Report on Year One and Year Two (April 2004 – December 2006) Activities in Support

of the

Cooperative Agreement between New Hampshire and the Minerals Management Service

for the Project Entitled

"Assessment of Sand Resources and the Geologic Environment of the Continental Shelf Offshore of New Hampshire"

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Forward

This report contains an overview of the first two years of activities for the cooperative agreement between New Hampshire and the Minerals Management Service. Since this is the first report for the five-year cooperative agreement, summaries of the rational for the project, progress on the major objectives being addressed, and a review of existing databases important to understanding the Quaternary geology of the New Hampshire shelf are given. In addition, a rationale approach to synthesizing the relatively large database is provided and progress to date reviewed. This includes the results of analyses of one of six defined focus areas where efforts are being concentrated. Finally, data gaps and directions for new work are presented.

Although the major efforts for this project to date have been directed towards identifying and synthesizing the major databases describing the geology and potential sand and gravel resources of the New Hampshire continental shelf, the cooperative agreement has contributed to educational programs at the University of New Hampshire by training several undergraduate and graduate students. Although student theses have not emerged from this work, two graduate students worked on the seismic analyses and core descriptions. In addition, several undergraduates helped with the analyses and data entry. All of the students were involved in discussions of the methodologies, as well as the geology of the region.

Finally, efforts continue to integrate the work conducted in New Hampshire with other cooperative programs in the region. For instance, our program organized a one day cruise in summer 2005 aboard the UNH R/V Gulf Challenger for bottom sediment sampling on the Merrimack River paleodelta. Scientists from the Massachusetts-MMS cooperative program participated in the cruise and samples were distributed to Boston University. In addition, we participated in two meetings hosted by Boston University and attended by MMS personnel and representatives from six institutions and agencies in the region (Massachusetts, New Hampshire, and Maine). The goal of these meetings was to provide updates of recent activities related to MMS mandates concerning potential sand and gravel resources in the northern Gulf of Maine and to foster interactions between cooperative programs. We will continue these efforts.

Executive Summary

A number of geological studies have been conducted on the New Hampshire (NH) continental shelf over the last several decades. However, the bulk of this work resides in student theses, reports and other forms of the gray literature. Unfortunately, no synthesis of this database has ever been completed, nor has the information been brought into modern geospatial information systems or similar software. Consequently, there is a real danger that much of this database will never be fully utilized and could eventually become lost. The first two years of the five-year cooperative agreement between New Hampshire and Minerals Management Service were directed at recovering, evaluating, and defining the best methodologies for synthesizing the earlier work and making the relevant information available through electronic media.

Databases recovered include geophysical records (analog) for ~1750 km of the NH shelf, grain size data for ~1200 bottom sediment samples, and 24 vibracores. Based on a review of the previous literature and these databases, six focus areas important to understanding the geology of the New Hampshire shelf or important as potential sand and gravel deposits were identified. The focus areas include: the Northern Sand Body; the Southern Sand Body, the Southern New Hampshire Nearshore; Offshore Drumlins; Portsmouth Harbor; and the Isles of Shoals. These focus areas will be used to guide the synthesis of the previous work in an effort to develop an understanding of the Quaternary geology of the New Hampshire shelf and adjacent areas. In addition, this effort will help characterize previously identified sand and gravel resources and make the information more readily available through GIS archiving and web serving. To date, review and synthesis of one of the six focus areas (Southern New Hampshire Nearshore) has been completed.

Using a side-scan sonar survey conducted in 1992 and 74 bottom sediment sampling stations, a new seafloor surficial geology map for the Southern New Hampshire Nearshore focus area was completed. The seafloor map reveals the heterogeneity of the bottom, which is typical of previously glaciated regions. However, despite the variability, some patterns emerge. For instance, the study area can be divided into a sandy southern section influenced by the Merrimack River and its paleodelta, a bedrock dominated central area, and mixed bottom types towards the north. The mixed bottom area tends to be very coarse, with a gravel platform associated with an eroding drumlin (Great Boars Head), exposed bedrock, gravels from reworked morainal deposits, and sandy nearshore shoals. Subbottom seismics, also obtained in 1992, along with 9 archived vibracores, indicate a transition from south to north in the subsurface as well. Several major sand bodies were identified that are close to shore and are interpreted to be abandoned ebb tidal deltas. However, due to the poor quality of the subbottom records several previously described sand bodies could not be verified.

Based on the work completed during the first two years of the cooperative agreement, the following recommendations are made for the next phase of work: complete the synthesis of the databases for the five remaining focus areas; conduct a new geophysical and coring survey on the shelf between the Merrimack River and Little Boars Head; and characterize the surficial geology and shore-types of the New Hampshire coastline.

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Part One: Introduction and Overview of Project

Rationale

The coast of New Hampshire has a number of recreational beaches that are important to the state and local economy including Hampton Beach, Seabrook Beach, Jennes Beach, and Wallis Sands. Because of shoreline erosion and storm damage, most public and private beaches in New Hampshire have coastal defense structures. In addition, several sections of shoreline are periodically nourished. For instance, Hampton Beach has spent millions of dollars to maintain its public beach. With the projected increase in sea level that will occur over the next half century (Gornitz and Lebedeff 1987; Emery and Aubrey 1991; Titus and Narayanan 1995), these problems will worsen and beach nourishment will become increasingly needed (Shevenell Gallen and Associates 1987; Rockingham Planning Commission 1991). Therefore, it is important to take steps now to accurately identify and characterize potential sand resources on the inner and outer continental shelf offshore of New Hampshire that can be used for beach nourishment and other public works projects. In addition, it is important to identify and characterize the coastal sites where erosion rates are high and nourishment may be needed (e.g., hotspots).

Over the last several decades there have been a number of studies concerned with the sedimentology and shallow stratigraphy of the New Hampshire continental shelf and adjacent areas (Figure 1). This work includes several graduate student theses in the 1970s and a series of projects that occurred in the 1980s and 1990s conducted by investigators from the University of New Hampshire and funded by federal and state agencies including the United States Geological Survey (USGS), National Science Foundation (NSF), and the Minerals Management Service (MMS). More recently, several major programs funded by the National Oceanic and Atmospheric Administration (NOAA) examining sedimentary environments and bottom habitats have occurred in support of the University of New Hampshire Open Ocean Aquaculture program and fishery habitat studies. Collectively, these studies provide the knowledge base to develop a general understanding of the geological environment of the region and identify potentially important sand and gravel bodies. The results of these efforts have been reported in theses, numerous final reports, several journal publications, and a bottom sediment map (Flight 1972; Mills 1977; Birch 1984a, 1984b, 1986a, 1986b; Anderson 1987; Birch 1988, 1989; Ward 1989, 1990, 1994, 2000; Ward and Anderson 1990; Ward and Birch 1993, 1996).

Despite these efforts, the overall sedimentological and stratigraphic characteristics (and controlling processes) of the continental shelf offshore of New Hampshire have not been analyzed and synthesized in a comprehensive manner. Furthermore, the available information has not been assembled into geospatial or geographic information systems (GIS) so that it can be easily retrieved and analyzed. The most detailed effort to date has been the aforementioned development of a surficial geology map. Although this map was based on some of the previous work cited above, the actual database was rather sparse. Consequently, the map does not include information on sand bodies (exact locations, boundaries, thickness, and characteristics).

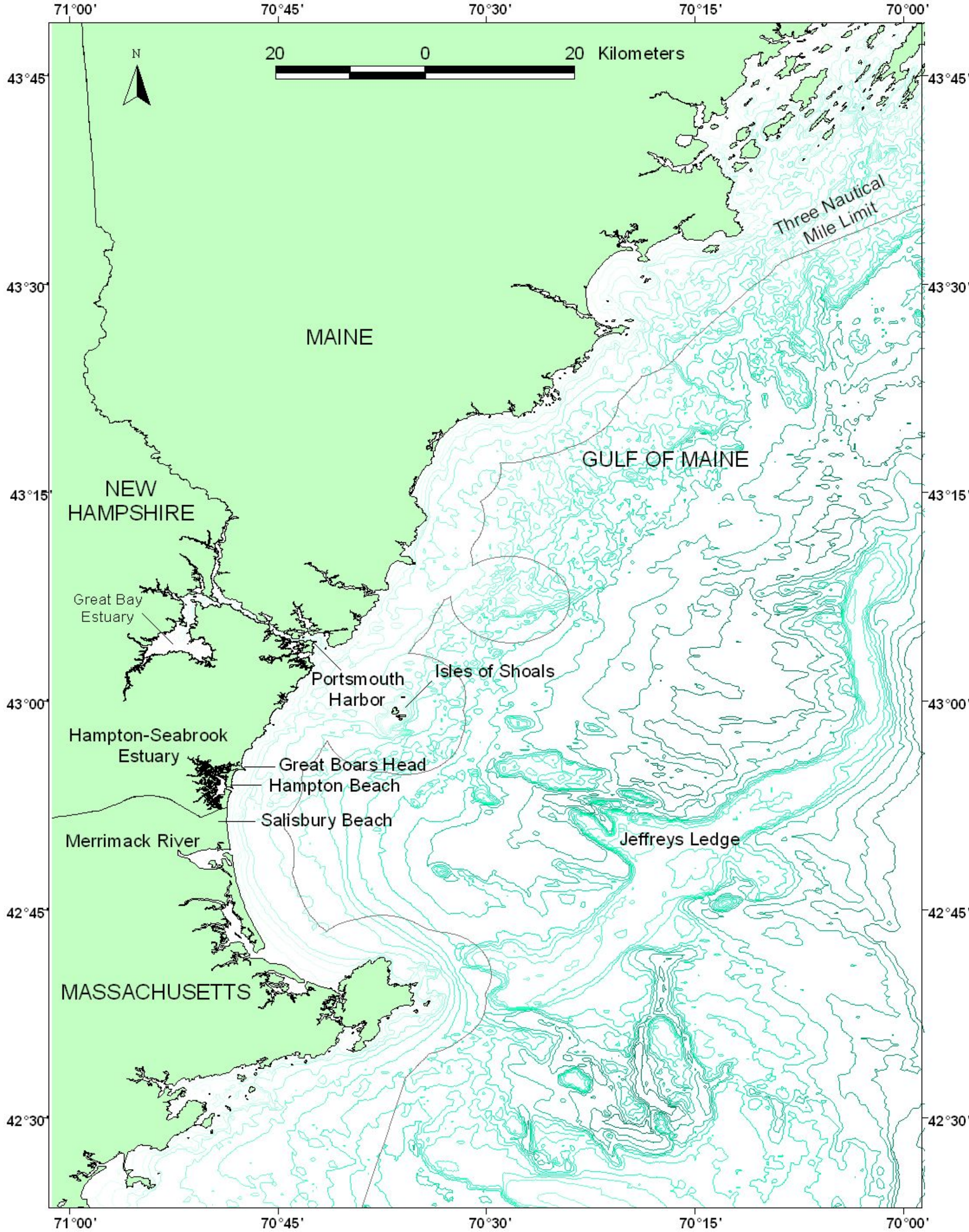


Figure 1. Location map of the New Hampshire shelf.

NH/MMS Cooperative Agreement

As a result of the concerns outlined in the previous section, a cooperative agreement was established between New Hampshire and the Minerals Management Service (MMS) in 2004 with the following goals and objectives.

"*The overall goals of the cooperative program between the University of New Hampshire, the New Hampshire Geological Survey (NHGS), and the Minerals Management Service is to describe the geologic environments of the inner and outer continental shelf offshore of New Hampshire and adjacent coastal environments (where beach nourishment may be needed in the future), accurately locate and characterize sand and gravel resources on the inner shelf, archive these data with the state's mapping files at the NHGS, and make these data available to the public in the form of CD-ROMs, web sites, and annual reports. In addition, the results of the work will be presented at scientific meetings and submitted to scientific journals. This will be a multi-year effort composed of steps based on previous work, determination of gaps in our understanding, and interactions with MMS. It is anticipated initial projects would be directed at synthesizing existing information on the inner and outer continental shelf and coast of New Hampshire; then progressing into new studies of potential sand resources such as the Merrimack paleodelta or other sites on the OCS as possible sources of material for coastal public works projects. In addition, it is anticipated that some of the new research will be done in conjunction with projects being conducted by adjoining states.*"

These goals and objectives of the cooperative agreement are in line with broader initiatives by the MMS and the USGS in the region and nationally. For instance, the Marine Aggregate Resources and Processes Project (MARP) seeks "to increase the scientific understanding of the Quaternary history of our continental shelves, the sedimentary character pertaining to sand supply and sand budgets for coastal-shelf systems, and the character and distribution of offshore sand and gravel resources that are suitable for beach nourishment".

Overview of the Report

To meet the goals and objectives of the NH/MMS Cooperative Agreement, our efforts during the first two years of the project have been directed at locating, recovering, re-analyzing where necessary, verifying where necessary, and synthesizing key studies and databases. This report summarizes the activities undertaken to achieve these objectives, the results of the work to date, and recommendations for the next phase of the cooperative agreement.

The remainder of this report is divided into several parts. Part Two provides a review of the tasks outlined in the 2004 and 2005 workplans and summarizes the progress made during the first two years of the cooperative agreement. Part Three reviews the most important databases that have been identified. Part Four reviews the general stratigraphic characteristics of the NH continental shelf based on the analysis and synthesis of a geophysical survey conducted in 1981 and 1982 (see Birch 1984a, 1984b). Part Five provides the rationale for directing the research efforts towards key focus areas on the New Hampshire shelf. Part Six presents the results of the analyses of the database for the Southern New Hampshire Nearshore Focus area. Part Seven provides an overview of gaps in the understanding of the New Hampshire shelf and gives recommendations for the highest priority research for addressing the goals of the NH/MMS Cooperative Agreement.

Part Two: Status of Project Tasks

The seven tasks listed below were presented in the NH/MMS Cooperative Agreement 2004 proposal and workplan to guide the initial efforts of the study. In this section the progress made on the tasks is reviewed.

1. Update the present sedimentological database for the continental shelf offshore of New Hampshire.

The bottom sediment database for the area offshore of New Hampshire that was previously developed for inclusion in the Gulf of Maine Sediment Database (produced by the USGS – see Poppe et al. 2003) has been updated with the results of several new studies including samples from Hampton-Seabrook Harbor, the University of New Hampshire Open Ocean Aquaculture (OOA) field site located south of the Isles of Shoals, and from the Jeffreys Ledge area (Figure 2). In total, these samples added ~660 stations to the New Hampshire Shelf and Estuary Bottom Sediment Database. Presently, ~1200 stations are now included in the database providing good coverage of most of the inner shelf areas offshore of New Hampshire and within the two estuaries (Great Bay Estuary and Hampton-Seabrook Estuary). However, several areas with limited coverage still remain.

2. Review existing seismic records and interpretations of the New Hampshire shelf by Birch (1984a, 1984b, 1986a, 1988) and Ward and Birch (1993, 1996, 1999).

Between 1981 and 1999, six geophysical surveys covered ~1750 km of the New Hampshire shelf (Figure 3). To date, subsets of the seismic records from each of the surveys has been analyzed depending on their area of coverage. The quality of the records is highly variable and a complete review of all the seismics is not warranted. Instead, the analyses have been directed towards six focus areas that have been identified for the New Hampshire shelf. The geophysical records from two of the focus areas have been completed. In addition, the seismic stratigraphy of the Quaternary deposits on the NH shelf and published by Birch (1984b) has been recovered and established in a GIS environment (discussed in Part Four).

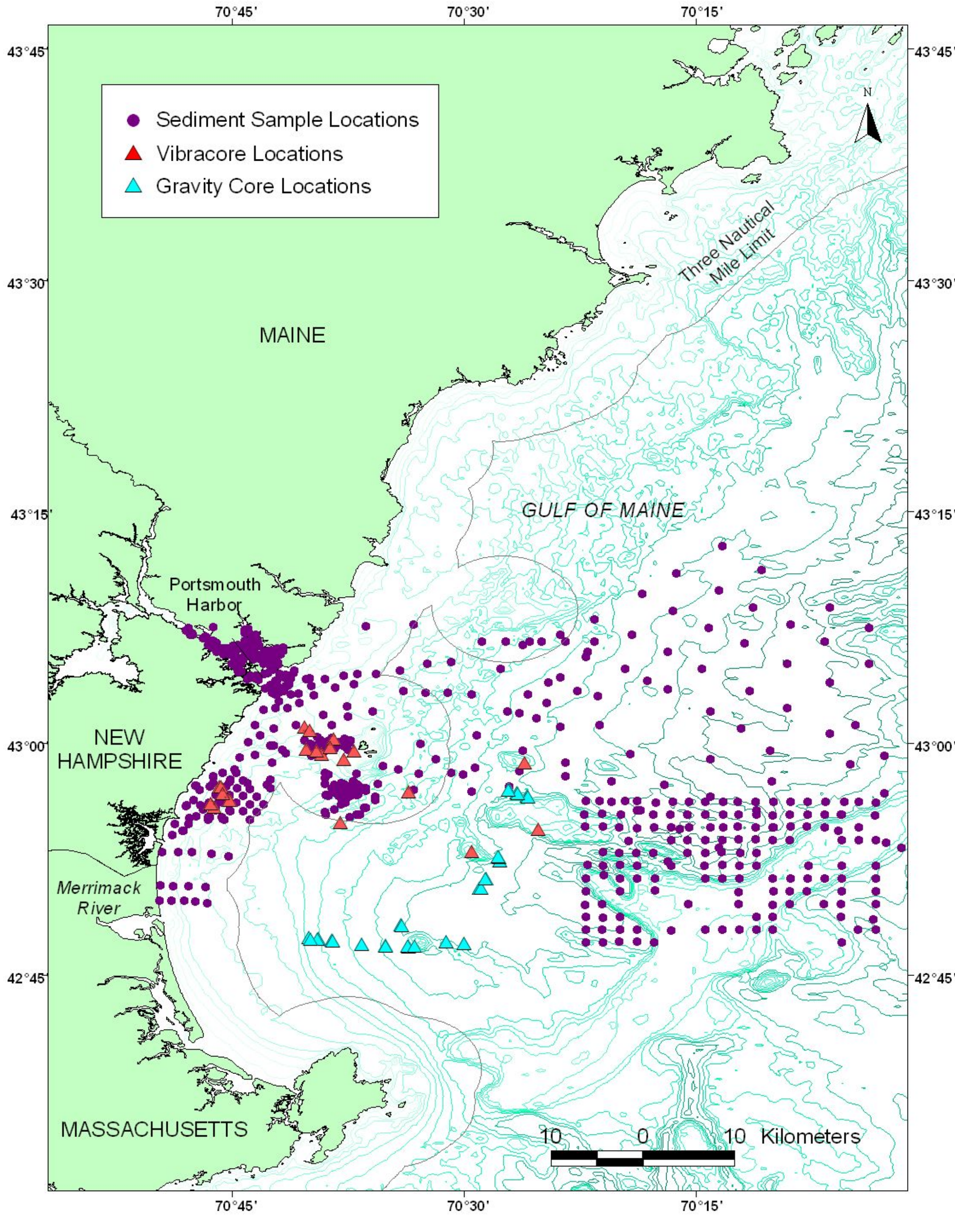


Figure 2. Locations of bottom sediment sampling stations included in the New Hampshire Shelf and Estuaries database. The database includes grain size and organic content data for ~1200 grab samples, gravity cores, and vibracore stations taken by the University of New Hampshire during the last three decades.

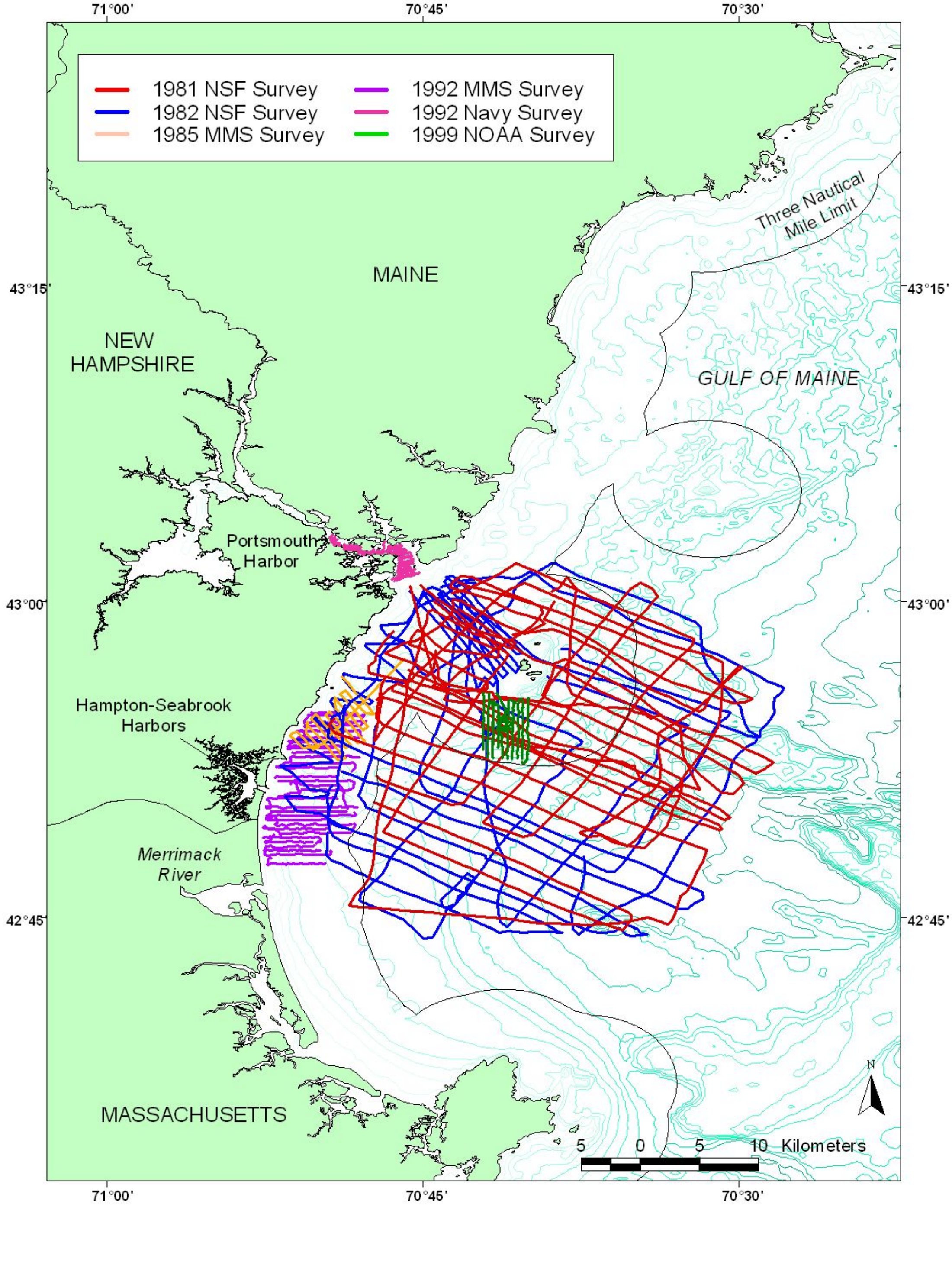


Figure 3. Seismic tracks from previous studies conducted by the University of New Hampshire.

3. Inventory and review existing records of vibracores from the continental shelf offshore of New Hampshire.

The vibracores collected during earlier Minerals Management Service sponsored research have been re-examined and re-logged. A subset of the core logs has been plotted in Rockware. Descriptions of the all of the vibracores are provided in Appendix 1.

4. Compile and synthesize the information from tasks one through three and update the surficial geology map of the continental shelf offshore of New Hampshire.

We anticipate addressing this task in the next phase of the project (year three of the cooperative agreement).

5. Initiate work to create maps of the New Hampshire coastal environment that will depict shoretypes, coastal sediment types, and potential sand and gravel sources to the beaches.

We anticipate addressing this task in the next phase of the project (year three of the cooperative agreement).

6. Identify information gaps and design new field and laboratory studies.

An evaluation of the information gaps in the mapping and characterization of sand and gravel deposits offshore of New Hampshire has been completed based on analyses to date and is presented in Part Seven of this report.

7. After review, transfer the GIS projects, databases, and other relevant information to the New Hampshire Geological Survey (NHGS) archives. In addition, prepare a CD-ROM, web site and report depicting project results.

The final report for the first two years of the project will be made available to the New Hampshire Geological Survey (NHGS). However, the broader objective of merging an updated nearshore surficial geology map of the New Hampshire shelf with NHGS surficial geology mapping efforts will not be completed until the next phase of the project.

Part Three: Databases

A summary of the most important databases that are being reviewed and synthesized for this project are listed below.

1981-1982 Seismic Survey

The seismic survey includes ~1300 km of subbottom profiling from a relatively closely spaced grid extending from near to the coastline between Portsmouth Harbor and the

Merrimack River and extending approximately 35 km seaward (Figure 3). The subbottom seismic profile unit consisted of a 300 joule E.G.&G. model 234 Uniboom system operated at a repetition rate of 0.5 s. Return echoes were picked up by towed hydrophones and recorded on dry paper with an EPA model 4100 recorder at a 0.25 s sweep rate. Location was determined by Loran C using a Northstar model 6000 system and was recorded by hand every 5 minutes. The work was funded by the National Sciences Foundation (PI: Dr. Francis Birch, University of New Hampshire).

1985 Seismic Survey

The seismic survey includes ~250 kms of subbottom seismic lines run in a relatively closely spaced grid off an area north of Hampton-Seabrook Harbor and south of Portsmouth Harbor (Figure 3). The survey focused on potential nearshore sand bodies (e.g., Southern Sand Body) that could be used as borrow sites for beach nourishment. The subbottom seismic profiler and navigation system was similar to those described above for the 1981-1982 seismic survey. Only analog records of the seismics are available. The work was funded by the Minerals Management Service (PI: Dr. Francis Birch, University of New Hampshire).

1992 Seismic Survey (Southern New Hampshire Nearshore)

The seismic survey included ~150 kms of subbottom seismic profiles and side-scan sonar records in a very closely spaced grid extending from the Merrimack River to north of Great Boars Head (Figure 3). The survey area focused on the nearshore area between the ~7 m to ~30 m isobaths. Subbottom seismic profiles were taken with an ORE model 140 unit broadcasting at a frequency of 3.5 kHz with variable power. The side-scan sonar unit was a Klein dual-frequency towfish (model 422S-101HF) operating at 100 and 500 kHz simultaneously. The backscatter was recorded on a Klein digital recorder (model 595) on thermal paper. Precision navigation was by provided by a UHF navigation system composed of a master transponder (Del Norte model 547) and three digital distance measuring units (Del Norte 547) with an accuracy of several meters. Although navigation was recorded in electronic files, only analog records of the subbottom seismic and side scan-sonar records are available. The work was funded by the Minerals Management Service (PI: Dr. Larry Ward, University of New Hampshire).

1992 Seismic Survey (Portsmouth Harbor)

Approximately 20 kms of subbottom seismic profiles and side-scan sonar lines were run in a relatively closely spaced grid in Portsmouth Harbor (Figure 3). The subbottom seismic unit, side-scan sonar unit and navigation system were basically the same as was used in the 1992 Southern New Hampshire Nearshore Seismic survey described above. Again, only hardcopies of the seismic records are available. The work was funded by the U.S. Navy (PI: Dr. Larry Ward, University of New Hampshire).

1999 Seismic Survey

Approximately 60 km of subbottom seismic profiles and side-scan sonar tracks were run in a tightly spaced grid ~2 kms south of the Isles of Shoals (Figure 3). The subbottom seismic unit consisted of an Edgetech Xstar, the side-scan sonar system was an Edgetech DF-1000, and the navigation and positioning system was a Northstar Differential GPS Navigation unit. Only analog records of the seismics are available. The work was funded by NOAA through UNH CINEMar program (PI: Dr. Larry Ward, University of New Hampshire).

1984 and 1988 Vibracoring Projects

Twenty-three vibracores were collected at key sites determined from the initial analyses of the 1981, 1982 and 1985 subbottom seismic profiles in order to verify interpretations of the acoustic records (Figure 2). Navigation was by Loran C with positions recorded by hand. The work was funded by the Minerals Management Service (PI: Dr. Francis Birch, University of New Hampshire). Half of each of these cores was available (although their condition had deteriorated) from Jackson Estuarine Laboratory.

Surficial Bottom Sediment and Gravity Coring Projects

From 1971 to 2005 approximately seven different studies conducted at the University of New Hampshire collected and analyzed surficial and near-surface bottom sediments on the New Hampshire inner shelf (and adjacent areas) and estuaries. This work was funded by a variety of sources including the University of New Hampshire (for student theses), the U.S. Navy (for sampling in the lower Piscataqua River), Minerals Management Service (for samples in potential sand resources on the continental shelf), NOAA/UNH CINEMar (for sampling at UNH OOA site and at Jeffreys Ledge), and the U.S. Corps of Engineers (for samples collected in Hampton and Seabrook Harbors). The results of this work reside in several databases now maintained as part of this project. In total, grain size information is available for ~1200 bottom sediments (812 from the shelf and 388 from the estuaries). The locations of the sediment samples are shown in Figure 2.

Much of this data was previously provided to the USGS at Woods Hole and was incorporated into the sediment database for the Gulf of Maine (Poppe et al, 2003, USGS Open-File Report 03-001). However, several studies examining the surficial sediments at various locations on the New Hampshire shelf were not available at that time. Therefore, a new, updated surficial sediment database for the New Hampshire shelf was developed for this project.

Part Four: General Seismic Stratigraphy of NH Shelf

Based on careful analyses of the 1981 and 1982 geophyscial surveys, Birch (1984a, 1984b) developed a generalized seismic stratigraphic model of the NH shelf that divided the Quaternary sediments into four major seismic units. Briefly, Unit 1 was deposited by glacial ice and is largely interpreted as lodgement tills. Unit 2 is sediments deposited during the sea-level highstand that occurred during deglaciation and consists largely of fine-grained material with sand lenses (equivalent to the Presumpscot Formation). Unit 3 is sediments deposited during the early Holocene sea-level lowstand and consists of sandy material off the Merrimack River (paleodelta) and finer-grained sediments eroded from the Presumpscot Formation further offshore. Unit Four are sandier sediments that were likely deposited during the late Holocene transgression.

During the present study, it was important to recover the original database developed by Birch (1984a, 1984b) and enter the information into a GIS platform. However, the original database was stored on magnetic tapes, which became contaminated over time. Therefore, the original data had to be recovered from hardcopies of the navigation and seismic reflector data (depth to reflectors and locations), scanned, verified, corrected, and re-entered into digital formats. This effort has been completed and the results displayed in Figures 4 through 7.

Part Five: Project Objectives and Focus Areas

Although the general Quaternary deposits on the NH shelf were described by Birch (1984a, 1984b) based on the 1981 and 1982 subbottom seismic surveys (described in Part Four), little detail was offered and only limited interpretations concerning development and controlling processes was presented. Therefore, the larger database needs to be re-analyzed and synthesized. However, reviewing and analyzing the entire collection of seismic records is not practical or warranted. Therefore, six areas that have excellent seismic coverage and are important to the general understanding of the formation of sand and gravel deposits or the Quaternary geology of the New Hampshire shelf were identified for further study. These focus areas include three sites where previous studies indicate major sand and gravel deposits occur (Northern Sand Body, Southern Sand Body and off Hampton-Seabrook Beach) and three sites that will provide important information about the sedimentology and stratigraphy of the area (Portsmouth Harbor, an area south of the Isles of Shoals, and an area further offshore that appears to be an eroded drumlin). These focus areas are shown in Figure 8.

The available databases and identified tasks for each focus area, as well as progress made on the tasks at the end of the second year of funding, are given in the following sections. Although substantial progress has been made for most of the focus areas (as noted within the description of each site), only the Southern New Hampshire Nearshore Survey has been completed. Therefore, the results of the work in this area have been expanded and are presented in a separate section (Part Six).

Northern Sand Body

Based on the 1981, 1982 and 1985 seismic surveys, five vibracores and ~twenty-five bottom sediment samples, Birch (1984b, 1986a, 1988) described a sand deposit referred to as the Northern Sand Body (NSB). The NSB, which is located just west of the Isles of

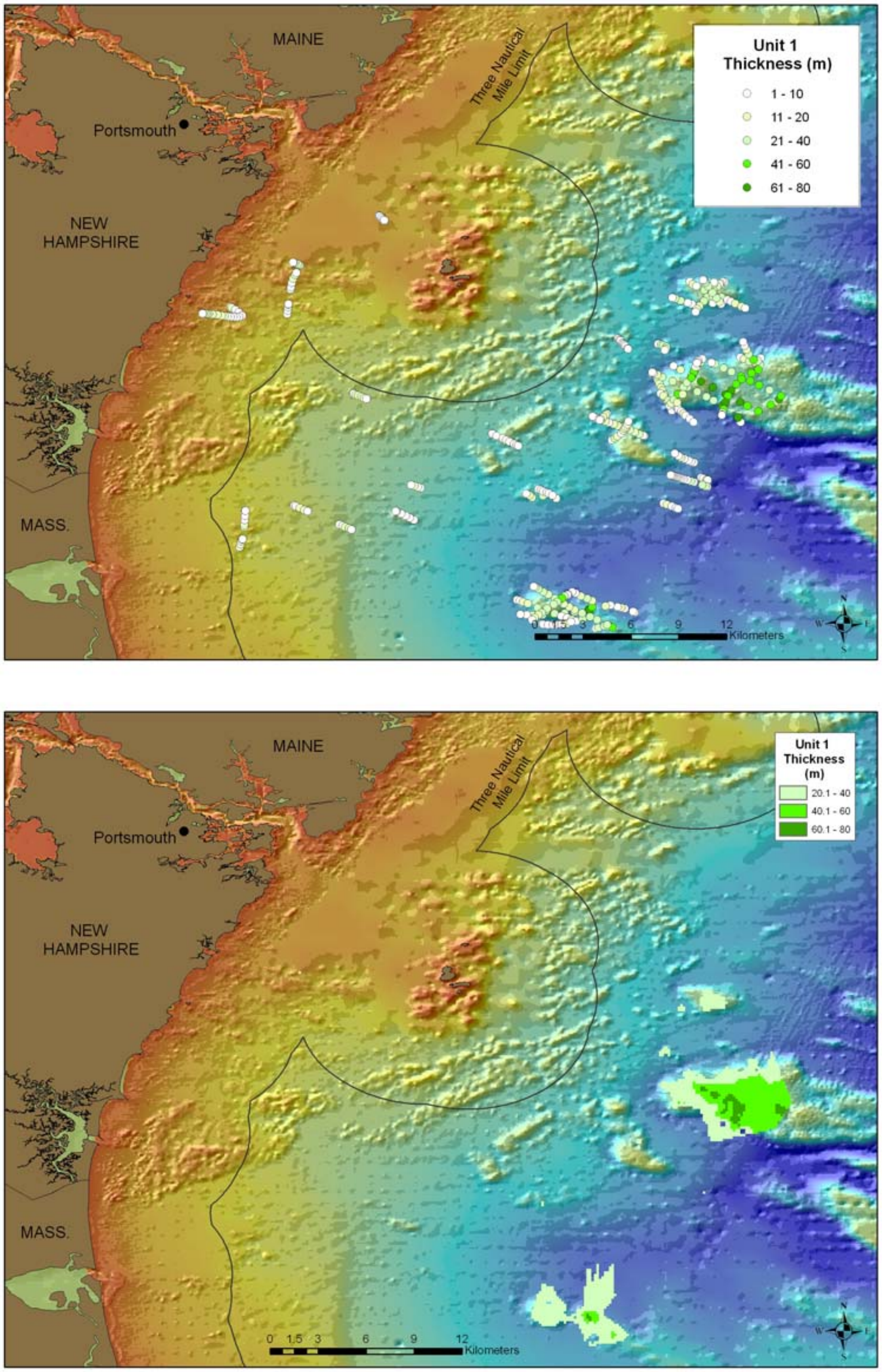


Figure 4. Distribution of Unit 1 on the New Hampshire shelf. Modified from Birch (1984b). Lower diagram is an isopach map of the thicker Unit 1 deposits.

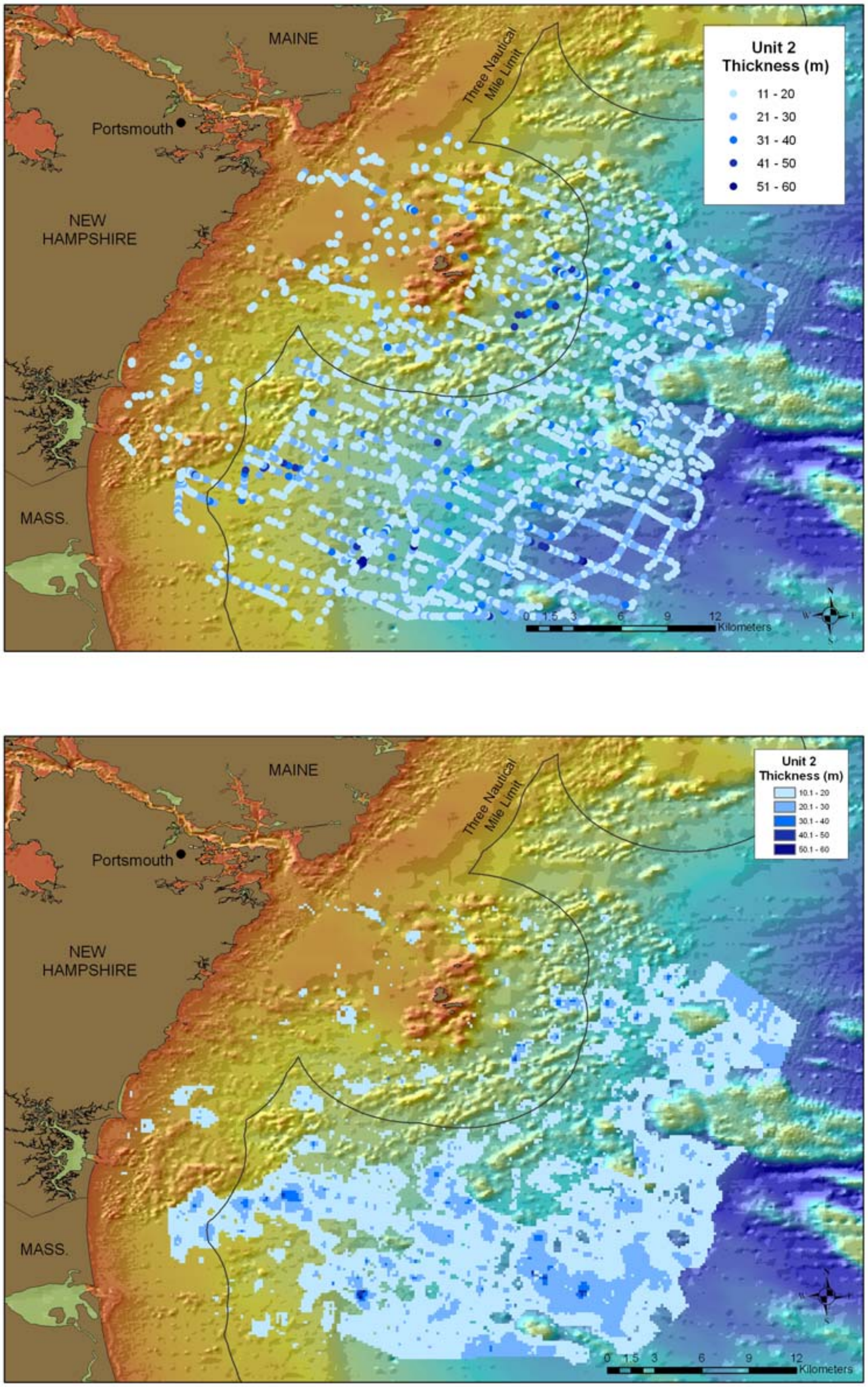
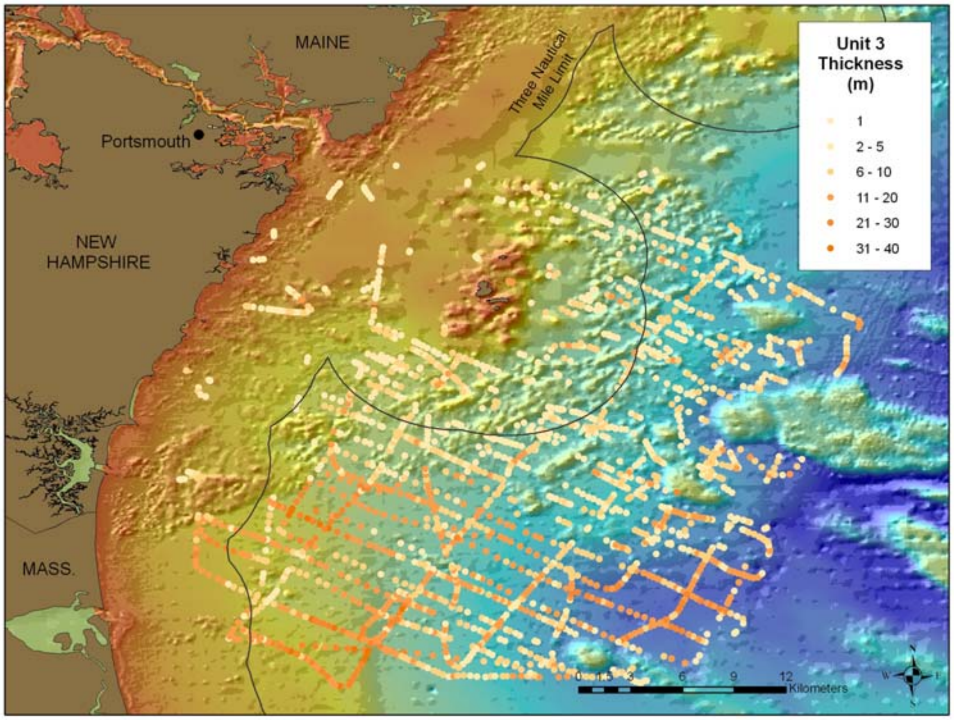


Figure 5. Distribution of Unit 2 on the New Hampshire shelf. Modified from Birch (1984b). Lower diagram is an isopach map of the thicker Unit 2 deposits.



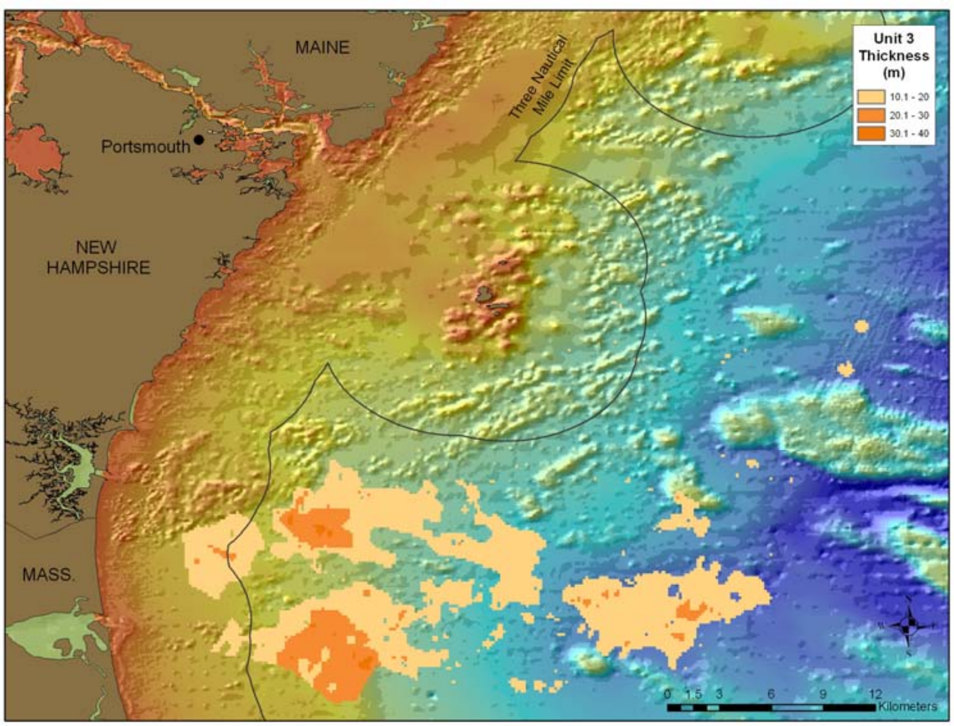


Figure 6. Distribution of Unit 3 on the New Hampshire shelf. Modified from Birch (1984b). Lower diagram is an isopach map of the thicker Unit 3 deposits.

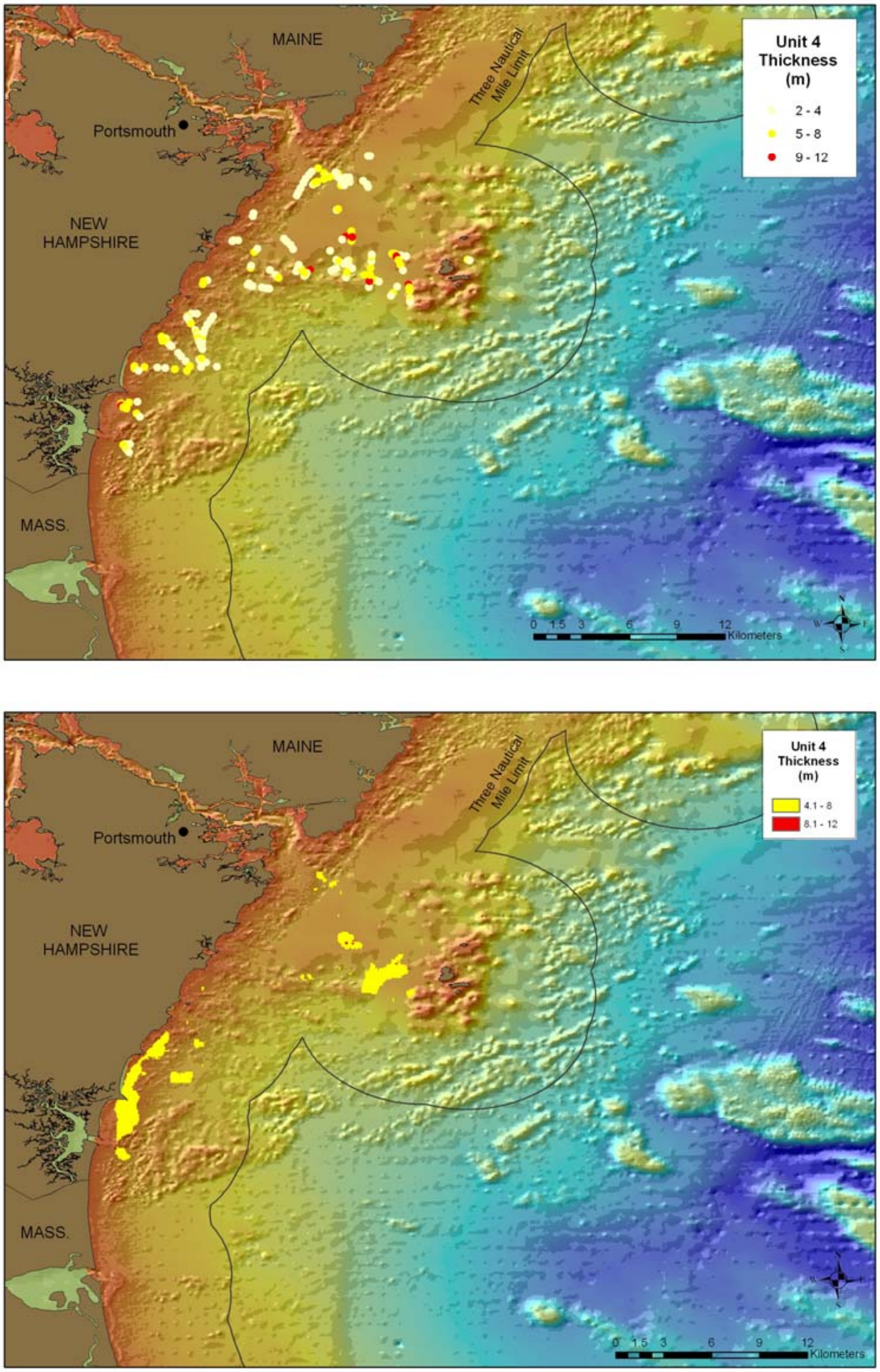


Figure 7. Distribution of Unit 4 on the New Hampshire shelf. Modified from Birch (1984b). Lower diagram is an isopach map of the thicker Unit 4 deposits.

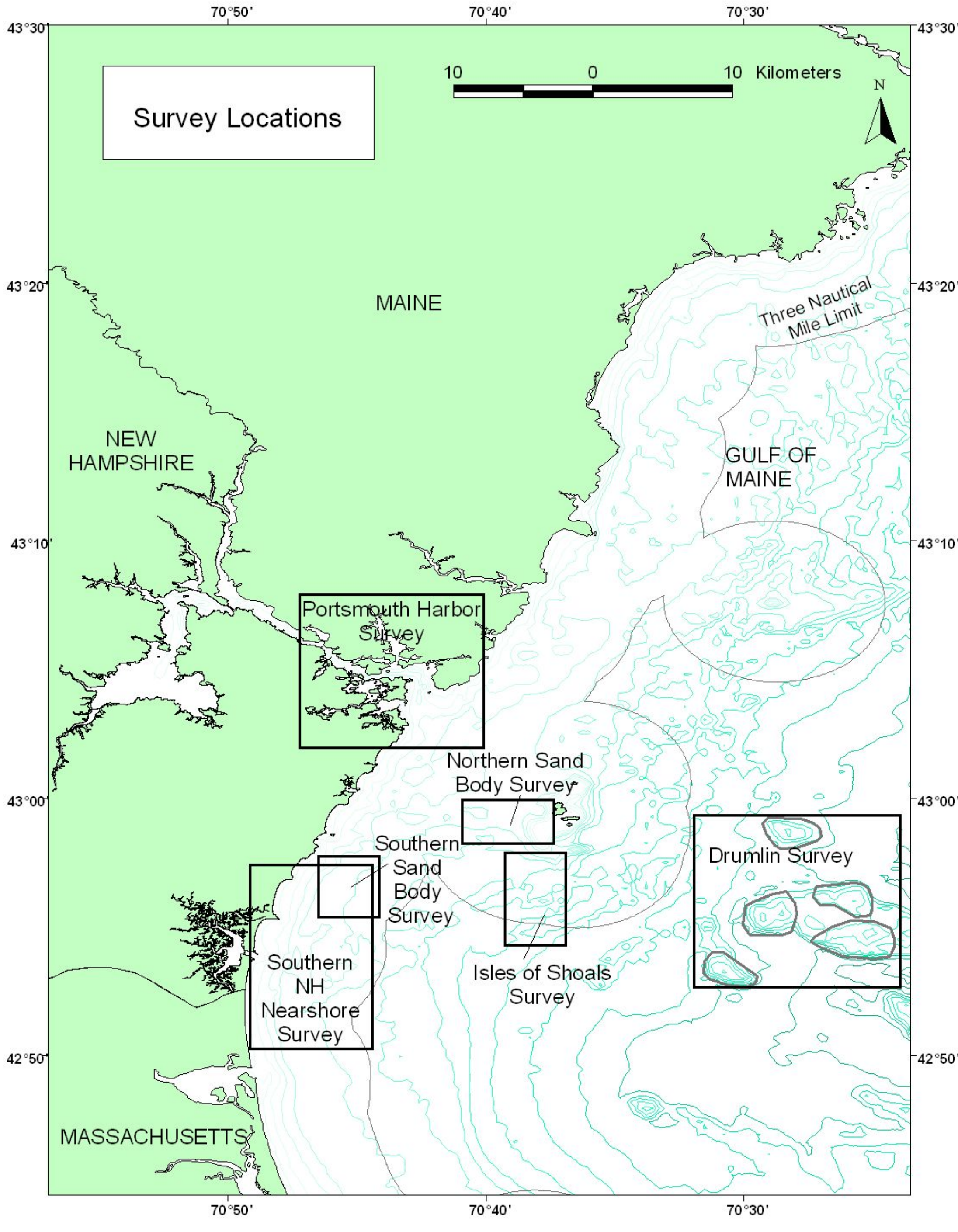


Figure 8. Location of areas offshore of New Hampshire that are the focus of the present project.

Shoals (Figures 8 and 9) has an estimated 25 million m^3 of sand. Consequently, this area is of interest due to its potential as a sand source, as well as understanding the development of sand deposits on the New Hampshire shelf.

During the present study, a detailed surficial sediment map, an isopach map of the sand thickness, and a stratigraphic model of the NSB are being developed. The surficial sediment map will be based on the relatively closely spaced surficial sediment samples. The isopach map and the stratigraphic model will be based on re-evaluation and interpretation of the subbottom seismic records and the five vibracores on and adjacent to the NSB. The results of each of these analyses will be synthesized in a GIS project. To date, the seismic records have been interpreted and the major reflectors identified. The vibracores have been described. The surficial sediment map, isopach map, stratigraphic model and GIS project remain as tasks.

Southern Sand Body

Based on same surveys described above for the NSB, Birch (1984a, 1986b, 1988) also described the Southern Sand Body (SSB) (Figure 7). The SSB, which also has an estimated 25 million m^3 of sand, is located within several kilometers of the coastline (Figures 8 and 10). The SSB is of interest to this study as a potential borrow site for beach nourishment (due to its proximity to important New Hampshire beaches) and to help our understanding the formation of sand deposits or shoals on the inner New Hampshire shelf. Similar to the NSB, a detailed surficial sediment map, an isopach map and a stratigraphic model are being developed from the seismic records, bottom sediment samples, and nine vibracores. All of this information will be depicted in a GIS project. To date, the vibracores have been logged and the sediment grain size data has been synthesized. Remaining tasks include the completion of the analysis of the seismic lines from the 1982 and 1985 surveys, development of the isopach map, and development of the stratigraphic model. As this area is considered a lower priority due to the initial analyses of the seismic lines and a more detailed focus area (Southern New Hampshire Nearshore Survey) providing overlapping coverage, the SSB will be completed at a later time.

Southern New Hampshire Nearshore Survey

Based on a detailed subbottom seismic and side-scan sonar survey and bottom sediment samples (Figures 8 and 10), Ward and Birch (1999) defined four sand bodies very close to shore that were interpreted as abandoned ebb tidal deltas. This area is of interest to this study due to the potential of these sand bodies as borrow sites for beach nourishment projects (close proximity to Hampton and Seabrook beaches). In addition, the results of the work in this area will further our understanding of coastal-inner shelf interactions and the impact of tidal inlets on inner shelf shoals through time.

To date, a detailed surficial sediment map, a sand isopach map and a description of the seismic stratigraphy have been developed from the seismic records, bottom sediment samples, and nine vibracores. All of this information is being depicted in a GIS project.

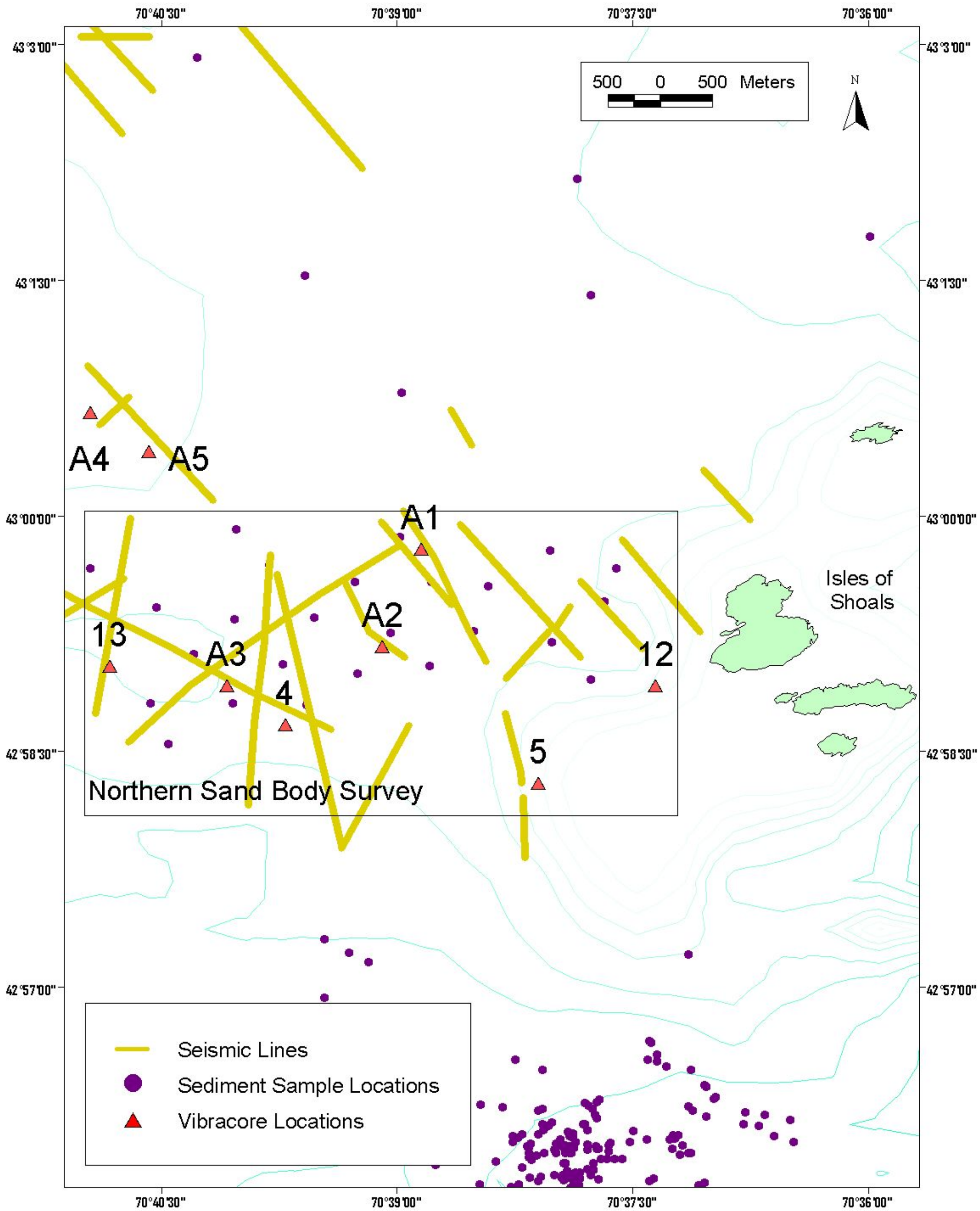


Figure 9. Location of seismic lines and sediment sampling stations in the vicinity of the Northern Sand Body.

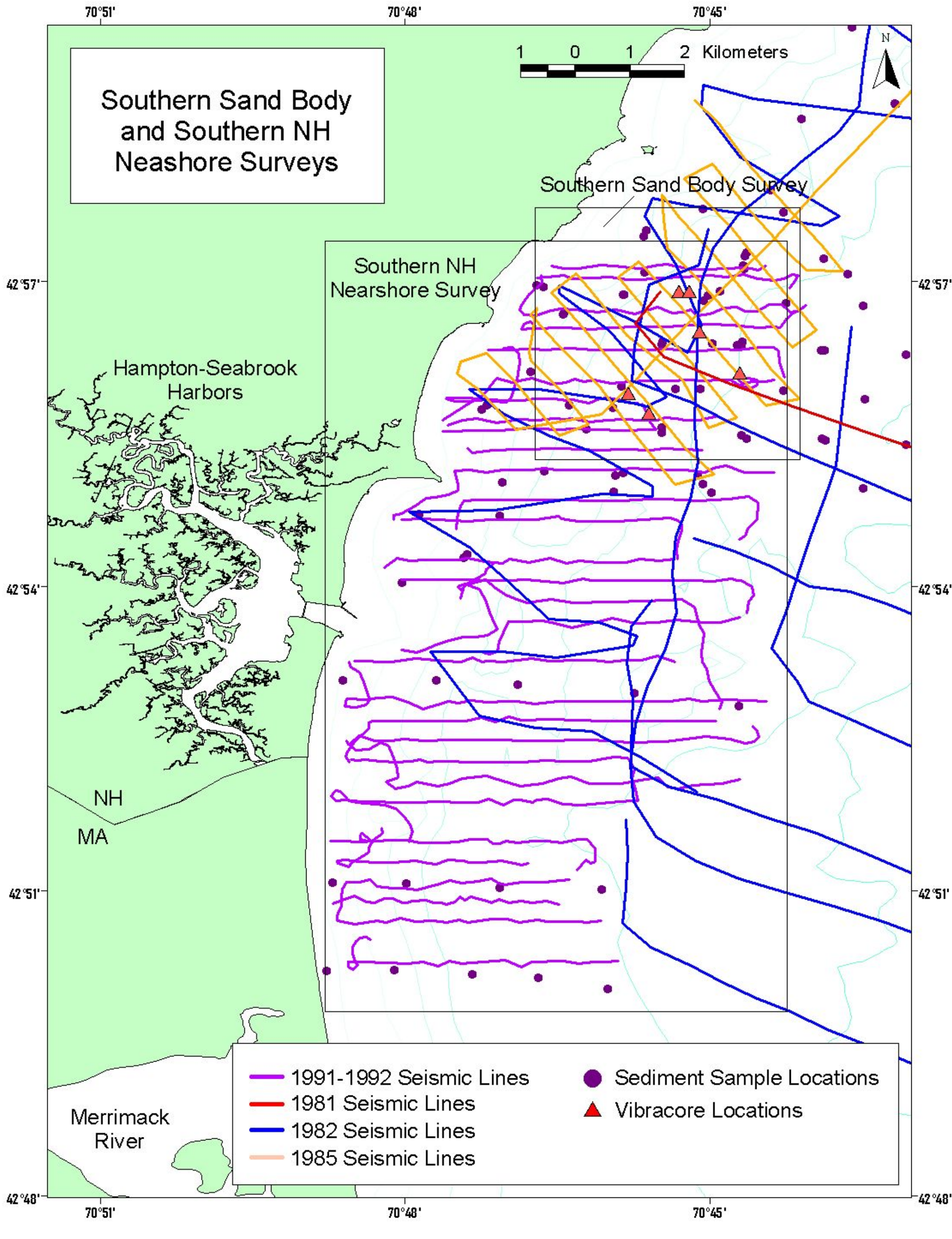


Figure 10. Location of seismic lines and sediment sampling stations in the Southern Sand Body and in the Southern New Hampshire Nearshore Survey focus areas.

Most of the objectives for this focus area have been completed and are discussed in more detail in Part Six.

Offshore Drumlin Survey

The database for the offshore drumlins is limited to several seismic lines and two vibracores (Figures 2, 3 and 8). In order to better understand the sedimentologic and stratigraphic characteristics of the drumlin deposits, the seismic lines will be analyzed and combined with the vibracore descriptions. To date, only the vibracores have been examined and logged. However, the appropriate seismic lines have been identified and will be analyzed in future efforts associated with this project. Due to the distance from shore and the lack of data, this area is considered low priority.

Portsmouth Harbor Survey

Today, the major rivers in New Hampshire flow into the Great Bay Estuary (Figure 1), where most of their sediment loads are deposited (Ward and Bub 2005). However, at lower sea levels, these rivers flowed through what is now the Great Bay Estuary and Portsmouth Harbor and extended onto the continental shelf. Undoubtedly, at the time of the lower sea levels, riverine sediments were introduced and deposited on the shelf. These deposits may be related to the sand deposits previously identified, such as the NSB and SSB. Therefore, Portsmouth Harbor was chosen to study in detail in order to further our understanding of riverine-inner shelf interactions and the formation of the shelf sand bodies (Figure 8).

Fortunately, a substantial database exists for Portsmouth Harbor (Figure 11) including a closely spaced subbottom seismic and side-scan sonar survey from 1992, several hundred bottom samples, and a number of gravity cores. This database is being used to develop a detailed bottom sediment map, a stratigraphic model, and an assessment of potential paleochannels. To date, the side-scan sonar and subbottom seismic records have been re-analyzed to complete and verify earlier analyses. This information has been used to develop a more accurate bottom sediment map of the estuary (Figure 12). In addition, this information has been entered into a GIS, along with the grain size information from the bottom sediment stations. Therefore, the primary remaining tasks are to synthesize the results of the seismic analyses, develop the stratigraphic model, and enter the information into the GIS project. These tasks will be completed in future efforts associated with this project.

Isles of Shoals Survey

A second area helpful to understanding the sedimentology and stratigraphy of the New Hampshire shelf and where a substantial database exists is at the University of New Hampshire Open Ocean Aquaculture program field site located a little over 1 km south of the Isles of Shoals (Figures 1 and 8). At this location closely spaced subbottom seismic and side-scan sonar records and over 300 bottom sediment samples provide a high resolution database of the sedimentologic and stratigraphic characteristics (Figure 13). In

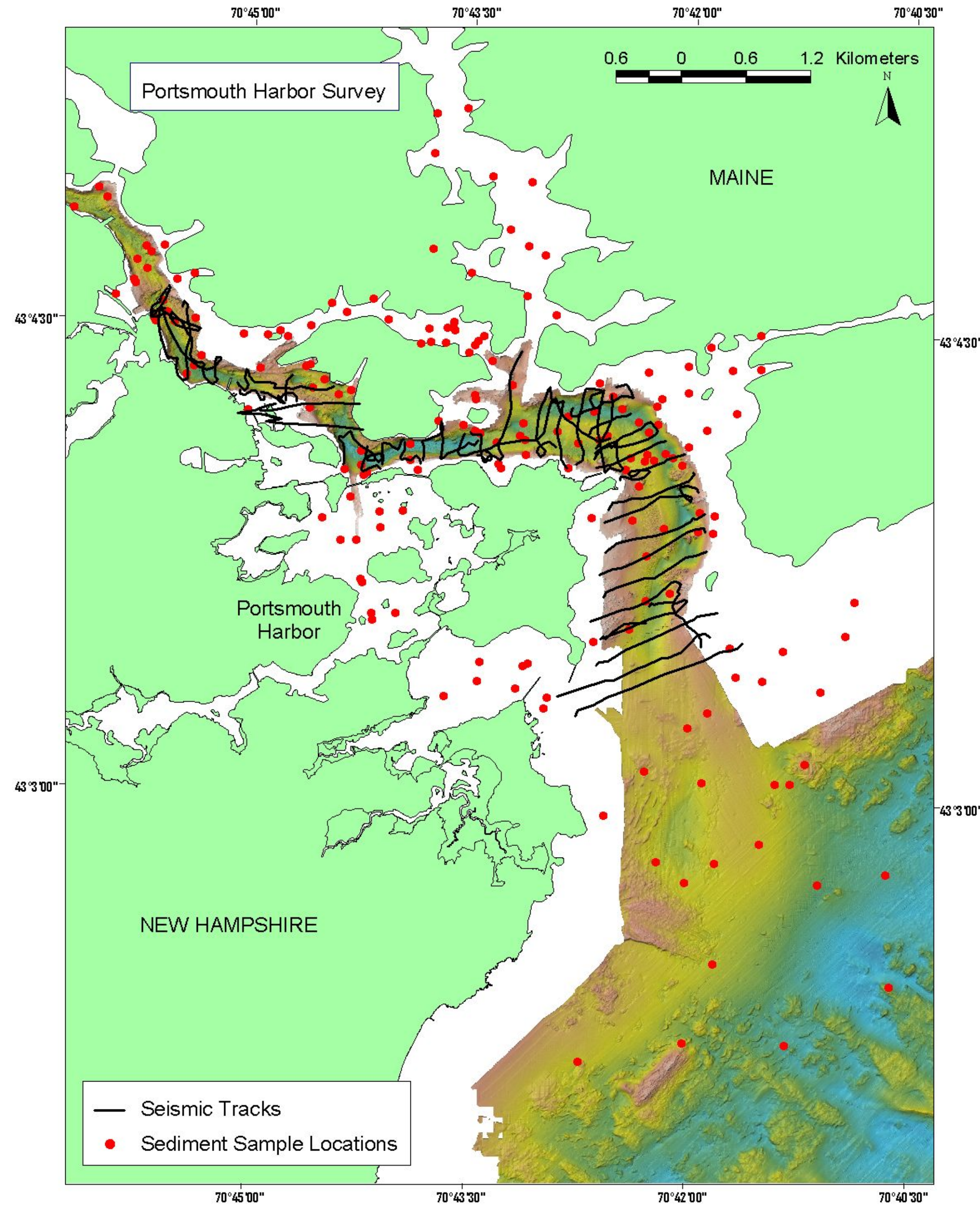


Figure 11. Location of seismic lines and sediment sampling stations in the Portsmouth Harbor area.

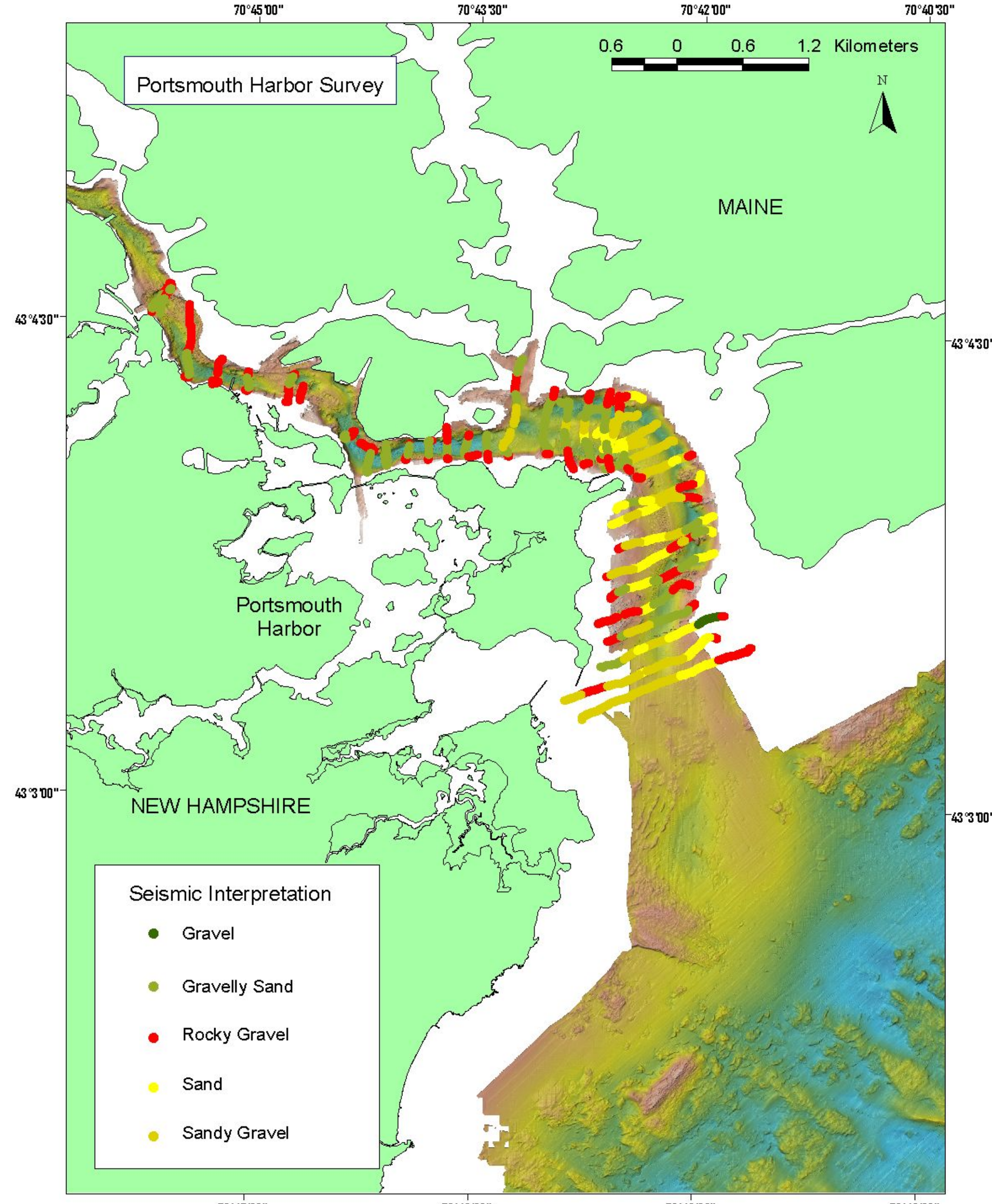


Figure 12. Distribution of the surficial sediments in Portsmouth Harbor based on the seismic survey and bottom sediment samples shown in Figure 11.

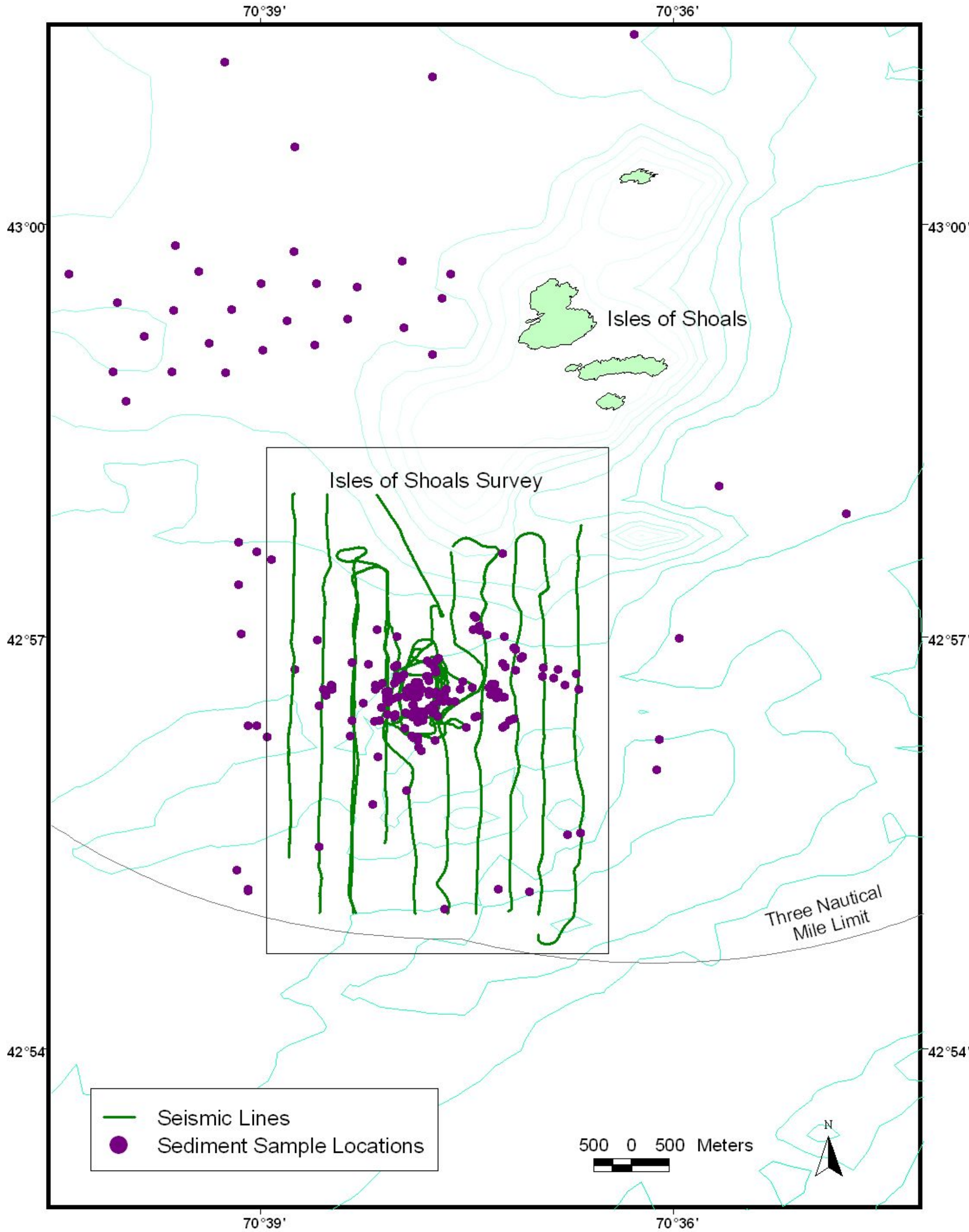


Figure 13. Location of seismic lines and bottom sediment samples in the Isles of Shoals focus area. The general location of the Northern Sand Body can also be seen from the cluster of sediment samples to the west of the Isles of Shoals.

order to better understand the influences of the extensive surface and subsurface bedrock on the major sedimentary units, this area was identified as a focus area.

To date, the side-scan sonar records have been interpreted and the results merged into a bottom sediment map. However, the subbottom seismic records have not been analyzed and verified, which will take a major effort. Finally, the GIS project for this area must be built and the stratigraphic model developed. The work for this area is considered a lower priority than the other focus areas and will be completed during future efforts.

Part Six: Southern New Hampshire Nearshore Focus Area

Rationale

Previous studies conducted in the southern New Hampshire nearshore region from the entrance to the Merrimack River to Little Boars Head (Figures 1 and 10) identified several sand bodies of interest to this project due to their proximity to important beaches and their relative closeness to shore. For example, Ward and Birch (1999) identified several relatively large sand deposits very close to shore that were described as likely abandoned ebb tidal deltas. In addition, Birch (1984b; 1986a; 1986b; 1988) identified a large nearshore sand body between Great Boars Head and Little Boars Head, which he referred to as the Southern Sand Body (SSB) (Figure 10). Despite the earlier work done in this area, the overall database and interpretations were not synthesize, nor were the results entered into GIS platforms. In addition, the side-scan sonar records had to be re-analyzed in order to verify and update our earlier interpretations using our present classification schemes. Therefore, the re-evaluation and synthesis of the database for this area was deemed a very high priority.

Data Analyses

A major task undertaken during this project was the development of an updated surficial geology map of the study area based largely on the MMS supported 1992 geophysical survey, which included side-scan sonar and subbottom seismics (Figure 14). Interpretation of the side-scan sonar records into bottom types was done using the classification scheme developed by Barnhardt et al. (1998) which utilizes sixteen categories originating from four end members – Rock (R), Gravel (G), Sand (S), and Mud (M). The classification is based on identifying the dominate bottom type (>50%) and, if necessary, adding a modifier (indicting that another seafloor type was present, but was subordinate to the dominant type). Based on this approach, the following bottom types emerge: R, Rock with Gravel (Rg), Rock with sand (Rs) and so on. Other combinations include Rm, G, Gr, Gs, Gm, S, Sr, Sg, Sm, M, Mr, Mg, Ms. The interpretation of the bottom types was verified where possible by bottom sediment samples (or locations where bottom sampling was attempted, but failed). These later areas are considered hard bottoms indicating either rock or gravel substrates. The interpretation of the side-scan sonar record was entered into a GIS project. Final mapping

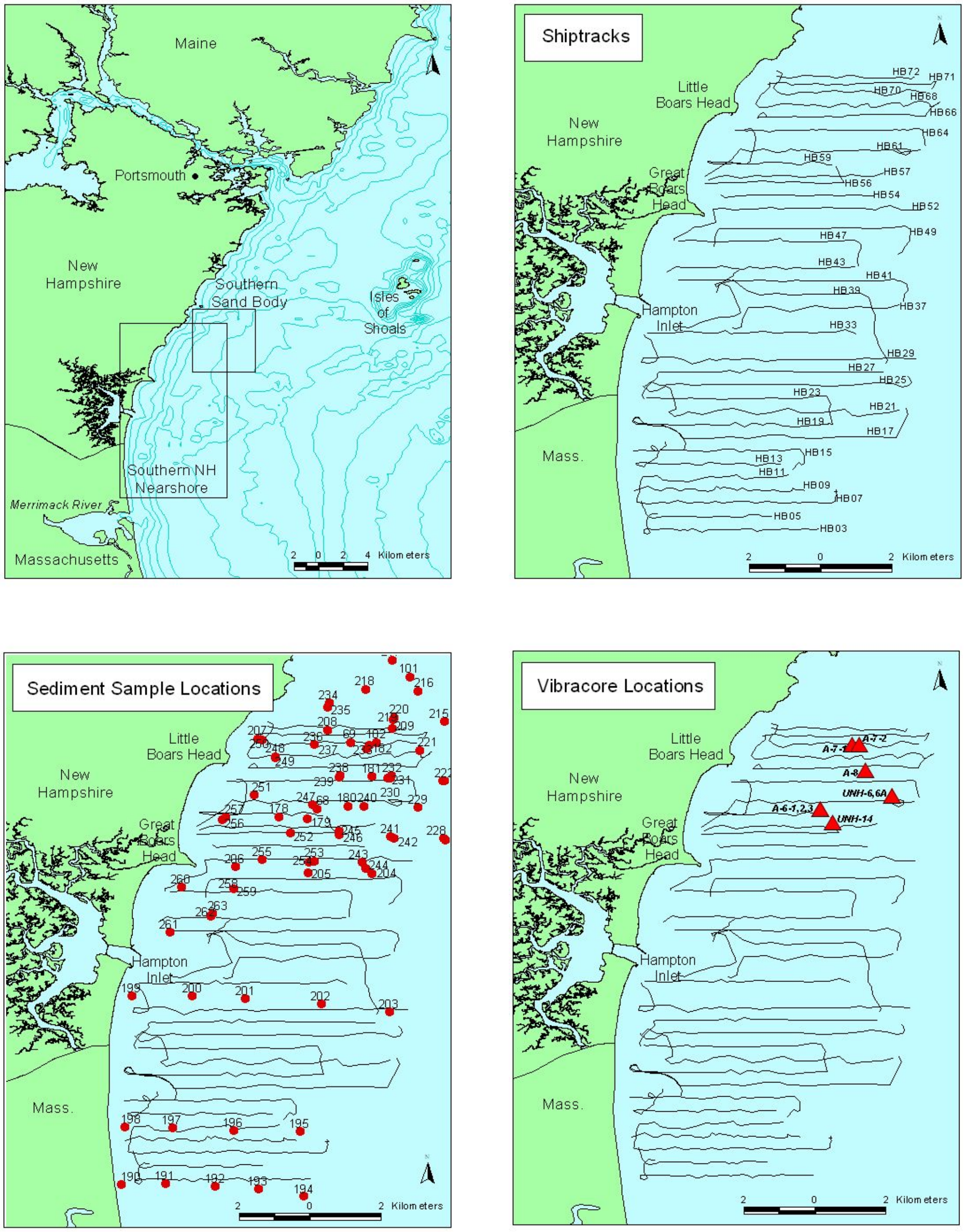


Figure 14. Location map showing the seismic lines (upper right), bottom sediment sampling stations (lower left) and vibracore stations (lower right) in the Southern New Hampshire Nearshore Focus Area (upper left).

of the surficial geology was done from the individual interpreted shiptracks and visually interpolating between lines to form polygons.

The subbottom seismic records from the 1992 geophysical survey were re-analyzed as well. Earlier analyses were restricted to identifying surficial sand layers, virtually ignoring the overall seismic stratigraphy. During the present study, the seismic stratigraphy was mapped where possible by tracing major reflectors visible on the seismic records onto drafting film. This was necessary since all the seismic records were analog (no digital records were available). Subsequently, the depth to each major reflector (using the travel time of sound in water) was determined at approximately one-minute intervals and entered into Excel spreadsheets. The major reflectors mapped included the seafloor, the depth to the base of any sand units, the surface and base of glacial marine sediments (analogous to the Presumpscot Formation described by Bloom 1963 for coastal Maine), and any hard reflectors (Figure 15). Although this procedure was time consuming and the quality of the seismic records marginal, some reasonable seismic stratigraphic records were recovered for a number of the subbottom seismic lines.

All vibracores taken in the focus area (Figure 14) were described in detail after several were examined and found to differ from the earlier core logs. Although one half of each vibracore was archived at Jackson Estuarine Research Laboratory since they were taken in 1984 and 1988, the quality of the cores was somewhat marginal. Unfortunately, the vibracores had been allowed to dry out and had been subjected to very hot conditions (in summer), as well as freezing (in winter). Nevertheless, the sediment types and major boundaries were identifiable. Sediment size, stratigraphic boundaries, and major features were visually determined and the information entered into Excel spreadsheets. Subsequently, each core description was used to create a core log using Rockware software. The core descriptions are given in Appendix 1.

Results and Discussion

Surficial Sediments. The characteristics of the seafloor were determined directly at 74 sites within the Southern New Hampshire Nearshore focus area. Forty-nine sediment samples were collected and analyzed for their grain size distribution, while no samples were recovered at twenty-five of the stations despite multiple attempts. At these sites the lack of success in obtaining samples is interpreted as an indication of a hard bottom, either bedrock or gravel.

In general, the mean grain sizes of the sediment samples ranged from very-fine sand to gravel (3.93 phi to -3.0 phi). The sediments were well-sorted to extremely-poorly sorted (0.4 phi to 3.9 phi). The sands tended to be negatively skewed, while the gravels were positively skewed. Where the sand deposits (abandoned ebb-tidal deltas discussed below) were sampled, the sediments tended to be fine to medium sands. Birch (1986a) reported that the mean grain size of the surficial sediment on a large aggregate deposit off North Hampton

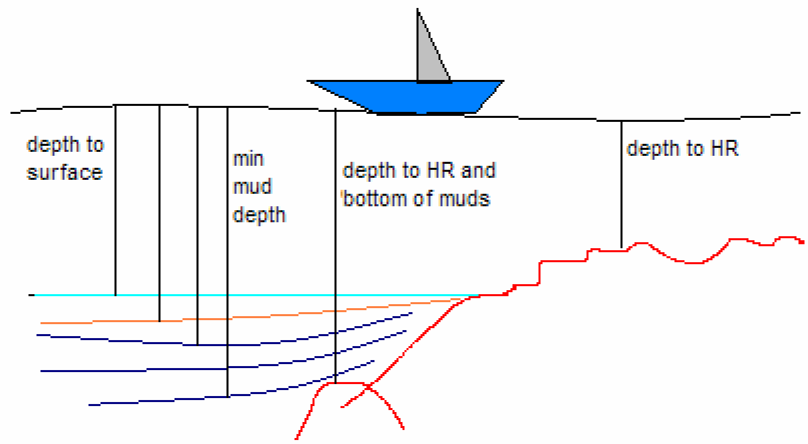


Figure 15. Schematic of major reflectors mapped for the Southern New Hampshire Nearshore focus area.

Beach (described as the Southern Sand Body) ranged from 2 phi to 3 phi or within the fine sand interval. Although the Southern Sand Body was not relocated during this survey, the reported textural characteristics appear to be similar to the deposits identified here.

The spatial distribution of the surficial bottom sediments and seafloor show several trends reflecting the changes in seafloor types from north to south and from shallower to deeper water depths. As expected, due to the influence of the Merrimack River, the bottom sediments sampled in the southern portion of the study area from transect HB03 to HB13 (Figure 14) are dominated by sand or gravelly sand, with varying amounts of gravel (Figure 16). Interestingly, the bottom sediments also tend to coarsen in a seaward direction with the % gravel and the mean grain sizes increasing (phi sizes decreasing) offshore. This trend of coarsening from sandy to more gravelly material offshore may reflect a limited volume of sand that is migrating landward with time as the barrier island system transgresses. Conversely, this trend may simply reflect finer-grained sediments being transported off the beaches during storm activity. This trend may be enhanced by the jetties at Hampton Harbor and at the entrance to the Merrimack River.

Northward between HB15 and HB57 (Figure 14), hard bottom areas composed of bedrock, or gravelly sediments with extensive bedrock outcrops, are much more common. However, the bottom is still sandy nearshore and some sand deposits associated with Hampton Inlet occur, but these appear to be limited.

The northern portion of the study area from approximately transect HB59 to HB72 (Figure 14) is a mixture of bottom types including sand, gravelly sand, gravel, and hard bottoms where no sediment samples were recovered (Figure 16). This trend reflects, in part, the lack of sources of sandier sediments south of the entrance to the Piscataqua River to Little Boars Head (Figure 1). In this area, the seafloor is largely composed of glacially derived sediments. This pattern indicates that the major sand sources to the southern New Hampshire inner shelf are from the Merrimack River and paleodelta.

Subsurface Sediments. In order to describe the subsurface sediments and verify seismic interpretations, a total of 9 vibracores were taken from six locations in 1984 and 1988. Multiple cores were taken at the same station at several sites in an effort to maximize core lengths. The vibracores were highly variable in length ranging from 1.32 m to 8.90 m (Appendix 1 and Figure 17). In general, the cores were taken in the vicinity of the Southern Sand Body mapped earlier by Birch (1984b). Vibracores A7(1) and A7(2) were taken along the northern boundary of the SSB focus area (Figure 14). A8, UNH6, and UNH6A were taken nearer the center, while A6(1), A6(2), A6(3) and UNH14 were taken nearer the southern portion of the SSB focus area.

The vibracores from the northern boundary of the SSB focus area, A7(1) and A7(2), are relatively short in length (1.31 and 2.05 m), likely reflecting the coarseness of the subsurface sediments (Appendix 1 and Figure 17). Both vibracores are composed of medium to coarse sands (matrix) with granule, pebbles, and some cobbles in the upper 1 to 2 m of the stratigraphic column. Since neither of these cores apparently completely

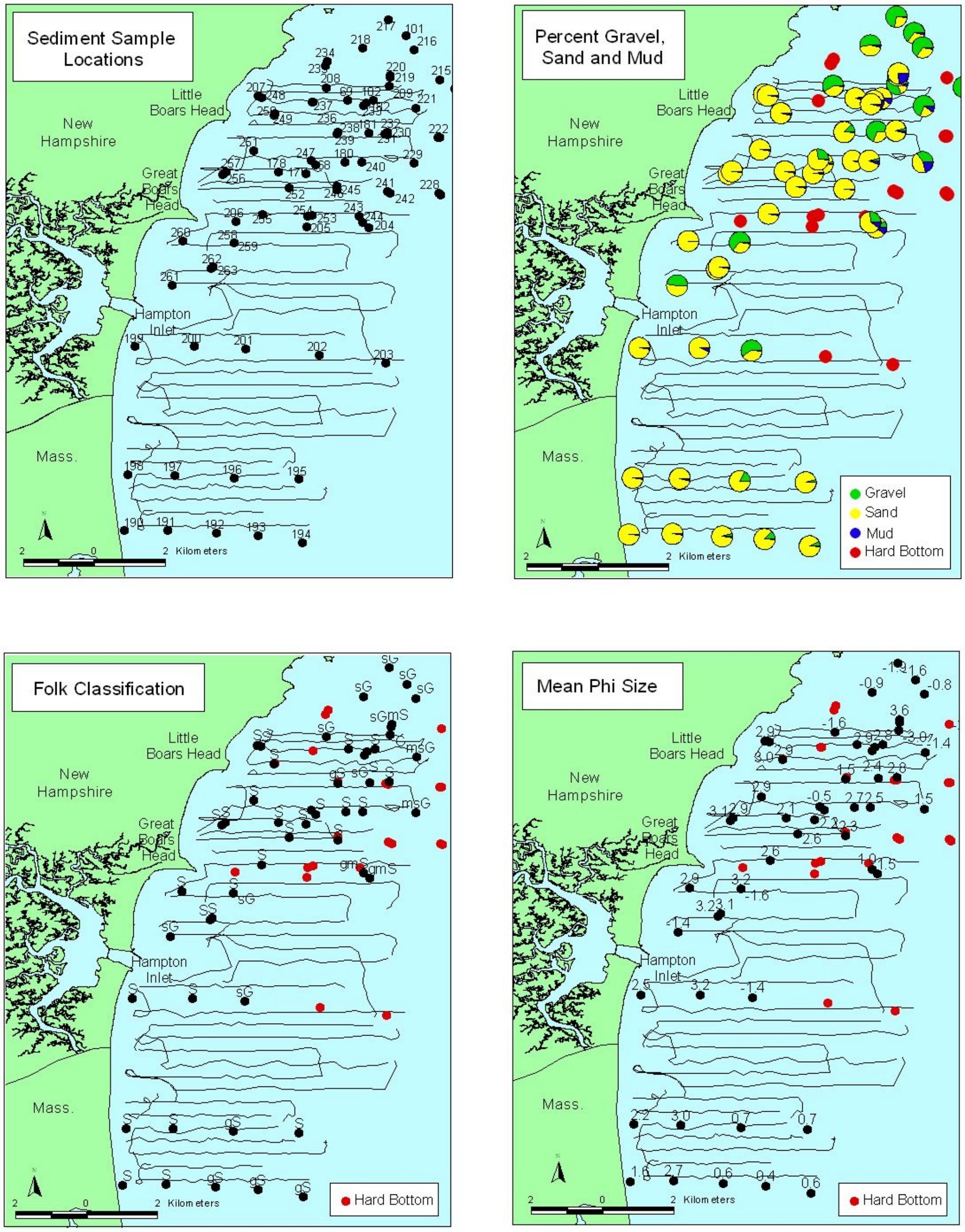


Figure 16. Surficial sediment grain size analyses results. Pie diagrams display the relative % gravel (green), % sand (yellow), and % mud (blue) in the samples (upper right). The classification of the bottom sediment sample based on the ratio of gravel, sand, and mud (Folk 1980) is also given for each sample (bottom left). G is gravel, S is sand, M is mud, sG is sandy gravel, gS is gravelly sand, mS is muddy sand, and mgS is muddy sandy gravel. Red circles indicate no sample was recovered at that station despite multiple attempts. The mean grain size is given on the lower right.

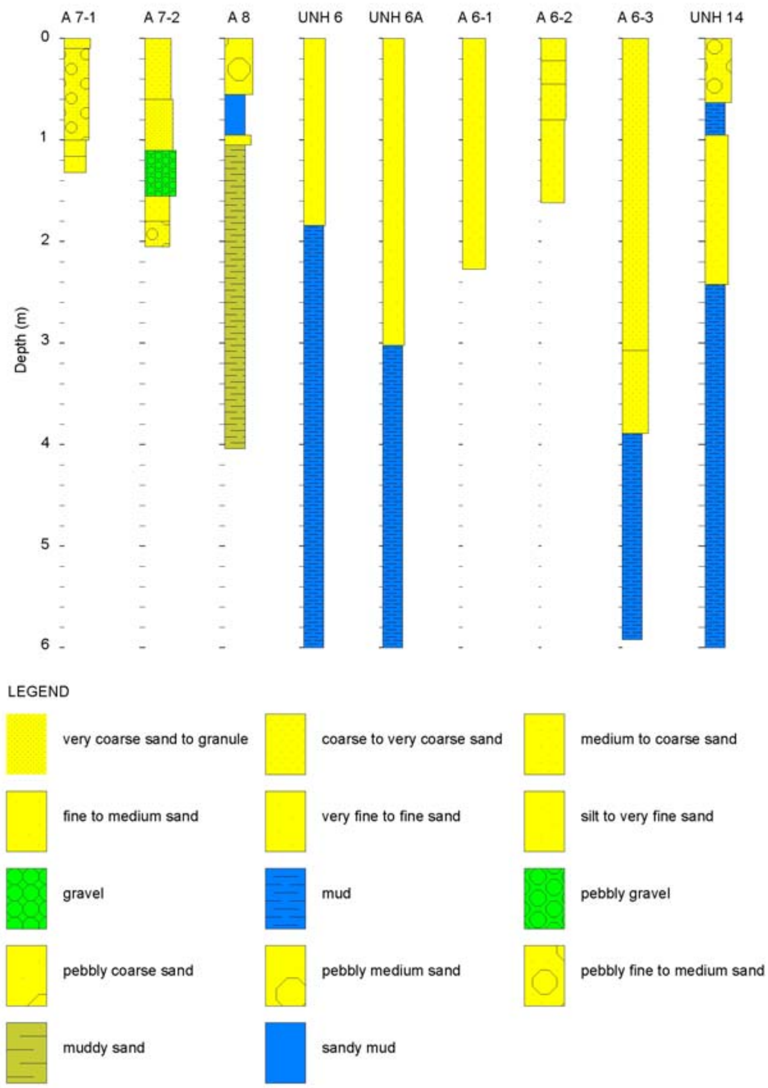


Figure 17. Core logs for the nine vibracores taken in the Southern Sand Body. Only the upper 6 m of each core are shown. Full descriptions of the cores are given in Appendix 1.

penetrated the coarser-grained sediments, the total thickness of the sands and gravels is not clear, but likely exceeds the 2.05 meters found in A7(2).

At sites UNH6 and UNH6A, the total lengths of the vibracores were greater than at sites A7(1) and A7(2) being 8.90, and 8.31 m, respectively (Appendix 1), However, the thickness of the coarser-grained sediments (~1 to 3 m) was similar (Figure 17). At UNH6 and UNH6A, the matrix sediments tended to be somewhat finer than at A7(1) and A7(2), being dominated by very-fine sands (matrix) with some pebbles. The remainder of the sediment column from these vibracores is composed of the finer-grained sediments of the Presumpscot Formation. Vibracore A8 was taken between the northern-most sites at A7(1) and A7(2) and the more central sites of UNH6 and UNH6A (Figure 14). This vibracore (A8) has the thickest sequence of coarser-grained material encountered with ~4 m of sand with pebbles, although the 0.55 m to 0.95 interval appears to be a sandy mud (Figure 17).

The vibracores taken further to the south at sites A6(1), A6(2), A6(3) and UNH14 (Figure 14) have similar characteristics as the cores taken at UNH6 and UNH6A. Here, sand thickness ranges from 2.27 m to 3.89 m (Appendix 1 and Figure 17). A6(1) and A6(2) are largely fine sands, while A6(3) has the thickest (3.89 m) and coarsest (medium to coarse) sands. Beneath the sands in A6(3), glacial marine sediments of the Presumpscot Formation are encountered. The vibracore taken at site UNH14 is composed of medium sands in the upper 0.63 m, but quickly fines to muddy to fine sands from 0.63 to 2.42 m. Glacial marine sediments are encountered at 2.42 m

Based on review of the vibracores, it appears the thickness of the coarse sediments in the vicinity of the previously identified SSB is less than 4 m. However, the vibracores limited penetration of the subsurface, especially closer to the northern boundary of the SSB, may indicate the existence of greater thicknesses of coarser-grained sediments.

Surficial Geology. Detailed examination of the 1992 side-scan sonar survey (Figure 14), coupled with ground truth data from the surficial sediment samples and vibracores discussed in the preceding sections, provided the baseline information to develop a surficial geology map of the study area.

The surficial geology (and seismic stratigraphy discussed in the next section) of the inner shelf from ~6 m to the ~30 m depth interval reveals a complex seafloor that is strongly influenced by: the Merrimack River to the south; the northeast-southwest structural trend of the outcropping bedrock that extends from near Hampton Inlet to the Isles of Shoals; and the most recent glaciation (Figures 14, 18, and 19). The interactions of these influences left behind a mix of seafloor types from fine-grained glacial marine sediments (Presumpscot Formation) underlying a thin veneer of sand winnowed from the Presumpscot to gravels and boulders provided by reworked morainal deposits. In addition, a major source of sediments to the coast and nearshore is a drumlin (Great Boars Head) situated at the northern end of Hampton Beach. Erosion of Great Boars Head undoubtedly supplied at least some sand to area beaches (e.g., Hampton Beach) and

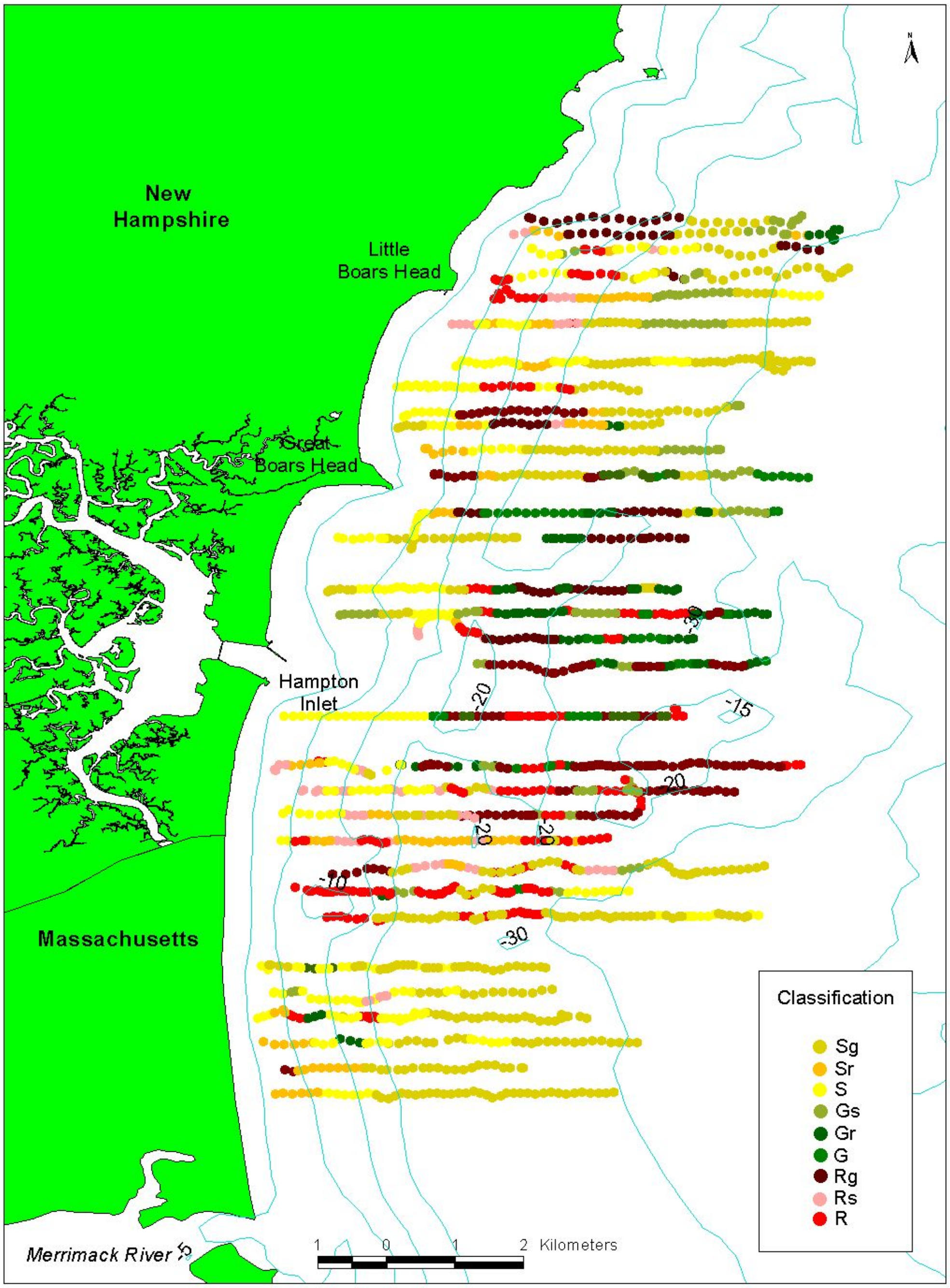


Figure 18. Seafloor classifications along the shiptracks in the Southern New Hampshire Nearshore focus area.

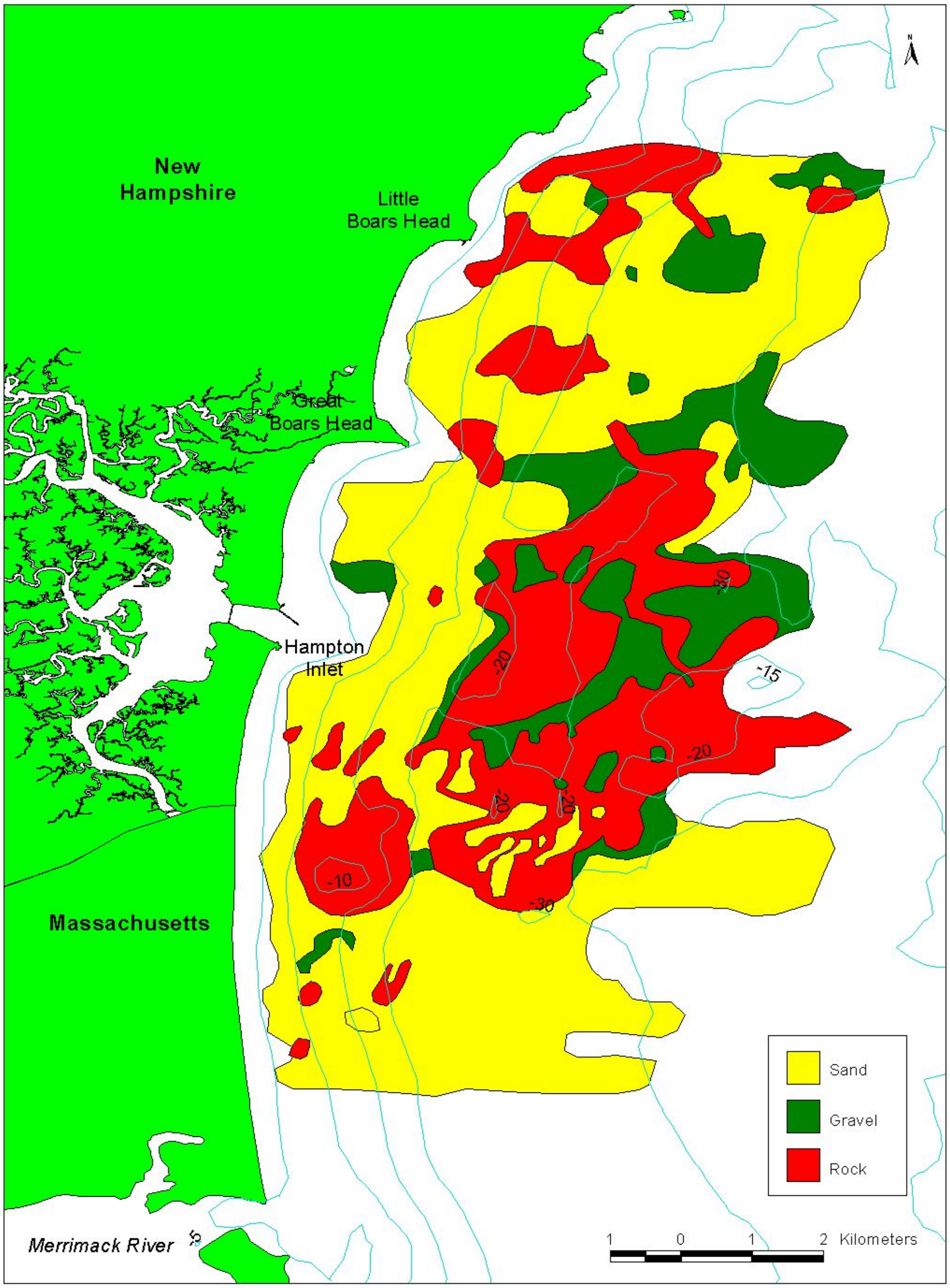


Figure 19. Seafloor surficial geology map for the Southern New Hampshire Nearshore focus area based on the seafloor classification shown in Figure 18.

has left a gravel platform (with boulders and cobbles, as well as smaller size gravels) that extends seaward.

The southern end of the study area closest to the Merrimack River (between HB03 and HB13), is dominated by sand and fine gravels, although rocky outcrops are common (Figure 20). Here, the bedrock is deeper than the area just to the north, allowing more accommodation room for sand. The sand is most likely supplied by the Merrimack River and the associated paleodelta, as well as longshore drift from the north.

Although rocky bottoms occurs throughout the study area, the seafloor is dominated by outcropping bedrock from about the HB17 to HB54 seismic lines (offshore of the Massachusetts and New Hampshire border to Great Boars Head and seaward of 15 m contour to the seaward limit of the survey in ~30 m of water) (Figure 20). The general structural trend of the outcropping bedrock along the inner shelf appears to be in a northeast-southwest orientation as indicated by the bathymetry. The areas between the rocky bottoms are largely gravel, although sand can be found as well.

Seaward of Great Boars Head the seafloor reflects the erosion of the glacial drumlin (transects HB47 to HB52), exhibiting a large amount of coarse sediments including gravels and gravelly sands (Figures 18). Boulders are common in the area as well. Northward of Great Boars Head from seismic lines HB56 to HB72, the bottom is a mixture of seafloor types with hard, rocky areas, as well as significant gravelly and sandy deposits (Figures 18 and 19). As discussed previously, an earlier study by Birch (1984b) indicated the sandy and gravelly areas seaward of the exposed rocky seafloor is a relatively thick sand deposit (termed by Birch as the Southern Sand Body or SSB). Unfortunately, the subbottom seismic system used by the 1992 subbottom survey lacked the ability to penetrate coarser bottoms and the SSB was not verified.

Seismic Stratigraphy. The subbottom seismic records to a large extent show the same pattern as was revealed by the surficial geology map. In general, the study area is dominated by the presence of bedrock, which reduces the accommodation space for thick sedimentary sequences. The sand deposits are generally thin and close to shore, likely being part of the barrier island complexes. Glacial marine sediments are common, usually draping over bedrock and underlying the surface veneer of sand and gravel. Birch (1984b; 1986a; 1986b; 1988) indicated the sand and gravel deposits in many cases were winnowed out of the underlying glacial marine sediments. Other factors important to the subsurface include the erosion and retreat of Great Boars Head (drumlin), migrations of Hampton Inlet prior to stabilization by jetties allowing multiple ebb tidal deltas to be deposited, and sea level changes resulting in a transgression, regression, and another transgression since the last glaciation (Kelley et al. 1995; Belknap et al. 2002).

It should be noted that the subbottom seismic records analyzed for this study were obtained using an ORE model 140 unit broadcasting at a frequency of 3.5 kHz with variable power. Although in some applications this unit provided some valuable records, overall it lacked the ability to penetrate many subsurface areas. Consequently, the seismic

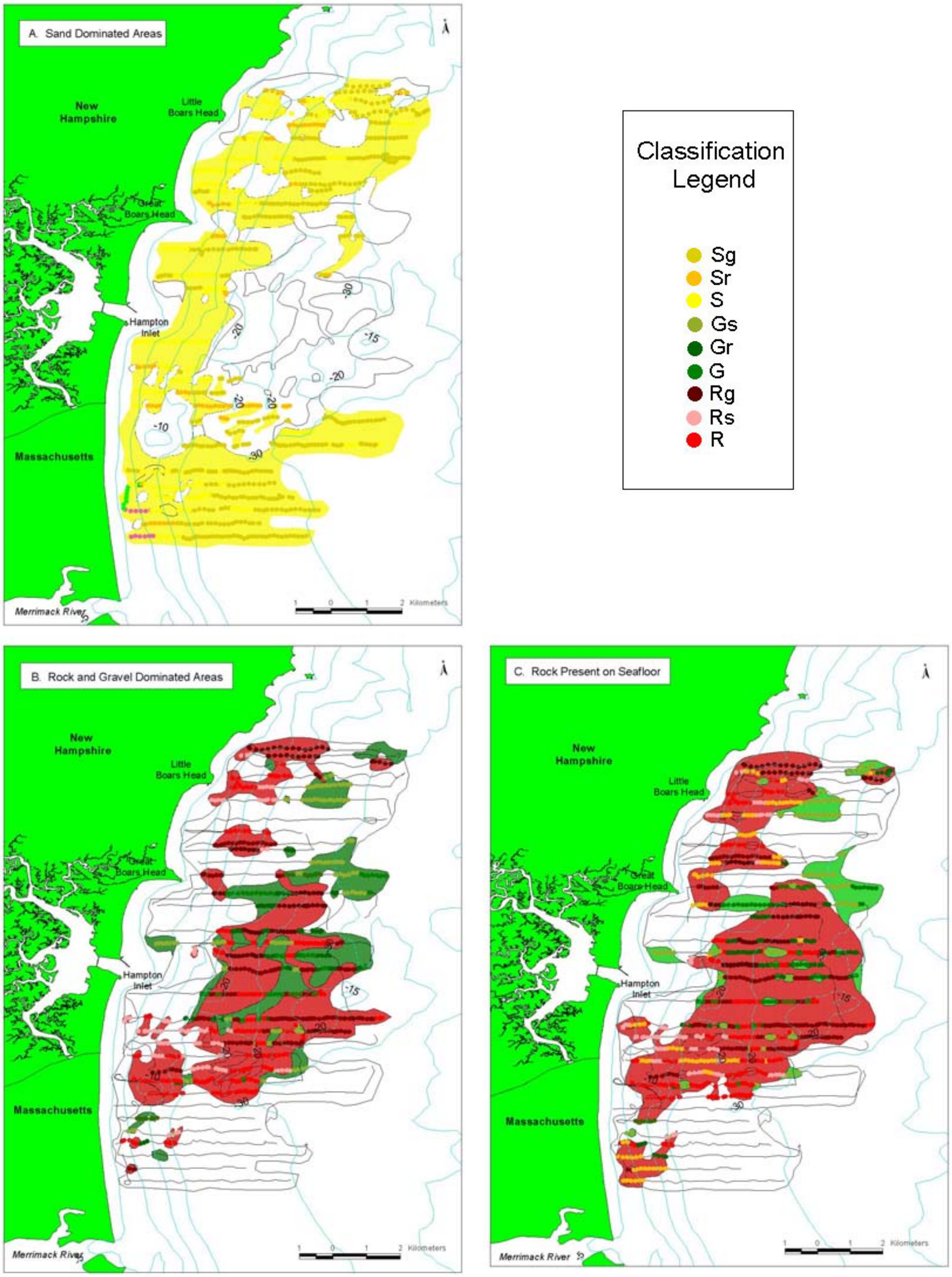


Figure 20. Seafloor types within the Southern New Hampshire Nearshore focus area. The southern area is dominated by sandy bottoms, while the more central area is dominated by rocky and gravelly bottoms (A). Panel B shows the region where rock outcrops dominate the seafloor (>50%). Panel C shows the regions where rock outcrops occur whether being the dominant or secondary seafloor type.

records vary from high quality in some areas to very low quality in others. As a result, the seismic coverage is incomplete. Nevertheless, general trends are discernible.

In the southern portion of the study area from HB03 to HB13 (Figure 14), the subbottom seismic records indicate the existence of several sand wedges. However, the sand deposits are frequently interrupted by bedrock, both outcropping or near the surface. For example, the subbottom seismic records for transect HB03 shows a subsurface reflector close to shore that is interpreted as the base of the sand wedge associated with the barrier island complex (Figure 21). Offshore, a coarsening of the surficial sediments into more gravelly material occurs as indicated by the side-scan sonar survey. Unfortunately, deeper reflectors are not visible in much of the record (due to the quality of the geophysical survey). However, this may indicate that the bedrock is deeper at this location. The subsurface reflectors in HB05 are not clear, but HB07 and especially HB09 (Figure 22) show a decrease in the thickness of the sand wedge and strong reflectors close to the surface indicting the presence of outcropping bedrock (verified by the side-scan sonar records). In this area, as is true for the entire study area, the sandy sediments are largely confined by bedrock to being adjacent to and part of the barrier island sequences.

The section of the study area from HB15 to HB33 is dominated by very coarse-grained sediments and outcropping bedrock, as was clearly seen in the surficial geology map (see Figure 19). Most of the subbottom seismic records have strong reflectors associated with bedrock and glacial marine sediments. For example, HB15 subbottom seismic record is interpreted as being composed of an undulating bedrock surface, exposed in numerous areas, that is covered by relatively thick glacial marine sediments (Presumpscot Formation) (Figure 23). Sand layers are limited to thin veneers on top of the glacial marine sediments. Again, it is likely that the winnowing of the glacial marine sediments is a source of the sand and gravel. However, there are several locations where relatively thick sand deposits occur close to shore as was seen further to the south. For example, HB33 subsurface reflectors indicate an extensive bedrock surface draped with the glacial marine sediments and a thick nearshore sand wedge. The location of HB33 near the entrance of Hampton Inlet indicates this feature is part of the active ebb tidal delta complex. However, the extensive outcropping bedrock in the vicinity of Hampton Inlet precludes the formation of the more typical ebb tidal delta systems. Again, the extensive bedrock control of the seafloor morphology, surficial geology, and stratigraphy of this area is demonstrated.

The nearshore shelf between HB35 and HB52 is similar to the sequences between HB15 and HB33 described above being dominated by bedrock, either exposed on the seafloor or underlying the glacial marine sediments. A thick sand wedge occurs close to shore between HB41 and HB47. Again, this sand body with thicknesses of ~8 m is associated with the barrier island sequence and is likely an abandoned ebb tidal delta deposit. However, Great Boars Head lies just to the north of the sand wedge and erosion of the drumlin may be the source of the sandy sediment that formed the deposit. Another sand wedge, perhaps also related to erosion of Great Boars Head, occurs north of the drumlin along HB56 to HB61. It is not clear whether this feature is related to erosion of the

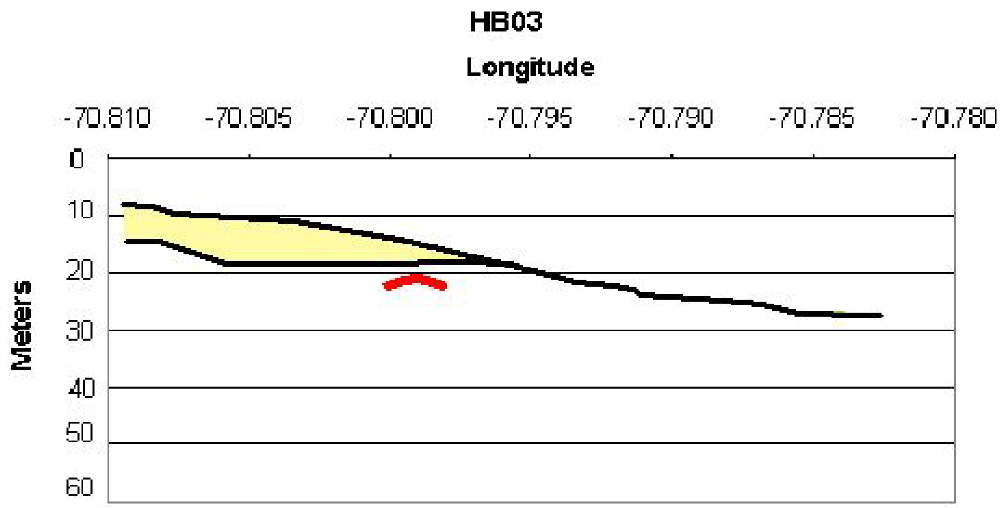


Figure 21. Schematic of the subbottom seismic record from transect HB03 (Figure 10). The length of the seismic section is about 2.5 km. Note the relatively thick sand wedge (yellow) adjacent to the barrier island. The red line at depth is a strong reflector associated with bedrock.

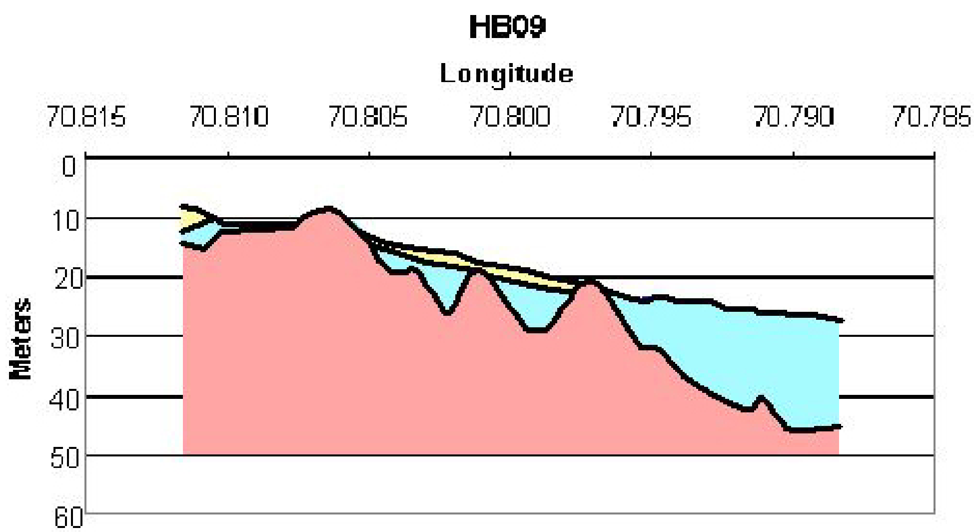


Figure 22. Schematic of the subbottom seismic record from transect HB09 (Figure 14). The length of the seismic section is about 2.5 km. HB09 is located about 1 km north of HB03, but the sand wedge is much smaller (yellow), indicating the variability over short distances. Bedrock is much more dominant (red), both outcropping and underlying glacial marine sediments (blue).

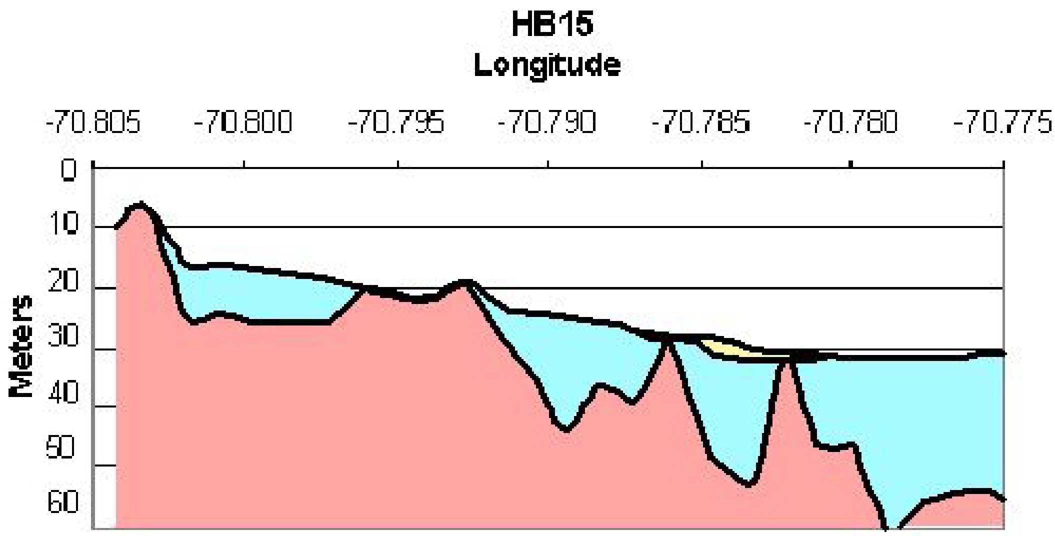


Figure 23. Schematic of the subbottom seismic record from transect HB15 (Figure 14). The length of the seismic section is about 2.5 km. HB15, located only a little over 2 km from HB03 is composed primarily of bedrock (red), which frequently outcrops, underlying thick units of glacial marine sediments of the Presumpscot Formation (blue). Sand (yellow) is limited to thin veneers at the seafloor that was likely winnowed out of the underlying glacial marine sediments.

drumlin or is an abandoned ebb tidal delta. The location along the coast does not preclude a possible former position of an inlet. The northern mixed bottom area shows a slightly different seismic stratigraphy with thin sequences of sedimentary deposits and a very hard bottom north of seismic line HB68 to the end of the 1992 survey area at HB72. In this area, very little penetration of the bottom by the seismics occurred indicating a hard bottom, perhaps composed of gravel and bedrock.

Sand Deposits. Based on the interpretation of the 1992 geophysical survey discussed above, the distribution and thickness of potential sand deposits along the southern New Hampshire inner shelf area was mapped and entered into a GIS environment (Figure 24). The original interpretation of the sand thicknesses was done during the earlier MMS funded work (Birch and Ward 1999). During the present study, the subbottom seismic records were more fully analyzed including mapping all major and visible reflectors (including bedrock). However, the attempts to verify the thicknesses of the sand deposits were only moderately successful due to the quality of the records. Therefore, the original interpretations of the records for the sand thicknesses have been maintained here. Verification will have to rely on a new geophysical survey.

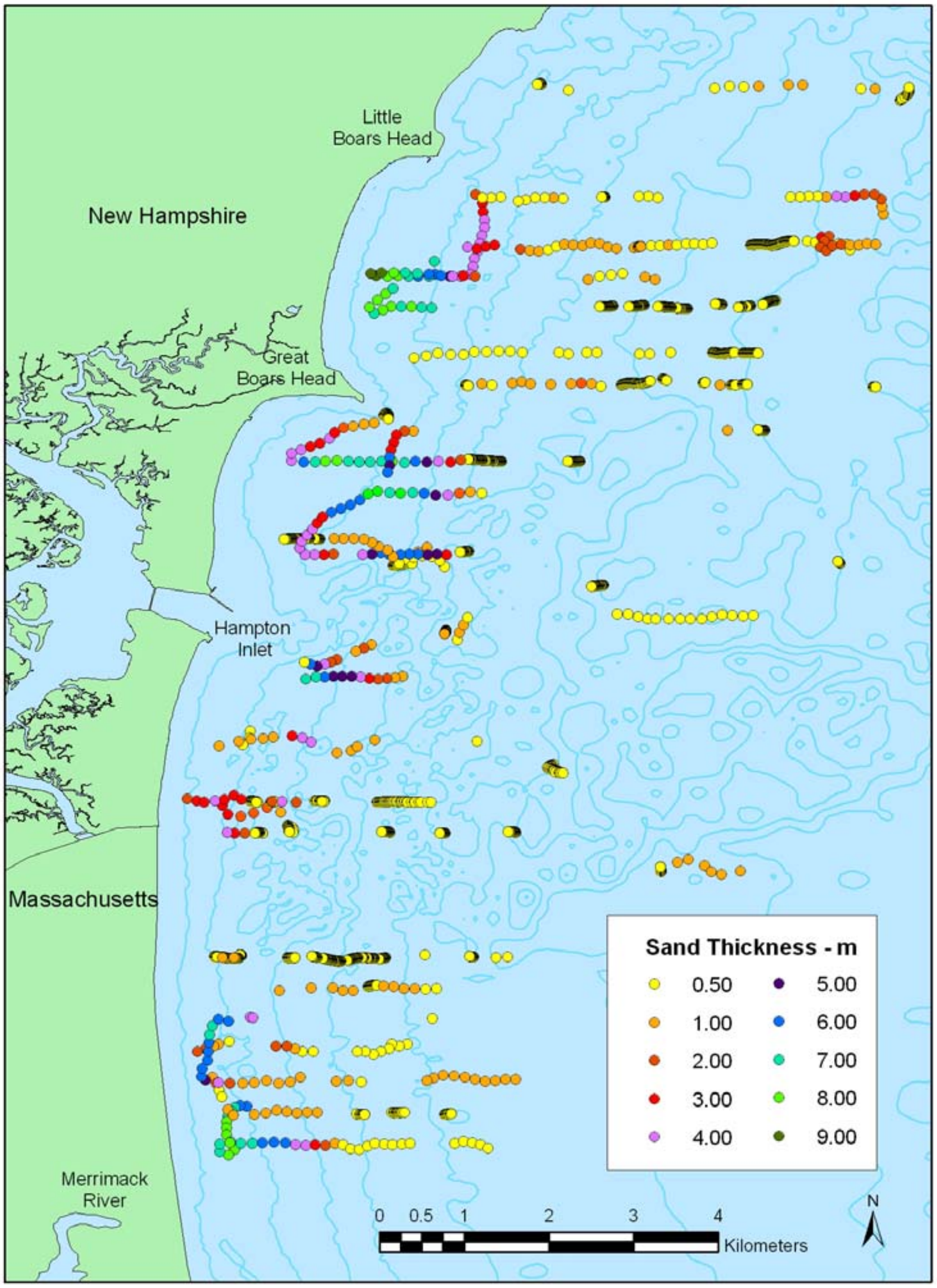


Figure 24. Sand thicknesses determined from the subbottom seismic survey in the Southern New Hampshire Nearshore focus area.

Four relatively large and significant sand deposits were identified within the study area. Maximum sand thicknesses exceeded 9 m (**Figure 25**). Several of the sand deposits are interpreted as abandoned ebb tidal deltas shoals related to formed positions of inlets in the barrier island system. Conversely, the sand bodies closest to Great Boars Head may be related to erosion of the drumlin.

Conclusions

Several relatively large sediment deposits greater than 6 m in thickness, presumably consisting largely of sand, were identified from the seismic survey. These sand bodies are located close to shore, often landward of outcropping bedrock, between the Merrimack River and Little Boars Head. One of the sand bodies is located just north of the Merrimack River entrance and is likely related to the ebb tidal delta complex and jetties stabilizing the channel. Similarly, a sand deposit is located off the present position of Hampton Inlet and is part of the ebb tidal delta complex. However, two northern sand deposits, which approach 2 km in their longest dimension and exceed 8 meters in thickness, are not found near any presently active inlets. These may be related to relic tidal channels or rivers at these sites. Conversely, the two large sand deposits are located adjacent to Great Boars Head and may be related to the erosion of this drumlin. Additional studies are required to verify the origin of these deposits.

Unfortunately, review of the entire data set for southern New Hampshire Nearshore Focus Area does not verify the existence, size, composition, and exact location of the nearshore sand bodies. Although the evidence does strongly indicate the characteristics and general location of these features, a new mapping effort will need to be undertaken to verify and locate the features using modern technologies (GPS, multibeam acoustic surveys, and a new geophysical survey for subbottom seismics). Subsequently, the sand bodies will need to be sampled via grabs and vibracores.

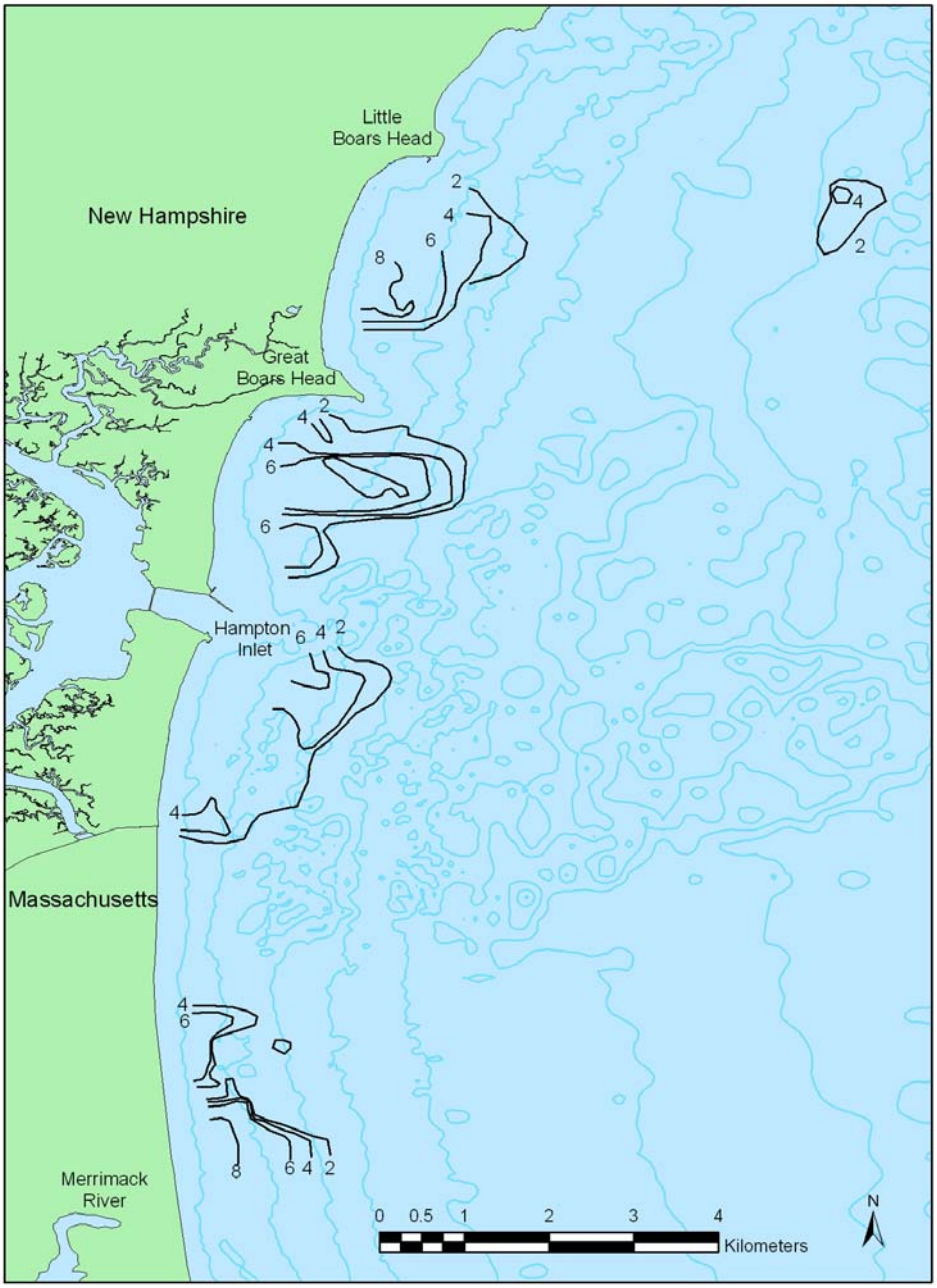


Figure 25. Sand thickness isopachs determined from the subbottom seismic survey for the Southern New Hampshire Nearshore focus area.

Part Six: Recommendations for Future Work

Based on the review presented in this report, several recommendations emerge for the next phase of work for the New Hampshire-Minerals Management Cooperative Agreement. This assessment is based on the original tasks outlined in the cooperative agreement, the retrieval and review of previous work, and the re-evaluation and synthesis of the database for the Southern New Hampshire Nearshore Focus area.

Major recommendations include:

1. Complete the review and synthesis of the databases for the five remaining focus areas on the New Hampshire shelf.

2. Conduct a new survey of the Southern New Hampshire Focus area to accurately identify and characterize the nearshore sand bodies including the abandoned ebb tidal delta complexes and the Southern Sand Body. A new survey must include state-of-the-art navigation, multibeam acoustic surveys, and subbottom seismic surveys. Following the geophysical work, new vibracores and surficial sediment samples need to be obtained for ground truth and for sediment characterization.

3. Merge the results of the previous recommendation (2) with the work being done on the Merrimack River and paleodelta by investigators from other institutions.

Acknowledgments

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Appendix 1: Descriptions of Vibracores from the New Hampshire Continental Shelf

Note: The "UNH" series was collected in 1984, while the "A" series was taken in 1988. The color of the section, based on the Geological Society of America Rock Color Chart, is given in parentheses under the Lithology

UNH - 1 (Lat. 42.97167, Long. 70.45667)		
Depth - m	Lithology	Description
0.00 – 0.04	medium sand (5Y5/2)	one 5 cm rock frag; two shell frags
0.04 – 0.26	silty clay (5GY6/1)	sharp contact; clay and sand lenses; rock frags to 1.6 cm
0.26 - 0.47	silty sand (5Y5/2);	indistinct contact; clay lenses; rock frags to 1.6 cm
0.47 – 0.67	sandy silt (5Y5/1)	sharp contact; clay lenses; rock frags to 5.6 cm
0.67 – 1.95	silty clay (5GY4/2)	indistinct contact; silty sand lenses; rock frags to 5.6 cm
1.95 – 2.04	silty sand (5GY4/2)	distinct contact; many rock frags to 0.6 cm
2.04 – 2.52	silty sand (5GY4/2)	distinct contact; sand streaks; rock frags to 0.5 cm
2.52 – 3.42	silty clay (5GY4/2)	new core section; large sand lens; rock frags to 7.5 cm

UNH - 2 (Lat. 42.90667, Long. 70.44333)		
Depth - m	Lithology	Description
0.00 - 0.26	clayey silt (5GY4/2)	shell frags; rock frags to 5 cm
0.26 – 1.20	silt (5GY5/2)	indistinct contact; rock frags to 8 cm
1.20 – 1.50	fine sand (10Y4/2)	indistinct contact; rock frags to 0.2 cm

UNH - 3 (Lat. 42.88500, Long. 70.50833)		
Depth - m	Lithology	Description
0.00 – 1.02	medium to coarse sand (10YR5/4)	moderately to poorly sorted; shell frags; rock frags to 5 cm
1.02 – 1.45	medium to coarse sand (10YR5/4	new core section; shell frags; rock frags to 7 cm
1.45 – 1.86	medium to coarse sand (10YR5/4	very small shell frags; rock frags less than 0.3 cm
1.86 – 2.56	fine to medium sand (10YR5/4)	lenses of coarse sand and gravel
2.56 – 2.58	coarse sand (10YR5/4)	new core section; rock frags to 1 cm

2.58 – 2.84	fine to medium sand (10YR5/4)	indistinct contact; one rock frag
2.85 – 3.04	fine sand (10YR/4)	indistinct contact
3.04 – 3.12	sandy silt (5YR4/4)	indistinct contact
3.12 – 3.40	fine sand and silt (10YR5/4)	indistinct contact; medium sand lens from 3.27 – 3.34 m (1.5 cm wide; burrow?)
3.40 – 3.50	fine to medium sand (10YR5/4)	indistinct contact; common rock frags to 3.5 cm; rare shell frags
3.50 – 3.61	medium to coarse sand (10YR5/4)	indistinct contact; very common rock frags to 3.5 cm; rare shell frags
3.61 – 3.64	very fine to fine sand and silt (5Y4/4)	distinct contact; very common rock frags to 1 cm; occasional shell frags
3.64 – 4.10	medium to coarse sand (10YR5/4)	distinct contact; very common rock frags to 1 cm; occasional shell frags
4.10 – 4.22	coarse sand (10YR5/4)	new core section; one rock frag 7 cm
4.22 – 4.72	medium sand (10YR5/4)	distinct contact; shell frags; rock frags to 3 cm
4.72 – 4.73	coarse sand (10YR5/4)	distinct contact
4.73 – 5.28	fine sand (5Y6/2)	distinct contact
5.28 – 5.44	very fine sand (5Y3/2)	distinct contact; lenses of biotite-rich sand
5.44 – 5.64	very fine sand and silt (5Y5/2)	distinct contact
5.64 – 6.07	very fine sand and silt (5Y5/2)	fine sand lenses throughout

UNH - 4 (Lat. 42.98000, Long. 70.65500)		
Depth - m	Lithology	Description
0.00 – 0.14	medium sand (10YR5/4)	shell frags; rock frags to 0.5 cm
0.14 – 0.19	fine sand (5Y7/2)	distinct contact

0.19 – 0.85	fine sand (N7)	shell frags; stained patches (5Y6/4)
0.85 – 1.74	fine sand (5Y4/2)	new core section; shell frags
1.74 – 2.59	fine sand (5Y4/2)	new core section; shell frags
2.59 – 3.46	fine sand (5Y4/2)	new core section; small patched of peat near base
3.46 – 4.99	fine sand and silt (5Y4/2)	new core section; shell frags; peat pods to 0.5 cm; mica rich
4.99 – 5.69	very fine sand and silt (5Y4/1)	new core section; shell frags; rock frags to 3 cm; abundant peat pods near base
5.69 – 6.46	silty clay (5Y4.5/1)	distinct contact; shell frags and stained sand pods (5YR);

UNH - 5 (Lat. 42.97500, Long. 70.63333)		
Depth – m	Lithology	Description
0.00 – 1.17	coarse shell hash (10YR5/4)	shell frags to 0.5 cm at surface; shell size fines downward; shell frags include echinoderms, sand dollars, bivalves, forams, snails
1.18 – 2.73	fine shell hash (5YR7/1)	new core section; section includes medium to coarse sand with rock frags to 1.5 cm; a few complete shells
2.73 – 3.22	very fine shell hash (5YR7/1)	new core section; some larger shell frags; rock frags to 6 cm
3.22 – 3.67	fine sand (5Y5/1)	distinct contact; many shell frags; rock frags to 2.3 cm
3.67 – 3.78	shell hash (5YR7/1)	distinct contact; some fine sand; rock frags
3.78 – 4.03	very fine sand (5YR5/1)	indistinct contact; shell frags; rock frags to 5 cm; sand and granule lenses
4.03 – 4.17	very fine sand (5GY6/1)	distinct contact; shell frags; rock frags to 3 cm
4.17 – 5.26	fine to medium sand (5Y4/1 to 5Y6/1)	new core section; shell frags; one unbroken shell; rock frags to 0.2 cm in irregular lenses
5.26 – 5.60	fine to medium sand (5Y6/1)	rock frags to 0.2 cm; lens of medium to coarse sand
5.60 – 6.91	fine to coarse sand (5GY6/1)	new core section; 0.8 cm shell hash lens at 5.88 m; rock frags to 8 cm

UNH - 6 (Lat. 42.93500, Long. 70.74500)		
Depth – m	Lithology	Description
0.00 – 0.10	very fine to fine sand (10YR5/5)	
0.10 – 1.04	very fine to fine sand (5Y6/2)	indistinct contact; rock frag at 16 cm; mica rich from 10 to 40 cm; biotite rich layers between 35 – 43 cm
1.04 – 1.54	fine sand (5Y4/2)	new core section; a few shell frags; a few rock frags to 5 cm at base of layer; biotite rich layer at 1.09 – 1.11 m
1.54 – 2.61	clay (mud) (5Y4/2)	distinct contact; a few shell frags; 1 articulated bivalve; 2 cm-scale sand lenses
2.61 – 4.14	clay (mud) (5Y4/2)	new core section; interior of core away from edges is N2 in color (in situ color?); several sand lenses
4.14 – 5.62	silty clay or clayey silt (5Y5/1)	new core section; a few shell frags; articulated shells in vertical sand streaks (life position and burrow fill?); silty sand lenses throughout
5.62 – 8.51	silty clay or clayey silt (5Y5/1)	two new core sections; both have a few shell frags; numerous cm-scale sand lenses or pods

UNH – 6A (Lat. 42.93500, Long. 70.74500)		
Depth - m	Lithology	Description
0.00 – 0.23	very fine sand (5Y6/2 to 10YR6/6)	well sorted; numerous shell frags in upper 19 cm; 1 large shell frag at 19 cm
0.23 – 1.02	very fine sand (5Y6/1)	well sorted; indistinct contact; biotite-rich laminae at 80 and 95 cm
1.02 – 2.00	very fine sand (5Y6/1 to 5Y7/1)	new core section; well sorted; biotite rich lenses throughout
2.00 – 2.34	very fine sand (5Y6/1)	indistinct contact; well sorted; muscovite rich between 260 – 275 cm; shell frags to 0.1 cm in lower 5 cm of layer
2.34 – 3.11	very fine sand (5Y4.5/1 to 5Y4/1)	distinct contact; well sorted;
3.11 – 8.32	silty clay or clayey silt (5Y5/1)	distinct contact; 3 new sections; sand lenses and pods throughout; shell at 3.24 m; shell at 5.23 m; shell frags at 6.64 m; shell at 7.47 m; shell at 7.69 m

UNH – 9 (Lat. 42.91333, Long. 70.63667)		
Depth - m	Lithology	Description
0.00 – 5.40	silty clay (mud) (5GY5/1)	3 core sections; cm-scale clayey silt lenses and pods; sand laminae in lower 50 cm; shell frags at 2.17 m; shells sparsely scattered throughout lower 15 cm; some rock frags at 40 cm
5.40 – 8.31	silty clay or clayey silt (mud) (5GY4/2)	2 new core sections; shell frags throughout; shell at 7.42 m; sand layer at 6.07 – 6.09 m

UNH – 10 (Lat. 42.94333, Long. 70.57000)		
Depth	Lithology	Description
0.00 – 1.18	silty clay (mud) (color varies 5R3/2, 5G4/2)	peat frag at 12 cm;
1.18 – 2.68	silty clay (mud) (5GY4/2)	new core section; numerous shell frags; silty or sandy laminae less than 1 cm throughout
2.68 – 4.19	silty clay (mud) (5GY4/2)	new core section; shell frags at 3.10 and 3.83 m; clay-rich laminae at 2.96 cm
4.19 – 5.69	silty clay (mud) (5GY4/2)	new core section; clay-rich laminae at 4.37, 4.42 and 5.18 cm
5.69 – 7.15	silty clay (mud)(5GY4/2)	shell frags at 6.12 and 6.42 m

UNH -12 (Lat. 42.98333, Long. 70.62333)		
Depth – m	Lithology	Description
0.00 – 0.33	fine to medium sand (5Y5/2)	fining downward to fine to very fine sand (N4); common shell frags to 13 cm; shell frags fine downward; occasional rock frags
0.33 – 1.93	clayey silt (5GY5/2)	distinct contact; new core section at 33 cm; numerous sand lenses (fine to medium) and pods containing shell frags
1.93 – 2.44	fine to medium sand (5Y4/2)	distinct contact; numerous rock frags to 10 cm; vibracore struck bedrock or boulder at bottom

UNH -13 (Lat. 42.98500, Long. 70.67000)		
Depth – m	Lithology	Description
0.00 – 0.83	fine sand (5GY4/2)	numerous shell frags
0.83 – 1.58	fine sand (5GY4/2)	new core section; numerous shell frags; cm-scale clay lenses and pods; rock frags to 3 cm
1.58 – 1.72	clayey silt or silty clay (5GY4/2)	distinct contact; 10-cm clay or silt pod at base

1.72 – 6.41	clayey silt or silty clay (5GY4/2)	four new core sections; numerous cm-scale fine to very fine sand lenses or pods (fining downward); shell frag at 3.99 and 5.34 m

UNH -14 (Lat. 42.92833, Long. 70.76000)		
Depth – m	Lithology	Description
0.00 – 0.22	fine sand (10YR6/4)	shell frags at 14 cm
0.22 – 0.51	fine sand (5Y7/2)	distinct contact; shell frags at base of layer; rock frag (6.4 cm) at 23 cm
0.51 – 0.62	fine sand (5Y7/2)	distinct contact; one biotite-rich lens
0.62 – 1.38	silt (10YR2/2)	distinct contact; grades downward to very fine to fine sand; 2 pods of very fine sand in upper half; organic rich; peat at 103 cm
1.38 – 2.36	very fine to fine sand (5Y5/2)	distinct contact; 2 biotite rich lenses in lower half of layer
2.36 – 3.50	silty clay or clayey silt (5GY4/2)	distinct contact; numerous sand lenses less than 1 cm; 5-cm concretion at 2.80
3.50 – 5.02	silty clay or clayey silt (5GY4/2)	new core section; few pods of silt and very fine sand, some contain shell frags
5.02 – 6.53	silty clay or clayey silt (5GY4/2)	new core section; vertical streak of very fine sand from 5.55 to 5.92 m
6.53 – 7.87	silty clay or clayey silt (5GY4/2)	shell frags at 6.60 m; rock frag at 6.60 m (1.5 cm); few vertical sand streaks

A-1 (Lat. 42.9950, Long. 70.6433)		
Depth - m	Lithology	Description
0.00 - 0.40	medium to coarse sand (5YR4/4)	moderate brown to moderate yellow brown color; coarse sand (0.5-1 mm) in top 10 cm; poorly sorted; occasional shell frags; 1 rk fragspebble (2.5 cm) at ~15 cm; coarsening upward; mainly quartz
0.40 - 0.50	medium to very coarse sand	darker color than layer above; poorly sorted; shell frags
0.50 - 0.80	medium sand	light olive gray color; small amount of coarse sand; moderately poorly to poorly sorted; mainly quartz
0.80 - 0.90	medium to coarse sand	grain sizes range from 0.25 to 1.00 mm; shell frags in upper part; mainly quartz
0.90 - 1.10	medium to coarse sand	grain sizes range from 0.25 to 1 mm; sand dollar frag at ~90 cm; mainly quartz

1.10 - 1.32	medium to coarse sand (5Y5/2 to 5Y3/2)	light olive gray to olive gray; moderately to poorly sorted in upper part; poorly sorted lower part; shell frags in upper part; sand dollar frag at ~1.30 m; mainly quartz
1.32 - 1.42	medium to coarse sand (5Y5/2) to (5Y3/2)	new core section; light olive gray to olive gray; shell frags at base; sand dollar frag: mainly quartz with dark mineral grains; small amount of coarse sand
1.42 - 1.92	medium sand (5Y3/2)	olive gray; shell frags common throughout; grains range from 0.25-0.5 mm; small amount of coarse sand (0.5 to1.0 mm)
1.92 - 2.12	medium to coarse sand	poorly sorted quartz sand; shell frags common; large clam shell at ~1.95 m
2.12 - 2.32	medium to coarse sand	olive gray; poorly sorted; shell frags common, shell frags; spiral shell frag; snad dollar frag
2.32 - 2.85	medium to coarse sand (5Y3/2)	light olive gray to grayish olive; poorly sorted; shell frags common, few pebbles
2.85 - 3.15	medium to very coarse sand (5Y5/2) to (5Y3/2)	new core section; light olive gray to olive gray; very poorly sorted, grains range from 0.25-1 mm; few pebbles up to 5 mm in size; occasional shell frags in lower half; clam shell frag;
3.15 - 3.50	fine to very coarse sand	slightly darker olive gray than layer above; occasional pebbles up to 9 mm; shell frags in lower part
3.50 - 3.70	fine sand (5Y 6/1)	light olive gray; some coarse grains 1- 2 mm, poorly sorted, mica flakes up to 4 mm, coarse sand layer near bottom; contains woody stems
3.70 - 4.00	fine sand (N6) to (5Y4/1)	medium light gray to olive gray ; moderate sorted towards top and moderate to well-sorted towards bottom, fine quartz sand ranging from 0.12-0.25 mm; mica content very high in places, some thin light and dark layers in basal part, mottled at base
4.00 - 4.39	fine to very fine sand (N5) to (5Y4/1)	medium gray; moderate sorted, thin dark layers between 1.30-1.35 m; coarse to very coarse mica rich olive gray layer at 1.35 m; mottled below the mica layer; lower 10 cm shows some mud content; mud ball at base

A-2 (Lat. 42.9867, Long. 70.6467)		
Depth - m	Lithology	Description
0.00 - 0.50	medium to coarse sand (10YR7/4) to (19YR4/2)	gray orange moderate yellow brown to dark yellowish brown towards base; poorly sorted medium to coarse quartz sand with occasional pebbles (4-8 mm); some fine and very coarse sand also present

0.50 - 1.03	fine to coarse sand (10YR4/2)	dark yellowish brown; poorly sorted quartz sand, some very coarse sand; occasional pebbles (2-5 mm), occasional mica flecks; few shell frags
1.03 - 1.88	medium to coarse sand (5Y5/2) to (5Y3/2)	new section of core; light olive gray to olive gray; poorly sorted; occasional pebbles (~ 2 to 7 mm), very small shell frags; mica flecks at `1.80 m; some fine sand
1.88 - 2.55	fine to coarse sand (5Y5/2) to (N3)	light olive gray to grayish olive in upper part and olive gray to dark olive (N3) in lower part; poorly sorted quartz sand; scattered mica flecks decreasing downward; occasional pebbles to 5 mm; occasional shell frags
2.55 - 3.10	fine to coarse sand (5Y4/1) to (5Y2/1)	new section of core; olive gray to dark gray in upper part, olive gray to olive black in lower part; medium to coarse grained towards top and fine to coarse grained towards base; poorly sorted ouartz sand; shell frags common; mica flecks up to 3mm common throughout
3.10 - 4.11	very fine to fine sand (5Y4/1)	olive gray to olive black; moderate to well sorted; organic matter with shell debris common, scattered mica flecks and biotite grains, fine grained towards base with some mud, one pebble at 0.85 m
4.11 - 5.61	very fine to fine sand, with mud (5Y6/1) to (5Y4/1)	new section of core; light olive gray to olive gray; moderately well sorted, dark patches in upper 40 cm , moderately stained, dark thin line may be mud or peat at ~5.2 m, shell frags common
5.61 - 7.13	very fine to fine sand, with mud (5Y4/1) to (5Y2/1)	new section of core; olive gray, olive gray to olive black in lower part; moderately well sorted; shell frags, mica flecks with few biotite flecks common throughout

A-3 (Lat. 42.9833, Long. 70.6600)		
Depth - m	Lithology	Description
0.00 - 0.30	fine sand (5YR6/1) to (5Y7/2)	light olive gray to yellowish gray at top; olive gray (5Y4/1) to medium dark gray (N4) in lower part; poorly sorted; common mica flecks; common shell frags
0.30 - 1.25	very fine to fine sand (5YR6/1) to (5Y4/1)	largely light olive gray to olive gray; moderately poorly sorted; common mica flecks; common shell frags
1.25 - 2.82	very fine sand (5YR6/1)	new section of core; light olive gray to olive gray; poorly sorted quartz sand; occasional pebbles (1.5-1.7 cm) from 1.25 to 1.55 m; common shell frags; rare mica flecks; wood or peat in basal part

2.82 - 4.34	very fine to fine sand (5YR4/1)	new section of core; olive gray to olive gray (5Y4); moderate to well sorted, common shell frags; mica flecks; poorly sorted, finer with higher mud content in lower part
4.34 - 5.81	very fine sand (5YR3/2) to (N4)	new section of core; olive gray to medium dark olive gray; mostly moderately well sorted; common shell frags, mica flecks; small bits of wood or peat; Becoming muddier with depth

A-4 (Lat. 43.0067, Long. 70.6717)		
Depth	Lithology	Description
0.00 – 0.14	fine to very coarse sand - gravelly (5YR6/1) to (5Y2/1)	light olive gray to olive black; poorly sorted; scattered pebbles (up to 1 cm) in upper half; pebbles and cobbles (4.3 cm) in lower half; large cobble at surface (8 cm)
0.14 – 0.68	medium to very coarse sand - gravelly (5Y4/1) to (5YR6/1)	olive gray to light olive gray; very-poorly sorted; pebbles and cobbles (6.5 cm); dropstones (up to 9.5 cm) at 30 - 40 cm, occasional shell frags
0.68 – 0.72	very fine sand and mud ((5Y4/1)	olive gray; mud lense
0.72 – 1.28	medium to very coarse sand - gravel (5Y4/1) to (5Y6/1)	olive gray to light olive gray; very poorly sorted; coarse to very coarse grains with fine sand matrix along; very common pebbles and cobbles to ~4 cm; shell frags; mud lense from ~1.10 to 1.25 cm
1.28 – 1.68	very coarse sand (5Y4/1) to (5Y6/1)	new core section; olive gray to olive black; very poorly sorted; pebbles and cobbles common (2-8 cm); shell frags common
1.68 – 1.93	coarse to very coarse sand - gravelly (5Y2/1) to (N4)	olive black to medium dark gray; very poorly sorted; scattered shell frags; common pebbles (up to 3.5 cm); some cobbles; mud lense with fine sand at base with sharp contact
1.93 – 2.78	very coarse sand - gravelly (5Y2/1) to (N4)	olive gray to medium dark gray; very poorly sorted; pebbles and cobbles (up to 8 cm) common; shell frags; mica content increasing; mud content increasing
2.78 – 2.81	mud (5Y4/1)	olive gray; mud lense at base of section

2.81 – 3.11	medium sand (5Y4/1)	new core section; olive gray, top 1cm olive black (5Y2/1); upper 1 cm has muddy sand; poorly sorted; 1 pebble (2 cm)
3.11 – 3.80	coarse sand (5Y4/1)	olive gray; scattered small pebbles
3.80 – 3.81	mud	mud lense
3.81 – 4.28	medium to coarse sand (5Y4/1)	olive gray; one wood fragment; mud lense at ~4.3 m (~4 cm thick) to end of section
4.28 – 4.31	mud	mud lense with sand pods inside
4.31 – 4.73	mud (5Y4/1) to (5Y2/1)	new section of core; olive gray to olive black; shell hash in upper part; occasional organic (dark) spots; gastropod test at~4.4 m
4.73 – 5.31	fine sand with mud (5Y4/1)	olive gray; common mica flecks, muddy lense in bottom part; sharp unconformity at base
5.31 – 5.74	coarse sand (N4) to (N3)	medium dark gray to dark gray; gradational contact with muddy lense (2.5 cm thick) at ~5.5 m depth; coarse sqnd below lense
5.74 – 5.81	very coarse sand - gravelly (N2)	dark gray; very coarse to gravelly sand; common pebbles

A-5 (Lat. 43.0033, Long. 70.6667)		
Depth	Lithology	Description
0.00 - 1.11	coarse to very coarse sand matrix with pebbles and cobbles - gravel (10YR)	upper 40 cm dark yellow brown, medium dark gray (N4) to dark gray in lower part; pebbles and cobbles common (up to 60 mm); gravels compose ~50% of sample
1.11 - 1.52	very coarse sand (N5)	new section of core; medium gray to medium dark gray; very coarse sand with pebbles (up to 50 mm)
1.52 - 1.61	granule - gravelly (N5)	medium gray to medium dark gray; pebbles (up to 40 mm) common; sharp contact with underlying mud
1.61 - 2.11	mud (5Y4/1)	olive gray to olive gray (5Y2/1); top 5 cm sandy mud
2.11 - 2.31	muddy sand or sandy mud (5Y4/1) to (5YR4/1)	new section of core; olive gray to brownish gray; organic spot, large shell frag

2.31 - 3.36	fine to coarse sand (N5)	medium gray to medium dark gray (N4); some coarse sand in lower part; coarsening downwrdt

A-6 (1) (Lat. 42.9317, Long. 70.7633)		
Depth	Lithology	Description
0.00 - 1.28	medium sand (5Y6/1)	light olive gray; well sorted; shell fragments towards at 20 to 40 cm; one pebble at 0.55 m depth; clean sands
1.28 - 2.27	medium sand (5Y6/1)	new section of core; light olive gray; well sorted; black organic rich lense at ~1.79 m depth

A-6 (2) (Lat. 42.9317, Long. 70.7633)		
Depth	Lithology	Description
0.00 - 0.22	fine to medium sand (5Y6/1)	light olive gray; well sorted; occasional shell frags; clean sands
0.22 - 0.45	fine to medium sand (5Y4/1)	olive gray; poorly sorted; occasional shell frags
0.45 - 0.80	fine to medium sand (5Y4/1)	olive gray; well sorted; occasional shell frags at 0.45 to 0.50 m
0.80 - 1.62	fine sand (5Y6/1)	light olive gray to olive gray (5Y 4/1); poorly sorted; mottled

A-6 (3) (Lat. 42.9317, Long. 70.7633)		
Depth	Lithology	Description
0.00 - 1.53	medium sand (10YR6/4)	light yellowish brown; well sorted; medium with some coarse sand; very homogeneous; organic debris in at ~1.5 m (speck)
1.53 - 3.07	medium sand (10YR6/4)	new core section; light yellowish brown; almost coarse sand; some bedding between ~2.6 to 2.9 m
3.07 - 3.89	medium sand (5Y6/1)	light olive gray; upper 25 cm medium sand; well sorted; coarse sand lense at ~3.4 m; pebbles (up to 40 mm) in lower part, sharp lower contact with mud
3.89 - 4.60	mud (5Y6/1)	light olive gray to olive gray (5Y 4/1); light brown (10YR6/4) near top
4.60 - 5.92	mud to (5Y4/1) (5Y6/1)	light olive gray to olive gray; common very fine sand pods; shell frag at 75 cm

A-7 (1) (Lat. 42.9483, Long. 70.7533)		
Depth	Lithology	Description
0.00 - 0.12	medium to coarse sand (5Y6/1)	light olive gray; upper 8cm coarse grained and poorly sorted, lower medium sand and moderately sorted

0.12 - 1.00	gravel (5Y4/1) to (10TR4/2)	olive gray in upper part, dark yellowish brown in middle and lower part; poorly sorted; fine to medium sand matrix in upper 40 cm gravel matrix below; pebbles and cobbles up to 70 mm
1.00 - 1.16	missing	
1.16 – 1.23	medium to coarse sand (10YR4/2)	sharp contact with layer below
1.232 - 1.32	mud and very fine sand (5Y6/1)	olive gray; poorly sorted; cobble (70 mm)

A-7 (2) (Lat. 42. 9483, Long. 70.7533)		
Depth	Lithology	Description
0.00 - 0.26	missing	
0.26 – 0.45	medium to coarse sand (5Y2/1)	olive back; poorly sorted;
0.45 – 0.49	coarse sand and granule (5Y6/1)	light olive gray; pocket of coarse sediments - coarse sand to granule with pebbles; large shell frag
0.49 – 1.12	coarse to very coarse, some granule and pebbles (5Y2/1) to (5Y6/1)	olive black at top to light olive gray to olive gray at base (5Y5/1); common pebbles (up to 35 mm); mud pod at ~0.75 m
1.12 - 1.53	gravel (5Y4/1)	new section of core; olive gray; poorly sorted; sharp lower contact; coarse sand and gravel; pebbles common; sand pod with pebble at ~1.35 m; sharp contact with underlying unit
1.53 - 1.80	medium to coarse sand matrix (5Y6/1) to (5Y4/1)	light olive gray to olive gray; poorly sorted; pebbles and cobbles common (up to 80 mm)
1.80 - 2.05	fine to medium sand (5Y4/1)	light olive gray;; poorly sorted; occasional pebbles (up to 50 mm)

A-8 (Lat. 42.9417, Long. 70.7517)		
Depth	Lithology	Description
0.00 - 0.55	coarse to very coarse sand (5Y6/1) to (5Y4/1)	light olive gray to olive gray; poorly sorted; shell frags in upper 12 cm and in basal part; common pebbles (mostly less than 1 cm, one 4 cm cobble; sharp contact with underlying muds

0.55 - 0.95	sandy mud (5Y6/1)	light olive gray; poorly sorted; sandy mud or muddy sand with granulates, pebbles, and cobbles (to 5 cm)
0.95 - 1.05	medium to coarse sand (5Y6/1)	light olive gray; poorly sorted; coarse sediments with pebbles and cobbles (up to 5 cm)
1.05 - 2.56	mud to fine sand (5Y6/1)	new core section; light olive gray; moderately sorted; pebbles (up to 50 mm) and cobbles (up to 12 mm) very common
2.56 - 4.04	mud to fine sand (5Y6/1) to (5Y4/1)	new section of core; light olive gray to olive gray; moderately sorted; pebbles (up to 50 mm) and cobbles (up to 80 mm) common