REVIEW OF GRANULAR RESOURCE POTENTIAL: SOUTH-CENTRAL BEAUFORT SEA with IDENTIFICATION OF FIELD INVESTIGATION TARGETS

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Submitted to:

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1 Introduction

Over the period December 1993, to March 1994 Lewis Geophysical Consulting was requested to review the resource potential of the South-Central area of the Beaufort Sea which has been named the Southern "Akpak Plateau" physiographic area (O'Connor, 1980). Figure 1-1 outlines the study area of some 2000 square km. which lies just to the north of North Point on Richards Island in the Mackenzie Delta of the Northwest Territories.

The study region contains the presently known, and previously utilized, Isserk granular resource borrow site which has been used through this report as a defining model guide in the search for new potential target resource areas within this present study region. This study encompasses the review of geophysical, bathymetric and geotechnical data collected and made available since 1987 after completion of the detailed resource analysis of the Isserk Borrow Area completed by Earth & Ocean Research Ltd. (1987). These data have been utilized to tentatively define a number of new possible resource targets based on the presently limited data coverage and outline both geophysical survey programs and borehole drilling site programs that would help to more fully define the lateral extents and resource qualities of these targets.

The report is organized as a brief review of the new data available followed by a series of location and tentative characterization map sheets and brief descriptions of the new target sites identified. These are supplemented with 45 new proposed borehole sites that would aid in the characterization and confirmation or rejection, as appropriate, of these sites as viable granular resource targets. A section on proposed geophysical surveys (line location and system recommendations) to more fully delineate the areal extent of these targets has been included as a basis for planning future programs in the region.

1.1 Authorization

This program was funded under SSC Contract No. A7134-3-0046/01-ST for the Department of Indian and Northern Affairs. The project has been a part of the Northern Oil and Gas Action Program [NOGAP] Project A4: "Granular Resources Inventory and Management" under the direction of Mr Robert J. Gowan of DIAND.

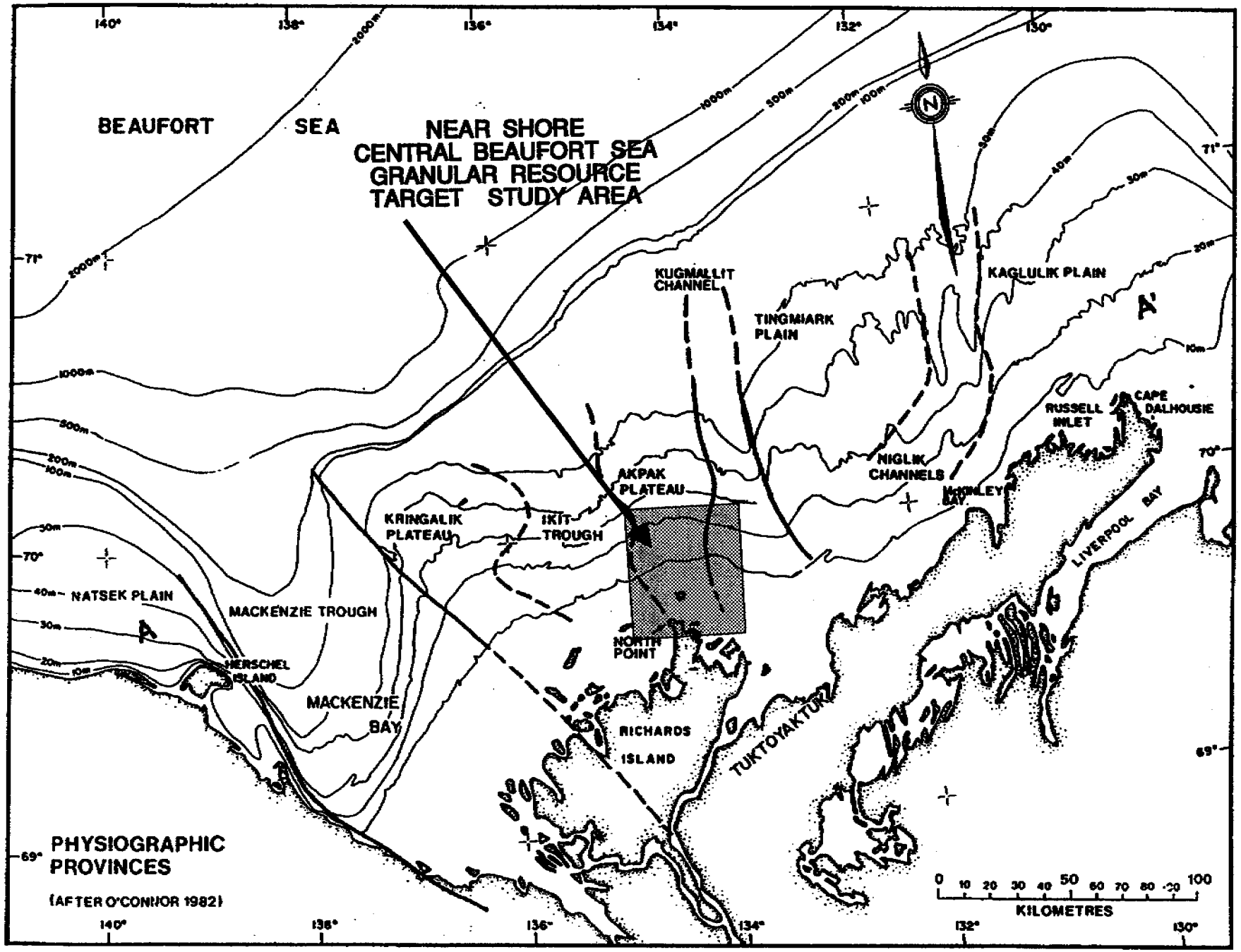


FIGURE 1 Near Shore Zone Central Beaufort Sea Granular Resource Target Study Area Location Map

2 Data Review Summary

The data review for this study involved utilization of the reports published prior to 1993 on the geology and granular resources associated with the South Central Beaufort Sea (Lewis, 1991, 1993, Lewis and Gilbert, 1988, Fortin, 1986, 1987, and 1989, Hill et.al., 1985 and 1991, Blasco et.al. 1990, Dallimore, 1991, and Dallimore and Taylor, 1993, O'Connor, 1980 and 1982, O'Connor and Missiuna, 1985 Meagher and Lewis, 1988, Jenner and Blasco, 1991, McGregor GeoScience Ltd, 1989, EBA Engineering Ltd, 1993). These reports have provided basic background information on the regional and local geological conditions and on the presently defined granular resources in the study region (Isserk Borrow Site Study, Meagher and Lewis, EOR, 1988). In particular, new data that has been made available since 1988 (post Isserk study, EOR, 1988) has been detailed and primarily utilized here in order to define new potential granular resource areas within the study boundaries. These data include geophysical studies carried out in 1988 and 1991 using newer (and better) geophysical survey systems, detailed bathymetric coverage of the study areas completed in 1986-88 by the Canadian Hydrographic Service (CHS) that were not available to the previous studies and more complete sampling and borehole data that has been supplemented since these earlier studies.

2.1 Geophysical Survey Data

The additional geophysical survey data that has been utilized in this study consists of the C.C.G.S NAHIDIK 1988 survey program conducted by Mr Steve Blasco of the Atlantic Geoscience Centre and Dr Jim Hunter of the Terrain Sciences Division of the Geological Survey of Canada, the 1988 Gulf Pipeline Route detailed geophysical study conducted by McGregor Geosciences for Gulf Canada Resources and a 1991 C.C.G.S. NAHIDIK study program conducted by Mr Steve Solomon of the GSC. Figure 2-1 (file FIG2-1.DXF) shows the track plots of these studies within the granular resource study area. The majority of survey data line kilometres of these new studies tend to be concentrated along the Gulf Pipeline Corridor though a number of regional survey lines at quite broad line spacings were completed on the NAHIDIK programs. Earlier survey data collected through the 1980's was also reviewed as appropriate and available but it was generally found that the quality and displays of these earlier data were not of sufficient quality and presentation detail to supplement and add to the interpretations provided by the latter studies.

The post 1988 studies were all conducted using the high resolution IKB Seistec boomer profiling system along with a 3.5/7.0 kHz profiler which provided a significant improvement in the definition of the Unit B reworked sediments in the area. These Unit B sediments are noted to comprise the Isserk granular resource deposit which had generally not been well defined acoustically by the earlier data collections (ref. EOR, 1988 and personal review). Because of these enhanced acoustic characteristics shown in these new data sets combined with the comprehensive borehole information at the Isserk site the geophysical data in the vicinity of the Isserk Site has been used as a baseline guide when reviewing data from other areas in the region.

2.2 Bathymetric Data

In addition to the geophysical data sets above a new bathymetric survey of the study region was completed during the summer field seasons of 1986 through 1988 by the Canadian Hydrographic Service. These CHS data were not available to the earlier studies of the area and it was decided to use the more detailed bathymetry to attempt to delineate and define seabed physiographic features that could potentially be indicators for granular resource targets within the area. The new bathymetric data set consisted of more detailed and positionally accurate coverage (100-150 m line spacing, ARGO positioning) than the previous Natural Resource Series Bathymetry maps that were compiled from a 1970-72 CHS survey of the area (400-500 m line spacing, DECCA positioning).

Figure 2-2 presents the one metre bathymetric contour map compiled from the 1986-1988 re-survey of the Central Beaufort region. The bathymetric contours were computer generated by Challenger Survey's & Services Ltd. under a separate contract to DIAND in 1994 using the digital data base provided by CHS. The new CHS data did not cover the entire study area however and the contours in the region just to the north and west of Pullen Island were produced from the earlier 1970-72 Beaufort bathymetric data. This is apparent on the present contour map by the much less detailed and more highly smooth one metre contours in this region. As a result the bathymetric contours in this region do not show the physiographic detail of the other regions of the map sheet.

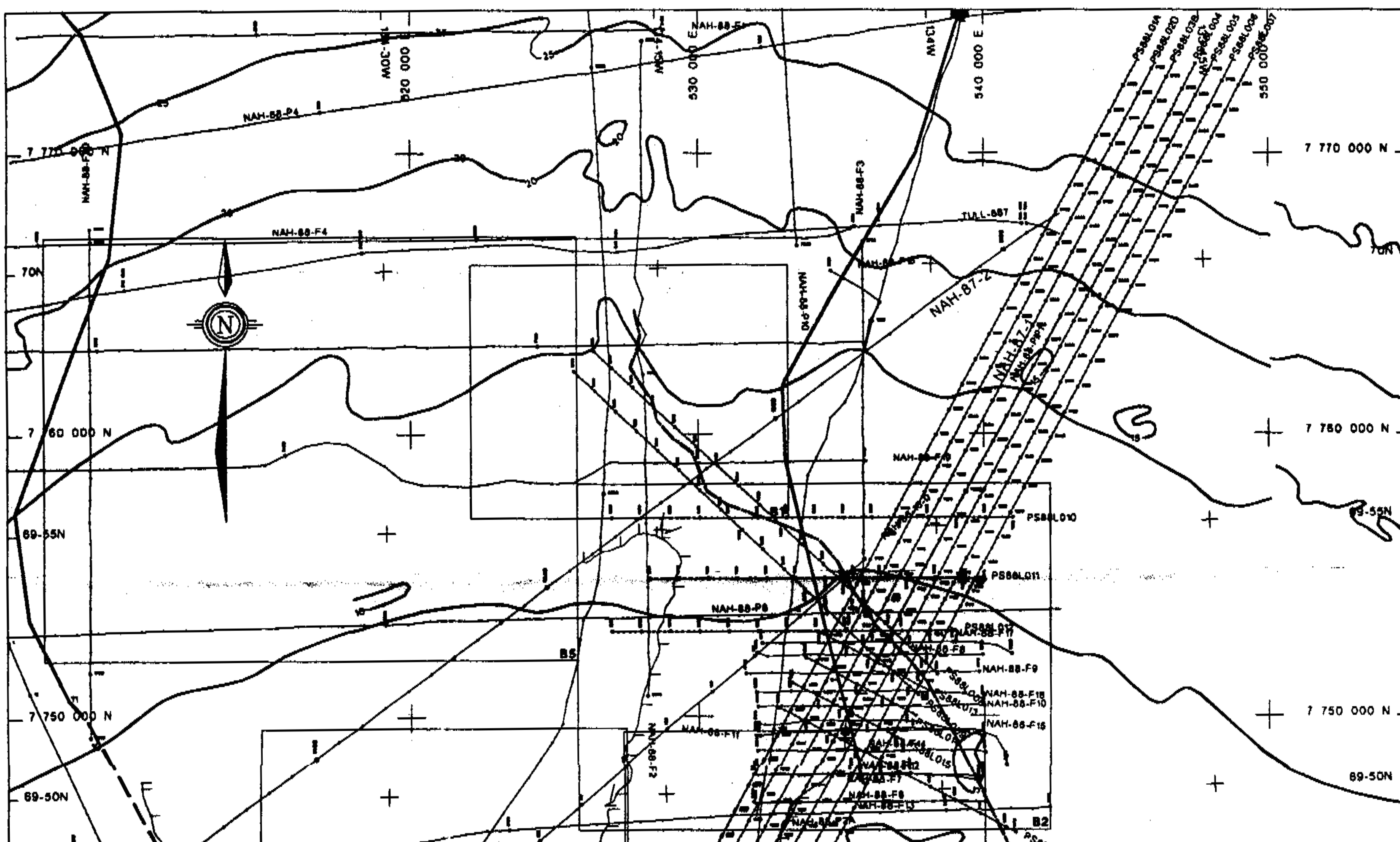
2.3 Borehole and Samples Data

A boundary search of the granular resource study area was completed on the Beaufort Sea ESEBASE borehole data set which consists of 2935 borehole and core samples within the entire Beaufort Sea region. This data base was compiled from industry and government studies in the area by EBA Engineering Consultants Ltd. under contract to DIAND and access to the ESEBASE program and data base were provided by Mr Steve Blasco of the Atlantic Geoscience Centre in Dartmouth. The initial data search was based solely on geographic co-ordinates (Southern Beaufort Granular Resource Target area) and resulted in 545 boreholes lying within the study area. In addition to the ESEBASE data search 21 additional boreholes and CPT test sites were located in the area completed during the 1990 Mega Transect study (Dallimore, 1991) that had not been incorporated into the ESEBASE database. Also CHS bottom sample information was compiled for this study area, which consisted of a 1972 sample base map (Pelletier ??) plotting S (for sand) and M (for mud) on approximately a 10 km grid for the Southern Beaufort (no further sample details available) and a total of 20 brief grab sample descriptions and locations collected during the 1986-88 hydrographic surveys (courtesy of Mike Woods, CHS Victoria, pers comm.)

Figure 2-3 is a map plot of all sample information presently available within the Southern Beaufort Study region. All ESEBASE boreholes in the area are indicated by circles bisected by a SW-NE diagonal with the SE half of the circle filled in along with there ESEBASE borehole name (CYAN colour in DXF files). Sub-searches were made on the ESEBASE data set to look for granular resource sands and/or gravels within the upper 3 m of the sediment column (ie. potentially exploitable without excessive stripping). A total of 162 of the boreholes were found to indicate sands (SM or SP) within the depth range of 0-1 m below the seabed in the study area. These boreholes have been indicated on the plot sheets by a + sign plotted through the centre of the borehole (+ sign and borehole YELLOW colour in DXF files). An additional search with the criteria of sand SP-SM mentioned in the borehole logs at depths between 1-2 m located 32 boreholes with this criteria. Note: using these search criteria boreholes that are continuous sands from 0-2 m or deeper would not be selected unless there was a specific notations of sands in the 1-2 m interval, thus some duplicates would be found and many with continuous sands from the seabed down would be missed but primarily those boreholes with muds overlying sands would be selected with this criteria. These boreholes have been indicated on the map sheet by a larger circle surrounding the primary borehole symbol (outer circle YELLOW colour in DXF files). A search with the criteria of sand SP-SM found within the depth range 2-3 m located 25 boreholes

in the study area (same Note as above applies). These boreholes have been indicated on the map sheet by a diamond shape square surrounding the borehole symbol (diamond YELLOW colour in DXF files). In addition to the above searches, a search of the data base was conducted for any mention of gravels or trace gravels within the depth range of 0-3 m. This search located 35 boreholes indicating gravels in the region. These boreholes are indicated by a half circle with the flat face oriented NW-SE and the filled side to the SW (filled circle RED colour in DXF files) that are plotted over the normal borehole symbol leaving a 3/4 filled circle with an open notch on the northern side of the circle.

In addition to the ESEBASE and Mega Transect boreholes the CHS sample data are displayed on the map sheet and are indicated simply by the letters M for muds, S for sands and G for gravels centred on the locations reported by CHS.



SURVEY KEY

NA9109	C.C.G.S. NAHIDIK 1991 CRUISE STEVE SOLOMON - AGC IKB SEISTEC/3.5 KHZ/SIDESCAN
NAH-88-F9	C.C.G.S. NAHIDIK 1988 CRUISE S. BLASCO (AGC) / J. HUNTER (TSD) - IKB SEISTEC/3.5 KHZ/ DUAL AIR GUN/SIDESCAN
PS88L011	M/V ARCTIC SUVEYOR 1988 GULF CANADA RESOURCES LTD. McGREGOR GEOSCIENCES LTD. IKB SEISTEC/3.5 KHZ/SIDESCAN
NAH-87-2	C.C.G.S. NAHIDIK 1987 CRUISE PHIL HILL (AGC) IKB SEISTEC/3.5 KHZ/BUBBLE PULSER/SIDESCAN
TULL-887	C.S.S. TULLEY C1988 CRUISE S. BLASCO (AGC) HUNTEC DUAL BOOMER/3.5 KHZ DUAL AIRGUN/SIDESCAN
NAH-88-21	C.C.G.S. NAHIDIK 1988 CRUISE K. MORAN (AGC) BOOMER (POOR)/3.5 KHZ/ SIDESCAN

NOTE: 5 M BATHYMETRIC CONTOURS BASED ON 1972 NATURAL RESOURCES BATHYMETRIC MAP

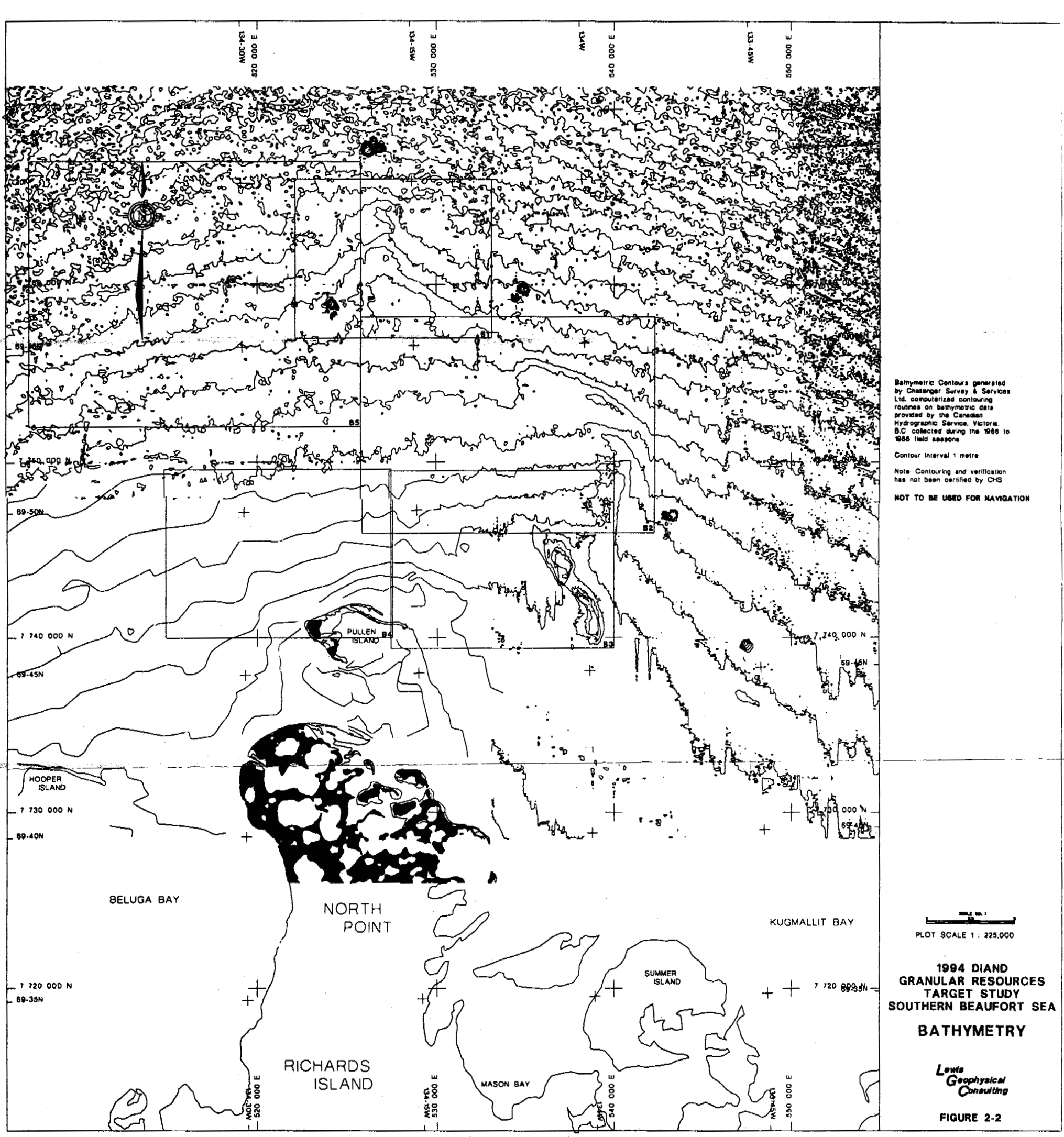
PLOT SCALE 1 : 225,000

1994 DIAND GRANULAR RESOURCES TARGET STUDY SOUTHERN BEAUFORT SEA

GOOD QUALITY SURVEY TRACK LINES

Lewis Geophysical Consulting

FIGURE 2-1



Bathymetric Contours generated by Challenger Survey & Services Ltd. computerized contouring routines on bathymetric data provided by the Canadian Hydrographic Service, Victoria, B.C. collected during the 1986 to 1988 field seasons.

Contour interval 1 metre

Note: Contouring and verification has not been certified by CHS

NOT TO BE USED FOR NAVIGATION

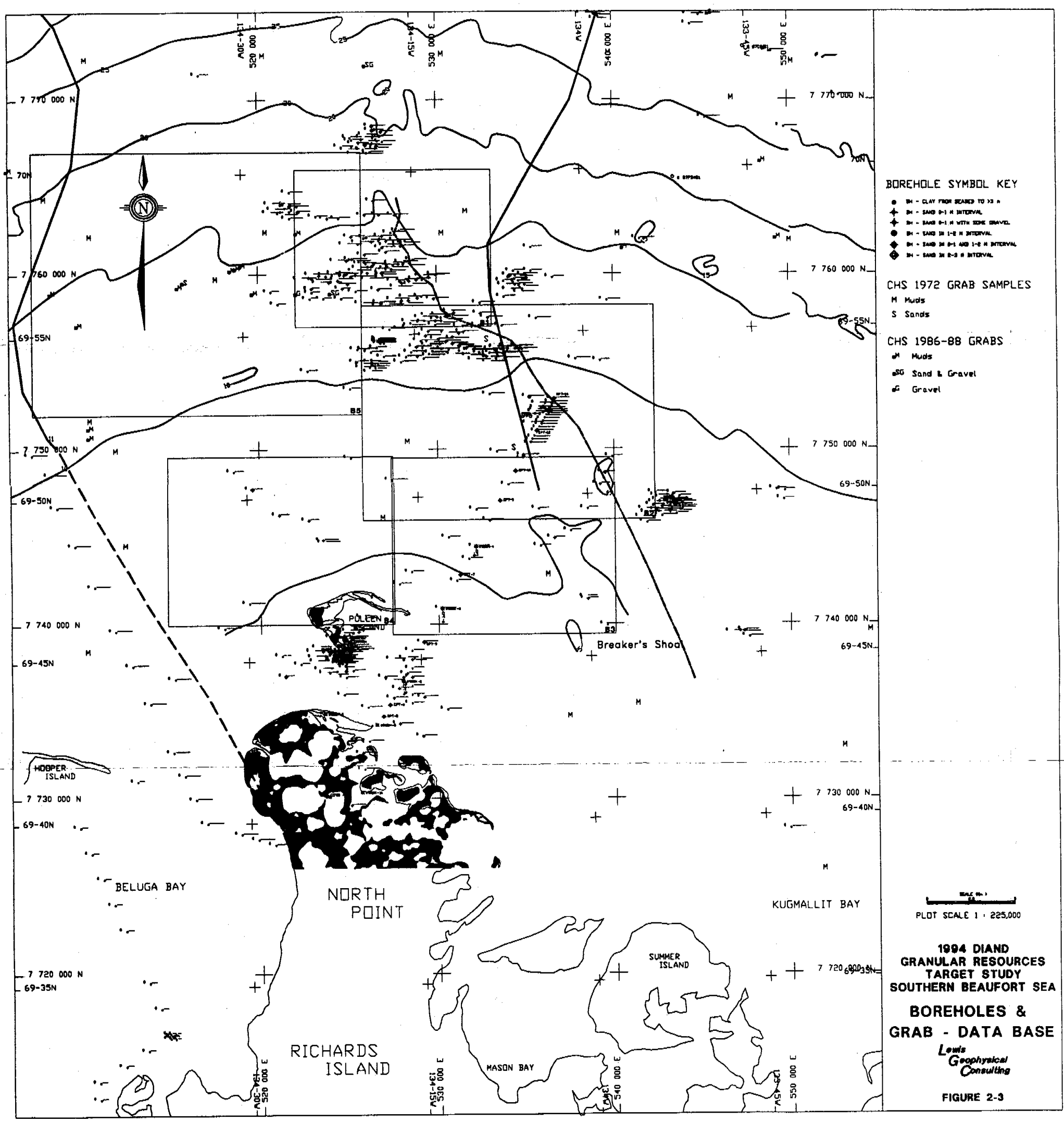
PLOT SCALE 1 : 225,000

1994 DIAND GRANULAR RESOURCES TARGET STUDY SOUTHERN BEAUFORT SEA

BATHYMETRY

Lewis Geophysical Consulting

FIGURE 2-2


7 770 000 N
7 760 000 N
7 750 000 N
7 740 000 N
7 730 000 N
7 720 000 N
69-55N
69-50N
69-45N
69-40N
69-35N
520 000 E
530 000 E
540 000 E
550 000 E
134-30W
134-15W
133-45W
BOREHOLE SYMBOL KEY
CHS 1972 GRAB SAMPLES
M Muds
S Sands
CHS 1986-88 GRABS
Muds
Sand & Gravel
Gravel
PLOT SCALE 1 : 225,000
1994 DIAND
GRANULAR RESOURCES
TARGET STUDY
SOUTHERN BEAUFORT SEA
BOREHOLES &
GRAB - DATA BASE
Lewis Geophysical Consulting
FIGURE 2-3
Breaker's Shoal
POLEEN BANK
HOOPER ISLAND
BELUGA BAY
NORTH POINT
RICHARDS ISLAND
MASON BAY
SUMMER ISLAND
KUGMALLIT BAY

3 Brief Area Description

The offshore model of the surfical geology of the Beaufort Sea outlined originally by O'Connor, 1980 and 1982 and expanded and detailed by Lewis 1991 and 1993 apply for this study region. The surficial sediments in the region that are of interest to this granular resource study consist of the Unit A recent marine clays which overly transgressional and nearshore higher energy depositional Unit B sediments resting unconformably on older (late Pleistocene) coarser grained sediments of terrestrial and alluvial depositional character that have been designated Unit C in the offshore models. Table 1 provides a summary description of the various units comprising the offshore seismo-stratigraphic geologic model for the southern Beaufort area (reproduced from Lewis 1993). This table summary provides tentative (lithologic and stratigraphic similarities) unit correlations to the onshore geology of the Richards Island Coastlands after Dallimore and Vincent, 1991 and Rampton, 1982 and 1988 as presented by Jenner and Blasco, 1991 (in Dallimore, 1991). There is a significant age discrepancy (in the order of 50,000 to 100,000 years) between the onshore and offshore geologies that has not as yet been resolved however.

Unit A marine clays sediments are generally not observed within water depths of less than about 15 to 17 m of water on the Akpak Plateau and throughout at least the southern two thirds of the study area the surficial deposits are considered to be primarily composed of the generally coarser grained silts and reworked sands of the Unit B materials. The region inshore of the 10 m isobath has been noted to contain an unusually thick (6-15 m) accumulations of Unit B sediments to within approximately one to two kilometres from the present shoreline that has tentatively been associated with a broad thermokarst basin where the permafrost front has been depressed to 90-100 m below the seabed (Dallimore and Taylor, 1993). Lewis, 1993 interprets this basin formation to be associated with the combination of a slowing in sea level rise occurring approximately 2500 years ago (Hill et.al., 1991) and an increase or diversion in the flow of warm fresh water from the East Channel of the Mackenzie. The slower sealevel rise has resulted in predominantly erosion rather than inundation of the coastlands which has produced the broad virtually flat shallow water shelf off the coast in this area. This broad shallow shelf combined with the outflow of Mackenzie's fresh warmer waters has effectively displaced the colder Arctic marine waters and thus the average annual seabottom temperatures are above the freezing point (Dallimore and Taylor, 1991). This has ultimately resulted in the degradation of the top of permafrost in water depths of less than 8-10 m along this portion of the coast. The formation of this thermokarst basin has effectively produced an inshore sediment trap area and the resultant

thicker sequence of Unit B materials that have been observed across the shelf area in this portion of the delta.

Based on the present understanding and interpretation of the offshore-onshore geology and particularly the known detail of distributions of the offshore sediments outlined in the previous paragraph the optimum regions for the search for granular resource materials are believed to be in the water depth ranges from approximately 8-10 m to 15-17 m and in the regions close to shore. The offshore 8 to 17 m water depth ranges would be optimum because accumulations of Unit A marine clays would be non-existent to minimal and the thicker probably predominant silts of the thermokarst basin infill material would also be minimal. This situation would leave the Unit C potential resource materials and the coarser faction basal Unit B materials closer to the seabed where they can be realistically recovered for utilization. Near shore regions within about 1-3 km of the coastline would also be optimal based on the fact that coarser materials produced from the erosion of the coastlands would likely be at or near the seabed in these regions and have not been covered by the finer silty materials that have predominantly infilled the broad inshore thermokarst basin feature. The inshore thermokarst basin region may contain some recoverable resource regions on a localized basis such as areas adjacent to any residual high features that might be encountered and are presently not mapped.

For a more comprehensive description of the onshore and offshore geology of the southern Akpak plateau the reader is referred to Lewis, 1991, 1993, Lewis and Gilbert, 1988, Fortin, 1986, 1987, and 1989, Hill et.al., 1985 and 1991, Blasco et.al. 1990, Dallimore, 1991, and Dallimore and Taylor, 1993, O'Connor, 1980 and 1982, O'Connor and Missiuna, 1985 Meagher and Lewis, 1988, Jenner and Blasco, 1991, McGregor GeoScience Ltd, 1989 and EBA Engineering Ltd, 1993.

TABLE 1: CENTRAL BEAUFORT SEA: SURFICIAL SEISMO-STRATIGRAPHIC GEOLOGIC MODEL SUMMARY

UNIT DESIGNATIONS Unit	Bounding Acoustic Reflectors	UNIT DESCRIPTIONS
A	seabed - B(gradational)	**Holocene - Marine Clays - no Onshore equivalent** Horizontal sequence of recent marine sediments deposited on the shelf following the last sea level rise. Generally restricted to water depths greater than 10 to 15 m. where it drapes the topographic features of the underlying sediments and is usually thickened within topographic lows. Seismo-acoustically transparent character with few to virtually no preserved internal reflecting horizons. Unit is most often heavily ice scoured to it's base. Ice scouring has destroyed any internal reflectors that may have been generated during deposition. The unit consists of grey to black, soft to firm clays or silty clays, usually containing traces of fine sand and organics, often in the form of fine laminations. Unit A is geotechnically defined by high water contents (usually > 50%) and low to very low shear strengths (1 to 30 kPa). Commonly due to the disrupted nature of these sediments a contact with the underlying Unit B materials cannot be detected with seismic methods and may only be described by a vague increase in internal reflectivity on high frequency seismic data. The base of Unit A grades into:
B	B - U/C or seabed - U/C	**Holocene - Transgressive Silts/Clays and Sands - no onshore equivalent (?Parsons Lake Fm?)** A transgressive sequence which includes deltaic, lagoonal and littoral sediments deposited in a complex high energy transitional environment related to rising sea level. Deposition of this unit presently continues in water depths of less than approximately 10 m near the coastline. Seismo-acoustically, Unit B is relatively transparent with flat lying to complex internal bedding structures which have in some areas been disrupted by ice scour resulting in an acoustic unit similar to A, though with a slightly increased internal reflectivity represented as a grey tone on the acoustic records. The A/B contact is very poorly defined on most acoustic records and normally consists of a 1 to 3 m thick gradational transition zone to slightly higher internal reflectivity when it can be identified at all acoustically. The unit is composed of a spatially discontinuous and highly variable sequence of thin, interbedded sands, silts and stiff clays. Geotechnically the unit is lower in water content (<50%) and typically though not always is stiffer with shear strengths in the range of 30 - 100 kPa. Unit B rests unconformably on:
C	U/C - Unit D or seabed - Unit D	**Early Holocene and Late Pleistocene - Fluvial & Paralic/deltaic and Outwash Sheet sands** **Onshore Correlation - Toker Point, Kittigazuit and Kidluit Formations ??** An underlying, older sequence which comprises coastal plain sand sediments. The B/C contact represents a subaerial erosional contact in some locations and a transgressional unconformity contact in others. In most areas of the Beaufort the contact acoustic reflector is commonly of high amplitude and generally smooth in nature. Within some regions (notably inshore areas and areas with coarser materials at seabed) the contact is highly variable in character and often becomes un-mappable. When visible on the acoustics it most often is interpreted as a subaerial erosional contact. Seismo-acoustically the unit is highly irregular in character with moderate to high internal acoustic backscatter. Internal acoustic structure, when observed, is primarily composed of numerous, varied amplitude, discontinuous and complex reflectors that are representative of complex cut and fill channelling in a virtually un-mappable spatial pattern. Occasionally bottomset and/or topset reflections of foreset bedding sequences are noted. The occurrence of ice bearing sediments in the form of Hummocky Acoustic Permafrost (HAPF) within this unit is widespread. In offshore regions (water depths greater than approx 25 m) HAPF reflections are predominantly at depths of 10 to 20 below the top of Unit C while in nearshore (8 - 15 m water depths) regions HAPF reflectors are noted throughout the unit C materials and are occasionally seen within 2 to 4 m of the top of Unit C. Unit C consists predominantly of fine to medium grained, grey or brown sand that is dense to very dense and relatively barren of fossils. The base of the unit is poorly defined on most high resolution acoustic records throughout the Central Beaufort Shelf and is usually inferred from the base of the complex bedding channel structures observed on the seismic records. Unit C overlies:

TABLE 1: (cont'd) CENTRAL BEAUFORT SEA: SURFICIAL SEISMO-STRATIGRAPHIC GEOLOGIC MODEL SUMMARY

(cont'd)

UNIT DESIGNATIONS Unit	Bounding Acoustic Reflectors	UNIT DESCRIPTIONS
D	Unit D - E	**Pleistocene - Marine Clay/Silts** **Onshore Correlation - Hooper Clay Formation ??** A sequence of fine grained silts and clays of predominantly marine origin. Acoustically the unit is transparent with only occasional faint, conformable bedding planes noted on the records. The top of the unit normally shows no distinct mappable acoustic reflecting horizon and is inferred from the bases of the lowest channel structures observed within the overlying Unit C. Radio Carbon age dating from an offshore sample at the Uviluk drill site on the eastern Tingmiark Plane from just above Unit E indicated an age of 21,000 years (Note: possibly for sediments of E_{ab} acoustic correlation uncertain at this time). These materials lie paraconformably on:
E_{ab}	E - E'	**Pleistocene - Marine Clay/Silts and Transitional Silts/Sands** **Onshore Correlation - ??? possibly lower Hooper Fm. ???** Horizon E representing a thin (2 m) frozen sand horizon which caps a continued sequence of marine silts and clays. Unit E_{ab} consists of the capping sand and the underlying marine sediments which infill the channel or basin structures observed on the E' reflecting horizon. Acoustically these sediments are only represented on the lower frequency airgun records at a low resolution. They show a moderate to strong reflecting character to horizon E with low amplitude vaguely defined reflections within the marine silty clays. Through the western half of the Central Beaufort study region E_{ab} is represented by local small channel fill structures on top of Horizon E'. Below Kugmallit Channel horizons E and E' diverge with Unit E_{ab} thickening toward the east and the overlying Unit D thinning to an onlapping pinchout below the Tingmiark Plain area in a line paralleling the Tuktoyaktuk Peninsula. Unit E_{ab} rest unconformably on:
E	E' to limit of seismics	**Pleistocene - Fluvial and Paralic/ Deltaic Outwash Sheet Sands** **Onshore Correlation - Kendall Sand Formation ???** A much older sequence of coarser grained sands that are commonly massively ice bonded forming the top of the main body of Acoustic Permafrost in the Beaufort region. Acoustically Horizon E' presents a high amplitude irregular and often discontinuous reflection (masked by overlying gas or HAPF) with a low relief (5 to 10 m) channelled topographic expression. In many areas (including regions of the Transect) horizons E' and E are observed to merge into a single acoustic reflection. Throughout most regions below Akpak Plateau and toward the east the E reflecting horizon represents the top of Stratigraphically controlled Acoustic Permafrost (SCAFP) in the region and mask all deeper reflection on high resolution seismics. Below this horizon the sediments are generally massive in character, though localized acoustic windows indicate repeated similar seismo-acoustic sedimentary sequences. The lateral equivalent unit at the Tarsuit well site suggests these sands are $\geq$ 27,000 years old, or older.

4 Potential Granular Target Site Selection

The following subsections detail the site selections of potential new granular resource targets in the study area and provide geophysical and borehole evidence for these criteria. A number of borehole targets are identified along with their present geophysical correlations if available. Also recommendations (systems and locations) for additional geophysical surveys are outlined.

4-1 Target Site Selection Criteria

Presently available geophysical and geotechnical data have been utilized to characterize the target sites outlined below when these data were available. Because of the irregular distribution of the present geophysical coverage in the study area the outside boundaries of the following targets are highly speculative in many instances and the present study is not intended to represent a definitive mapping of the granular resource targets in the region and should not be interpreted as such. In areas where little or no good quality geophysical or borehole information was available the seabed physiographic similarities shown in the bathymetric data alone have been used to at least provide a rough boundary of what are felt to be potential granular resource targets.

Throughout the majority of this study the Isserk Borrow Site area has been used as a type area for the geophysical data of a potentially good or viable granular resource target area. Two geophysical survey lines were collected during the 1988 Gulf Pipeline Survey Program that were of high quality and the characteristics observed on these lines have been used as a model to base the identification and mapping of the new site areas. Figure 4-1 shows a 1:50,000 scale map of the recent geophysical survey track plots and present borehole coverage of the Isserk Granular Resource area showing the location of the type section examples of Figures 4-2 through 4-5. These four type section figures show the IKB Seistec seismic profiles along side the borehole descriptions closest to the survey line at those locations. The seismic records all show the shallowest regional unconformity surface interpreted as the top of Unit C (designated U/C on diagrams) to be from 4 to 10 m below the seabed within the Isserk site area. The reflection patterns of the sediments above the unconformity surface typically show well defined near horizontal bedding structures with a relatively high degree of internal reflectivity which correlates to the surficial sands and trace gravels of the borehole logs. With the exception of Figure 4-3 (borehole IB80-88) all of the seismic records also show a very high amplitude seabed multiple reflection which is conspicuous by it's absence in other regions of thick (>0.5-1.5 m) surficial clay or silt

sediments. The record of Figure 4-3 shows a broken irregular multiple reflection that correlates with a patchy recent infill of clay/silts as suggested on the borehole and seismic records. This character is consistent with its location near the eastern boundary of the Isserk Borrow area. Correlating 3.5/7.0 kHz profiler records for these figures typically show a short and sharp, strong seabed reflection and correlating multiple reflections with little or no definition of the sub-surface reflecting horizons. These characteristics with some modifications were observed on other survey lines data in the areas and have been used along with whatever sample and borehole information that was available in the area to define the targets described below.

Figure 4-6 (1:225,000) and Enclosure 1 (1:75,000) show a location map of all of the target sites that have been observed and tentatively mapped within the study area. There have been five different types of potential granular resource sites identified based on their acoustic responses, seismo-stratigraphic relationships and/or bathymetric characteristics. Sites identified by C/x(number) are characteristic of areas where the Unit C unconformity is at or very near (<1 m.) to the seabed with highly reflective acoustic characteristics and a generally smooth seabed (no ice scouring apparent on seismics). The internal bedding in these areas tends to be highly complex (varied depositional environments) or massive with little or no internal bedding visible on the high resolution seismic records. The C/x sites are likely quite variable in granular resource quality and may grade from silt/clay through to gravels or frozen sediments over very short lateral or vertical distances. These sites are identified by a tight diagonal cross hatch on the figures.

The second type of target site is designated by GS/x(number) and are sites of the same or similar acoustic characteristics to the type section records of the Isserk Borrow area (site GS/1). These sites are basically reworked sediments forming Unit B that have a relatively smooth seabed character and show a strong seabed multiple and/or little or no penetration of the 3.5 kHz profiler data. Internal bedding is typically horizontal and may in local areas show cross bedding or foresets structures suggestive or bar or sand-spit migration. The sites labelled GS (Good or high probability sites) have at least some sample or borehole information available that confirms the presence of sands. These sites have been identified by the tight horizontal hatching on the figures.

The sites designated PS/x(number) are essentially the same acoustically as the GS sites but there is no confirming borehole or sample information available, or what sample information is available is in conflict or ambiguous with regard to the acoustic characteristics. The PS (Poor or moderate probability sites) are indicated by the tight diagonal hatching on the figures.

The BA/x(number) sites are potential resource targets that have been identified solely on the basis of bathymetric character as observed on the new bathymetric data set contours and have no seismic data or borehole data available for confirmation or further characterization. Bathymetric sites were selected based on smoother (less convoluted) seabed bathymetric contours (assuming less ice scour preservation likely due to non-cohesive sediments ie. sands) that bulge slightly to seaward suggesting a possible residual (more resistant to ice and wave erosion) bathymetric high feature. These sites are presently considered to be of low to very low granular resource probability though have been identified as areas of future geophysical and/or geotechnical investigations. The BA sites are indicated by the broad vertical hatching on the site maps.

Finally the sites label GV/x(number) are speculatively presented as possible lag gravel source areas. These two sites are essentially the two crests of the Breakers Shoal in the southeastern region of the site investigation area. There is presently no geophysical of geotechnical data available directly on these sites and they have been designated as such based on the logic that these bathymetric highs must be recently inundated island features. Also, it has apparently been reported that the seabed on these features consisted of lag gravels by Jim Hunter of the Terrain Sciences Group based on some of their earlier programs in the area (personal comm. with Bob Gowan). The GV sites are identified by the irregular speckled hatch patterns on the map sheets.

The individual numbering of the target sites has basically followed the pattern of commencing with the lowest numbers for each type of site area from the northwest quadrant of the study area and progressing in a clock-wise direction as far as possible. There is no attempt to rank the resource potential of these sites based on there numbering scheme.

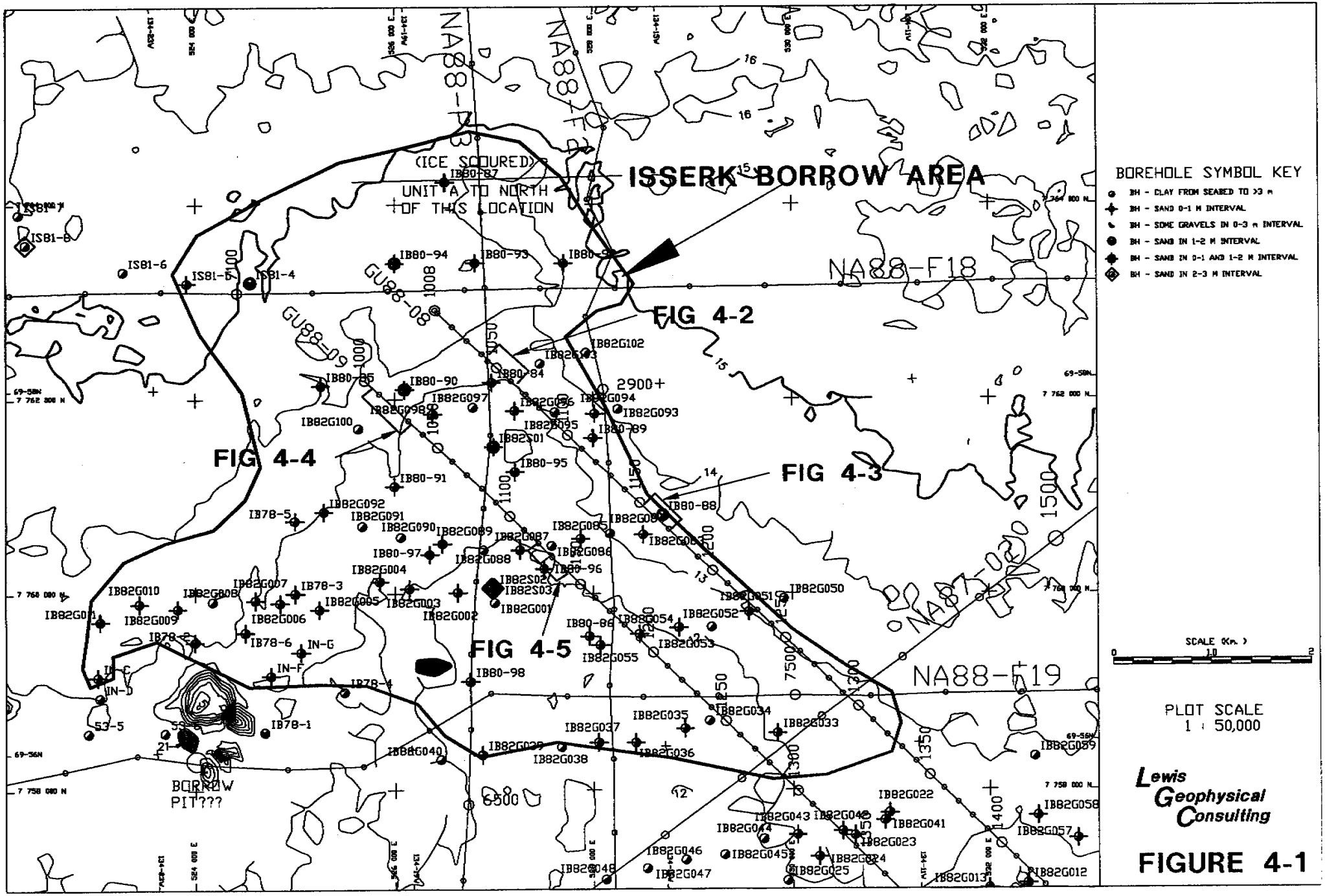
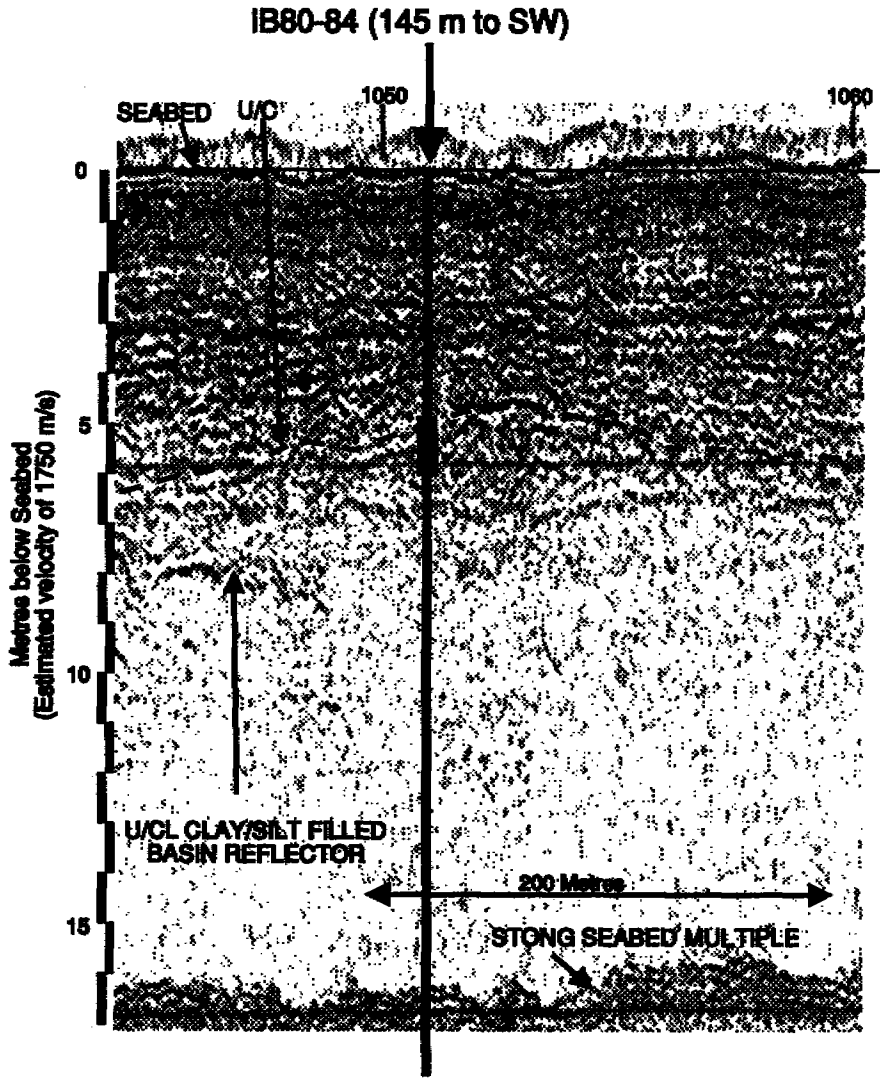

ISSERK BORROW AREA
(ICE SCOURED)
UNIT A TO NORTH
OF THIS LOCATION
FIG 4-2
FIG 4-3
FIG 4-4
FIG 4-5
NA88-F18
NA88-F19
BORROW
PIT???
BOREHOLE SYMBOL KEY
BH - CLAY FROM SEABED TO >3 m
BH - SAND 0-1 M INTERVAL
BH - SOME GRAVELS IN 0-3 m INTERVAL
BH - SAND IN 1-2 M INTERVAL
BH - SAND IN 0-1 AND 1-2 M INTERVAL
BH - SAND IN 2-3 M INTERVAL
SCALE (Km.)
PLOT SCALE
1 : 50,000
Lewis
Geophysical
Consulting

FIGURE 4-1



DEPTH (m)	USC	SOIL SYMBOL	IB80-84 DESCRIPTION OF SOILS WATER DEPTH - 13.4m	SAMPLE TYPE
0.0	SP-SM		SAND (SP-SM) - gravelly, maximum 25mm	
1.0			. subrounded & smooth, medium to fine	
			. grained (gap graded), saturated	
2.0	SP-SM		. - some gravel	
			. - trace of gravel, maximum 10mm,	
3.0			. medium to fine-grained, saturated,	
			. olive grey	
4.0			. - trace of silt, medium to fine	
			. grained, moist, olive grey	
5.0	GP-GM		NO RECOVERY	
			FINES WASHING OUT	
6.0			GRAVEL (GP-GM) - sandy, trace silt and	
			. clay, maximum particle size 25mm,	
7.0	SM		. angular, moist, dark grey	
			SAND (SM) - silty, some clay and organics	
8.0			. trace of shell fragments, very dense	
			. moist, dark grey	
9.0	SM		. - trace of organic pockets	
			. - trace of clay, compact, wet	
10.0			. - organic streaks, sand content	
			. increasing, wet to saturated	
11.0			. - very dark grey (5Y 3/1)	
			. - AND SILT, trace organics, fine	
12.0			. grained, uniform, wet to moist, very	
			. dark grey (5Y 3/1)	
13.0	SM		SAND (SM) - (continued)	
			. - silty fine-grained, poorly graded,	
14.0			. uniform, saturated, dark olive grey	
			. - some silt to silty, fine-grained,	
15.0			. uniform, wet, olive brown	
			. - SAND (sp-sm) - trace of silt, fine	
16.0			. grained, uniform, saturated, olive	
			. brown	
17.0				
18.0				
	SP-SM		SAND (SP-SM) - trace of silt, trace of	
19.0			. coal fragments, medium to fine	
			. grained, wet, olive brown,	
20.0			. individual fine-grained sand lenses	
21.0			SAND (SP-SM) - (continued)	
			- silty, fine-grained	
			CLAY - silty, trace of sand, stiff, moist	
			. very dark grey	
			END OF BOREHOLE AT 21.4m	

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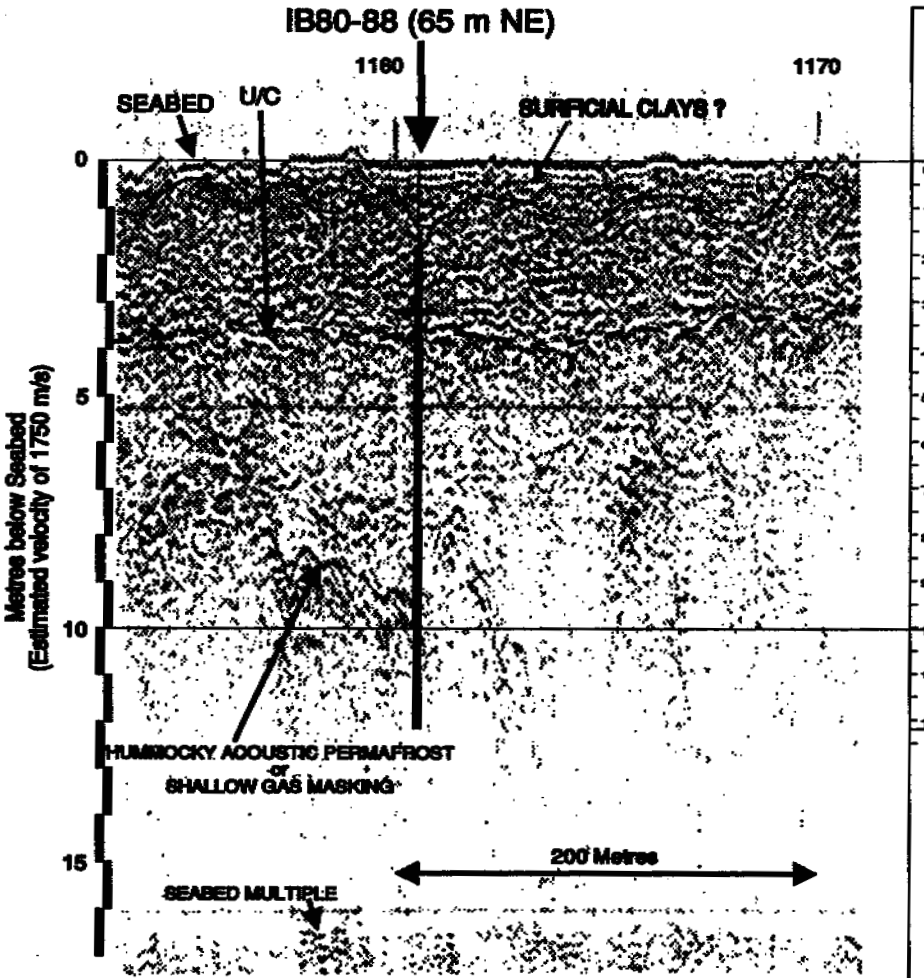
FIGURE 4-2



DEPTH (m)	USC	SOIL SYMBOL	IB80-88 DESCRIPTION OF SOILS
			WATER DEPTH - 14.9m
0.0			. CLAY (cl) - some silt, some sand, trace of shell fragments, interbedded, medium to fine-grained sand lenses to 10mm, dense and wet. Clay, medium plastic, soft, damp, dark grey
1.0			
2.0	SM		- becoming firm
3.0	SM		. SAND (SM) and CLAY - interbedded clay (some silt, trace of organics and shell fragments, laminated, firm, damp, dark grey). Sand (medium to fine-grained, dense, wet)
4.0	SM		- lenses to 30mm
5.0	SM		- wet sand
6.0	SM		. SAND (SM) AND SILT - with occasional clay laminations to 5mm, compact, wet, dark grey
7.0	SM		- medium to fine-grained, pebbles to 10mm, damp
8.0	SM		- trace of clay, fine-grained, homogeneous
9.0	SM		- trace of coarse-grained, rounded, trace of silt lenses to 5mm, moist, dark grey
10.0			- medium to fine-grained with occasional clay lenses 30-50mm, moist, wet
	SM		- trace of shell fragments
11.0			- micaceous, homogeneous, wet to saturated if not bonded
12.0	SM		- some silt, medium to fine-grained, micaceous, homogeneous, saturated, dense, dark brownish grey
			- predominantly medium-grained, laminated, homogeneous, dark brownish grey (2.5Y 3/2)
			- trace of fine-grained, trace of silt micaceous, homogeneous, saturated
			. SAND (SM) and SILT - (continued)
			- trace of shell fragments, trace of fine-grained, predominantly medium grained, dense, saturated, dark greyish brown
			- medium-grained
			. END OF BOREHOLE AT 12.2m

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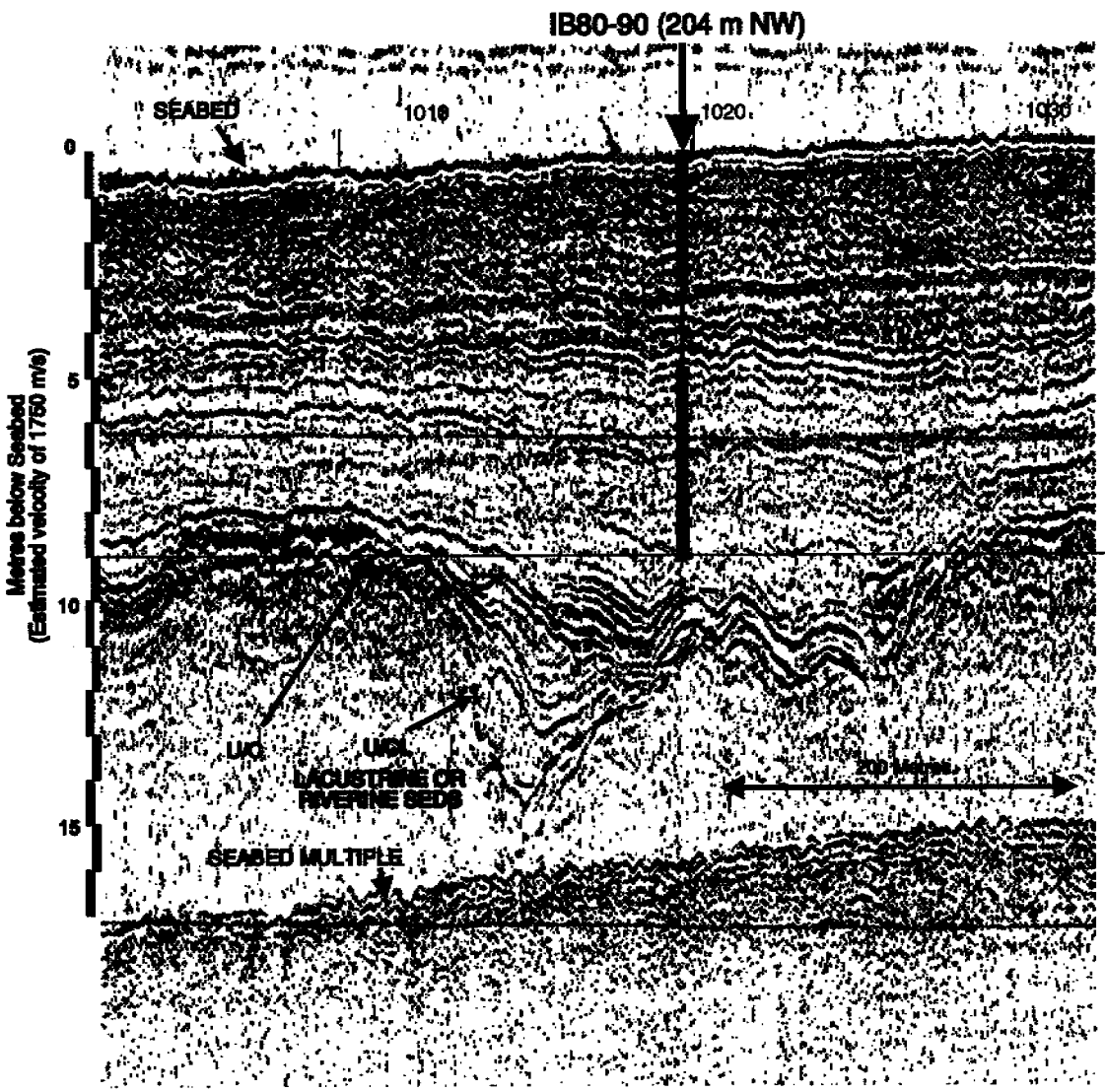
FIGURE 4-3



DEPTH (m)	USC	SOIL SYMBOL	IB80-90 DESCRIPTION OF SOILS WATER DEPTH - 13.4m
0.0			SAND (sp-sm) - fine-grained, clean, uniform, wet, olive grey - trace of shell fragments and organic streaks, occasional silt laminations (SM) - silt laminations, moist - cleaner (SP-SM) - trace to some clay
1.0	SM		
2.0	SP-SM		
3.0			
4.0	CL		CLAY (CL) - some silt and organic streaks medium to low plastic, very stiff, very dark grey - trace wood fragments and organic pockets, low plastic - silty, trace fine-grained sand, low plastic, very stiff, moist, very dark grey
5.0	SP-SM		
6.0			
7.0	SM		
8.0			
9.0	SM		SAND (SP-SM) - trace silt, fine-grained, uniform, wet, dark olive grey - some silt, fine-grained, uniform, wet, very dark grey - horizontal silt laminations to 4mm - regularly spaced silty clay laminations with a trace of shell fragments
			SILT (ml) - clayey, trace fine-grained sand, moist, very dark grey - clayey sand laminations to 100mm, wet, non plastic (SM) - trace gravel, moist, very dark grey, compact - and sand (SM), frequent sand laminations (up to 150mm) some clay, compact, wet, dark grey to black
			END OF BOREHOLE AT 9.1m

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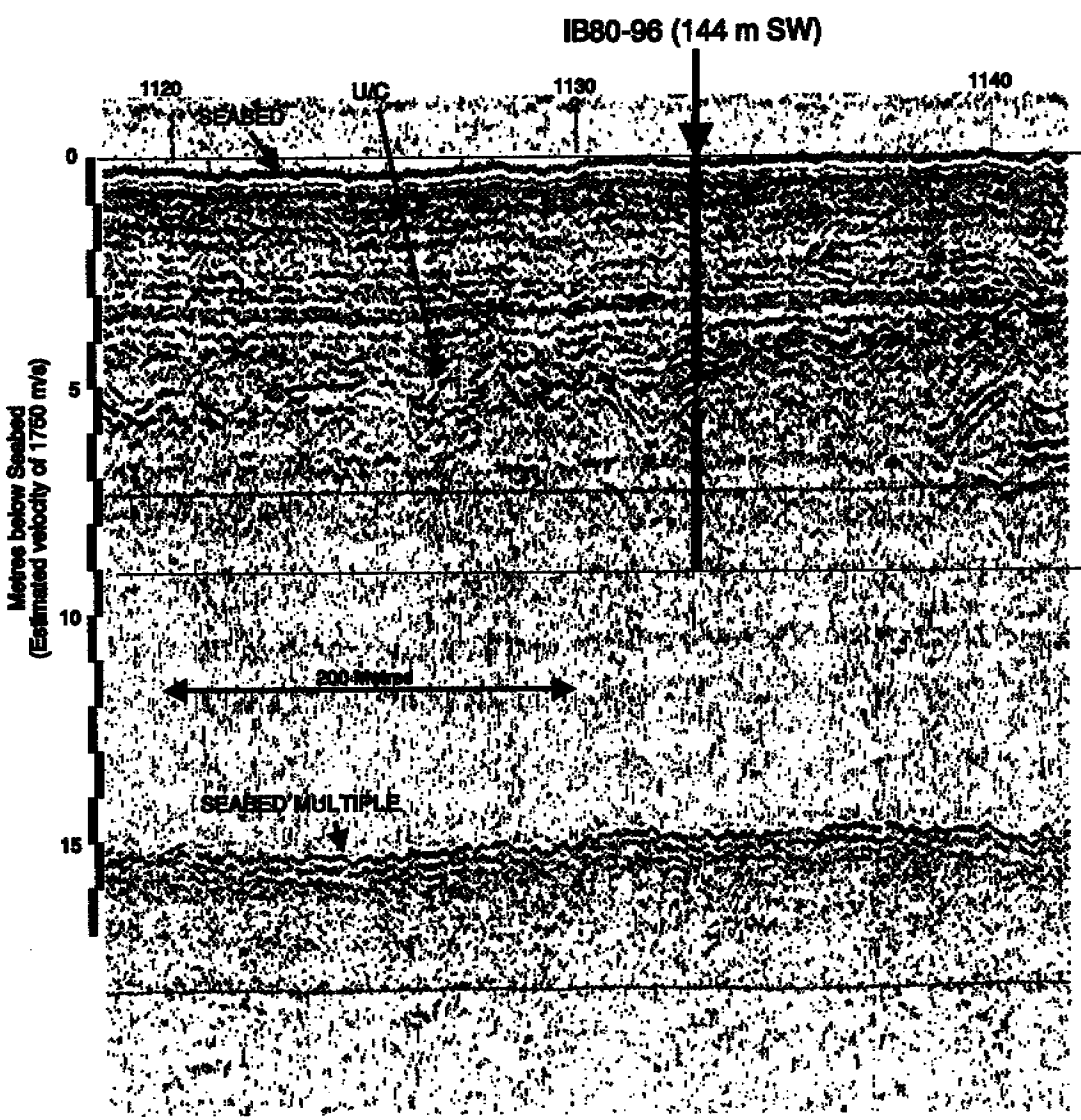
FIGURE 4-4



DEPTH (m)	USC	SOIL SYMBOL	IB80-96 DESCRIPTION OF SOILS
			WATER DEPTH - 11.9m
0.0			SAND (SP-SM) - trace silt, fine-grained, uniform, saturated, greyish brown
1.0	SP		- trace coarse-grained and medium grained, trace shell fragments
2.0			- trace coarse-grained to 5mm, angular smooth, wet
3.0	SP-SM		- trace silt, fine-grained, uniform, compact, moist to wet, greyish brown
4.0			- dense
5.0			- trace shell fragments, dense, moist to wet
6.0			- trace silt, with interbedded silty clay and organic streaks, moist, dark grey
7.0			
8.0			SAND and CLAY - interbedded, moist to wet
9.0			SAND (SM) - some silt to silty, fine grained, homogeneous, uniform, dense, moist to wet, dark grey
			- silty
			- trace to some silt, fine-grained, uniform, wet, dark grey
			END OF BOREHOLE AT 9.1m

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FIGURE 4-5

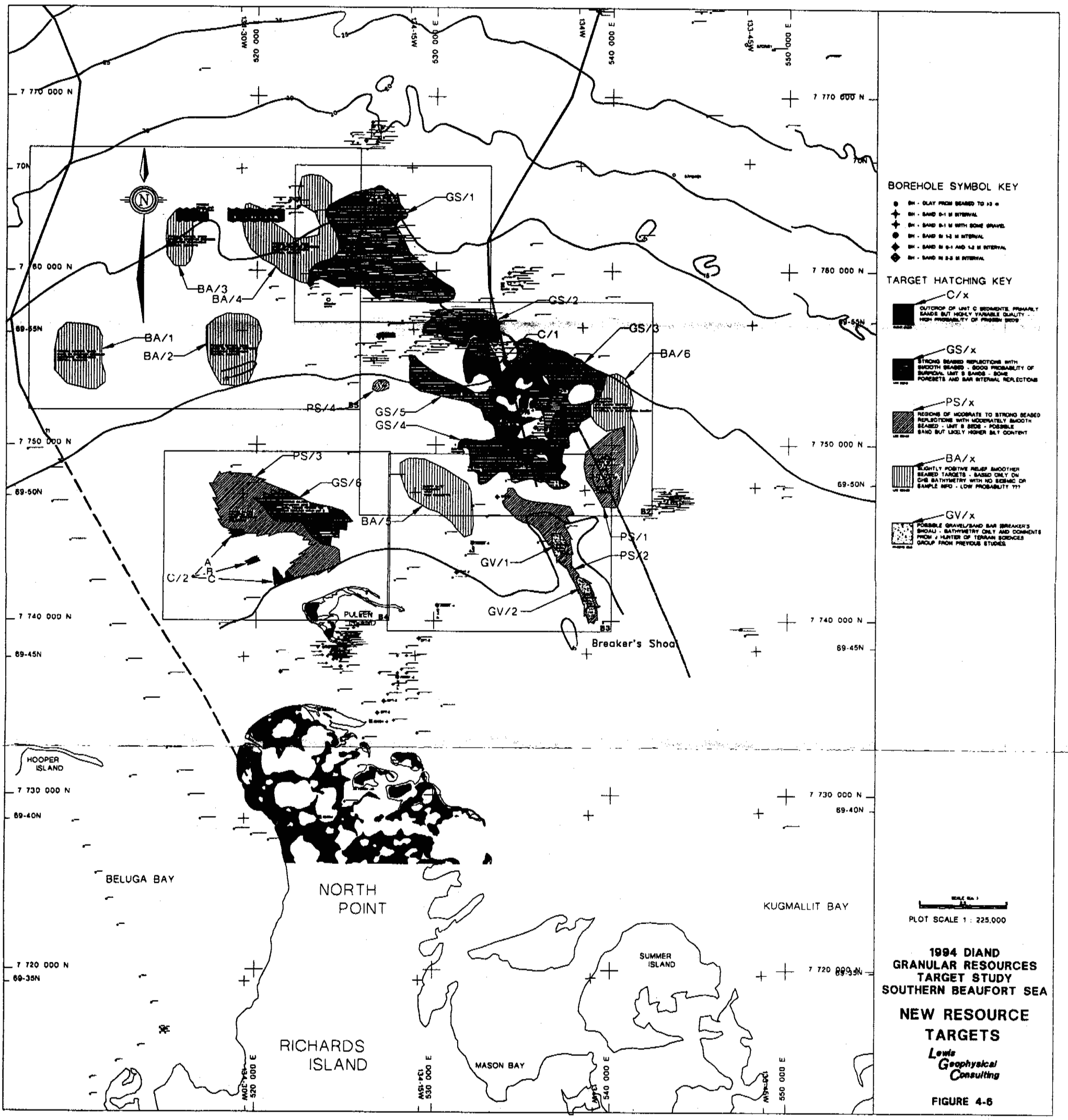
520 000 E
530 000 E
540 000 E
550 000 E
7 770 000 N
7 760 000 N
7 750 000 N
7 740 000 N
7 730 000 N
7 720 000 N
69-55N
69-50N
69-45N
69-40N
69-35N
GS/1
GS/2
GS/3
GS/4
GS/5
GS/6
C/1
BA/1
BA/2
BA/3
BA/4
BA/5
BA/6
PS/1
PS/2
PS/3
PS/4
GV/1
GV/2
C/2
A
B
C
PULLEN
Breaker's Shoal
HOOPER ISLAND
BELUGA BAY
NORTH POINT
RICHARDS ISLAND
MASON BAY
SUMMER ISLAND
KUGMALLIT BAY
BOREHOLE SYMBOL KEY
TARGET HATCHING KEY
C/x
GS/x
PS/x
BA/x
GV/x
PLOT SCALE 1 : 225,000
1994 DIAND
GRANULAR RESOURCES
TARGET STUDY
SOUTHERN BEAUFORT SEA
NEW RESOURCE
TARGETS
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FIGURE 4-6

4-2 Resource Target Map Sheets

With the aim of providing reasonable physical size and working scale visual presentation of the resource target sites the map sheet of Figure 4-6 has been sub-divided into five smaller scale working map sheets. The index outlines of these working map sheets has been presented on Figures 2-2 and 4-6 and the sheets have been designated as map sheets B1 through B5, beginning from the Isserk Borrow site area in the north of the study grid and progressing clockwise around to the northwest. These map sheets are presented as Figures 4-7 to 4-11 and include a visual representation of the locations of proposed boreholes and geophysical survey grids discussed below.

4-2-1 Sheet B1 - Isserk

Map sheet B1 is shown in Figure 4-7 at a plot scale of 1:50,000 covering the present Isserk Borrow area. The boundaries of the Isserk area have been slightly modified from the EOR, 1988 report based on the additional geophysical and geotechnical data that was available during this study. The Isserk site has been given the designation GS/1 under the current site numbering scheme. At this time no additional borehole sites have been proposed for this site area as the present sampling coverage is quite extensive. It is advised that the four east west and 3 north south proposed geophysical survey lines shown on the map sheet be run during a future survey program to act as a baseline example and truthing check of a known granular resource area for the particular geophysical systems that are employed on that survey program. These lines may also aid in the understanding of the site area sedimentary structures, in particular they may provide some clues as to the source area for these granular sediments which is still in question.

4-2-2 Sheet B2 - Pipeline

Map sheet B2 shown in Figure 4-8 at a plot scale of 1:50,000 represents the most complex region in the study area with a significant number of potential granular resource targets. This sheet has been referred to as the Pipeline sheet since one of the tentatively planned pipeline routes from the Amauligak discovery site to North Point passes through this region. As a result this area has had the most extensive recent geophysical coverage of any of the map sheets presented in this study and there has been extensive borehole and geotechnical testing completed along the pipeline corridor at least.

At the core of the granular resource targets on this map sheet is the central C1 site which is generally oval in shape with a long axis of 9.1 km oriented along a bearing of 326° True and a short axis width of approximately 3.6 km. This target represents a region where the Unit C sediments are exposed or very nearly exposed at the seabed. The boundaries of this target area are quite complex as far as could be mapped from the present coverage and show a number of residual basins and embayments that contain finely banded reflections of probable lacustrine clays. The basin and embayment structures are interpreted to be remnants of thermokarst lakes on the old land surface and would likely represent poor borrow regions. Permafrost (Hummocky Acoustic Permafrost) is commonly within 5 to 8 m of the seabed through some portions of this site as evidenced during the pipeline borehole transects through the region. Resource quality may be highly variable in this region as the seismic records show considerable variations in internal bedding character and structure over distances of only tens to hundreds of metres. In order to map these fine scale bedding structures survey line spacings in the order of 50 m or less would be necessary. Eleven possible borehole sites have been specified within the region to test the variability of the potential resource throughout a broader region of the site area. Figures C1-1 through C1-11 presented in Section 4-3 on the proposed borehole sites indicate some of the varied acoustic responses and interpreted resource characteristics expected within this site area. At this time reasonably extensive survey coverage over this site area is available and it is considered that the broad coverage of geophysical lines outline on Figure 4-8 would only provide a basic correlation coverage of the target. Should more detailed information on the site be required a limited extent sub-survey grid of 50 or 100 m line spacing could be set up to provide the site specific information that would be required to map the actual internal structures of the Unit C potential resources.

Possible resource site GS2 is located in the northwest corner of the map sheet area. This site is acoustically similar to the Isserk granular resource area with a strongly reflective seabed and a well defined multiple reflection. The Unit C regional unconformity is typically 2 to 6 m below the seabed which defines this site to be composed of coarser faction Unit B materials, likely reworked and distributed during the inundation of the C1 site area. Numerous samples indicating sands have been taken over the site, however they were all from the Gulf 1982 M.V. Broderick program which was a gravity coring study that seldom had core depths of greater than about 15 cm. and quantitative granular resource analysis was not completed. As a result no definitive statement can be made as to the resource quality of this site area. The acoustic records on this site show slightly less internal backscatter character than the central portions of the Isserk site and therefore may contain less gravel fraction, borehole or vibro-coring would be required on this site to confirm this. Also, the boundaries of this site are based on limited seismics at present and a 100 to 150 m line spacing geophysical survey

grid with sidescan data would significantly help in defining the areal extent of this site. No source direction indicator structures were apparent on the presently available seismics and therefore a north-south, east-west grid is currently proposed but could be re-oriented to optimize structure definition with some additional data.

Possible resource site GS3 lies to the north and east of the central C1 site. This site is again acoustically similar to the Isserk site but grades out over the boundary of the Kugmallit Channel which runs along the eastern edge of the C1 site. The acoustics suggest a slightly stronger seabed return and multiple reflection in the northern portion of the site area which may indicate slightly coarser sands or even some gravel content in this region. The records also suggest that the granular materials are most likely a veneer structure overlying clays and silts deeper in the Unit B section. Quality of this resource target is presently unknown as the only samples in the site in the northwestern corner were very short and had not been quantitatively analyzed. A series of 3 boreholes has been proposed for this site area. Geophysically this site is relatively well covered by the present seismics but should an improvement in systems be achieved in future (particularly heave compensation) a more detailed grid could be useful.

Resource site GS4 lies along the southern side of the C1 site. Again the seismics show relatively strong seabed and multiple reflections much like the Isserk area though with lesser internal backscatter reflectivity. This may imply that resource quality is actually quite poor and it is ambiguous as to whether this site should fall into the "PS" series. A series of five borehole or probe holes has been proposed over this site area primarily to test resource quality. The area is quite well covered by the present geophysical survey information and the same criteria noted above should apply to additional survey. This resource target may represent a residual overwash transport of the coarser fraction of sediments as the C1 target site was inundated and has been continually eroded by wave actions. This is suggested by the south facing foreset bedding structure observed along the southern boundary of the site at proposed borehole site GS4-5.

Site GS5 is an east-west elongate structure lying on the western side of site C1 about 2 km to the south of site GS2. This target generally shows a moderate strength seabed and multiple reflection return with a quite high degree of internal backscatter reflectivity within the Unit B sediments overlying Unit C materials. These characteristics suggest that there may be a thin veneer of clays and silts overlying either coarser sands with some unknown percentage of gravels or cobbles, or that the internal backscatter may be generated by heavily paleoscoured finely banded silt/clay beds. Though this site contained no previous sample information the relatively strong backscatter and strengths of acoustic

returns in general make it an interesting possible gravel site, thus it has been designated as a "GS" site. Only one proposed borehole site was outlined for this site, primarily because the seismic coverage on the site was extremely limited. This site should be covered by a detailed 100-150 m grid in a future geophysical survey as very little information is presently known about it (particularly if sampling shows it to actually be a gravelly site). Also the present shape and boundaries of this site are highly in question and the orientation of the structure is inconsistent with present understandings of sediment mobility and currents in the region. Thus a presently unknown source area may lie to the west.

Site PS1 is an unique and unusual possible resource site within the southwestern corner of the map sheet. The acoustics indicate a strong well defined seabed multiple through this region and shows eastward lee slope (eastward migrating) sandwave or mudwave features on the seabed. The sandwave features imply mobile surficial sands prograding over the basal finer silts and clays commonly associated with the Kugmallit Channel. Boreholes presently completed in the site area are ambiguous with some reporting sands and others not, which would be consistent with a thin mobile layer of sands in the area. The reported sands are described as fine and silty but there is presently no quantitative analysis of these sands that could confirm their viability as a granular resource. Two boreholes have been proposed in the site area, one on top of a sand wave feature and one in the basal area between sand waves. Since these sandwaves are likely dynamic in nature the exact location would have to be determined on site (with sidescan or acoustic profiles) as the locations were presently chosen from data collected almost 6 years ago and presently the rate of movement of these features is unknown. Detailed survey and possible resurvey at intervals (sidescan mosaic) could be completed to attempt to determine the rates of movement and true orientation of these features should these sandwaves prove to be a viable granular resource.

Site area PS4 is a very small region approximately 1.5 km to the west of the western end of the GS5 site. This target site is based on only one survey line and may actually be an extension of the GS5 target though additional geophysical survey would be required to link these sites. As presently defined this site is thought to be too small and isolated to be of much significance.

The last site completely within the B2 map area is the BA6 site along the eastern side of the map area and lies within the Kugmallit Channel. This site is presently defined only by bathymetric data with no geophysical of borehole confirmations. The northern portion of the site may be an extension of the GS3 target and the southern portion of the site is suspected to be an extension or expansion of the PS1 target area of mobile sediment features. One borehole is proposed in this region at present and the

area should be surveyed with seismic and sidescan to confirm the present interpretations. Of the Bathymetrically defined target site areas this one shows the most likelihood of being a viable granular resource area.

4-2-3 Sheet B3 - Breakers Shoal

Map sheet B3 shown in Figure 4-9 at a plot scale of 1:60,000 represents the region around Breakers Shoal in the southwestern portion of the map area. There are four granular resource targets on this map sheet plus the southern portions of three of the targets discussed on map sheet B2.

Two potentially gravel and sand resource targets are identified as the two isolated shoal crests of the Breakers Shoal feature. These have been identified as GV1 and GV2 in the southeastern quadrant of the map sheet. There is no geophysical or borehole information within the current data sets to cover these areas and they have been identified as potential gravel resource areas on the logic that these features represent recently inundated island features and there is a strong likelihood of residual gravel/cobble lags being present. Also a verbal report of gravel on the seabed on these shoals was provided by Dr Jim Hunter of the Terrain Sciences Division of the GSC to Mr Bob Gowan (Gowan, pers comm.). Two proposed borehole sites have been located on these shoal features though it is anticipated that the regions may not be accessible to a winter drilling program because of ice ridging around these shoals. Possible summer sampling could be achieved from a small boat or zodiac under ideal weather conditions of virtually no wind and swell.

Target site PS2 is the area surrounding the breakers shoal peaks with an extension toward the northwest. The northwestern extension area does contain some limited geophysical coverage which indicates a moderately reflective seabed with a reasonably strong and well defined multiple reflection. The seismic data in this area commonly show shallow gas in the Unit B sediments which is commonly associated with clays and silts or decaying peat like materials, and the top of Unit C is deep (8-12 m) and generally is quite poorly defined on the records (gas masking?). It is interpreted that the sands in this region would likely be a mobile surficial veneer that is generally quite thin and may be silty and of poor resource quality. Six proposed borehole or probe holes have been defined in this region, primarily as a check on resource quality and verification. Four additional geophysical survey lines have been laid out, again mostly as confirmation with new systems. Additional survey lines have not been identified in the immediate vicinity of the Breakers Shoal because of the navigational hazard that this region presents. Any lines that could be obtained under good weather conditions would be useful in this area.

Target site BA5 is a primarily bathymetrically-defined site in the northwestern quadrant of the survey area. This site lies over the border of the bathymetric contour change between the 1980's data sets and the early 70's data sets and is therefore not of particularly high quality. Essentially the area has been defined by the slight seaward bulge in the relatively smooth bathymetric contours. The southeastern portion of this site area does contain some moderate to poor quality seismic data which suggests that the seabed is composed of silts or silty sands however and the primary area in question is the region toward the northwestern end of the target site. Essentially this site is defined to be consistent with the other bathymetric sites picked on sheet B5, but it is felt to be generally a low probability site area.

4-2-4 Sheet B4 - Pullen New Site

Map sheet B4 shown in Figure 4-10 at a plot scale of 1:60,000 represents a new target area defined in this study which is centred about 5 km to the north-northwest of Pullen Island. Three types of target feature are noted on this sheet, some local outcrops of Unit C materials designated sites C2-A, B and C in the southwest, a broad area of type PS target area in the central portion and a region of GS type target area on the northeastern side of the target group area. These targets have been defined on the basis of only 5 geophysical survey lines passing through the region and therefore their boundaries have been shown primarily as a sawtooth edge indicating a high degree of uncertainty as to their exact locations.

Target sites C2-A, B and C are small local regions of Unit C outcrop that are poorly constrained and most likely of variable resource quality. They all show strong seabed reflections with well defined seabed multiples suggesting surficial sands or silty sands and very highly reflective Unit C materials within about one metre of the seabed. The basal Unit C materials may represent lag gravel materials or they could be still frozen and/or gas charged which would produce virtually the same acoustic response. Two proposed borehole sites are defined within these targets for the primary purpose of determining resource quality.

Target area PS3 is a poorly defined area to the north and east of the C2 site areas. The few acoustic lines through this region indicate a strong seabed reflection with well defined seabed multiple reflections. Through much of this region the sub-surface reflections are masked by shallow gasses which makes detailed characterization and thickness definitions of the surficial Unit B materials virtually impossible

from the acoustic data available. Also because of this, through much of this region the top of Unit C is not observed and may be either deep of shallow in the area. The northwestern portion of this target site has been roughly defined by a gentle seaward bulge in the bathymetric contours with no seismic or borehole confirmation at present. Three proposed borehole sites are defined in this area for confirmation of granular resource and to assist in understanding the geological setting of this target feature.

Target area GS6 along the northeastern side of the target grouping is the region that first drew attention to this area. Seismics through this region indicate a strong seabed reflector with well defined multiple reflections, and the region is virtually free of shallow gas masking areas which allow an interpretation of the internal bedding structures seen within the Unit B sediments that are typically masked in the PS3 site area. Through this region a number of bar or spit and foreset bedding structures are visible on the Seistec records which suggest the presence of sandy materials in the section. This region also contained three boreholes indicating the presence of sands within the shallow section with borehole III-4 indicating a 3.8 m thickness of good quality clean sands. Six additional borehole sites have been defined in this target as verification of the resource quality and also to assist in the geological interpretation and definition of this site area.

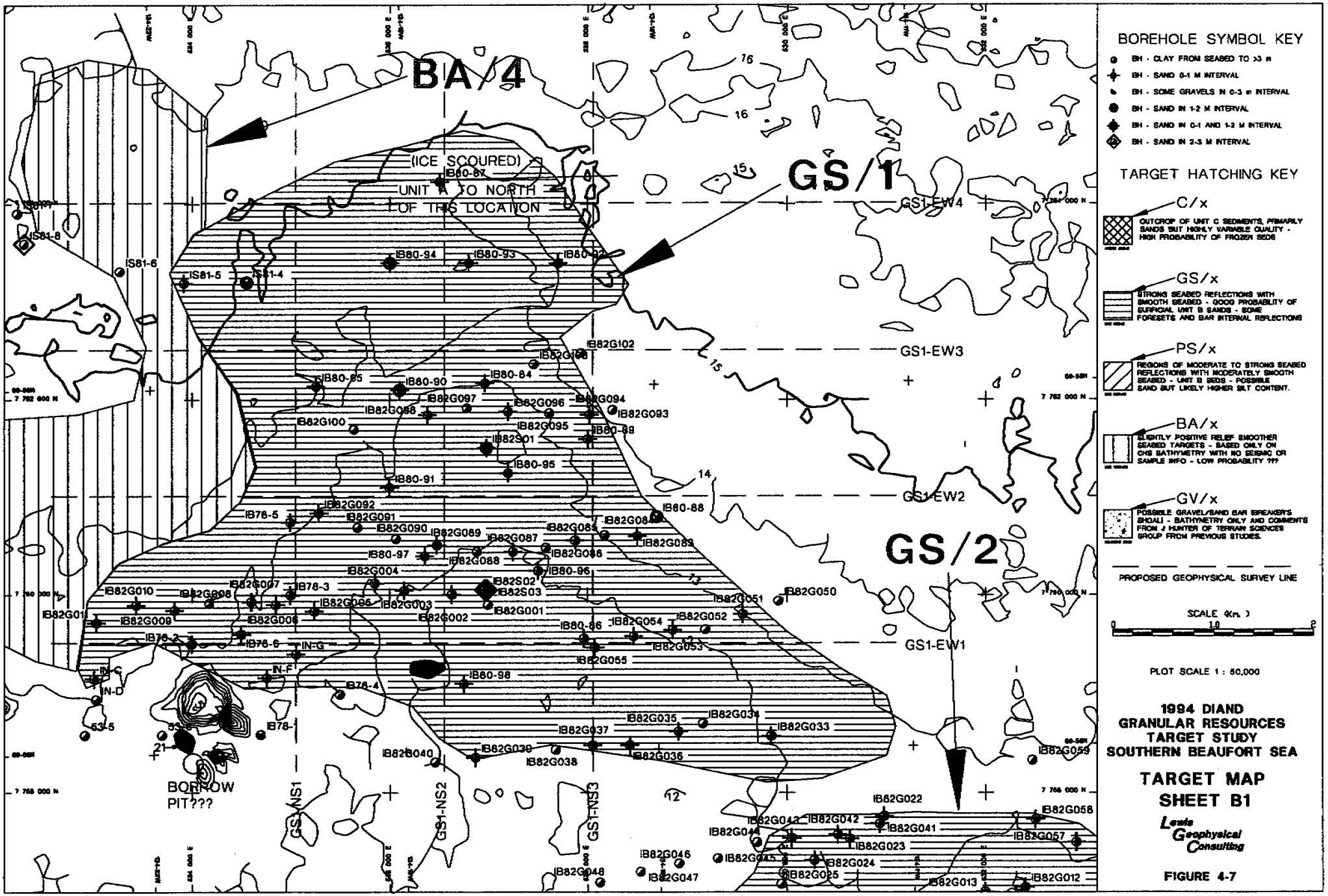
A proposed geophysical survey grid of 8, 9 km long east-west and 10, 7 km long north south lines is proposed for this site area. The grid is laid out in a 1 km grid spacing and infill lines at sub-grid spacings of 100-150 m would be recommended over the GS6 region in order to better map and interpret the complex bedding structures presently seen on the two lines that intersect this region.

4-2-5 Sheet B5 - Western Bathy

Map sheet B5 shown in Figure 4-11 at a plot scale of 1:60,000 represents the identified potential granular resource sites in the western portion of the study area. There are few geophysical survey lines through this area and the ones that do transect the region show a general thickening of the Unit B sediments toward the west into the Kugmallit Channel physiographic area. Essentially five site areas have been outlined on this map sheet and four of these are defined solely on the basis of the new bathymetric contour data. The other defined target area is a region in the north central portion of the map area where one survey line shows the top of Unit C to be within 1-1.5 m of the seabed. This target is actually overlapped by the bathymetrically defined sites.

The bathymetric target sites BA1, 2, 3 and 4 have been selected on the basis of slightly smoother seabed contours (less convoluted) which may indicate that the seabed sediments are less cohesive in nature (ie sands or silty sands) and that they do not preserve the ice scouring that is seen within most of the marine clay regions of Unit A sediments further toward the north. Normally these smoother sediment contours are also seen to bulge slightly seaward which suggests that they may be slightly more resistant residual highs which may also indicate sandy or coarser grained materials. With the lack of geophysical and geotechnical data over these target sites resource quality is in total question. At this time no proposed boreholes have been selected for these sites but broadly spaced geophysical survey lines have been defined at least as an initial coverage of these sites. Should the on-site geophysics prove to be promising, additional survey lines could be run and sample sites selected. Of the sites outlined, site BA4 is closest to the Isserk area and at this time would appear to be the most promising site.

The C3-A and B targets are partially encompassed within the BA3 and BA4 bathymetric sites. Presently the one seismic line passing through this site area indicates a relatively thin veneer of Unit B silts (or fine sand) overlying Unit C materials within approximately 1 to 1.5 m of the seabed. The significant gaps in the present data would be addressed by the survey grid outline on the map sheet and a more comprehensive interpretation of these target would have to wait on these additional survey lines.


BA/4
GS/1
GS/2
(ICE SCOURED)
UNIT A TO NORTH
OF THIS LOCATION
GS1-EW4
GS1-EW3
GS1-EW2
GS1-EW1
GS1-NS1
GS1-NS2
GS1-NS3
BORROW
PIT???
BOREHOLE SYMBOL KEY
BH - CLAY FROM SEABED TO >3 m
BH - SAND 0-1 M INTERVAL
BH - SOME GRAVELS IN 0-3 m INTERVAL
BH - SAND IN 1-2 M INTERVAL
BH - SAND IN 0-1 AND 1-2 M INTERVAL
BH - SAND IN 2-3 M INTERVAL
TARGET HATCHING KEY
C/x
OUTCROP OF UNIT C SEDIMENTS, PRIMARILY SANDS BUT HIGHLY VARIABLE QUALITY - HIGH PROBABILITY OF FROZEN SEDS
GS/x
STRONG SEABED REFLECTIONS WITH SMOOTH SEABED - GOOD PROBABILITY OF SURFICIAL UNIT B SANDS - SOME FORESETS AND BAR INTERNAL REFLECTIONS
PS/x
REGIONS OF MODERATE TO STRONG SEABED REFLECTIONS WITH MODERATELY SMOOTH SEABED - UNIT B SEDS - POSSIBLE SAND BUT LIKELY HIGHER SILT CONTENT.
BA/x
SLIGHTLY POSITIVE RELIEF SMOOTHER SEABED TARGETS - BASED ONLY ON CHS BATHYMETRY WITH NO SEISMIC OR SAMPLE INFO - LOW PROBABILITY ???
GV/x
POSSIBLE GRAVEL/SAND BAR BREAKERS (SHOAL) - BATHYMETRY ONLY AND COMMENTS FROM J HUNTER OF TERRAIN SCIENCES GROUP FROM PREVIOUS STUDIES.
PROPOSED GEOPHYSICAL SURVEY LINE
SCALE (Km.)
0
1.0
2
PLOT SCALE 1 : 50,000
1994 DIAND
GRANULAR RESOURCES
TARGET STUDY
SOUTHERN BEAUFORT SEA
TARGET MAP
SHEET B1
Lewis Geophysical Consulting
FIGURE 4-7

GS/2
GS/3
C/1
BA/6
GS/5
GS/4
PS/4
BA/5
PS/1
B2-NS1
B2-EW1
THIN SURFICIAL
SURFICIAL FORESETS
C OUTCROP VARIABLE QUAL
BATHYMETRIC PROMONTORY WITH SMOOTH CONTOUR SUGGESTING NON-COHESIVE MATERIALS ?? MOBILE SURFICIAL SANDS??
WAVEFORMS ON SEABED WITH MODERATE REFLECTIVITY AND WELL FORMED MULTIPLE REFLECTOR
SANDWAVES?? OR SILTY MUDWAVES??
THIN ? UNIT B S
BA5-1-N SMOOTH BATHY PROMONTORY ????? POOR PROSPECT??
STRONGER SEABED REFLECTIVITY
GS2-1-S
GS3-2-S
GS3-1-S
GS3-3-S
GS4-1-S
GS4-2-S
GS4-3-S
GS4-4-S
GS4-5-S FORESETS
GS5-1-S
C1-8-S
C1-11-S
C1-10-S POS GRV
C1-9-S
C1-1-S
C1-2-S
C1-3-S
C1-4-S
C1-5-S
C1-6-S
C1-7-S
BA5-2-S
PS1-1-S
PS1-2-S TROUGH
PS2-1-S
PS2-2-S
PS2-3-S
PS2-4-S
PS2-5-S
PS2-6-N
CPT-14
CPT-10
CPT-9
CPT-12
90BH-5
TSD-NPE
SD/PT
AKP88S17
AWBH3
BA6-1-N
BS502
BS503
BS411
BS414
BS413
BS412
2120-4
L30-P1G
MB86GC03
MB86GC04

▼ PROPOSED SAMPLE LOCATIONS

BOREHOLE SYMBOL KEY

- BH - CLAY FROM SEABED TO >3 m
- BH - SAND 0-1 M INTERVAL
- BH - SOME GRAVELS IN 0-3 m INTERVAL
- BH - SAND IN 1-2 M INTERVAL
- BH - SAND IN 0-1 AND 1-2 M INTERVAL
- BH - SAND IN 2-3 M INTERVAL

TARGET HATCHING KEY

C/x — OUTCROP OF UNIT C SEDIMENTS, PRIMARILY SANDS BUT HIGHLY VARIABLE QUALITY - HIGH PROBABILITY OF FROZEN SEDS

GS/x — STRONG SEABED REFLECTIONS WITH SMOOTH SEABED - GOOD PROBABILITY OF BURFICIAL UNIT B SANDS - SOME FORESETS AND BAR INTERNAL REFLECTIONS

PS/x — REGIONS OF MODERATE TO STRONG SEABED REFLECTIONS WITH MODERATELY SMOOTH SEABED - UNIT B SEDS - POSSIBLE SAND BUT LIKELY HIGHER SILT CONTENT.

BA/x — SLIGHTLY POSITIVE RELIEF SMOOTHER SEABED TARGETS - BASED ONLY ON CHS BATHYMETRY WITH NO SEISMIC OR SAMPLE INFO - LOW PROBABILITY ???

GV/x — POSSIBLE GRAVEL/SAND BAR BREAKERS SHOALI - BATHYMETRY ONLY AND COMMENTS FROM J HUNTER OF TERRAIN SCIENCES GROUP FROM PREVIOUS STUDIES.

PROPOSED GEOPHYSICAL SURVEY LINES

SCALE (Km.) 0 1.0 2

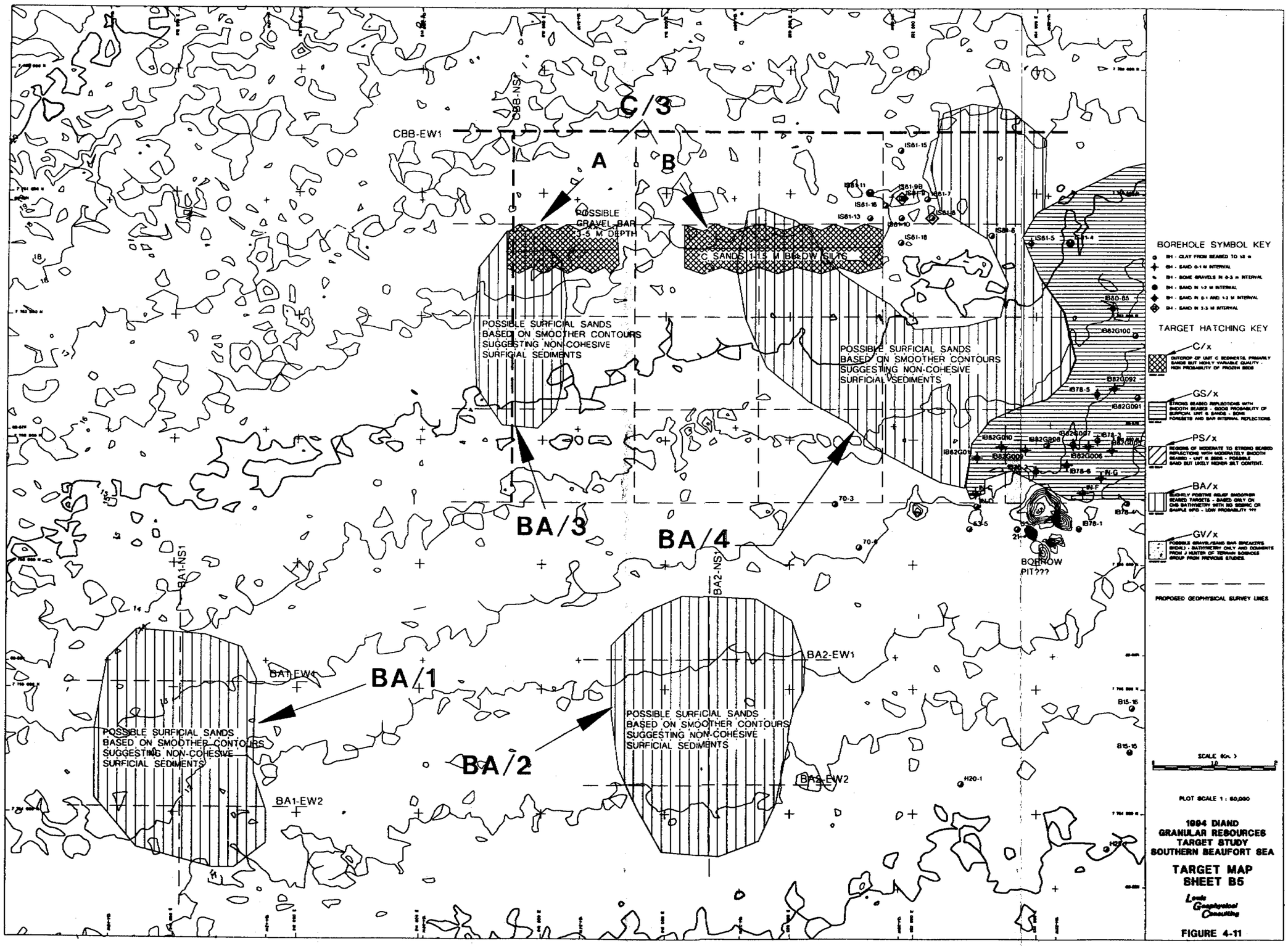
PLOT SCALE 1 : 50,000

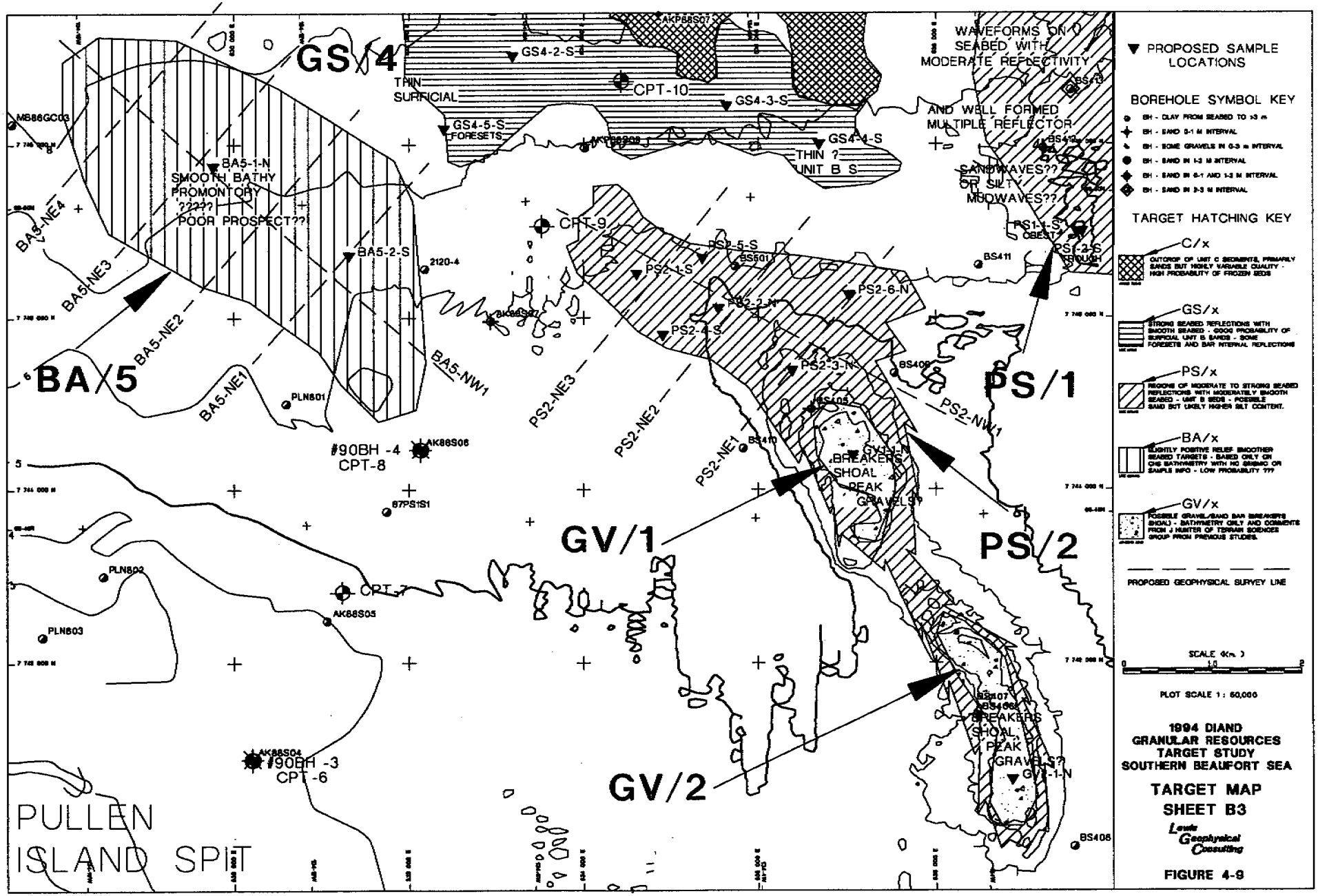
1994 DIAND GRANULAR RESOURCES TARGET STUDY SOUTHERN BEAUFORT SEA

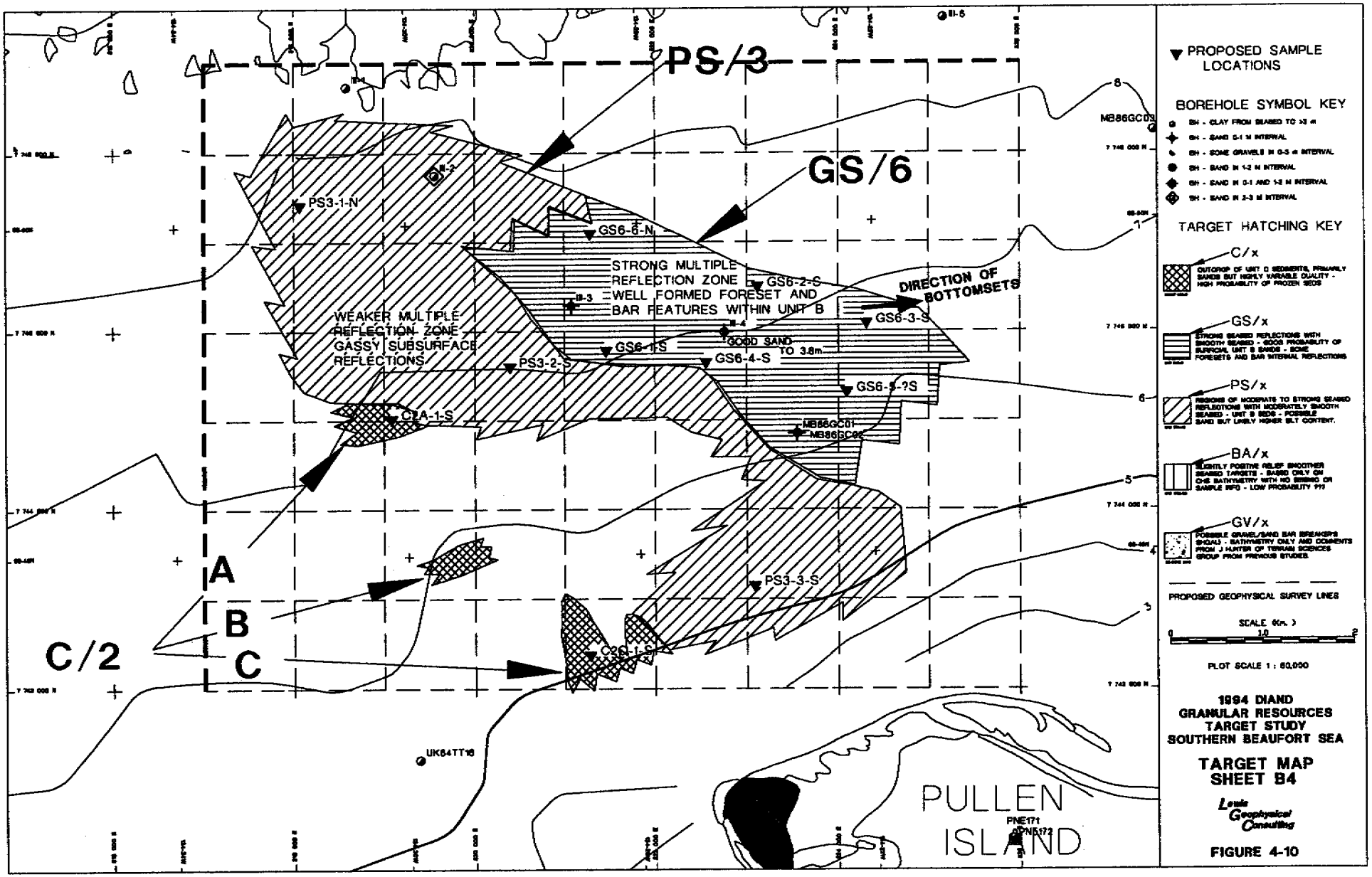
TARGET MAP SHEET B2

Lenis Geophysical Consulting

FIGURE 4-8


C/3
CBB-NS1
CBB-EW1
A
B
POSSIBLE GRAVEL BAR 1-5 M DEPTH
PC SANDS 1-1.5 M BSB-DW SILTS
POSSIBLE SURFICIAL SANDS BASED ON SMOOTHER CONTOURS SUGGESTING NON-COHESIVE SURFICIAL SEDIMENTS
POSSIBLE SURFICIAL SANDS BASED ON SMOOTHER CONTOURS SUGGESTING NON-COHESIVE SURFICIAL SEDIMENTS
BA/3
BA/4
BA1-NS1
BA1-EW1
BA/1
BA/2
POSSIBLE SURFICIAL SANDS BASED ON SMOOTHER CONTOURS SUGGESTING NON-COHESIVE SURFICIAL SEDIMENTS
BA1-EW2
BA2-NS1
BA2-EW1
POSSIBLE SURFICIAL SANDS BASED ON SMOOTHER CONTOURS SUGGESTING NON-COHESIVE SURFICIAL SEDIMENTS
BA2-EW2
BORROW PIT???
IS81-15
IS81-11
IS81-9B
IS81-9
IS81-7
IS81-16
IS81-8
IS81-13
IS81-10
IS81-18
IS81-6
IS81-5
IS81-4
IB80-B5
IB82G100
IB82G092
IB78-5
IB82G091
IB82G097
IB78-3
IB82G080
IB82G098
IB82G081
IB82G009
IB82G006
IB78-6
BI-G
BI-F
BI-E
IB78-4
IB78-1
70-3
70-9
63-5
21
H20-1
B15-16
B15-15
BOREHOLE SYMBOL KEY
BH - CLAY FROM SEABED TO x.x m
BH - SAND 0-1 M INTERVAL
BH - SOME GRAVELS IN 0-3 m INTERVAL
BH - SAND IN 1-2 M INTERVAL
BH - SAND IN 0-1 AND 1-2 M INTERVAL
BH - SAND IN 2-3 M INTERVAL
TARGET HATCHING KEY
C/x
OUTCROP OF UNIT C SEDIMENTS, PRIMARILY SANDS BUT HIGHLY VARIABLE QUALITY - HIGH PROBABILITY OF FROZEN BEDS
GS/x
STRONG SEABED REFLECTIONS WITH SMOOTH SEABED - GOOD PROBABILITY OF SURFICIAL UNIT B SANDS - SOME FORESETS AND BAR INTERNAL REFLECTIONS
PS/x
REGIONS OF MODERATE TO STRONG SEABED REFLECTIONS WITH MODERATELY SMOOTH SEABED - UNIT B SEEN - POSSIBLE SAND BUT LIKELY HIGHER SILT CONTENT.
BA/x
SLIGHTLY POSITIVE RELIEF SMOOTHER SEABED TARGETS - BASED ONLY ON CHS BATHYMETRY WITH NO SEISMIC OR SAMPLE INFO - LOW PROBABILITY ???
GV/x
POSSIBLE GRAVEL/SAND BAR BREACHES (SHOAL) - BATHYMETRY ONLY AND COMMENTS FROM J HUNTER OF TERRAIN SCIENCES GROUP FROM PREVIOUS STUDIES
PROPOSED GEOPHYSICAL SURVEY LINES
SCALE (Km.)
10
PLOT SCALE 1 : 50,000
1984 DIAND GRANULAR RESOURCES TARGET STUDY SOUTHERN BEAUFORT SEA
TARGET MAP SHEET B5
Lewis Geophysical Consulting
FIGURE 4-11


GS/4
BA/5
GV/1
GV/2
PS/1
PS/2
THIN SURFICIAL
GS4-2-S
GS4-3-S
GS4-5-S FORESETS
GS4-4-S THIN ? UNIT B S
CPT-10
WAVEFORMS ON SEABED WITH MODERATE REFLECTIVITY AND WELL FORMED MULTIPLE REFLECTOR
SANDWAVES?? OR SILTY MUDWAVES??
BA5-1-N SMOOTH BATHY PROMONTORY ????? POOR PROSPECT??
BA5-2-S
BA5-NE4
BA5-NE3
BA5-NE2
BA5-NE1
BA5-NW1
CPT-9
PS2-5-S
PS2-1-S
PS2-2-N
PS2-4-S
PS2-6-N
PS2-3-N
PS2-NE3
PS2-NE2
PS2-NE1
PS2-NW1
PS1-1-S CREST
PS1-2-S TROUGH
GV1-1-N BREAKERS SHOAL PEAK GRAVELS?
GV1-1-N
#90BH -4 CPT-8
#90BH -3 CPT-6
CPT-7
PULLEN ISLAND SPIT
MB86GC03
AK88S06
AK88S05
AK88S04
87PS1S1
PLN601
PLN602
PLN603
2120-4
BS411
BS409
BS410
BS405
BS407
BS406
BS408
PROPOSED SAMPLE LOCATIONS
BOREHOLE SYMBOL KEY
TARGET HATCHING KEY
C/x
GS/x
PS/x
BA/x
GV/x
PROPOSED GEOPHYSICAL SURVEY LINE
SCALE (Km.)
PLOT SCALE 1 : 50,000
1994 DIAND GRANULAR RESOURCES TARGET STUDY SOUTHERN BEAUFORT SEA
TARGET MAP SHEET B3
Lewis Geophysical Consulting
FIGURE 4-9


PS/3
GS/6
C/2
A
B
C
PS3-1-N
GS6-6-N
STRONG MULTIPLE
REFLECTION ZONE
WELL FORMED FORESET AND
BAR FEATURES WITHIN UNIT B
GS6-2-S
GS6-3-S
DIRECTION OF
BOTTOMSETS
WEAKER MULTIPLE
REFLECTION ZONE
GASSY SUBSURFACE
REFLECTIONS
GS6-1-S
GS6-4-S
GOOD SAND
TO 3.8m
PS3-2-S
GS6-5-?S
C2A-1-S
MB86GC01
MB86GC02
PS3-3-S
C2C-1-S
UK84TT16
PULLEN
ISLAND
PNE171
PNE172
PROPOSED SAMPLE
LOCATIONS
BOREHOLE SYMBOL KEY
TARGET HATCHING KEY
C/x
GS/x
PS/x
BA/x
GV/x
PROPOSED GEOPHYSICAL SURVEY LINES
SCALE (Km.)
PLOT SCALE 1 : 60,000
1994 DIAND
GRANULAR RESOURCES
TARGET STUDY
SOUTHERN BEAUFORT SEA
TARGET MAP
SHEET B4
Lewis
Geophysical
Consulting
FIGURE 4-10

4-3 Borehole Target Sites

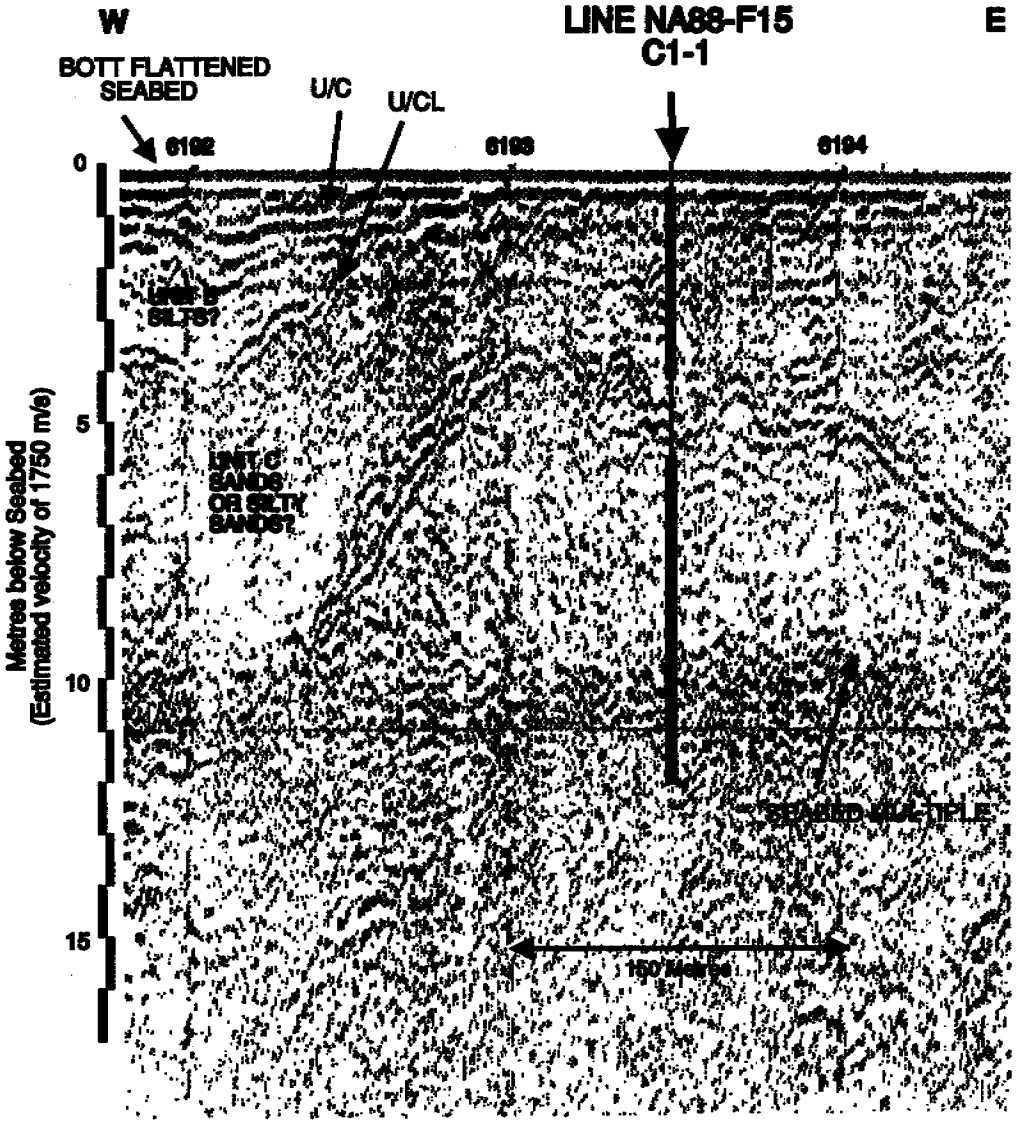
At this time proposed borehole site selections have been made for a possible winter drilling program from the new target areas of map sheets B2, B3 and B4. Selection of winter drilling targets has essentially been limited to these three map sheets for a number of reasons. First it was considered unlikely that a winter drilling program would be able to reach areas in water depths of greater than about 12-15 m because of progressively roughening ice conditions in the ice shear zone which usually falls in this water depth zone. Secondly Map Sheet B1 covers the Isserk area and already has considerable borehole coverage, and thirdly map sheet B5 contains only speculative bathymetric targets which should be surveyed geophysically first and their distance offshore and from logistics base would make them unlikely to be economically reached during a winter drilling program.

Proposed borehole locations are indicated by filled triangles (▾) on the map sheets and have been designated by a SITE_ID-BH_No-Seismic or No seismics coding. The boreholes are detailed in Table 2 for Map Sheet B2, Table 3 for Map Sheet B3, and Table 4 for Map Sheet B4. The tables give the UTM co-ordinates for each proposed borehole site, the expected water depths at the site, the correlating seismic line and fix number, if available, and a brief description of the predicted sediment conditions at the borehole site. If seismic data was available for the site location a figure is provided giving more detailed site condition predictions and showing the correlating seismic data. To avoid confusion in this section the Figures have been numbered by their SITE_ID coding numbers and will be maintained as such here.

TABLE 2: PROPOSED BOREHOLES MAP SHEET B2

PROP. SAMPLE NO	UTM EASTING	UTM NORTHING	WATER DEPTH (m)	SEISMIC SURVEY LINE	FIX TIME LOCATION	SEDIMENT PREDICTIONS / GEOLOGICAL COMMENTS MAP SHEET B2
C1-1-S	534,323.45	7,749,840.23	8.3	NA88-F15	6,193.5	Unit C sands @ seabed - @ 5 m clay or frozen sand - Fig C1-1 for detail
C1-2-S	534,915.37	7,749,840.23	8.1	NA88-F15	6,197.3	Unit C sands @ seabed - poss clay horizon or froz sand shallow - Fig C1-2
C1-3-S	535,698.64	7,749,853.51	8.1	NA88-F15	6,202.5	Unit C sands (gravels ?) @ seabed - see Fig C1-3 for detail
C1-4-S	536,476.40	7,749,839.21	8.1	NA88-F15	6,207.7	Unit C sands (grav ?) @ or very near seabed - see Fig C1-4 for detail
C1-5-S	534,698.86	7,750,884.88	8.9	NA88-F16	6,290.0	1.1 m surficial sand/silt over Unit C - See Fig C1-5 for detail
C1-6-S	534,168.20	7,750,893.81	9.1	NA88-F16	6,293.5	0.3-0.4 m cover over Unit C - poss ice or gravel bar at 3 m - See Fig C1-6 for detail
C1-7-S	533,614.63	7,750,893.81	9.1	NA88-F16	6,297.2	1 m veneer over Unit C sands / gravels ? - see Fig C1-7 for detail
C1-8-S	533,230.68	7,754,476.47	10.5	NA88-P1	1,733.0	1-2 m coarse surf lag over Unit C - gassy or cobbles ? see Fig C1-8 for detail
C1-9-S	537,201.97	7,751,521.77	9.1	NA88-F9	5,795.8	Steep dipping Unit C sands at seabed - ? good quality ? - Fig C1-9
C1-10-S	534,039.27	7,751,500.49	9.3	NA88-F9	5,775.0	1 m silt/sand veneer over Unit C - Poss gravel /cobbles - Fig C1-10
C1-11-S	537,183.06	7,752,589.63	9.3	NA88-F8	5,711.0	1.6 m sand/silt over poss sand/grav basin infill ?? See Fig C1-11 for detail
TSD-PF	534,842.00	7,749,512.00	8.0			Approx 20 m from BH-AKP88S07 - 40 m depth log attached
TSD-NPF	535,920.00	7,751,500.00	9.0			Approx 16 m from BH-87PS2S1 - 19.2 m depth, log attached

PROP. SAMPLE NO	UTM EASTING	UTM NORTHING	WATER DEPTH (m)	SEISMIC SURVEY LINE	FIX TIME LOCATION	SEDIMENT PREDICTIONS / GEOLOGICAL COMMENTS MAP SHEET B2
GS2-1-S	533,456.47	7,756,182.49	11.5	NA88-P1	1,745.0	1.2 m surficial sand over complex B and into C @ 3.5 m - see Fig GS2-1 for detail
GS3-1-S	537,279.33	7,754,849.15	10.0	GU88-11	1,450.0	Approx 2.6 m of surficial sands (poss grav ?) see Fig GS3-1
GS3-2-S	535,949.84	7,754,857.24	9.9	GU88-11	1,380.0	Approx 2.5 m of surfical sands (poss grav ?) see Fig GS3-2
GS3-3-S	539,094.21	7,753,680.04	9.0	GU88-7B	1,690.0	1.5 m surficial mobile sands ? on bathy rise See Fig GS3-3 for detail
GS4-1-S	532,339.36	7,749,733.91	8.1	NA88-F15	6,181.0	Approx 2 m fine sand to silty sand over thick banded clays. See Fig GS4-1 for detail
GS4-2-S	533,189.18	7,749,008.58	7.6	GU88-2C	1,350.0	Approx 1.1 m fine sand to silty sand over thick banded clays. See Fig GS4-2 for detail
GS4-3-S	535,623.00	7,748,442.05	7.2	GU88-6A	1,380.0	Approx 2 m fine sand to silty sand over Unit C sands ??. See Fig GS4-3 for detail
GS4-4-S	536,678.05	7,748,002.13	6.9	NA88-F12	5,991.5	Approx 2.3 m fine sand to silty sand over thick banded clays. See Fig GS4-4 for detail
GS4-5-S	532,397.46	7,748,176.51	7.4	NA88-P1	1,691.0	Foreset beds (sands?) 1-2.8 m depth - see Fig GS4-5 for detail
GS5-1-S	531,058.80	7,753,000.18	9.7	GU87-12	1,200.0	Thin mud over hi refl re-worked sands 0.5-2.4 over C poss grav - see Fig GS5-1 for detail
PS1-1-S	539,573.28	7,746,989.95	4.8	NA88-F13	6,084.1	Sand/Mud wave crest - see Fig PS1-1 - unknown resource quality ??
PS1-2-S	539,637.47	7,746,989.95	5.0	NA88-F13	6,084.5	Sand/Mud wave trough - see Fig PS1-2 - unknown resource quality ??
BA6-1-N	540,432.87	7,752,660.68	9.0	NO SEIS		Bathy promontory - assumed surfical sands unknown thickness and quality



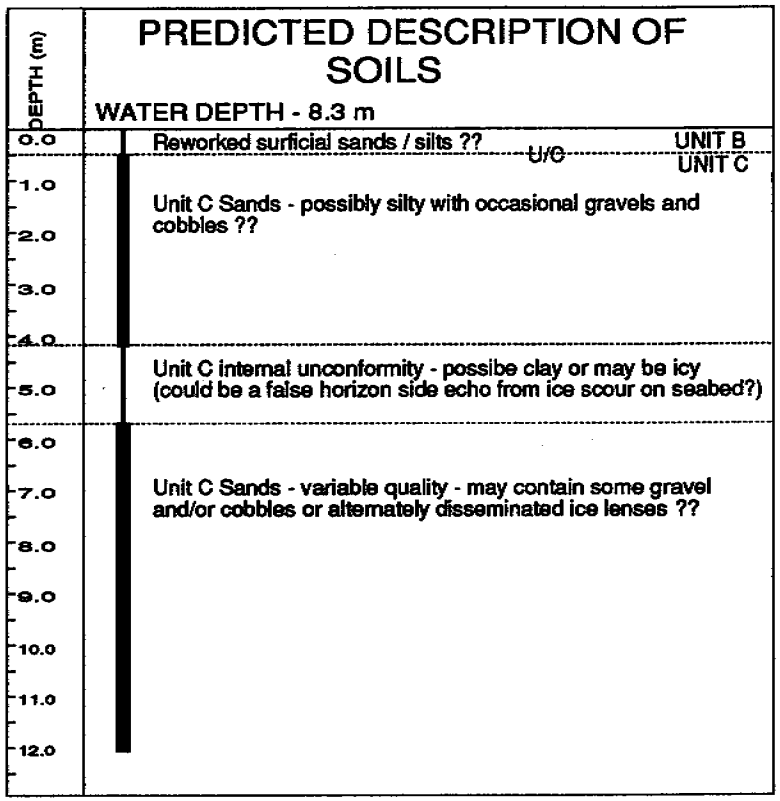


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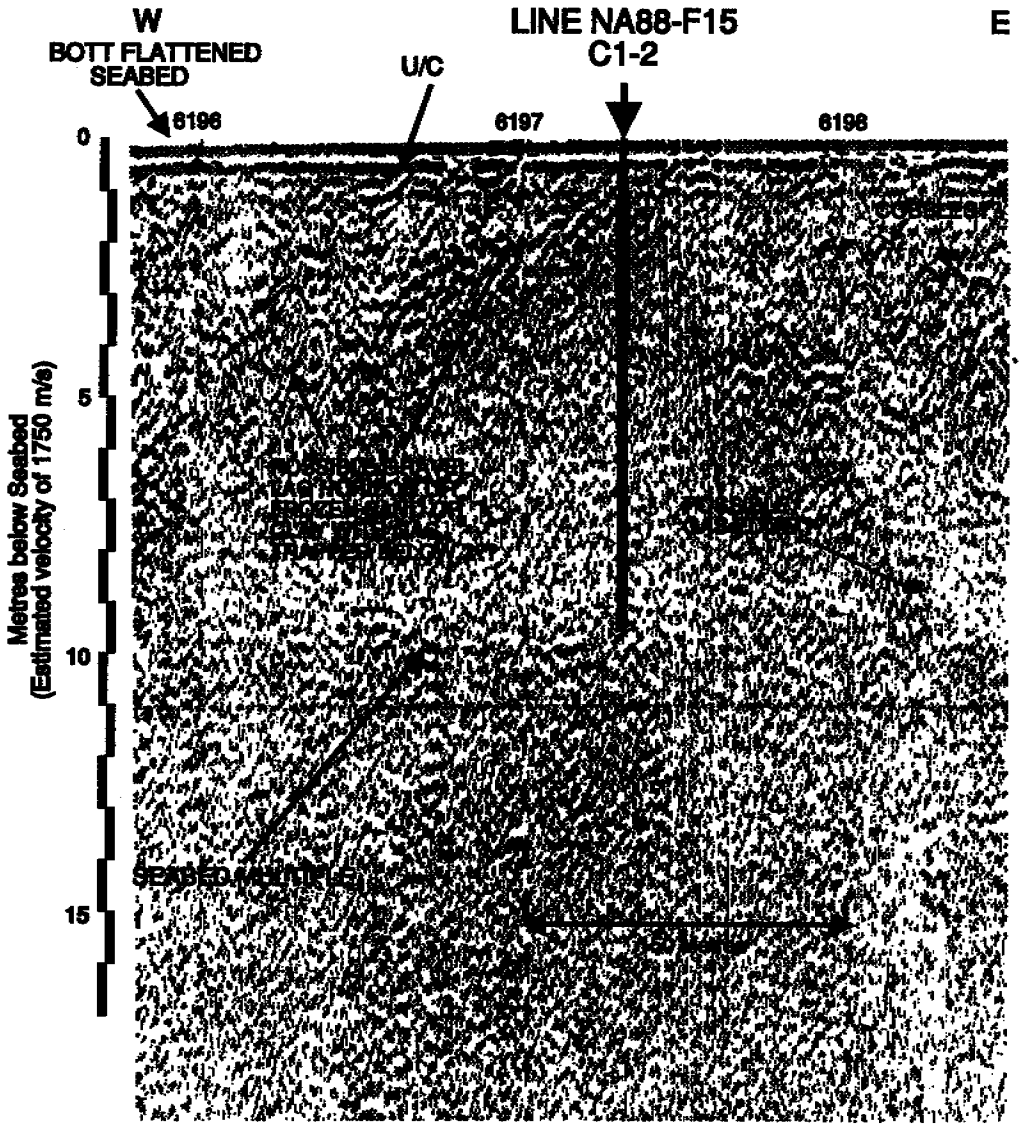
FIGURE: C1-1



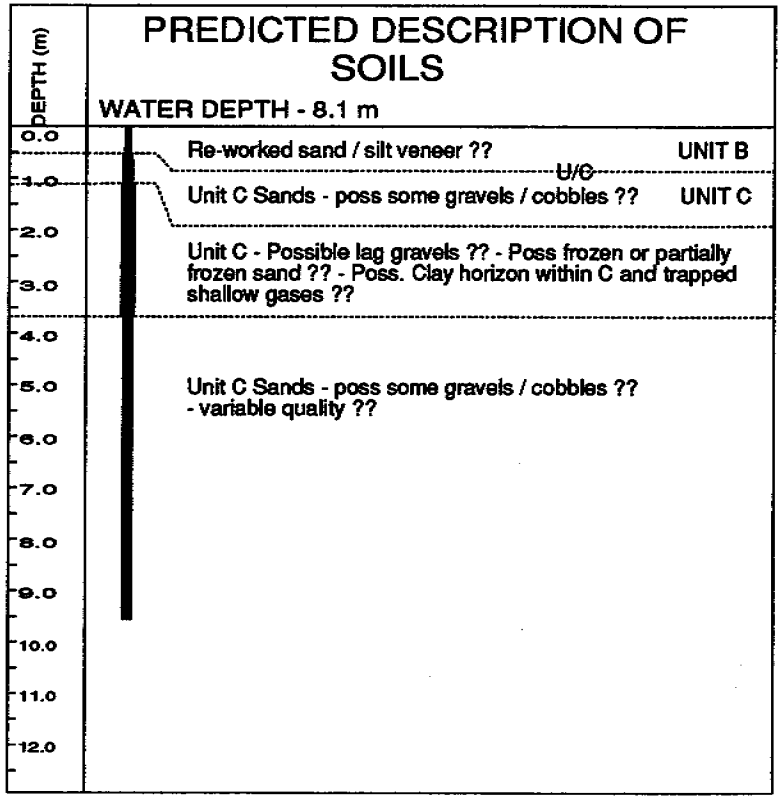


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FIGURE: C1-2

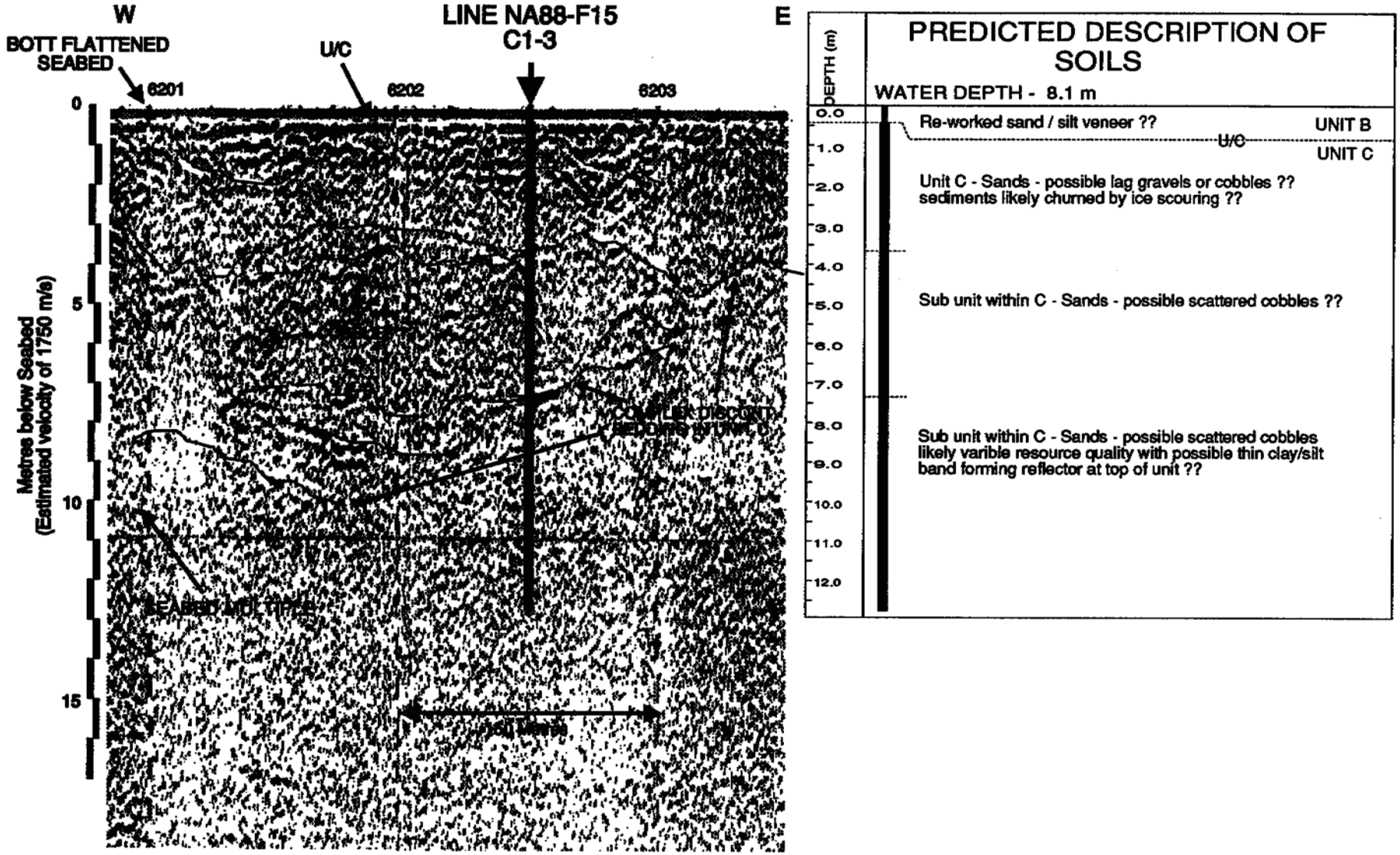

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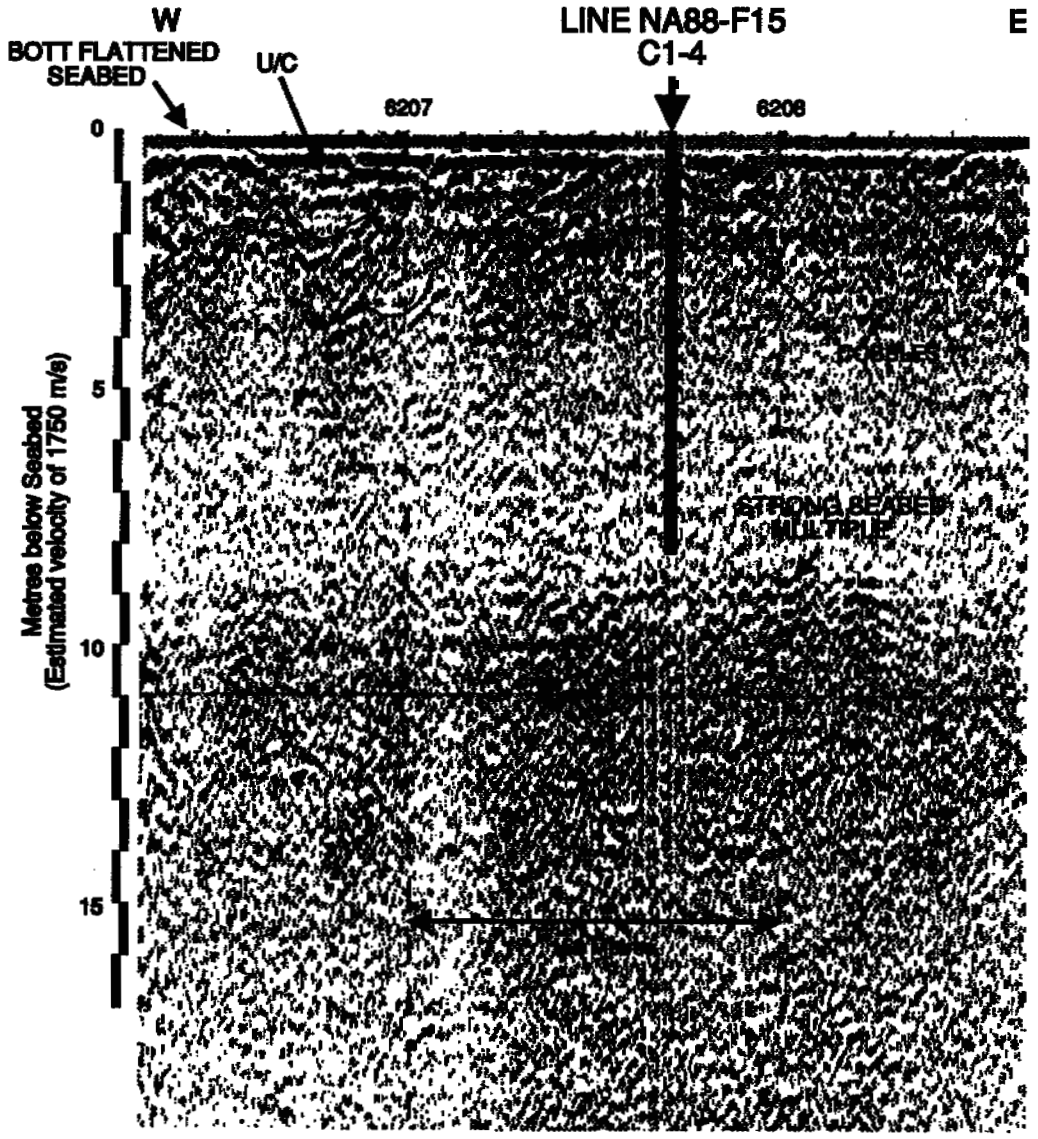
FIGURE: C1-3



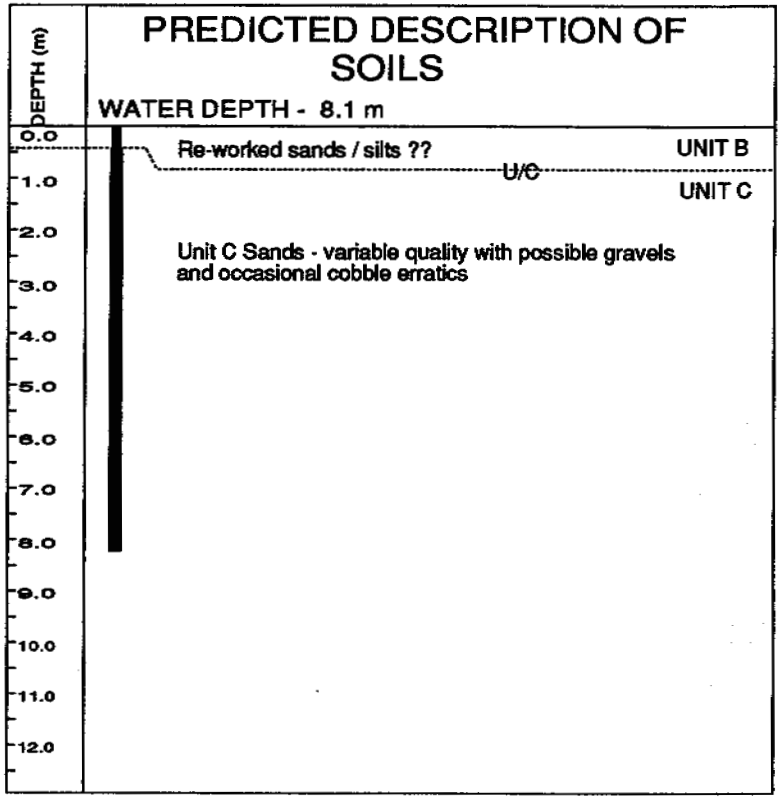


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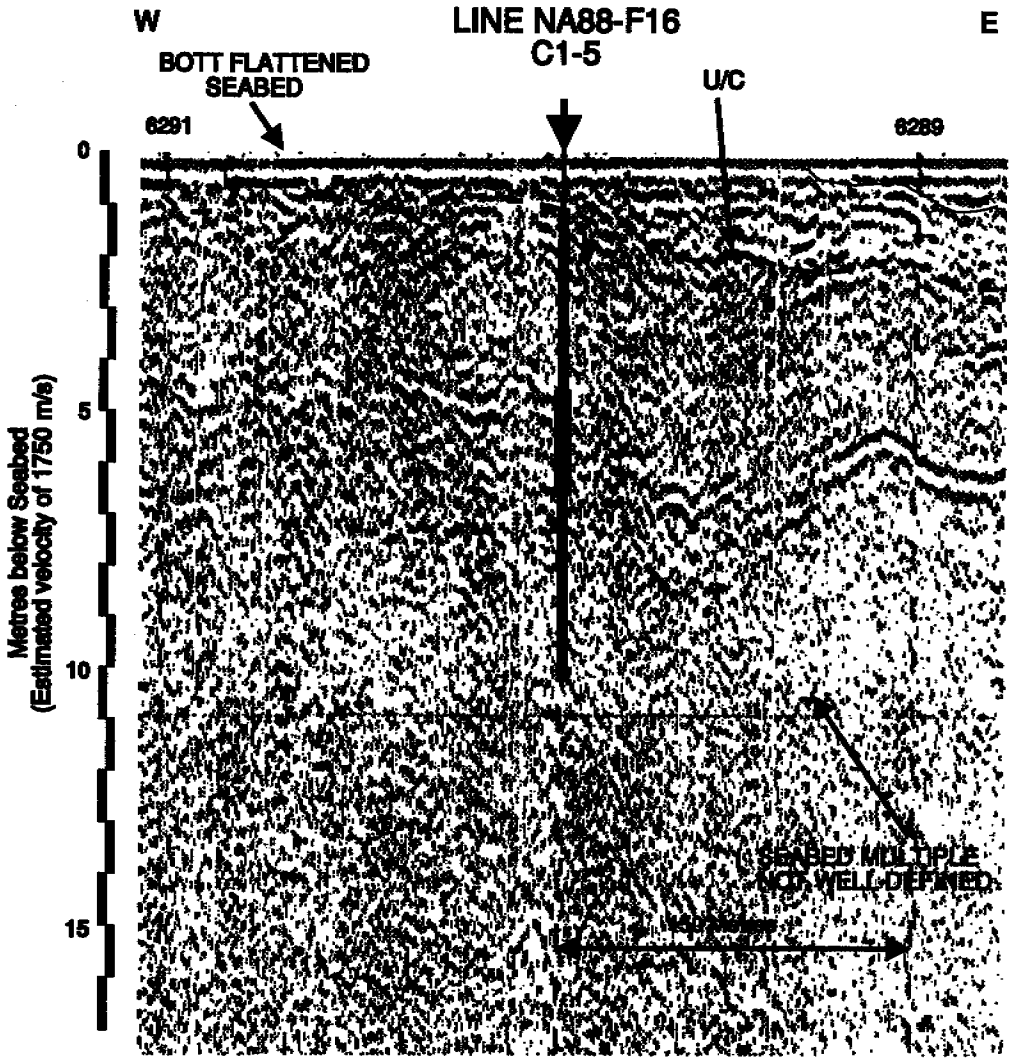
FIGURE: C1-4



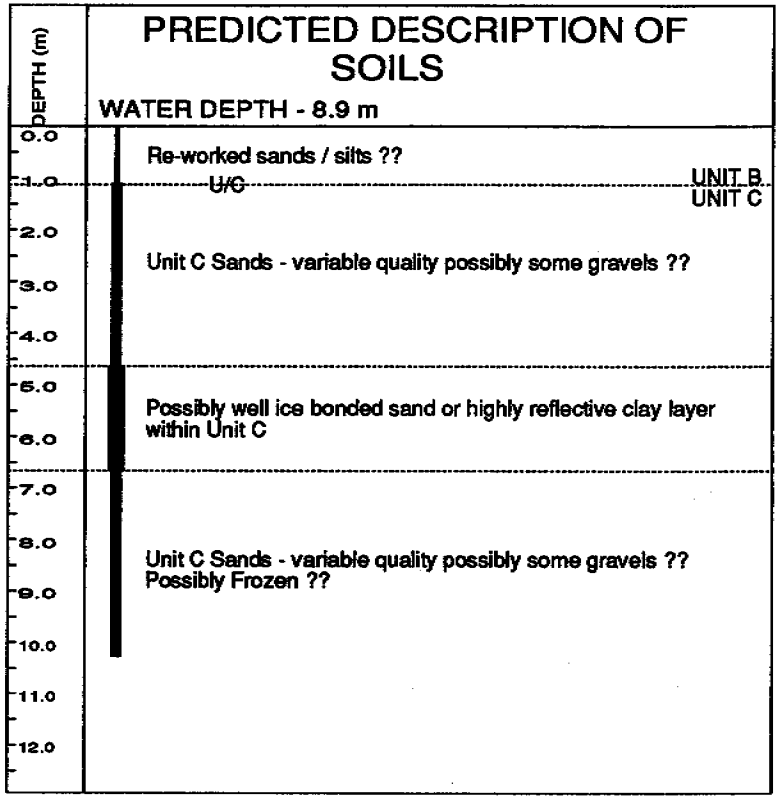


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FIGURE: C1-5

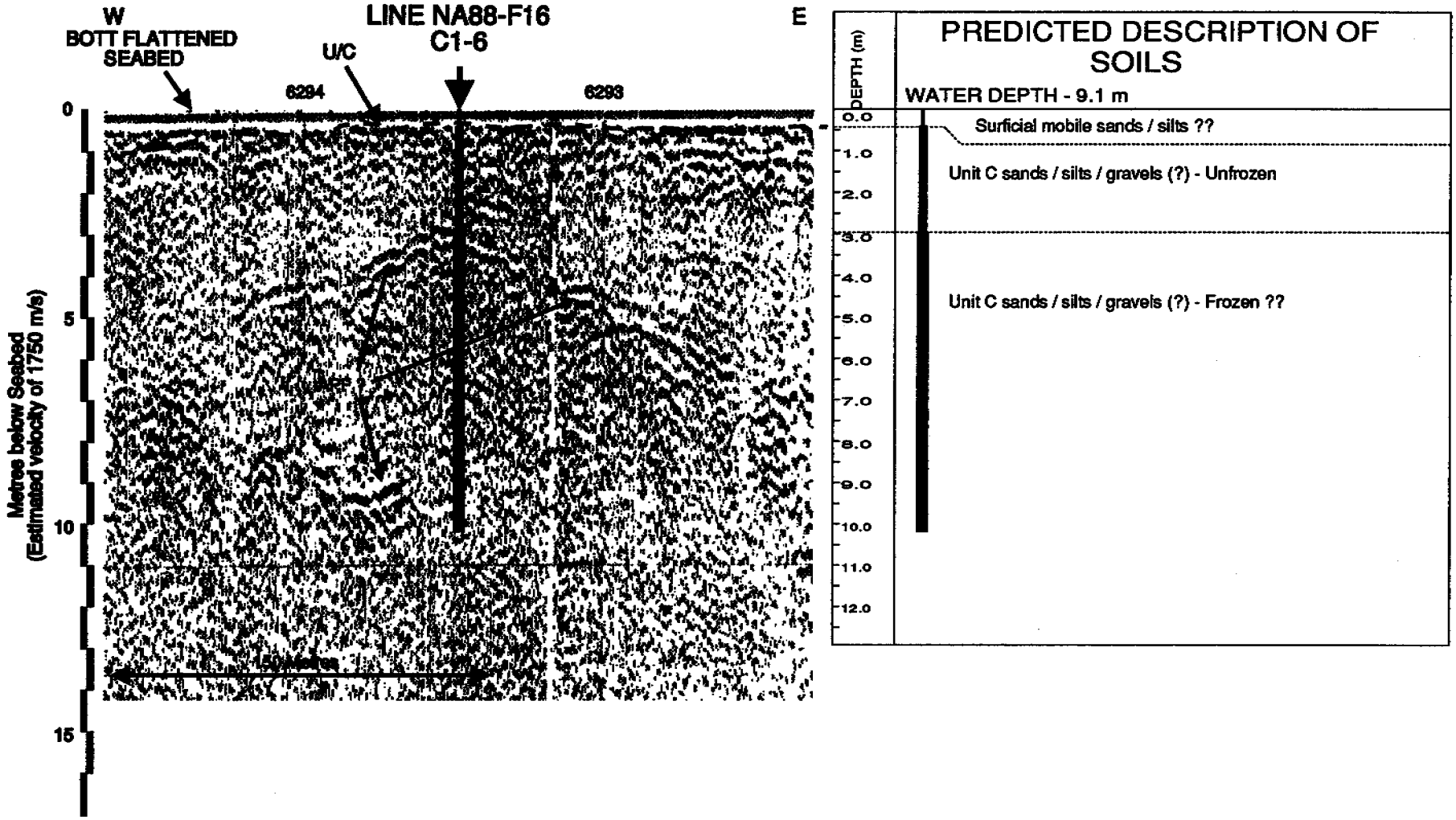

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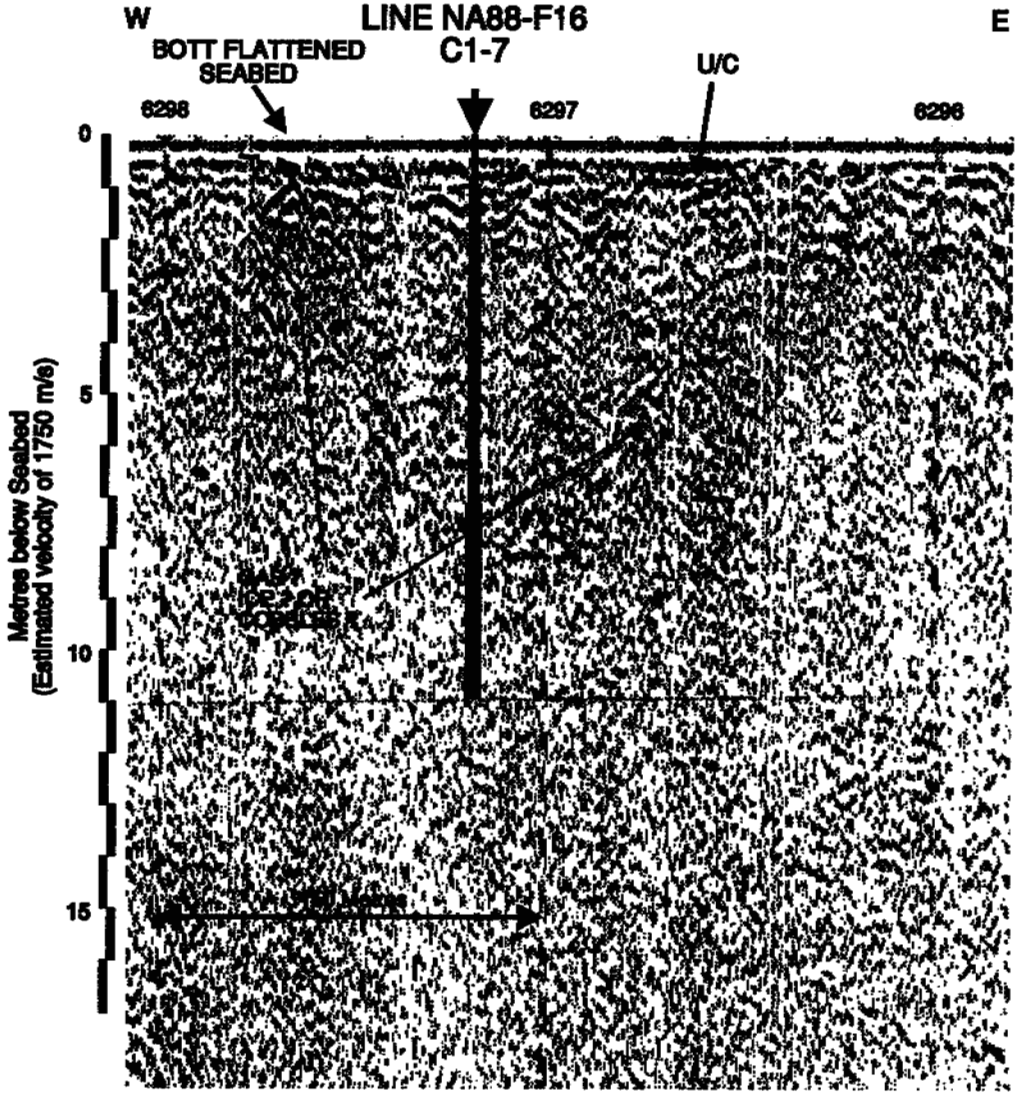
FIGURE: C1-6



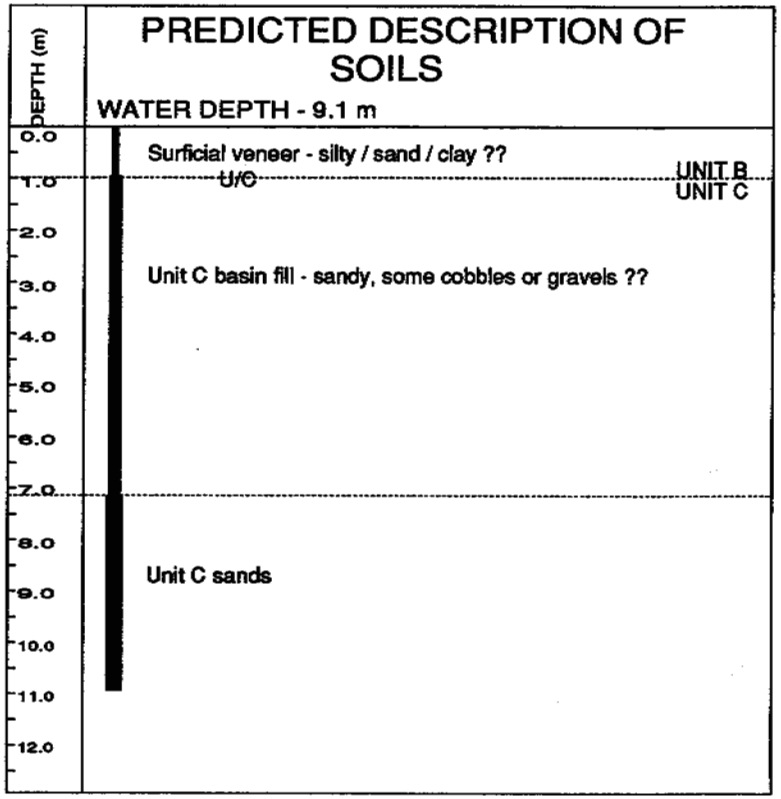


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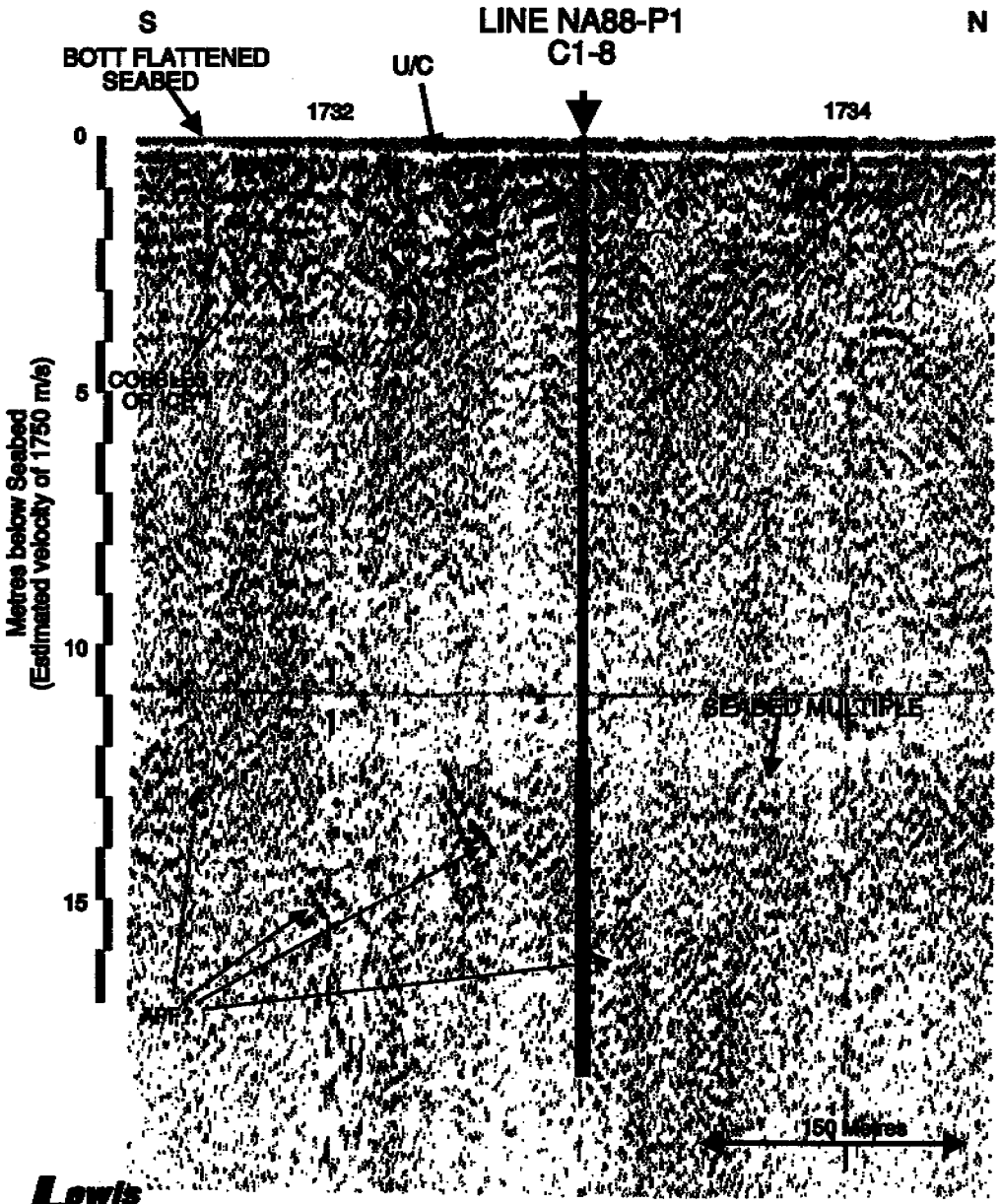
FIGURE: C1-7



DEPTH (m)	PREDICTED DESCRIPTION OF SOILS WATER DEPTH - 10.5 m
0.0 – 1.0	Re-worked lag deposits ? - sand / gravel /silt ?? - Unit B or C ??
2.0 – 12.0	Unit C sediments - Sands / gravels / silts - possibly cobbles ? depositional structures destroyed by freeze - thaw process poss. partially frozen with hyperbolae indicating frozen seds or cobbles and gravels ??
	?? main Permafrost body ??

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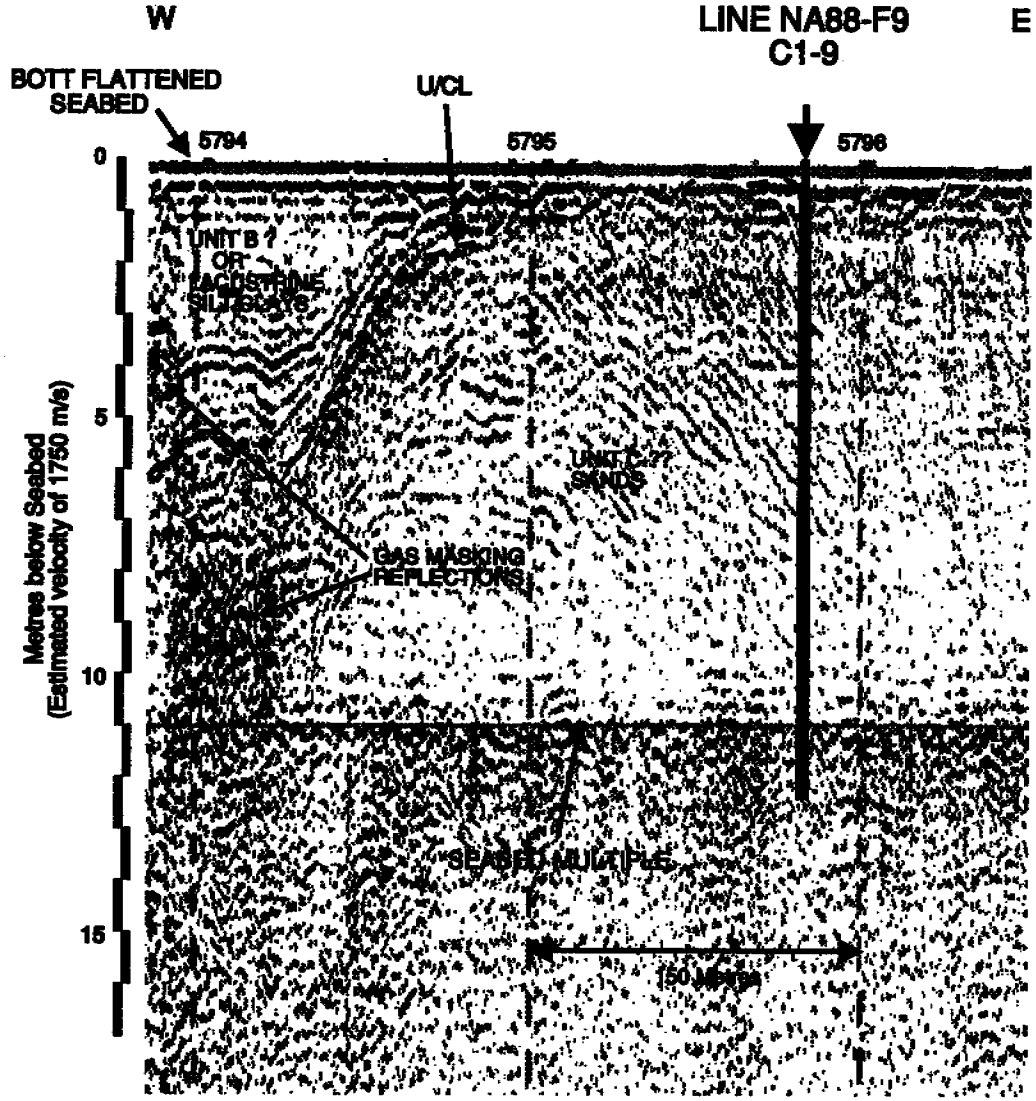
FIGURE: C1-8



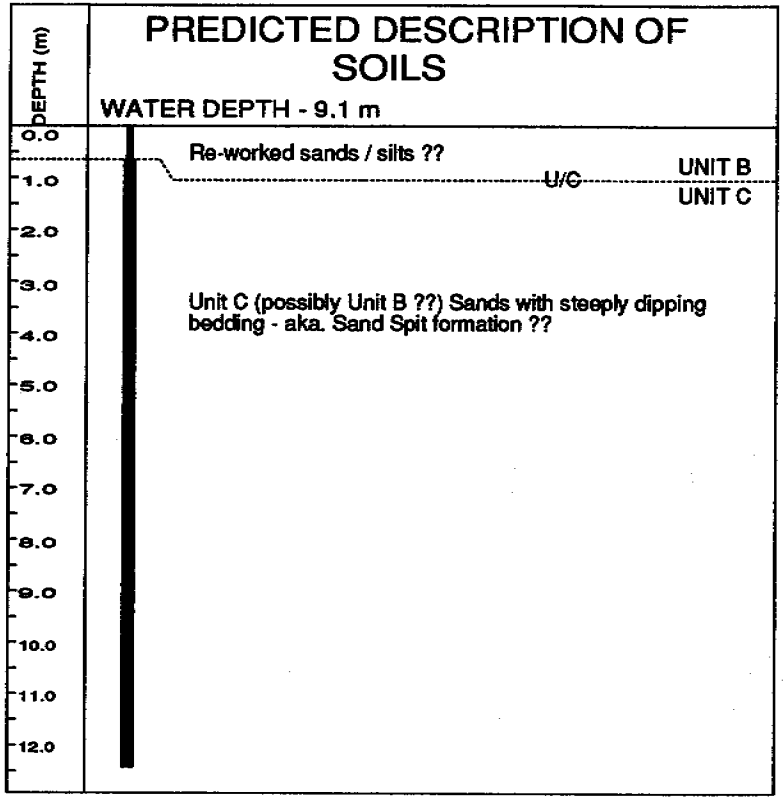


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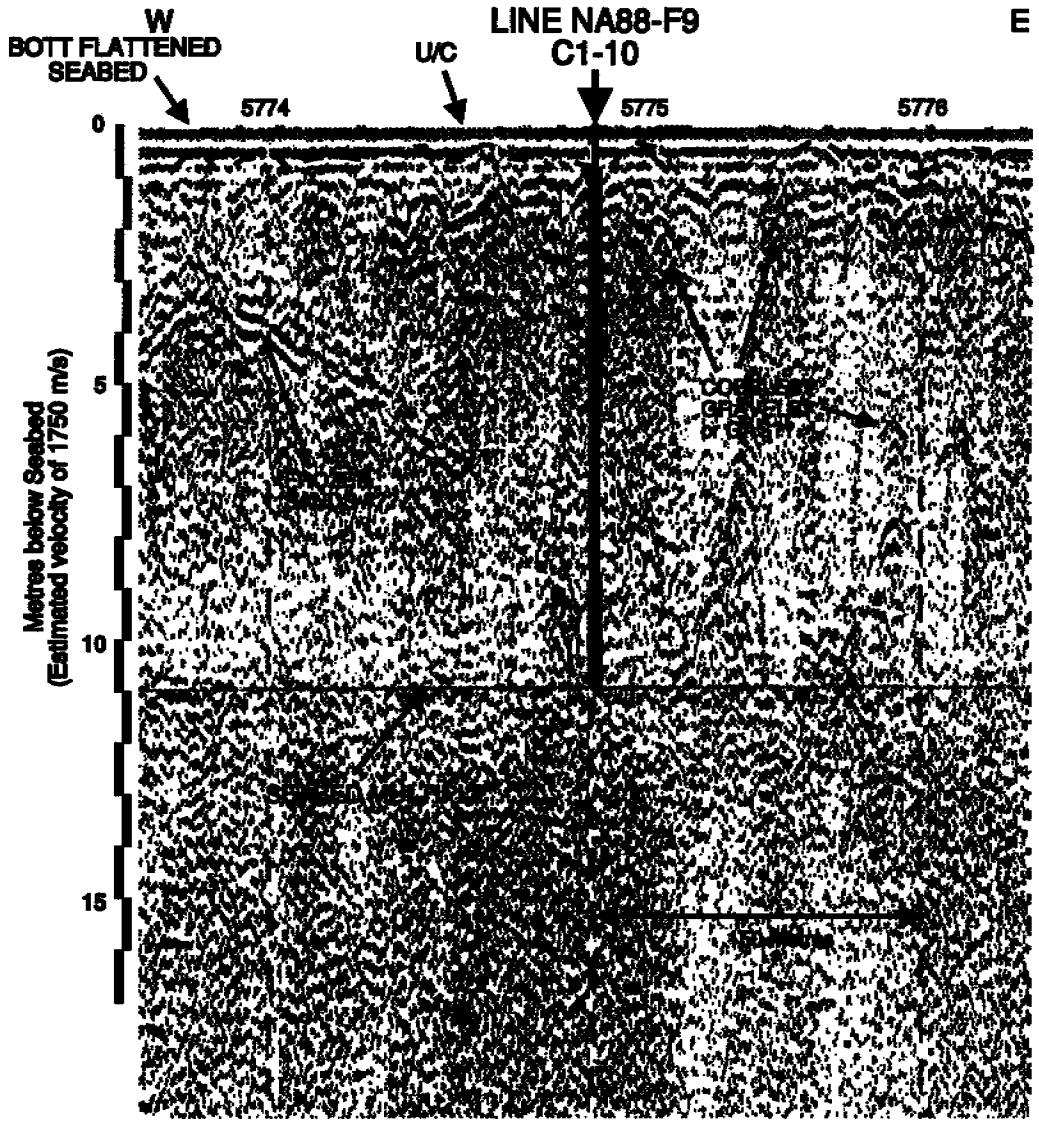
FIGURE: C1-9



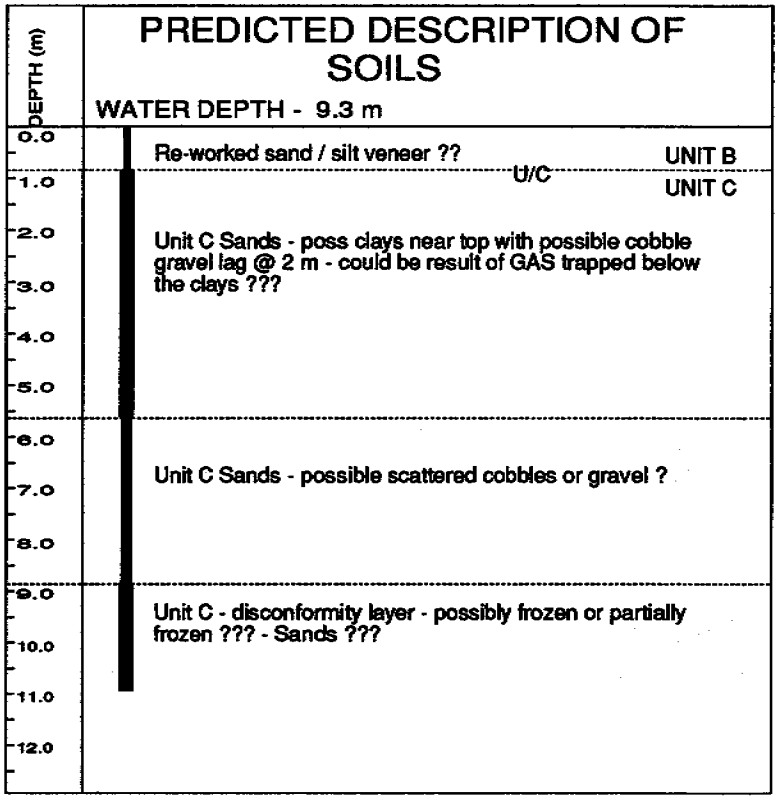


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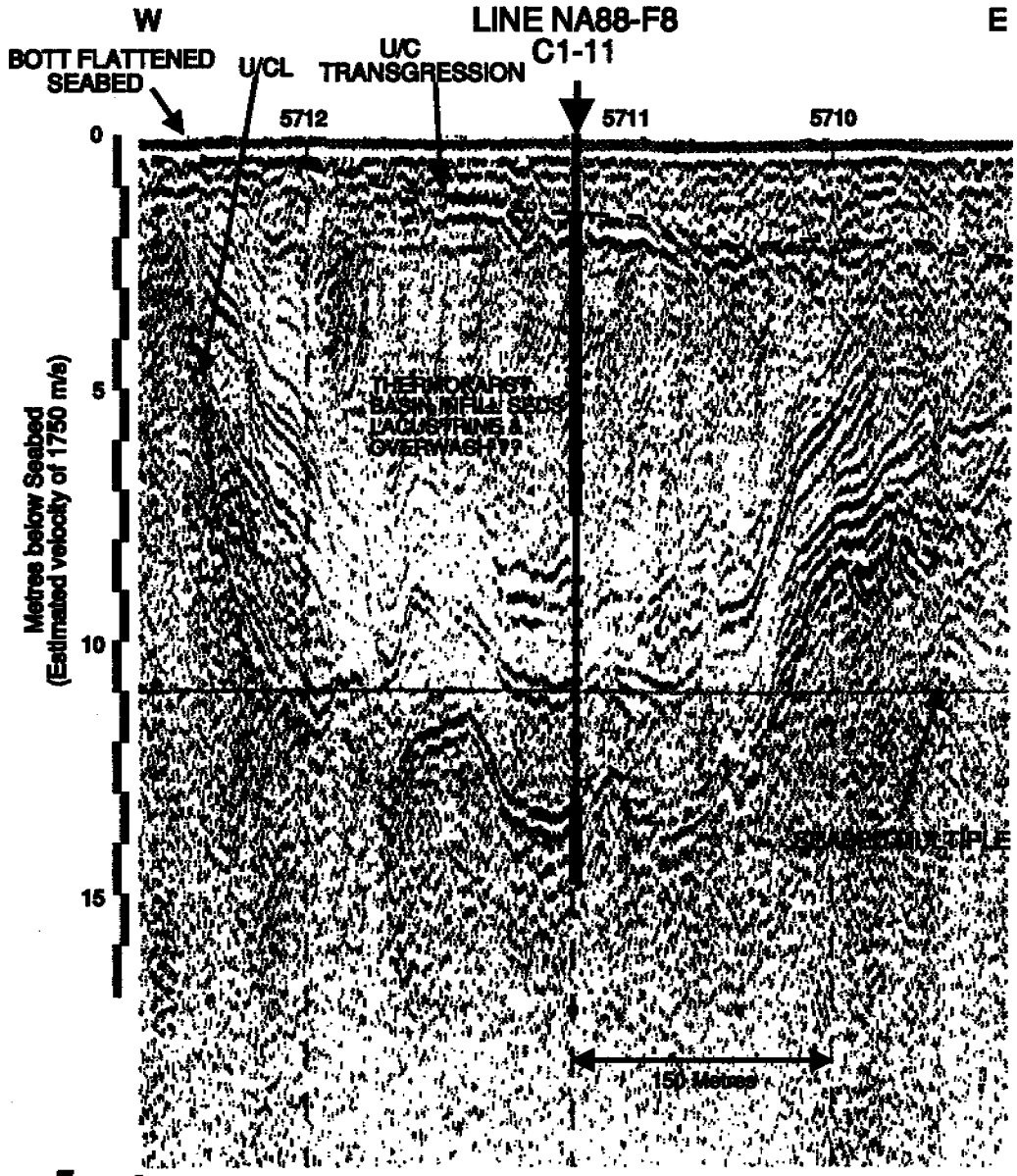
FIGURE: C1-10



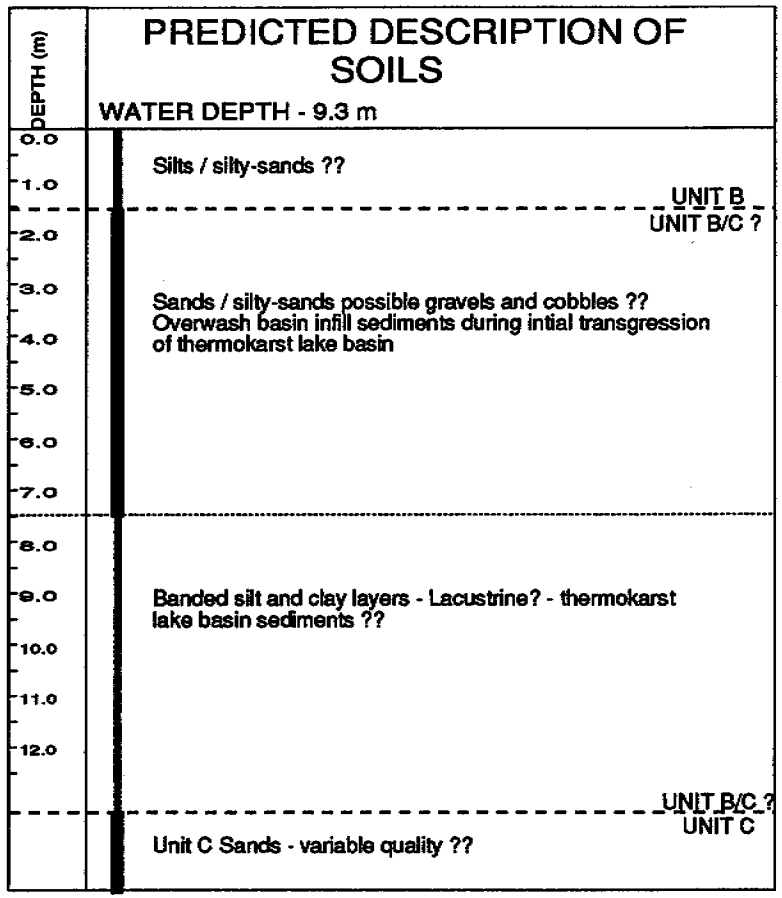


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FIGURE: C1-11

NEAR TSD-PF

PIPELINE ROUTE, SITE 2	DRILL SHIP : M.V. FRANK BRODERICK	BOREHOLE NO: AKP88S07
	DRILL RIG : SIMCO 5000	Project No: 0101-4912B
ORIGINAL BOREHOLE NO. PS88S12, 4912-07	WATER DEPTH: 8.7m	ELEVATION: -8.700 (m)

SAMPLE TYPE ■ DISTURBED ⊘ NO RECOVERY ⊠ SPT ▤ A-CASING ▥ SHELBY TUBE ▮ CORE

Symbols for SOILS

■ D50 (um) ■ 40 80 120 160
◆ % SAND ◆ 20 40 60 80
PLASTIC M.C. LIQUID 20 40 60 80

DEPTH (m)	USC	SOIL SYMBOL	Symbols for SOILS	SAMPLE TYPE	SAMPLE NO	SPT(N)	ICE DESCR	TEMPERATURE	DEPTH (m)
0.0			SILT – clayey, trace to some sand, soft, low plastic, olive brown		1B		NOT FROZEN	7.85	0.0
1.0			SAND – trace of silt, shell fragments and organic pockets, fine to medium grained, uniform, grey brown						1.0
2.0					2A 2B			3.03	2.0
3.0			– trace of gravel to 5mm, occassional silty clay lens, becoming coarser, dark grey brown		3A				3.0
4.0			– becoming more dense						4.0
5.0					4A				5.0
6.0									6.0
7.0			– thinly bedded below 6.4 metres,		5A				7.0
8.0			– darker		6A				8.0
9.0					7		FROZEN, Nbn		9.0
10.0									10.0
11.0									11.0
12.0			– trace of mica platelets		8		Nf		12.0
13.0									13.0
14.0									14.0
15.0					9		Nbn		15.0
16.0			– thinly laminated, becoming clean – becoming light brown						16.0
17.0			– Driller notes easier drilling						17.0
18.0					10		Nbe		18.0
19.0			– trace of gravel to 20mm maximum diameter						19.0
20.0									20.0
21.0					11		Nbe		21.0
22.0			– clay seams interspersed throughout, trace of shell fragments						22.0
23.0									23.0
24.0					12		Nbe		24.0
25.0							NOT FROZEN		25.0

Geological Survey of Canada
Dartmouth, Nova Scotia

LOGGED BY: WVG RVW KWJ	COMPLETION DEPTH: 40.0 m
REVIEWED BY: WVG	COMPLETE: 88-08-07
Fig. No:	Page 1 of 2

PIPELINE ROUTE, SITE 2	DRILL SHIP : M.V. FRANK BRODERICK	BOREHOLE NO: AKP88S07
	DRILL RIG : SIMCO 5000	Project No: 0101-4912B
ORIGINAL BOREHOLE NO. PS88S12, 4912-07	WATER DEPTH: 8.7m	ELEVATION: -8.700 (m)

SAMPLE TYPE: DISTURBED | NO RECOVERY | SPT | A-CASING | SHELBY TUBE | CORE

Symbols for SOILS

■ D50 (um) ■ 40 80 120 160
◆ % SAND ◆ 20 40 60 80
PLASTIC M.C. LIQUID 20 40 60 80

DEPTH (m)	USC	SOIL SYMBOL	SAMPLE TYPE	SAMPLE NO	SPT(N)	ICE DESCR	TEMPERATURE
25.0							
						– trace to some silt, becoming very fine grained, grey brown	
26.0							
27.0							
				13			
28.0						– uniform, light brown	
29.0							
30.0							
				14A		FROZEN Nbe	
31.0							
32.0							
33.0							
				15A		Nbe	
34.0						– some gravel to 10mm maximum diameter	
35.0							
36.0							
				16		Nbe	
37.0							
38.0							
39.0						CLAY – silty, organics disseminated throughout sample, organic odour, organic layer at 39.9 metres, very thinly laminated, soft, low plastic, dark olive grey	
				17B		NOT FROZEN 4.01	
40.0						END OF BOREHOLE (40.0 metres)	
41.0							
42.0							
43.0							
44.0							
45.0							
46.0							
47.0							
48.0							
49.0							
50.0							

DEPTH (m)

Geological Survey of Canada
Dartmouth, Nova Scotia

LOGGED BY: WVG RVW KWJ	COMPLETION DEPTH: 40.0 m
REVIEWED BY: WVG	COMPLETE: 88-08-07
Fig. No:	

NEAR - TSD - NPF

DEPTHS ARE REFERENCED BELOW SEABED	DRILL RIG – SIMCO 5000	BOREHOLE NO: 87PS2S1
	DRILL SHIP – KIGGIAK	Project No: EBA # 101-4724
ORIGINAL BOREHOLE NO. 87PS2S1	WATER DEPTH – 10.0m	ELEVATION: -10.000 (m)

SAMPLE TYPE ■ DISTURBED ⊘ NO RECOVERY ⊠ SPT ▤ A-CASING ▥ SHELBY TUBE ▯ CORE

Symbols for SOILS

DEPTH (m)	USC	SOIL SYMBOL	SAMPLE TYPE	SAMPLE NO	SPT(N)	ICE DESCR	TEMPERATURE
0.0	CL			1A 1B		UNFROZEN	4.92
1.0							
2.0							
3.0							
4.0				3A 2A 2B			2
5.0							
6.0							
7.0	CL			3B			
8.0							
9.0	MH			4A 4B 4C			0.15
10.0							
11.0							
12.0							
13.0	SM			5A			
14.0							
15.0							3.92
16.0	SM			6A 6B 6C 6D			
17.0							
18.0							
19.0						UNFROZEN	
20.0							
21.0							
22.0							
23.0							
24.0							
25.0							

CLAY (CL) – and silt, trace of sand, mica platelets visible, homogeneous, low plasticity, stiff, moist, olive grey

– firm

– trace of sand in thin interbedded seams, soft

SILT (MH–ol) – organics, shell fragments, very thin parallel laminae of silt and organics, fiberous organics becoming more abundant with depth, more shells with depth, high plasticity, soft to firm, wet, black

SAND (SM) – silty,some clay, fine-grained, dilatant, moist, soft, grey

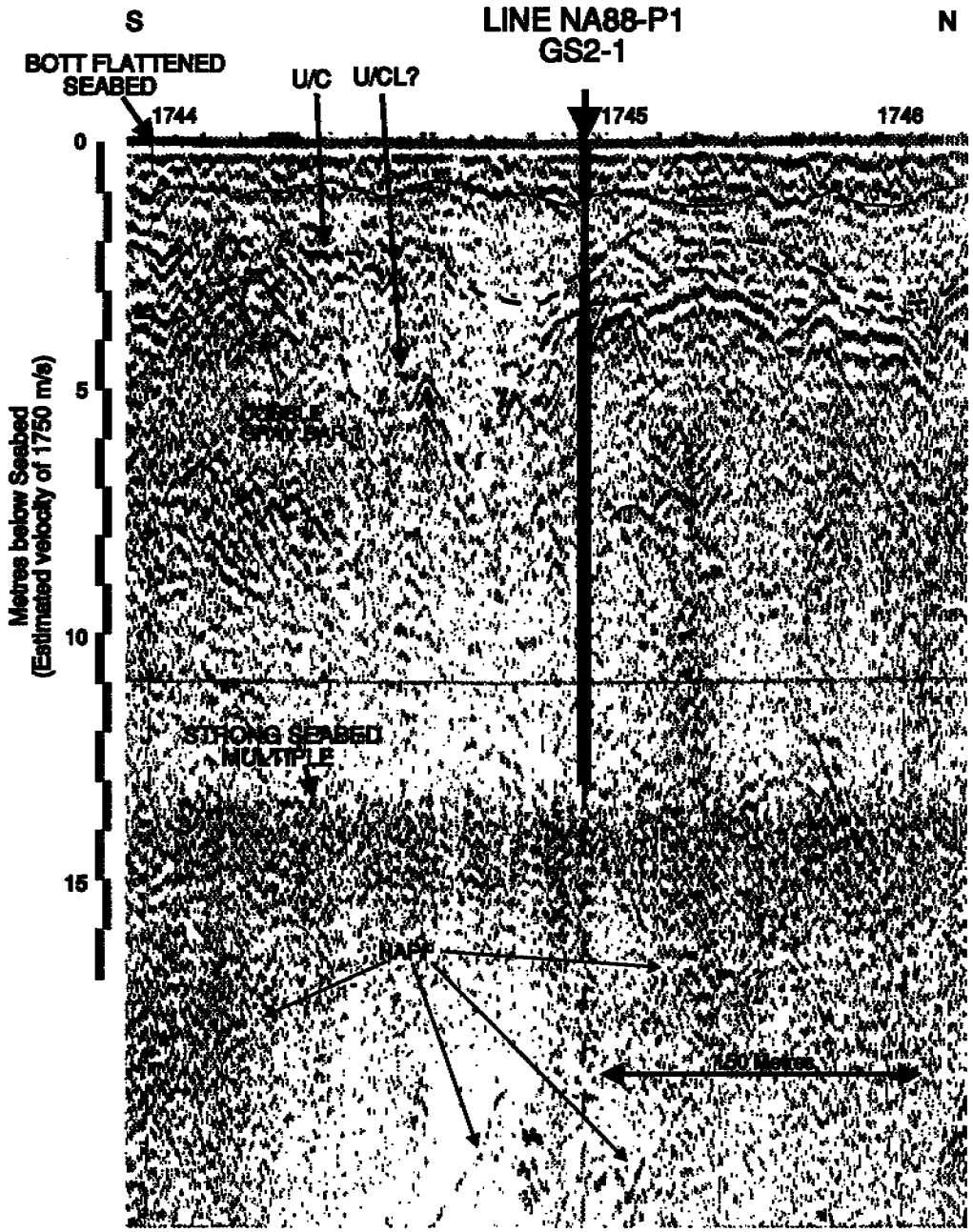
SAND (SM) – (cont'd)
– dark olive grey (5Y 3/2)

– assumed fine to medium-grained sand, cleaner than above

END OF BOREHOLE AT 19.2m

■ D50 (um) ■ 40 80 120 160
◆ % SAND ◆ 20 40 60 80
PLASTIC M.C. LIQUID 20 40 60 80

Geological Survey of Canada Dartmouth, Nova Scotia	LOGGED BY: BAB JWC REVIEWED BY: TRM SMK Fig. No: 4724B-3
	COMPLETION DEPTH: 19.2 m COMPLETE: 87-09-01
	Page 1 of 1



DEPTH (m)	PREDICTED DESCRIPTION OF SOILS WATER DEPTH - 11.5 m
0.0	
1.0	Re-worked surficial sands (gravel ?) deposits (strong mult)
2.0	Silt / silty sands ?? UNIT B
	U/C
3.0	Silt / sands ? Lacustrine or shore-face deposits ?? Unit B or C ?
	U/CL UNIT C
4.0	
5.0	
6.0	
7.0	Unit C seds - Sands / silts / (clays?) / (gravels??) variable quality - sed structures distorted by freeze / thaw
8.0	
9.0	
10.0	
11.0	
12.0	

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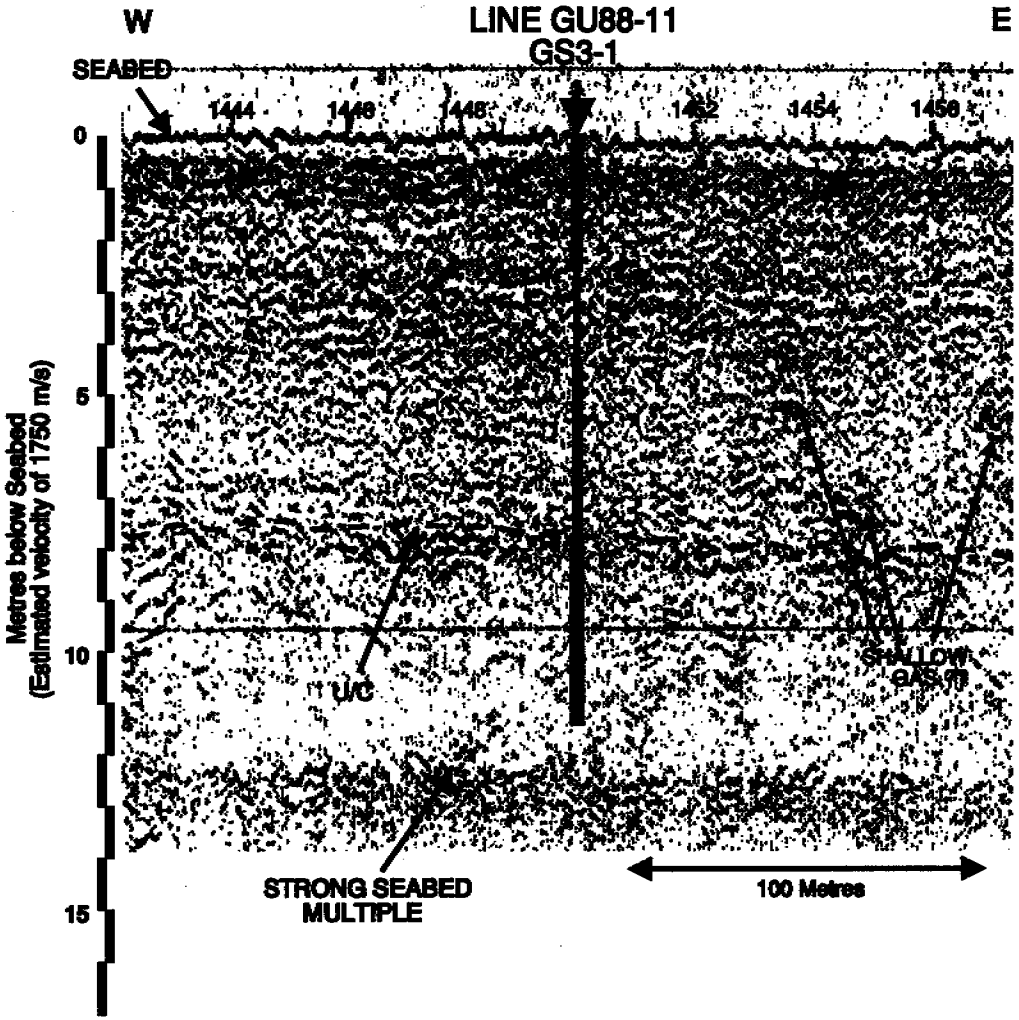
FIGURE: GS2-1



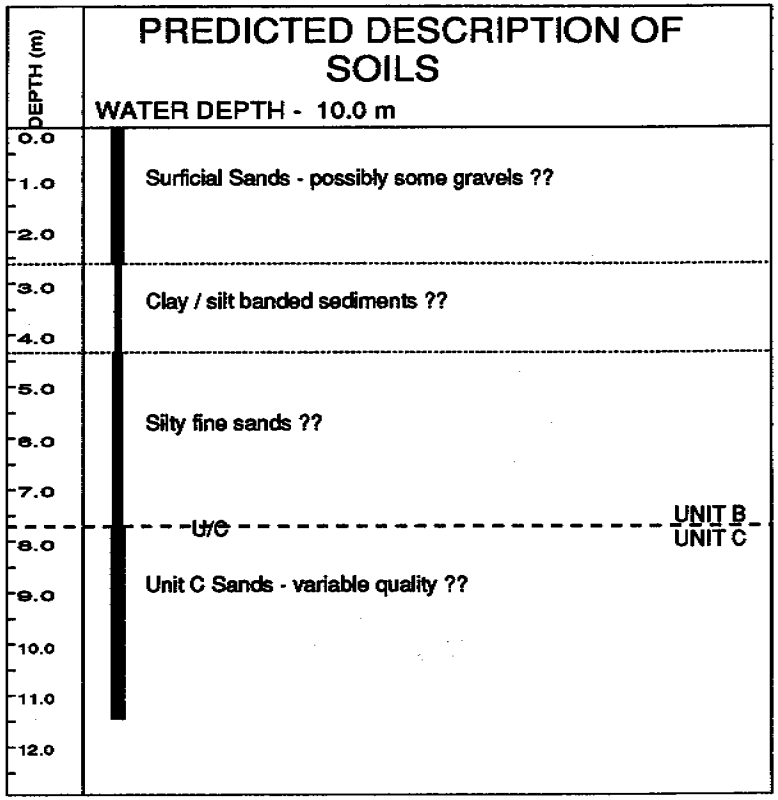


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FIGURE: GS3-1

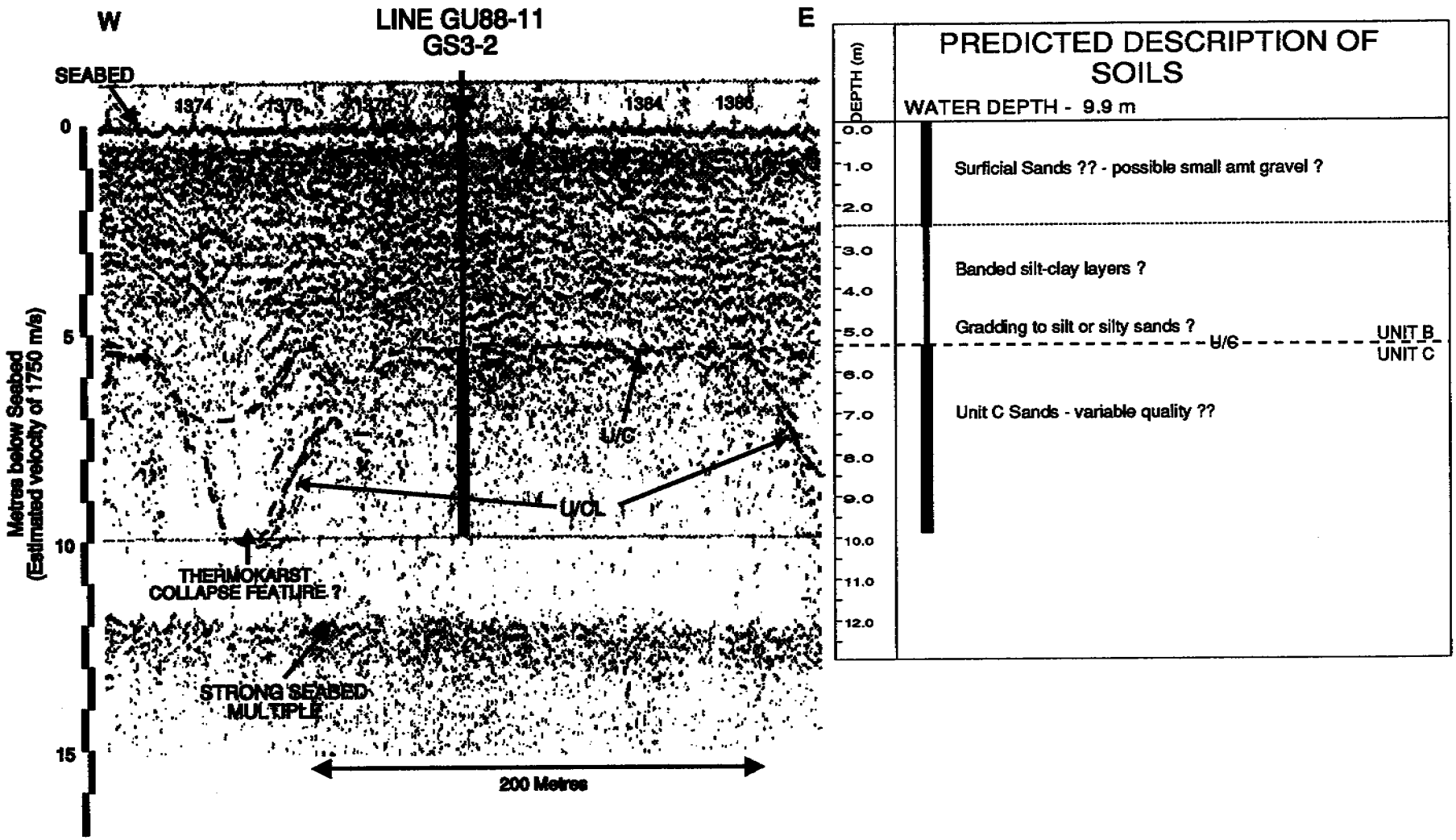

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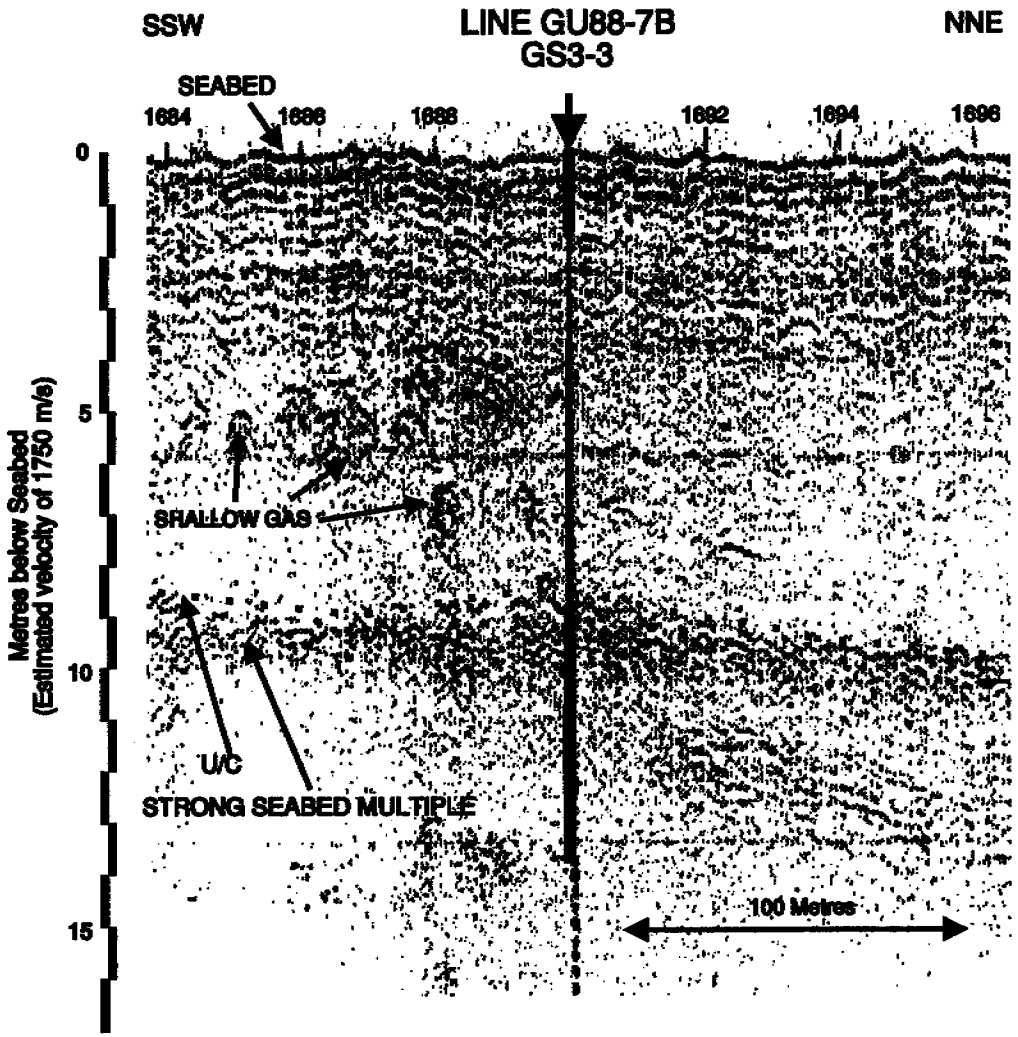
FIGURE: GS3-2



DEPTH (m)	PREDICTED DESCRIPTION OF SOILS WATER DEPTH - 9.0 m
0.0 1.0	Surficial mobile (?) sands - strong multiple reflection and gentle bathymetric rise
2.0 3.0	Finely banded reflections - silty / clay / sands ??
4.0 5.0 6.0 7.0 8.0	Very weakly banded reflections - predominantly silts ?? strong hyperbolic reflections just south of drill site suggest shallow gas migrating upward (no clay capping horizon) through these sediments
U/C ??	UNIT B UNIT C
9.0 10.0	Lacustrine (?) basin edge deposits - likely sandy - main lacustrine basin to north of drill site
11.0 12.0	Normal Unit C sediments - sands ? of variable quality

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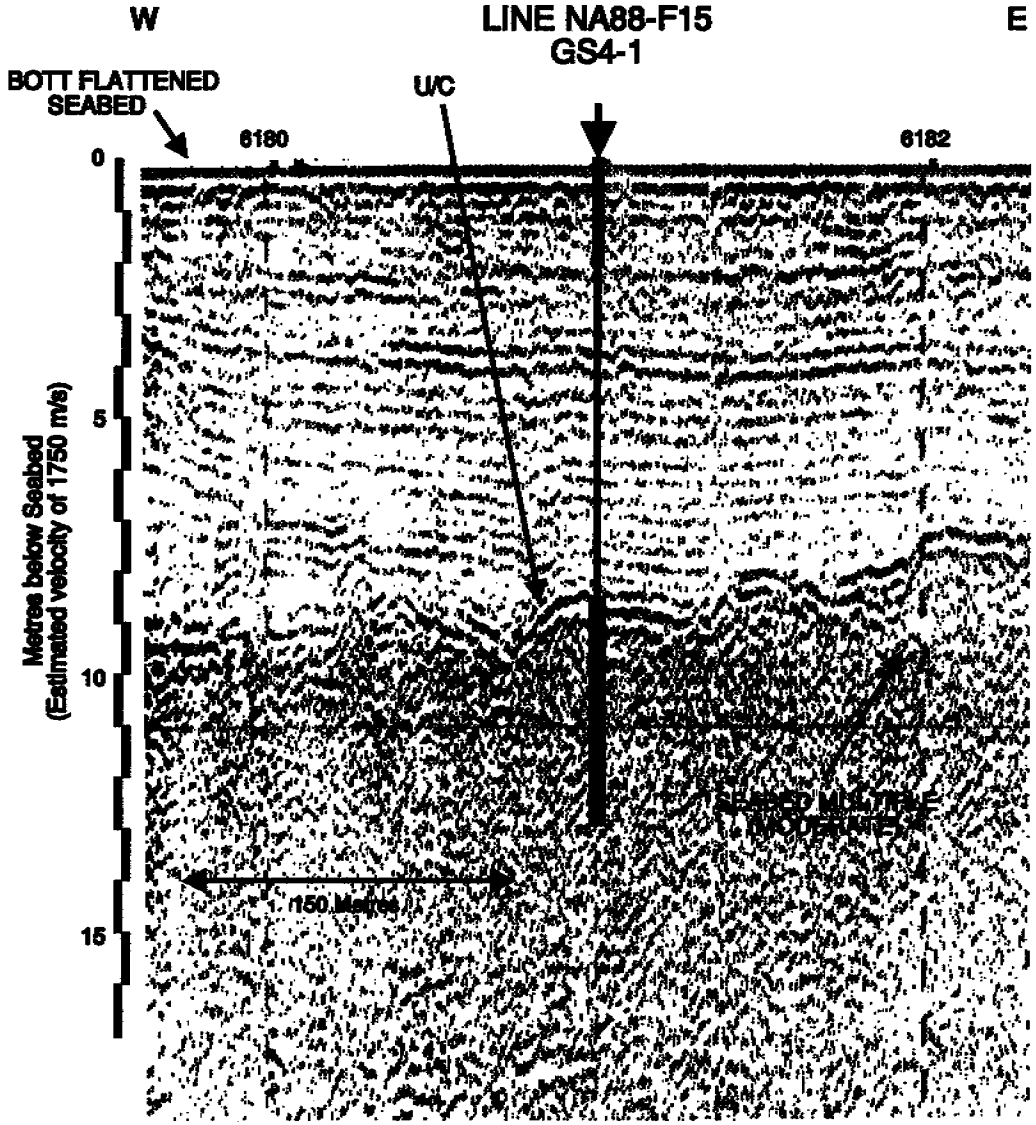
FIGURE: GS3-3



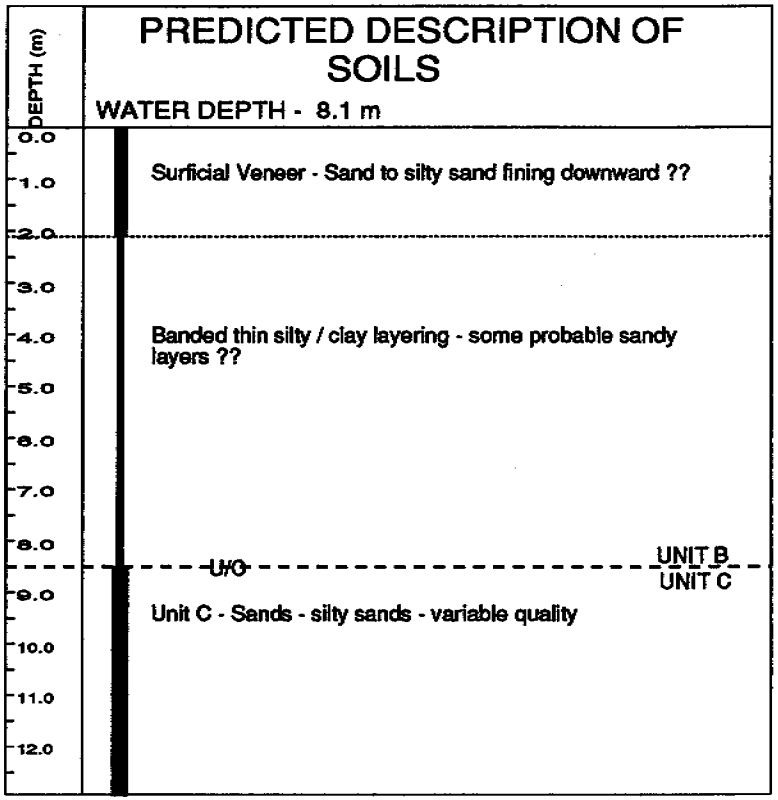


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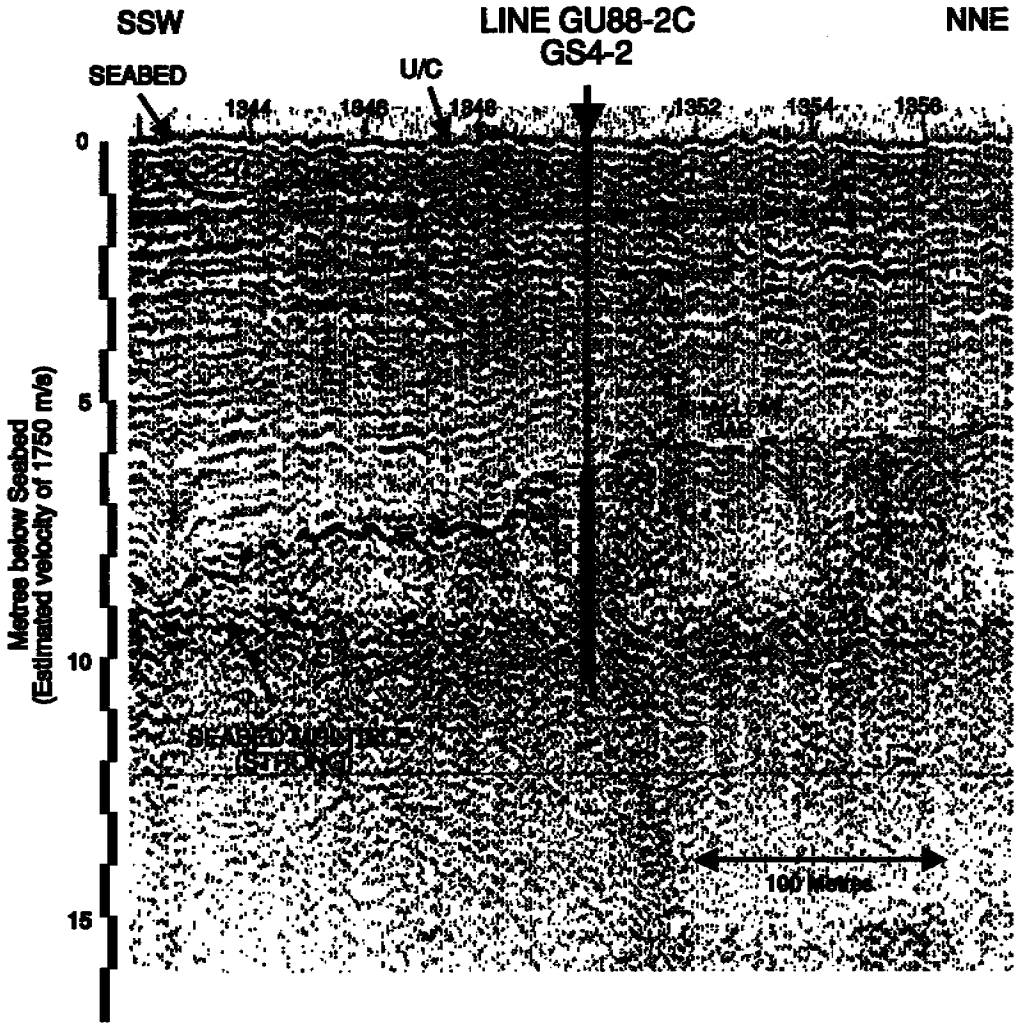
FIGURE: GS4-1



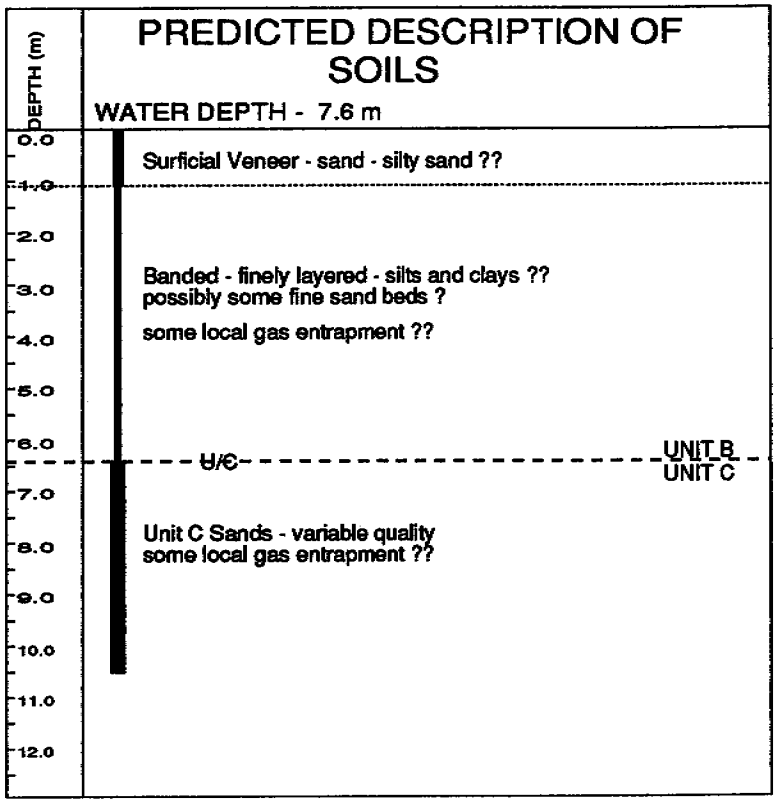


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FIGURE: GS4-2

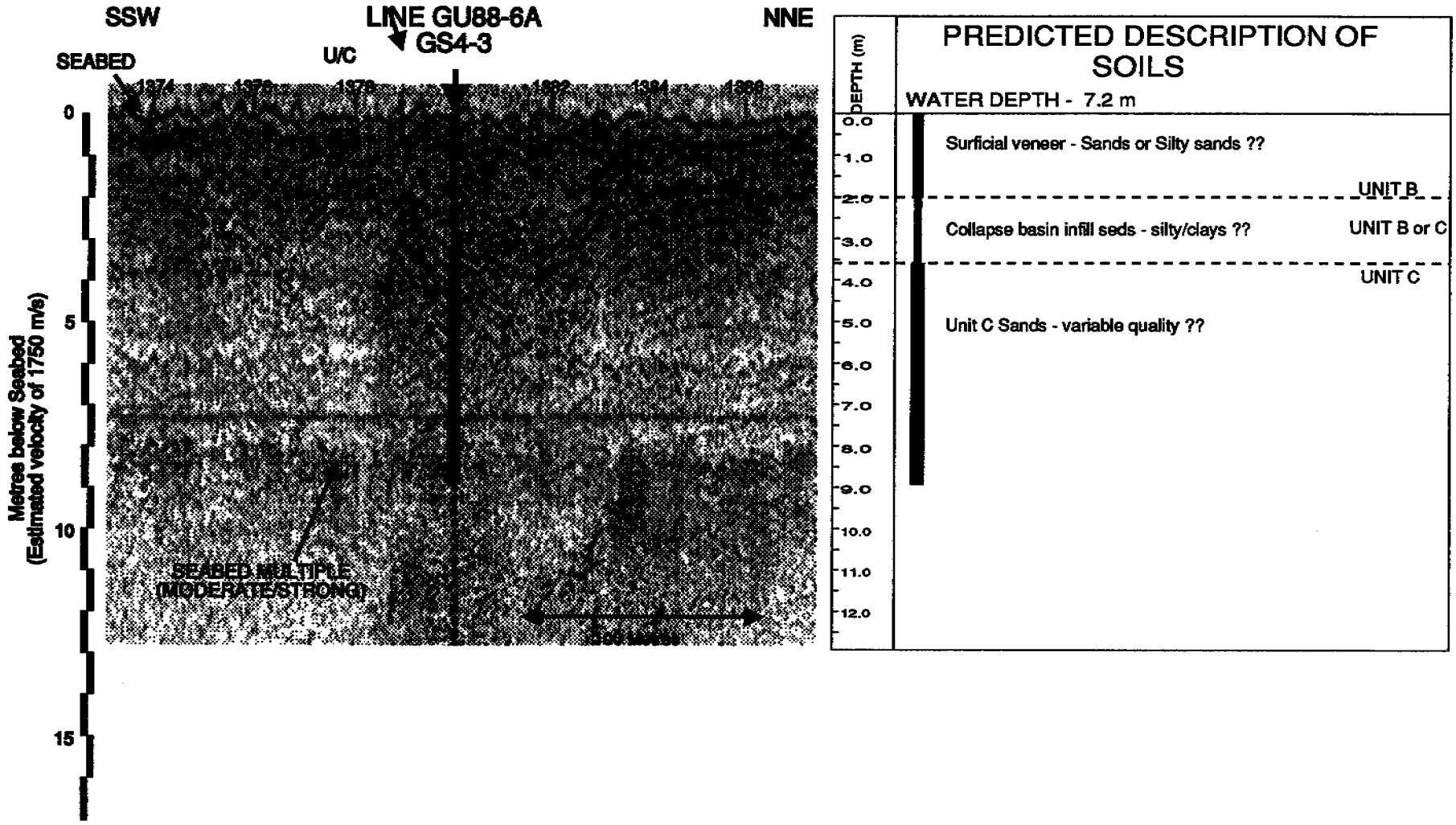

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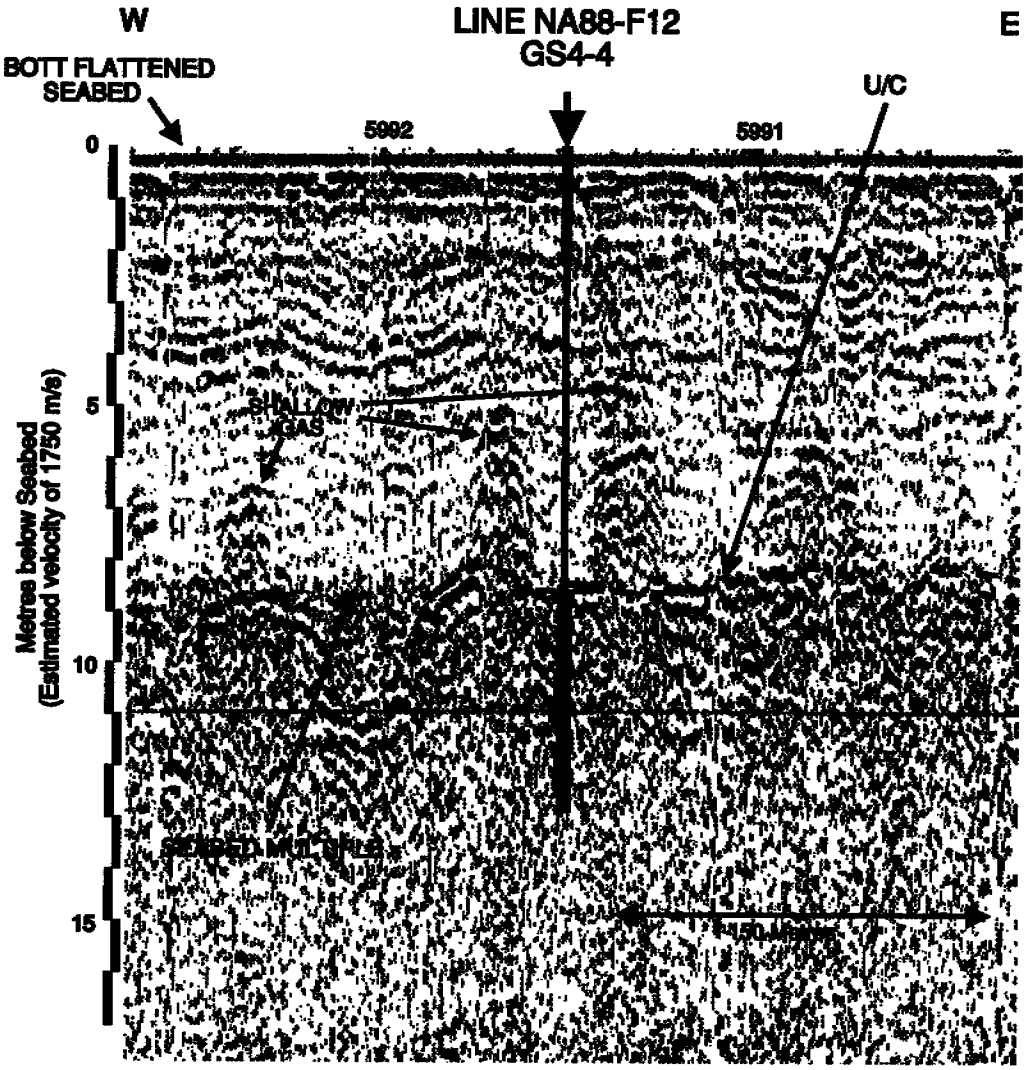
FIGURE: GS4-3



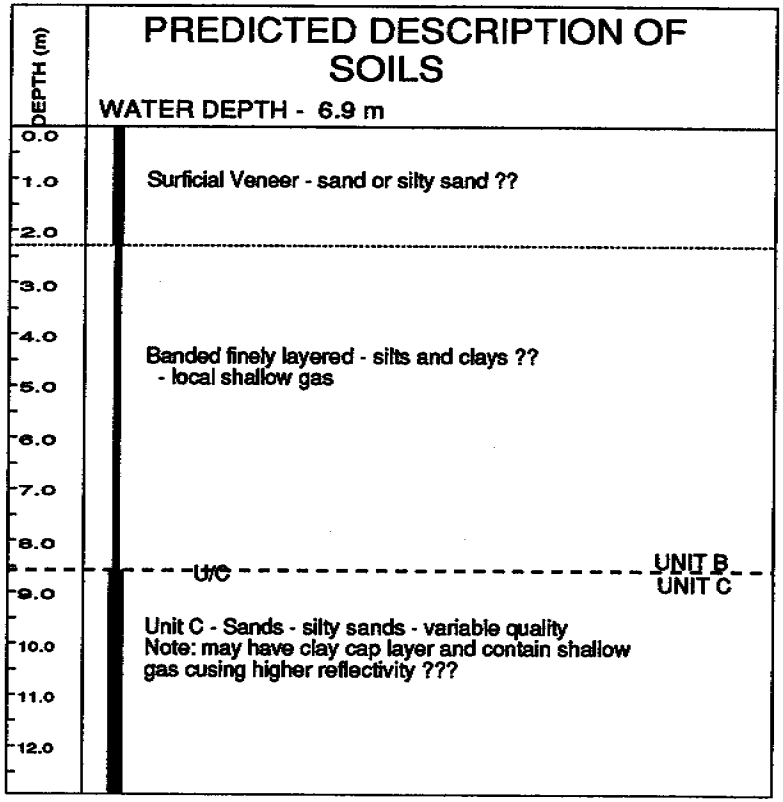


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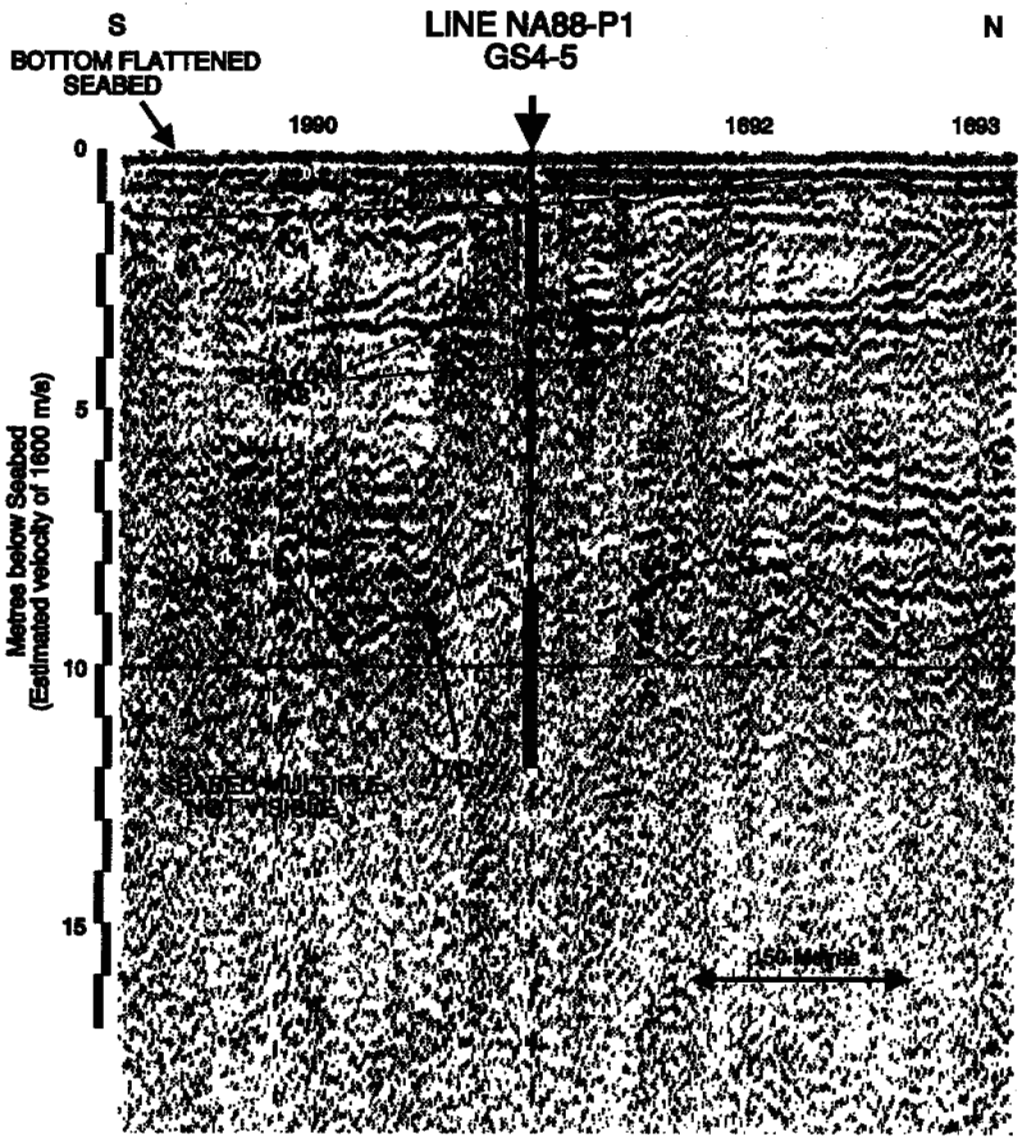
FIGURE: GS4-4



DEPTH (m)	PREDICTED DESCRIPTION OF SOILS WATER DEPTH - 7.4 m
0.0	Silt or silty sand ?? - no multiple reflection apparent
1.0 – 2.0	Sands fair to good quality ?? - forset reflection character
3.0	Bottomset near horizontal reflections - likely fines - silt/clay ?
4.0 – 5.0	Massive to weakly bedded character - silts of sandy silts ??
6.0 – 7.0	Strongly banded character - thin silty / clay seds ?? possibly lacustrine origin ??
8.0	UNIT B / UNIT C
9.0 – 12.0	Unit C - likely sands of variable quality - insufficient coherent reflections to make assessment from seismics.

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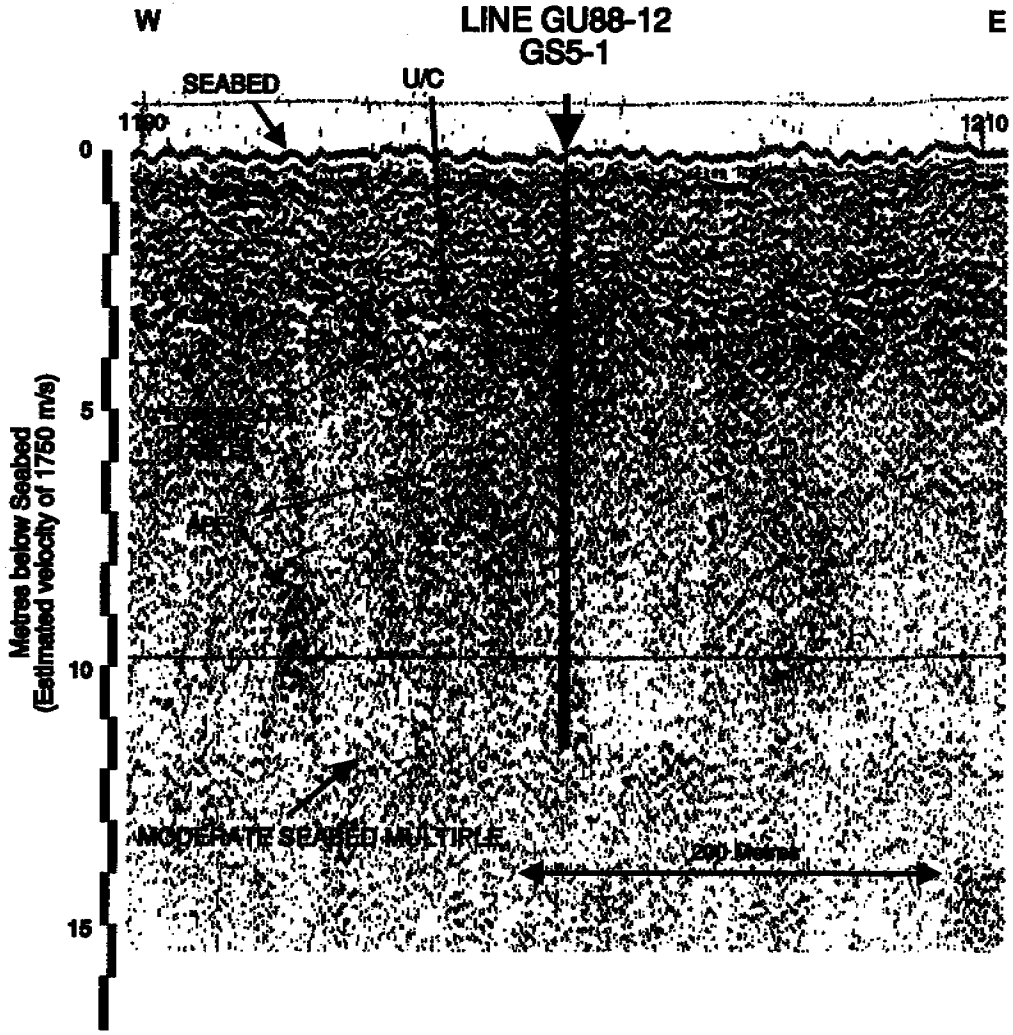
FIGURE: GS4-5



DEPTH (m)	PREDICTED DESCRIPTION OF SOILS WATER DEPTH - 9.7 m	
0.0	Clay / Mud surface veneer ????	
1.0	Re-worked sands with some gravel content ?? or banded clay / silts within saturated paleoscour zone ??	
2.0	U/C	UNIT B / UNIT C
3.0	Very highly reflective zone - either lag gravel bar ?? or disseminated ice crystals ??	
4.0		
5.0		
6.0		
7.0	Normal Unit C sands of variable quality - likely FROZEN ??	
8.0		
9.0		
10.0		
11.0		
12.0		

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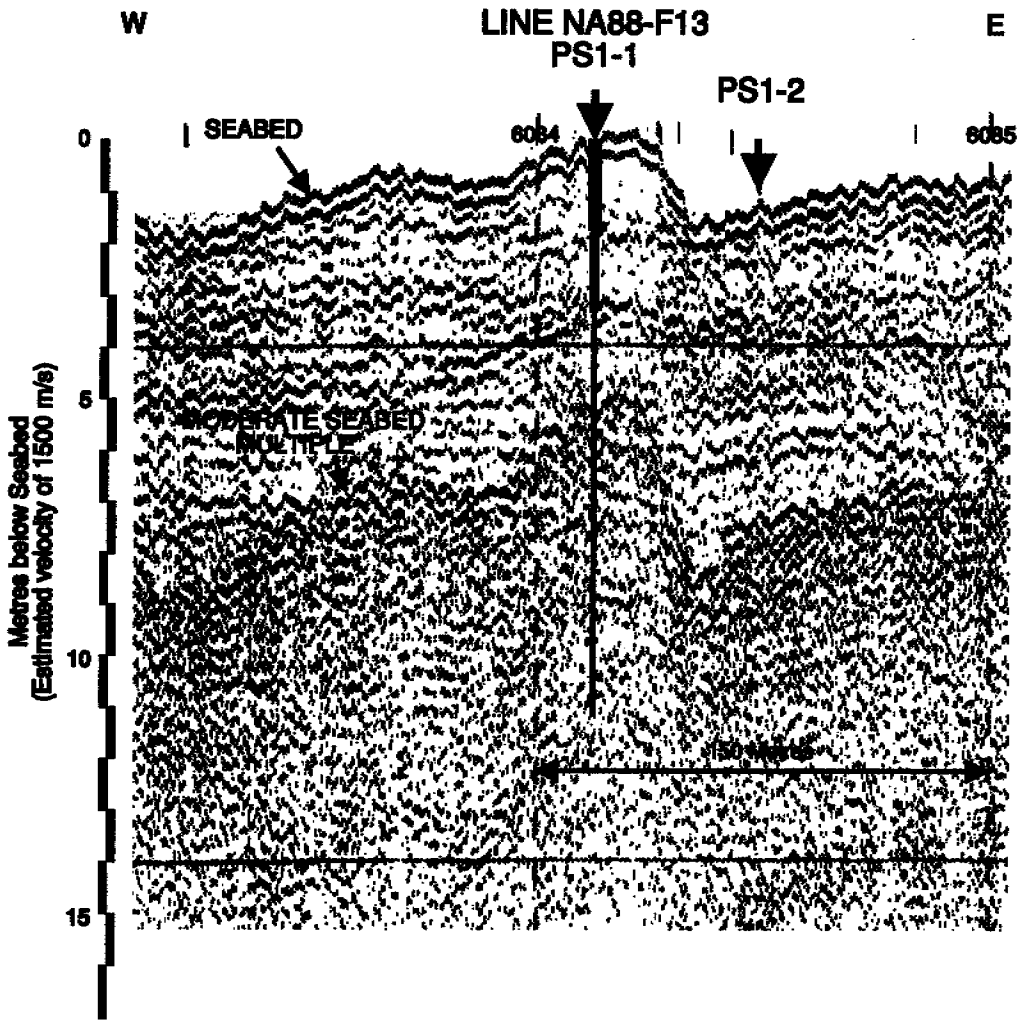
FIGURE: GS5-1



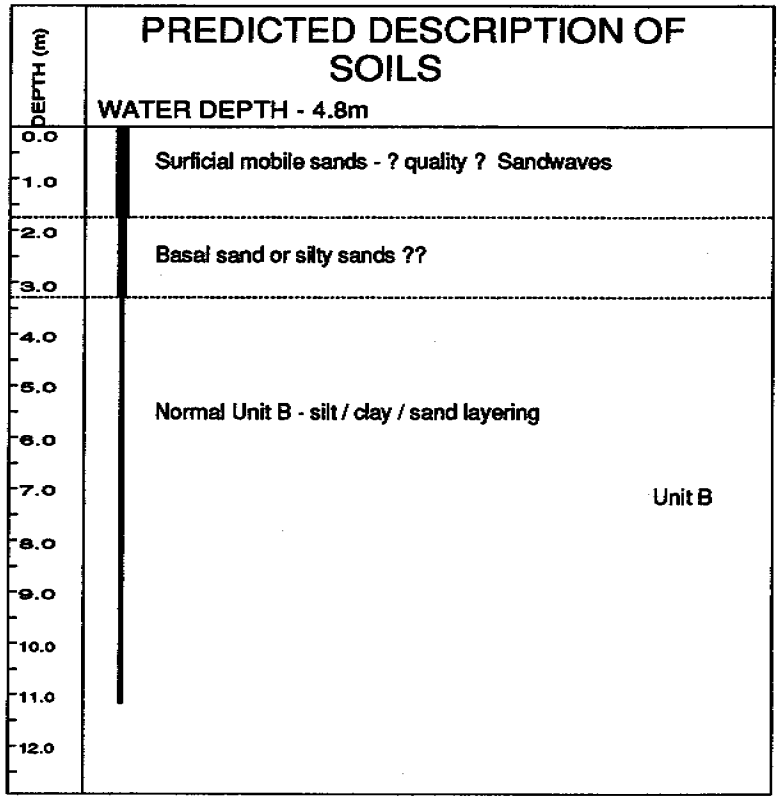


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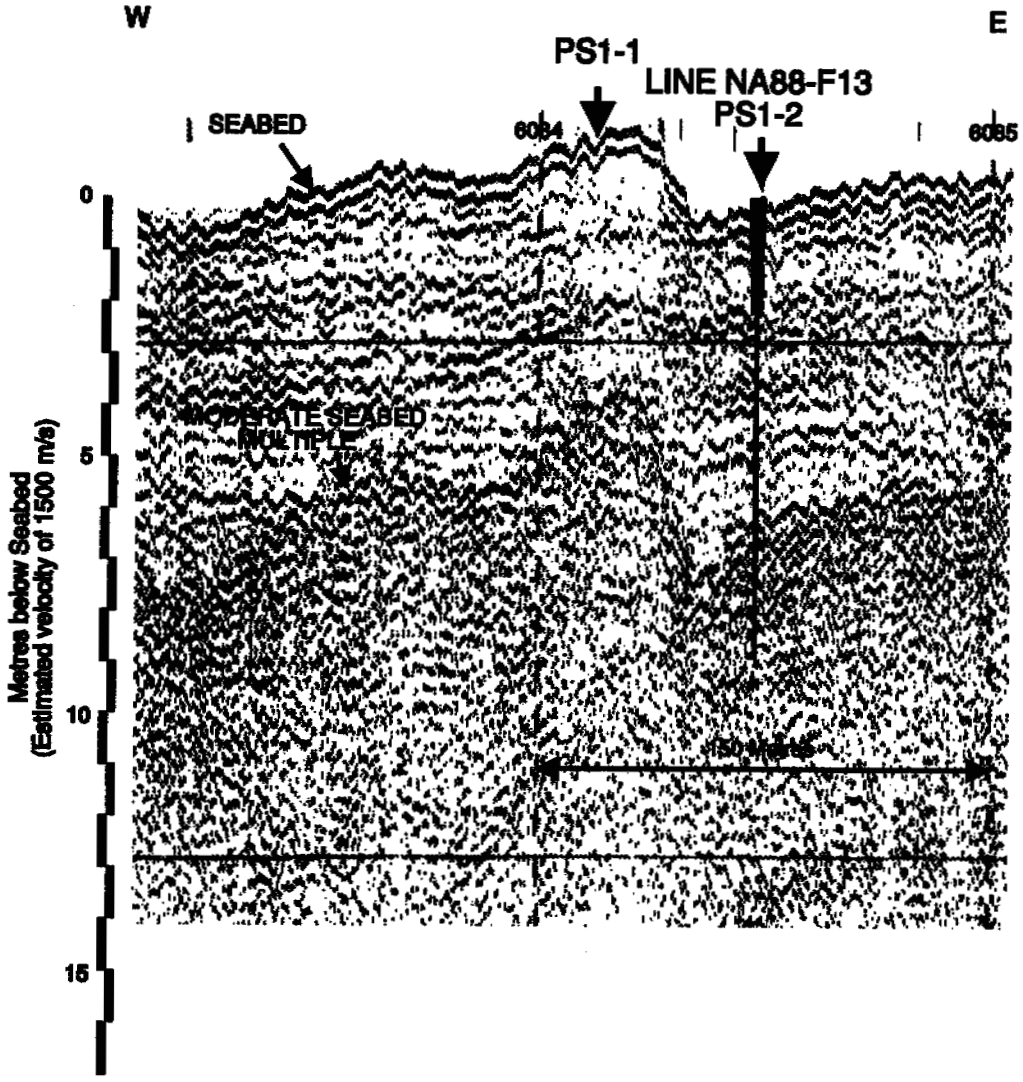
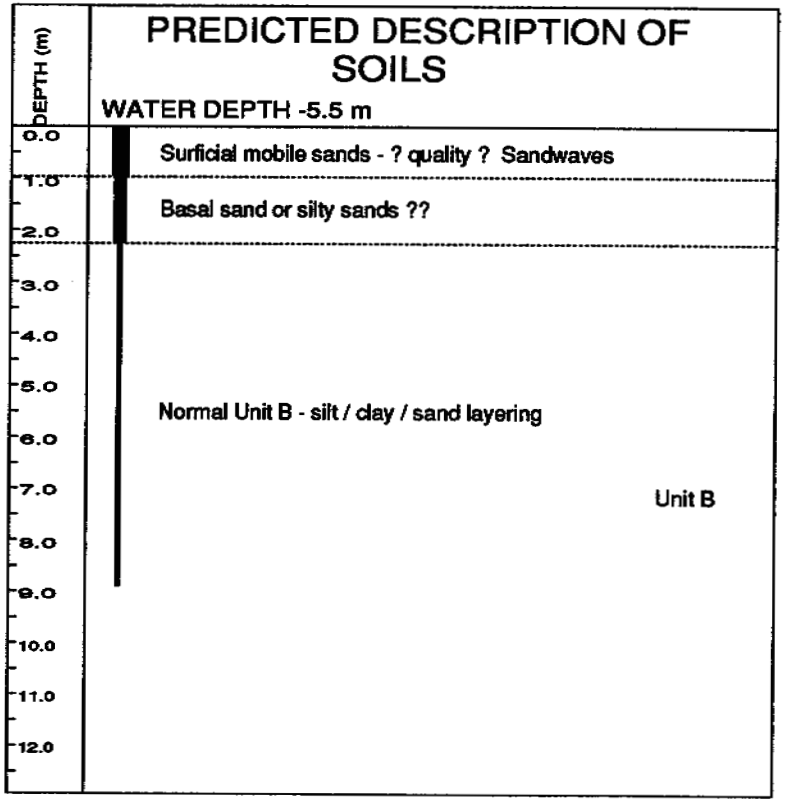
FIGURE: PS1-1





NOTE: EXACT LOCATIONS ON SITE WILL LIKELY REQUIRE USE OF SECTOR SCAN SONAR AS RECORD IS 6 YRS OLD AND MOBILE FEATURES MAY NO LONGER BE IN SAME LOCATIONS

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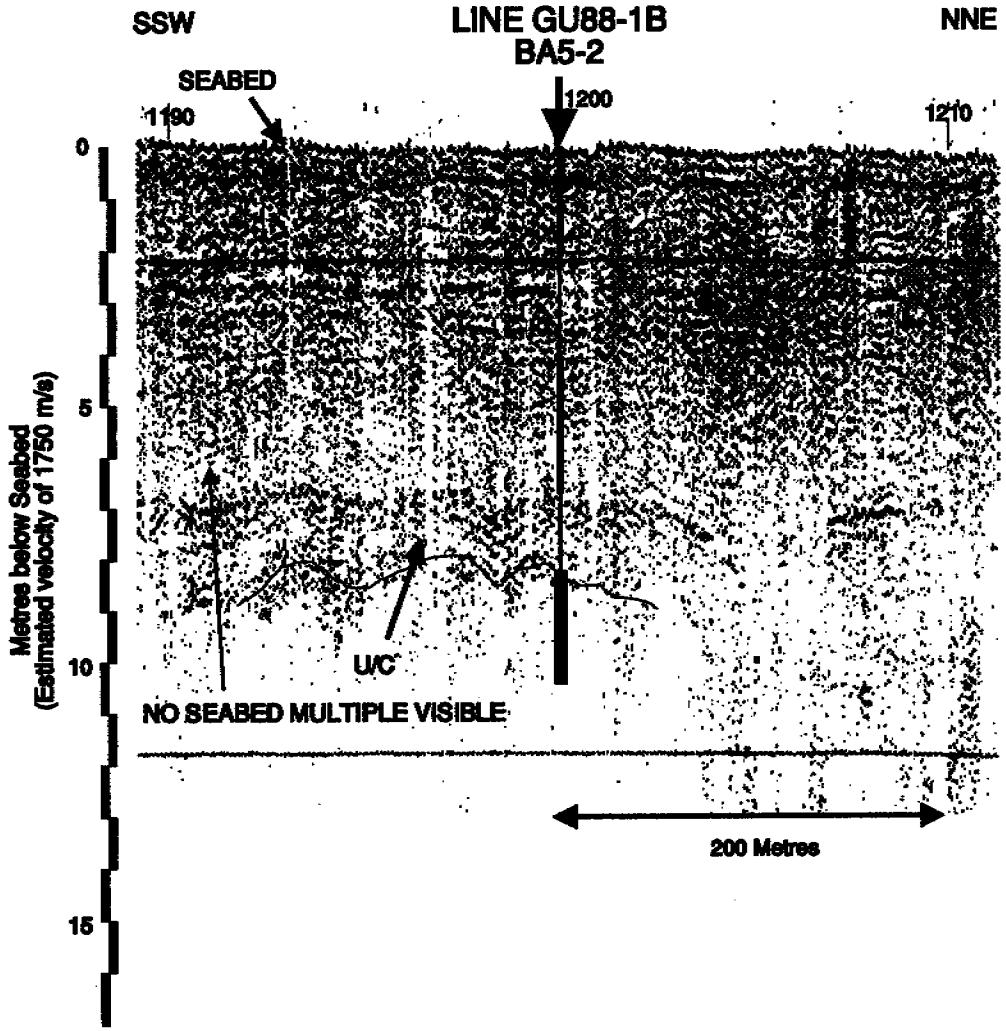
FIGURE: PS1-2

TABLE 3: PROPOSED BOREHOLES MAP SHEET B3

PROP. SAMPLE NO	UTM EASTING	UTM NORTHING	WATER DEPTH (m)	SEISMIC SURVEY LINE	FIX TIME LOCATION	SEDIMENT PREDICTIONS / GEOLOGICAL COMMENTS MAP SHEET B4
BA5-1-N	529,752.33	7,747,744.61	7.3			Assumed surficial sands - bathy rise only with smoothed contours - poor prospect ??
BA5-2-S	531,313.22	7,746,716.70	6.3	GU88-01B	1,200.0	**? Silt or sandy silt @ seabed - no multiple visible - poor prospect - Fig BA5-2 for detail
PS2-1-S	534,588.19	7,746,499.96	5.8	GU88-06A	1,270.0	**Thin sand or silty sand Unit B at seabed - 1.5 m thick ?? - Fig PS2-1 for detail
PS2-2-N	535,533.40	7,746,105.10	4.9	none		Assumed surficial sands - derived from breakers shoal - possible Unit C ??
PS2-3-N	536,380.32	7,745,379.77	3.8	none		Assumed surficial sands - derived from breakers shoal - possible Unit C ??
PS2-4-S	534,888.81	7,745,793.94	5.3	GU88-07B	1,245.0	**Thin sand @ seabed - 1.5-2 m thick - Unit B over gassy silts ? - See Fig PS2-4 for detail
PS2-5-S	535,345.51	7,746,684.51	6.0	GU88-07B	1,296.0	**Thin sand @ seabed - 1 m thick and thinning to north - See Fig PS2-5 for detail.
PS2-6-N	537,007.57	7,746,259.61	5.5	none		Assumed surficial sands - derived from breakers shoal - possible Unit C ??
GV1-1-N	537,056.71	7,744,399.07	1-2	none		Unit C with lag gravel armour - possibly frozen within 3-5 m of seabed ??
GV2-1-N	538,848.84	7,740,660.82	1-2	none		Unit C with lag gravel armour - possibly frozen within 3-5 m of seabed ??



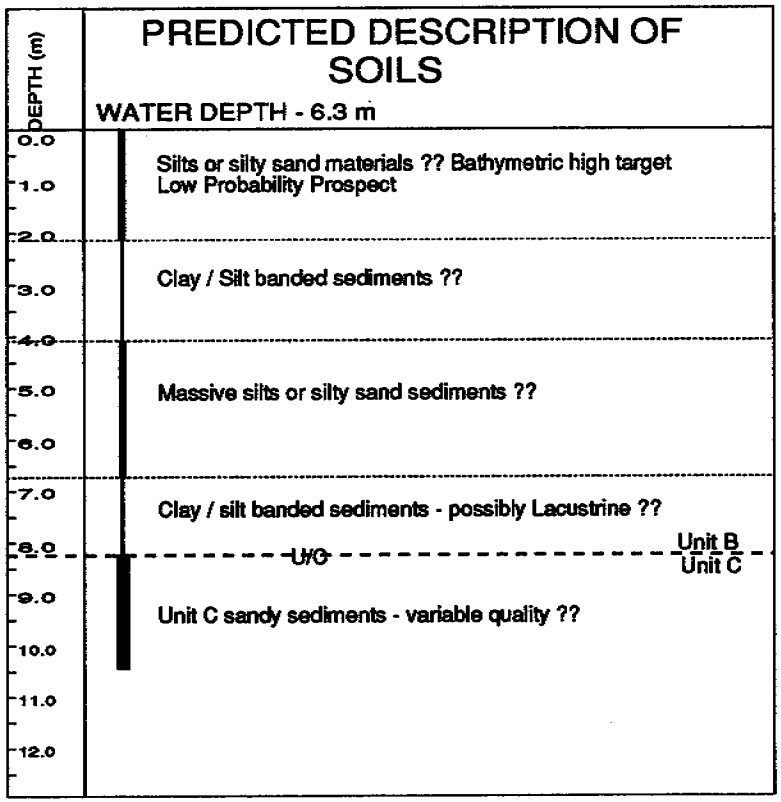


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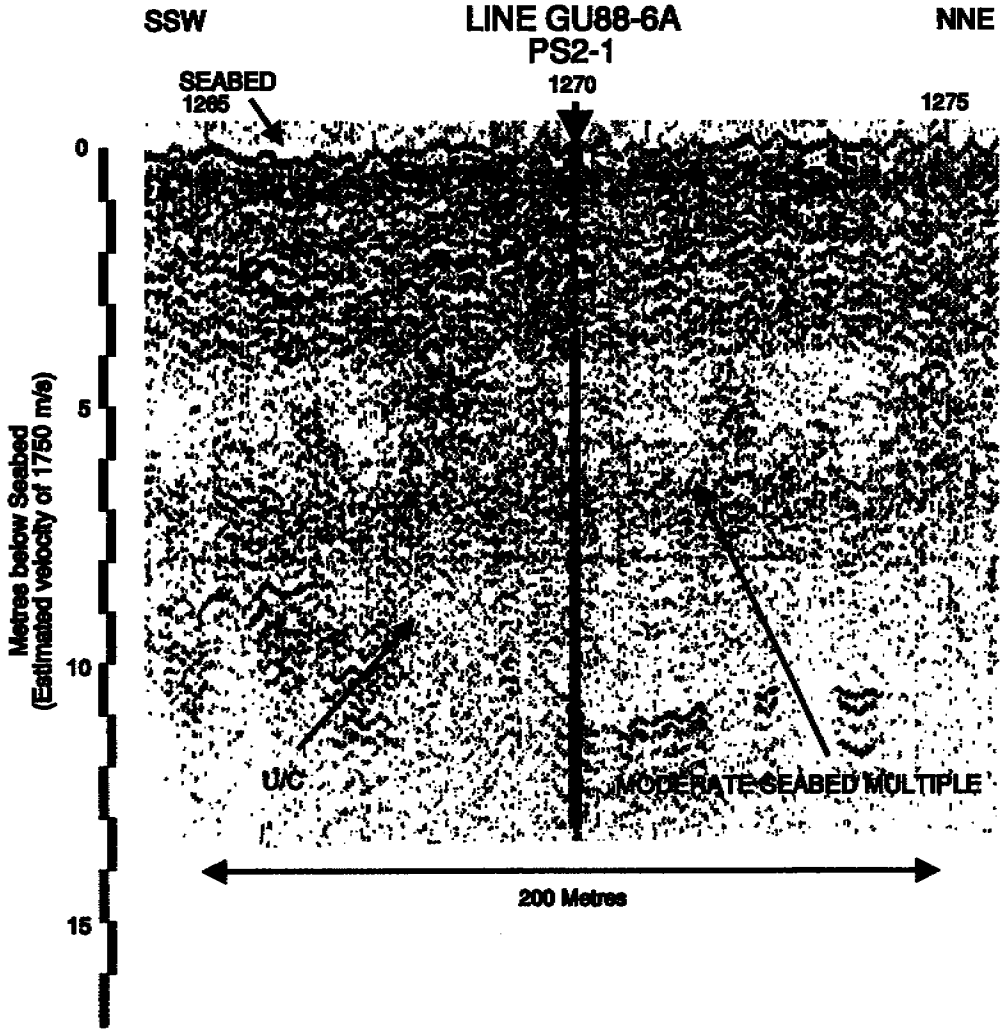
FIGURE: BA5-2



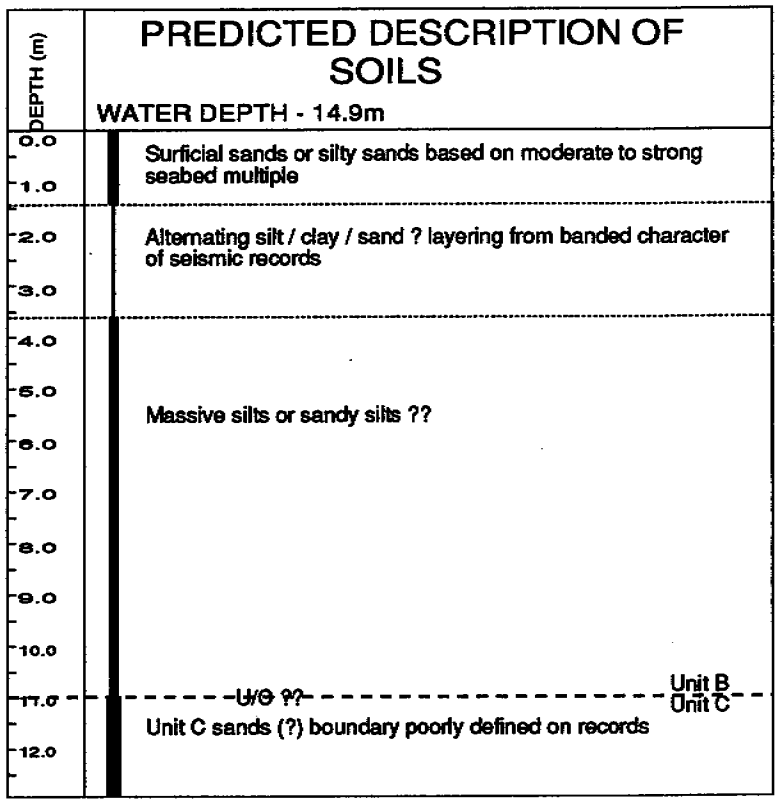


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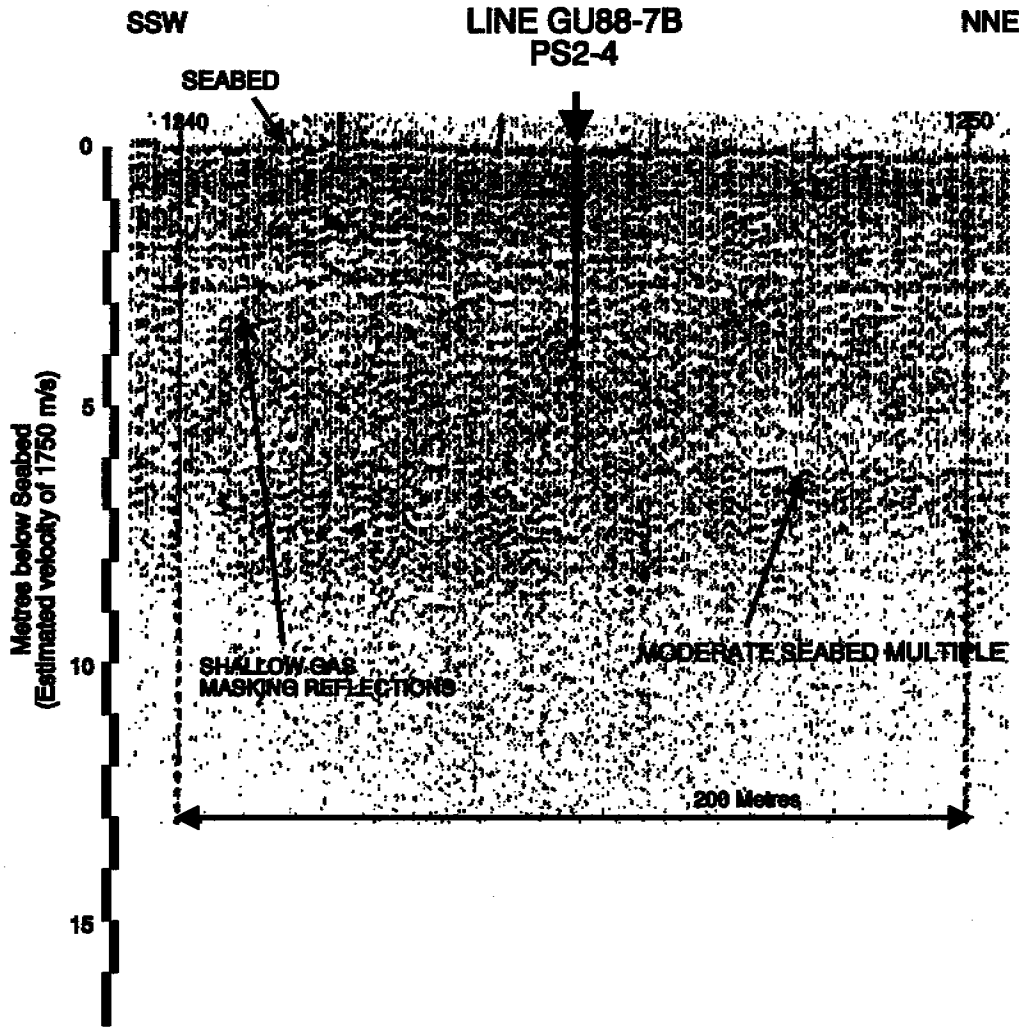
FIGURE: PS2-1



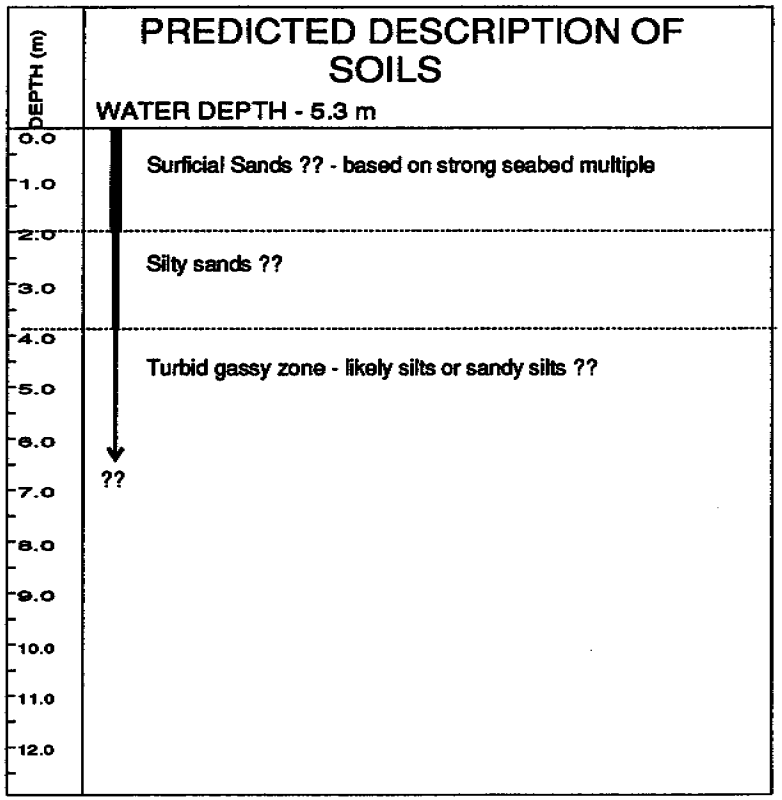


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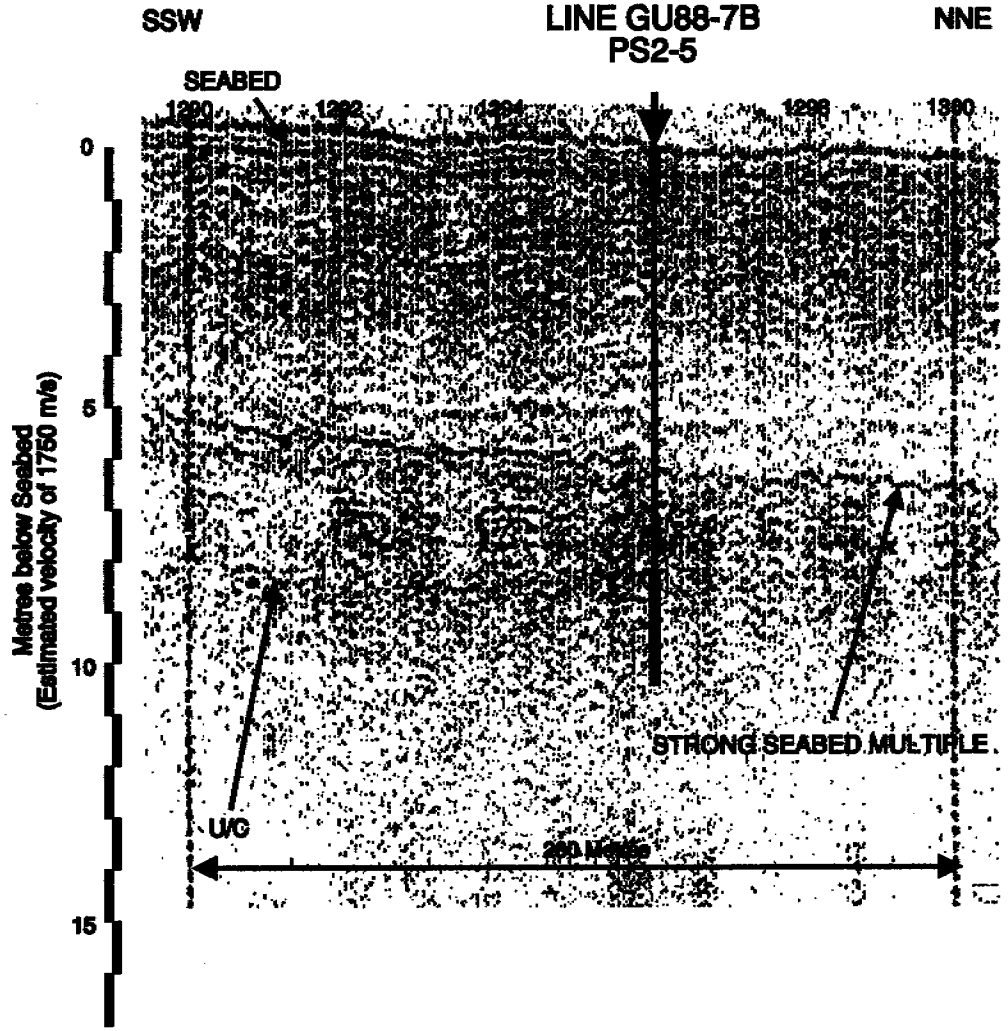
FIGURE: PS2-4



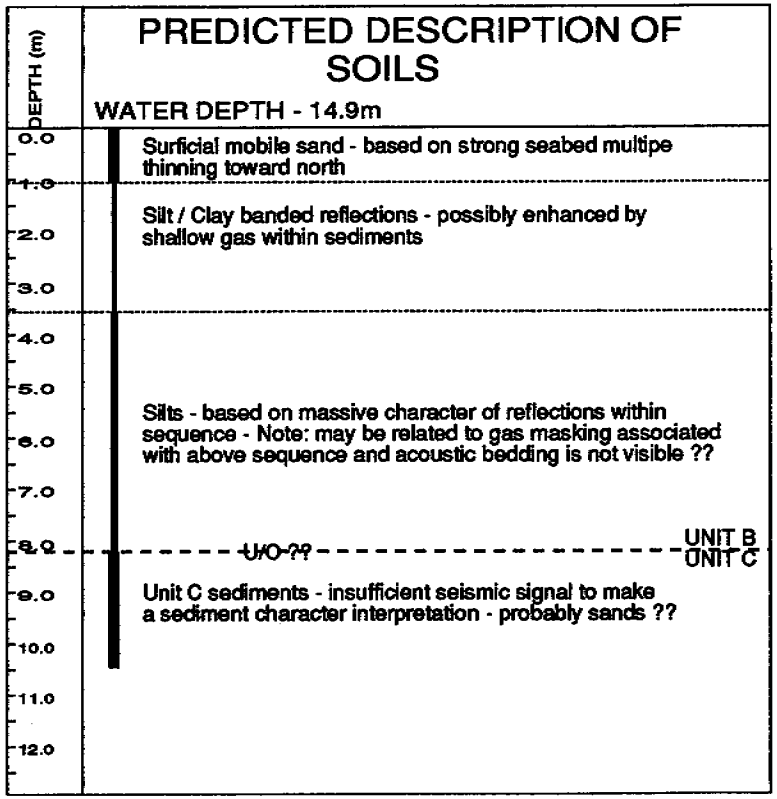


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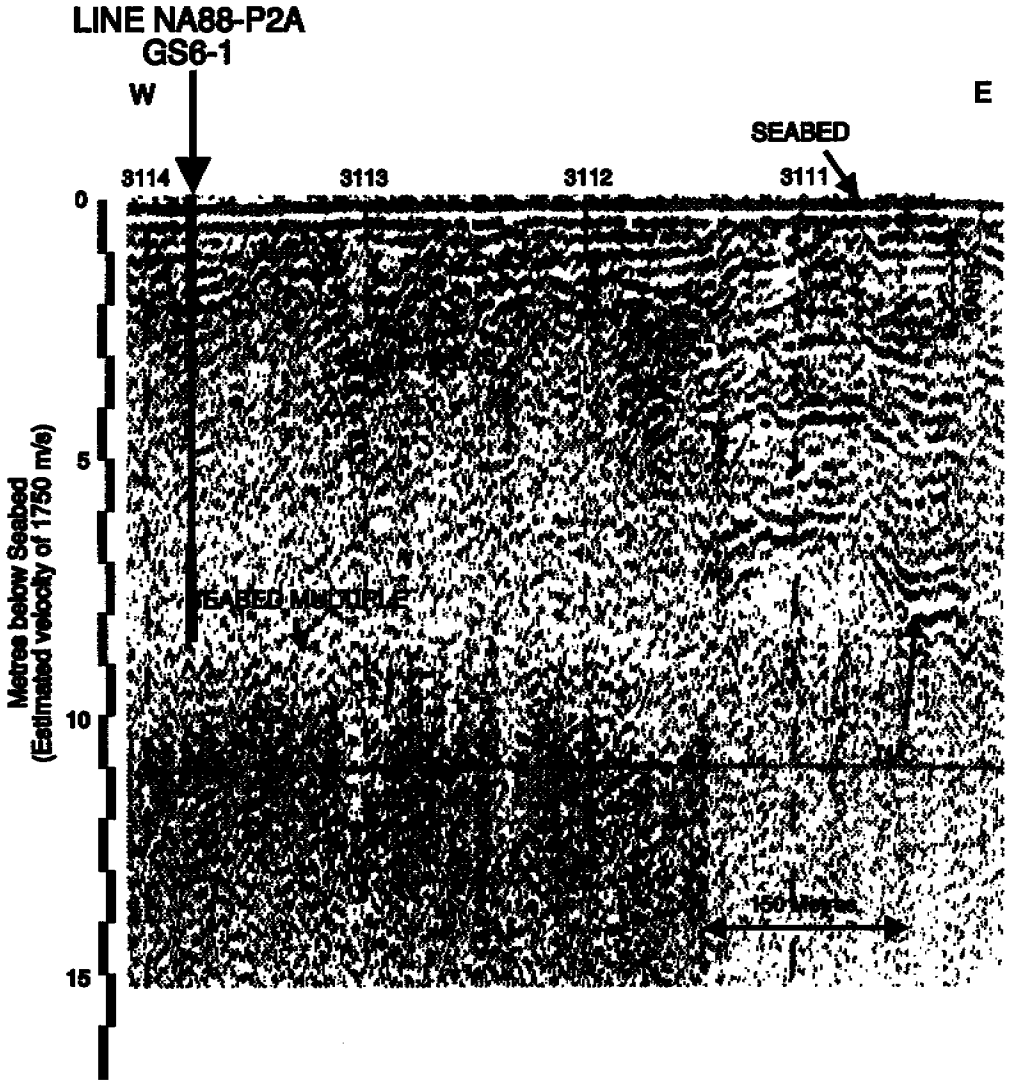
FIGURE: PS2-5

TABLE 4: PROPOSED BOREHOLES MAP SHEET B4

PROP. SAMPLE NO	UTM EASTING	UTM NORTHING	WATER DEPTH (m)	SEISMIC SURVEY LINE	FIX TIME LOCATION	SEDIMENT PREDICTIONS / GEOLOGICAL COMMENTS MAP SHEET B3
GS6-1-S	521,459.39	7,745,776.77	7.1	N88-P2A	3113.8	**Possible 2.3 m surficial sands @ southern boundary of GS6 area - See Fig GS6-1 for detail
GS6-2-S	523,112.78	7,746,499.96	7.2	N88-P3	6418.5	Record missing this section - est 2-3 m of surficial foreset sand or silty sand at seabed.
GS6-3-S	524,306.57	7,746,085.79	6.7	N88-P2A	3094.0	**Surficial sand - possibly good quality - See Fig GS6-3 for details
GS6-4-S	522,549.12	7,745,643.72	6.8	N88-P3	6411.8	**Surficial sands - complex re-worked Unit B - See Fig GS6-4 for details
GS6-5-?S	524,089.78	7,745,315.39	6.2	N86-13	97	poor seis - assume surfical sands - unknown quality and thickness - test southern extent of body
GS6-6-N	521,280.18	7,747,092.24	7.7	none	----	Assume surfical sands Unit B - unknown quality and thickness - test northern extent of body
PS3-1-N	518,063.02	7,747,411.99	7.8	none	----	Possible surficial sand body northern extent - sands may be at 2-3 m depth in this area ???
PS3-2-S	520,385.60	7,745,597.50	7.0	N88-P2A	3120.0	**Surficial sands & shallow Unit C - poss source area for GS6 - Fig PS3-2 for detail
PS3-3-S	523,080.98	7,743,139.39	5.2	NA91	250/2048.8	**Surficial sands - approx 1 m thick over shallow Unit C Fig PS3-3 for detail
C2C-1-S	521,277.29	7,742,368.99	5.1	NA91	250/2030	**1 m surficial mobile layer over Unit C poss gravels or gassy ?? - Fig C2C-1 for detail
C2A-1-S	519,080.49	7,745,014.95	7.8	NA91	249/2055	**1.1 m surficial mobile sand? over Unit C. Fig C2A-1 for detail



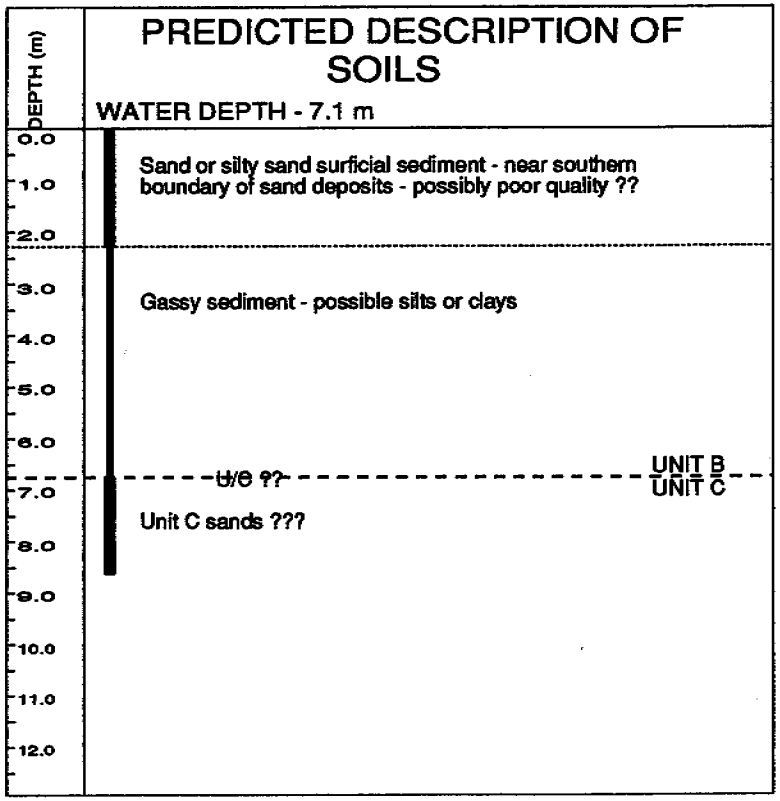


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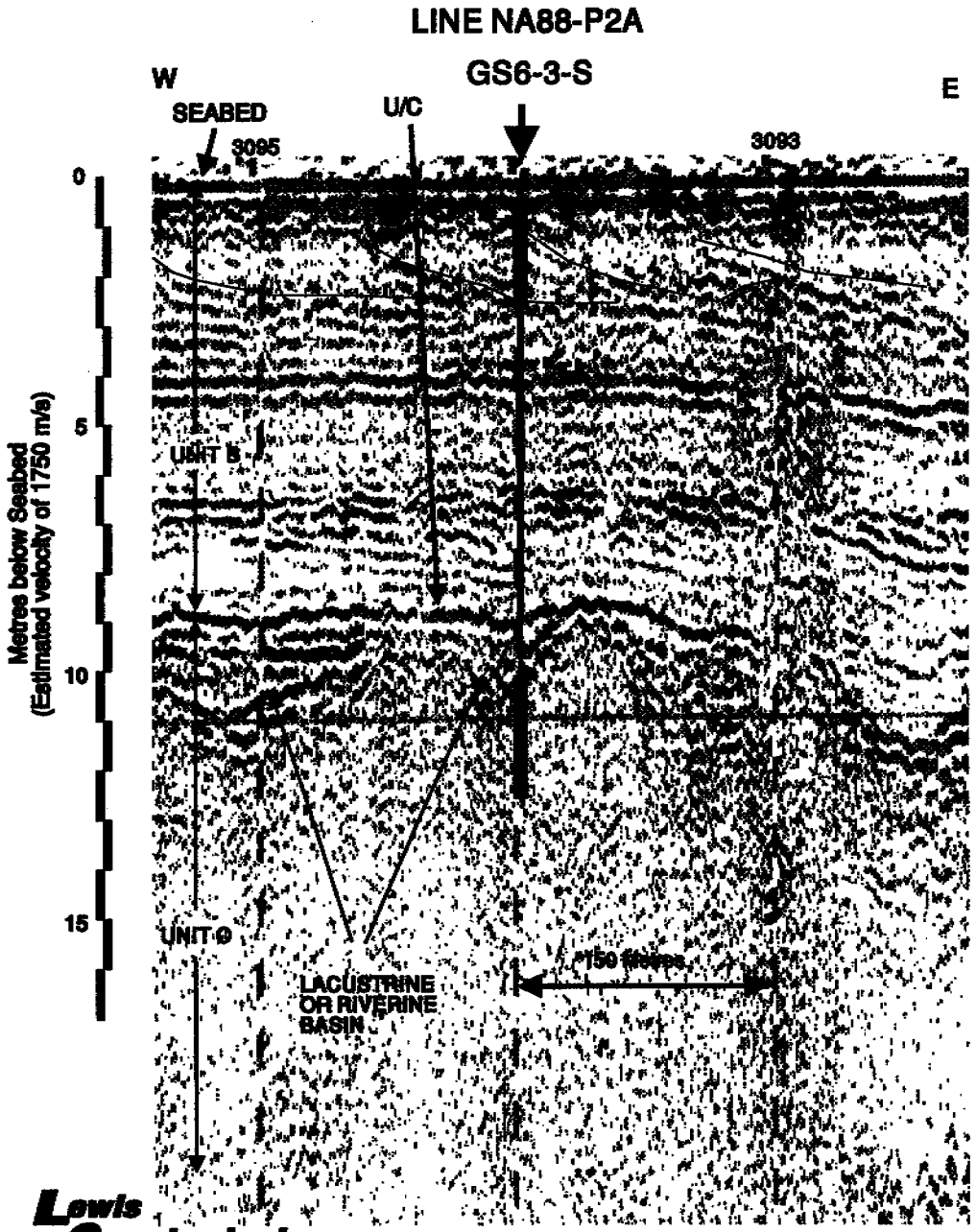
FIGURE: GS6-1



DEPTH (m)	PREDICTED DESCRIPTION OF SOILS WATER DEPTH - 6.7 m
0.0	Surficial muds - silts of silty sands
1.0	Foreset beds - medium to fine grained sands with some silts - unknown possibly GOOD borrow quality
2.0	
3.0	Distal bottomset beds - fine sand grading to clays at base
4.0	
5.0	Possible second foreset sequence - fine sands or silts ??
6.0	U/C ???
7.0	Lacustrine or shallow marine silts and clays - distal sequence
8.0	UNIT B
	U/C — UNIT C
9.0	Lacustrine or riverine basin fill - silts and clays ?
10.0	
11.0	Sands of Unit C - variable quality
12.0	

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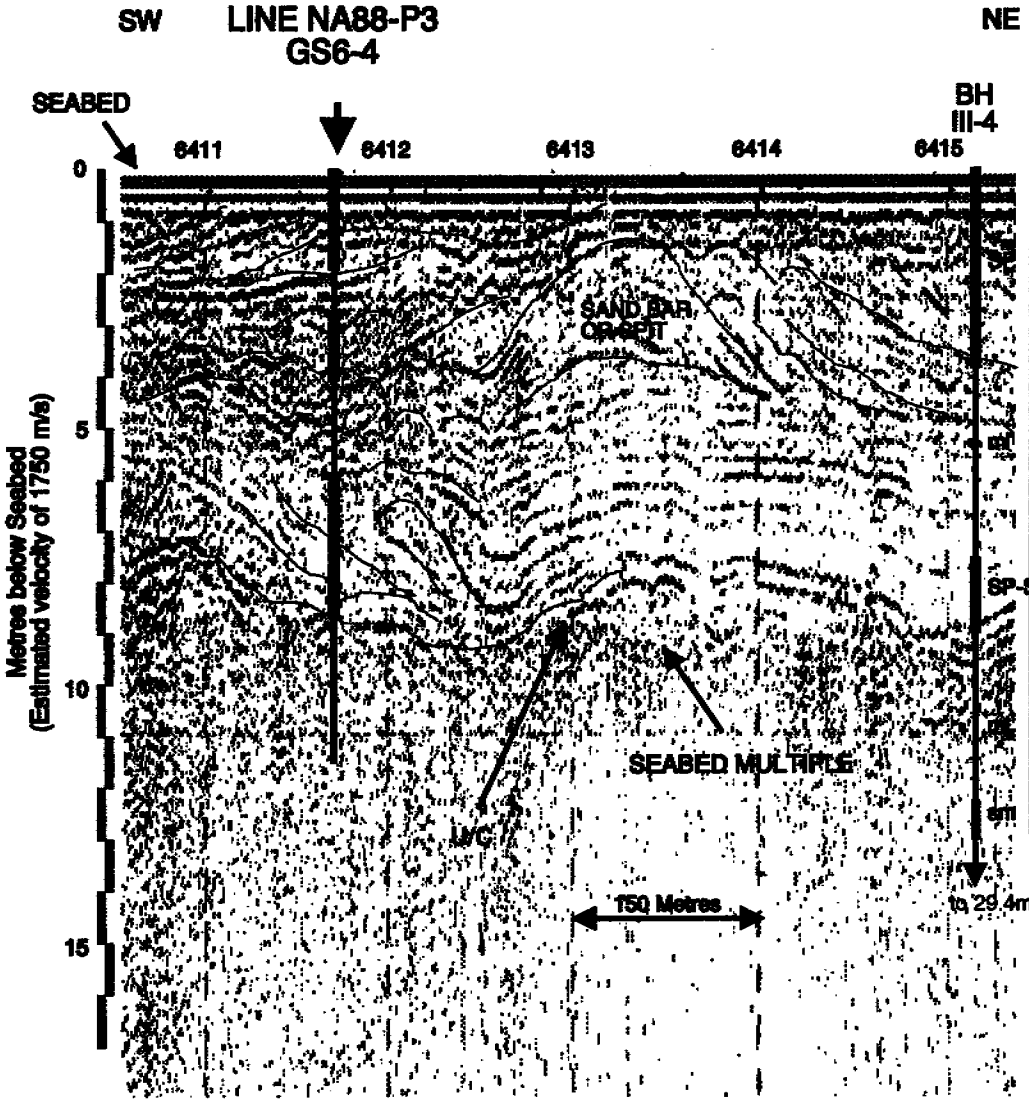
FIGURE: GS6-3



DEPTH (m)	PREDICTED DESCRIPTION OF SOILS WATER DEPTH - 6.8 m
0.0 – 1.0	Surficial sand - foreset beds - ? Good Quality ?
2.0	? Clay silt bottomset reflection sequence
3.0 – 4.0	complex reflections - possible slump debris or sandy current derived bedforms
5.0	Complex bedforms - extension of offshore silts - possibly coarser grained at this locatiotion
6.0 – 7.0	Moderately dipping foresets - possibly sands or silty sands
8.0	U/C — UNIT B / UNIT C
9.0 – 12.0	Unit C sediments - primarily sands of variable quality ??

Note: Borehole log for III-4 Attached

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FIGURE: GS6-4

DEPTHS ARE REFERENCED BELOW SEABED	DRILL RIG – BECKER	BOREHOLE NO: III–4
	DRILLED FROM ICE	Project No: EBA # 1–965.2
ORIGINAL BOREHOLE NO. III–4	WATER DEPTH – 7.5m	ELEVATION: –7.500 (m)

SAMPLE TYPE ■ DISTURBED ▨ NO RECOVERY ⊠ SPT ▤ A-CASING ▥ SHELBY TUBE ▮ CORE

Symbols for SOILS

DEPTH (m)	USC	SOIL SYMBOL	SAMPLE TYPE	SAMPLE NO	SPT(N)	D50 (um) 40 80 120 160 / % SAND 20 40 60 80 / PLASTIC M.C. LIQUID 20 40 60 80	ICE DESCR	TEMPERATURE	DEPTH (m)
0.0									0.0
1.0	SP						UNFROZEN		1.0
2.0									2.0
3.0									3.0
4.0									4.0
5.0									5.0
6.0									6.0
7.0									7.0
8.0	SP–SM								8.0
9.0									9.0
10.0									10.0
11.0									11.0
12.0									12.0
13.0	SM						UNFROZEN		13.0
14.0									14.0
15.0									15.0
16.0									16.0
17.0									17.0
18.0									18.0
19.0									19.0
20.0									20.0
21.0	SM						UNFROZEN		21.0
22.0									22.0
23.0									23.0
24.0									24.0
25.0									25.0

SP: SAND (SP) – medium grey brown, fine grained, trace silt

– trace to some silt, trace of organics

SILT (ml) – dark grey brown, sandy, trace clay and organics

– some sand

SP–SM: SAND (SP–SM) – medium to dark grey–brown, trace silt, trace of organics

– some gravel (max 60mm)

SILT (ml) – sandy, trace of clay and organics

SM: SAND (sm) – silty, trace of fine gravel

– trace clay

SILT (ml) – dark grey, some sand, trace of clay, stiff

– some sand to sandy

SAND (sm) – medium brown, very fine, some silt

SAND (sm) AND SILT – medium brown, fine grained, trace of clay

SM: SAND (SM) – medium brown, very fine, some silt

UNFROZEN

UNFROZEN

UNFROZEN

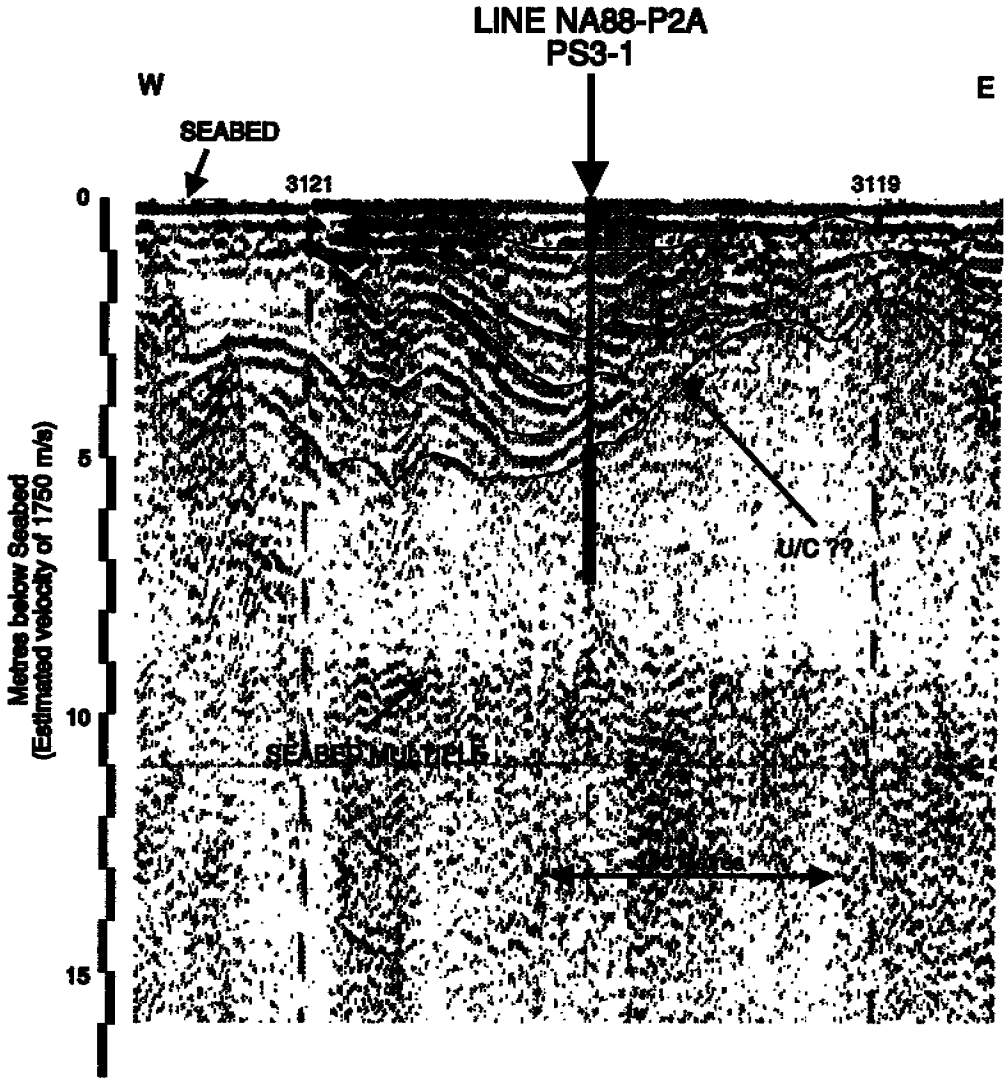
Geological Survey of Canada Dartmouth, Nova Scotia	LOGGED BY: JH	COMPLETION DEPTH: 29.4 m
	REVIEWED BY: TRM SMK	COMPLETE: 75–04–26
	Fig. No:	

DEPTHS ARE REFERENCED BELOW SEABED	DRILL RIG – BECKER	BOREHOLE NO: III–4
	DRILLED FROM ICE	Project No: EBA # 1-965.2
ORIGINAL BOREHOLE NO. III–4	WATER DEPTH – 7.5m	ELEVATION: –7.500 (m)

SAMPLE TYPE ■ DISTURBED ▨ NO RECOVERY ⊠ SPT ▤ A-CASING ▥ SHELBY TUBE ▯ CORE

DEPTH (m)	USC	SOIL SYMBOL	Symbols for SOILS	SAMPLE TYPE	SAMPLE NO	SPT(N)	■ D50 (um) ■ 40 80 120 160 ◆ % SAND ◆ 20 40 60 80 PLASTIC M.C. LIQUID 20 40 60 80	ICE DESCR	TEMPERATURE	DEPTH (m)
25.0										25.0
26.0										26.0
27.0										27.0
28.0										28.0
29.0										29.0
30.0			END OF BOREHOLE at 29.4m							30.0
31.0										31.0
32.0										32.0
33.0										33.0
34.0										34.0
35.0										35.0
36.0										36.0
37.0										37.0
38.0										38.0
39.0										39.0
40.0										40.0
41.0										41.0
42.0										42.0
43.0										43.0
44.0										44.0
45.0										45.0
46.0										46.0
47.0										47.0
48.0										48.0
49.0										49.0
50.0										50.0

Geological Survey of Canada Dartmouth, Nova Scotia	LOGGED BY: JH	COMPLETION DEPTH: 29.4 m
	REVIEWED BY: TRM SMK	COMPLETE: 75-04-26
	Fig. No:	Page 2 of 2



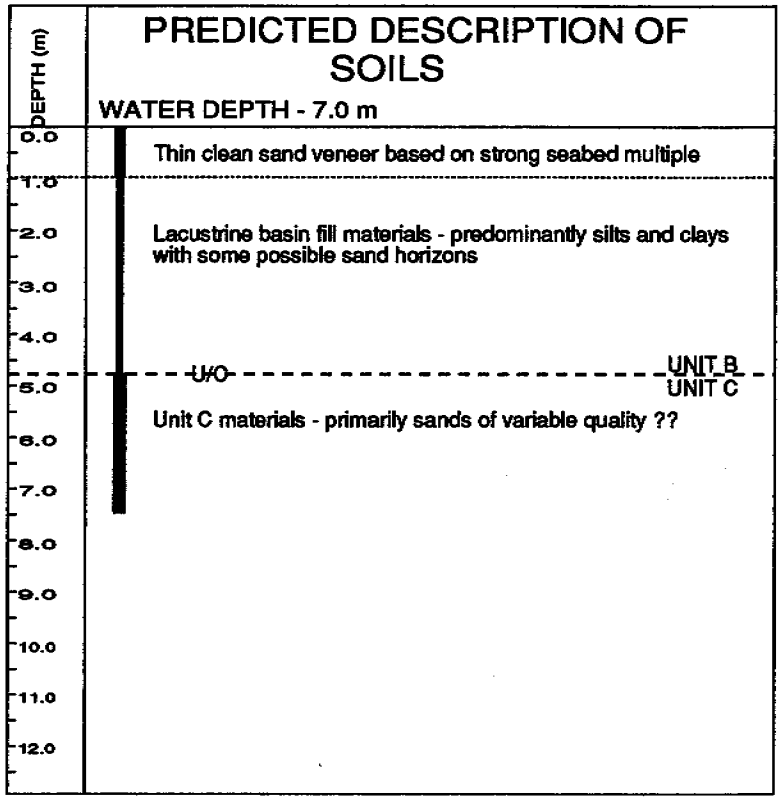


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FIGURE: PS3-2

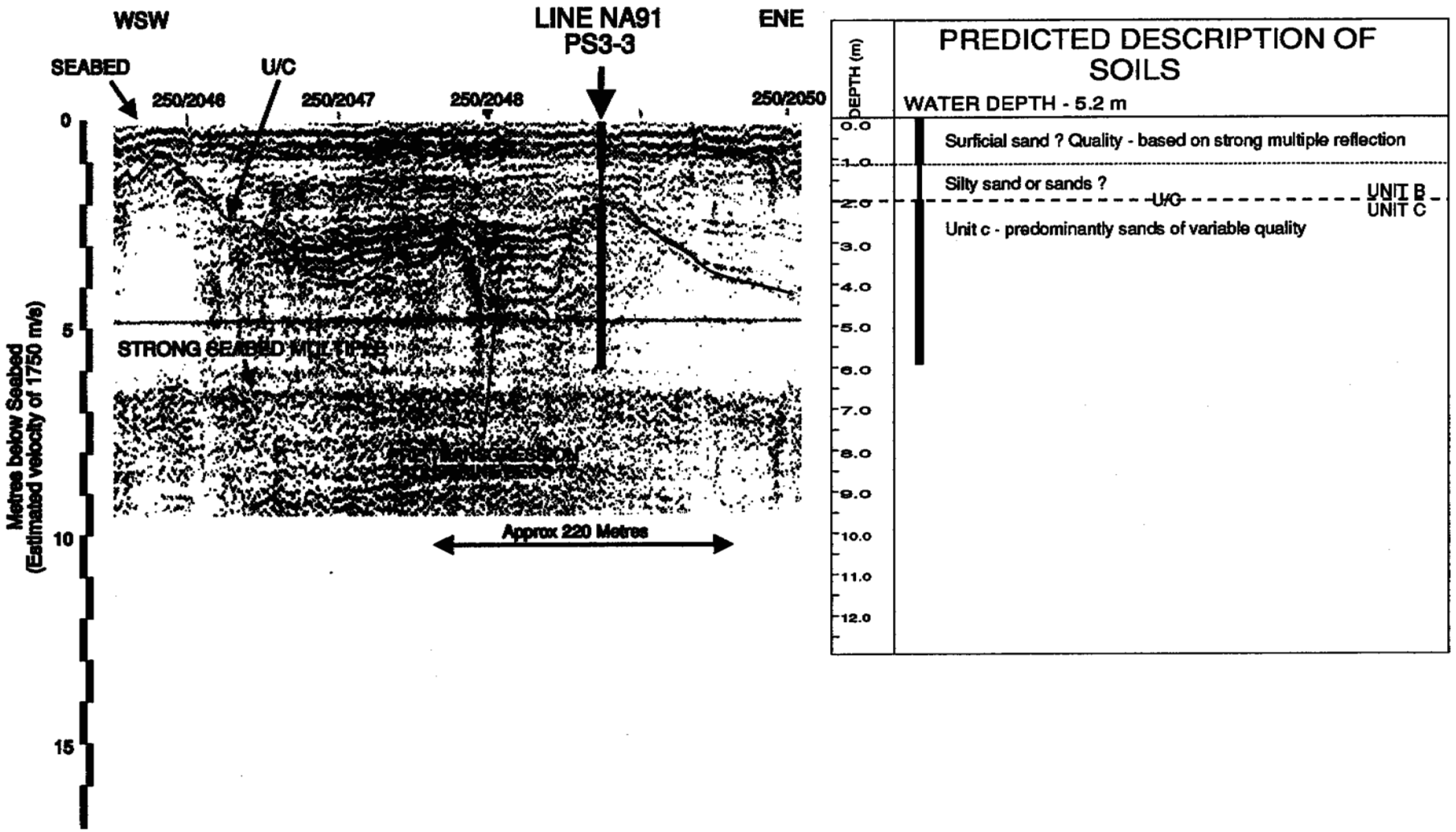

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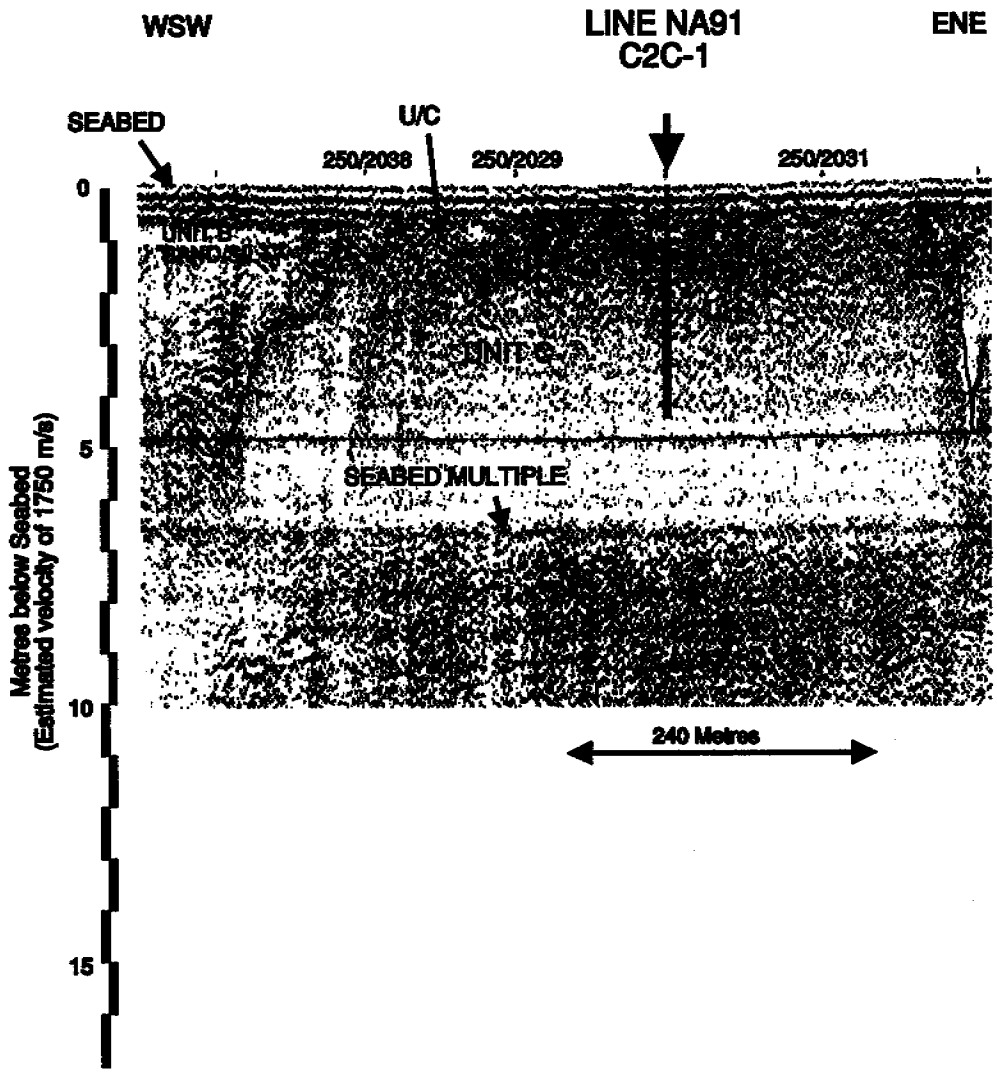
FIGURE: PS3-3



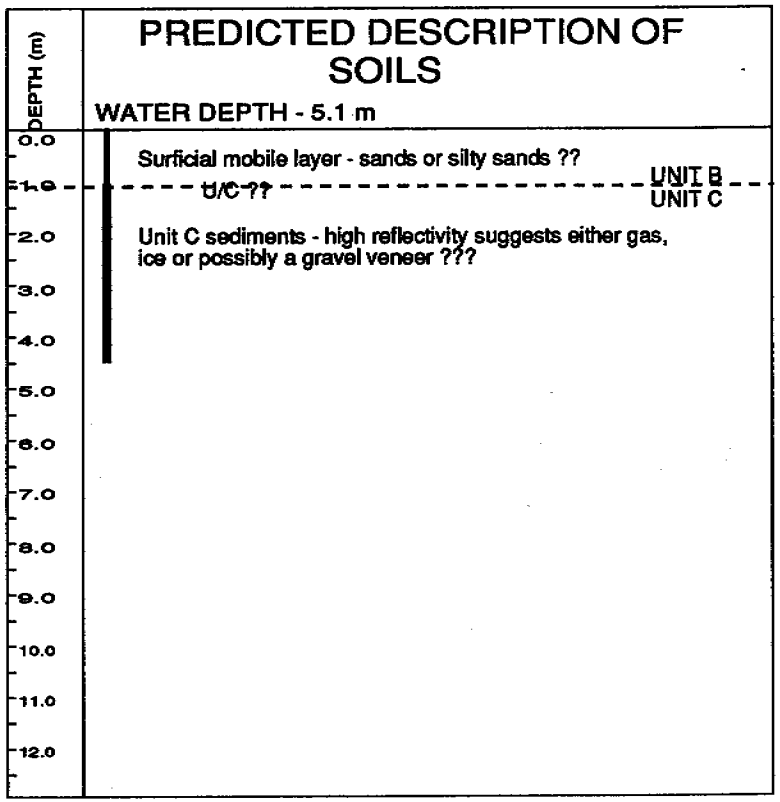


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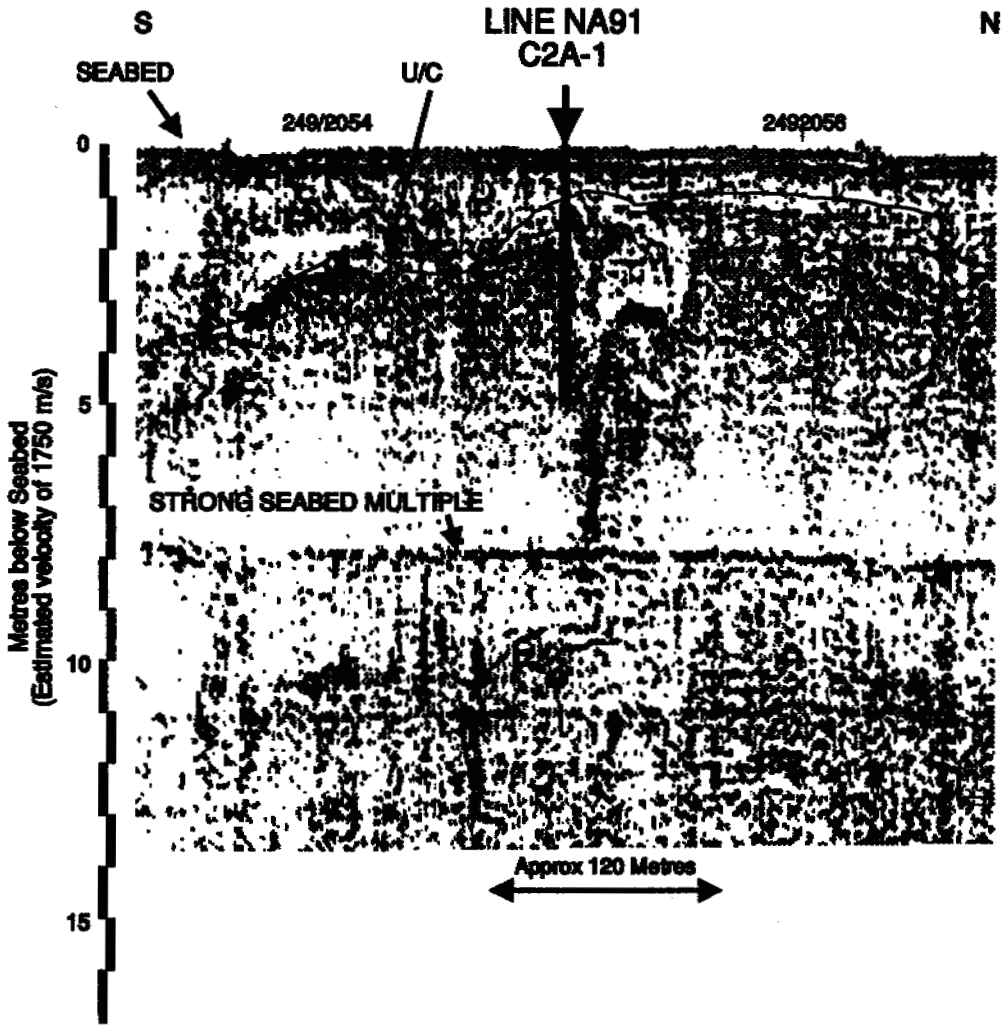
FIGURE: C2C-1



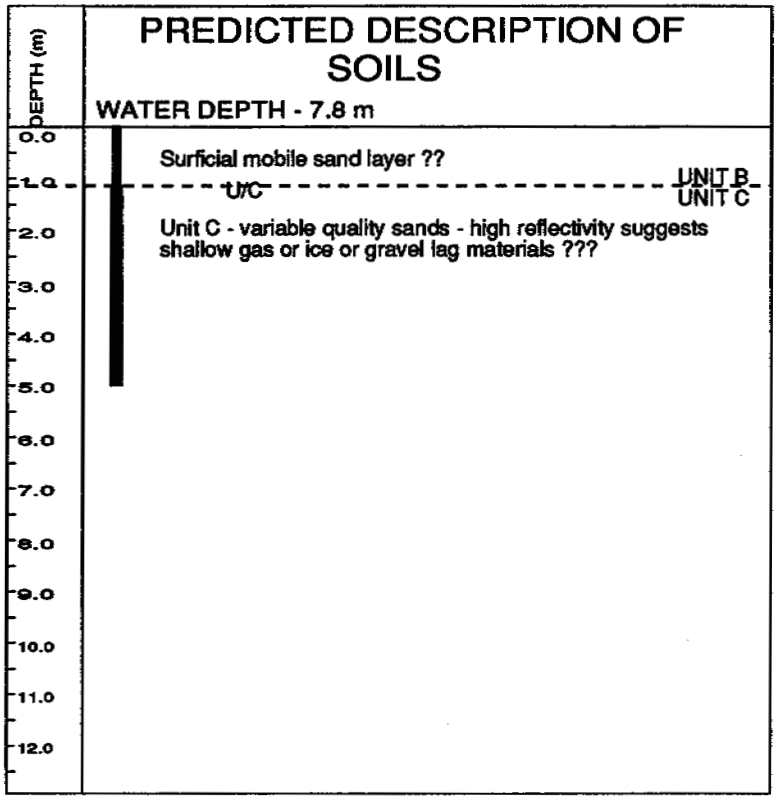


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FIGURE: C2A-1

4-4 Geophysical Survey Recommendations

One of the requirements of this report has been to outline a set of geophysical survey recommendations that would be appropriate for a future geophysical survey program to further investigate the resource potential and areal and volume extents of the outlined (and any other new) target areas. The following sections outline the survey equipment that would most likely provide the best definition and mapping of the potential granular resource areas. It should be noted here that future geophysical systems developments may alter the specific systems defined here and due consideration should be given to new or novel approaches that may not be outlined below when making a final selection. Secondly a series of survey line coordinates are provided for the map areas and target areas presented in this report. The survey lines presented in this study are meant to provide a minimal basic regional coverage of these site areas and if high detail (resource evaluation) is warranted of a particular site area it is recommended that a fine tuned (optimum orientation) detailed grid of 100 to 150 m or less line spacing be implemented where required. The final orientations and line spacings would best be defined after completion of and at least an on board evaluation of the presently defined basic survey grid coverages.

4-4-1 Geophysical Survey Equipment Recommendations

The following sub-sections outline a detailed equipment and basic operating summary for a granular resource study program within the 5 m to 30 m water depth regions of the South Central Beaufort Sea study area.

4-4-1-1 Navigation

Survey navigation for this study will require positioning accuracies of +/- 10 m or better in order to provide precise repositioning for follow on sampling and ultimate resource recovery and utilization. The navigation system should provide virtual real time accurate positioning such that preplanned track lines can be run for the purpose of sidescan mosaic production and ensuring proper ship steering. In order to achieve this objective real time vessel position display is required on a bridge display for helm control. The navigation system will be required to display vessel position at intervals of not greater than about 3 seconds and to be capable of logging these positions to disk or tape and of providing an external fix marking control pulse (5 V TTL or contact closure of 1 to 300 ms length) to be interfaced to the survey

systems. Fix marks pulses should be generated at intervals of distance along the survey track and the interval should be operator controllable (nominally 50 to 200 m). These fix marks should be correlated to a shot point number (selectable as incrementing or decrementing by one at each distance interval) and to Julian day and time and in particular the position and time and SP no. at the fix mark must be logged to a digital storage media. Optionally one or more digital RS232 input/output signal lines interfaced to the survey systems may be required to provide shot number and/or time and/or position data and/or smoothed vessel speed and/or input digital bathymetry to be logged with the navigation data depending on the final systems selection.

The actual position measurement systems can be radio positioning systems such as ARGO (non-line of site) or Syledis (line of site) and would require establishment of appropriate base stations along the coastline and acceptable calibration procedures. The system could also be a Differential Global Positioning System (DGPS) with a suitable shore reference station established in the region. The radio link to the survey vessel would have to be capable of maintaining coverage throughout the survey area. Alternately a system such as the new STARFIX II DGPS might be utilized as long as proper satellite links can be maintained within the Southern Beaufort area and confirmation of this can be made prior to mobilization.

4-4-1-2 Bathymetry

Bathymetric systems for this survey program are not considered to be critical since the region has been recently well surveyed by CHS. Thus accurate tide and draught control would not be required and a bar check would only be used to basically setup the systems for reasonable accuracy in the area. The bathymetric system would primarily be utilized for small scale bottom feature characterization. If utilized for this purpose it should be a heave compensated system in order to remove the effects of vessel motion so that small scale bathymetric features such as ice scours and mounds or seabed waveforms can be clearly identified on the hard copy graphic displays. The system must be capable of receiving and displaying navigational fix marks to log onto the paper displays either as a line marking or as an alpha-numeric such as that produced by a TSS Annotator system.

Heave compensated digital output of the bathymetric system may be logged to the navigation data files and if so should be logged at intervals of less than 10 m along the survey line to accommodate small scale physiographic features such as ice scours. This would be an optional requirement but if logging is greater than at the 10 m distance interval it is felt that it would not be worthwhile.

Bathymetric sounders such as the Atlas Deso 20, Edo Echotrac, or even a Raytheon 719B 200 kHz system (or equivalent) relatively narrow beam systems would be considered suitable as long as they can be interfaced to a system such as the TSS 300 series or Hippy heave compensators (or equivalent).

4-4-1-3 Sidescan Sonar

Slant range corrected sidescan sonar imagery is considered to be an important requirement for characterization of the seabed materials and to identify features such as ice scours (or lack thereof) which are often relatively clear indicators of clayey cohesive sediments at the seabed. A 100 kHz system providing good acoustic ranging to 125 to 150 m either side of the track line would be considered a minimal basic system. Optionally a higher frequency "500/330 kHz" system, preferably run simultaneously with the 100 kHz system is considered desirable for finer detailed imagery with possible definition of sand ripples and or gravel patches on the seabed. If ranges of over 100 m can be reliably obtained with the higher frequency system this would be preferable as the sole sidescan system for the survey (this has not been commonly possible using the Klein 500 kHz System in the past).

The system should be capable of operations in the 5 to 30 m of water in the site area. This may involve a forward "over the bow" tow mounting for the shallower areas and a stern mount winch system for the deeper areas. It will be necessary to interface the sidescan system to the fix marking system generated by the navigation and the sidescan system should be interfaced to a smoothed vessel speed digital output signal produced by the navigation as well in order to produce a one to one aspect ratio hard copy final graphic display record. Sidescan data should be recorded either on an analogue or digital recording media in addition to a hard copy display for possible mosaic production of detailed grid survey regions. If possible a towfish heading sensor (optional) should be incorporated into the towfish and the data recorded with the sidescan information to accommodate digital mosaicing skew corrections applied during composite digital mosaic production if this route is taken on any detailed survey grids.

Sidescan systems such as the Klein 595, EG&G 260 series or Simrad MS 992 or an equivalent system would be considered acceptable.

4-4-1-4 Seismics

Subbottom profiling systems are considered to be the most important aspect of the proposed granular resource geophysical survey. For this aspect of the survey high, to very high, seismostratigraphic resolutions, in the range of 15 to 50 cm, and moderate penetration (10-25 m) is considered to be of primary importance in the interpretation of the sedimentary structures associated with the Unit C pre-transgression and Unit B transgressional sediments that are likely to contain granular resource materials. Prior experience in the area indicates that the combination of a 3.5/7.0 kHz profiler and a high resolution Boomer system produce reasonable results in the sedimentary materials of the southern Akpak Plateau. The profiler system will typically show significant penetrations in the softer clay/silt regions (poor granular resource) and will show a short and sharp high amplitude return signal, but virtually no subbottom penetration, in areas of granular resource. The boomer system will show significant penetration in both situations which allows stratigraphic interpretations of the possible resource targets and may allow a thickness and therefore volume estimation of the granular resource targets encountered.

Previous survey experience in the Beaufort region has also indicated that the high resolution boomer and profiler records are seriously degraded by swell and heave motions of anything greater than 20-30 cm, making the more subtle detailed interpretation of the shallow stratigraphy difficult to virtually impossible. These heave conditions exist for an estimated 50-80% of the time in the Beaufort area during the summer survey seasons and as a result some form of heave compensation or correction function is highly desirable on the systems that will be employed. This is particularly important for the high resolution boomer data as subsurface stratigraphy interpretation is the primary goal of this system. Because of the significant micro-topography on the seabed caused by ice scouring a post collection bottom smoothing (TSS swell filter type) or simple bottom tracking and flattening process is inadequate in regions of ice scouring (clayey areas, typically in water depths of greater than about 10-12 m). As a result of this an active heave compensation system would be highly beneficial and desirable for the boomer system if it can be made available and in a worst case a swell filter or bottom flattening process would be a minimal requirement.

Profiler systems such as the Rathyeon PTR 3.5/7.0 kHz, the ORE Pipeliner or standard profiler or an equivalent system would be considered acceptable. An IKB Seistec Line & Cone Array Boomer System is presently the most highly recommended high resolution boomer system since it was specifically designed and developed for the shallow water and subseabed conditions of the Southern Beaufort Sea.

The Line & Cone receiver has proved very good at fine definition (15-30 cm resolution) of the shallow stratigraphy of the Unit B sediments in the area (to top of Unit C) and when run in combination with a short (2-6 m) horizontal towed array (IKB. EG&G, or NSRF) has provided penetrations of 15-30 m into the Unit C materials when operated with a boomer sound source (using a separate display). It is understood that an active heave compensation system could be incorporated into the Line and Cone / boomer system (has not actually been implemented as yet though) but a swell filtering type heave correction system would be necessary for the towed array signal due to the independent towing configurations of that source-receiver combination. Alternate or additional systems such as CHIRP profilers or other new or novel source receiver combinations will be considered, though, to the author's knowledge these systems have not been used in the region before and would have to be proved in some way before they could be considered as the stand-alone primary system.

The subbottom systems will have to be integrated into the navigation fix marking system and the data should be recorded either to an analogue or digital recording system for possible future replay and enhancements of the graphic display records. Due consideration should be given to sequencing the firing of the sidescan and seismic systems such that minimal cross talk interference is produced on all systems. Any and all forms of onboard or post survey data processing that may assist in seabed and subseabed sediment characterizations and classification will be given due consideration as long as they are adequately documented.

4-4-1-5 Sampling

Although seabed sampling is not considered to be a primary function of the geophysical survey systems program definition a minimal sampling capability would be desirable during the survey program to augment and confirm the remote systems data. As a minimal requirement, a Van Veen or Shipek grab sampler would be required as a fast method of confirming granular materials at the seabed. A one to two metre long, relatively light weight, gravity corer could also be useful in regions that a thin veneer of soft cover is suspected. Samples containing significant granular materials should be preserved and subsequently analyzed for grain size and fines content to assess their suitability as a granular resource.

Coring or grab sampling would be conducted on an opportunity basis such as during survey equipment or moderate weather downtime, or if a particular question has arisen from review of the collected seismic or sidescan data and would not be expected to occupy more than 1-5% or program time.

4-4-2 Site Grids and Survey Line Coordinates

In the process of completing this preliminary mapping study of granular resource areas in the Southern Beaufort sea a series of proposed geophysical survey lines have been laid out. The proposed survey lines have been shown on the maps of Figures 4-7 through 4-11 as dashed lines. These maps were generated using the UTM coordinate system based on UTM Zone 8 (135°W Longitude, Central Meridian, Clarke 1866 spheroid) and all start and end line coordinates are provided in UTM Northing and Easting based on this mapping system.

Lines in map area B1 essentially are of minimal and limited extent as the Isserk sand body has been reasonably well studied in the past but not with high quality, high resolution seismics. The seven lines listed in Table 5 are designed to provide a basic 1.5 km spacing 7.2 by 8.5 km grid over the Isserk Resource body. This grid is defined primarily as a record quality and similarity check over a known resource area for the systems to be utilized for the geophysical study along the lines of a standards test procedure. This grid would be intended as a baseline reference for studies of the new sites and should reasons exist for a detailed comprehensive understanding of the Isserk resource body itself this grid should be filled in with 150 m spaced lines in at least one orientation. This grid should be the first run during the geophysical survey program to verify acceptable systems operation.

TABLE 5: PROPOSED GEOPHYSICAL LINES - MAP AREA B1

LINE ID	SOL EASTING	SOL NORTHING	EOL EASTING	EOL NORTHING	LINE LENGTH (km)
GS1-NS1	525050	7765400	525050	7758200	7.2
GS1-NS2	526550	"	526550	"	"
GS1-NS3	528050	"	528050	"	"
GS1-EW1	522600	7759500	531100	7759500	8.5
GS1-EW2	"	7761000	"	7761000	"
GS1-EW3	"	7763500	"	7763500	"
GS1-EW4	"	7764000	"	7764000	"
				TOTAL KM	55.2

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Table 6 provides base line coordinates for an 11 by 13.5 km survey grid that would completely cover the resource target areas defined on map sheet B2. The present survey grid has been laid out at 1.5 km line spacings with 9 lines in a north-south orientation and 7 lines in an east-west orientation. This grid structure would not provide sufficiently detailed coverage to fully map the more complex boundaries of all of the resource targets but would touch on all target areas identified at present to allow comparison to the coverage that presently exists from the presently more dense Nahidik 88 and Gulf 88 surveys. Should a significant improvement in the geophysical data quality be obtained during this proposed survey grid it is assumed that additional fill in lines could easily be added, or alternately some other more optimum grid orientation, at tighter 100-500 m line spacings that would improve on the present mapping of the specific targets.

TABLE 6: PROPOSED GEOPHYSICAL LINES - MAP AREA B2

LINE ID	SOL EASTING	SOL NORTHING	EOL EASTING	EOL NORTHING	LINE LENGTH (km)
9 N-S Lines @1.5 km sp. to north of B2-NS1	529000	7758000	529000	7747000	11.0
7 E-W Lines @1.5 km sp. to east of B2-EW1	528000	7748000	541500	774800	13.5
				TOTAL KM	193.5

The nine proposed survey lines over the two sites defined in map area B3 are detailed in Table 7. These lines cover the bathymetrically defined BA5 target and the northern extension of the PS2 target area. The BA5 site is a presently poorly defined area and would initially be covered by the simple 4 line grid to determine if more detailed coverage is worthwhile. If that is the case, additional lines at 100-500 m line spacings should be defined for this area. The PS2 site is very shoal to the south and would be hazardous to survey at the best of times. As a result only the northern portion of this area is covered by proposed survey lines. Again infill lines at 100-500 m line spacings could be defined on an as needed basis once the initial coverage has been completed. In addition a survey line that would be bathymetrically controlled for safe vessel operation should be run completely around the Breakers Shoal.

This would best be conducted during very good weather conditions and normally would have to be coordinated very closely with the vessel captain as he would be ultimately responsible for vessel safety and where the vessel could operate. The purpose of this line would be to determine if other extensions of recoverable granular resource extend in any direction around the shoal itself that would warrant further geophysical survey.

TABLE 7: PROPOSED GEOPHYSICAL LINES - MAP AREA B3

LINE ID	SOL EASTING	SOL NORTHING	EOL EASTING	EOL NORTHING	LINE LENGTH (km)
BA5-NW1	528000	7742900	532500	7745300	6.0
BA5-NE1	520213	7745482	532223	7747790	3.0
BA5-NE2	529425	7746098	531435	7748405	"
BA5-NE3	528637	7746713	530647	7749021	"
BA5-NE4	527849	7747329	529859	7749637	"
PS2-NW1	538343	7747742	533701	7747257	4.7
PS2-NE1	535800	7744682	537515	7746813	1.7
PS2-NE2	534861	7745025	536575	7747155	"
PS2-NE3	533921	7745367	535636	7747498	"
				TOTAL KM	24.8

In the New Site area of map sheet B4 a 7 by 9 km rectangular grid survey of one kilometre spaced lines is initially proposed. This survey would detail the presently poorly defined boundaries of the target sites on the map sheet and additional survey lines at 100-500 m spacings could be completed to fill in detail of areas that appeared most promising. The north-south and east-west base lines (bold on figure) are detailed in Table 8 and the remaining lines of the grid would be stepped out at one km intervals to the south and east of these bases lines respectively. The southeastern region of the grid lies very close to Pullen Island and survey lines would likely have to be cut short in this area at whatever water depth is considered safe for vessel operation. It is presumed that a vessel that would access the region at least in to the 5 m water depth contour would be available for the survey.

TABLE 8: PROPOSED GEOPHYSICAL LINES - MAP AREA B4

LINE ID	SOL EASTING	SOL NORTHING	EOL EASTING	EOL NORTHING	LINE LENGTH (km)
10 N-S Lines @1.0 km sp. to south of B4-NS1	517000	7749000	517000	7742000	7.0
8 E-W Lines @1.0 km sp. to east of B4-EW1	517000	7749000	526000	7749000	9.0
				TOTAL KM	142,0

Map Sheet B5 contains four bathymetrically defined target prospects that are generally considered to be of relatively low probability of containing acceptable quality granular resource materials. Three survey grids have been defined to cover these target site areas and are detailed in Table 9. Target area BA1 is a speculative bathymetry only site region based only on a slight bulge and smoothing in the bathymetric contours. This site would initially be surveyed with three short reconnaissance lines that would have to be evaluated on board to determine if additional survey is required. Site BA2 falls in the same category and again three reconnaissance lines would be required to define any further survey requirements. The northern BA3 and 4 and C3 sites have been defined by bathymetry and one previous geophysical survey line that suggests that Unit C materials are near the seabed in this region. Because of this additional information and the fact that the Isserk site area lies just to the east of these targets a 10 line 6 by 10 km survey grid at 1.5 and 2.0 km line spacing has been defined to provide the basic mapping that would be necessary to further detail this site area. Because of the predominant eastward current direction and migration of sediments observed in other areas it is speculated that this region may be the source area for the Isserk granular resource body and this grid should help in determining if this is the case. Again based on presently available information additional infill survey lines would have to be defined on site as these data are collected.

TABLE 9: PROPOSED GEOPHYSICAL LINES - MAP AREA B5

LINE ID	SOL EASTING	SOL NORTHING	EOL EASTING	EOL NORTHING	LINE LENGTH (km)
BA1-NS1	510100	7752500	510100	7757500	5.0
BA1-EW1	508300	7756100	512200	7756100	3.9
BA1-EW2	508300	7754100	512200	7754100	3.9
BA2-NS1	518700	775300	518700	7757800	4.8
BA2-EW1	516700	7756500	520700	7756500	4.0
BA2-EW2	516700	7754500	520700	7754500	4.0
5 N-S Lines @2.0 km sp. to east of CBB-NS1	515500	7759000	515500	7765000	6.0
5 E-W Lines @1.5 km sp. to south of CBB-EW1	514500	7765000	524500	7765000	10.0
				TOTAL KM	105.6

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5 Summary and Conclusions

Within the mapping region of the South Central Beaufort Sea, presently available high resolution geophysical and geotechnical data has been reviewed with the express purpose of mapping new potential granular resource areas under the NOGAP Task A4 mandate. A total of one known and proven (Isserk) and 19 possible granular resource targets have been identified within this region. These sites have been mapped, categorized as to potential resource and presented within the presently restricted limits of the available data coverage. 45 proposed borehole sites have been selected inside the 12 m water depth contour for a spring drilling program from these new site areas and these proposed boreholes have been presented along with predictions of the expected sediment conditions at each location. The sediment predictions are based on qualitative analysis of the seismic data available and extrapolation of the closest available geotechnical sampling data, when possible, and therefore require confirmation by direct sampling.

In addition to the proposed borehole locations an outline for a proposed geophysical survey to assist in further definition and confirmation or rejection of the possible resource site areas is provided. This outline describes and details what is presently considered the best technical systems available for a granular resources remote sensing study in the area, and provides basic geophysical survey program line listings covering the identified target areas. The proposed survey line coverage consists of 521 line km of survey that would typically require some 4 to 6, 24 hour survey days to complete when line turns and transits are included. This survey outline is considered to be a basic preliminary review of the proposed sites and that significant infill lines would be added as the survey progresses on the sites that proved to be the most promising. It is anticipated that these infill lines would at least double and possibly more than triple the total line kilometres required for an adequate analysis of these site areas.

This study has not re-defined the current understanding of the shallow seismo-stratigraphy within the southern Akpak Plateau - Isserk area but has confirmed the area as a region where the shallowest regional unconformity (top of Unit C) is at or near the seabed in the 10 to 20 m water depth zone. There is presently no indication or confirmation of a glacial ice front edge in the Isserk region seen within the present data sets (as suggested by Fortin, 1989). The data reviewed does strongly indicate that the Isserk borrow materials consist of a re-worked, Unit B, transgressional deposit. Present data coverage does not show a "logical" source area or suggest that some as yet un-mapped exposed Unit C outcrop may exist that would contain higher concentrations of gravels in the immediate vicinity of the Isserk site. Many of the new sites identified (GS and PS sites) in this study are of similar seismic and

seismostratigraphic depositional character to the Isserk sand body, though most of these newer sites do not appear to contain the higher levels of gravel that are observed at Isserk. The other primary sites are regions of exposed or very thinly covered Unit C in the offshore region and these sites are believed to be the remnants of the most recently inundated offshore islands that once existed on the Akpak Plateau area. These exposed targets areas and the sediments lying deeper in the section are believed to be the equivalents of the (possibly Toker Point pebbly clay) Kittigazuit and Kidluit sands in the onshore and are likely to be of highly variable resource quality requiring local borehole confirmation of quality before use. The remaining bathymetrically mapped sites (BA sites) are based on minimal or no geophysical or sampling and are considered to be the least promising of the granular resource targets that have been identified.

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BOREHOLE SYMBOL KEY

- BH - CLAY FROM SEABED TO >3 m
- BH - SAND 0-1 M INTERVAL
- BH - SAND 0-1 M WITH SOME GRAVEL
- BH - SAND IN 1-2 M INTERVAL
- BH - SAND IN 0-1 AND 1-2 M INTERVAL
- BH - SAND IN 2-3 M INTERVAL

TARGET HATCHING KEY

C/x
OUTCROP OF UNIT C SEDIMENTS, PRIMARILY SANDS BUT HIGHLY VARIABLE QUALITY - HIGH PROBABILITY OF FROZEN SEDS
ANSI37 500<0

GS/x
STRONG SEABED REFLECTIONS WITH SMOOTH SEABED - GOOG PROBABILITY OF SURFICIAL UNIT B SANDS - SOME FORESETS AND BAR INTERNAL REFLECTIONS
LINE 500<0

PS/x
REGIONS OF MODERATE TO STRONG SEABED REFLECTIONS WITH MODERATELY SMOOTH SEABED - UNIT B SEDS - POSSIBLE SAND BUT LIKELY HIGHER SILT CONTENT.
LINE 500<45

BA/x
SLIGHTLY POSITIVE RELIEF SMOOTHER SEABED TARGETS - BASED ONLY ON CHS BATHYMETRY WITH NO SEISMIC OR SAMPLE INFO - LOW PROBABILITY ???
LINE 1000<90

GV/x
POSSIBLE GRAVEL/SAND BAR (BREAKER'S SHOAL) - BATHYMETRY ONLY AND COMMENTS FROM J HUNTER OF TERRAIN SCIENCES GROUP FROM PREVIOUS STUDIES.
AR-CONC 50<0

SCALE (Km.) 0 2.5 5

PLOT SCALE 1 : 75,000

1994 DIAND GRANULAR RESOURCES TARGET STUDY SOUTHERN BEAUFORT SEA

NEW RESOURCE TARGETS

Lewis Geophysical Consulting

ENCLOSURE 1