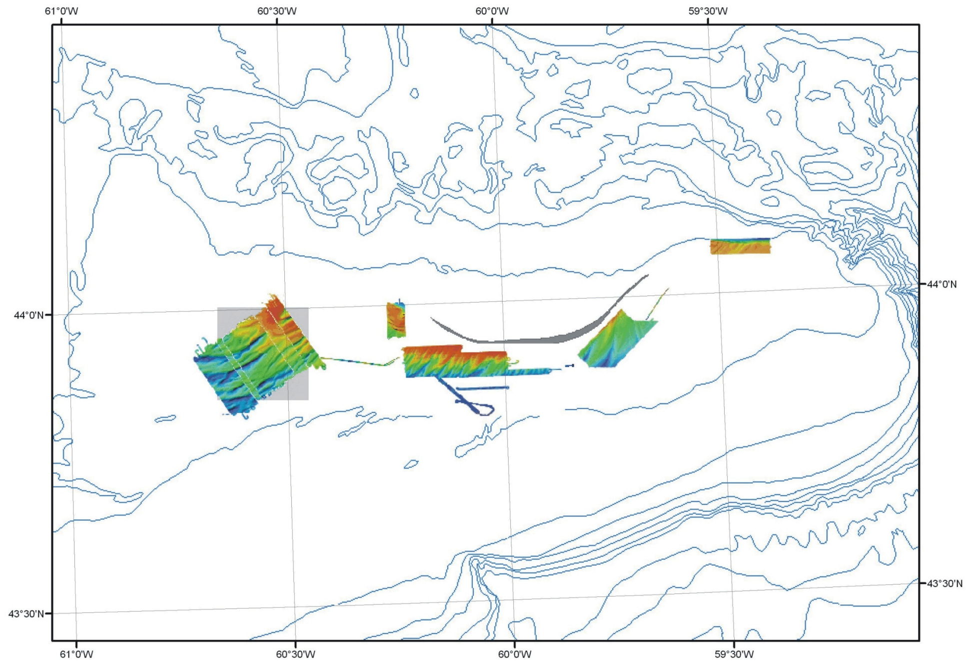


Fig. 5 Sites with serial multibeam surveys on Sable Island Bank.

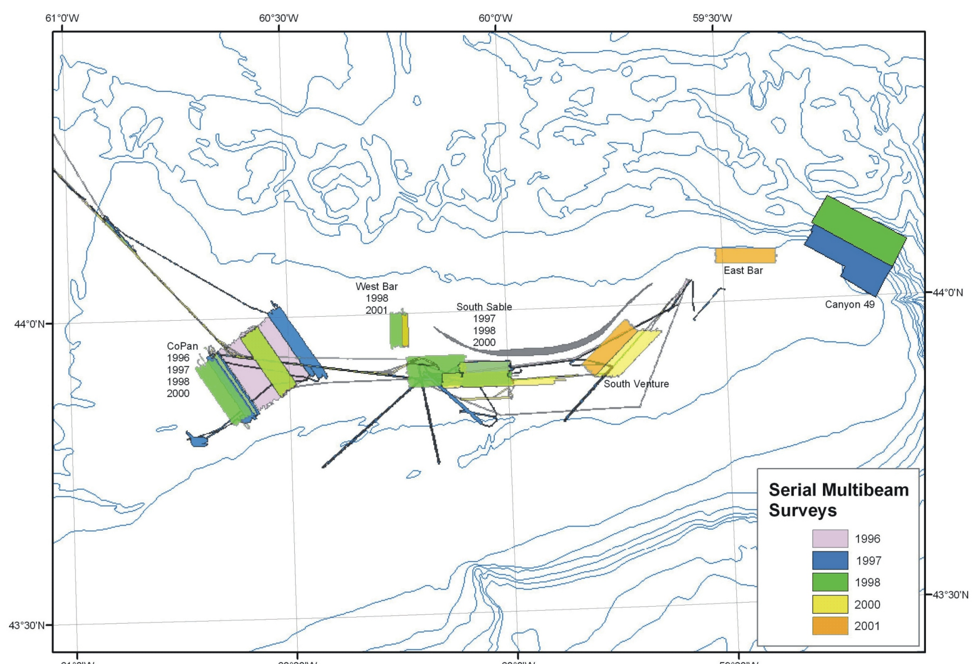


Fig. 6 The years and areas of serial surveys conducted on Sable Island Bank.

and non-GSCA geophysical survey lines on Sable Island Bank have been incorporated in the Sable database. Ship's tracks were attributed with cruise, day time, and survey instrument. Fig. 7 shows the control track lines of the available geophysical surveys on Sable Island Bank. Green indicates GSCA survey lines and brown non-GSCA survey lines. Fig. 7 demonstrates that the Scotian slope and the areas to the immediate south and west of Sable Island on the bank are well surveyed, while coverage is relative less on the western Sable Island Bank.

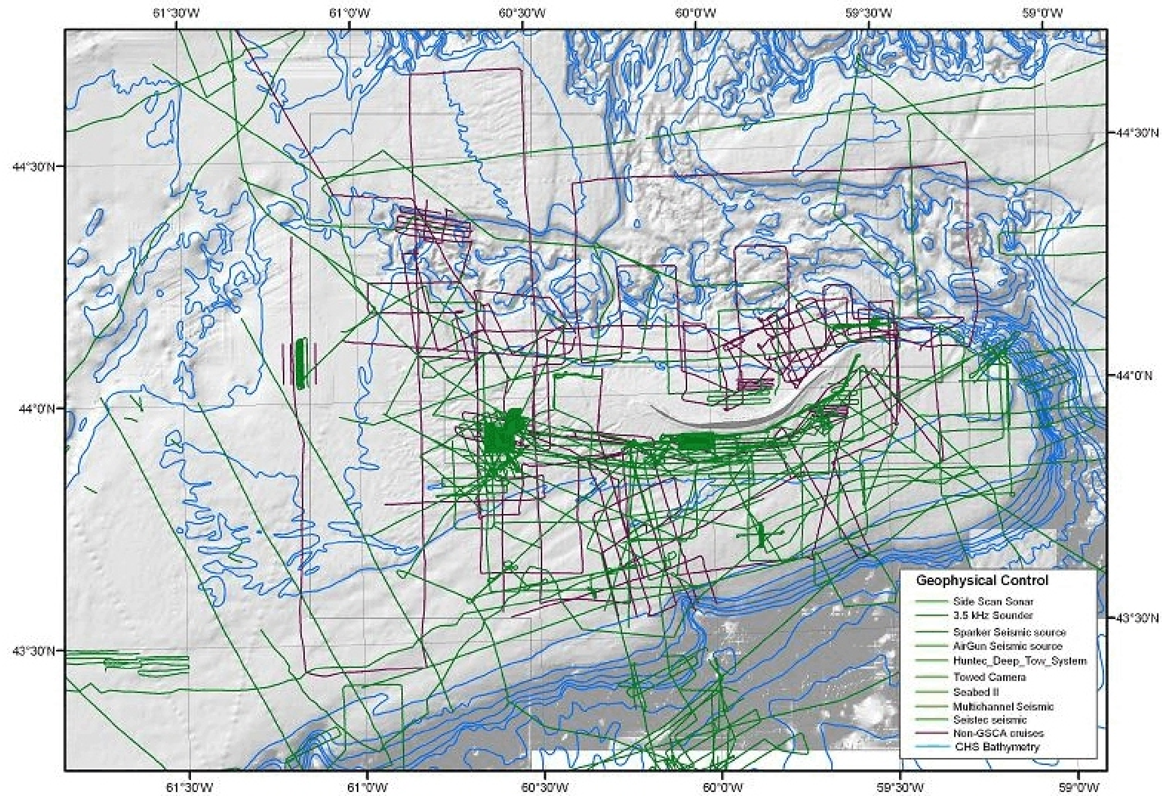


Fig. 7 The control track lines of available geophysical surveys on Sable Island Bank.

4.3 Sediment Type and Grain Size

A recently initialized priority of the GOM program is a set of A-series maps of the Sable Island Bank and surrounding areas. One important component of this is the sediment texture on the seabed. Under the various components of the Hazards project and the ESSIM project, considerable effort has gone into establishing the best possible quality and distribution of seabed sample data. Sample data vary greatly, largely biased by the type of sampler (eg. gravel underestimated by grabs and cores, overestimated by dredges). Furthermore, multibeam and sidescan data provide qualitative information on seabed material, as do photographs. These various data types all need incorporation into a characterization of seabed sediment type.

Bottom sediment samples collected by GSCA were compiled from the GSC Expedition Database (ED) and these control stations are displayed in Fig. 8. Stations in Fig. 8 can be queried using the Identify tool of ArcView for key information on cruise number, station type, date and time of sample collection, station position and water depth. This is demonstrated by Fig. 9. Bottom sample coverage is reasonably good for the study area (Fig. 8). Southeastern and southwestern banks and an area immediately to the west of Sable Island are identified as areas with less samples. Core control stations on Sable are shown in Fig. 10 which includes both GSCA cores and industry cores. This map shows that cores are concentrated in shallow waters around the Sable Island and in the deep waters off the Logan Canyon. Again key information on cruise number, core type, date and time of core collection, and station position and water depth can be displayed using the Identify tool of ArcView.

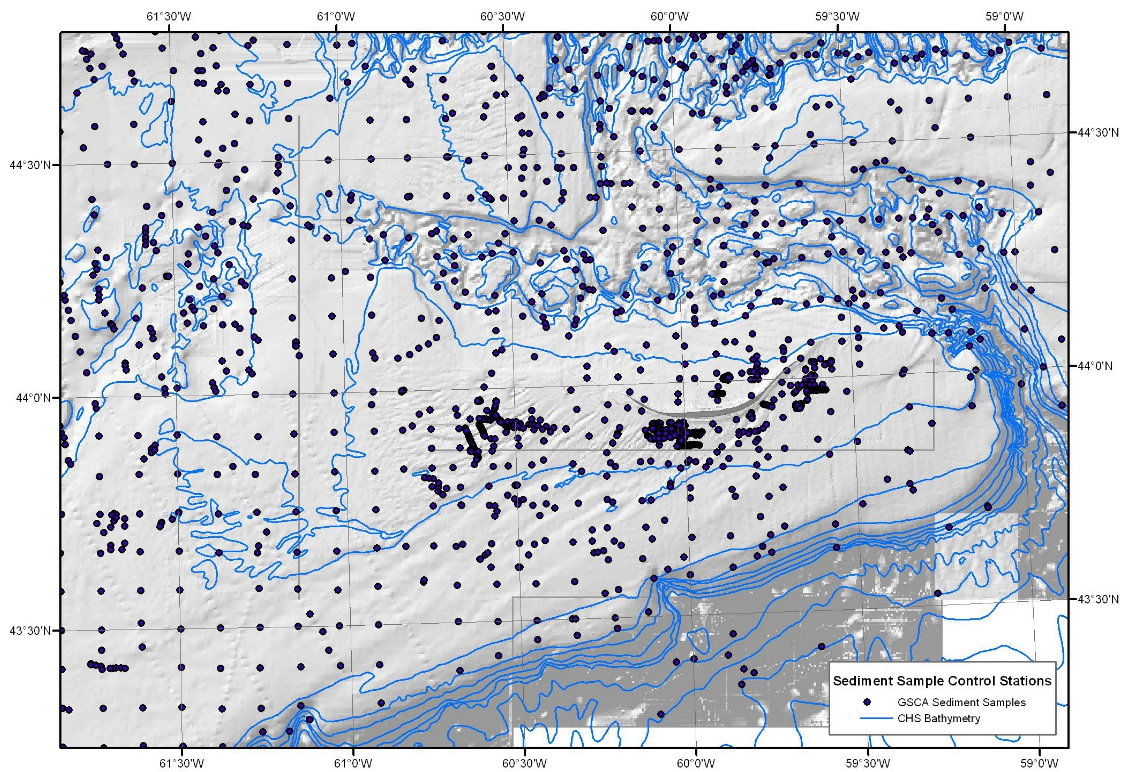


Fig. 8 Sediment sample control stations on Sable Island Bank.

The sidescan data, samples and cores shown respectively in Figures 7, 8 and 10 were analyzed for sediment types and these are displayed in Fig. 11. Textural interpretation of sidescan data earlier than 1988 was made according to Amos et al. (1988). For seabed samples from grabs,

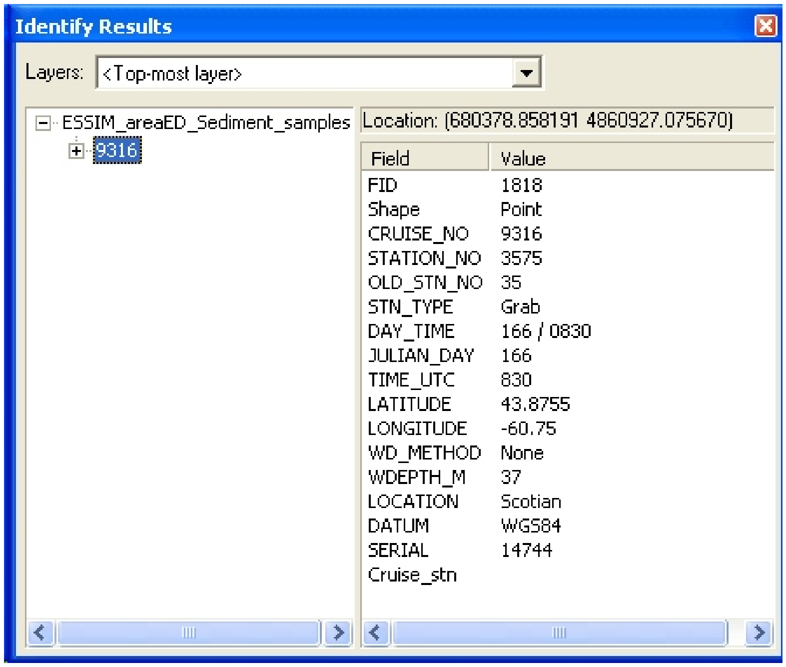


Fig. 9 Information obtained by querying seabed sample stations.

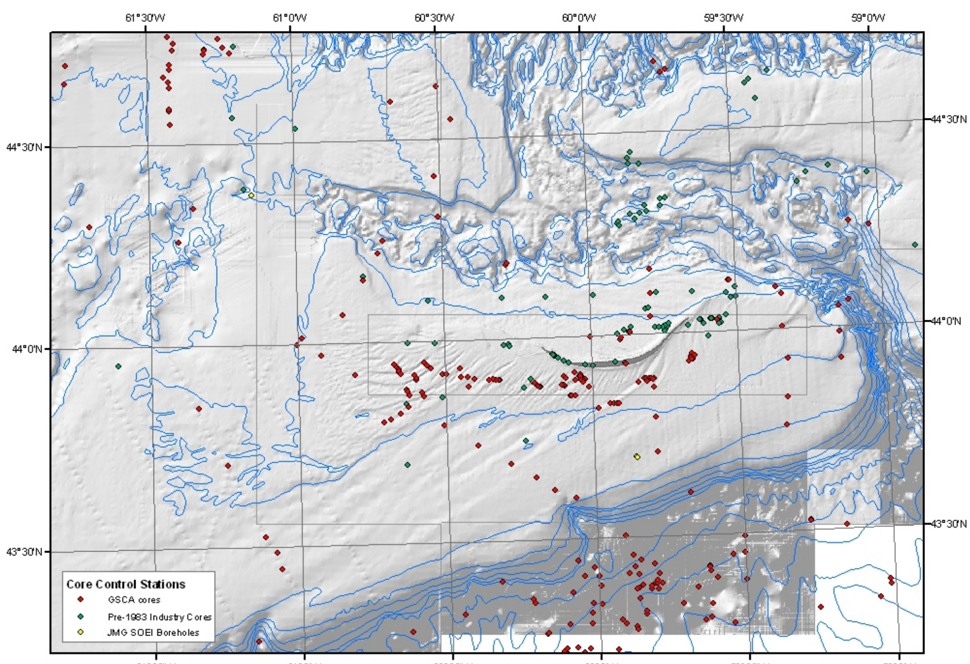


Fig. 10 Core control stations on Sable Island Bank.

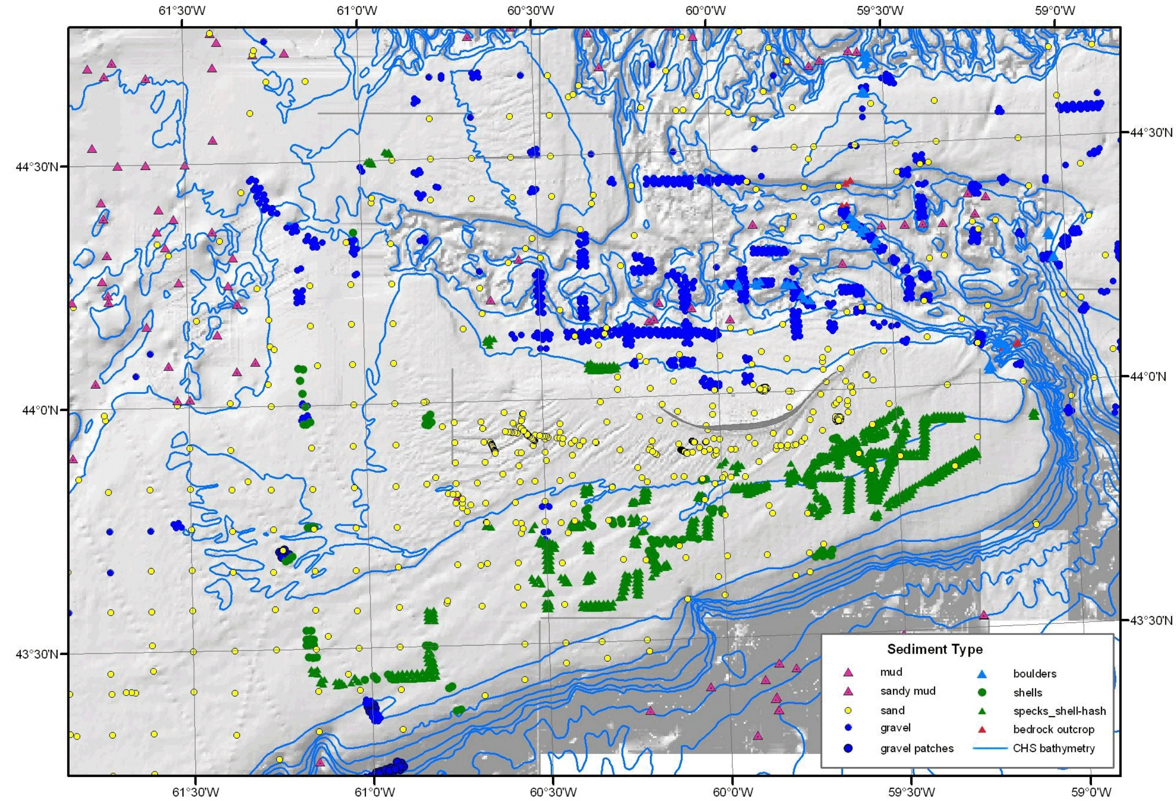


Fig. 11 Overall sediment types map for Sable Island Bank

cores and boreholes, the relative percentages of gravel, sand, silt and clay were differentiated and Folk (1954) classification was applied. Key information such as expedition number, grab or core type, sample location, station depth, percentage of sediment type, and Folk sediment classification were included in the attribute table and can be queried from the database. An example of the information queried from a station in the sediment type map is displayed in Fig. 12. The main sediment types observed in the Sable Island Bank area include mud, sand, gravel-boulders, shells and rare bedrock outcrops. Sand predominantly occurs on the banks, while mud and gravels are generally observed in the adjacent basins. Sandy mud is also observed as the transition between the sand and mud distributions. Shells and specks (patches of concentrated shells or shell fragments) are mostly found on the southern outer bank between 50 to 100 m water depths.

The map of mean grain size of the sand fraction presented in Amos and Nadeau (1988) and Amos et al. (1988) has been regenerated as a query-able mean grain size contour map in Fig. 13. As described by Amos and Nadeau (1988), there is a general trend of deceasing grain size from the western to eastern Sable Island Bank. Patches of coarse and very coarse sand (mean

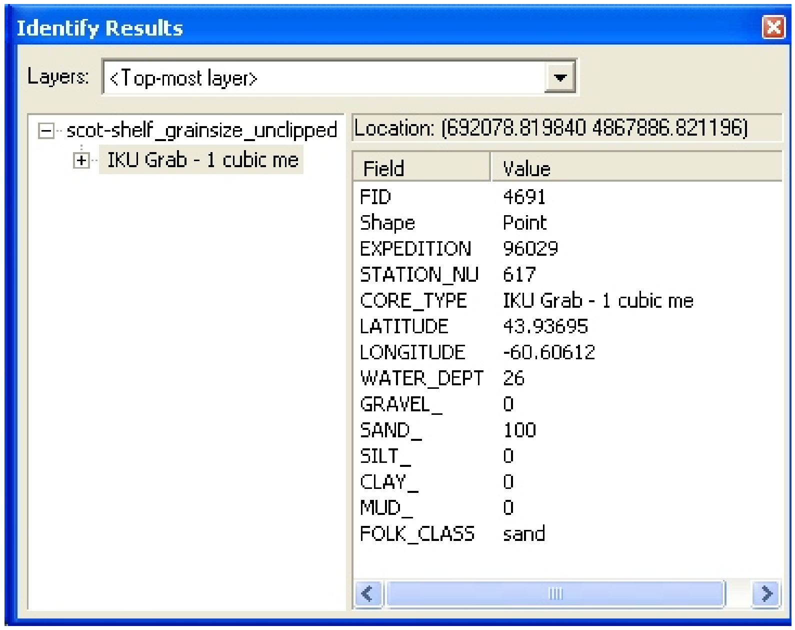


Fig. 12 Information obtained by querying the stations in the sediment type map.

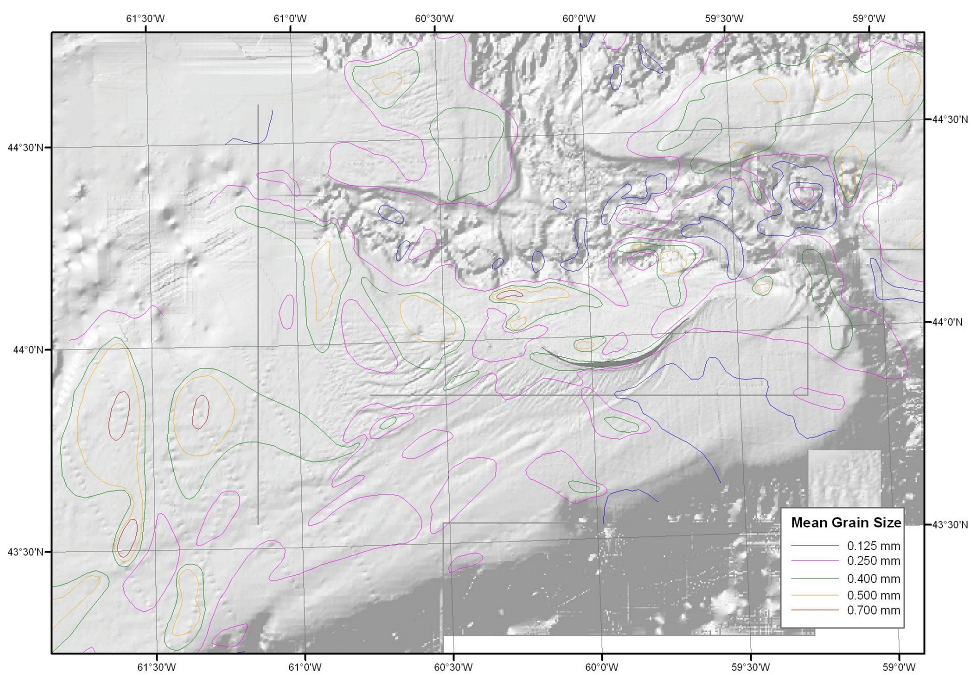


Fig. 13 A queryable mean grain size contour map for Sable Island Bank

grain size D $\geq$0.5 mm) occur in extreme west (Western Bank). Sand fraction grain size decreases eastward to medium sand (0.5 mm > D $\geq$0.25 mm) on western Sable Island Bank, fine sand (0.25 mm > D $\geq$0.125 mm) on the south-central bank, and ultimately very fine sand (D < 0.125 mm) on the southeastern bank before sediment becomes coarser to medium sand on the eastern bank again. Patches of medium sand also occur on Northern Spur and the northern bank, while very fine sand is also found in the lows in the adjacent basin.

As part of a parallel project (X32), a significant effort has been taken to incorporate the grain size data from at least 500 additional bottom samples and to quality control all grain size analysis data. Unfortunately, the grainsize statistics (eg. Skewness, kurtosis, and possibly mean grainsize) contained in the GSCA ED database appear unreliable and will have to be regenerated. The grain size data of all GSCA cruises as well as additional industry sample analyses will require a format normalization. When this is completed, not only will the mean grain size map in Fig. 13 be considerably improved, but maps of sediment sorting and skewness will also be available for the Sable Island Bank area.

4.4 Bedforms

Many of the ships tracks displayed in Fig. 7 have associated sidescan data that were analyzed for bedform types and distribution by Amos et al. (1988). For the Bedforms theme, the interpretations of sidescan data by Amos et al. (1988) have been used to generate the overview of bedform type and distribution map. Key medium to large scale bedforms recognized from sidescans include large-wave ripples (LWR), 2-D and 3-D megarriples, linguoid megaripples, and sand ribbons (see Amos and King, 1984, for definitions). These are presented in Fig. 14. LWR are more likely to occur around the island in depths shallower than 70 m with a few exceptions on the southwestern bank (Fig. 14). Megaripples and sand ribbons generally tend to occur in deeper waters on the outer bank, although sidescan surveys along transects across sand ridges have demonstrated the wide distribution of megaripples in the troughs of sand ridges in water depths from 15 to 50 m (Li et al., 2003). There is some tendency for 2-D megaripples to occur in shallower waters than their 3-D counterparts, suggesting that stronger currents in shallow waters could be responsible for this distribution. However, more data and detailed examination are needed to further establish this pattern.

A compilation phase is presently ongoing. Sidescan and seismic data will be analyzed so that targeted bedform types can be mapped and attributed in terms of size, orientation and degree of "freshness" (qualitative indication of bedform mobility). This compilation will represent a vast improvement over the 1988 catalogue in that it incorporates the attributes, much more new data and also deals with the superposition of various bedform types. In addition, bedform attributes including waterdepth, heights, apparent wavelengths, and skewness have been measured from the interpreted geologic sections from high resolution seismic profiles. These comprise attributes of nearly 6000 bedforms (Campbell, 2001, King, 2002b). These attributes are not currently linked to bedform-type classification.

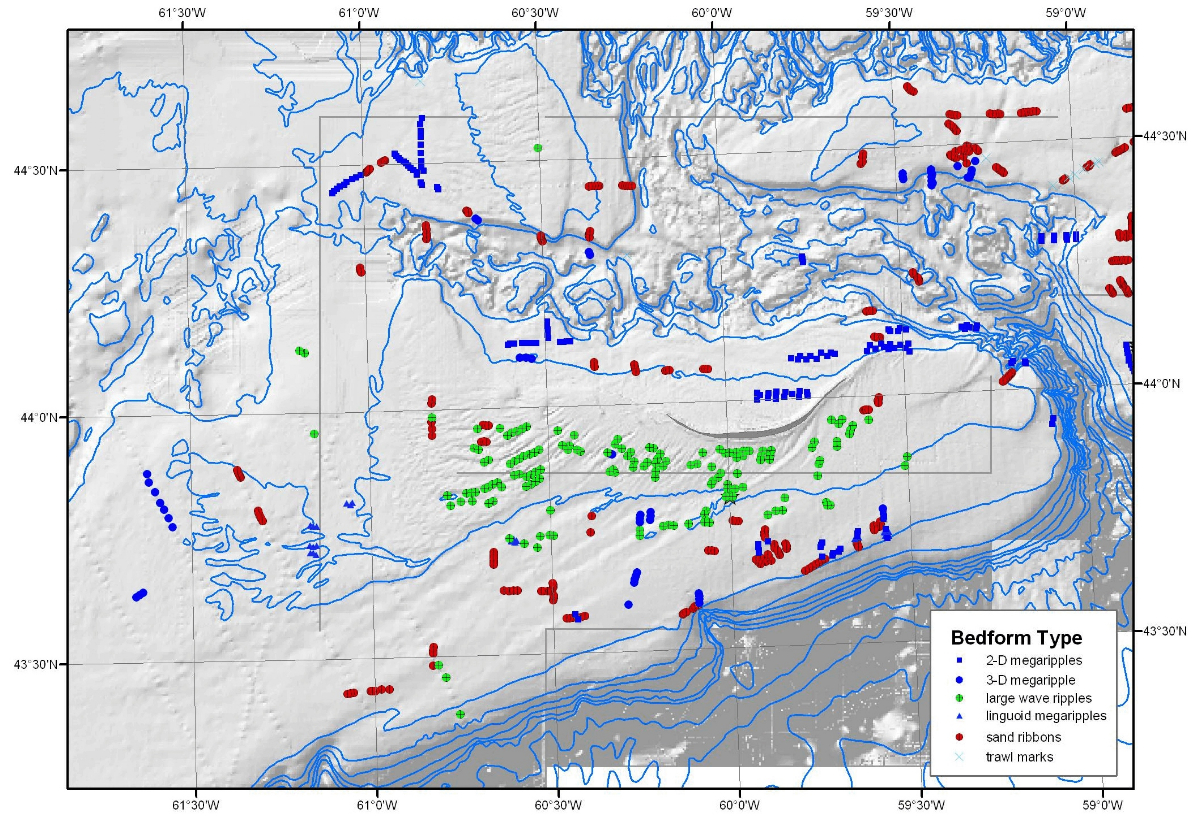


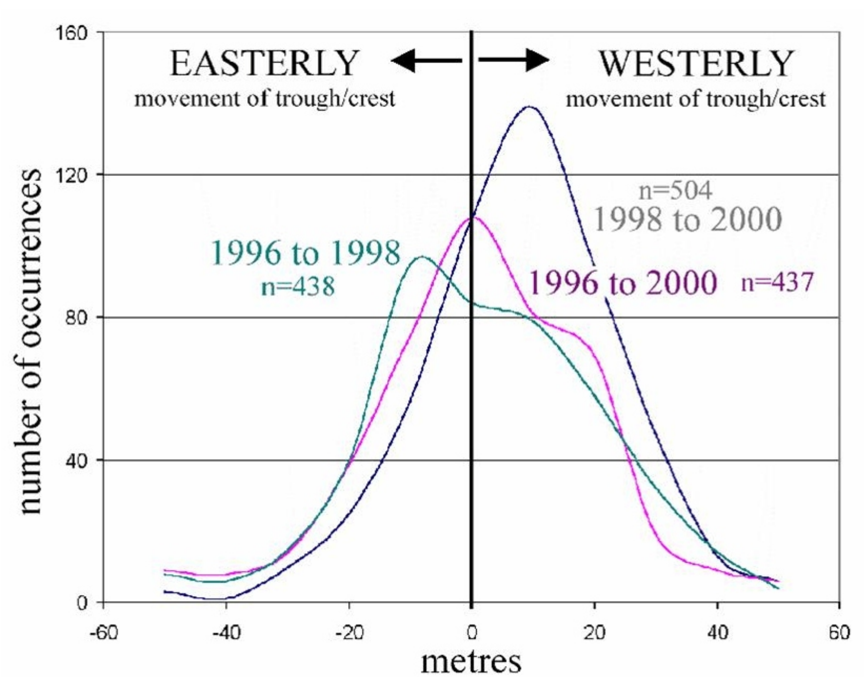
Fig. 14 Bedform types and distribution on Sable Island Bank.

Using the mutibeam data from the CoPan and South Sable sites (presented in section 4.1), bedform metrics tied to bedform classification have been obtained along profiles normal to sand ridge crestlines and are included in the Sable database (mb_bedform_metrics_ss and mb_bedform_metrics_copan). The attribute tables of these layers can be opened and the Selection by Attributes procedure can be used to select bedform types and calculate their statistics (e.g. height, wavelength, symmetry , etc.). The shifts of bedform crests and troughs in ridge-normal profiles from serial surveys were used to determine the sand ridge migration rate and direction. The summaries of bedform metrics and the histograms of sand ridge migration rates derived from the CoPan and South Sable multibeam data (Figs. 15a and 15b) can be accessed through the hyperlink button (the lightening symbol) on the ArcMap tool bar. Detailed description of these measurement methods and results are given in Li et al. (2003).

CHS bathymetry charts collected since mid-1980s over Sable Island Bank have been filtered, gridded and digitally compiled (King, unpublished map) to generate digital bathymetry with 200 m gridding close to Sable Island and 400 m gridding in deeper water areas. This gridded digital bathymetry data was used to trace out the crests and troughs of sand ridges on Sable Island Bank which are shown in Fig. 16. Comparing with the sand ridge delineations by Hoogendoorn and Dalrymple (1986) based on bathymetric maps, this newly derived data has significantly increased the number of sand ridges and extended the distribution beyond the 50 m depth on both the southern and northern bank.

The metrics of bedforms measured from the CoPan area multibeam data. Height and wavelength are in m and steepness and symmetry are dimensionless. Numbers in brackets indicate total measurements for each type of bedform.

	Minimum	Maximum	Average (median for symmetry)	Standard Deviation
Sand ridges (345)				
Height	0.91	13.1	4.6	3.0
Wavelength	410	8240	1680	1330
Steepness	0.00059	0.0092	0.0031	0.0016
Symmetry	0.29	2.82	0.91	0.39
Sandwaves (614)				
Height	0.10	4.16	0.53	0.50
Wavelength	20	990	220	150
Steepness	0.00064	0.0126	0.0029	0.0016
Symmetry	0.33	3.28	0.96	0.46

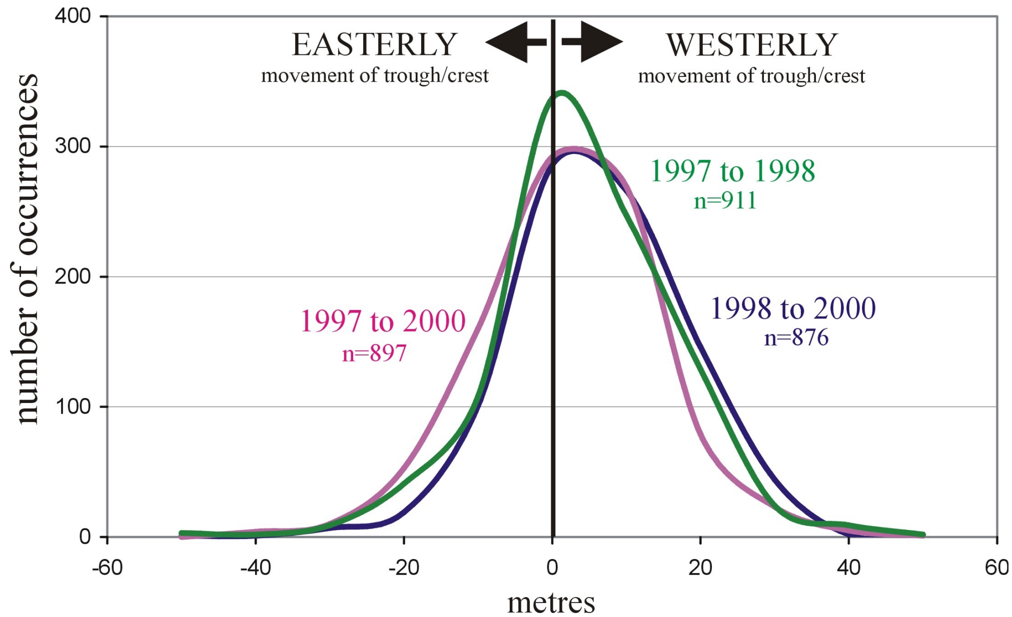


Histograms of sand ridge migration measured from profiles for multibeam surveys 1996-1998, 1998-2000 and 1996-2000 for the CoPan site. n indicates the number of measurements for each serial comparison.

Fig. 15a The summaries of bedform metrics and the histograms of sand ridge migration rates derived from the CoPan multibeam data.

The metrics of bedforms measured from the South Sable area multibeam data. Height and wavelength are in m and steepness and symmetry are dimensionless. Numbers in brackets indicate total measurements for each type of bedform.

	Minimum	Maximum	Average (median for symmetry)	Standard Deviation
Sand ridges (130)				
Height	1.0	9.3	3.5	1.9
Wavelength	450	2880	1090	540
Steepness	0.0013	0.0053	0.0033	0.0012
Symmetry	0.19	3.24	1.05	0.61
Sandwaves (751)				
Height	0.09	2.88	0.45	0.33
Wavelength	21	885	130	93
Steepness	0.0009	0.0119	0.0036	0.0016
Symmetry	0.16	5.00	1.03	0.59
Gutters (141)				
Height	0.05	0.81	0.19	0.14
Wavelength	12	113	35	19
Steepness	0.0015	0.0133	0.0052	0.0022
Symmetry	N/A	N/A	N/A	N/A



Histograms of sand ridge migration measured from profiles for surveys 1997-1998, 1998-2000 and 1997-2000 for the South Sable site. n indicates the number of measurements for each serial comparison.

Fig. 15b The summaries of bedform metrics and the histograms of sand ridge migration rates derived from the South Sable multibeam data.

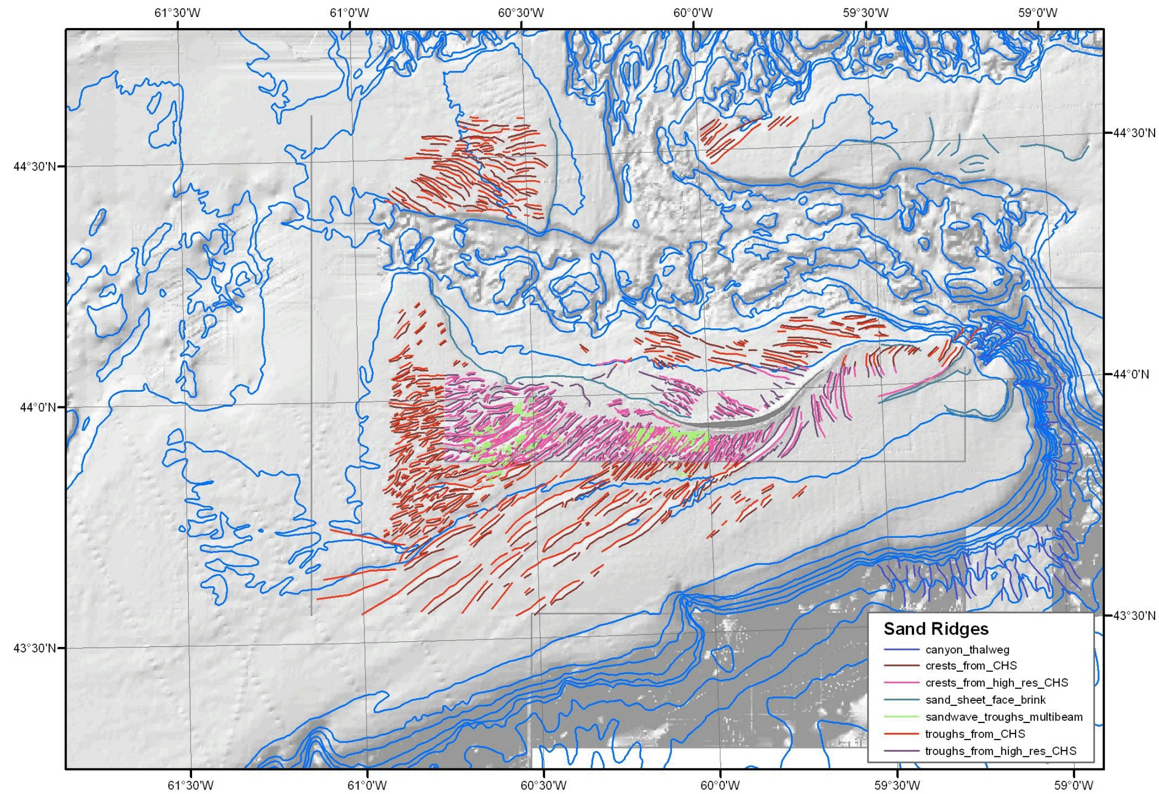


Fig. 16 Crests and troughs of sand ridges derived from gridded digital CHS bathymetry data.

4.5 Sediment Dynamics Datasets

Various seabed instrumentation packages have been used by GSCA to collect in situ hydrodynamics and sediment transport data on Sable Island Bank. The key instruments include Ralph, SOBS, and S4 current meters. As background information, these instrument packages and key sensors on them will be briefly described here.

Ralph is a computer controlled, autonomous, bottom-landing instrumented platform used for in situ near-bed hydrodynamics and seabed response measurement and monitoring in marine environments (Heffler, 1984; 1996; Li et al., 1999). The key sensors on Ralph include:

- Pressure sensor with compass and tilt senor to measure water depth, Ralph frame orientation and tilt
- four Marsh McBirney Electro-Magnetic Current Meters (EMCM4) for velocity profile measurements
- six Optical Backscatter Sensors (OBS6) to measure the concentration of suspended

sediment at various heights

- 2 Acoustic Backscatter Sensors (ABS) to measure seabed elevation (scour) and suspended sediment concentration profiles
- An Imagenex sector scanning profiling sonar (SSP) to provide a 5 m scan profile for bedform height and scour depth measurements
- An Imagenex sector scanning imaging sonar (SSI) to provide 2-dimensional scanning images of the seabed for bedform and scour patterns.
- An underwater digital video camera system (DULCE) to monitor sediment transport and bedform development.

In some recent deployments, Ralph was also equipped with two ADVOs (Acoustic Doppler Velocimeter Oceans) to measure velocity and turbulence at 60 and 70 cm above the seabed.

SOBS was an instrumented tripod similar to Ralph, but designed more specifically for monitoring seabed responses and suspended sediment concentration profiles. It was equipped with a pressure transducer for wave measurement and six Optical Backscatter Sensors in a vertical array for suspended sediment concentration profile measurements. The seabed response was monitored using a Sony 101 video camera.

S4 meters are commercially available, self-contained, spherical wave-current meters from InterOcean Systems Inc. They measure depth, waves, current magnitude and direction. They were mounted on a aluminum tubular frame at 50 cm above the bed. For some deployments, a single OBS (Cyclops) was attached to the S4 frame to measure suspended sediment concentration at a fixed height.

There have been approximately 20 deployments of various sediment dynamics instruments since the early 1990s, and these deployment sites are displayed in Fig. 17. Most of the deployments were in the inner shelf with water depths less than 100 m. In 2003, however, a modified Ralph for deep-water measurements was deployed on the upper Scotian slope (not shown in Fig. 17) through a GSCA-Dalhousie collaborative project.

For each deployment, the following information on instrument configuration, sampling method, and data summary can be obtained by querying (Fig. 18):

CRUISE_NO	cruise number
DPLOY_NAME	deployment name
DPLOY_YEAR	deployment year
DPLOY_DAY	deployment day
DPLOY_TIME	deployment time
DPLOY_DURA	deployment duration (from-to mm/dd/yy)
LATITUDE/LONGITUD	deployment position
WDEPTH_M	water depth (in m)
LOCATION	geographical location

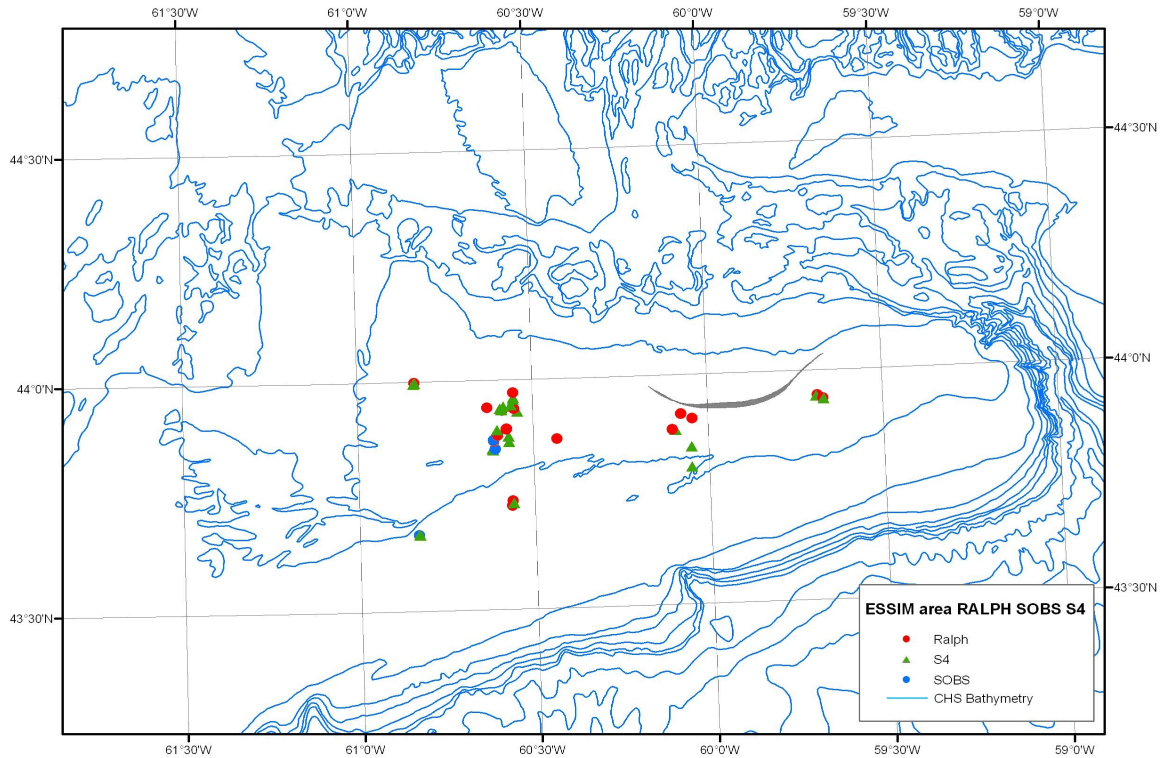
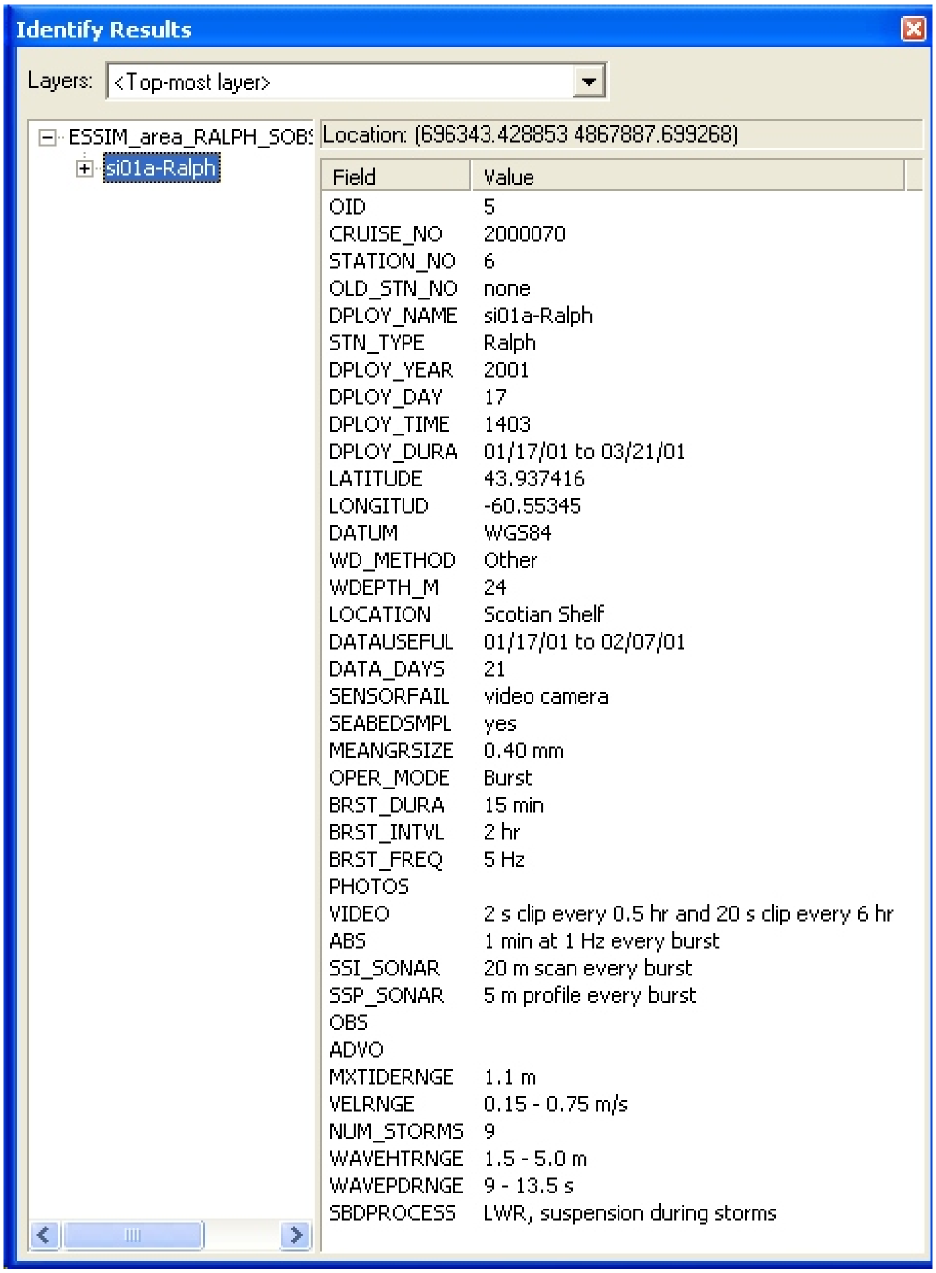


Fig. 17 Sites and types of sediment transport instruments deployed on Sable Island Bank since early 1990s.

DATAUSEFUL	duration of recorded useful data (from-to mm/dd/yy)
DATA_DAYS	number of days of useful data
SENSORFAIL	sensors that failed
SEABEDSMPL	if seabed samples taken (yes or no)
MEANGRSIZE	mean grain size of bottom sample
OPER_MODE	operation mode (burst or continuous sampling)
BRST_DURA	burst duration
BRST_INTVL	burst interval
BRST_FREQ	burst frequency
PHOTOS	configuration for subsea time-lapse camera
VIDEO	configuration for digital video camera
ABS	sampling method for Acoustic Backscatter Sensors
SSI_SONAR	sampling method for Sector Scanning Imager sonar
SSP_SONAR	sampling method for Sector Scanning Profiler sonar
OBS	sampling method for Optical Backscatter Sensors (on S4)
ADVO	sampling method for Acoustic Doppler Velocimeter
MXTIDERNGE	maximum tide range

VELRNGE	range of observed peak flow velocity
NUM_STORMS	number of storms (significant wave height ≥ 0.5 m)
WAVEHTRNGE	range of observed peak significant wave height
WAVEPDRNGE	range of observed peak wave period
SBDPROCESS	observed seabed processes



Field	Value
OID	5
CRUISE_NO	2000070
STATION_NO	6
OLD_STN_NO	none
DPLOY_NAME	si01a-Ralph
STN_TYPE	Ralph
DPLOY_YEAR	2001
DPLOY_DAY	17
DPLOY_TIME	1403
DPLOY_DURA	01/17/01 to 03/21/01
LATITUDE	43.937416
LONGITUD	-60.55345
DATUM	WGS84
WD_METHOD	Other
WDEPTH_M	24
LOCATION	Scotian Shelf
DATAUSEFUL	01/17/01 to 02/07/01
DATA_DAYS	21
SENSORFAIL	video camera
SEABEDSMPL	yes
MEANGRSIZE	0.40 mm
OPER_MODE	Burst
BRST_DURA	15 min
BRST_INTVL	2 hr
BRST_FREQ	5 Hz
PHOTOS	
VIDEO	2 s clip every 0.5 hr and 20 s clip every 6 hr
ABS	1 min at 1 Hz every burst
SSI_SONAR	20 m scan every burst
SSP_SONAR	5 m profile every burst
OBS	
ADVO	
MXTIDERNGE	1.1 m
VELRNGE	0.15 - 0.75 m/s
NUM_STORMS	9
WAVEHTRNGE	1.5 - 5.0 m
WAVEPDRNGE	9 - 13.5 s
SBDPROCESS	LWR, suspension during storms

Fig. 18 Information on instrument configuration, sampling method, and data summary that can be queried for each sediment transport dataset.

5. Summary and Discussion

As joint efforts of the Offshore Geohazard project (X27) and ESSIM project (X32) in the Geoscience for Ocean Management (GOM) program, existing and new data, including repeat surveys and in situ sediment dynamics measurements, have been compiled and interpreted to develop an integrated and readily accessible seabed stability GIS database for the Sable Island Bank area on Scotian Shelf. The vision is to make the database a powerful system to store, manage, display and analyze spatial bedform mobility and geohazard data and thus a useful tool for stakeholders to effectively assess the distribution, nature and mobility or risk potential of bedforms and geohazards on Sable Island Bank.

In the first phase (2003/04) of the staged development of the database, the concept and themes of the database were developed. The key themes of the database, at this stage, include Bathymetry, Geophysical Surveys, Sediment Type and Grain Size, Bedforms, Other Geohazards, Sediment Dynamics Datasets, and Sediment and Bedform Mobility. The personal geodatabase, constructed within the ArcMap desktop application, was populated with some existing data. Query-able general bathymetry data and contour map were included in the bathymetry theme to provide the morphological outline of the Sable Island Bank area and the common background for other themes of the database. A shaded relief image was also generated primarily from CHS bathymetry data to better depict the bank edge, the highs and lows in the adjacent basin, and the scales and distribution of sand ridges on the bank. Geo-referenced images of serial multibeam surveys collected since 1996 at several sites were incorporated in the Bathymetry theme, and the polygon map of the serial multibeam coverage was also generated to effectively display the years and areas of the serial surveys. Attributed ship's tracks of both GSCA and non-GSCA geophysical surveys were included in the Geophysical Surveys theme. The information on sediment types and the distribution and characteristics of bedforms and other geohazards compiled from the sidescan and seismic surveys showed that the Scotian Slope and the areas to the immediate south and west of Sable Island on the bank are well surveyed, while coverage is relative less on the western Sable Island Bank.

In the Sediment Type and Grain Size theme, bottom samples and cores collected by GSCA (also some industry cores/boreholes) have been compiled to generate sediment sample and core-borehole control maps. Bottom sample coverage is reasonably good for the study area. but parts of the southeastern and southwestern bank and an area immediately to the west of Sable Island are identified as areas with gaps. The sidescan data, samples and cores have been analyzed to produce a sediment type map. Of the main sediment types on Sable, sand predominantly occurs on the banks, while mud and gravels are generally observed in the adjacent basins. Sandy mud is also observed as the transition between the sand and mud distributions. The map of mean grain size of the sand fraction presented in Amos and Nadeau (1988) has been regenerated as a query-able mean grain size contour map which demonstrates a general trend of deceasing grain size from the western to eastern Sable Island Bank. For the Bedforms theme, the interpretations of sidescan data by Amos et al. (1988) have been used to generate the overview of bedform type and distribution map. The compiled bedform data show that large-wave ripples are more likely to occur around the island in depths shallower than 70 m, while megaripples and sand ribbons generally tend to occur in deeper waters on the outer bank. Sidescan surveys along transects across sand ridges have also demonstrated the wide distribution of megaripples in the troughs of sand ridges in water depths < 50 m. The mutibeam data from CoPan and South Sable have been processed to obtain metrics and distribution of sand ridges, sand waves and megaripples. Ridge-normal profiles from serial multibeam surveys were analyzed to determine the statistics on sand ridge (trough) and superimposed bedform migration rate and direction. Towards compiling metrics and distribution of targeted bedforms, the gridded digital CHS bathymetry data were used to trace out the crests and troughs of sand ridges on Sable Island Bank. This has significantly increased the number of sand ridges and extended the distribution of sand ridges to areas deeper than 50 m.

Approximately 20 sediment dynamics datasets have been collected since the early 1990s using various GSCA seabed instrumentation packages. These data have been inventoried, described and incorporated in the Sediment Dynamics Data theme so that these deployments can be geographically displayed and each site can be queried for key information such as instrument configuration, sampling method, and the summary of collected data.

The overall goal in the second phase (2004/05) of the database development, is to populate the database with approximately 50% of available data. For the Bathymetry theme, CHS data will be combined with all available multibeam data to generate a DEM with the highest resolution bathymetry presently available. The effort to incorporate at least an additional 500 bottom samples and to quality control all grain size analysis data will be completed so that the grain size data will be updated such that maps of sediment sorting and skewness will be generated. The existing industry wellsite survey maps and the processing/GIS attribution of post 1988 sidescan (bedform and backscatter) data comprise the largest datasets necessary for bedform and seabed texture distribution GIS themes and the bulk of compilation will be completed in this phase. Another source of seabed material information is from a recent DFO hydraulic jet trawl survey (D. Roddick, 2003 personal comm.). These data have been made available and compiled into GIS. The results from all these tasks will contribute to the update of the sediment type map, the overall bedform distribution map, but more importantly the distribution and metrics map of targeted bedforms (sand ridges, sand waves, megaripples, large-wave ripples). Wind and wave data will be analyzed to derive storm statistics for incorporation into the Sediment and Bedform Mobility theme.

As for new data and surveys, geological/geophysical data over targeted bedforms and geohazards were collected on the Hudson 2000030a, 2001021 and 2004037 surveys and initial compilations are underway. As well, the GSCA instrumentation platform RALPH was deployed at the CoPan site to measure/monitor the hydrodynamics and mobility of targeted bedforms in a sand ridge trough. These data will be processed and summaries incorporated in the database. A short Hudson expedition is planned for the 2005 spring to re-survey targeted bedforms and geohazards. Two deployments of RALPH are also planned in 2005 to obtain field measurements of nearbed hydrodynamics and bedform development and mobility at the DRDC site and on the outer shelf. In the last phase of the database development (2005/06), the focus will be on the further update of the overall bedform and geohazard distribution themes, the completion of distribution and metrics maps for all targeted bedforms, and assessment of sediment and bedform mobility based on the integration of repeat surveys, storm data and model predictions. The eventual goal with these varied types of data is to merge metocean, sediment transport modeling and serial seabed observation so as to have some degree of sediment mobility predictive capability for a given storm condition. The first and second phases of compilation represent a significant step towards this goal.

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