GEOLOGICAL SURVEY OF CANADA
OPEN FILE 7420 (revised)

Grand Banks Scour Catalogue (GBSC) GeoDatabase

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Canadian Seabed Research Ltd.

Grand Banks Scour Catalogue (GBSC) GeoDatabase

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Grand Banks Scour Catalogue GeoDatabase

ABSTRACT

In the late 1990's and early 2000's, NRCan, through the Geological Survey of Canada (GSC), conducted research on the distribution and severity of seabed iceberg scour on the Grand Banks. One of the key products of that work was a research database that recorded the location and geometric parameters for all mapped seabed scours on the Grand Banks. The Grand Banks Scour Database (GBSC) was developed under GSC contract to Canadian Seabed Research Ltd. (CSR) and updated sporadically when funding allowed new data to be captured. With the wind-down of GSC work on Grand Bank seabed scour, it is important to formalize the database and release a standardized database in a documented and publicly accessible format. This report documents the development of a simplified GIS Geodatabase that represents the key scour parameters.

The scours recorded in the GBSC were identified and measured from various geophysical data sets including; sidescan sonar, multibeam sonar, sub-bottom profiler, single beam echo sounder, and high resolution single channel seismic (Huntec) systems. The GBSC survey coverage consists of an irregular network of regional lines (22,704 km) and site surveys (4762 km^2) conducted by the GSCA and the petroleum industry.

The simplified GBSC Geodatabase compiled during this study contains 5366 iceberg furrow features and 2680 iceberg pit features. The interaction of ice and seafloor sediments may result in a variety of ice scour types and shapes. Features stored in the GBSC include furrows, furrows with an associated pit (s), individual pits and Pit Chains. Iceberg furrows and pits have been recorded in water depths ranging from 49 to 350 m and within sediment types of Predominantly Sand, Sand & Gravel, and Gravel. Although a significant number of furrows occur within each 10° orientation bin the general orientation mode of the GBSC furrow population is northeast – southwest. Furrow length ranges from 5 m to 10,216 m, with a mean length of 584.7 m while Pit area ranges from 84 m^2 to 111,300 m^2, with a mean area of 6193 m^2. Furrow width measurements range from 1 to 208 m with a mean width of 26 m. Furrow depth ranges from 0.1 m to 7.0 m, with a mean depth of 0.88 m while Pit depth ranges from 0.1 m to 8.3 m, with a mean of 1.92 m.

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STATEMENT OF ACCESS

Copies of the digital open file report and associated Geodatabase may be obtained free download through GEOSCAN (http://geoscan.nrcan.gc.ca/). Additional information or analysis of the GBSC may be obtained from Canadian Seabed Research Ltd. (902-827-4200 or info@csr-marine.com).

1.0 INTRODUCTION AND OVERVIEW

1.1 INTRODUCTION

Icebergs calved from glaciers in Greenland and the eastern Canadian arctic are carried southward by the Labrador Current. Some of these icebergs are carried through the Avalon Channel, along the outer margin of the Grand Banks, and across the shallow water area of the Grand Banks, see Figure 1.1.1. The Labrador Current is the main driving force for the iceberg drift patterns around the bank periphery, although local storms, rotary currents and tidal effects may alter these patterns considerably thus causing seabed scouring by icebergs in comparatively shallower waters on the interior of the Banks.

Icebergs with deep keels that impact the seabed produce scour related features such as linear furrows and circular pits that can be identified on high resolution geophysical data sets, see Figure 1.1.2. Extreme depths of iceberg furrows and pits of 8 metres have been measured from geophysical data collected over the Grand Banks. These observations indicate the potential disruptive forces of icebergs interacting with the seabed and any seabed production structures they were to encounter.

Two scour populations are identified on northeast Grand Bank (Fader and King, 1981; Lewis and Barrie, 1981). In water depths greater than about 110 metres, a dense pattern of partially buried and degraded scours are recognized. These are believed to be relict, formed prior to and during a low sea-level stand between 12,000 and 16,000 years B.P. (Geonautics, 1989). The modern post-glacial population is thought to be more sparsely represented. In water depths of less than approximately 110 metres, relict scours were eroded during the low sea-level stand and all scours observed are believed to represent post-glacial or modern scours. The modern scour population is superimposed on the relict population in water depths greater than about 110 metres.

Data on the frequency, distribution, size, and character of iceberg scours and pits has been compiled since the late 1970's. Various databases and database updates have been compiled from seabed data collected over the Grand Banks (d'Apollonia and Lewis, 1981; Nordco, 1984; King and Gillespie, 1986; Geonautics, 1989; and Geonautics, 1991).

In the late 1990's and early 2000's, NRCan, through the Geological Survey of Canada (GSC), conducted research on the distribution and severity of seabed iceberg scour on the Grand Banks. One of the key products of that work was a research database developed to track the location and geometric parameters for all mapped seabed scours on the Grand Banks. The Grand Banks Scour Catalogue (GBSC) was developed under contract by Canadian Seabed Research Ltd. (CSR) and updated sporadically when funding allowed new data to be captured. With the wind-down of the GSC work on Grand Banks seabed scour, it is important to formalize the database and release a standardized database in a documented and publicly accessible format. This report documents the development of a simplified GIS Geodatabase that represents the key scour parameters.

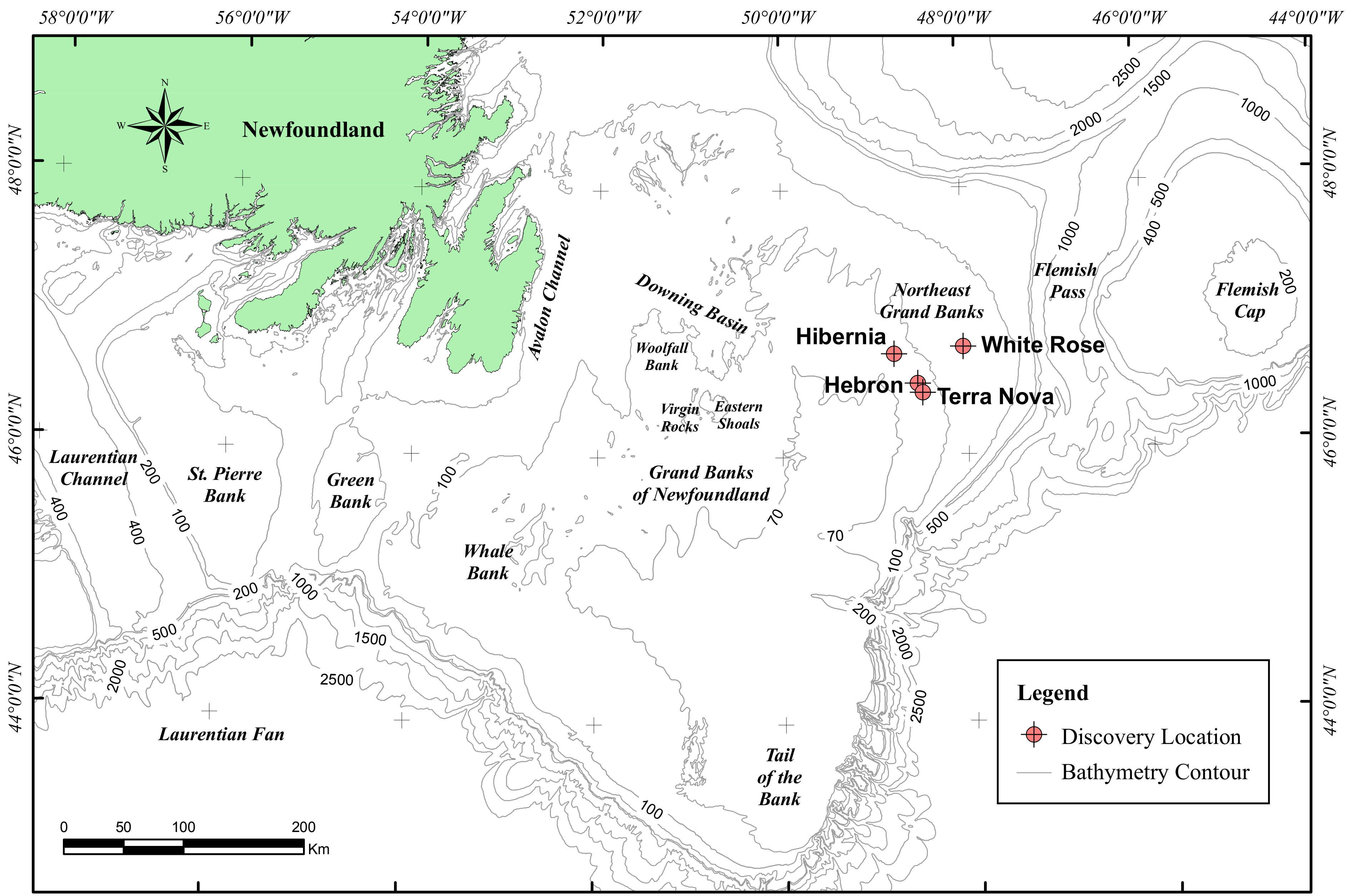

Figure 1.1.1 - Grand Banks of Newfoundland Location Map.

ICEBERG SCOUR PROCESS

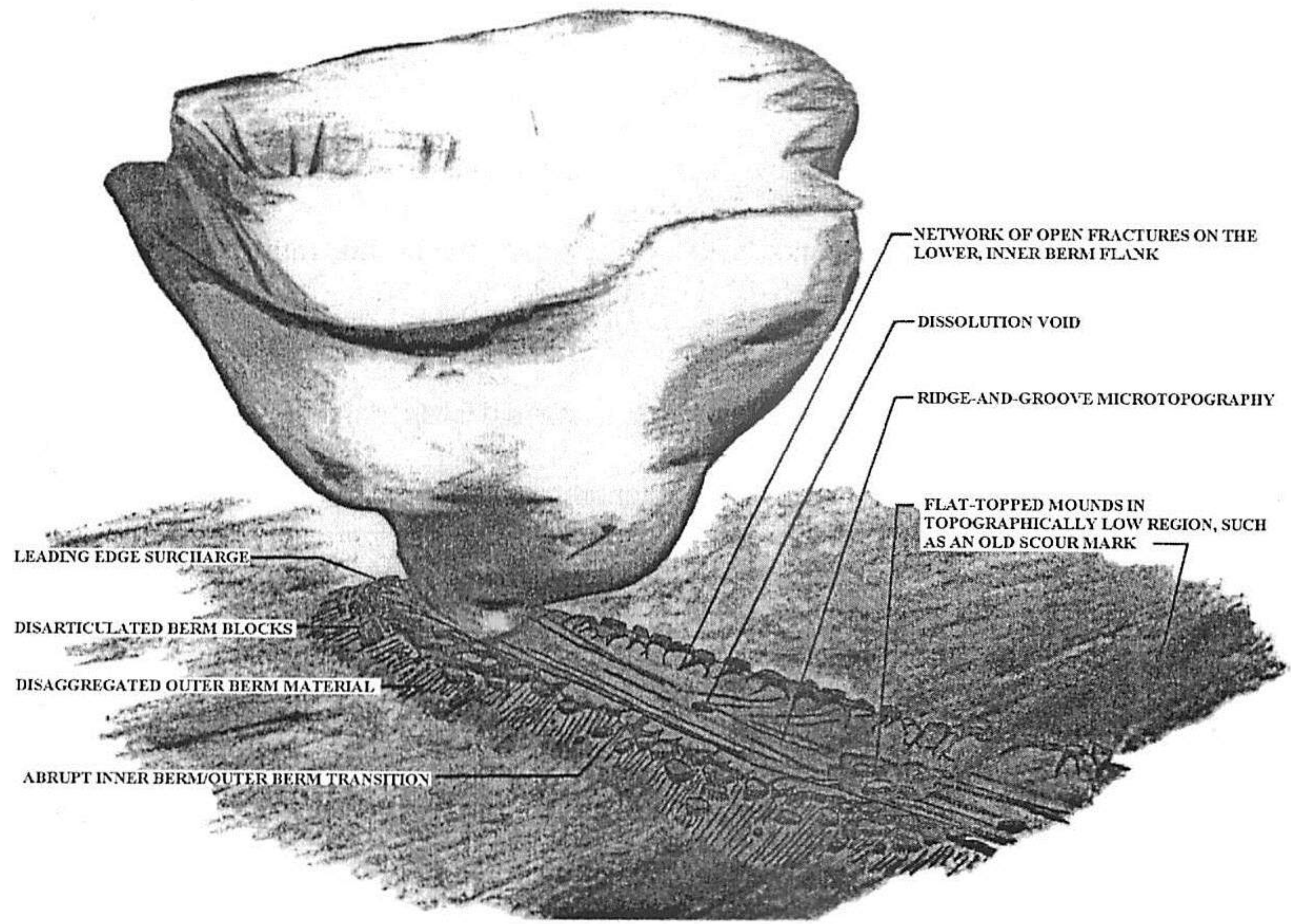

Figure 1.1.2 - The process of Ice Scouring formed by Icebergs (from Woodworth-Lynas, 1992 and modified by King, 2002).

1.2 PROJECT OVERVIEW

Canadian Seabed Research was contracted by the Geological Survey of Canada to complete the following objectives.

- Using the latest unpublished version of the GBSC, and in consultation with the Scientific Authority, select the key scour parameters to transfer to a new simplified scour database appropriate for use and exploration by the non-specialist.
- Provide project specific scripts/routines to summarize the dataset into a simplified database that removes or simplifies field formats and codes, and removes non-standard records that may lead to incorrect use of the database.
- Compile the scour database in ArcGIS format and include key layers such as bathymetry, survey coverage, wells, land mass, etc. to provide context for the database user.
- Produce documentation that gives background on the GBSC, the sources of data, assumptions made in the production of the simpler database, a database dictionary and Metadata for the database.

1.3 DELIVERABLES

1. An ArcGIS 9.3 format Geodatabase of the simplified GBSC.
2. A report (in digital form) detailing and illustrating the results.

1.4 REPORT OVERVIEW

This section presents a general overview of the report structure. The following Table 1.4.1 defines the acronyms used in this report.

Table 1.4.1 – Acronym Definitions

Acronym	**Definition**
AGC	Atlantic Geoscience Center
CSR	Canadian Seabed Research, Ltd
DTS	Deep Tow System
ESRI	Environmental Systems Research Institute
GBS	Gravity Base Structure

Acronym	Definition
GBSC	Grand Banks Scour Catalogue
GIS	Geographic Information System
GSC	Geological Survey of Canada
GSCA	Geological Survey of Canada, Atlantic
Km	Kilometre
M	Metres
MBE	Multibeam Echosounder
NAD	North American Datum
NRCan	Natural Resources Canada
SBP	Sub-Bottom Profiler
SSS	Sidescan Sonar System
UTM	Universal Transverse Mercator

Section 2 of the report provides an overview of the GBSC. Section 3 includes a description of each GBSC Feature Class; Reference Feature Classes within Section 3.1, Survey Feature Classes within Section 3.2 and Iceberg Feature Classes within Section 3.3. An exploration of the key scour attributes found within the Geodatabase is presented within Section 4. All figures included with this report are presented in the North American Datum of 1983 (NAD83), and projected to Universal Transverse Mercator projection (UTM Zone 22).

2.0 GRAND BANKS SCOUR CATALOGUE

This section provides an overview of the GBSC including a discussion of data sources and ice scour mapping methodologies.

2.1 OVERVIEW

The Grand Banks Scour Catalogue (GBSC) is the most complete record of ice scour features detected on the Grand Banks, containing 12,026 records or segments of iceberg furrow (n=9329) and pit (n=2707) features. In contrast to the earlier East Coast Ice Scour database, which provided scour statistics within 2 km line segments (Geonautics, 1989), the GBSC includes records for individual iceberg scour features. The 12,026 segments stored within the GBSC represent 7853 individual ice scour events, and include information on the feature type (i.e. furrow or pit), location, and physical dimensions. Approximately 23% of the GBSC records are iceberg created pits. These are essentially point source features, formed by the grounding or rolling of icebergs, with a mean depth of 3.0 metres. The distribution of iceberg-created pits on the Grand Banks was previously documented by Davidson and Simms (1997).

The GBSC was compiled by Canadian Seabed Research Ltd. (CSR) for the Geological Survey of Canada - Atlantic (GSCA) between 1992 and 1995 (Myers et. al.1995). The GBSC incorporates ice scour data obtained from several sources, including the Mobil Scour database (Nordco 1982 and 1984), the ESRF 4000 Series repetitive mapping program (Geonautics, 1991), GSCA Regional Cruises, and Industry Wellsite Surveys. The database was modified in 1996 by CSR (Myers & Campbell) and included the addition of scours mapped within the Terra Nova discovery site. The GBSC underwent a major update between 1999 and 2004 (Campbell et. al., 2004) to include recent GSCA and industry wellsite surveys.

The scours recorded in the GBSC were identified and measured from various geophysical data types including; sidescan sonar, multibeam sonar, sub-bottom profiler, single beam echo sounder, and high resolution single channel seismic (Huntec) systems. Ice scour related features are well-suited to detection by sidescan sonar (Figure 2.1.1) and multibeam sonar (Figure 2.1.2) systems. Further discussion of scour measurement techniques and system resolutions are presented in “Study of Iceberg Scour & Risk in the Grand Banks Region” (KRCA, 2000).

The GBSC survey coverage consists of an irregular network of regional lines and site surveys acquired by the GSCA, and site specific wellsite surveys conducted by the petroleum industry. The greatest concentration of survey data, and consequently the greatest number of recorded scours, is associated with the high level of petroleum exploration within the Jeanne d’Arc sub-basin in water depths of 80-150 metres.

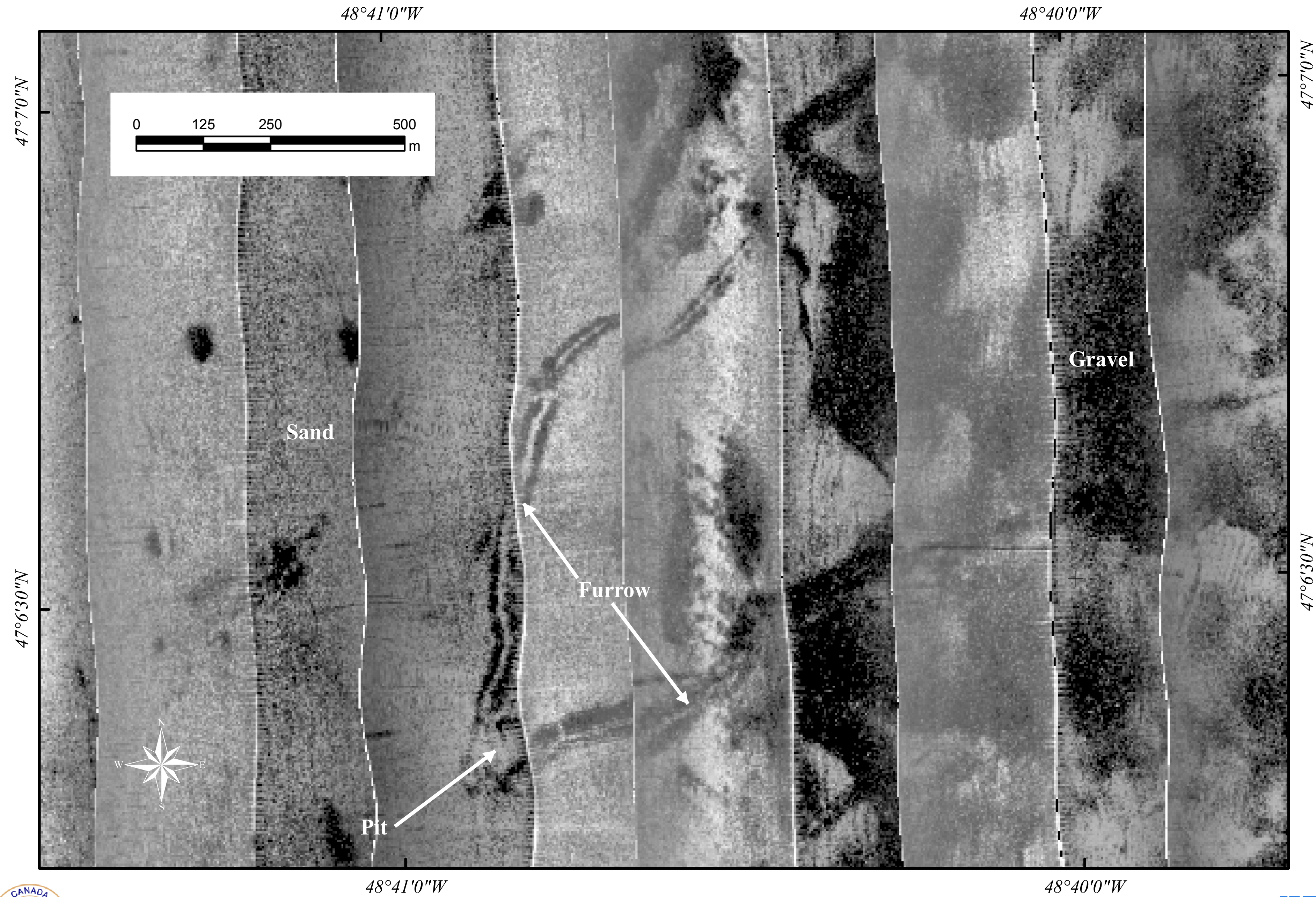

Figure 2.1.1 - Sidescan Sonar mosaic over East Flying Foam site illustrating furrow and pit features.

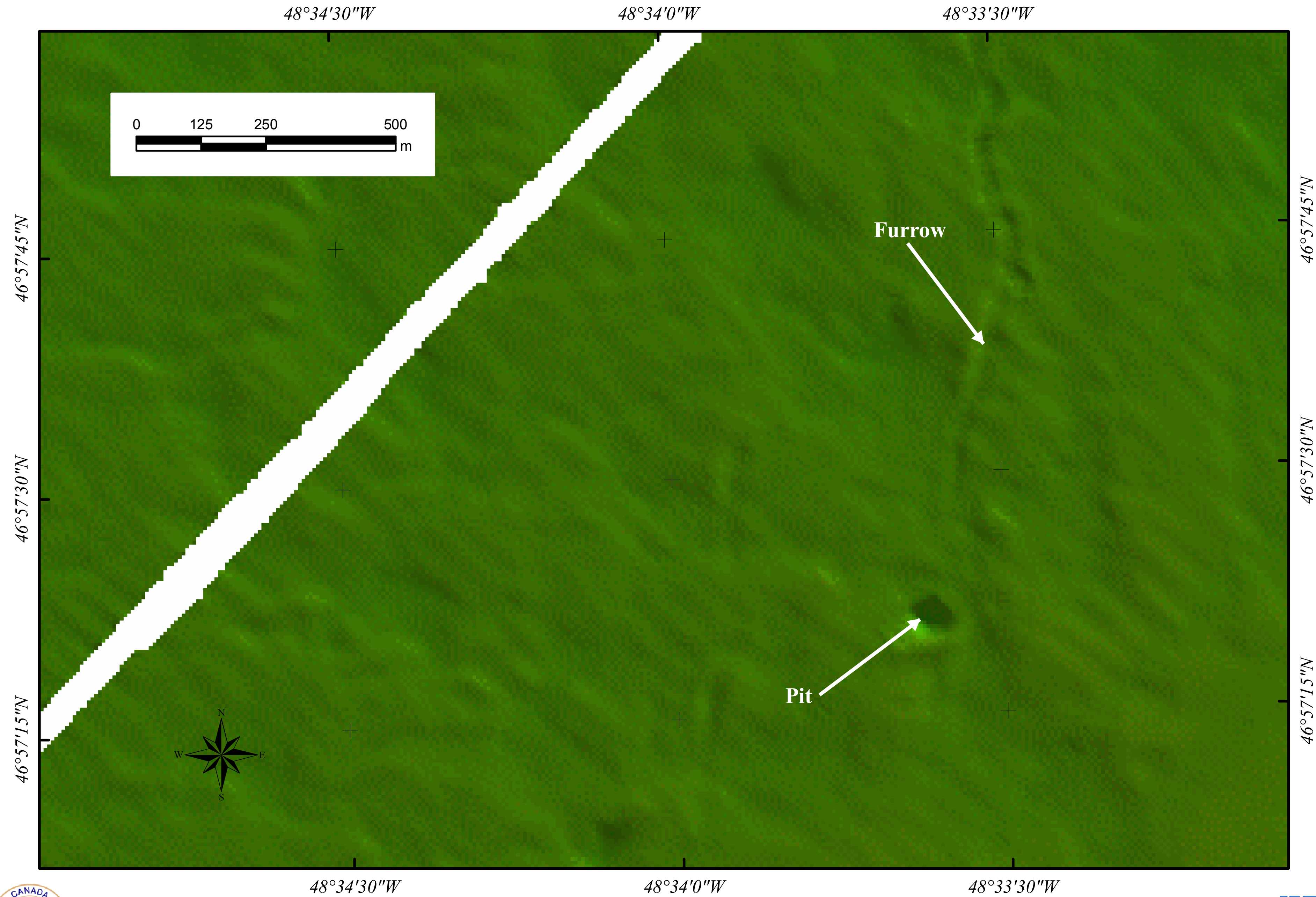

Figure 2.1.2 - Multibeam shaded relief image over GSC 98-024 Baseline Site illustrating furrow and pit features.

2.2 Data Sources & Mapping Methodology

The Grand Banks Scour Catalogue includes scour data incorporated from previous databases, as well as scour measurements obtained by CSR and others. Tables 2.2.1 and 2.2.2 provide a summary of the data sources including survey year, equipment types, water depth range and number of features mapped.

The geophysical data analyzed during the GBSC compilation and subsequent updates were mapped based on the following methodology.

In water depths less than 110 metres, all features interpreted to be iceberg scours were included. In water depths greater than 110 metres, the scour population is comprised of both relict scours and recent scours. Recent scours were identified within the total scour population on the basis of their sharp or fresh appearance on the sidescan and multibeam records, see Figure 2.2.1. This process, while somewhat subjective, was necessary to filter probable relict scours in order to build a database representative of modern scour activity.

Scour identification is dependent on a number of factors including; sidescan / multibeam data quality, the type of system employed, sidescan range, surficial sediment type, complexity of sediment bedforms, and interpreter experience. Past studies have shown that interpreter variability can be quite significant not only in measuring scour attributes but also in the identification of scours (Geonautics, 1989 and Gilbert et al., 1989). During the GBSC compilation, scour identification and measurement of scour parameters was carried out by skilled interpreters.

The scour measurement procedure employed during the compilation and subsequent GBSC updates was designed to provide detailed information on individual scour events (furrows & pits). Prominent variations in one or more scour attributes along the observed length of an individual event were incorporated into the database. Individual scour events were measured as one or more segments based primarily on a change in type (furrow vs pit), orientation, or width. Each scour measured was assigned a unique scour identification number. All segments comprising a single scour event were assigned the same scour identification number.

Many of the earlier scour records are incomplete due to differences in the recording procedures associated with the various data sources used in compiling the GBSC. For example, the original Mobil database (Nordco, 1982) only included scour type, location, and scour depth for features identified on regional survey lines.

Each of the main sources of ice scour data used to construct the GBSC are documented below and displayed within Figures 2.2.2 and 2.2.3.

2.2.1 Mobil Ice Scour Catalogue

The Mobil Ice Scour Catalogue represented the first significant ice scour database for the Grand Banks that contained information on individual scour features. It was compiled from various sources including regional lines surveyed by industry and government, and from wellsite survey data. The original database, compiled using data available to 1981 (Nordco, 1982), was augmented with additional wellsite and regional survey data available to 1983 (Nordco, 1984). The regional and wellsite surveys used to compile the original (1982) and update (1984) databases are listed in Tables 2.2.1 and 2.2.2 and displayed within Figures 2.2.2 and 2.2.3.

There are significant differences in the scour data recorded in the Mobil Ice Scour Catalogue compared to the more recent GBSC data sources. These are summarized below.

In the original compilation (1982), scour depth and scour position were the only parameters recorded from regional survey data. Sidescan sonar records were only used to distinguish between furrow and pit features. Consequently only those scours which crossed the survey line, representing a small fraction of the total observed population, were recorded in the original database. For the wellsite surveys, scours observed on both sidescan and profiler records, and pits observed on profiler records, were included in the original database.

For the 1984 update, all fresh looking scour features observed on both sidescan and sub-bottom data sets were included for the regional survey lines and wellsites. The scour data records from the update study contain most of the scour parameters contained in the GBSC, including; scour type (scour or pit), plan shape, length, width, orientation and scour depth measurements.

For the wellsites, survey reports were reviewed and the original geophysical records were analyzed as required to obtain the necessary statistical data (Nordco, 1984). However, in some cases, it appears that scour depth, width, and length measurements were obtained from the wellsite survey report.

Scour clarity was not recorded, and only fresh unmistakable scour features were entered into the database. The more recent GBSC sources included a scour clarity parameter allowing the inclusion of less distinct features, which were nevertheless considered to be probable scours.

Scour depths were typically measured to the nearest 0.5 metre for most of the scours recorded from wellsite data, and a considerable portion of the scours recorded from regional survey data.

2.2.2 Post-1983 AGC/GSCA Surveys (1992 GBSC compilation)

For the original 1992 Grand Banks Scour Catalogue compilation, scour measurements were obtained from nine cruises conducted by the Atlantic Geoscience Centre (AGC), now the Geological Survey of Canada Atlantic (GSCA), between 1983 and 1990, see Table 2.2.1 and Figure 2.2.2. The majority of these surveys included two sidescan systems and the Huntec DTS sub-bottom profiler. Details of individual cruises are summarized in Myers et al. (1995).

Scour reduction and digital database compilation for Dawson 89-009 and the ESRF 4000 Series portion of the Dawson 90-021 cruises were conducted by Geonautics, following procedures described by Geonautics Limited (1991). Scour measurements for the remainder of the AGC data sets were reduced by Canadian Seabed Research (Myers et al., 1995), with the exception of six scours at the Hibernia GBS mosaic site (part of Cruise 87-014) which were obtained from a surficial geology map constructed by King (1990). All scour features observed in water depths less than 110 metres were incorporated into the GBSC. In water depths greater than 110 metres, only those scours which displayed a relatively fresh[a] acoustic morphology were recorded, thus excluding the population of older degraded scours which are interpreted to be relict scours formed at the end of the last glaciation (Fader and King, 1981).

Data reduction techniques and scour parameter measurements were similar for both CSR Ltd. and Geonautics Ltd. Individual scours were recorded as one or more segments, with each scour segment representing a significant change in at least one scour parameter. Scour length, width, and orientation were measured directly from the sonograms, and subsequently processed for slant-range and ship-speed corrections to obtain true scour dimensions. Scour depth, profile shape, and berm dimensions were measured directly from sub-bottom profiler records. Most of the scour dimensions have an associated data qualifier code, which provides additional information on the particular scour parameter. For example, the length qualifier parameter indicates whether all or only part of a scour was observed on the sonogram. Scour records reduced by Geonautics do not include scour depth qualifier or sediment type information. In addition to scour dimensions, scour records include information on the geophysical systems, data quality, scour clarity, and sediment type.

2.2.3 Post-1983 Wellsites (1992 GBSC compilation)

A total of twenty-one wellsite survey reports released prior to 1993 were reviewed as part of the 1992 GBSC compilation. Nine of the twenty-one reports contained detailed scour measurements.

Of these, four surveys conducted in water depths less than 110 metres were selected for inclusion into the GBSC, see Table 2.2.2 and Figure 2.2.3. All of the information for these scours was obtained from the wellsite survey reports. The original geophysical data sets were not examined. Survey reports from the deeper water sites did not distinguish between recent and relict scours and were thus excluded from the GBSC.

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[a] Scour features are described as fresh (modern) vs. relict if they have sharp, distinct berms, evident troughs, modest to no infill, and are not cross-cut by older, degraded furrows.

2.2.4 1996 GBSC Update

In 1996, Canadian Seabed Research was contracted to update the GBSC for additional sidescan data collected over the Terra Nova petroleum discovery site during Scientific Mission 94-021 conducted by the GSCA (Sonnichsen, 1994), see Table 2.2.1 and Figure 2.2.3. Prior to this update, the majority of GBSC scour records from the Terra Nova site were identified on sidescan data collected during AGC Cruise 88-108.

A digital mosaic of the 94-021 sidescan data, constructed by the GSCA, was used in identifying scours and measuring scour dimensions and positions. This mosaic was corrected for towfish layback and geo-referenced to NAD 83 horizontal datum (UTM Zone 22 Projection). Additional scours incorporated from the 88-108 data were mapped directly from the layback-corrected sidescan data.

A total of 49 additional scours were appended to the GBSC during the 1996 update project; 35 features from the 94-021 survey, and 14 features from the 88-108 survey. A total of 33 scour records from the Terra Nova Site area were deleted from the GBSC as part of the 1996 GBSC update. Twenty-one of these scours were duplicate scour records and 12 were features that were misinterpreted as scours during the construction of the GBSC in 1992.

2.2.5 1999-2004 GBSC Update

The 1999 – 2004 revisions to the GBSC included the interpretation and reduction of geophysical data acquired by the GSCA between 1988 and 2003, six industry wellsite surveys, and one industry regional survey conducted by Husky in 1988, see Tables 2.2.1 and 2.2.2. Ice scour mapping was conducted by CSR, Fugro, Terraquest and Strattech during this update. Ice scour mapping methodology included all scour features observed in water depths less than 110 metres. In water depths greater than 110 metres, only those scours which displayed a relatively fresh acoustic morphology were recorded. The majority of individual scours were recorded as one or more segments, with each scour segment representing a significant change in at least one scour parameter although scour segment mapping was not always adhered to by Strattech.

A summary of the datasets compiled during the 1999-2004 update include.

- Data collected during Husky 1988, Needler 88-108, Hudson 90-021, and Matthew 96-011 were reviewed during a repetitive ice scour study over the White Rose area by Terraquest (Cummings & Sonnichsen, 1997).

- Ice scours were mapped over the East Flying Foam site by Strattech under contract to McGregor GeoScience.

- Fugro provided ice scour mapping and databases for the South Nautilus and Hebron-Brent's Cove wellsites.

- Strattech under contract to the GSC provided ice scour mapping and databases of the 98-024 Baseline site, 94-021 ESRF site, and 99-031 Repetitive Mapping site.

- CSR conducted ice scour mapping over the White Rose area from three wellsites (A-17, L-08, and N-30) as well as GSC regional lines from Cruises 98-034 and 99-031 within the area.

- CSR under contract to the GSC provided ice scour mapping of GSC regional Cruises 98-034, 99-031, 2001-038 and 2003-033.

Details of individual cruises are summarized in Campbell et al. (2004). For each of the datasets scour features were digitized from digital sidescan and multibeam sonar georeferenced imagery. Although the data reduction techniques differ for this update compared to previous GBSC sources (i.e. scour locations digitized from geo-referenced image), the primary scour parameter measurements have not changed.

Scour width was measured from the sidescan or multibeam georeferenced images as the distance between the lateral berm crests which occur on either side of the furrow or pit incision. An average width measurement was recorded for each segment. The accuracy of scour width measurements was estimated to be on the order of +/- 2 to 5 metres. Scour berms were not apparent for many severely degraded ice scours, which were only detected as low-reflectivity lineations related to infilling of the scour incision by fine grained sediment. The scour width recorded for these features was expected to be less than that recorded for more recent or fresh scour events.

Scour length was measured automatically within ArcGIS as the length of the digitized scour centreline. However, many scours extend beyond the sidescan data coverage on regional survey lines and have recorded lengths which were less than the true length. True scour lengths were easily and accurately measured where 100% seafloor survey coverage exists, such as Wellsite and recent GSCA site surveys.

Scour orientation was calculated by determining the angle between the digitized scour centreline endpoints.

One major change is ice scour depth and berm height measurements have been obtained from multibeam bathymetry for the 98-024 Baseline and Matthew 96-011 White Rose sites. Multibeam data collected over the ESRF4000 series lines in 2004 (Sonnichsen & King, 2011) were not available during the 2004 update of the GBSC. Traditional Huntec sub-bottom and single beam echosounder data were utilized for the other datasets where available. Profile shape was obtained directly from sub-bottom profiler records.

Scour depth and length have an associated data qualifier code, which provides additional information on the particular scour parameter. In addition to scour dimensions, scour records include information on the geophysical systems, data quality, scour clarity, scour plan shape, scour type, berm development and sediment type.

2.3 Duplicate Scours

In areas covered by more than one survey, some scours may have been identified from two or more data sets and entered into the GBSC more than once. The potential for duplicate scours is greatest in areas of overlapping wellsite coverage, or where regional survey lines cross grid or wellsite survey areas. A preliminary examination of the GBSC revealed that approximately 15% of the recorded scours occur within 100 metres of another scour mapped from a different survey data set. While this does not mean that all nearby scours are duplicates, it indicates that the potential for duplicates is significant.

During the 1999-2004 update potential duplicate features were assigned an error code. This error code was instrumental in removing known duplicates during this project, see Section 3. It is likely that duplicate scours may still exist in the GBSC but the number is not considered large enough to alter population statistics.

2.4 Interpreter Variability

Due to the qualitative nature of sidescan data, there is a certain degree of interpreter variability inherent in ice scour mapping even with the use of experienced interpreters. Variation in the measurement of scour dimensions and, perhaps more importantly, in the number of ice scours detected by different interpreters are both known to exist. The most comprehensive study of interpreter variability was conducted during the construction of the East Coast Scour Database (Geonautics Limited, 1989). A limited comparison of interpreter variability was also conducted during the compilation of the GBSC (Myers et al., 1995). Results of repetitive mapping programs are also available to assess variability in the detection ice scour features (Geonautics Limited, 1991; Myers and Campbell, 1996).

In the Geonautics (1989) program, five experienced interpreters were involved in re-analysing randomly selected sonogram segments to assess interpreter variability in the detection and measurement of ice scours. Results of this study indicate an average interpreter variability of between 10% and 30% for measurements of scour length, width, depth, and orientation. Extreme variability values recorded for each key scour parameter ranged from 35% to 116%. Similarly, the number of scours detected varied by less than 30% for most of the interpreters involved in the study, with an extreme value of 133% for one of the interpreters. Extreme variability is attributed to small sample sizes or different interpretations in areas of complex surficial geology. A more limited interpreter variability study conducted during the compilation of the GBSC involved only two interpreters (Myers et al., 1995). Differences in scour parameter measurements for the GBSC study fall within the limits of variability determined by Geonautics. With respect to scour detection, 73% (54 of 74 total features) of the total number of scours recorded in the GBSC study were identified by both interpreters. The remaining 27% of recorded features were only recorded by one or the other interpreter. Differences in scour detection were most pronounced within an area of complex sediment bedforms.

Repetitive mapping programs conducted at the Hibernia-White Rose region (Geonautics, 1991; ESRF 4000 Series) and at the Terra Nova development site (Myers and Campbell, 1996) included a re-interpretation of the original baseline data sets. The number of scours detected during the re-interpretation studies was more than double that originally recorded at each site; 83 total ice scours versus 40 original scours at the 4000 Series site, and 71 total ice scours compared to 35 scours originally recorded at the Terra Nova site. In both comparisons, it is apparent that the original interpreters conducted a conservative scour interpretation, identifying only very prominent features. This is partly due to the fact that in the original studies, an interpreter only had the choice of including or omitting an indistinct or uncertain feature. During the re-interpretation studies, interpreters recorded a qualitative assessment of scour clarity which allowed for the inclusion of less prominent features which are, nevertheless, considered as possible or probable ice scours. It is expected that significantly lower scour densities will be associated with data sources which did not include a qualitative assessment of scour clarity.

In summary, interpreter variability is an important factor to be considered in assessing the risk to subsea installations presented by ice scouring process. Following the recommendations of Geonautics (1989), end users should allow for a possible variation of 30% in the scour parameter measurements extracted from ice scour databases. Similarly, scour density estimates calculated from the recorded scour population should allow for a minimum 30% variation due to interpreter variability in the detection of scour features.

Table 2.2.1 – Grand Banks Scour Catalogue; GSC (Atlantic) and Regional Surveys

Survey Name	Survey Year	Equipment Types[1]	Water Depth (m)	Number of Segments: Furrows	Number of Segments: Pits
Mobil Ice Scour Catalogue (1982)					
Hudson 80-010	1980	1, 7	64-236	427	20
AGC/C-CORE (8000 Series)	1980	4, 7	80-160	49	6
Unknown Survey	-	-		2	0
Mobil Ice Scour Catalogue (1984 Update)					
Baffin 81-012	1981	1, 3, 7	71-118	30	7
Baffin 82-039	1982	3, 7	67-92	3	0
Hudson 83-033	1983	1, 3, 7	83-100	8	2
Hibernia Pipeline	1983	4, 7	69-156	41	182
South Hibernia Pipeline Route	1980	4, 7	75-160	5	27
Geonautics/D'Apollonia	1982	4, 7	60-190	72	75
Grand Banks Scour Catalogue (1992 Compilation)					
Hudson 84-024	1984	1, 3, 7	57-160	88	52
Hudson 85-005	1985	1, 3, 7	49-144	108	8
Pandora II 85-057	1985	3, 10	92-154	95	2
Hudson 86-017	1986	1, 3, 7	72-128	103	47
Hudson 86-018	1986	1, 3, 7	66-163	350	39
Hudson 87-014	1987	1, 3, 7	57-88	46	0
Needler 88-108	1988	1, 3, 7	66-182	564	71
Dawson 89-009	1989	1, 3, 7	85-223	166	77
Dawson 90-021 (ESRF)	1990	2, 4, 7	77-148	320	16
Dawson 90-021 (regional)	1990	2, 4, 7	62-177	352	26
Grand Banks Scour Catalogue (1996 Update)					
Hudson 94-021 (Terra Nova)	1994	1, 5, 10	92-97	63	0
Grand Banks Scour Catalogue (1999-2004 Update)					
Husky Oil (White Rose)	1988	3	120-138	43	2
Needler 88-108 (White Rose)	1988	1, 3, 7	126	1	0
Hudson 90-021 (White Rose)	1990	2, 4, 7	120-135	25	0
Hudson 94-021 (ESRF 4000)	1994	1, 5, 10	80-105	285	24
Matthew 96-011 (White Rose)	1996	5, 11	120-138	42	36
Matthew 98-024 (Baseline)	1998	5, 7, 11, 12	90-134	1516	261
Hudson 98-034 (Regional)	1998	5, 7, 10	59-248	291	68
Hudson 98-034 (White Rose)	1998	5, 7, 10	118-162	41	12
Hudson 99-031 (Regional)	1999	5, 7, 10	65-353	166	87
Hudson 99-031 (White Rose)	1999	5, 7, 10	110-135	22	3
Hudson 99-031 (Repetitive Mapping)	1999	5, 7, 10	112-217	340	181
Hudson 2001-038	2001	5, 7, 10	88-125	70	7
Hudson 2003-033	2003	5, 7, 10	82-172	456	107

Table 2.2.2 – Grand Banks Scour Catalogue; Wellsite Surveys

Number of Segments

Survey Name	Operator	Survey Year	Equipment Types[1]	Water Depth (m)	Furrows	Pits
Mobil Ice Scour Catalogue (1982)						
Ben Nevis	Mobil	1979	4, 9	99-101	15	0
Hibernia P-15	Chevron	1979	4, 9	81-83	3	1
Hibernia North	Mobil	1979	4, 9	80-86	4	0
Tempest North	Mobil	1979	4, 10	144-162	89	0
Trave/White Rose	Mobil	1979	4, 9	114-146	93	0
'4000 Series'	Mobil	1979	4, 10	80-150	82	0
Cumberland J-87	Mobil	1980	4, 9	190-232	2	82
Dana North and South	Mobil	1980	4, 7, 9	204-257	14	158
Hebron	Mobil	1980	4, 9	84-94	5	0
Nautilus C-92	Mobil	1980	4, 7, 9	86-91	7	0
Ragnar	Mobil	1980	4, 7, 9	186-221	3	56
Rankin	Mobil	1980	4, 7, 9	72-80	16	0
West Hibernia	Mobil	1980	4, 9	76-80	8	0
White Rose Flank	Mobil	1981	4, 7	104-120	90	0
Mobil Ice Scour Catalogue (1984 Update)						
Archer Flank	Mobil	1982	3, 4, 8	115-133	120	94
Bonanza M-71	Mobil	1982	4, 8	183-212	12	140
Dominion	Mobil	1982	4, 7	156-166	14	129
Linnet E-63	Mobil	1982	3, 4, 8	124-178	73	43
Saronac	Mobil	1982	4, 8	169-204	88	256
Mara	Mobil	1983	4, 7	82-102	107	10
Titus	Mobil	1983	4, 7	168-206	6	153
Voyager	Mobil	1983	4, 7	97-102	6	0
Grand Banks Scour Catalogue (1992 Compilation)						
North Ben Nevis (Husky)	Petro-Canada	1984	4, 7	102	1	0
North Ben Nevis; Rev-1	Petro-Canada	1984	4, 7	100-102	30	4
Burin Bonne Bay	Husky	1985	4, 7	101-109	18	3
South Brook	Petro-Canada	1988	3, 8	89-91	6	0
Grand Banks Scour Catalogue (1999-2004 Update)						
East Flying Foam	Amoco	1996	4, 9, 10	85-113	336	30
South Nautilus	Chevron	1998	6, 10	81-91	343	15
White Rose L-08	Husky	1998	6, 10	119-123	61	15
White Rose A-17	Husky	1999	6, 10	117-121	98	15
White Rose N-30	Husky	1999	6, 10	116-128	187	44
Hebron / Brents Cove	Chevron	1999	6, 10	78-103	1202	14

[1]Equipment Types

Sidescan: 1 (BIO 70 kHz), 2 (Klein 50 kHz), 3 (Klein 100 kHz), 4 (ORE 100 kHz), 5 (Simrad 120 kHz), 6 (Edgetech 100 kHz)

Profiler: 7 (Huntec DTS), 8 (NSRF V-Fin), 9 (ORE 3.5 kHz), 10 (Echosounder)

Multibeam: 11 (EM100), 12 (EM3000)

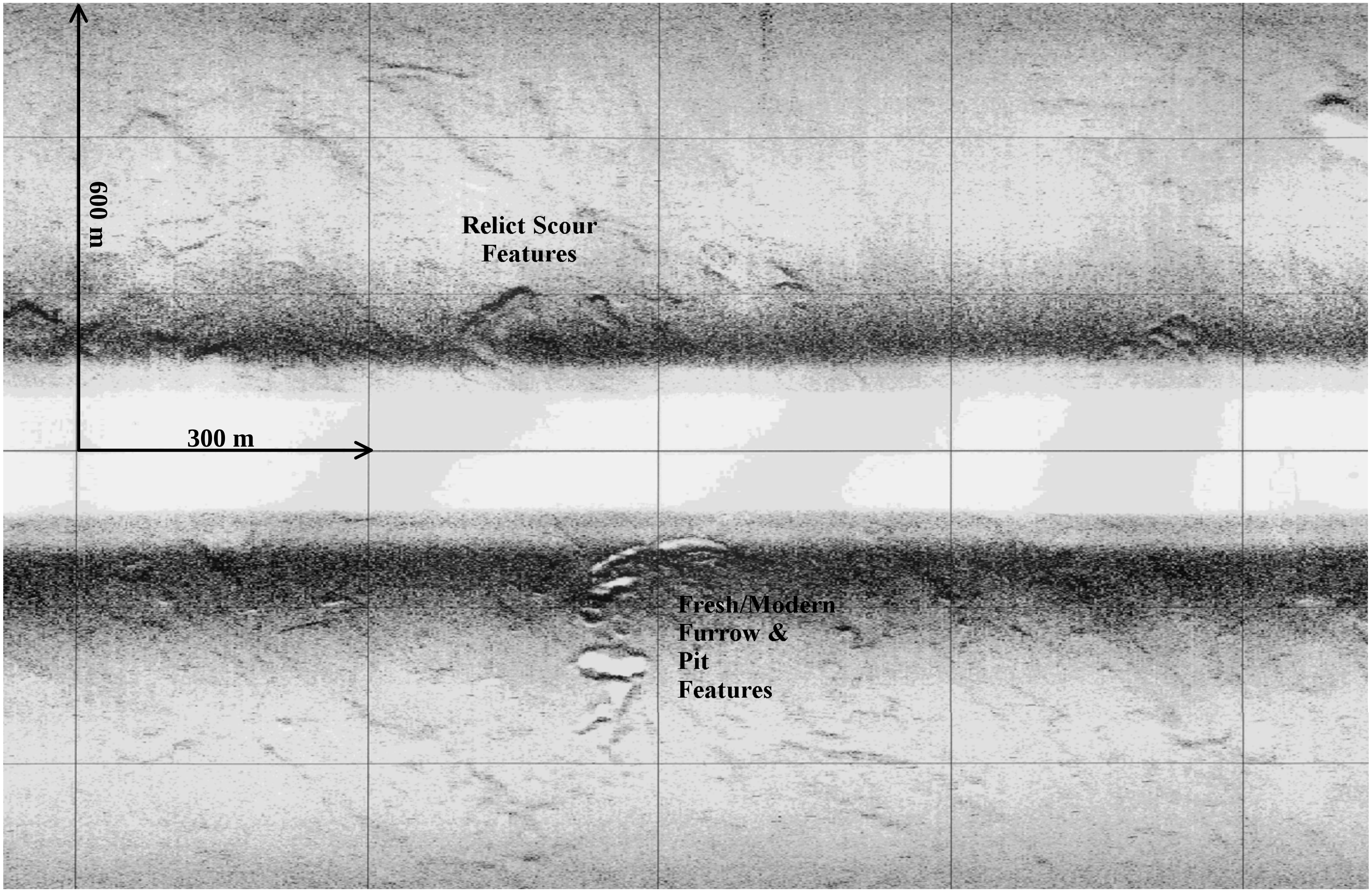


Figure 2.2.1 - Sidescan sonar record within 148 m water depth illustrating fresh/modern furrow and pit features in relation to relict features. The data was acquired during GSC 2003-033 along the eastern Avalon Channel.

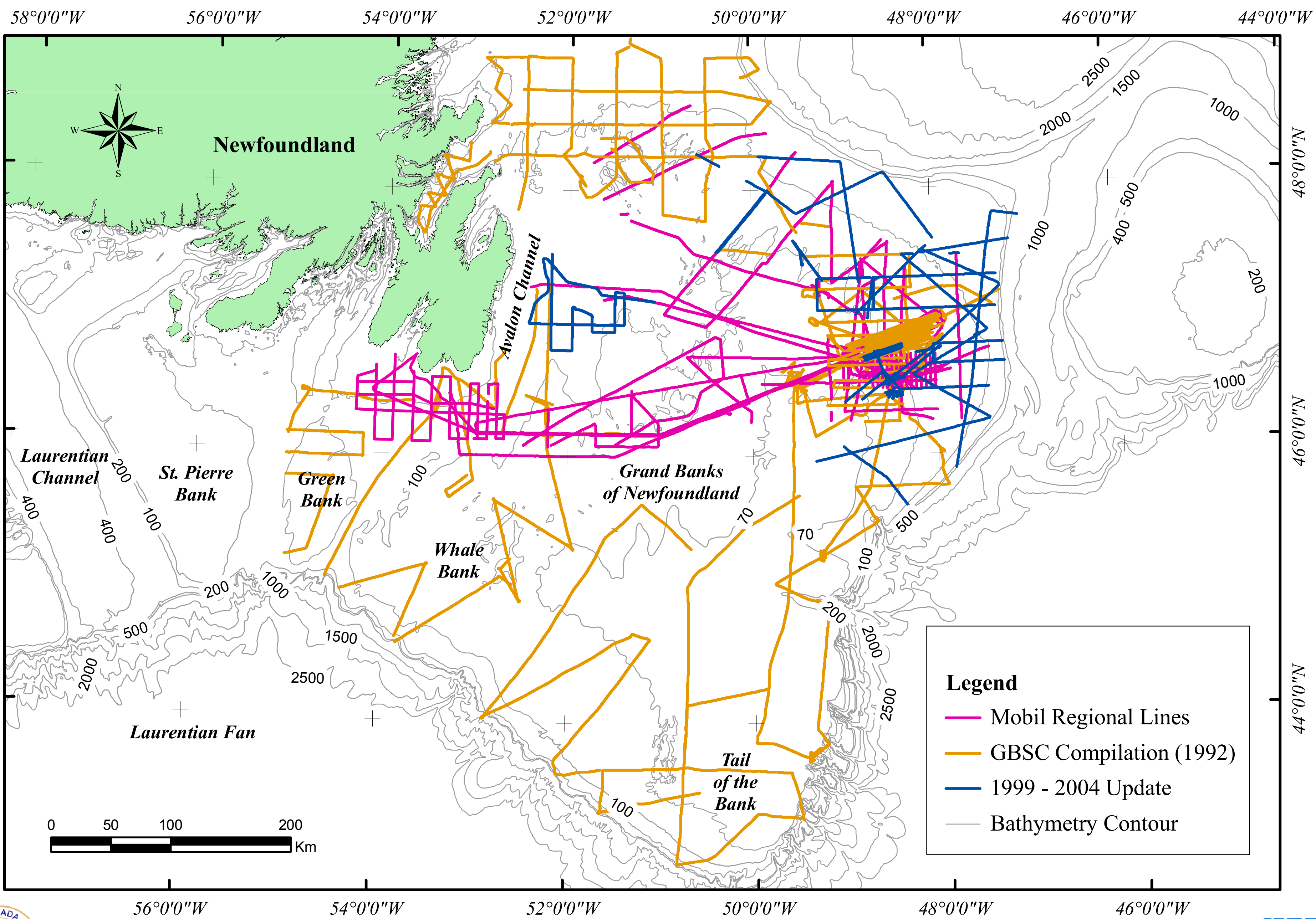


Figure 2.2.2 - GBSC Regional Survey Line Locations According to Data Sources.

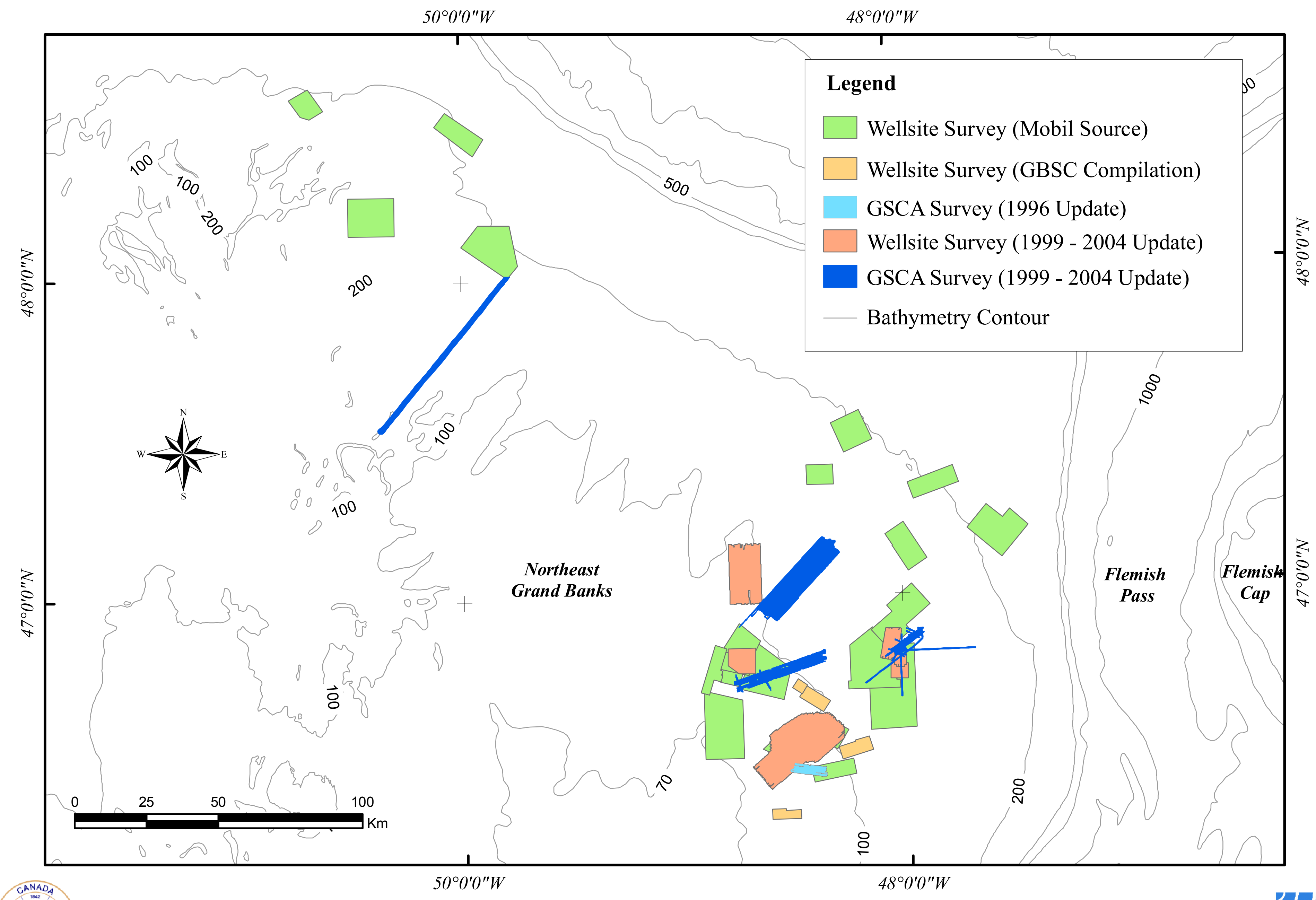


Figure 2.2.3 - GBSC Industry Wellsite and GSCA Site Survey Locations According to Data Sources.

3.0 GBSC GEODATABASE

All of the datasets documented within the following sub-sections were compiled into the GBSC Geodatabase which is provided with this report in ESRI ArcGIS 9.3 format. The Geodatabase (GBSC.gbd) contains the following Feature Classes.

<u>Reference Feature Classes (Section 3.1 & Appendix I)</u>

- Well Locations
- Marine Atlas Regional Bathymetry
- Newfoundland Coastline

<u>Survey Feature Classes (Section 3.2 & Appendix II)</u>

- NAVBASE Regional Survey Lines
- GBSC Site Survey Areas
- GBSC Survey Extent of all Areas Surveyed

<u>Iceberg Scour Feature Classes (Section 3.3 & Appendix III)</u>

- GBSC Furrows
- GBSC Furrows with Associated Pits
- GBSC Pit Features
- GBSC Furrows with One EndPoint Mapped

The GBSC Geodatabase geodetic parameters and recommended projection are as follows.

GeoDatabase Geodetic Parameters		**Projection**
Horizontal Datum:	NAD83	Projection: Universal Transverse Mercator, Zone 22
Prime Meridian:	Greenwich	Central Meridian: 51°W
Angular Unit:	Degree	False Easting: 500000.00
		False Northing: 0.000000
		Scale Factor: 0.999600
		Latitude of Origin: 0.0
		Linear Unit: Metre

Appendix IV includes a summary list and description of Files / Feature Classes included within the GBSC geodatabase. The geodatabase is included on disk as Appendix V.

3.1 REFERENCE FEATURE CLASSES

The reference Feature Classes are included to provide context for the database user, see Figure 3.1.1. The BATHYMETRY Feature Class includes the Marine Atlas regional bathymetry contours of the area. The NEWFOUNDLAND Feature Class represents the coastline of the island of Newfoundland and the WELL_LOCATIONS Feature Class includes the locations of exploration and production wells across the Grand Banks.

A description of the database fields within each reference Feature Class is included within Appendix I.

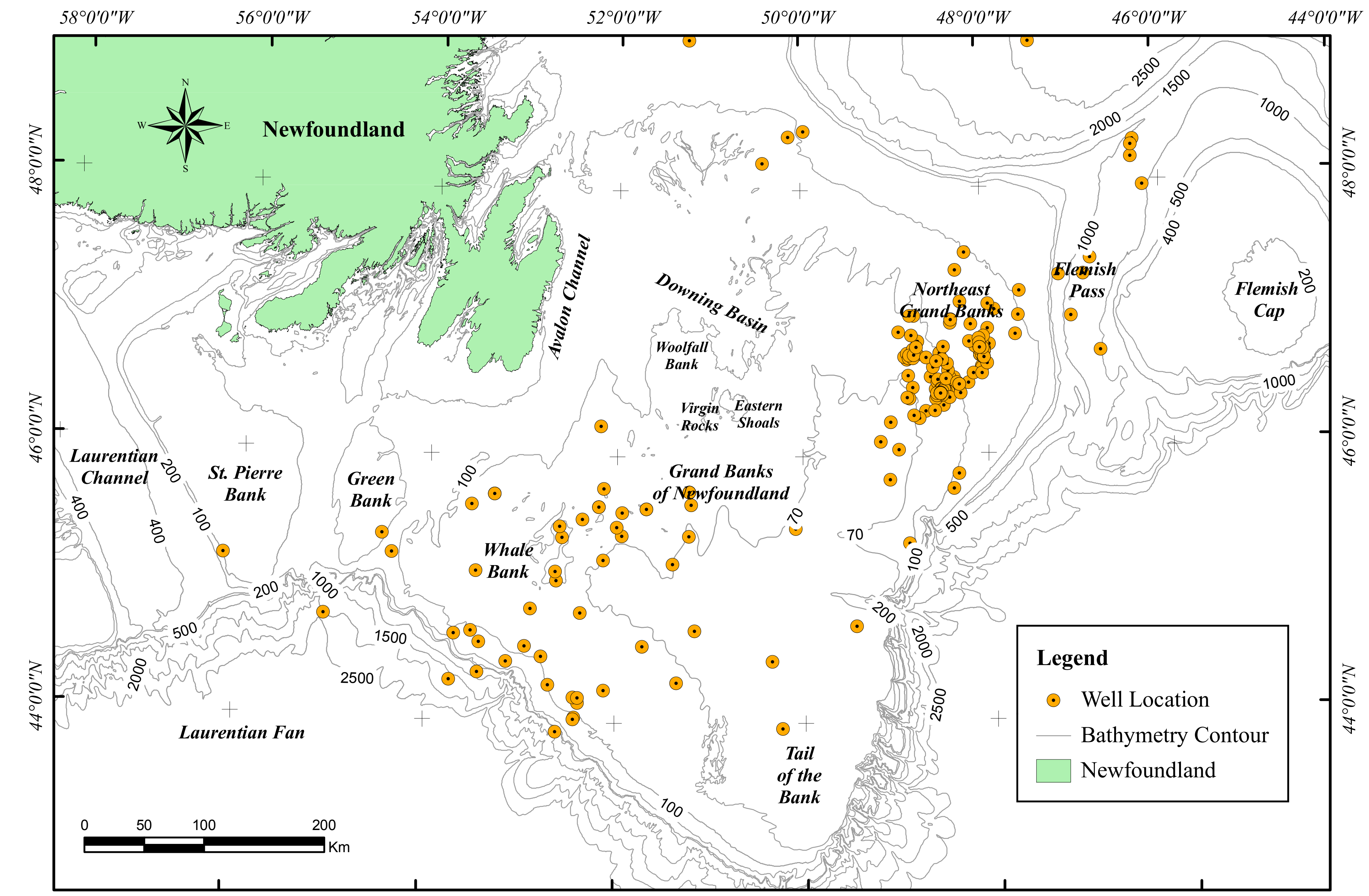


Figure 3.1.1 - GBSC Reference Feature Classes Well_Locations (as of October 2011), Bathymetry, and Newfoundland.

3.2 SURVEY FEATURE CLASSES

The GBSC survey Feature Classes include regional and site survey locations where various geophysical data sets including; sidescan sonar, multibeam sonar, sub-bottom profiler, single beam echo sounder, and high resolution single channel seismic (Huntec) systems were acquired. The scours recorded in the GBSC were identified and measured from the geophysical data collected over these areas. A description of the database fields within each survey Feature Class is included within Appendix II.

The Feature Class NAVBASE_SURVEY_LINES was compiled from the point navigation database NAVBASE. This Feature Class represents the regional survey lines reviewed for iceberg scour features, see Figure 3.2.1.

The NAVBASE_SURVEY_LINES Feature Class is a line/vector geometry type which includes 367 survey lines. Each line represents the survey vessel trackline and includes attributes such as cruise identifier, survey line identifier, start of line day/time, end of line day/time, effective swath coverage, and survey line length.

The GBSC_SITE_SURVEYS Feature Class is a polygon geometry type which includes 41 survey areas. Each polygon represents the extent of the industry wellsite or GSC site survey, see Figure 3.2.2. Each survey polygon includes information on the company or government organization that the survey was performed, the survey company, survey year, types of survey equipment, cruise identifier, and size of area surveyed.

The GBSC_SURVEY_EXTENT Feature Class was compiled from NAVBASE_SURVEY_LINES and GBSC_SITE_SURVEYS. It includes one complete polygon that represents the entire extent of seabed surveyed, see Figure 3.2.3. This was accomplished by first buffering NAVBASE_SURVEY_LINES according to the effective survey swath. The buffered regional survey lines were then merged with the site survey areas and dissolved to create one polygon representing the total GBSC survey area extent which includes 17,485 km^2.

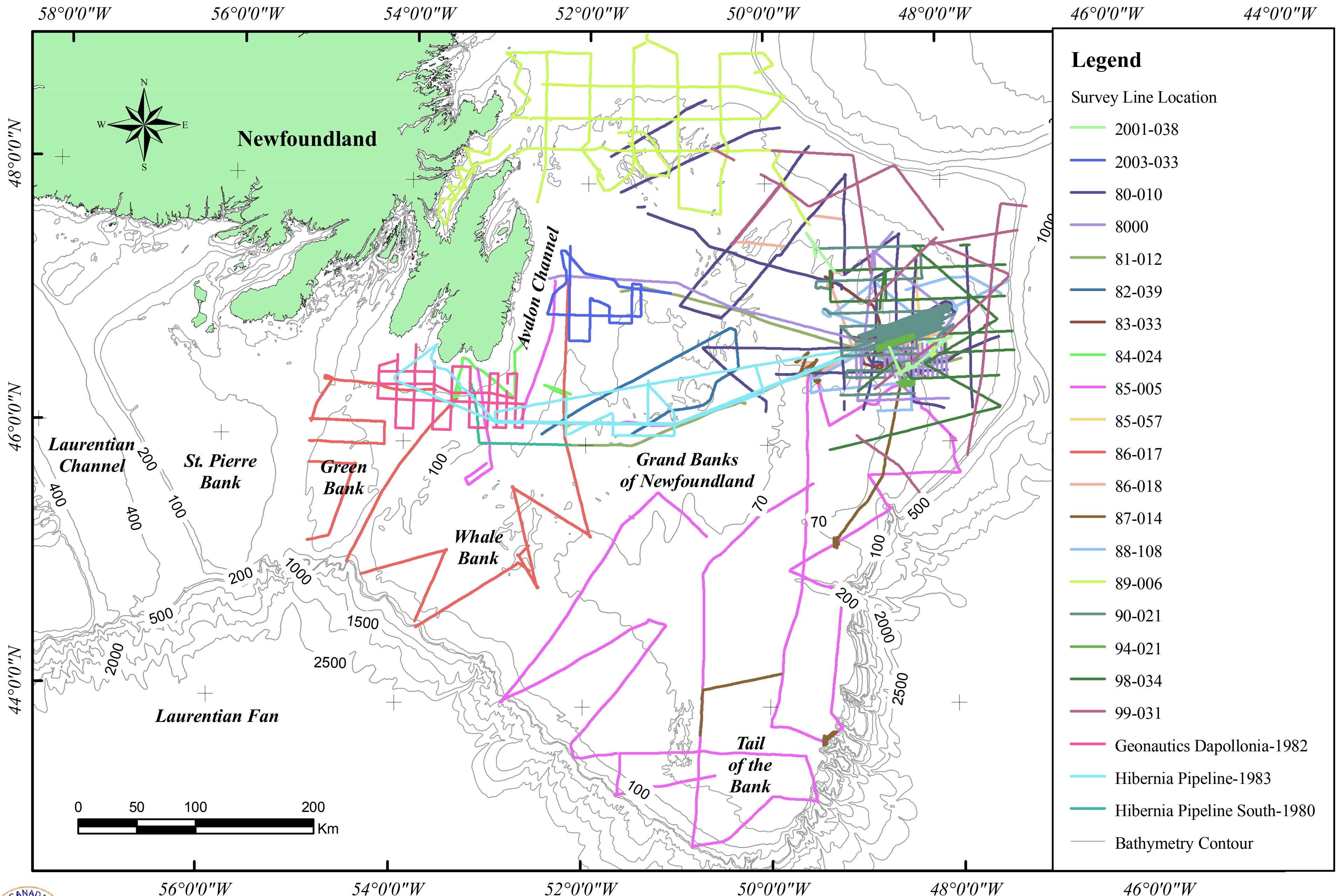


Figure 3.2.1 - GBSC Regional Survey Line Locations According to Cruise ID, stored within NAVBASE_SURVEY_LINES Feature Class.

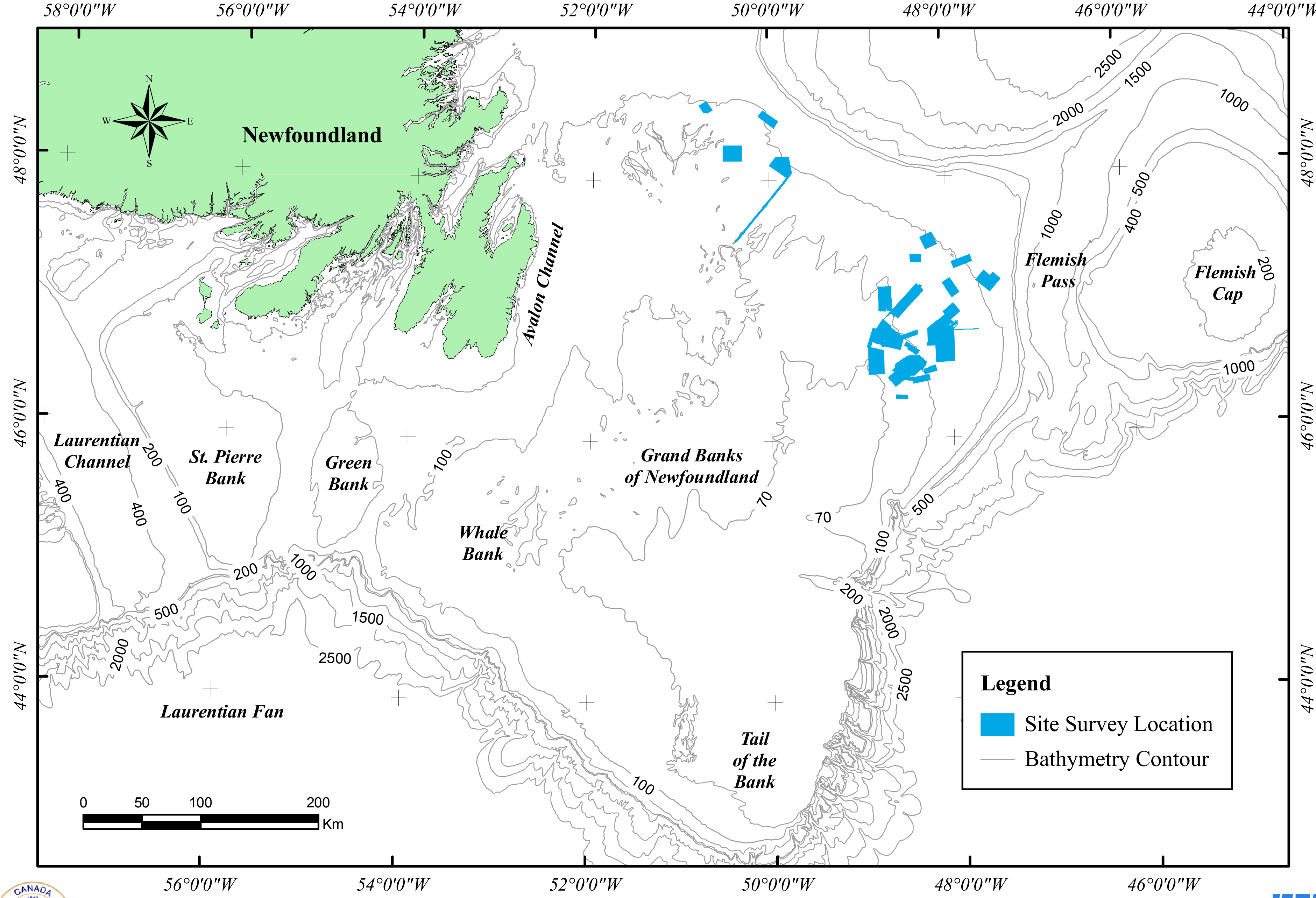


Figure 3.2.2 - GBSC_SITE_SURVEYS Feature Class of Well Site and GSC Site Survey Locations.

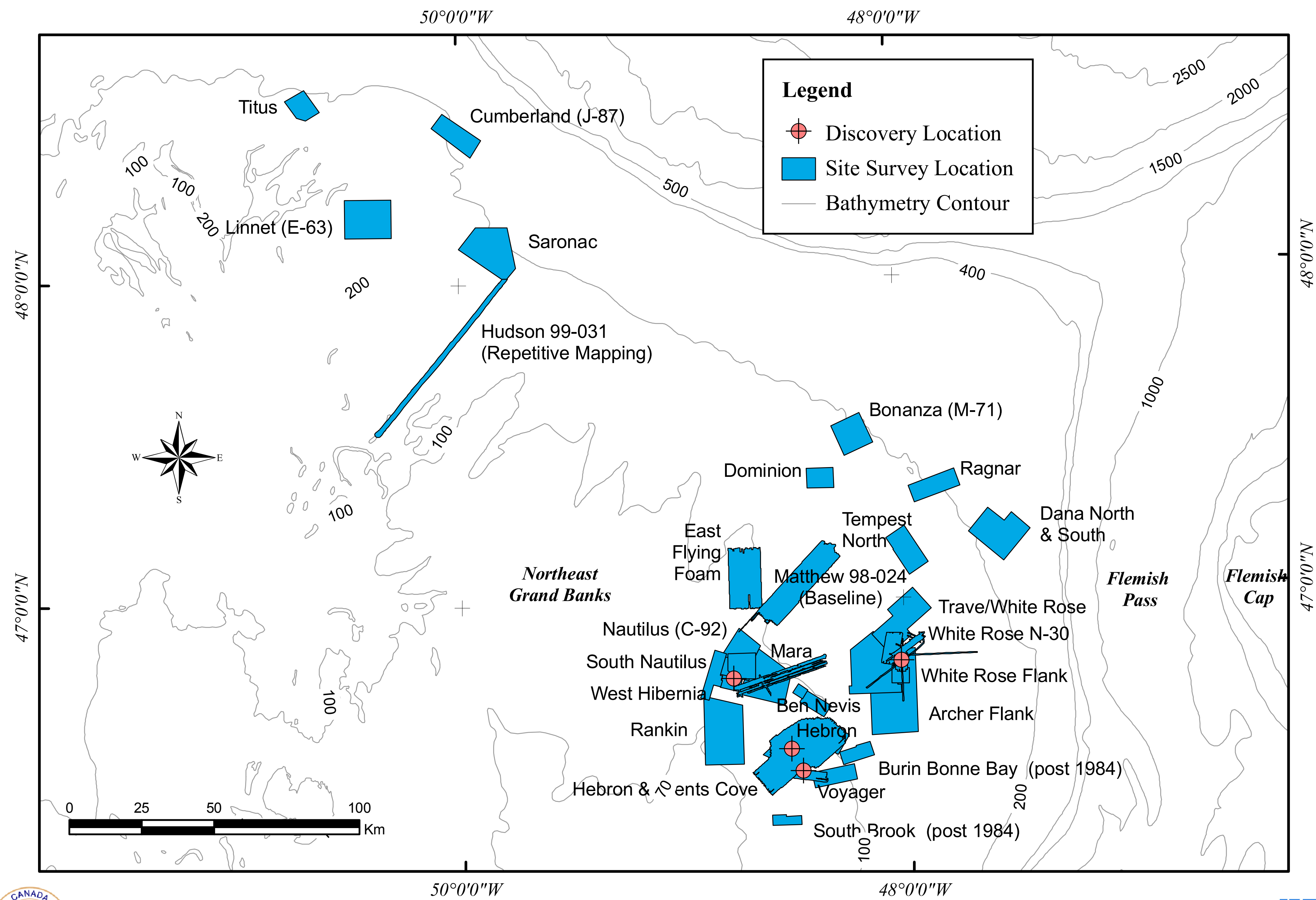


Figure 3.2.3 - GBSC_SITE_SURVEYS Feature Class of Well Site and GSC Site Survey Locations over the Northeast Grand Banks.

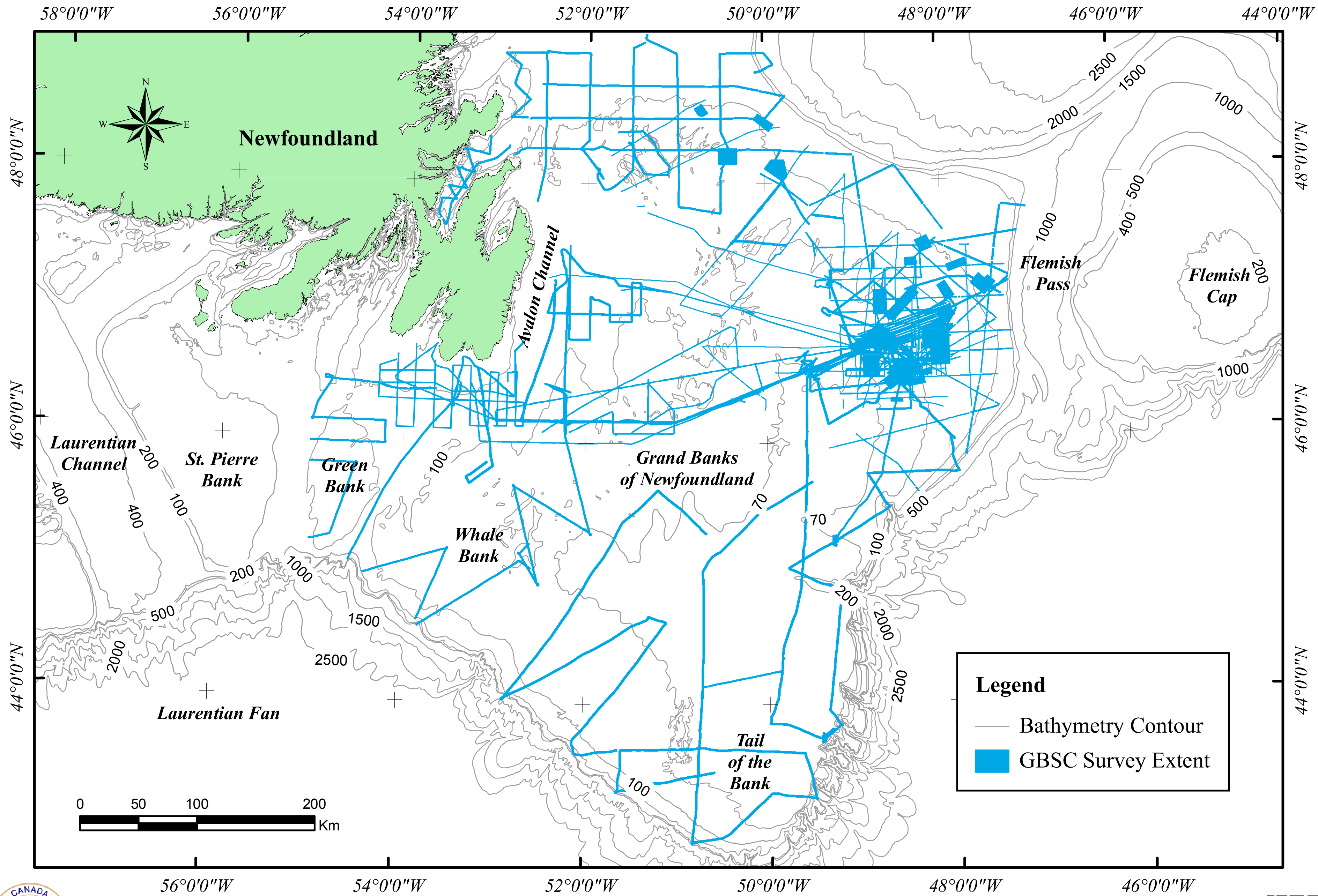


Figure 3.2.4 - GBSC_SURVEY_EXTENT Feature Class of all areas surveyed.

3.3 ICEBERG SCOUR FEATURE CLASSES

Ice scour is defined as the disturbance of the seabed sediments as a result of contact by icebergs or sea-ice ridges. Ice scours identified over the Grand Banks were formed as a result of icebergs contacting the seafloor. Iceberg scours represent furrow and pit features. An iceberg furrow is a long linear or curvilinear feature formed as the keel of a moving iceberg gouges the seafloor sediments. Iceberg Pits are circular or elliptical features formed by the grounding or rolling of an iceberg. They can form as individual events or associated with furrows as termination features. The term pit and crater have been used interchangeably by researchers in previous Grand Banks research. Furrow and pit features are typically bordered by raised berms composed of the seafloor sediments displaced during the scouring process. The authors define an iceberg scour event as a complex feature of furrows or furrow (s) / pit (s) interpreted to have formed by the same iceberg.

The original GBSC includes individual scour events recorded as one or more segments based primarily on a change in type (furrow vs pit), orientation, or width. The GBSC Geodatabase iceberg scour related Feature Classes represent summarized or simplified databases of individual scour events extracted from the original GBSC segment database. Specific scripts/routines were written by CSR to summarize the GBSC in order to convert field formats and codes, and to remove non-standard records that may lead to incorrect use of the database.

Prior to the extraction of features from the original GBSC a detailed review was undertaken of those scour segments identified with an error code representing a possible positioning error or duplicate record. A total of 497 segments representing 325 scour events were removed during this review. Of the 497 segments 455 were duplicates and 42 were coded as having a possible positioning error.

The iceberg scour related Feature Classes compiled from the GBSC are discussed within the following sub-sections and include;

1. GBSC_FURROWS - Iceberg Furrows.
2. GBSC_FURROWS_WITH_PITS – Iceberg Furrows with one or more associated pits.
3. GBSC_FURROWS_ONEENDPOINT – Iceberg Furrows with only one endpoint mapped.
4. GBSC_PITS – Includes all individual pits or those associated with Furrows stored within GBSC_FURROWS_WITH_PITS.

A complete listing and description of the database fields within each of the four Feature Classes is presented in Appendix III.

3.3.1 GBSC Furrows Feature Class (GBSC_FURROWS)

The GBSC_FURROWS Feature Class is a line/vector geometry type which includes 4405 iceberg Furrows, see Figure 3.3.1 and 3.3.2. Each line represents the digitized centerline of the furrow trough.

The events within this Feature Class include Furrows with one or more segments from the original GBSC database.

The GBSC segments associated with each event were joined within ArcGIS based on the SCOUR_ID. The attributes for each furrow were extracted or summarized and stored within the GBSC_FURROWS database as documented below. Specific scripts/routines were written by CSR to summarize the GBSC in order to convert field formats and codes, and to remove non-standard records that may lead to incorrect use of the database.

- SCOUR_ID
  This is a unique numeric identifier assigned to each furrow event and is the same identifier as that stored in the original GBSC. This field can be used to link those scours stored in the GBSC_FURROWS Feature Class to the original GBSC.

- SOURCE
  This field identifies the original database or geophysical data source.

- CRUISE
  This field identifies the regional or site survey the scour was interpreted from. Additional identifiers were assigned to GSCA regional cruises where data was collected over a specific area.

- BATHYMETRY
  Water depth in metres at the scour location. Where WD_VAR (see below) information exists the bathymetry value represents the minimum water depth along the scour event obtained from the available survey bathymetry contour coverage or multibeam grid file. Of the 4405 furrows, 4325 have a recorded bathymetry value ranging from 51 to 350 m.

- WD_VAR
  The difference in the minimum and maximum water depth (in metres) recorded along the length of the scour event. The water depth variation value was determined using site specific bathymetry coverage from either single beam echosounders or multibeam sonar. Of the 4405 furrows, 1851 have a measured water depth variation ranging from 0 to 15 m.

- TYPE
  Identifies the furrow or pit type. The furrow types stored within GBSC_Furrows include Linear Furrows (n=2650), Sinuous Furrows (n=736), Arcuate Furrows (n=904), and poorly defined Furrows (n=115).

- SBP
  Identifies the type of profiling system utilized from which scour depth and berm height measurements were recorded.

- DEPTH
  Depth in metres of the furrow event measured below the interpreted unscoured seafloor. Where more than one segment depth was available the depth represents the maximum furrow depth recorded along the scour event extracted from the original GBSC segment database. System

resolution depth was ignored if one or more segments in the original GBSC included a measured depth.

Of the 4405 furrows, 1540 furrows have a recorded depth ranging from 0.1 to 6.0 m. Of these 1540 furrows, 782 have a measured depth and 758 have a system resolution depth of 0.3 m (n=379), 0.5 m (n=326) and 1.0 m (n=53) recorded in the database.

- DEPTH_Q
  This qualifier describes the scour depth measurement or the lack of depth measurement.

- WIDTH
  Width is measured in metres from berm crest to berm crest perpendicular to the scour orientation. For linear furrows (n=2650) the width measurement represents the average width of the scour segment as measured by the interpreter and recorded in the original GBSC segment database. For the remaining population the width represents the weighted average width of the Furrow event calculated from the original GBSC segment database. The segment width was weighted according to the segment length. Segments with a width of 0 were not included in the weighted average calculation.

  Of the 4405 furrows, 3859 furrows have a recorded width ranging from 1 to 208 m.

- LENGTH
  Length measured in metres, represents the true length where two endpoints were observed (see Length_Q). For the Feature Class GBSC_Furrows the length represents the total length of the furrow event and ranges from 5 to 10,216 m.

- LENGTH_Q
  Length Qualifier is used to describe the scour length measurements. This field describes the presence of end points and thus the quality of the length data for the entire scour event.

- ORIENT
  Orientation of the furrow as a degree value between 0 and 179. This parameter does not indicate the actual direction in which scouring took place. Orientation within GBSC_Furrows was calculated utilizing the ArcGIS Tool Linear Directional Mean.

- BERM_HT
  Height in metres of the scour berm above the unscoured seafloor. Represents the maximum Furrow berm height recorded within the original GBSC segment database. Of the 4405 furrows, 605 furrows have a recorded berm height ranging from 0.1 to 2.5 m.

- PROFILE
  Describes the scour shape as seen on the sub-bottom profiler record at the location where the maximum depth was recorded. Of the 782 furrows with a measured depth, 240 have a profile shape description.

- SYSTEM
  Includes the type of sidescan sonar system or multibeam sonar system used for scour mapping.

- QUALITY
  Includes a qualitative assessment of the sidescan or multibeam data quality.

- CLARITY
  Includes a qualitative evaluation of the relative clarity and sharpness of the scour as it appears on the sidescan or multibeam sonar data.

- BERM_DEV
  Berm Development indicator is a qualitative assessment of the scour berms as observed on sidescan sonar records.

- SED_TYPE
  The sediment lithology at the measured scour location as interpreted from sidescan sonar records. The sediment types stored within GBSC_Furrows include Predominantly Sand (n=1775), Sand & Gravel (n=1398), and Gravel (n=897). 395 furrows have no sediment type available.

- COMMENTS
  This field contains analyst's notes.

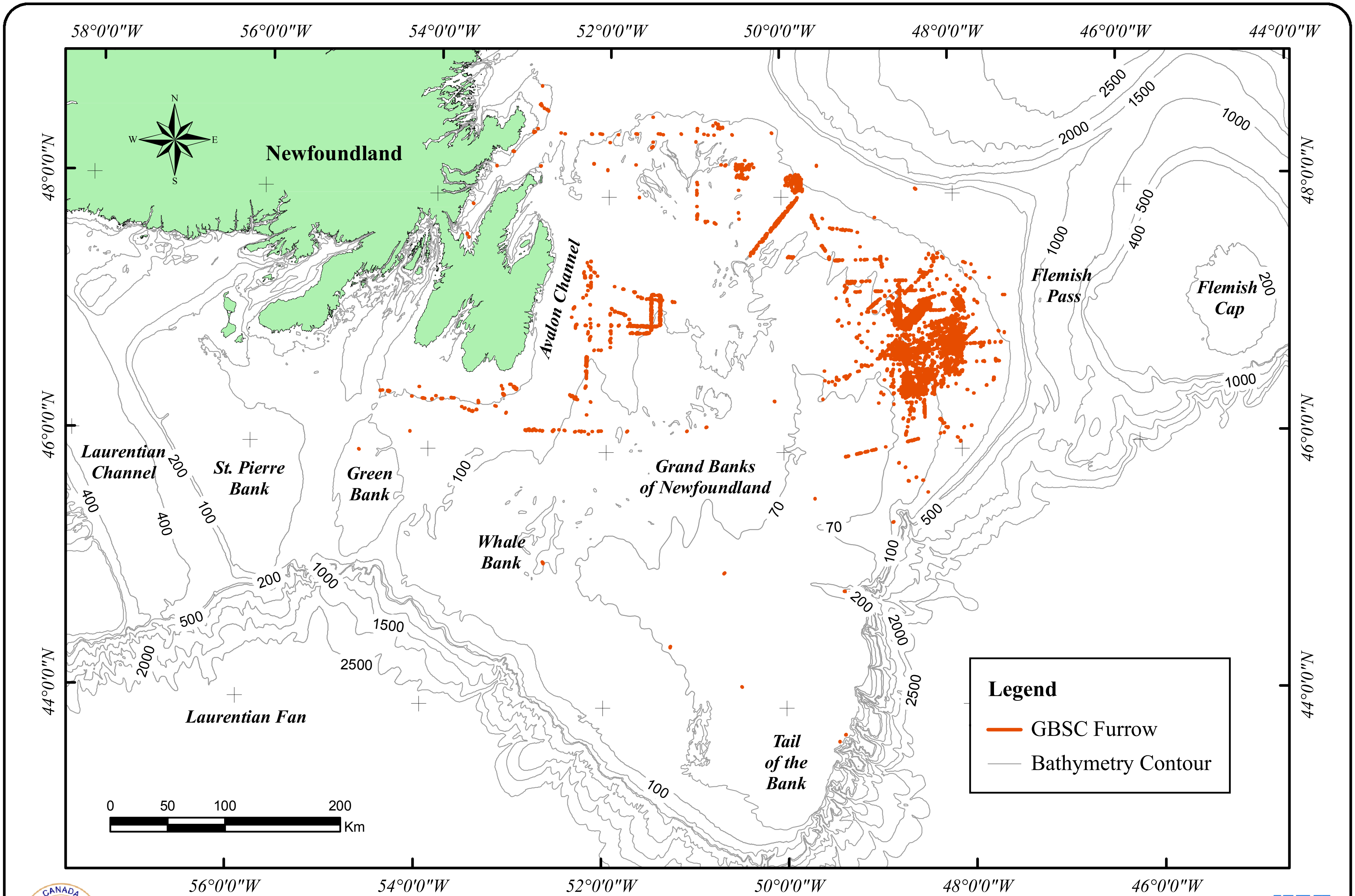


Figure 3.3.1 - GBSC_FURROWS Feature Class of Iceberg Furrow Locations.

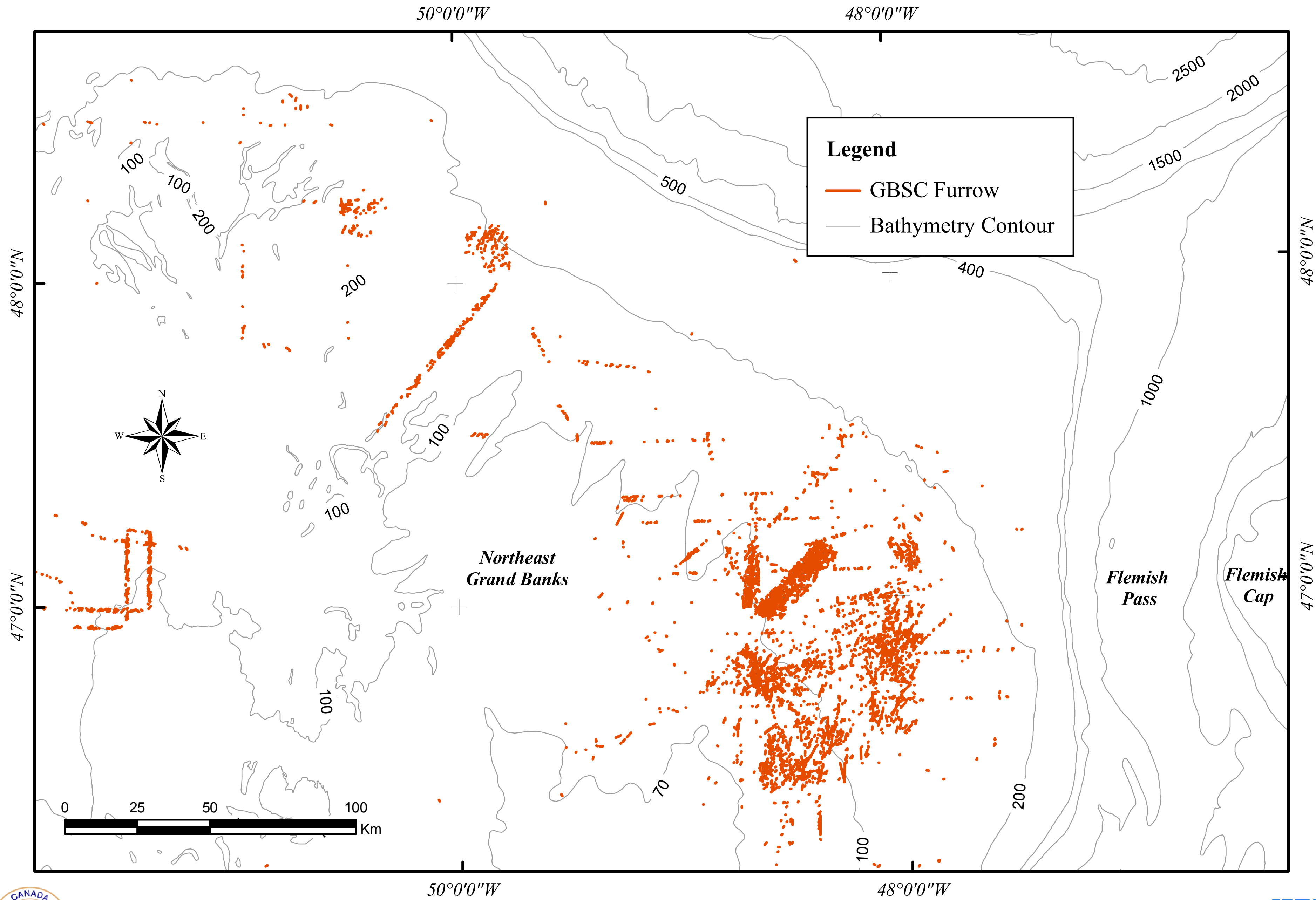


Figure 3.3.2 - GBSC_FURROWS Feature Class of Iceberg Furrow Locations over the Northeast Grand Banks.

3.3.2 GBSC Furrows with Pits Feature Class (GBSC_FURROWS_WITH_PITS)

The GBSC_FURROWS_WITH_PITS feature class is a line/vector geometry type which includes 344 ice scour events, (Figure 3.3.3 and 3.3.4). Each line represents the digitized centerline of the scour event trough. The scour events within this Feature Class include Furrows with associated termination pits.

The GBSC segments associated with each scour event were joined within ArcGIS based on the SCOUR_ID. The attributes for each scour event were extracted or summarized and stored within the GBSC_FURROWS_WITH_PITS database as documented below. Specific scripts/routines were written by CSR to summarize the GBSC in order to convert field formats and codes, and to remove non-standard records that may lead to incorrect use of the database.

- SCOUR_ID
  This is a unique numeric identifier assigned to each scour event and is the same identifier as that stored in the original GBSC. Pits stored in the GBSC_PITS Feature Class can be linked to their associated Furrows within the GBSC_FURROWS_WITH_PITS Feature Class through the SCOUR_ID field.

- SOURCE
  This field identifies the original database or geophysical data source.

- CRUISE
  This field identifies the regional or site survey the scour was interpreted from. Additional identifiers were assigned to GSCA regional cruises where data was collected over a specific area.

- BATHYMETRY
  Water depth in metres at the scour location. Where WD_VAR (see below) information exists the bathymetry value represents the minimum water depth along the scour event obtained from the available survey bathymetry contour coverage or multibeam grid file. Of the 344 scour events, 335 have a recorded bathymetry value ranging from 51 to 187 m.

- WD_VAR
  The difference in the minimum and maximum water depth (in metres) recorded along the length of the scour event. The water depth variation value was determined using site specific bathymetry coverage from either single beam echosounders or multibeam sonar. Of the 344 furrows, 103 have a measured water depth variation ranging from 0 to 13 m.

- TYPE
  Identifies the furrow or pit type. The furrow types stored within GBSC_FURROWS_WITH_PITS include Linear Furrow with Pit (s) (n=131), Sinuous Furrow with Pit (s) (n=128), and Arcuate Furrow with Pit (s) (n=85).

- SBP
  Identifies the type of profiling system utilized from which scour depth and berm height measurements were recorded.

- DEPTH
  Depth in metres of the furrow event measured below the interpreted unscoured seafloor. Where more than one segment depth was available the depth represents the maximum furrow depth recorded along the scour event extracted from the original GBSC segment database. System resolution depth was ignored if one or more segments in the original GBSC included a measured depth. The depth of pit features were excluded in the calculation of maximum depth, see GBSC_PITS for pit depth information.

  Of the 344 furrows with associated pit (s), 178 furrows have a recorded depth ranging from 0.1 to 1.6 m. Of these 178 furrows, 148 have a measured depth and 30 have a system resolution depth of 0.3 m (n=19) and 0.5 m (n=11) recorded in the database.

- DEPTH_Q
  This qualifier describes the scour depth measurement or the lack of depth measurement.

- WIDTH
  Width is measured in metres from berm crest to berm crest perpendicular to the scour orientation. For linear furrows with associated Pit (s) (n=131) the width measurement represents the average width of the furrow segment as measured by the interpreter and recorded in the original GBSC segment database. For the remaining population the width represents the weighted average width of the Furrow event calculated from the original GBSC segment database. The segment width was weighted according to the segment length. Associated pit segments and those with a width of 0 were not included in the weighted average calculation.

  Of the 344 furrows with associated pit (s), 317 furrows have a recorded width ranging from 1 to 110 m.

- LENGTH
  Length measured in metres, represents the true length where two endpoints were observed (see Length_Q). For the Feature Class GBSC_FURROWS_WITH_PITS the length represents the total length of the scour (Furrow & Pit) event and ranges from 33 to 9,690 m.

- LENGTH_Q
  Length Qualifier is used to describe the scour length measurements. This field describes the presence of end points and thus the quality of the length data for the entire scour event.

- ORIENT
  Orientation of the scour event as a degree value between 0 and 179. This parameter does not indicate the actual direction in which scouring took place. Orientation within GBSC_FURROWS_WITH_PITS was calculated utilizing the ArcGIS Tool Linear Directional Mean. Associated pit features were excluded in this calculation.

- BERM_HT

Height in metres of the scour berm above the unscoured seafloor. Represents the maximum furrow berm height stored within the original GBSC segment database. All associated pit features were excluded in this calculation, Pit berm height is stored within GBSC_PITS

Of the 344 furrows with associated pit (s), 128 furrows have a recorded berm height ranging from 0.1 to 1.8 m.

- PROFILE

  Describes the scour shape as seen on the sub-bottom profiler record at the location where the maximum depth was recorded. Of the 317 furrows with a measured depth, 20 have a profile shape description.

- SYSTEM

  Includes the type of sidescan sonar system or multibeam sonar system used for scour mapping.

- QUALITY

  Includes a qualitative assessment of the sidescan or multibeam data quality.

- CLARITY

  Includes a qualitative evaluation of the relative clarity and sharpness of the scour as it appears on the sidescan or multibeam sonar data.

- BERM_DEV

  Berm Development indicator is a qualitative assessment of the scour berms as observed on sidescan sonar records.

- SED_TYPE

  The sediment lithology at the measured scour location as interpreted from sidescan sonar records. The sediment types stored within GBSC_FURROWS_WITH_PITS include Predominantly Sand (n=149), Sand & Gravel (n=97), and Gravel (n=83). 15 furrows have no sediment type available.

- COMMENTS

  This field contains analyst's notes.

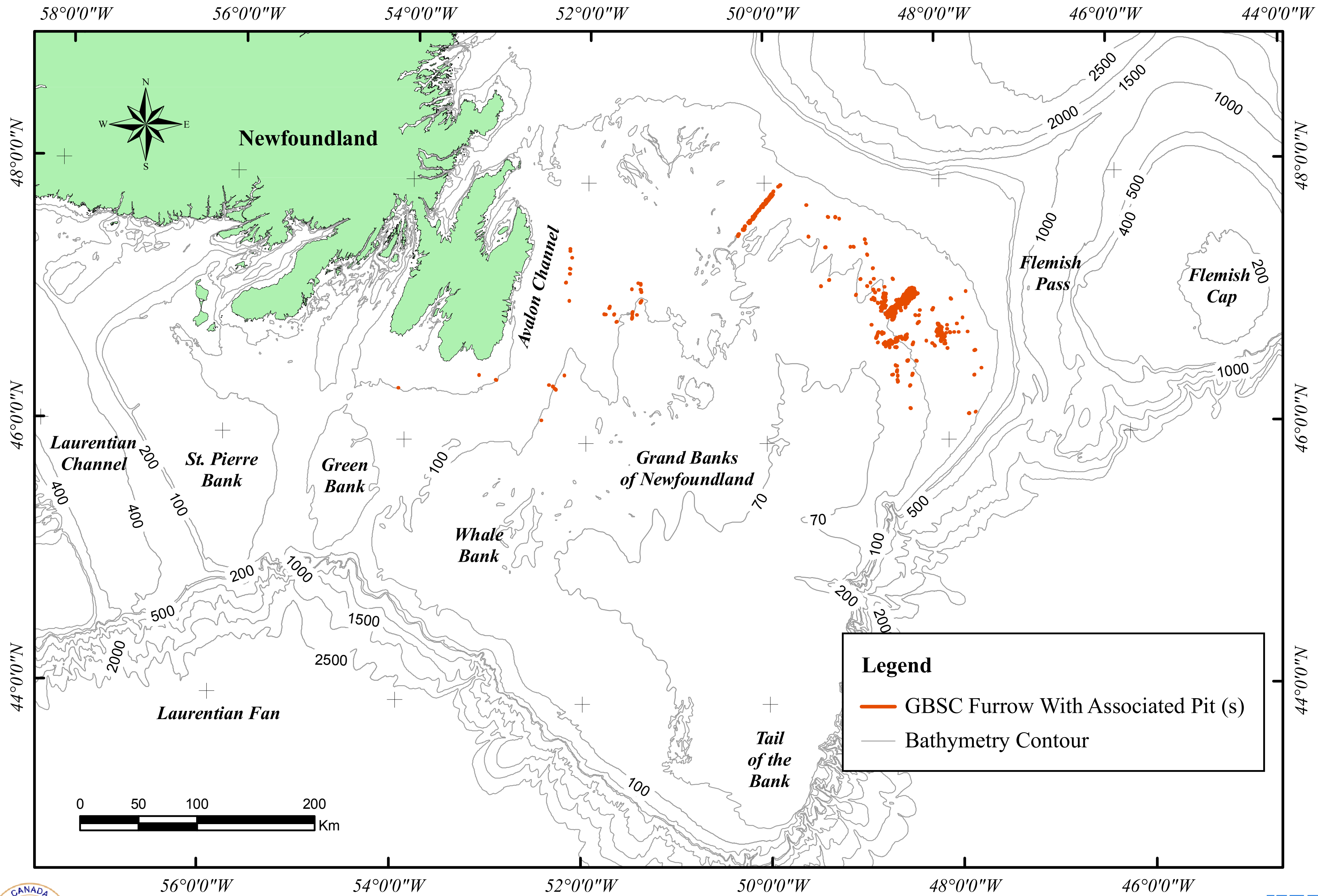


Figure 3.3.3 - GBSC_FURROWS_WITH_PITS Feature Class of Iceberg Furrows with associated pits.

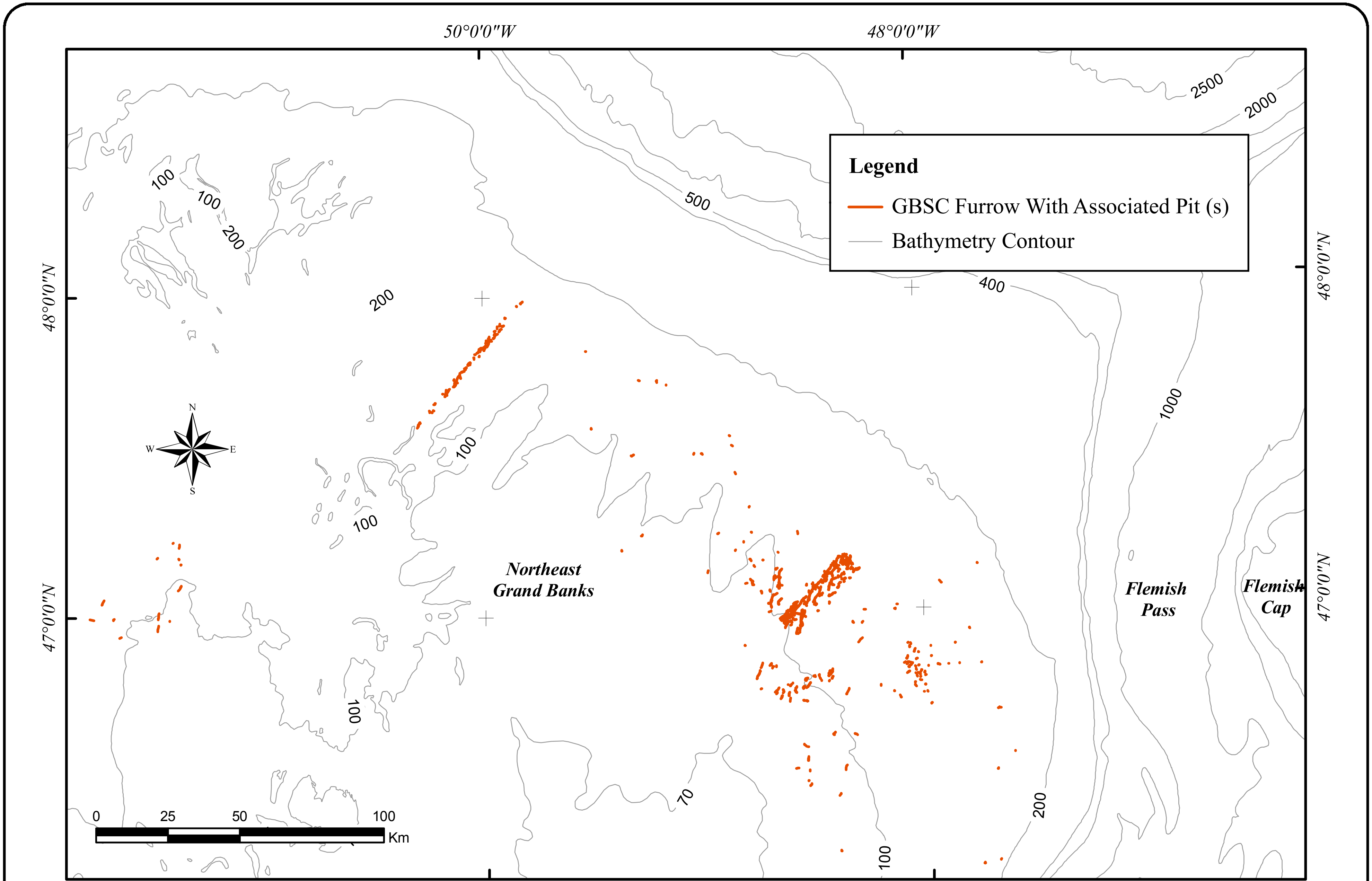


Figure 3.3.4 - GBSC_FURROWS_WITH_PITS Feature Class of Iceberg Furrows with associated pits over the Northeast Grand Banks.

3.3.4 GBSC Furrow Point Feature Class (GBSC_FURROWS_ONEENDPOINT)

The GBSC_FURROWS_ONEENDPOINT Feature Class is a point geometry type which includes 617 iceberg furrows, see Figure 3.3.5 and 3.3.6. These furrows include Mobil Source ice scours stored in the original segmented GBSC with only one end point coordinate. These furrows only have one end point as a result of the mapping methodology utilized during the interpretation of the geophysical data. In the original compilation (1982), scour depth and scour position were the only parameters recorded from regional survey data. Sidescan sonar records were only used to distinguish between furrow and pit features. Consequently only those scours which crossed the survey line, representing a small fraction of the total observed population, were recorded in the original database.

These furrows were extracted directly from the original GBSC segment database and did not contain information for all of the scour parameters. The database fields within this Feature Class are as follows.

- SCOUR_ID
  This is a unique numeric identifier assigned to each furrow event and is the same identifier as that stored in the original GBSC. This field can be used to link the furrows to the original GBSC.

- SOURCE
  This field identifies the original database or geophysical data source. All of the furrows are Mobil source.

- CRUISE
  This field identifies the regional or site survey the scour was interpreted from.

- BATHYMETRY
  Water depth in metres at the furrow location. All of the furrows (n=617) have a recorded bathymetry value ranging from 64 to 257 m.

- TYPE
  Identifies the furrow type. The furrow types include Linear Furrows (n=72), Sinuous Furrows (n=10), Arcuate Furrows (n=13), and poorly defined Furrows (n=522).

- SBP
  Identifies the type of profiling system utilized from which scour depth and berm height measurements were recorded.

- DEPTH
  Depth in metres of the furrow event measured below the interpreted unscoured seafloor as stored in the original segment GBSC database.

  Of the 617 furrows, 579 furrows have a recorded depth ranging from 0.3 to 7.0 m. Of these 579 furrows, 507 have a measured depth and 72 have a system resolution depth of 0.5 m recorded in the database.

- DEPTH_Q
  This qualifier describes the scour depth measurement or the lack of depth measurement.

- WIDTH
  Width is measured in metres from berm crest to berm crest perpendicular to the scour orientation as stored in the original segment GBSC database. Of the 617 furrows, 154 furrows have a recorded width ranging from 3 to 150 m.

- LENGTH
  Length measured in metres, represents the true length where two endpoints were observed (see Length_Q). Of the 617 furrows, 76 furrows have a recorded length ranging from 40 to 3370 m.

- LENGTH_Q
  Length Qualifier is used to describe the scour length measurements. This field describes the presence of end points and thus the quality of the length data for the entire scour event.

- ORIENT
  Orientation of the furrow as a degree value between 0 and 179 as stored in the original segment GBSC database. This parameter does not indicate the actual direction in which scouring took place. Of the 617 furrows, 98 furrows have a recorded orientation ranging from 0 to 178 degrees.

- SYSTEM
  Includes the type of sidescan sonar system used for scour mapping.

- SED_TYPE
  The sediment lithology at the measured scour location as interpreted from sidescan sonar records. The sediment types stored within this Feature Class include Predominantly Sand (n=293), Sand & Gravel (n=264), Gravel (n=25), Glacial Marine Sediment (n=5), and Glacial Till (n=25). Five furrows have no sediment type available.

- COMMENTS
  This field contains analyst's notes.

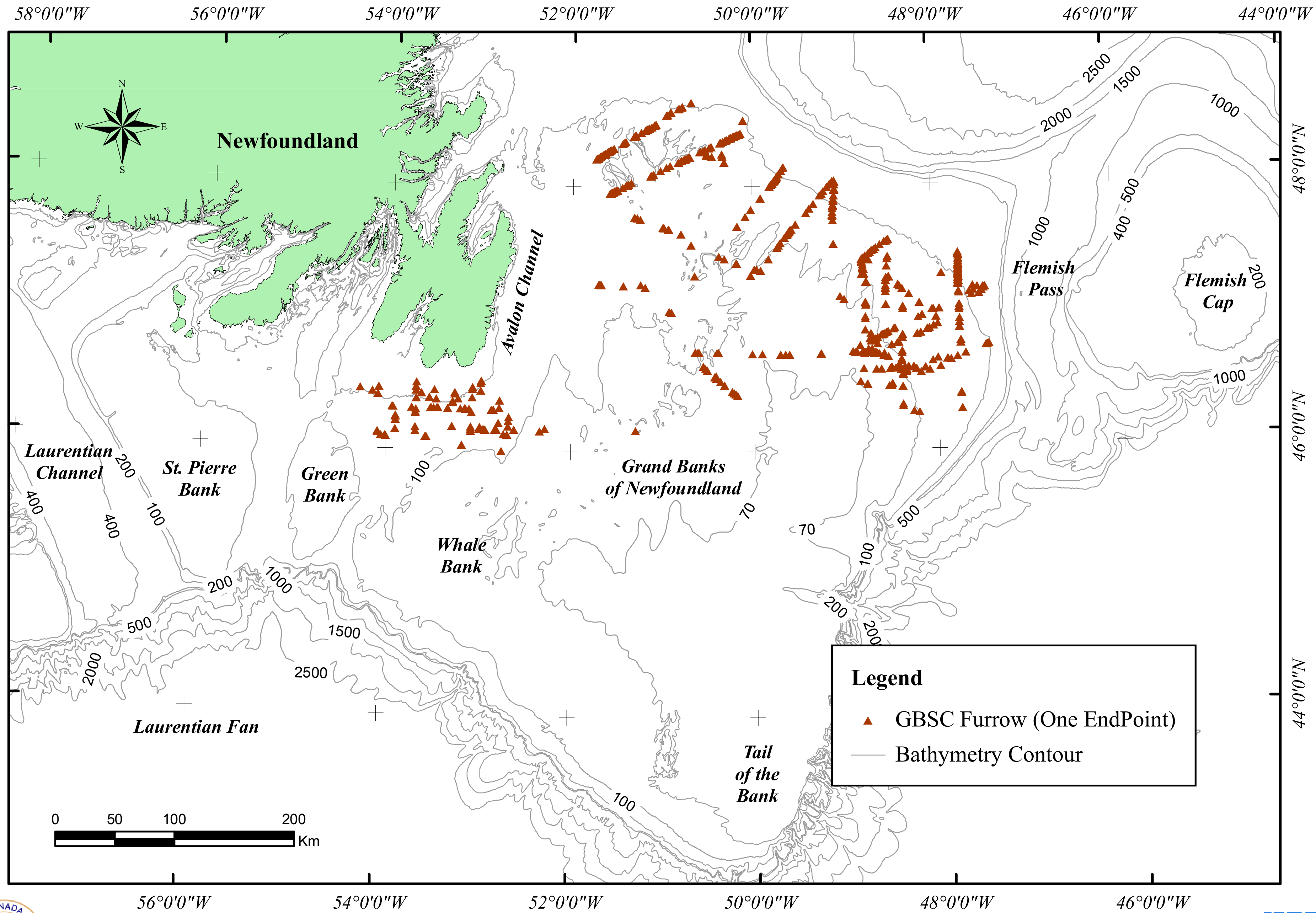


Figure 3.3.5 - GBSC_FURROWS_ONEENDPOINT Feature Class of Iceberg Furrows with one endpoint mapped.

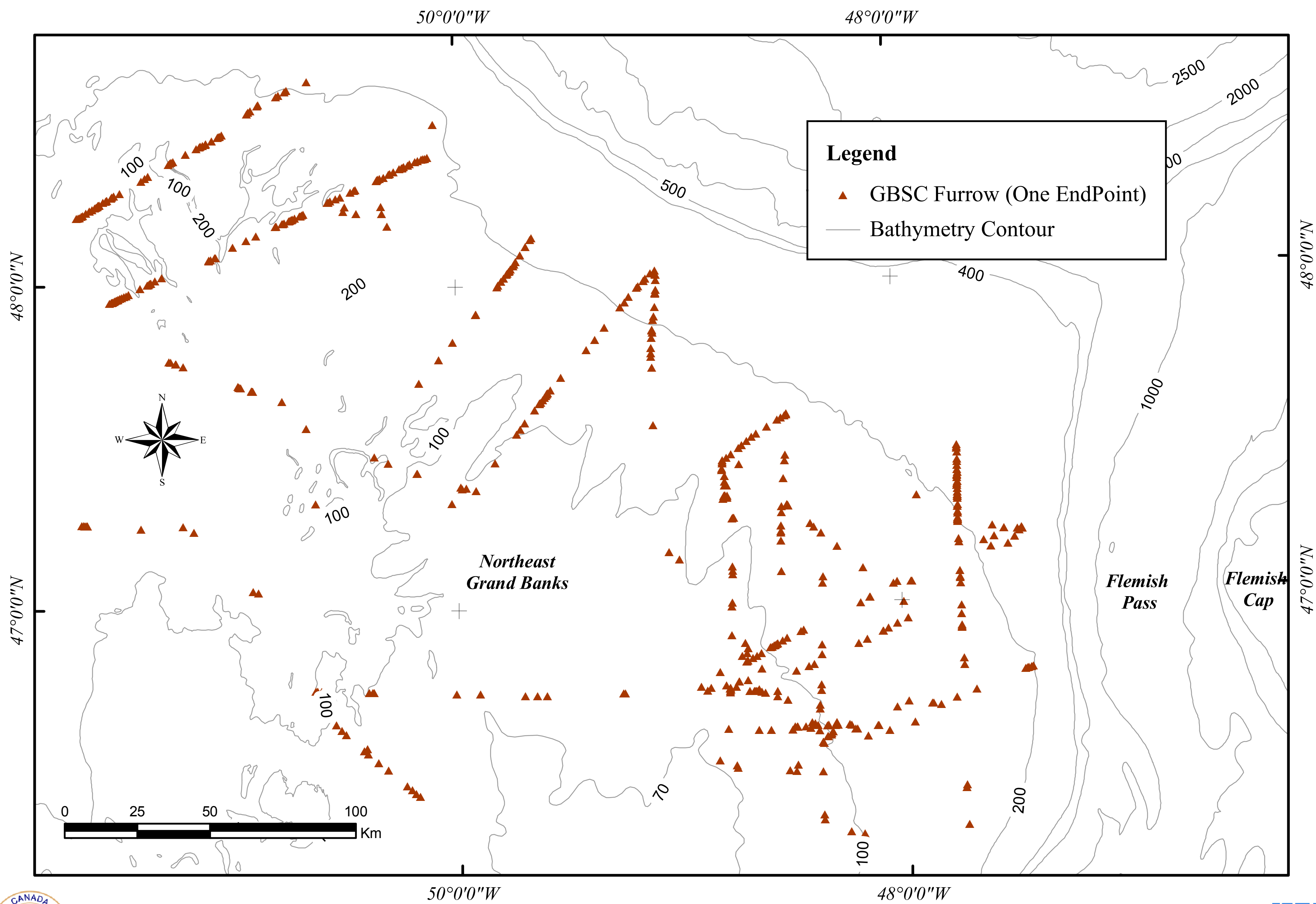


Figure 3.3.6 - GBSC_FURROWS_ONEENDPOINT Feature Class of Iceberg Furrows with one endpoint mapped over the Northeast Grand Banks.

3.3.3 GBSC Pit Feature Class (GBSC_PITS)

The GBSC_PITS Feature Class is a point geometry type which includes 2680 iceberg pits, see Figure 3.3.7 and 3.3.8. The features include all individual Iceberg Pits or those associated with Furrows. These pits were extracted directly from the original GBSC segment database and include the following database fields.

- SCOUR_ID
  This is a unique numeric identifier assigned to each scour event and is the same identifier as that stored in the original GBSC. Pits stored in the GBSC_PITS Feature Class can be linked to their associated Furrows within the GBSC_FURROWS_WITH_PITS Feature Class through the SCOUR_ID field.

- SOURCE
  This field identifies the original database or geophysical data source.

- CRUISE
  This field identifies the regional or site survey the pit was interpreted from. Additional identifiers were assigned to GSCA regional cruises where data was collected over a specific area.

- BATHYMETRY
  Water depth in metres at the pit location. Of the 2680 pit features, 2669 have a recorded bathymetry value ranging from 49 to 285 m.

- TYPE
  Identifies the pit type. The pit types stored within GBSC_PITS include Pit (n=2101), Pit Chain (n=150), and Pit (s) associated with a Furrow (n=429).

- SBP
  Identifies the type of profiling system utilized from which the pit depth and berm height measurements were recorded.

- DEPTH
  Depth in metres of the pit measured below the interpreted un-scoured seafloor as stored in the original segment GBSC database. Of the 2680 pit features, 1174 pits have a recorded depth ranging from 0.1 to 8.3 m. Of these 1174 pits, 1152 have a measured depth and 12 have a system resolution depth of 0.3 m (n=7) and 0.5 m (n=5) recorded in the database.

- DEPTH_Q
  This qualifier describes the scour depth measurement or the lack of depth measurement.

- WIDTH
  Width is measured in metres from berm crest to berm crest perpendicular to the Pit's longest axis or the orientation of the scour event in the case of those pits associated with furrows. The Pit width is the same as that recorded in the original segment GBSC database. Of the 2680 pits, 2598 pits have a recorded width ranging from 5 to 350 m.

- LENGTH
  Length measured in metres, represents the true length where two endpoints were observed (see Length_Q). For the Feature Class GBSC_PITS the recorded length represents the Pit's longest axis. Of the 2680 pits, 1259 have a recorded length ranging from 11 to 573 m.

- LENGTH_Q
  Length Qualifier is used to describe the pit length measurements. This field describes the presence of end points and thus the quality of the length data for the pit feature.

- ORIENT
  Orientation of the scour event as a degree value between 0 and 179. This parameter does not indicate the actual direction in which scouring took place. Orientation represents the Pits longest axis or the orientation of the scour event for those pits associated with furrows. Of the 2680 pits, 1260 have a recorded orientation ranging from 0 to 179 degrees.

- BERM_HT
  Height in metres of the pit berm above the unscoured seafloor. Represents the maximum berm height stored within the original GBSC segment database. Of the 2680 pits, 255 have a recorded berm height ranging from 0.1 to 3.3 m.

- PROFILE
  Describes the scour shape as seen on the sub-bottom profiler record at the location where the maximum depth was recorded. Of the 1152 pits with a measured depth, 20 have a profile shape description.

- SYSTEM
  Includes the type of sidescan sonar system or multibeam sonar system used for scour mapping.

- QUALITY
  Includes a qualitative assessment of the sidescan or multibeam data quality.

- CLARITY
  Includes a qualitative evaluation of the relative clarity and sharpness of the scour as it appears on the sidescan or multibeam sonar data.

- BERM_DEV
  Berm Development indicator is a qualitative assessment of the scour berms as observed on sidescan sonar records.

- SED_TYPE
  The sediment lithology at the measured pit location as interpreted from sidescan sonar records. The sediment types stored within GBSC_PITS include Predominantly Sand (n=1427), Sand & Gravel (n=791), and Gravel (n=290). 172 pits have no sediment type available.

- COMMENTS
  This field contains analyst's notes.

- PIT_ID

  This unique numeric identifier allows the user to relate or join the GBSC_PITS feature Class database to the corresponding records within the original GBSC segmented Database.

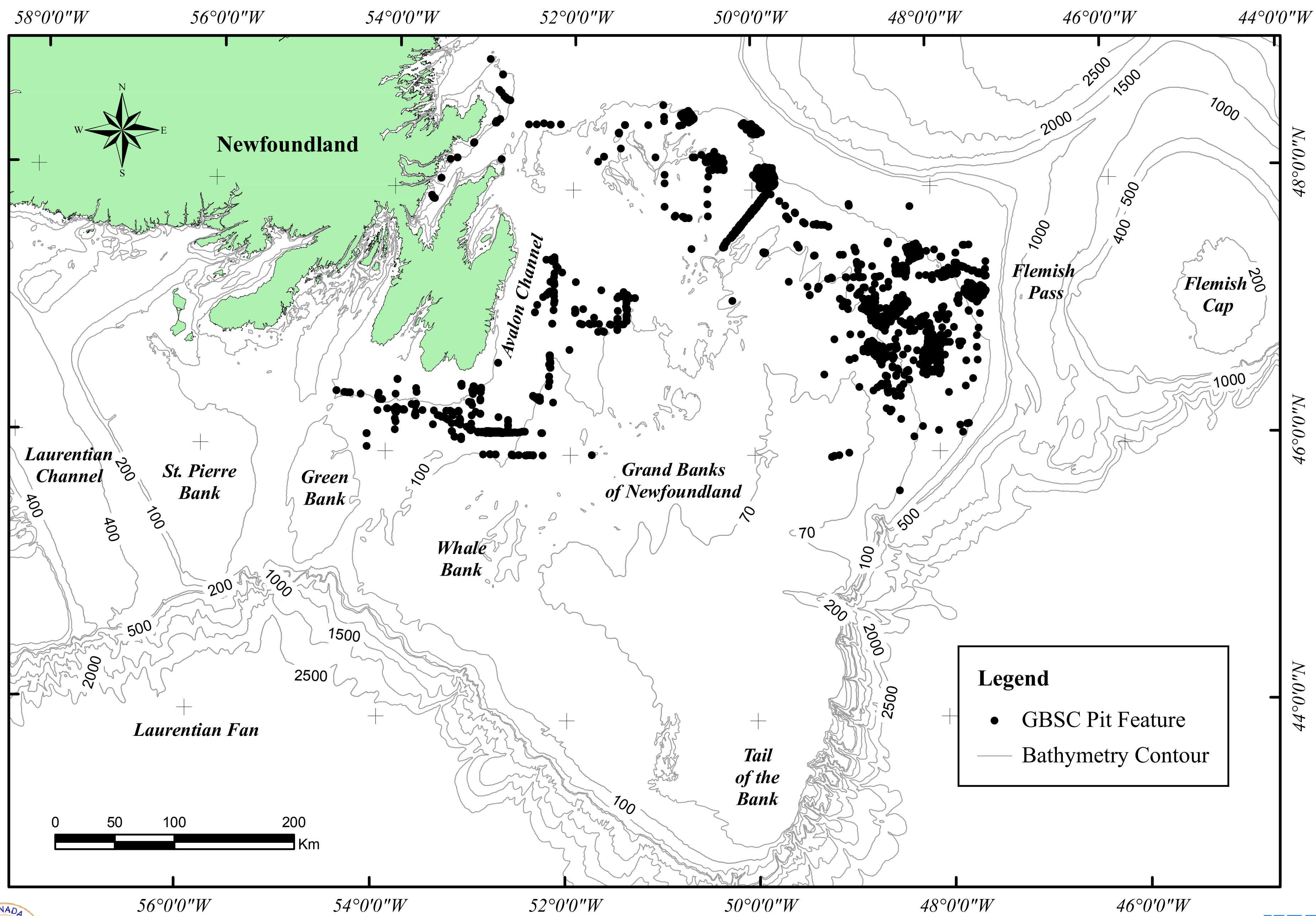


Figure 3.3.7 - GBSC_PITS Feature Class of Iceberg Pit Locations.

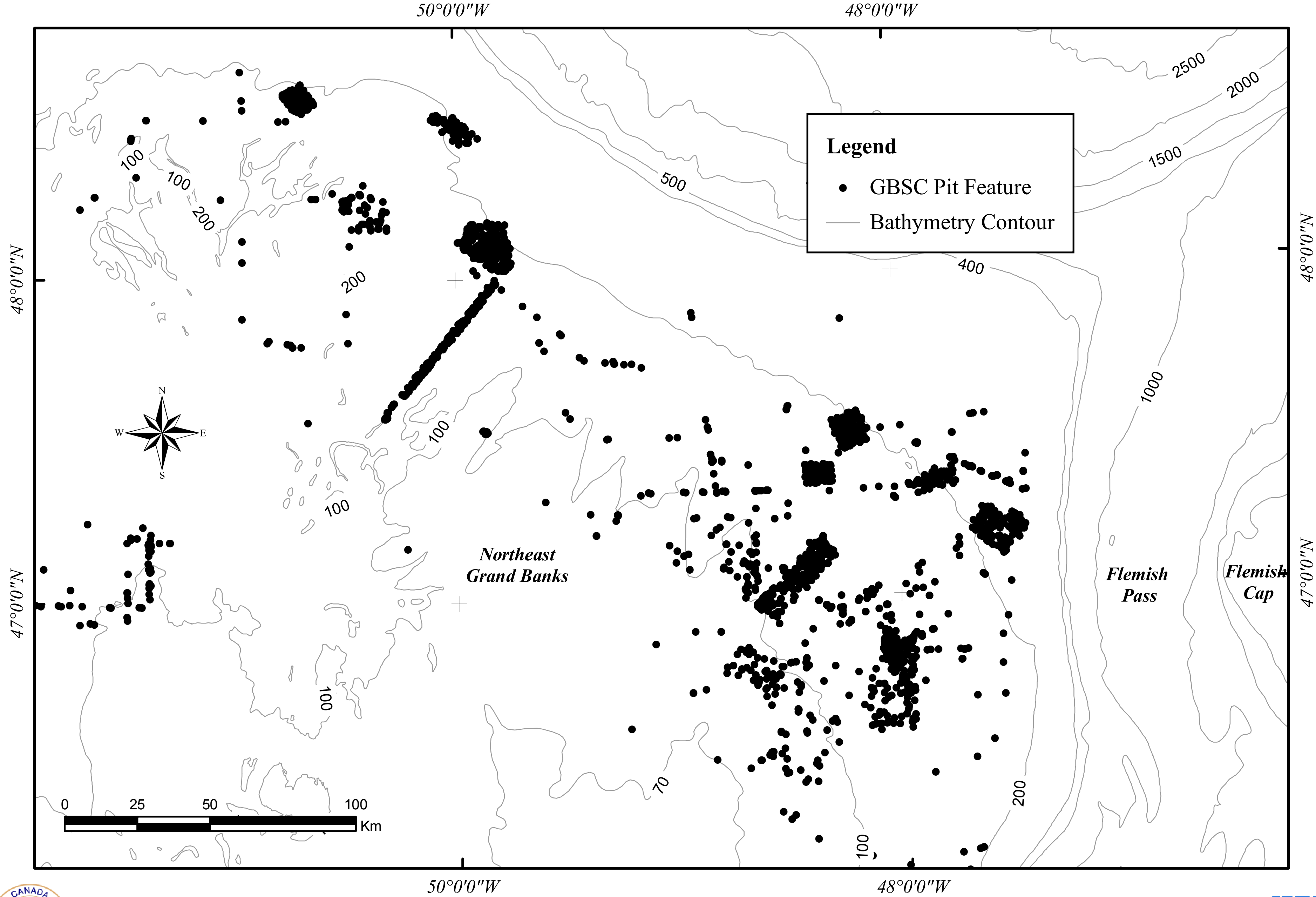


Figure 3.3.8 - GBSC_PITS Feature Class of Iceberg Pit Locations over the Northeast Grand Banks.

4.0 GBSC DATA EXPLORATION

The following section presents an exploration of the GBSC Geodatabase scour feature classes. This data exploration is presented as an example of the types of information that may be obtained from the database.

4.1 OVERVIEW

The Grand Banks Scour Catalogue was compiled from various sources including the Mobil scour database, ESRF 4000 repetitive mapping program, GSCA Regional Cruises, and Industry Wellsite Surveys. The database contains a total of 8046 georeferenced ice scour features with key parameters such as width, length, depth, orientation, and bathymetry being measured for each feature.

Of the 8046 scour features, 5366 are furrow features, and 2680 are pit features. Pits include all features stored in the Feature Class GBSC_PITS. Furrows include all features stored in the Feature Classes 1) GBSC_FURROWS, 2) GBSC_FURROWS_WITH_PITS, and 3) GBSC_FURROWS_ONEENDPOINT. Ice scour feature classes are described in Section 3.3. A statistical summary of the GBSC furrow and pit populations are presented in Table 4.1.1.

Table 4.1.1 - Ice Scour Feature Parameter Summary

Parameter	Furrows	Pits
Total Number of Features	5366	2680
REGIONAL BATHYMETRY		
Water Depth Range	51 m - 350 m	49 m - 285 m
Mean Water Depth	116.9 m	151.6 m
DEPTH		
Number of Features with Measured Depth (depth_q = 1)	1425	1162
Maximum Depth	7.0 m	8.3 m
Minimum Depth	0.1 m	0.1 m
Mean Depth	0.71 m	1.94 m
Number of Features with Measured Depth and System Resolution Depth (depth_q = 1 or 2)	2285	1174
Maximum Scour Depth	7.0 m	8.3 m
Minimum Scour Depth	0.1 m	0.1 m
Mean Scour Depth	0.88 m	1.92 m
Number of Scours with depth >= 1.0m	496	975
BERM HEIGHT		
Number of Features with Measured Berm Height	733	255
Maximum Berm Height	2.5 m	3.3 m

Parameter	Furrows	Pits
Minimum Berm Height	0.1 m	0.1 m
Mean Berm Height	0.51 m	0.65 m
LENGTH		
Number of Features with Measured Length	4825	1259
Maximum Length	10216 m	573 m
Minimum Length	5 m	11 m
Mean Length	585 m	84 m
Number of Features with Two Endpoints Seen or Observed with Confidence (Length_q = 2)	1809	1030
Maximum Length	9690 m	371 m
Minimum Length	0 m	0 m
Mean Length	505 m	82 m
WIDTH		
Number of Features with Measured Width	4330	2598
Maximum Width	208 m	350 m
Minimum Width	1 m	5 m
Mean Width	26 m	66 m
WATER DEPTH VARIATION ALONG TRACK		
Number of Furrows with Measured Water Depth Variation	2709	-
Maximum Water Depth Variation	15	-
Minimum Water Depth Variation	0	-
Mean Water Depth Variation	1	-
Number of Furrows with Water Depth Variation = 0m	1619	-
Number of Furrows with Water Depth Variation >= 5.0m	44	-

4.2 Scour Parameter Analysis

4.2.1 Bathymetry

Bathymetry is vital to understanding the expression and magnitude of many geological processes, including ice scouring. It is therefore important to study individual parameters in relation to bathymetry in order to determine the potential impact of scouring on a sub-sea installation. All scour features observed in water depths less than 110 metres were incorporated into the GBSC. In water depths greater than 110 metres, only those scours which displayed a relatively fresh acoustic morphology were recorded, thus excluding the population of older degraded scours which are interpreted to be relict scours formed at the end of the last glaciation (Fader and King, 1981).

Figure 4.2.1 displays the distribution of furrows and pits according to bathymetry. Bathymetry for furrows ranges from 51 m to 350 m, with an average water depth of 117 m. The majority of furrows (60.6%) are located in water depths of 90 m to 130 m. Pit bathymetry ranges from 49 m to 285 m, with an average of 152 m water depth. The highest concentration (12.2%) occurs between 120 to 130 m water depth. The distribution of the pit population is variable compared to the furrow population.

Water depth for a scour feature can also vary along the track of the scour. The difference between the minimum and maximum bathymetry recorded along a scour event is referred to as the water depth variation. The water depth variation along the track of a scour has also been defined as "Rise Up" (Sonnichsen & King, 2011). The greatest variation in water depth along a furrow in the GBSC is 15 m, and occurs in water depth of 149 to 164 m. The mean water depth variation throughout the database is 1 m. There are 44 scour events with a variation in water depth greater than or equal to 5 m.

4.2.2 Sediment Type

The geometry of an iceberg scour is influenced by the type, thickness and strength of the seafloor sediment. The sediment lithology at the measured scour location was interpreted from sidescan sonar records for 92% of the furrows and 94% of the pits within the GBSC. The majority of sediment types stored within the GBSC include Predominantly Sand, Sand & Gravel, and Gravel. Figure 4.2.2 includes the distribution of furrows and pits according to sediment type.

4.2.3 Type and Shape

The interaction of ice and seafloor sediments may result in a variety of ice scour types and shapes. When an iceberg drifts into an area where the water depth is less than its draft the keel will displace the sediment to form a furrow or pit feature. The Type parameter yields evidence regarding the nature of the scouring process. For example, during the scouring process some icebergs may ground temporarily or permanently forming an inline or termination pit. Similarly, icebergs may contact the seabed independent of a furrow event creating an isolated pit or pit chain.

Of the 8046 scour features mapped, 5022 are furrows with no associated pit, 344 are furrows with an associated pit (s), and 2680 are pits. The 2680 pits include 2101 isolated Pit events, 150 Pit Chains (n=150), and 429 Pits with an associated Furrow. Figure 4.2.3 and 4.2.4 include the spatial distribution of scour features according to type.

Furrows with no associated pit (s) can be further divided based on the shape of the furrow; 2722 are linear furrows, 746 are sinuous furrows, 917 are arcuate furrows, and 637 are coded as poorly defined furrows. The shape of furrows with an associated pit (s) include 131 linear, 128 sinuous, and 85 arcuate.

4.2.4 Furrow Length

The furrow length parameter should be considered in sub-sea installation design models for it may influence the potential extent of damage, given a parallel scouring direction of the ice keel. Scour length measurements are often limited by the swath of the multibeam or sidescan sonar system and seldom reflect the true length of the scour. Ice scours were assigned a length qualifier code which indicates whether two endpoints were observed, one endpoint was observed or no endpoints were observed. Pit length was not included in this summary, see Pit Area (Section 4.2.5).

The distribution of furrows according to length, binned in 200 m intervals, is shown in Figure 4.2.5. Furrow length ranges from 5 m to 10,216 m, with a mean length of 584.7 m. The majority of furrows

(55.4%) have lengths less than 400 m. There are 725 furrows with lengths greater than 1000m, accounting for approximately 15% of all furrows with a recorded length. The longest furrow (10,216 m) was mapped from the 98-024 multibeam dataset and is located in water depth ranging from 106 to 109 m.

Table 4.2.1 presents a summary table of furrow length for features with an associated water depth (n = 4735) according to 50 m water depth intervals.

Table 4.2.1 – Furrow Length Summary According to Water Depth

Water Depth	N	Minimum (m)	Maximum (m)	Mean (m)	Median (m)	Std. Dev	N furrows ≥ 1000 m
50m - 100m	1524	5	6489	599.8	384	658.6	253
100m - 150m	2781	10	10,216	592.7	345	826.3	409
150m - 200m	388	40	4200	531.8	390	511.7	50
200m - 400m	43	77	2978	548.6	370	526.3	8

4.2.5 Pit Area

Iceberg pit area was calculated by multiplying the length and width measurements within the database. Approximately 47% of the GBSC pit population have a measured length and width. The Pit distribution by area, binned in 2500 m² intervals, is displayed in Figure 4.2.6. Pit area ranges from 84 m² to 111,300 m², with a mean area of 6193 m². The majority of pits (64%) have areas less than 5000 m², and only 74 pits have an area greater than 20,000 m². The pit with the largest area (111,300 m²) is a termination pit within 130 metres water depth mapped from sidescan sonar data acquired during Cruise 99-031.

4.2.6 Furrow Orientation

Orientation values in the GBSC are recorded from 0° to 179° and do not infer actual scouring direction. The orientation parameter defines the angle at which an ice keel could intersect a sub-sea structure. If the preferred orientation (mode) of scouring in the region is at right angles to a sub-sea structure such as a cable or pipeline, there is a higher risk of damage due to the increased number of possible intersections. The lateral extent of damage resulting from keel impacts at right angles would likely be limited to the width of the scouring ice keel. Conversely, when the orientation mode is parallel to a pipeline or cable, the intersection risk is minimised, but a greater degree of damage may occur, since the zone of disruption may extend along the length of the sub-sea structure.

Figure 4.2.7 and Table 4.2.2 include the distribution of orientation for GBSC furrows with a recorded orientation. Although a significant number of furrows occur within each 5° and 10° orientation bins, a strong preferred orientation component occurs within 0 – 5°, 35 – 40°, and 45 – 50°, with each interval having more than 200 furrow features. The general orientation mode of the GBSC furrows is northeast – southwest.

Table 4.2.2 – Summary of Furrow Orientation

Orientation	Number of Furrows	Percentage
0 - 10	315	5.87
10 - 20	306	5.7
20 - 30	374	6.97

Orientation	Number of Furrows	Percentage
30 - 40	412	7.68
40 - 50	397	7.4
50 - 60	392	7.31
60 - 70	325	6.06
70 - 80	275	5.12
80 - 90	244	4.55
90 - 100	214	3.99
100 - 110	217	4.04
110 - 120	191	3.56
120 - 130	162	3.02
130 - 140	167	3.11
140 - 150	165	3.07
150 - 160	213	3.97
160 - 170	230	4.29
170 - 180	248	4.62

4.2.7 Furrow Width

The extent of possible lateral damage to a sub-sea installation caused by an ice keel is partly an expression of the impacting keel's width. Furrow width is measured from berm crest to berm crest and was recorded for 4330 (81%) of the furrow features stored in the GBSC. Pit width was not included in this summary, see Pit Area (Section 4.2.5).

Width measurements of furrow features range from 1 to 208 m with a mean width of 26 m. Figure 4.2.8 illustrates the distribution of furrows according to width. The highest concentration of furrows (32.5 %), have width values between 10 and 20 m. The vast majority of furrows (91.9%) are less than 50 m wide, and only 25 furrows are greater than 100 m wide. The widest furrow (208 m) is a linear furrow located in 104 m water depth mapped from the 98-024 multibeam dataset.

Table 4.2.3 presents the distribution of furrow width according to water depth for those features with an associated width and bathymetry value (n = 4242). Mean and median width increase with increasing water depth. The 100 to 150 m bathymetry range contains the greatest number of furrows with widths ≥ 100 m, at 22. A scatter plot of furrow width according to bathymetry is presented in Figure 4.2.9. The linear curve on the graph indicates a slight increase in width as water depth increases.

Table 4.2.3 – Furrow Width Summary According to Water Depth

Water Depth	N	Minimum (m)	Maximum (m)	Mean (m)	Median (m)	Std. Dev	N furrows ≥ 100m
50m - 100m	1506	2	128	23.8	20	15.78	8
100m - 150m	2316	1	208	27.1	23	19.24	22
150m - 200m	378	5	125	30.3	29	15.91	1
200m - 400m	42	8	100	42.1	45	21.07	1

4.2.8 Scour Depth

The depth parameter is perhaps the most important measurement in estimating the minimum trenching depths required for a sub-sea installation. Scour depth is a variant parameter, depending on a number of factors including: size of the gouging ice keel, scour age, amount of infill, bathymetry, physiographic location, and the geotechnical soil conditions. The scour depth parameter represents a measurement that is derived from the acoustic data at some time after the passage of the ice keel. As a result, these values are considered minimum values. For example, upon scouring, some immediate sediment backfill may take place, especially in sandy or silty sediment. Subsequent to this, the scour may become infilled by hydrodynamic reworking, normal sedimentation, bioturbation or by additional scouring by other ice keels. Depth has been recorded for both furrow and pit features and is measured below an interpreted un-scoured seafloor datum.

The histograms displayed in Figure 4.2.10 illustrate the distribution of furrows (top) and pits (bottom) according to depth. The spatial distribution of furrows and pits over the Northeast Grand Banks area are presented in Figures 4.2.11 and 4.2.12 respectively. Each feature has been color coded by depth. For furrows, the deepest features are found in the eastern portion of the Grand Banks, in water depths less than 200 m. Pit features with depths greater than 5 m are more widespread, extending along the north east portion of the survey area and with deep features (greater than 5 m) in each 50 m bathymetry interval.

Of the 5366 furrow features mapped, 2285 (42.6%) have an associated depth value. Scour depth for furrows ranges from 0.1 m to 7.0 m, with a mean depth of 0.88 m. The majority of furrow features have depths less than or equal to 0.5 m. There are 319 furrows (14%) with depth values greater than 1 m and only 2 furrows have a depth greater than 5.0 m.

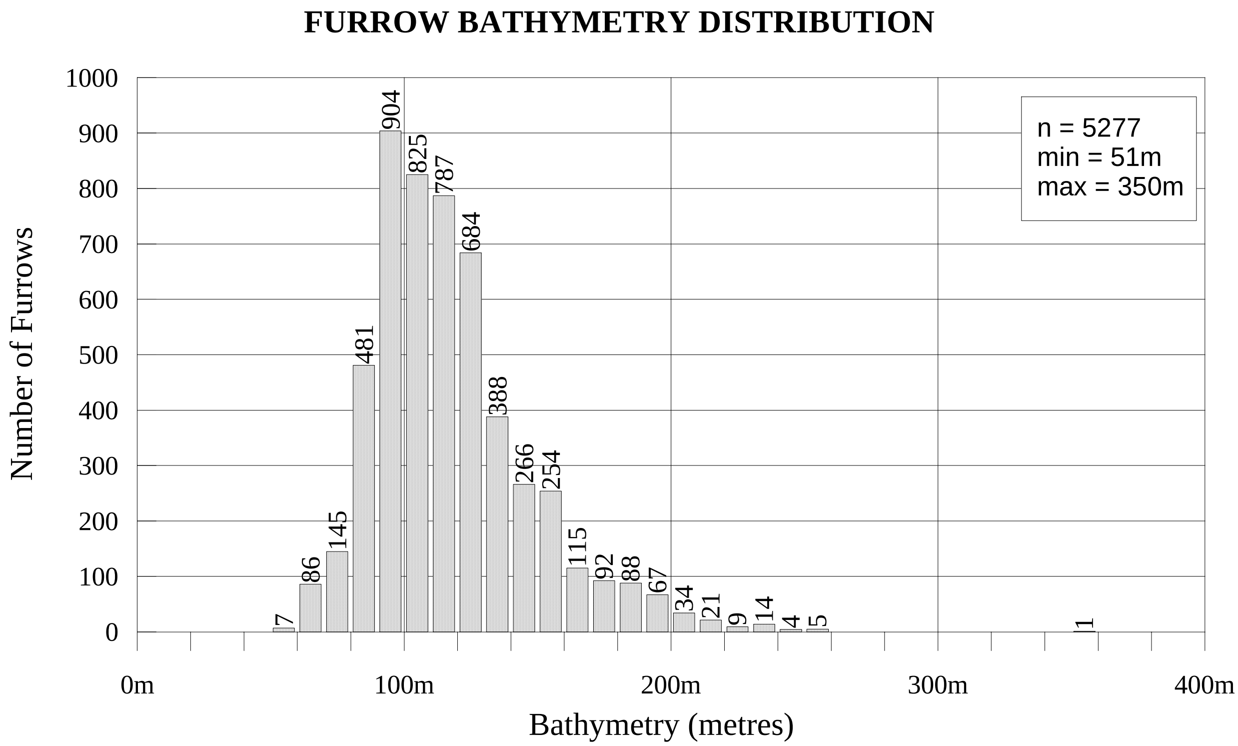
Of the 2680 pit features mapped, 1174 (43.8%) have an associated depth value. Pit features have depth values ranging from 0.1 m to 8.3 m, with a mean of 1.92 m. The majority of pit features (61.9%) have depths between 0.5 – 2.0 m. There are far more deep pits than furrows, with 848 (72.2%) pit features having depths greater than 1 m and 25 pits with a depth greater than 5 m.

Table 4.2.4 presents the distribution of scour depth according to 50 m water depth intervals. The deepest furrow (7 m) occurs at 154 m water depth and was mapped from Huntec data acquired during Cruise 80-010. The water depth interval with the greatest number of furrow depths ≥ 2.0 m is between 150 and 200 m (n= 87). The deepest pit (8.3 m) occurs at 110 m water depth and was mapped from multibeam data acquired during Cruise 98-024. The greatest amount of pits with depth depths ≥ 2.0 m occurs within the 150 to 200 m water depth interval (n=281). The mean depth for both furrows and pits increases with increasing water depth from 50 to 200 m. Scatterplots illustrating the relationship of depth vs bathymetry are presented in Figure 4.2.13 for furrows and pits. The linear curves on the graphs indicate an increase in depth as water depth increases.

Table 4.2.4 – Scour Depth Summary According to Water Depth

FURROWS							
Water Depth	N	Minimum (m)	Maximum (m)	Mean (m)	Median (m)	Std. Dev.	N furrows ≥ 2.0 m
50m - 100m	591	0.1	3	0.53	0.5	0.35	9
100m - 150m	1266	0.1	3.5	0.57	0.5	0.41	35
150m - 200m	364	0.3	7	1.41	1	0.97	87
200m - 400m	60	0.5	2.6	1.19	1	0.52	5
PITS							
Water Depth	N	Minimum (m)	Maximum (m)	Mean (m)	Median (m)	Std. Dev.	N pits ≥ 2.0 m
50m - 100m	60	0.3	7	1.37	1	1.31	11
100m - 150m	328	0.1	8.3	1.31	1	1.09	61
150m - 200m	465	0.5	8	2.26	2	1.18	281
200m - 400m	321	0.5	8	2.15	2	1.14	184

A scatter plot showing the relationship between furrow width and depth is presented in Figure 4.2.14. Each symbol represents an individual scour. The linear curve representing this population indicates a slight increase in depth as incision width increases.



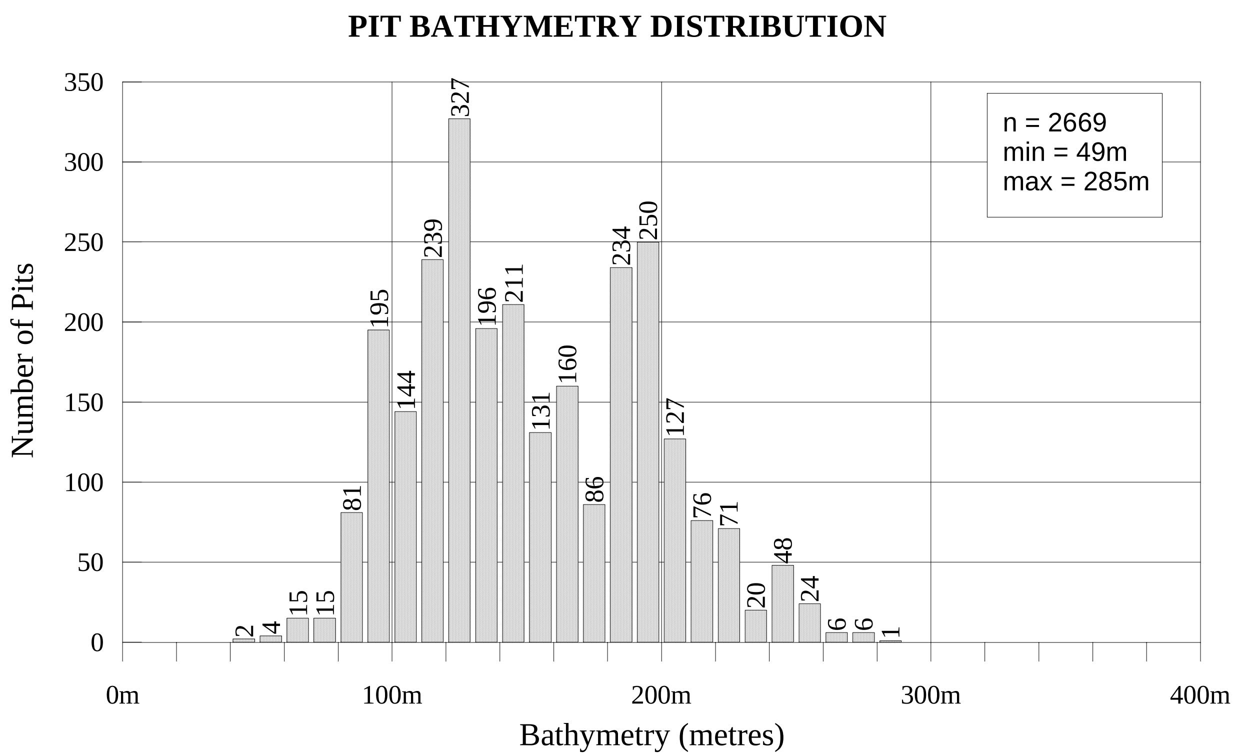
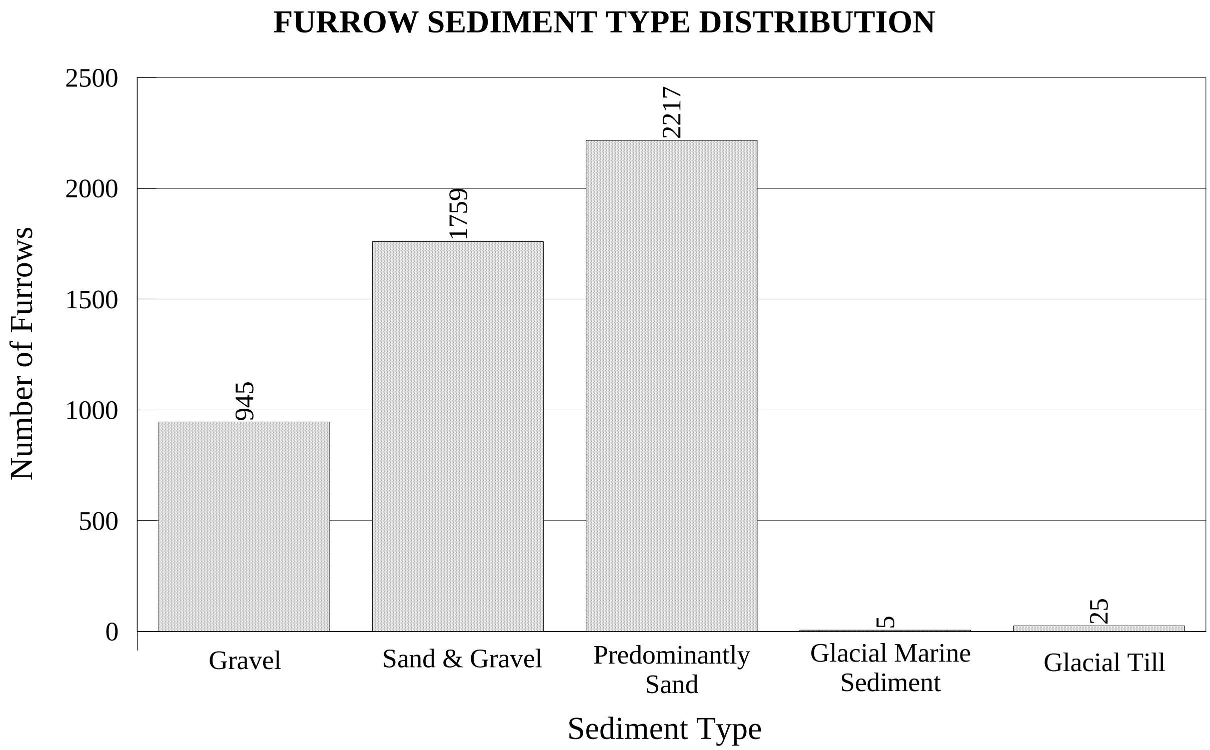


Figure 4.2.1 - Histograms showing the distribution of furrows (n = 5277) and pits (n = 2669) by bathymetry, binned in 10 m intervals, for all scours with an associated water depth



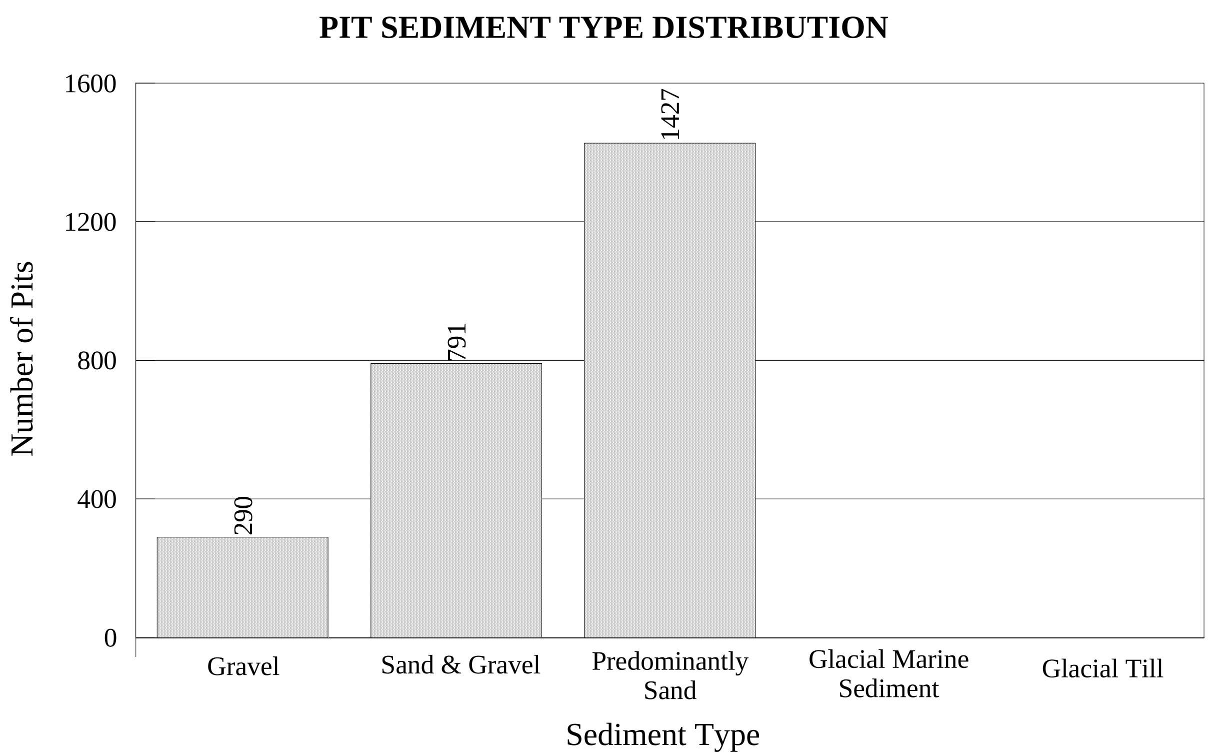


Figure 4.2.2 - Histograms showing the distribution of furrows (n = 5277) and pits (n = 2669) according to Sediment Type, for those scours with an assigned Sediment Type.

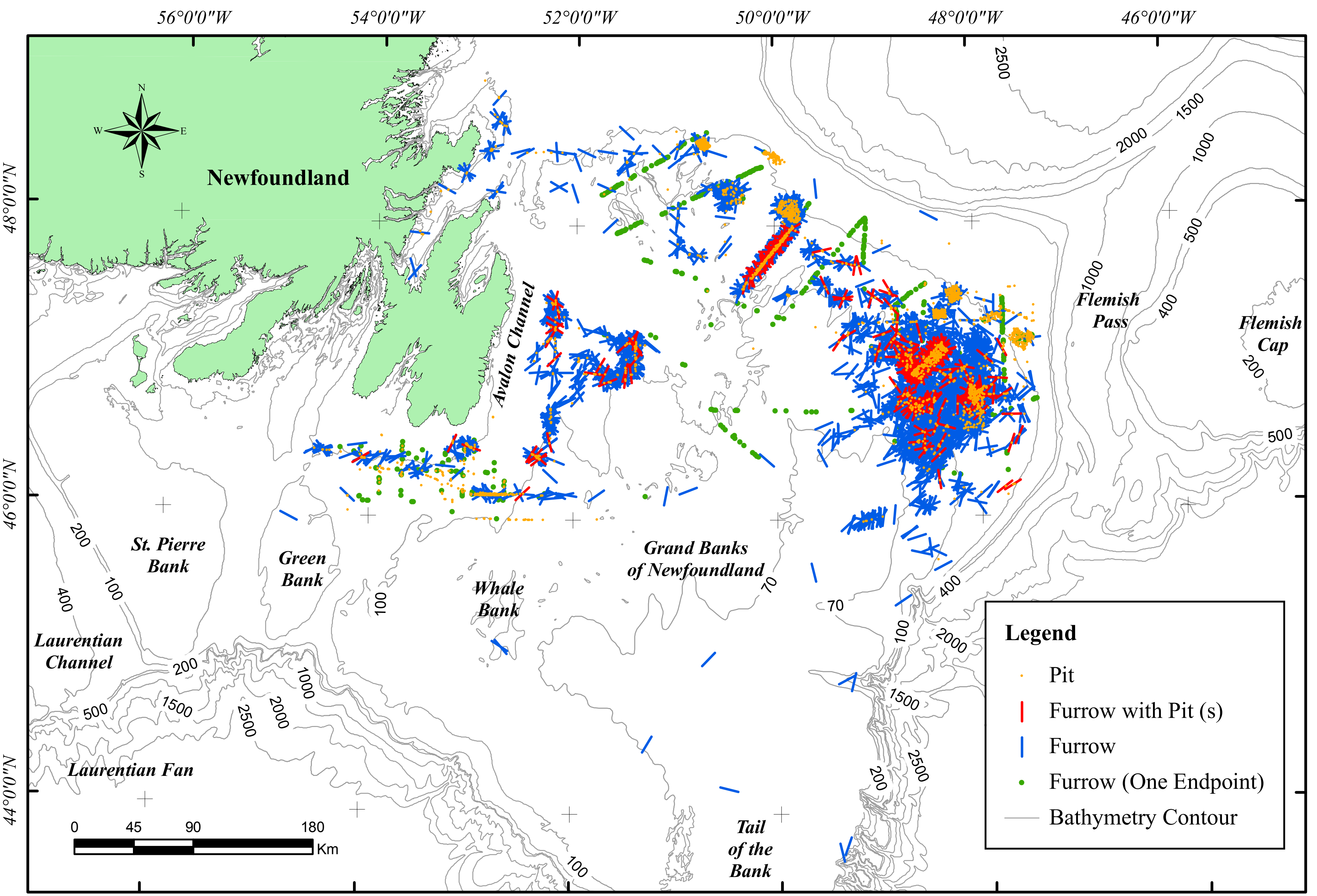
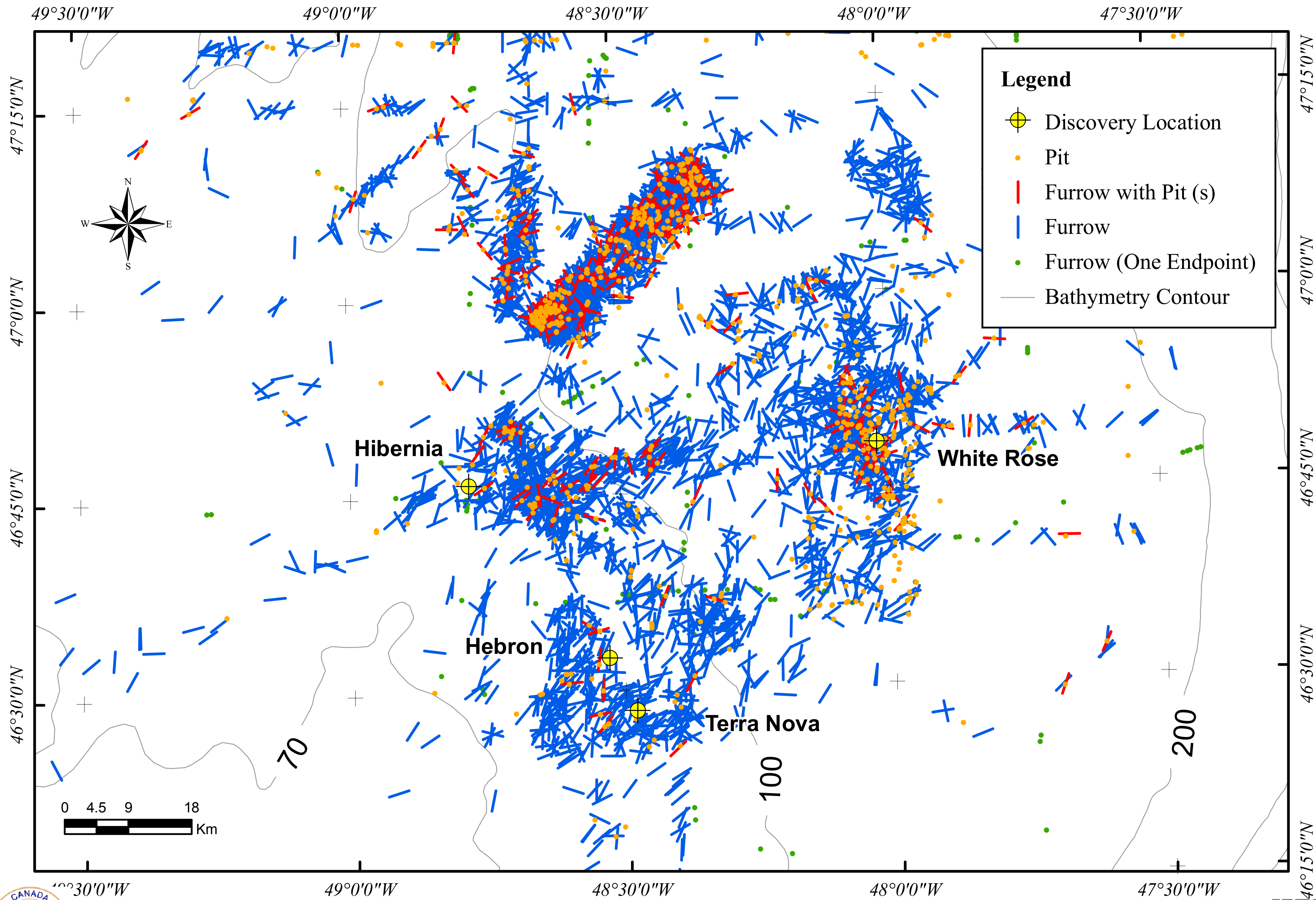


Figure 4.2.3 - Spatial Distribution of Scours according to Type.



4.2.4 - Spatial Distribution of Scours according to Type, over the Northeast Grand Banks.

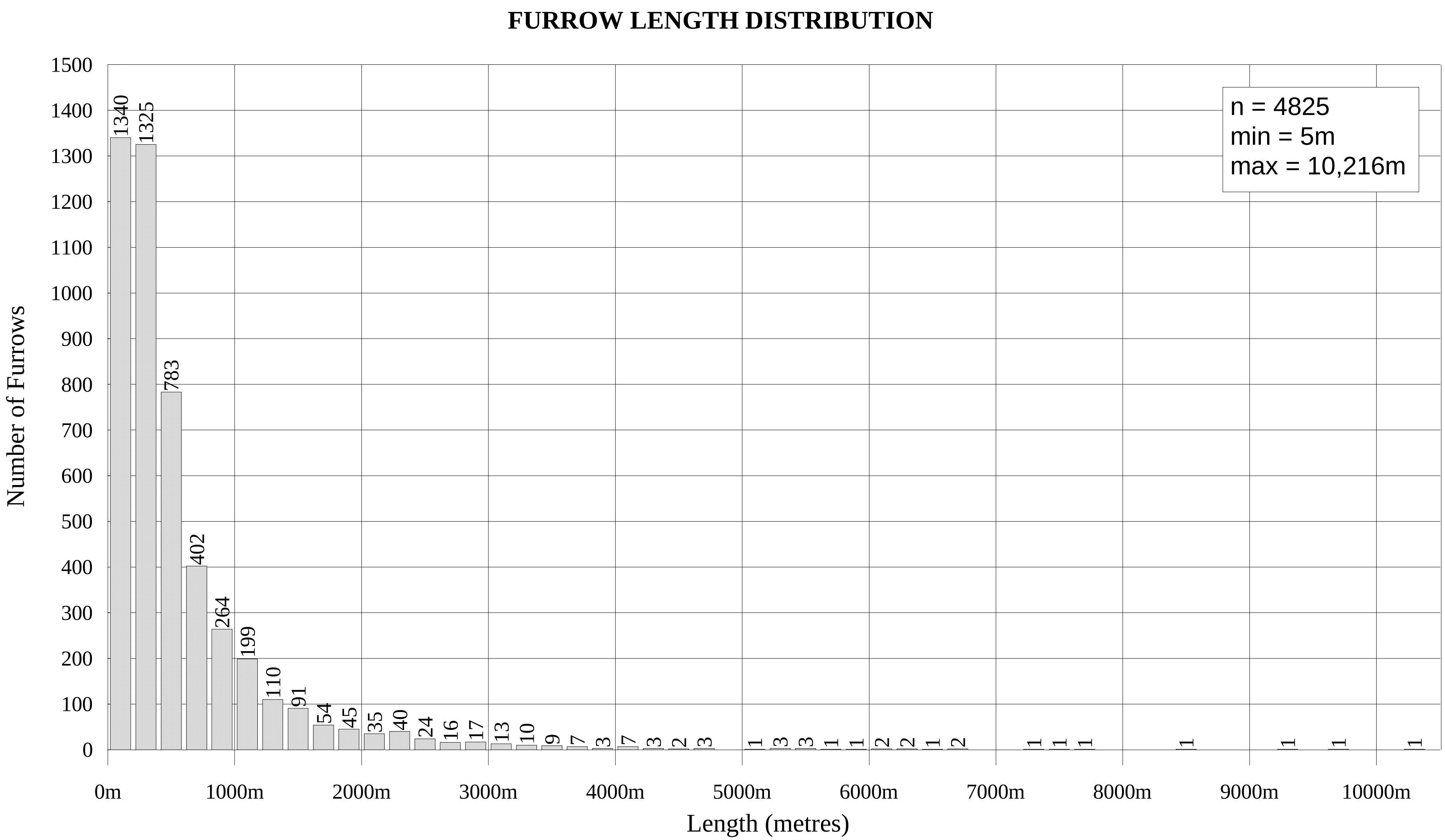


Figure 4.2.5 - Histogram illustrating the distribution of furrows according to length, binned in 200m intervals (n = 4825).

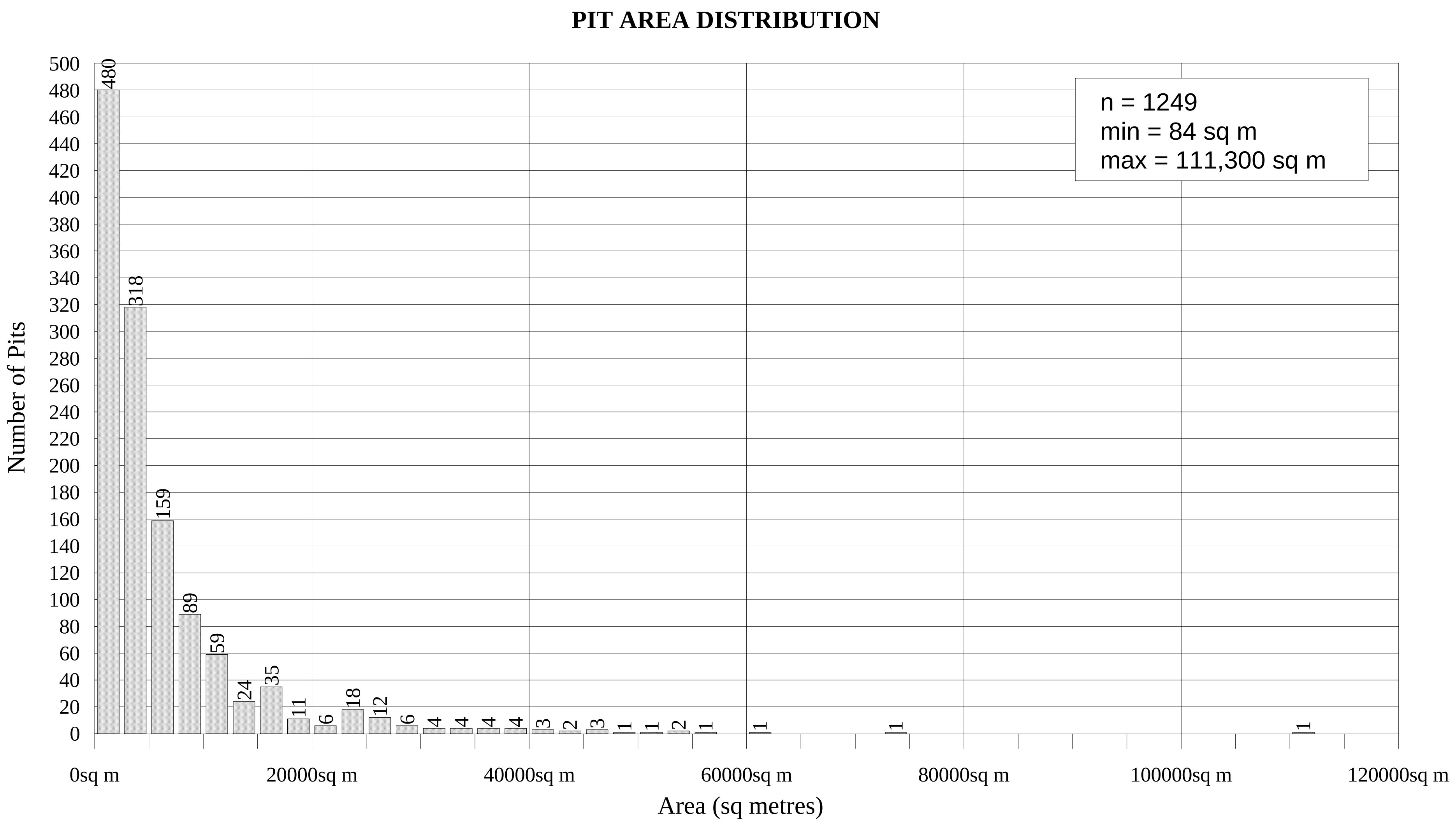


Figure 4.2.6 - Histogram showing the distribution of pit events according to area, binned in 2500 sq m intervals (n = 1249).

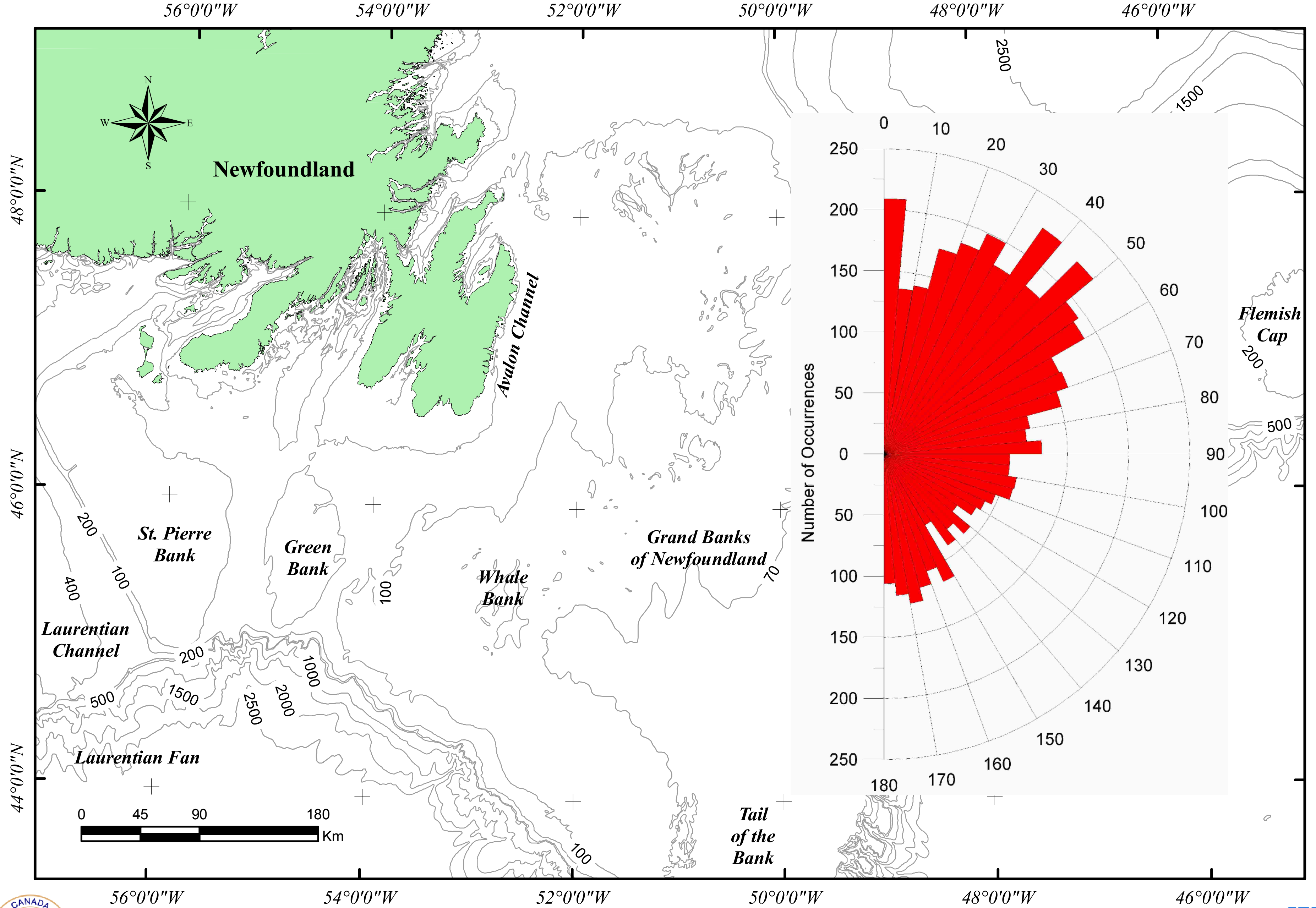


Figure 4.2.7 - Distribution of furrows according to orientation (n = 4847).

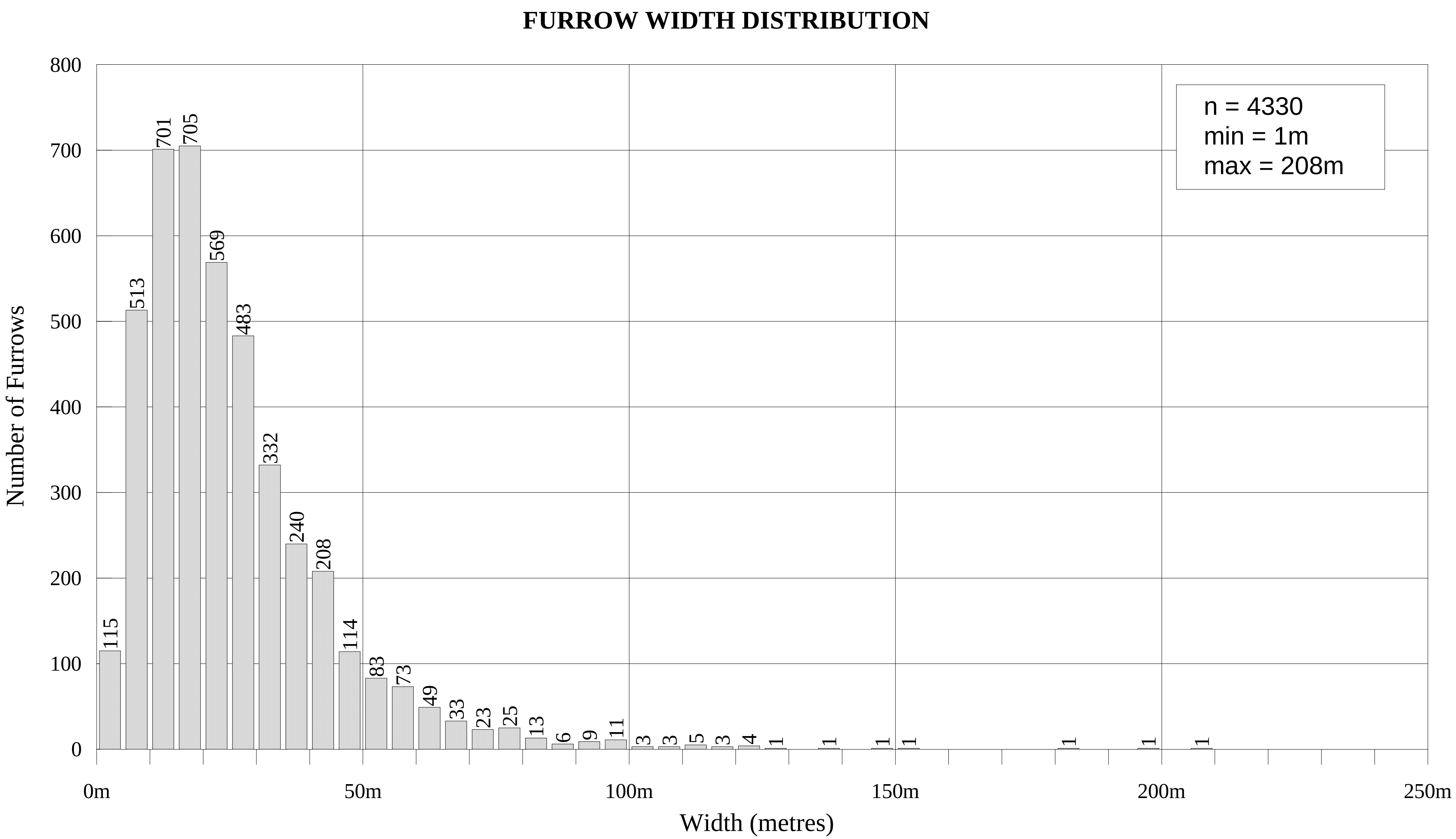


Figure 4.2.8 - Histogram showing the distribution of furrows according to width, binned in 5m intervals, for furrows with an associated width measurement (n = 4330).

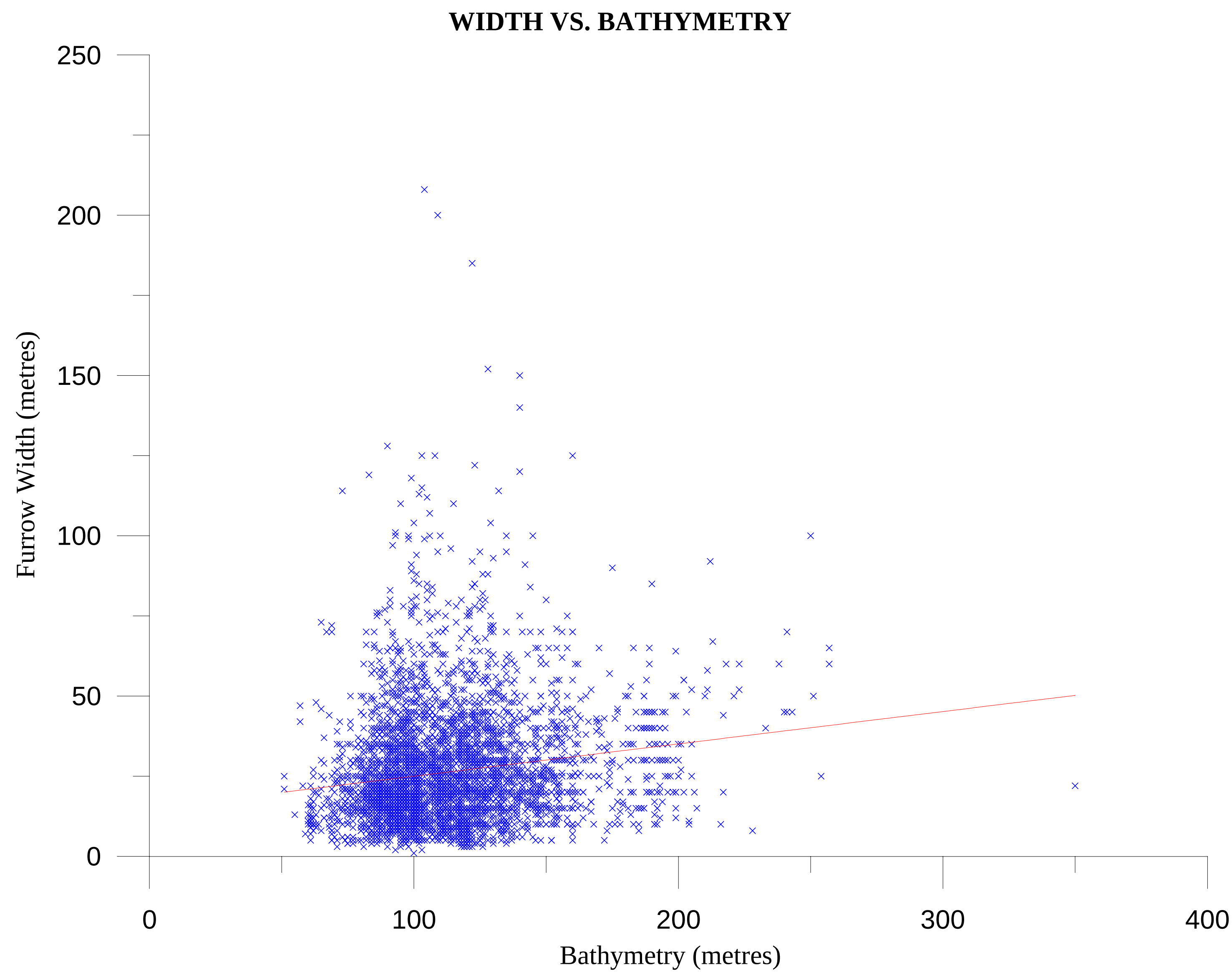
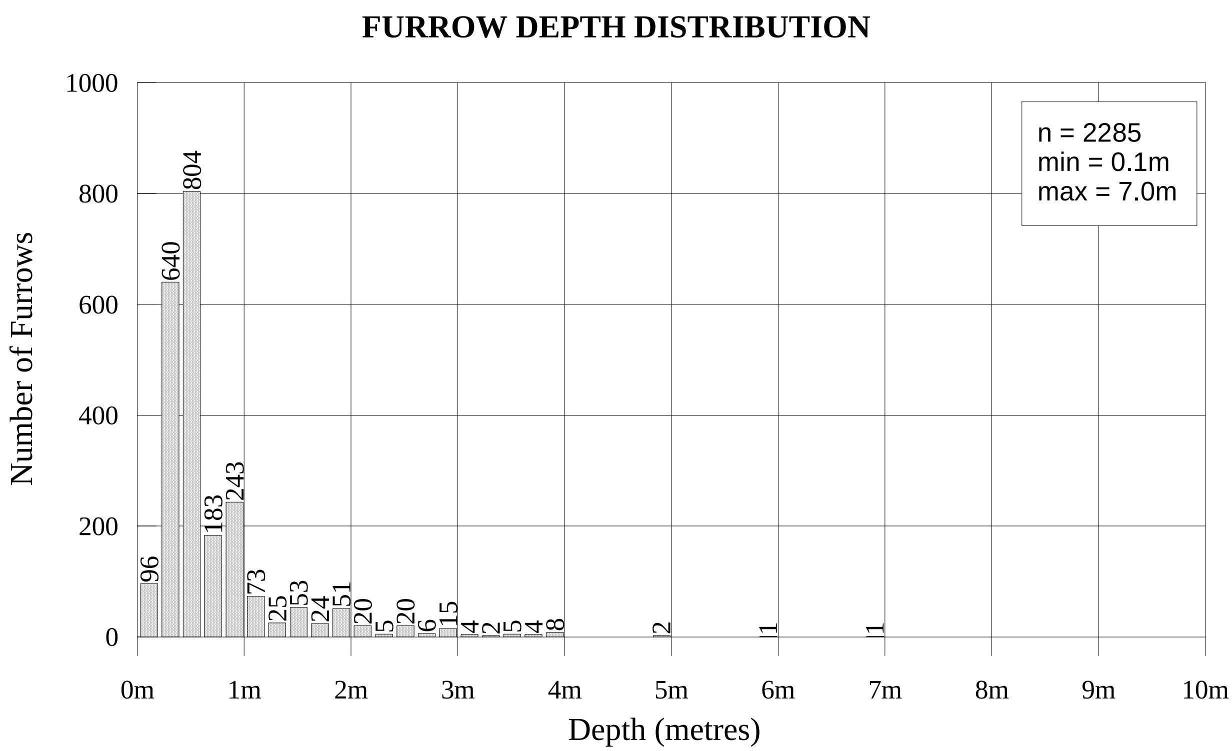


Figure 4.2.9 - Scatterplot showing the relationship between furrow width and bathymetry, n = 4242.



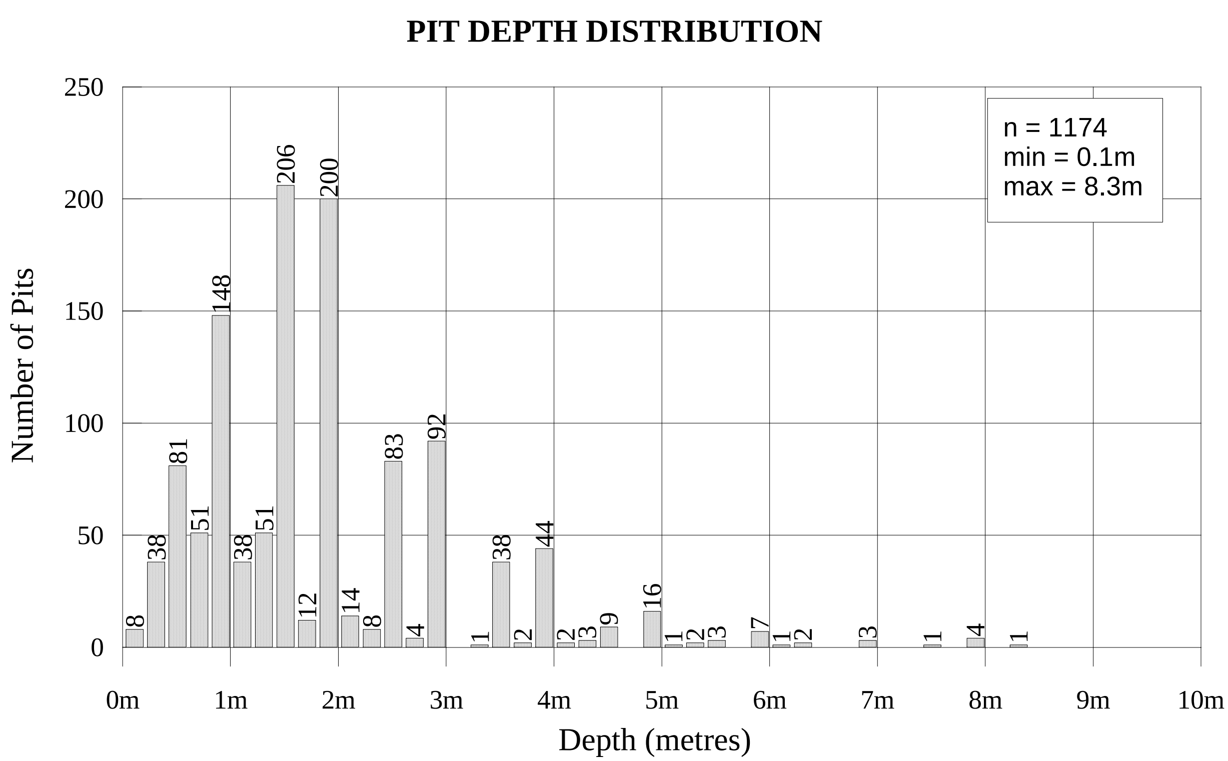
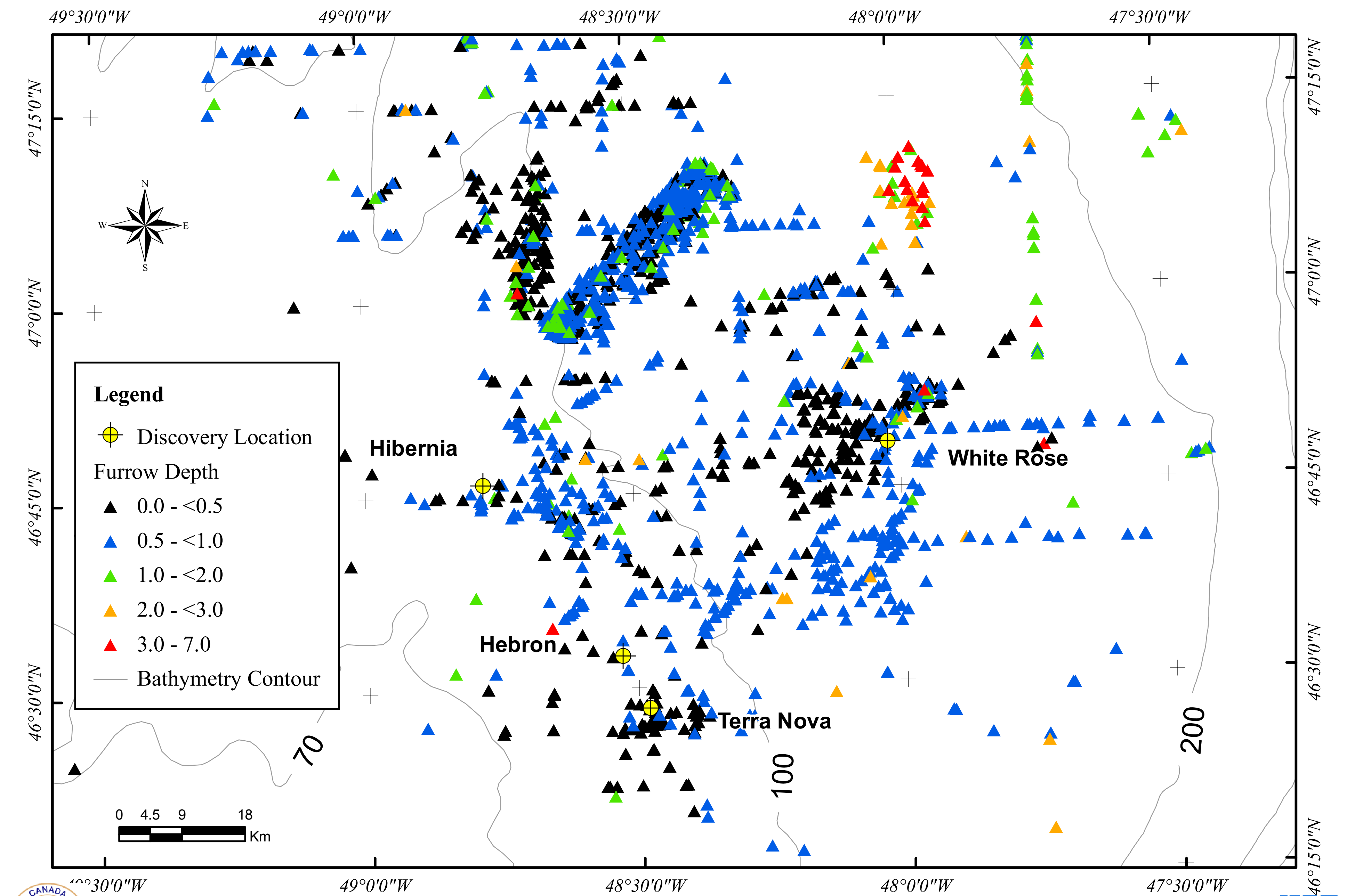
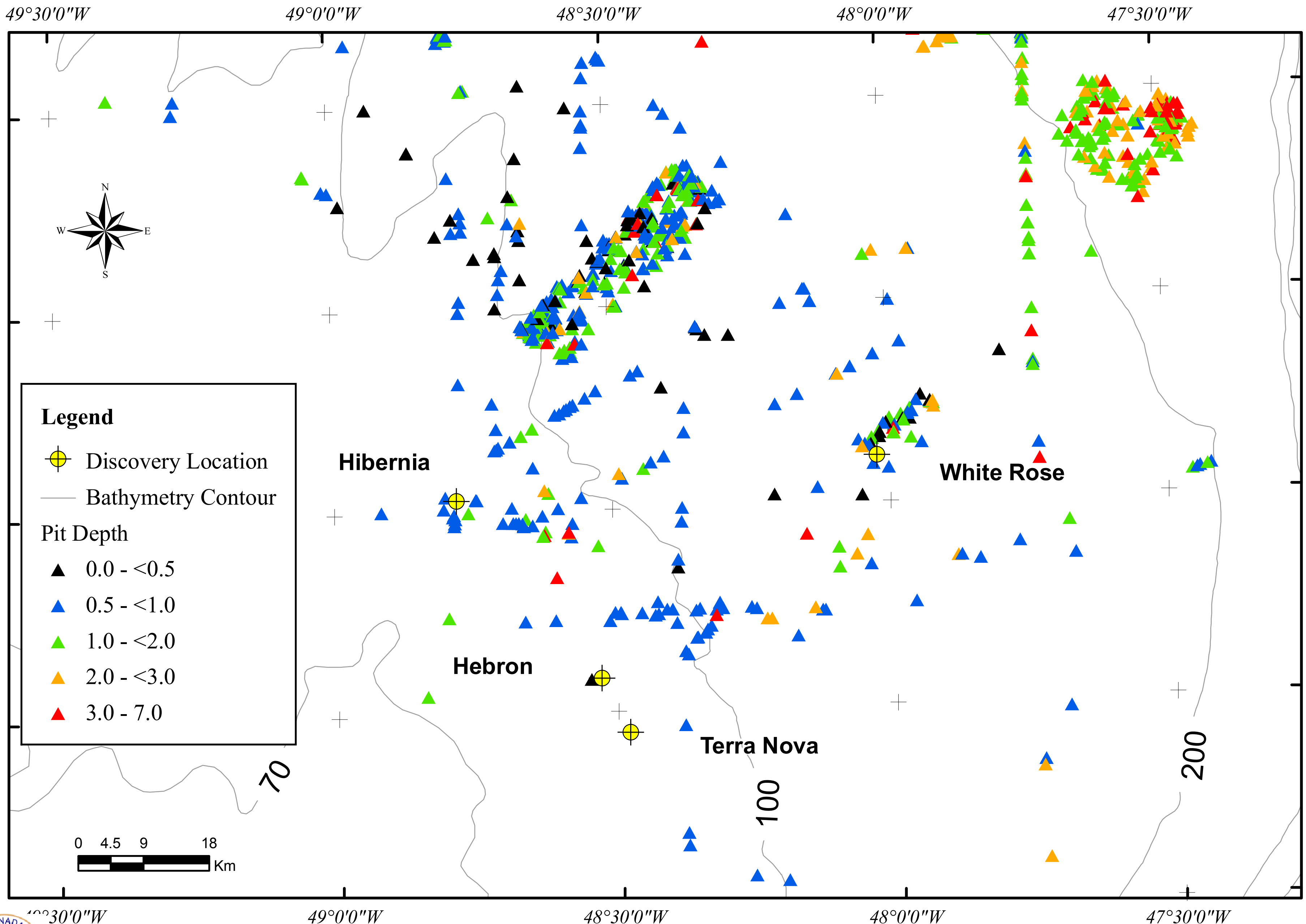


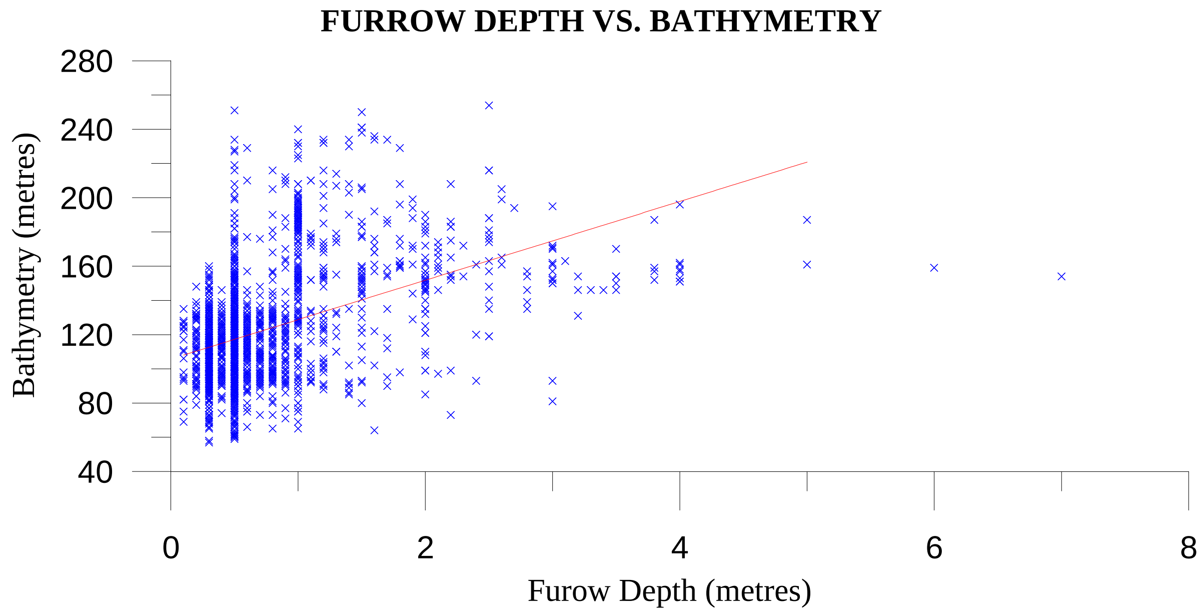
Figure 4.2.10 - Histograms showing the distribution of furrows (n = 2285) and pits (n = 1174) by depth, binned in 0.2 m intervals, for those features with a recorded depth.



4.2.11 - Spatial Distribution of Furrows according to Depth, over the Northeast Grand Banks.



4.2.12 - Spatial Distribution of Pits according to Depth, over the Northeast Grand Banks.



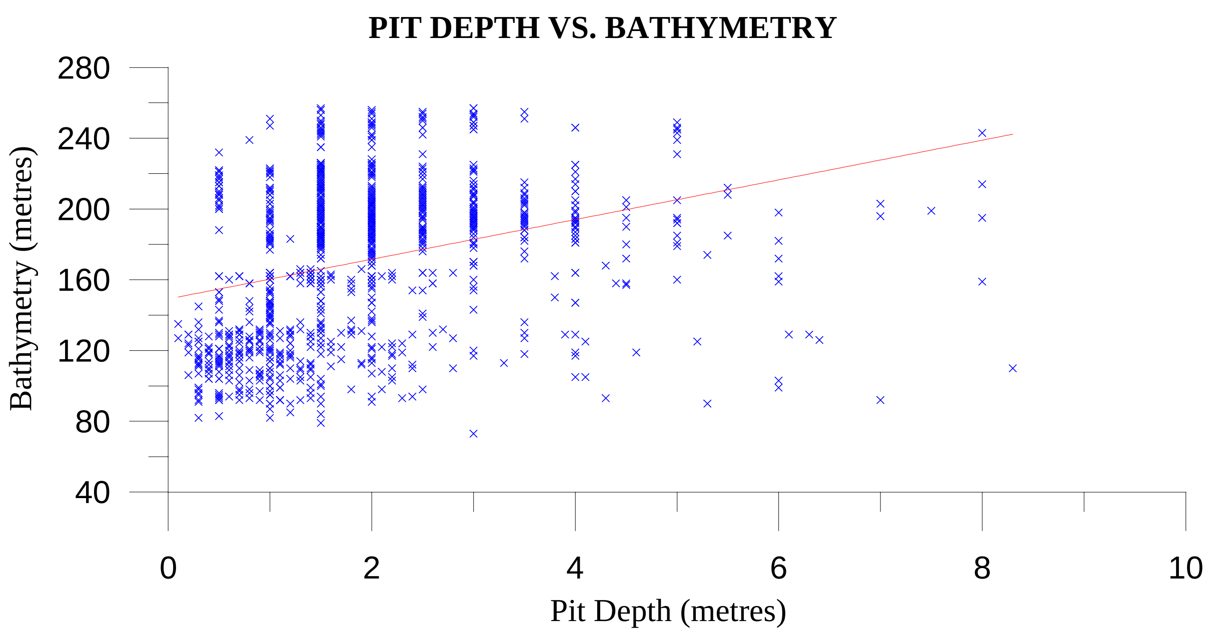


Figure 4.2.13 - Scatterplots showing the relationship between depth vs. bathymetry for the population of furrows (n = 2285) and pits (n = 1174).

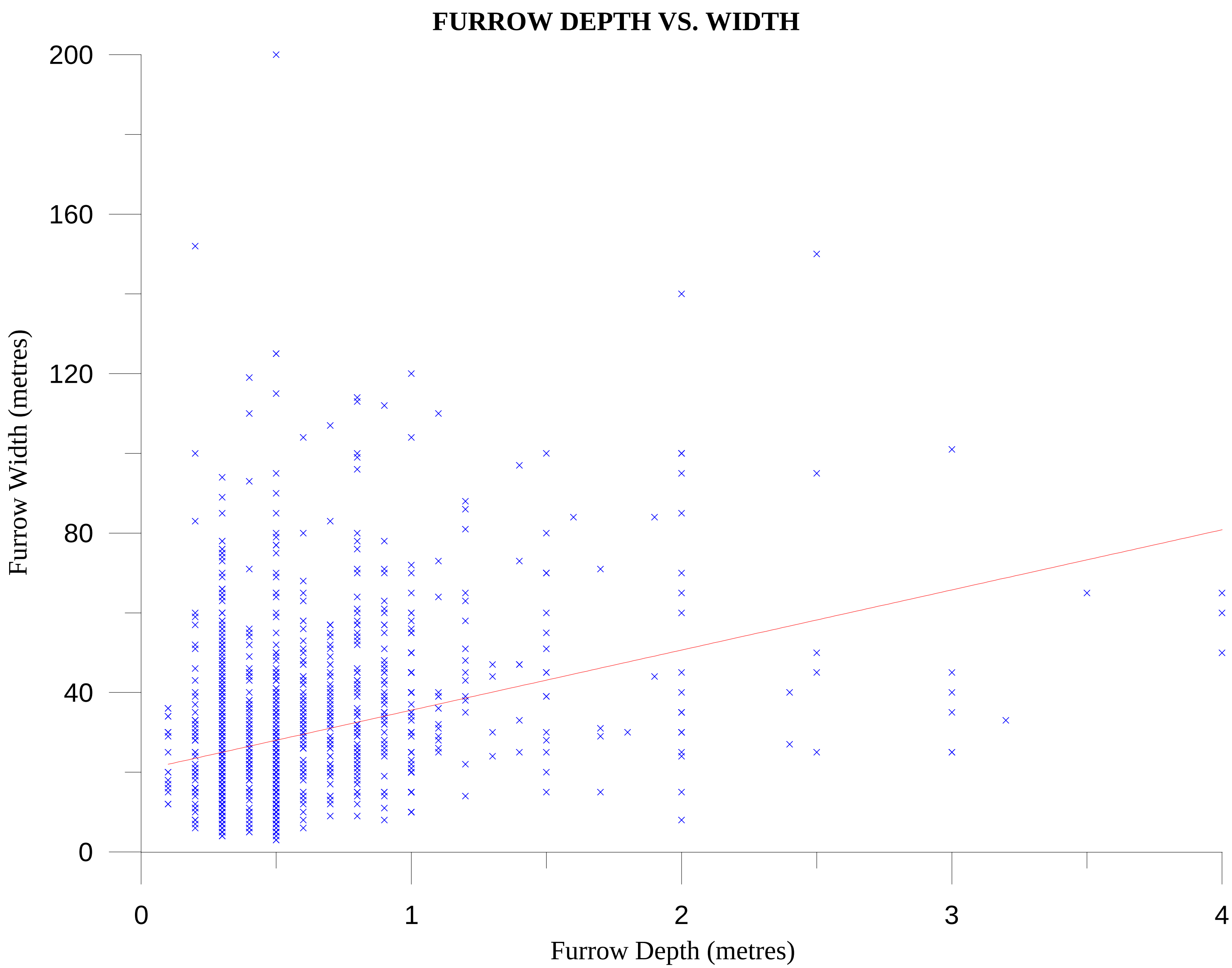


Figure 4.2.14 - Scatterplot showing the relationship between furrow depth and width (n = 1675)

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APPENDIX I

GRAND BANKS SCOUR CATALOGUE (GBSC) GEODATABASE REFERENCE FEATURE CLASS FIELD DESCRIPTIONS

REFERENCE FEATURE CLASSES

This appendix describes the structure and content for the Grand Bank Scour Catalogue Geodatabase Feature Classes; WELL_LOCATIONS, BATHYMETRY, NEWFOUNDLAND. The following tables list the structure and give a brief description of the attribute fields within each Feature Class.

Feature Class	Feature Class Type	Number of Data Records
WELL_LOCATIONS	Point	357
BATHYMETRY	Line	5213
NEWFOUNDLAND	Polygon	1487

WELL_LOCATIONS

WELL_LOCATIONS was provided by the GSC as an ASCII file and includes the locations of exploration and production wells across the Grand Banks.

Field	Field Name	Description	Type	Length	Precision	Scale
1	WELL_NAME	Well Name Identifier	Text	254	0	0
2	LAT_DD	Latitude of Well Location (Decimal Degrees)	Double	8	8	6
3	LONG_DD	Longitude of Well Location (Decimal Degrees)	Double	8	8	6

BATHYMETRY

The BATHYMETRY Feature Class was provided by the GSC in DXF format and includes the Marine Atlas regional bathymetry contours of the area.

Field	Field Name	Description	Type	Length	Precision	Scale
1	BATHYMETRY	Bathymetry in metres	Short	4	0	0

NEWFOUNDLAND

The NEWFOUNDLAND Feature Class represents the coastline of the island of Newfoundland.

APPENDIX II

GRAND BANKS SCOUR CATALOGUE (GBSC) GEODATABASE SURVEY FEATURE CLASS FIELD DESCRIPTIONS

SURVEY FEATURE CLASSES

This appendix describes the structure and content for the Grand Bank Scour Catalogue Geodatabase Feature Classes; NAVBASE_SURVEY_LINES, GBSC_SITE_SURVEYS, and GBSC_SURVEY_EXTENT. The following tables list the structure and give a brief description of the attribute fields within each Feature Class. Each field is then described in detail.

Feature Class	Feature Class Type	Number of Data Records
NAVBASE_SURVEY_LINES	Line	367
GBSC_SITE_SURVEYS	Polygon	41
GBSC_SURVEY_EXTENT	Polygon	1

NAVBASE_SURVEY_LINES

NAVBASE_SURVEY_LINES was compiled from the point navigation Database NAVBASE. This Feature Class represents the regional survey lines reviewed during the GBSC compilation and 1999-2004 update.

Field	Field Name	Description	Type	Length	Precision	Scale
1	CRUISE	Cruise Identifier	Text	30	0	0
2	LINE	Survey Line Identifier	Text	20	0	0
3	S_DAYHHMM	Start of Line Day, Hour, Minute	Long	8	0	0
4	E_DAYHHMM	End of Line Day, Hour, Minute	Long	8	0	0
5	EFF_SWATH	Effective Swath Width (metres)	Short	2	0	0
6	LENGTH	Survey Line Length (metres)	Long	13	12	3

1) FIELD NAME: CRUISE — UNIQUE CRUISE IDENTIFIER

This field identifies the regional survey from which the scour was interpreted.

CRUISE	Number of Survey Lines
2001-038	8
2003-033	16
80-010	18
8000	53
81-012	7
82-039	3
83-033	13
84-024	5

CRUISE	Number of Survey Lines
85-005	4
85-057	1
86-017	7
86-018	14
87-014	7
88-108	22
89-006	23
90-021	28
94-021	23
98-034	26
99-031	38
Geonautics_Dapollonia-1982	24
Hibernia_Pipeline-1983	25
Hibernia_Pipeline_South-1980	2

2) FIELD NAME: LINE **SURVEY LINE IDENTIFIER**

This field identifies the survey line number assigned during the survey or during the compilation of NAVBASE.

3) FIELD NAME: S_DAYHHMM **START OF LINE**

This field identifies the start time of the survey line in Julian Day, Hour and Minute.

4) FIELD NAME: E_DAYHHMM **END OF LINE**

This field identifies the end time of the survey line in Julian Day, Hour and Minute.

5) FIELD NAME: EFF_SWATH **SURVEY SWATH**

This field includes the effective swath of the sidescan sonar system in metres. This value represents the outer sidescan range limit, which could be effectively used by the interpreter to identify and measure scours. This field was used to create the polygon representing the area surveyed along the regional survey lines within Feature Class GBSC_SURVEY_EXTENT

6) FIELD NAME: LENGTH **SURVEY LINE LENGTH**

The field records survey line length in metres.

GBSC_SITE_SURVEYS

GBSC_SITE_SURVEYS Feature Class includes polygons that represent the extent of each industry and GSC site survey.

Field	Field Name	Description	Type	Length	Precision	Scale
1	OPERATOR	Site or Government Operator	Text	12	0	0
2	SURVEYOR	Surveyor	Text	12	0	0
3	SURVEY_YR	Survey Year	Short	4	0	0
4	GBSCCRUISE	Cruise Identifier	Text	50	0	0
5	SITE_NAME	Survey Site Name	Text	40	0	0
6	SUBBOTTOM	Sub-bottom System	Text	12	0	0
7	SIDESCAN	Sidescan Sonar System	Text	12	0	0
8	AREA_KM	Area Surveyed (km^2)	Double	11	10	3

1) FIELD NAME: OPERATOR — INDUSTRY OR GOVERNMENT

This field provides a reference name for each major data set. It refers to the company or government organization for which the survey was performed.

- Amoco
- Chevron
- Husky
- Husky/BV
- Mobil
- Petro-CanadaGSCA (Geological Survey of Canada, Atlantic)

2) FIELD NAME: SURVEYOR — SURVEY FIRM

This field refers to the survey company that performed the survey and or reported on the data collected.

3) FIELD NAME: SURVEY_YR — SURVEY YEAR

This field defines the year of data acquisition.

4) FIELD NAME: GBSCCRUISE — CRUISE IDENTIFIER

This field identifies the corresponding GBSC Cruise identifier.

5) FIELD NAME: SITE_NAME **SURVEY SITE NAME**
This field contains the survey site name.

6) FIELD NAME: SUBBOTTOM **SUB-BOTTOM SYSTEM**
This field contains the sub-bottom profiler system utilized during the survey.

7) FIELD NAME: SIDESCAN **SIDESCAN SONAR SYSTEM**
This field contains the sidescan sonar system utilized during the survey.

8) FIELD NAME: AREA_KM **AREA SURVEYED**
This field includes the seafloor area surveyed in square kilometres.

GBSC_SURVEY_EXTENT

GBSC_SURVEY_EXTENT Feature Class was compiled from NAVBASE_SURVEY_LINES and GBSC_SITE_SURVEYS. It includes one complete polygon that represents the entire extent of seabed surveyed.

Field	Field Name	Description	Type	Length	Precision	Scale
2	AREA_KM	Area Surveyed (km^2)	Double	11	10	3

1) FIELD NAME: AREA_KM **AREA SURVEYED**
This field includes the seafloor area surveyed in square kilometres.

APPENDIX III

GRAND BANKS SCOUR CATALOGUE (GBSC) GEODATABASE ICEBERG SCOUR FEATURE CLASS FIELD DESCRIPTIONS

ICEBERG SCOUR FEATURE CLASSES

This appendix describes the structure and content for the Grand Bank Scour Catalogue Geodatabase Feature Classes; GBSC_Furrows, GBSC_Furrows_with_Pits, GBSC_Pits, and GBSC_Furrows_OneEndPoint. The following table lists the structure and gives a brief description of the attribute fields. Not all of the attribute fields are present in each of the Feature Classes. Each field is then described in detail including documentation of any conversions made from the original GBSC segmented database.

Feature Class	Feature Class Type	Number of Records
GBSC_FURROWS	Line	4405
GBSC_FURROWS_WITH_PITS	Line	344
GBSC_FURROWS_ONEENDPOINT	Point	617
GBSC_PITS	Point	2680

Field	Field Name	Description	Type	Length	Precision	Scale
1	SCOUR_ID	Unique Scour Identifier	Long	6	6	0
2	SOURCE	Data Source	Short	2	2	0
3	CRUISE	Cruise Identifier	Text	50	0	0
4	BATHYMETRY	Bathymetry (metres)	Short	4	4	0
5	WD_VAR	Water Depth Variation	Short	2	2	0
6	TYPE	Furrow/Pit Type	Text	25	0	0
7	SBP	Profiling System	Text	35	0	0
8	DEPTH	Furrow/Pit Depth (metres)	Float	5	4	1
9	DEPTH_Q	Depth Qualifier	Short	2	2	0
10	WIDTH	Furrow/Pit Width (metres)	Long	6	6	0
11	LENGTH	Furrow/Pit Length - (metres)	Long	6	6	0
12	LENGTH_Q	Length-Endpoint Qualifier	Short	2	2	0
13	ORIENT	Furrow/Pit Orientation	Short	4	4	0
14	BERM_HT	Furrow/Pit Berm Height (metres)	Float	5	4	1
15	PROFILE	Profile Type	Text	1	1	0
16	SYSTEM	Sidescan/Multibeam System	Text	25	0	0
17	QUALITY	Data Quality	Short	2	2	0
18	CLARITY	Furrow/Pit Clarity	Short	2	2	0
19	BERM_DEV	Berm Development	Short	2	2	0
20	SED_TYPE	Sediment Type	Short	2	2	0
21	COMMENT	Interpreter Comments	Text	254	0	0
22	PIT_ID	Pit Identification Number	Long	8	8	0

1) FIELD NAME: SCOUR_ID **Unique Scour Event Identifier**

A unique numeric identifier was assigned to each furrow, pit or furrow/pit event. Within the original segmented GBSC a scour may contain more than one segment; each segment had the same scour identification number. A summary of all Scour ids are presented below. Scour_id may not be continuous due to removal of duplicates during this project.

• GBSC scour events prior to GBSC 1999-2004 Revisions	1 to 4894
• East Flying Foam - 1996	4895 to 5091
• 88-108, 90-021, 96-011, Husky88 (White Rose)	5092 to 5186
• South Nautilus - 1998	5187 to 5279
• 94-021 (ESRF 4000)	5280 to 5471
• 98-024 (Baseline)	5472 to 6146 & 7008 to 7343
• White Rose - A17, L08, N-30 (1998 & 1999)	6147 to 6365
• 98-034, 99-031 (White Rose)	6366 to 6418
• Hebron - Brents Cove - 1999	6419 to 6750
• 99-031 (RepMap)	6751 to 7007
• 2003-033	7344 to 7723
• 99-031 (Regional Lines)	7724 to 7877
• 98-034 (Regional Lines)	7878 to 8134
• 2001-038	8135 to 8173

Pits stored in the GBSC_PITS Feature Class can be related or joined to their associated Furrows within the GBSC_FURROWS_WITH_PITS Feature Class through the SCOUR_ID field.

2) FIELD NAME: SOURCE Original Data Source

This field identifies the original database or geophysical data source. The following table describes each source and associated codes.

SOURCE	DESCRIPTION	Number of Records (Feature Class)			
		GBSC Furrows	GBSC Furrows With Pits	GBSC Furrows OneEndPoint	GBSC Pits
1	POST-1984 Regional GSCA Cruises (Regional Survey Lines)	1578	139		707
2	GSCA Site Specific Surveys (100% seafloor coverage)	889	124		299
3	POST-1984 Industry Wellsite Hazard Surveys (100% seafloor coverage)	744	60		140
4	ESRF 4000 Series (Regional Survey Lines, locally 75% coverage)	389	21		40
5	GSCA Cruise 89006	99			77
6	MOBIL - Regional Lines (Original)	3		459	26
7	MOBIL - Regional Lines (Update)	30		123	284
8	MOBIL - Wellsite Surveys	673		35	1107
	Total Records	4405	344	617	2680

The Source codes are the same as those used in the original GBSC segment database.

3) FIELD NAME: CRUISE — Unique Cruise Identifier

This field identifies the regional or site survey from which the scour was interpreted. Additional identifiers were assigned to GSCA cruises where data were collected over a specific area.

CRUISE	DESCRIPTION	Number of Records (Feature Class)			
		GBSC Furrows	GBSC Furrows With Pits	GBSC Furrows OneEndPoint	GBSC Pits
Unknown Survey††	Unknown Survey	1		1	
4000	4000 Series (Mobil, 1979)				
8000*	8000 Series (1980)	3		44	6
2001-038	Hudson 2001-038	32	2		7
2003-033	Hudson 2003-033	277	21		107
80-010	Hudson 80-010			415	20
81-012	Baffin 81-012			26	3
82-039	Baffin 82-039			3	
83-033	Hudson 83-033			8	2
84-024	Hudson 84-024	42	6		52
85-005	Hudson 85-005	50	2		8
85-057	Pandora II 85-057	39			2
86-017	Hudson 86-017	59	2		47
86-018	Hudson 86-018	153	8		39
87-014	Hudson 87-014	24			
87-014_GBS	Hudson 87-014	6			
88-108	Needler 88-108	286	16		70
88-108_White_Rose	Needler 88-108	1			
89-006	Dawson 89-006	99			77
90-021	Dawson 90-021	395	14		40
90-021_White_Rose	Dawson 90-021	12			
94-021_4000	Hudson 94-021	165	21		24
94-021_Terra_Nova	Hudson 94-021	32			
96-011_White_Rose	Matthew 96-011	17	1		36
98-024_Baseline	Matthew 98-024	804	123		261
98-034	Hudson 98-034	189	8		68
98-034_White_Rose	Hudson 98-034	23	4		12
99-031	Hudson 99-031	80	10		87
99-031_RepMap	Hudson 99-031	127	44		181
99-031_White_Rose	Hudson 99-031	14	2		3
Archer_Flank-1982	Mobil Wellsite Survey	109		1	89

CRUISE	DESCRIPTION	Number of Records (Feature Class)			
		GBSC Furrows	GBSC Furrows With Pits	GBSC Furrows OneEndPoint	GBSC Pits
Ben_Nevis-1979	Mobil Wellsite Survey	2		1	
Bonanza -1982	Mobil Wellsite Survey	12			139
Burin_Bonne_Bay-1985	Husky/BV Wellsite Survey	16			
Cumberland-1980 (J-87)	Mobil Wellsite Survey	1		1	82
Dana_North_South-1980	Mobil Wellsite Survey	2		12	158
Dominion-1982	Mobil Wellsite Survey	14			129
East_Flying_Foam-1996	Amoco Wellsite Survey	169	17		30
Geonautics_Dapollonia-1982	Geonautics\Dapollonia-1982			71	75
Hebron_Brents_Cove-1999	Chevron Wellsite Survey	313	9		14
Hebron-1980	Mobil Wellsite Survey	1		3	
Hibernia_North-1979	Mobil Wellsite Survey	1		2	
Hibernia_Pipeline_South-1980†	Mobil Pipeline Route Survey			5	27
Hibernia_Pipeline-1983	Mobil Pipeline Route Survey	30		10	177
Hibernia-1979 (P-15)	Chevron Wellsite Survey			3	1
Husky88	Husky Oil-M.V. Maersk Placentia	30			2
Linnet-1982	Mobil Wellsite Survey	67		6	43
Mara-1983	Mobil Wellsite Survey	87			7
Nautilus-1980	Mobil Wellsite Survey	5		2	
North_Ben_Nevis_Rev1-1984	Petro-Canada Wellsite Survey	1			
North_Ben_Nevis-1984	Petro-Canada Wellsite Survey	17			4
Ragnar-1980	Mobil Wellsite Survey	2		1	56
Rankin-1980	Mobil Wellsite Survey	14		2	
Saronac-1982	Mobil Wellsite Survey	88			250
South_Brook-1988	Petro-Canada Wellsite Survey	6			3
South_Nautilus-1998	Chevron Wellsite Survey	78	6		15
Tempest_North-1979	Mobil Wellsite Survey	89			
Titus-1983	Mobil Wellsite Survey	6			153
Trave_White_Rose-1979	Mobil Wellsite Survey	79			
Voyager-1983	Mobil Wellsite Survey	5			
West_Hibernia-1980	Mobil Wellsite Survey	8			
White_Rose_A17-1999	Husky Oil Clearance Survey	40	5		15
White_Rose_Flank-1981	Mobil Wellsite Survey	80			
White_Rose_L08-1998	Husky Oil Clearance Survey	20	8		15
White_Rose_N30-1999	Husky Oil Clearance Survey	83	15		44
	Total Records	4405	344	617	2680

† This cruise comprised of two Mobil cruise codes (not described in the Mobil documentation). It was identified as the 1980 C-Core southern route survey by matching scours with digital navigation tracks supplied by GSCA.

†† This code was not described in the Mobil documentation.

* Cruise 8000 includes the 1980 C-Core survey of the Northern Pipeline Route.

The only change to the original GBSC Cruise codes is Cruise 4 has been changed to "Unknown Survey".

4) FIELD NAME: BATHYMETRY   Scour Bathymetry (metres)

This field records water depth in metres at the scour location. Data for GSCA cruises examined by CSR prior to the GBSC 2000 update were obtained from the survey's bathymetric logs, refer to Myers et. al. (1995). During the GBSC (1999-2004) update scour bathymetry was obtained through a spatial join of the GBSC and survey soundings provided by the GSC. Where WD_VAR information exists the bathymetry value represents the minimum water depth along the scour event obtained from the available survey bathymetry contour coverage or multibeam grid file. Where no bathymetry data was available the BATHY field was coded with a -1.

Ice Scour Feature Class	Bathymetry Range (metres)	Number of Records with no Bathymetry (Value = -1)
GBSC_Furrows (n=4405)	51-350	80
GBSC_Furrows_with_Pits (n=344)	51-187	9
GBSC_Furrows_OneEndPoint (n=617)	64-257	0
GBSC_Pits (n=2680)	49-285	11

5) FIELD NAME: WD_VAR   Water Depth Variation along the Scour Event

This field records the difference in minimum and maximum water depths (in metres) recorded along the length of the scour event. The water depth variation value was determined using site specific bathymetry coverages from either single or multibeam echosounders. A null code of 99 indicates water depth variation was not measured.

Ice Scour Feature Class	Water Depth Variation Range (metres)	Number of Records with no Water Depth Variation Recorded (Value = 99)
GBSC_Furrows (n=4405)	0-15	2554
GBSC_Furrows_with_Pits (n=344)	0-13	103
GBSC_Furrows_OneEndPoint (n=617)	-	617
GBSC_Pits (n=2680)	-	2680

6) FIELD NAME: TYPE **Furrow or Pit Type**

This field identifies the furrow or pit type according to the visible characteristics shown on the sidescan sonar or multibeam DTM. The following descriptions were used.

DESCRIPTION	Number of Records (Feature Class)			
	GBSC Furrows	GBSC Furrows With Pits	GBSC Furrows OneEndPoint	GBSC Pits
Linear Furrow	2650		72	
Sinuous Furrow	736		10	
Arcuate Furrow	904		13	
Linear Furrow with Pit (s)		131		
Sinuous Furrow with Pit (s)		128		
Arcuate Furrow with Pit (s)		85		
Pit				2101
Pit Chain				150
Termination Pit				429
Poorly Defined Furrow	115		522	
Total Records	4405	344	617	2680

This field was compiled from the codes stored in the original GBSC segment database fields PLN_S, TYPE and interpreter COMMENTS.

7) FIELD NAME: SBP — Profiling System

This field identifies the type of profiling instrument / system utilized in recording the data from which gouge depth and berm height measurements were taken.

PROFILING SYSTEM	Number of Records (Feature Class)			
	GBSC Furrows	GBSC Furrows with Pits	GBSC Furrows OneEndPoint	GBSC Pits
3.5 kHz	63	2	36	7
Huntec	2241	158	574	1691
Modified KleinSSS	12			
Multibeam Sonar	835	121		296
NSRF V-Fin	276	1	7	522
No System	103	6		26
Single Beam EchoSounder	835	56		131
Unknown	40			7
Total Records	4405	344	617	2680

This field was compiled from the numeric codes stored in the original GBSC segment database field SBP.

8) FIELD NAME: DEPTH **Furrow / Pit Depth (metres)**

This field contains depth measured in metres below an interpreted unscoured seafloor from the available sub-bottom profiling system, single beam echosounder or multibeam sonar system. A depth measured from multibeam data represents the maximum depth of the scour event. A depth measurement from all other profiling systems represent the maximum instantaneous depth of the scour event along the survey transect. The profiler system resolution is used where the interpreter is confident the scour depth is greater than 0 but the depth can not be measured due to data quality/system resolution, see Depth Qualifier field. Depths were measured from the available profiler system records as indicated in the SBP field. Depth of 0 indicates no depth measurement recorded.

For the Feature Classes GBSC_Pits and GBSC_Furrows_OneEndPoint the depth represents the depth recorded in the original GBSC segment database.

For the Feature Class GBSC_Furrows the depth represents the maximum furrow depth recorded along the scour event extracted from the original GBSC segment database. System resolution depth was ignored if one or more scour event segments in the original GBSC contained a measured depth.

For the Feature Class GBSC_Furrows_with_Pits the depth represents the maximum furrow depth recorded along the scour event. The depth of pit features was excluded in the calculation of maximum depth. Pit depths are stored in the GBSC_PITS Feature Class.

Ice Scour Feature Class	**Scour Depth Range (metres)**	**Number of Records with no Depth Recorded (Value = 0)**
GBSC_Furrows (N=4405)	0.1 - 6.0	2865
GBSC_Furrows_with_Pits (n=344)	0.1 - 1.6	178
GBSC_Furrows_OneEndPoint (n=617)	0.3 - 7.0	38
GBSC_Pits (n=2680)	0.1 - 8.3	1506

The following table presents scour depth statistics according to profiler type.

PROFILING SYSTEM	**Scour Depth Range (Feature Class)**			
	GBSC Furrows	GBSC Furrows with Pits	GBSC Furrows OneEndPoint	GBSC Pits
3.5 kHz	0.3 - 1.8	0.6 - 0.7	0.5	0.3 - 0.5
Huntec	0.1 - 3.0	0.1 - 1.5	0.3 - 7.0	0.3 - 8.0
Modified KleinSSS	0.3 - 0.8	-	-	-
Multibeam Sonar	0.1 - 3.2	0.1 - 1.6	-	0.1 - 8.3
NSRF V-Fin	0.5 - 3.0	0.5	0.5 - 1.0	0.8 - 8.0
Single Beam EchoSounder	0.3 - 6.0	0.3 - 1.2	-	0.3 - 2.4

9) FIELD NAME: DEPTH_Q Depth Qualifier

The depth qualifier is used to describe the scour depth measurement or the lack of a depth measurement. The following table describes the associated codes for this field.

DEPTH_Q	DESCRIPTION	Number of Records (Feature Class)			
		GBSC Furrows	GBSC Furrows With Pits	GBSC Furrows OneEndPoint	GBSC Pits
1	Scour depth measured or obtained from report.	785	137	507	1166
2	Confident scour depth is less than the recorded depth (0.3, 0.5 or 1.0 metres).	758	30	72	12
3	Scour depth not measured	2862	177	38	1502
	Total Records	4405	344	617	2680

The Depth_q field in the original GBSC segment database included eight codes.

10) FIELD NAME: WIDTH **Furrow / Pit Width (Metres)**

Scour width is measured in metres from an interpreted berm crest to berm crest perpendicular to the scour orientation. A value of 0 indicates the width was not measured.

For the Feature Classes GBSC_Pits and GBSC_Furrows_OneEndPoint the width measurement represents the average width of the scour segment as measured by the interpreter.

For the Feature Class GBSC_Furrows the width represents the weighted average width of the Furrow event calculated from the original GBSC segment database. The segment width is weighted according to the segment length. Segments with a width of 0 were not included in the weighted average calculation.

For the Feature Class GBSC_Furrows_with_Pits the width represents the weighted average width of the Furrow event calculated from the original GBSC segment database. The segment width is weighted according to the segment length. Pit segments and those with a width of 0 were not included in the weighted average calculation.

Width measurements for all Mobil source records and those records compiled during the creation of the GBSC were not slant range corrected. As a result, the actual scour width will be slightly greater than that recorded. However, for the majority of scours the difference is less than the precision with which scour width can be measured on the sidescan record. At extreme fish heights and width measurements taken in the innermost ranges of the sidescan record scour width may be 20-35% greater than that recorded. This worst case scenario probably affects less than 1% of the records.

All width measurements obtained during the 1996 modifications and GBSC 1999-2004 update were made from slant range corrected sidescan sonar data or from processed multibeam sonar DTM. The accuracy of the width measurement will vary slightly according to the interpreter as well as the sidescan range or multibeam DTM resolution.

Ice Scour Feature Class	Width Range (metres)	Number of Records with no Width Recorded (Value = 0)
GBSC_Furrows (N=4405)	1 - 208	546
GBSC_Furrows_with_Pits (n=344)	1 - 110	27
GBSC_Furrows_OneEndPoint (n=617)	3 - 150	463
GBSC_Pits (n=2680)	5 - 350	82

11) FIELD NAME: LENGTH **Furrow / Pit Length (metres)**

This field records scour length in metres. A value of 0 indicates the length was not measured.

The methods used to calculate scour length vary from source to source. For the CSR-Post 1984 GSC Regional Cruises (GBSC compilation) database, the start and end points of each scour segment were recorded (i.e. time, offset, Port and Starboard Channel) and the scour length calculated from the resultant UTM co-ordinates of the start and end points. For the ESRF 4000 Series and 89006 sources, scour length was measured from the sidescan record. The methods used to obtain scour length in metres have not been documented in the Mobil report or the post-1984 well site surveys. Scour length was measured from the interpreted sidescan mosaic for the GBS site.

All length measurements obtained during the 1996 modifications and GBSC 1999-2004 update were calculated automatically in a GIS environment based on the digitized interpreted centerline of the scour segment from slant range corrected sidescan sonar data or from the multibeam sonar DTM.

For the Feature Classes GBSC_Pits and GBSC_Furrows_OneEndPoint the length measurement represents the length stored in the original GBSC segment database.

For the Feature Class GBSC_Furrows the length represents the total length of the furrow event.

For the Feature Class GBSC_Furrows_with_Pits the length represents the total length of the scour (Furrow & Pit) event.

Ice Scour Feature Class	Length Range (metres)	Number of Records with no Length Recorded (Value = 0)
GBSC_Furrows (N=4405)	5 - 10216	0
GBSC_Furrows_with_Pits (n=344)	33 - 9690	0
GBSC_Furrows_OneEndPoint (n=617)	40 - 3370	541
GBSC_Pits (n=2680)	11 - 573	1421

12) FIELD NAME: LENGTH_Q Scour Length Qualifier

A length qualifier is used to inform the user about the scour length measurements. This field describes the presence of end points and thus the quality of the length data for the entire scour event. The following table describes the codes used.

LENGTH_Q	DESCRIPTION	Number of Records (Feature Class)			
		GBSC Furrows	GBSC Furrows With Pits	GBSC Furrows OneEndPoint	GBSC Pits
1	1 Endpoint - Seen or Inferred with Confidence.	853	123	14	221
2	2 Endpoints - Seen or Inferred with Confidence.	1588	216	5	1030
3	Data Quality Does Not Allow Resolution to define endpoints.	837	2	34	31
4	No Endpoints - Scour Extends Beyond Swath.	440	3	7	3
5	Unknown	687	-	557	1395
	Total Records	4405	344	617	2680

13) FIELD NAME: ORIENT Furrow / Pit Orientation

This field contains scour orientation, corrected to grid north and represented as a degree value between 0 and 179. This parameter does not indicate the actual direction in which scouring took place. Care should be taken not to infer direction from orientation. All features comprising a scour have orientations less than 180 degrees. Records with no orientation value are coded with 999.

For the Feature Classes GBSC_Pits and GBSC_Furrows_OneEndPoint the orientation measurement represents the orientation value stored in the original GBSC segment database.

Orientation within GBSC_Furrows and GBSC_Furrows_with_Pits was calculated utilizing the ArcGIS Tool Linear Directional Mean. All pit features were excluded in this calculation.

Ice Scour Feature Class	Orientation Range (degrees)	Number of Records with no Orientation (Value = 999)
GBSC_Furrows (N=4405)	0 - 179	0
GBSC_Furrows_with_Pits (n=344)	0 - 179	0
GBSC_Furrows_OneEndPoint (n=617)	0 - 178	519

GBSC_Pits (n=2680)	0 - 179	1420

14) FIELD NAME: BERM_HT **Berm Height**

Berm height refers to the height in metres of the scour berm profiled by the system indicated in the SBP field. Berm height is measured above the interpreted "pre-scour" seafloor on the profiler record.

For the Feature Class GBSC_Furrows_OneEndPoint berm height was not measured in the original GBSC segment database.

For the Feature Class GBSC_Pits the berm height measurement represents the maximum berm height value stored in the original GBSC segment database fields BERM_HT1 and BERM_HT2.

Berm Height within GBSC_Furrows and GBSC_Furrows_with_Pits represents the maximum Furrow berm height within the original GBSC segment database. All pit features were excluded in this calculation, Pit berm height is stored within GBSC_Pits.

If no berm height was measured, a value of 0 is recorded. This is the case for the majority of features recorded on sidescan.

Ice Scour Feature Class	Berm Height Range (metres)	Number of Records with no Berm Height Recorded (Value = 0)
GBSC_Furrows (N=4405)	0.1 - 2.5	3800
GBSC_Furrows_with_Pits (n=344)	0.1 - 1.8	216
GBSC_Furrows_OneEndPoint (n=617)	-	0
GBSC_Pits (n=2680)	0.1 - 3.3	2425

15) FIELD NAME: PROFILE — Scour Profile

Profile describes the scour shape as seen on the sub-bottom profiler record at the location where the maximum berm height was recorded.

PROFILE	DESCRIPTION	Number of Records (Feature Class)			
		GBSC Furrows	GBSC Furrows With Pits	GBSC Furrows OneEndPoint	GBSC Pits
	No Data	4165	324	-	2660
A	Asymmetrical	135	11	-	13
S	Symmetrical	68	7	-	3
V	V-notch (no berms)	37	2	-	4
	Total Records	4405	344	0	2680

Scour profile was not determined for Mobil, GBS-Mosaic Site, Post-1984 Well-site sources, 94-021 ESRF 4000 Series, 98-024 Multibeam Site, 1998 South Nautilus, 1998 Hebron Brents Cove, 1998/1999 Husky White Rose Clearance Surveys, East Flying Foam, 96-011 White Rose.

16) FIELD NAME: SYSTEM — Sonar System

This field includes the type of sidescan sonar system or multibeam sonar system used for scour mapping.

SONAR SYSTEM	Number of Records (Feature Class)			
	GBSC Furrows	GBSC Furrows With Pits	GBSC Furrows OneEndPoint	GBSC Pits
B.I.O. 70 kHz	571	29	415	263
Edgetech 100 kHz	534	43		103
Klein 100 kHz	237	5	37	63
Klein 50 kHz	307	14		38
O.R.E. 100 kHz	995	17	164	1427
Simrad 120 kHz	941	112		490
Simrad EM100 95 kHz	762	107		255
Simrad EM3000 300 kHz	57	17		41
Unknown	1		1	
Total Records	4405	344	617	2680

17) FIELD NAME: QUALITY — Data Quality

Data quality is a qualitative assessment of the sidescan record or multibeam sonar DTM quality. In general terms, the higher the data quality, the greater the interpreter confidence in scour identification.

QUALITY	DESCRIPTION	Number of Records (Feature Class)			
		GBSC Furrows	GBSC Furrows With Pits	GBSC Furrows OneEndPoint	GBSC Pits
0	No data available	746	-	-	1424
1	Poor	20	1	-	3
2	Fair	369	36	-	133
3	Good	1101	108	-	489
4	Very Good	2120	196	-	575
5	Excellent	41	3	-	55
8	Unknown	1	-	-	-
9	Unknown	7	-	-	1
	Total Records	4405	344	0	2680

18) FIELD NAME: CLARITY — Scour Clarity

Scour clarity is a qualitative evaluation of the relative clarity and sharpness (edge or boundary definition) of the scour as it appears on the sidescan sonar record or multibeam DTM. As per the Data Quality indicator, interpreter confidence in scour identification was greater for scours with a higher degree of Scour Clarity.

CLARITY	DESCRIPTION	Number of Records (Feature Class)			
		GBSC Furrows	GBSC Furrows With Pits	GBSC Furrows OneEndPoint	GBSC Pits
0	No data	918	17	-	1454
1	Barely distinct	636	29	-	45
2	Poor Clarity & Sharpness	1154	58	-	249
3	Moderately Clear & Sharp	1217	117	-	502
4	Clear & Sharp	443	120	-	413
5	Very Clear & Sharp	29	3	-	16
9	Unknown	8	-	-	1
	Total Records	4405	344	0	2680

19) FIELD NAME: BERM_DEV **Berm Development**

The Berm Development indicator is a qualitative assessment of scour berms as observed on sidescan sonar records.

BERM_DEV	DESCRIPTION	Number of Records (Feature Class)			
		GBSC Furrows	GBSC Furrows with Pits	GBSC Furrows OneEndPoint	GBSC Pits
0	No data available	2011	204	-	1920
1	No Berms Observed	1273	60	-	225
2	Poorly Developed Berms	914	63	-	400
3	Well Developed Berms	199	17	-	134
9	Unknown	8	-	-	1
	Total Records	4405	344	0	2680

20) FIELD NAME: SED_TYPE **Sediment Lithology**

The field records sediment lithology at the measured scour location as interpreted from sidescan sonar records. The following table describes the lithology codes used in the database.

SED_TYPE	DESCRIPTION	Number of Records (Feature Class)			
		GBSC Furrows	GBSC Furrows With Pits	GBSC Furrows OneEndPoint	GBSC Pits
0	No data available	395	15	5	172
1	Gravel	837	83	25	290
2	Sand & Gravel	1398	97	264	791
3	Predominantly Sand	1775	149	293	1427
4	Glacial Marine Sediments	-	-	5	-
5	Glacial Till	-	-	25	-
	Total Records	4405	344	617	2680

21) FIELD NAME: COMMENT **Comments**

This field contains analyst's notes. Primarily scour-related comments, but also includes comments relating to surficial geology, geophysical records, and non-scour seabed features.

22) FIELD NAME: PIT_ID **Unique Identification Number**

This field was incorporated into the original segmented GBSC database during the 1996 modifications and populated with a unique identification number. The PIT_ID field only occurs in the GBSC_PIT Feature Class

The ID was calculated by multiplying the SCOUR_ID by 100 and adding the SEG (Segment) value.

ID = SCOUR_ID *100 + SEG

This allows the user to easily relate or join the GBSC_PIT Feature Class databases to the corresponding record within the original GBSC segmented Database.

APPENDIX IV
GBSC GEODATABASE FILE SUMMARY

GEODATABASE FILE SUMMARY

The disk included within Appendix V contains the GBSC Geodatabase (GBSC.gdb) and associated ArcGIS project. The geodatabase file must be in the same folder as the ArcGIS project to ensure the Feature Classes within the geodatabase are maintained.

GBSC_Geodatabase.mxd – ArcGIS project with all Feature Classes loaded from the geodatabase.

GBSC.gdb – The geodatabase in which Feature Classes are stored. A summary list and description of each Class follows.

Reference Feature Classes (Section 3.1 & Appendix I)

- WELL_LOCATIONS – point Feature Class of exploratory and production well locations.
- BATHYMETRY - line Feature Class of Marine Atlas regional bathymetry contours.
- NEWFOUNDLAND – polygon Feature Class represents the coastline of the island of Newfoundland.

Survey Feature Classes (Section 3.2 & Appendix II)

- NAVBASE_SURVEY_LINES - line Feature Class of the survey vessel tracklines.
- GBSC_SITE_SURVEYS – polygon Feature Class of industry and GSC site survey areas.
- GBSC_SURVEY_EXTENT - polygon Feature Class of all Areas Surveyed.

Iceberg Scour Feature Classes (Section 3.3 & Appendix III)

- GBSC_FURROWS – line Feature Class of Iceberg Furrows.
- GBSC_FURROWS_WITH_PITS – line Feature Class of Iceberg Furrows with associated Pits.
- GBSC_PITS – point Feature Class of all individual Iceberg Pits or those associated with Furrows.
- GBSC_FURROWS_ONEENDPOINT – point Feature Class of Iceberg Furrows with only one endpoint mapped.

APPENDIX V

GBSC GEODATABASE

The Grand Banks Scour Catalogue (GBSC) GIS compilation is included as part of this Open File.

The GBSC is provided as a published map file (.pmf) package that can be opened with ESRI®'s ArcReader™ (included), and as an ESRI® File Geodatabase™.