F I N A L   R E P O R T

FLORIDA SOUTHEAST COAST RECONNAISSANCE OFFSHORE SAND SEARCH (ROSS)

Prepared for
Florida Department of Environmental Protection
Bureau of Beaches and Coastal Systems
3900 Commonwealth Boulevard
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URS

CPE
COASTAL PLANNING & ENGINEERING, INC.

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In January of 2001 The Florida Department of Environmental Protection (FDEP) Office of Beaches and Coastal Systems (OBCS) contracted with URS Corporation to develop a database that can be addressed, searched and manipulated through an online query builder as well as ArcIMS Geographic Information System (GIS) routines that provide access over the Internet (Web) for compiling and disseminating available coastal and nearshore data. The project was titled the “Reconnaissance Level Regional Sand Search for the Florida Panhandle” or SandPan for short.

The project involved gathering together into one central enterprise database the relevant data from historical, present and future studies conducted in the Panhandle region of the Florida Gulf Coast. Granularmetric, geophysical, and spatial data were included, as well as an annotated bibliography of all references related to nearshore and coastal processes which are instrumental in locating and characterizing sand sources for use in the overall context of the Florida coastal management plan. This data is instrumental in minimizing the cost of initial data searches needed for each nourishment project undertaken by FDEP contractors.

In February of 2003, the OBCS, at that time renamed the Bureau of Beaches and Wetland Resources (BBWR), again contracted with URS to continue development of the database and online components of the Sandpan database project with Florida’s southwest Gulf Coast as the project area. One benefit of this new project was the teaming of URS with Coastal Planning and Engineering (CPE) of Boca Raton, Florida. With this addition of a more project-focused coastal engineering firm, the Sandpan reconnaissance framework could be more focused at the individual beach nourishment project level. With the union of these two fundamental ways of searching and viewing the available data, it was determined by BBWR that Sandpan needed to be expanded to include the new classes of data that can be of value in engineering beach nourishment operations. This new database and associated Web site is called the “Reconnaissance Offshore Sand Search” or ROSS (Figure 1-1).

With the completion of the Southwest Gulf Coast Sand Search, the newly named Bureau of Beaches and Coastal Systems (BBCS) approved the continuation of the ROSS project to encompass the entire Florida Atlantic coast. The work was organized and authorized into a series of “Phases”. There are four Phases that correspond to the three regional sand search areas for the Atlantic Coast and an east coast field study plan. Phase I is the southeast and includes Dade, Broward and Palm Beach Counties, Phase II is the central region made up of Martin, St. Lucie, Indian River and Brevard counties, Phase III is the northeast region which includes Volusia, Flagler, St. Johns, Duval and Nassau counties and Phase IV is the field work portion of the contract. The regional sand searches were set up on an overlapping time schedule, with the field work to be run concurrently. The overall work for each sand search Phase was designed along the same parameters to produce similar outcomes. This report represents the first of a three report series for the Florida Atlantic Coast.

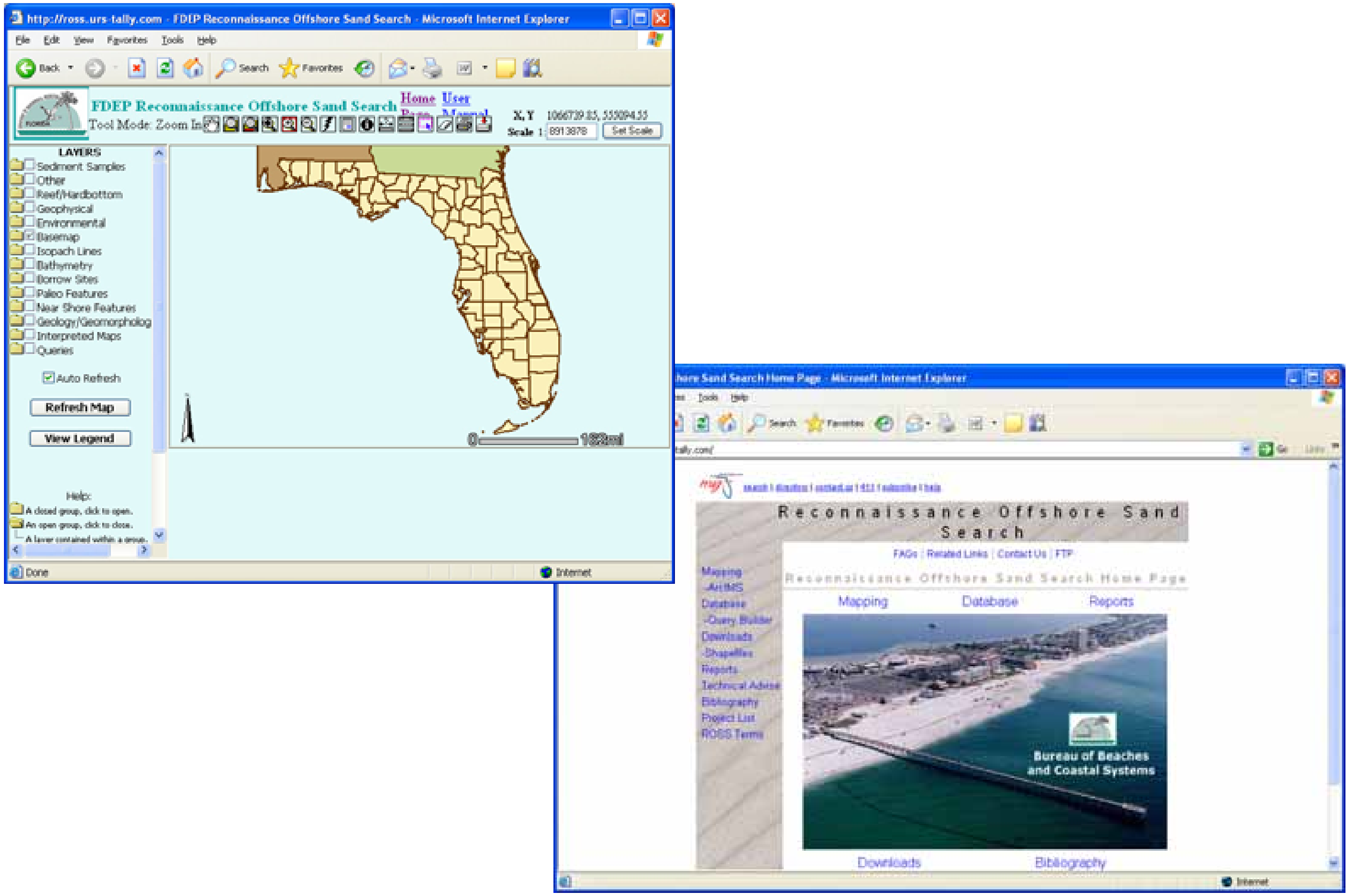


Figure 1-1. The Reconnaissance Offshore Regional Sand Search (ROSS) Home Page and the ROSS Internet Map Service (IMS) Page.

2.1 LEGACY DATA: THE SEARCH PROCESS

Using the same approach that was used during the original Sandpan and subsequent Southwest Florida Gulf Coast projects, URS and CPE conducted an exhaustive literature search for relevant applicable data. This included all previous reports, core logs, sediment sampling data, isopach maps and other geotechnical, geophysical, bathymetric or sedimentological data available that specifically identifies or studies the distribution of offshore sand resources of the Florida Southeast Atlantic coast. This information was obtained from the BBCS, the Florida Geological Survey, the University of Florida, the University of South Florida, the Florida State University, the U.S. Army Corp of Engineers (USACE), the U.S. Geological Survey (USGS), the Minerals Management Service (MMS), and previous studies conducted by various consultants contracting with the BBCS.

Additionally, the Florida Atlantic Coast Sand Search has presented opportunities that were not available in the Panhandle and Southwest Gulf Coast sand searches. The most important aspect is the effort that individual counties have extended with their own beach management programs. This has led to the development of expertise among these entities that has been used as an aid in determining the types and amounts of data in the region and as a contribution to the development of the sand resource and geological conceptual model.

As of this report date, seventy-eight datasets have been added to ROSS for the Southeast Phase I region. This brings the number of datasets to 126. These sources include theses, dissertations, and government and consultant reports. A total of 2,038 samples, 744 cores, 183 jet probes and approximately 750 miles of geophysical data have been added during this phase of the project. This has increased the database to approximately 10,325 sand samples, 3,405 cores, 183 jet probes and over 5,750 miles of geophysical data in the form of sub-bottom profile images. Also, following the lessons learned during the two previous sand search studies, old paper rolls, which were subject to deterioration, were retrieved and scanned to a digital format for preservation. Included in these are the original geophysical records from the 1990 Coast of Florida Study graciously lent to URS by Dr. Donald K. Stauble of the U.S. Army Corp of Engineers Coastal and Hydraulics Laboratory.

2.2 DATA SELECTION PROCESS FOR ROSS

With the need to focus on data which enhances the database without diminishing storage capacity, and therefore slowing down the search and retrieval process, URS and CPE developed a Data Acquisition and Entry Plan. This plan was used as the framework for deciding which data will be incorporated into ROSS and which data will be archived outside of the database for the Southeast project. An example of this selection process could include data from a previous study of a borrow site. If a series of cores were taken from a site that was subsequently developed, storing all the sample data from these cores may be unnecessary. Taking a representative sample of the cores which adequately describes the area would be appropriate. Storing only this data would save space, as well as limit the return hits from the database, consequently speeding up the query process. The original individual records will be kept in an electronic archive, but they will not be in the database or on the associated ftp site.

2.3 THE DATABASE

2.3.1 Data Types

Two basic types of data are stored in the database. The first is tabular data used to store information about sediment properties. The original Sandpan database schema consisted of thirteen data tables that include three associated look-up tables. These tables contained data related to the sediment sample itself. Included were fields for sediment grain size, texture, mineralogy, both Munsell and descriptive color, organic content, shell content, heavy mineral content, collection method, location information, core layer information, the analytical methods used in analysis, and both Wentworth and USC classification schemes. Project information like project name, managing agency, contact names, project date, driller and collection methods are also included. Several other geologic parameters like sphericity, angularity, and gradation have also been recorded.

The new ROSS database schema is an expansion of the Sandpan schema and currently includes thirty-three relational data tables. The database has been expanded and enhanced to allow for more comprehensive search and comparison functions than previously available. Several new tables were added so that searches could be structured that would return data on descriptive properties of sediment layers found within cores. Included are tables which store layer structure, lithology, and textural qualifiers. The capabilities for using descriptive information about sediment and sediment layer properties have been enhanced by adopting the U.S. Army Corps of Engineers standard core description procedures for characterizing sediments and core layers.

With the addition of the more project-focused analysis that includes storing data on core layers, the expanded database now contains these column headings:

AGENCY_ID
AGENCY_NAME
ANALYTICAL_METHOD_ID
ANALYTICAL_METHOD_NAME
ANALYTICAL_METHOD_DESCRIPTION
ANGULARITY_ID
ANGULARITY
PK_BIBSUMMARY
AUTHOR
AUTHOR_LAST_NAME
AUTHOR_INITIALS
TITLE
KEYWORDS
PAPER_YEAR
ABSTRACT
PUBLISHER
CALCULATION_METHOD_ID
CALCULATION_METHOD_NAME
COLOR_TONE_ID
COLOR_TONE
COLOR_ID
COLOR
CONTACT_ID
CONTACT_NAME
CONTACT_PHONE
CORE_LAYER_QUALIFIER_ID
CL_CORE_LAYER_ID
STX_SOIL_TEXTURE_ID
SD_SOIL_DESCRIPTOR_ID
ST_SOIL_TYPE_ID
L_LITHOLOGY_ID
S_SORTING_ID
QUALIFIER
CORE_LAYER_ID
CORE_CORE_ID
LS_LAYER_STRUCTURE_ID

CALCULATION_METHOD_DESCRIPTION
COLLECTION_METHOD_ID
COLLECTION_METHOD
COLLECTION_METHOD_DESCRIPTION
COLOR_DESCRIPTOR_ID
COLOR_DESCRIPTOR
COLOR_MATRIX_ID
CT_COLOR_TONE_ID
CD_DESCRIPTOR_ID
COL_COLOR_ID
COLOR_TONE_ID
CM_COLLECTION_METHOD_ID
PRJ_PROJECT_ID
DRL_DRILLER_ID
COLLECTION_DATE
CORE_TOP_ELEVATION
CORE_LENGTH
CORE_DIAMETER
X_COORD
Y_COORD
STATE_X
STATE_Y
STATE_ZONE
LONGITUDE
LATITUDE
LORAN_X
LORAN_Y
PENETRATION_DEPTH
RECOVERED_LENGTH
DIRECTION
OVERBURDEN
DEPTH_RX
GROUNDWATER_ELEVATION
PERCENT_RECOVERED
CORE_IDENTIFIER
DRILLER_ID
DRILLER_NAME
DRILL_TYPE
AGN_AGENCY_ID
USCS_USCS_CLASSIFICATION_ID
CMTX_COLOR_MATRIX_ID
BOTTOM_OF_LAYER_INTERVAL
TOP_OF_LAYER_INTERVAL
MUNSELL_HUE_WET
MUNSELL_VALUE_WET
MUNSELL_CHROMA_WET
CORE_LAYER_COMMENTS
CORE_LAYER_IDENTIFIER
CORE_ID
LAYER_STRUCTURE
LAYER_STRUCTURE
LITHOLOGY
HUE
VALUE
CHROMA
CMTX_COLOR_MATRIX_ID
PROJECT_ID
AGN_AGENCY_ID_POSSESSING
AGN_AGENCY_ID_MANAGING
CON_CONTACT_ID
PROJECT_NAME
PROJECT_DATE
PROJECT_LOCATION
HORIZONTAL_COORDINATE_SYSTEM
HORIZONTAL_DATUM
VERTICAL_DATUM
PROJECTION
SAMPLE_ID
PRJ_PROJECT_ID
LAB_LAB_ID
AM_ANALYTICAL_METHOD
SLU_SPHERICITY_ID
ALU_ANGULARITY_ID
CM_COLLECTION_METHOD_ID
USCS_USCS_CLASSIFICATION_ID
CMTX_COLOR_MATRIX_ID
MUNSELL_HUE_DRY
MUNSELL_VALUE_DRY

GUEST_NAME
PK_GUESTBOOK
GUEST_ORG
GUEST_EMAIL
GUEST_DATE_VISIT
GUEST_COMMENT
GUEST_EMAIL_UPDATE
LAB_ID
LAB_NAME
LAB_ADDRESS
LAYER_STRUCTURE_ID
SAMPLE_DATE
SAMPLE_COMMENTS
ANALYSIS_DATE
LAB_REMARKS
X_COORD
Y_COORD
STATE_X
STATE_Y
STATE_ZONE
LORAN_X
LORAN_Y
LONGITUDE
LATITUDE
RANGE_MONUMENT
RM_TRANSECT_LOCATION
TOP_OF_SAMPLE_INTERVAL
BOTTOM_OF_SAMPLE_INTERVAL
GRAB_ELEVATION
MEAN
MEDIAN
STD
SKEWNESS
KURTOSIS
MEAN_ORIGINAL
MEDIAN_ORIGINAL
STD_ORIGINAL
SKEWNESS_ORIGINAL
KURTOSIS_ORIGINAL
MUNSELL_CHROMA_DRY
MUNSELL_HUE_WET
MUNSELL_VALUE_WET
MUNSELL_HUE_WASHED
MUNSELL_VALUE_WASHED
MUNSELL_CHROMA_WASHED
MUNSELL_HUE_UNKNOWN
MUNSELL_VALUE_UNKNOWN
MUNSELL_CHROMA_UNKNOWN
SAMPLE_IDENTIFIER
CARBONATE_DISSOLVED
HEAVY_MINERALS_DISSOLVED
ORGANICS_REMOVED
SHELL_FRAGMENTS_REMOVED
PHI
USCS_COBBLE
USCS_COARSE_GRAVEL
USCS_FINE_GRAVEL
USCS_COARSE_SAND
USCS_MEDIUM_SAND
USCS_FINE_SAND
USCS_SILT
USCS_CLAY
WW_BOULDER
WW_COBBLE
WW_GRAVEL
WW_PEBBLE
WW_VERY_COARSE_SAND
WW_COARSE_SAND
WW_MEDIUM_SAND
WW_FINE_SAND
WW_VERY_FINE_SAND
WW_SILT
WW_CLAY
WW_COLLOID
SAMP_SAMPLE_ID
CL_CORELAYER_ID
VIRTUAL_SAMPLE
PK_SITEINFO

CALC_CALC_METHOD_ID_MEAN
CALC_CALC_METHOD_ID_MEDIAN
CALC_CALC_METHOD_ID_STD
CALC_CALC_METHOD_ID_SKEW
CALC_CALC_METHOD_ID_KURT
PCT_FINES
PCT_PAN_FRACTION
PCT_CARBONATE
PCT_SHELL_FRAGMENTS
PCT_HEAVY_MINERALS
PCT_ORGANICS \
SAMPLE_DATA_YN
CORE_DATA_YN
DISPLAY_GROUP
SOIL_DESCRIPTOR_ID
SOIL_DESCRIPTOR
SOIL_TEXTURE_ID
OIL_TEXTURE
SOIL_TYPE_ID
SITE_QUESTION
SITE_INFO
USERMAN
USERMAN_LOCATION
COLUMN_NAME
ALIAS
DESCRIPTION
DISPLAY_ORDER
DISPLAY_YN
PHI_RANGE
SOIL_TYPE
SORTING_ID
SORTING
STANDARD_DEVIATION
SPHERICITY_ID
SPHERICITY
USCS_CLASSIFICATION_ID
CLASSIFICATION_NAME
CLASSIFICATION_DESCRIPTION

The second type of data stored in the database is spatial data. Spatial features along with their accompanying attributes reside in the ORACLE relational database as Spatial Database Engine (SDE) layers. These spatial features are stored much like any other data types, as a string of characters or as a number. This enables the end user to optimize the abilities of this corporate database management system to manipulate large datasets and relate them to a geographic location on the earth.

Important issues that users need to understand are the restrictions and caveats involved with any of the data sets. To accomplish this goal, metadata (or data about the data) have been created for each data set and each spatial layer. These metadata conform to the Federal Geographic Data Committee (FGDC) requirements. The FGDC coordinates the development of the National Spatial Data Infrastructure (NSDI). The NSDI encompasses policies, standards, and procedures for organizations to cooperatively produce and share geographic data. The 17 federal agencies that make up the FGDC are developing the NSDI in cooperation with organizations from state, local and tribal governments, the academic community, and the private sector. For more information, see www.fgdc.gov.

2.3.2 Accessing the Database

Access to the ORACLE database is possible using one of three methods. The most direct is to click on the Query Builder link found on the ROSS homepage (Figure 2-1). This link will take you directly to the online Enhanced Query Builder page (Figure 2-2).

The Enhanced Query Builder is a custom-built application that allows the user to create Structured Query Language (SQL) statements. These SQL statements access real-time data from the ORACLE relational database. Unique WHERE clause statements may be constructed by the user that are added to an SQL statement one criteria at a time. These SQL statements are what tell the computer to retrieve all the data for which the set of conditions are true. These statements may be set to return data from all of the thirty-three tables residing in the ROSS database. Once the query is executed, the data matching the search criteria are returned on the Sand Sample Query Results page.

At the bottom of the Sand Sample Query Results page there are three other options provided to the user. These are accessed by clicking on one of the three buttons found at the bottom of this page. These will enable the user to either "Download Data", in a Tab delimited format, "Go Back" to the Enhanced Query Builder to perform another query, or spatially "View in ArcIMS" the data that was returned by the query. A detailed Users Guide for the Enhanced Query Builder can be found in Appendix A.

The second way to access the ROSS database is through the online Internet Map Service (IMS) which is accessible through the ROSS homepage ArcIMS link. The IMS site was initially developed using the ESRI "out of the box" ArcIMS software. Appendix B contains the user's guide for the ROSS Interactive Mapping site.

Figure 2-3 is a screen capture of the on-line mapping page within the ROSS Web site. On the left side of the image are folders, which contain the many different "layers" with which the user may interact. These layers are the spatial representations of the tabular data residing in the Oracle database. Most of these layers have been created especially for this project, with data generated by this project. However, some of these layers, including the Artificial Reefs, Sea Grass Beds, and others, were downloaded from other sites and incorporated in the ROSS on-line mapping. This illustrates the versatility of on-line mapping. Designers can combine data and information accessed over the Internet with local data for display, query, and analysis. For instance, environmental issues in potential renourishment areas are a concern. As an on-line search of state government spatial data repositories was conducted, many shapefiles dealing with environmental issues were found at the Florida Geographic Data Library (FGDL). These shapefiles were subsequently downloaded from the FGDL site, re-projected and added to the ROSS site.

The third way to access data residing in the ROSS database is to download the data directly to the users' own workstation. By using the Downloads link on the ROSS homepage the user is taken to a location where all the data residing in the database is available for quick and easy download (Figure 2-4).

This data is stored as SDE layers in both spatial and tabular format. Spatial data is in shapefile format, therefore allowing the user to add these to their own Geographic Information System (GIS), combining them with other shapefiles that the user may have developed or received from other sources. Shapefiles contain data from a relational database management system (RDBMS). The RDBMS may be pulled out of the shapefile as a stand-alone portable format to be used with the ArcView software on a local machine. Downloading the tabular data is accomplished through the Enhanced Query Builder. This data may be downloaded in a tab-delimited format compatible with several analytical and graphing software packages. The user may download all or part of the data.

By design, the ROSS site currently does not include tools used for composite statistical analysis, as the Bureau of Beaches and Coastal Systems (BBCS) does not desire to constrain the design professional to any particular suite of analytical products. The intent of this project web site is to allow the user to view the data spatially over the Web, to be able to query the data on several different levels and to download this data to their own workstation for advanced analysis.

2.4 DATA ENTRY

To accommodate the various entities that will supply data for inclusion into the ROSS database, two separate data entry tools will be made available. The first is a purpose-built Microsoft Access front end and the second is the commercially available software gINT.

The Microsoft Access front end is a customized data entry form that makes use of a user-friendly graphical user interface or GUI. From the main page of the front end the user will be able to access the appropriate page for data input (Figure 2-5).

A PROJECT INFORMATION page includes places to enter pertinent information on the project (Figure 2-6). This includes Project name, location, managing agency, and contacts.

Project level parameters are also defined. These parameters are entered in fields that define the projection information and horizontal and vertical datums. There is a Grade Scale field that allows the user to select which of three grain-size recording measures were used: phi, millimeter, or sieve size. For example, by choosing phi, as shown in Figure 2-6, the user then checks the appropriate boxes for the phi values used. This information will later determine, in the “Add a Sample” page data entry form, which fields will be available for data entry. This acts as a quality control feature to help eliminate incorrect data entries.

Once Project Information is recorded, the user may proceed to enter data. If cores were collected for the project, the user needs to click on the CORES button on the main page of the front end, pulling up the Core Entry page. Here, data relative to the collection location, elevation, penetration, recovery and other detailed information of the core is entered (Figure 2-7).

After data from the core is entered, information on the actual core layers may be added. This is a new feature of the *enhanced* ROSS database. In the old Sandpan design, only the core location information was stored. With the ROSS design the user may add data describing the core layers themselves. Click on the Add Layer Information For This Core button and the Core Layer Information page appears (Figure 2-8). On this page a user will be able to enter layer structure, composition, texture, lithology and sediment type. There is also a comments field for use in adding any other information the user finds pertinent.

The next step in entering data is to input individual sample information. This data entry tool recognizes two Sample types, Samples from a Core and Grab Samples. To enter information about a Core Sample, click the Add Sample To This Core button on the Core Entry form. To enter information about Grab Samples, click the Grab Samples button on the Main Page. The Sample Entry Page or Sample Information Interface (Figure 2-9) is used for adding data related to the individual sample. Included are fields for all data columns residing in the database relating to sediment samples. On the bottom portion of the page is a series of boxes representing phi sizes used in the sieving analysis. Some of these boxes are open and some are shaded.

The open boxes with values beside them are the same phi sizes set as the phi sizes on the Project Information page. When the user originally set up the project and chose the phi sizes, these were then transferred to this page, therefore only allowing data to be input into the correct fields. This eliminates the likelihood of the user placing data values in the wrong category.

The second data entry tool has been chosen because of its multi-faceted abilities. This is the commercially available gINT software. The data output formats for core logs and various other engineering and geological tools from the gINT software have been adopted by the Jacksonville District Army Corps of Engineers (USACE). The developers of gINT have taken the database table structure created for the ROSS database and incorporated it into commercially available software for contractors. Contractors will then be able to input data into this structure and deliver it to BBCS for almost seamless entry into the ROSS database.

2.5 OTHER FEATURES AND TOOLS

2.5.1 The Annotated Bibliography

Another feature of the ROSS Web site is the searchable Annotated Bibliography (Figure 2-10). There are currently over 900 references in the database covering topics on sediments found on the continental shelf, sedimentary processes, sea level curves and fluctuations, and the resulting changes in the shoreline over the last 12,000 years.

A large portion of these references are theses, dissertations and reports not readily accessible. The Annotated Bibliography page is designed to allow the user to search by the Author’s last name, title of the paper or key word(s). There may also be an accompanying summary or abstract of the paper provided, copyrights permitting.

2.5.2 Web Site (ross.urs-tally.com)

The ROSS Web site is the means to an end. By navigating through the Web site, all the ROSS data, on-line interactive mapping, query builders to access the database, data downloads, reports, shapefiles and the annotated bibliography are available at the touch of a button. There is a New Users page with frequently asked questions that may help in understanding the functions of this Web site. New questions and answers will be posted as they are received and answered.

The ROSS database and Internet Map Service were created to provide a wide variety of users online access to both spatial and tabular data. This site will enable BBCS staff, coastal engineers, the academic community and the general public to view and download all relevant data from historical, current and future studies conducted around the state of Florida.

The ROSS Web site was designed with three intentions. The first is to allow users to view data spatially over the web and be able to download this data in both tabular and shapefile format to a personal workstation for advanced analysis. The second is to give the coastal engineering community the ability to cut the cost of an initial design and permitting phase of a beach nourishment project. By compiling all the available data together in one easy-to-use location, more detailed evaluations of sand deposits needed for these projects may be conducted. Finally, the database has located and digitally-preserved a large portion of data that once resided in perishable formats.

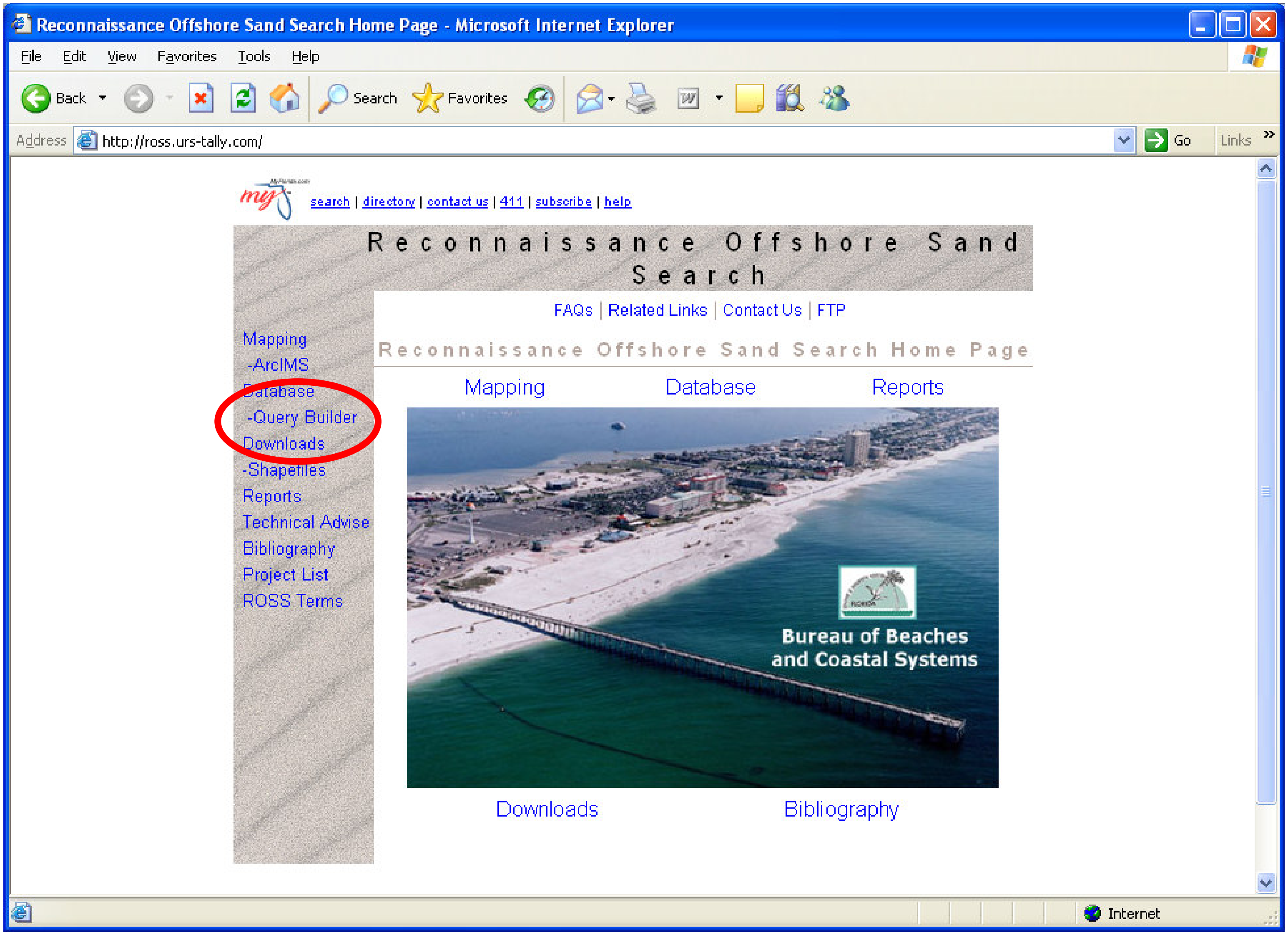


Figure 2-1. The ROSS home page showing the Query Builder link.

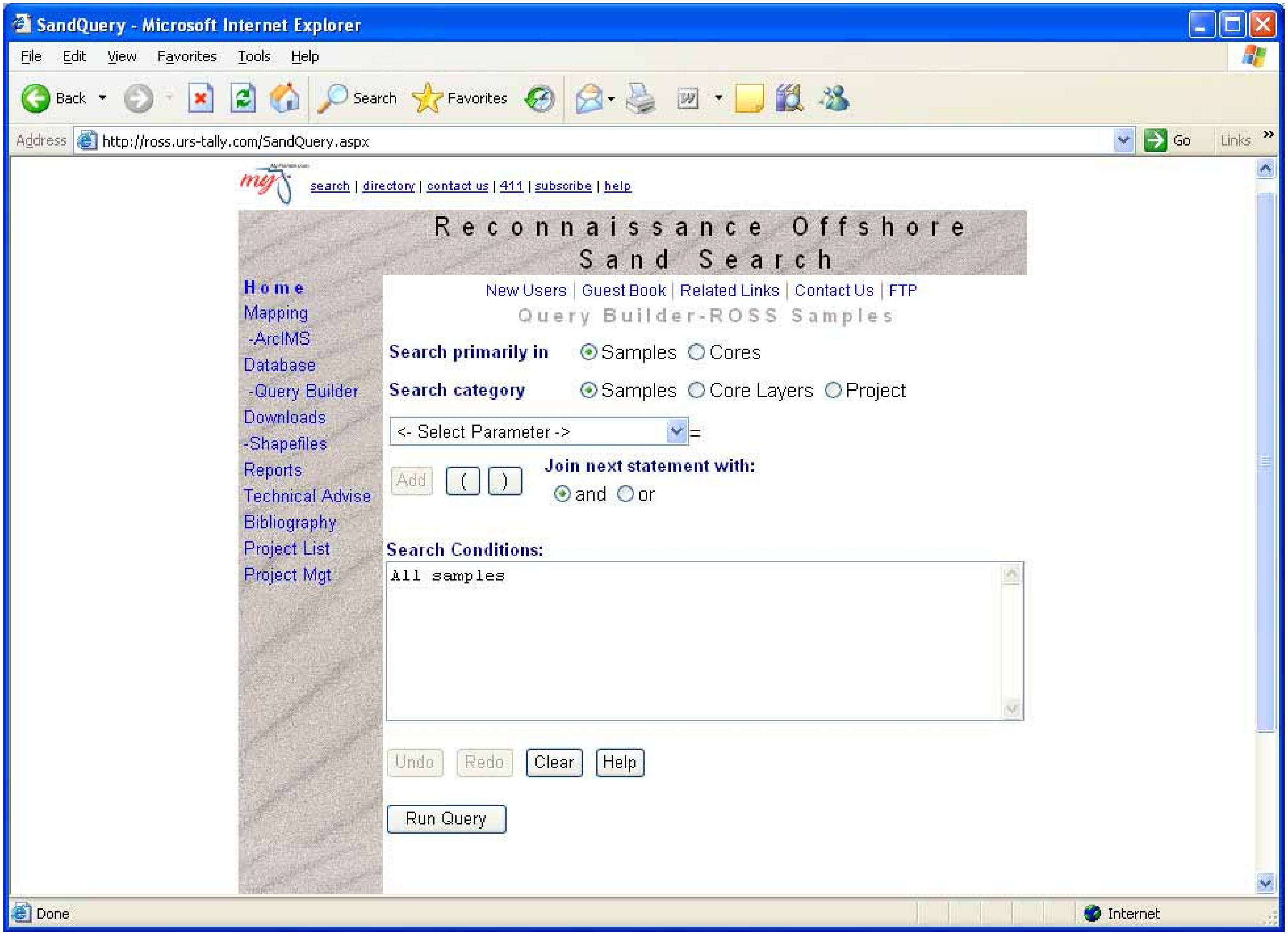


Figure 2-2. The Enhanced Query Builder page.

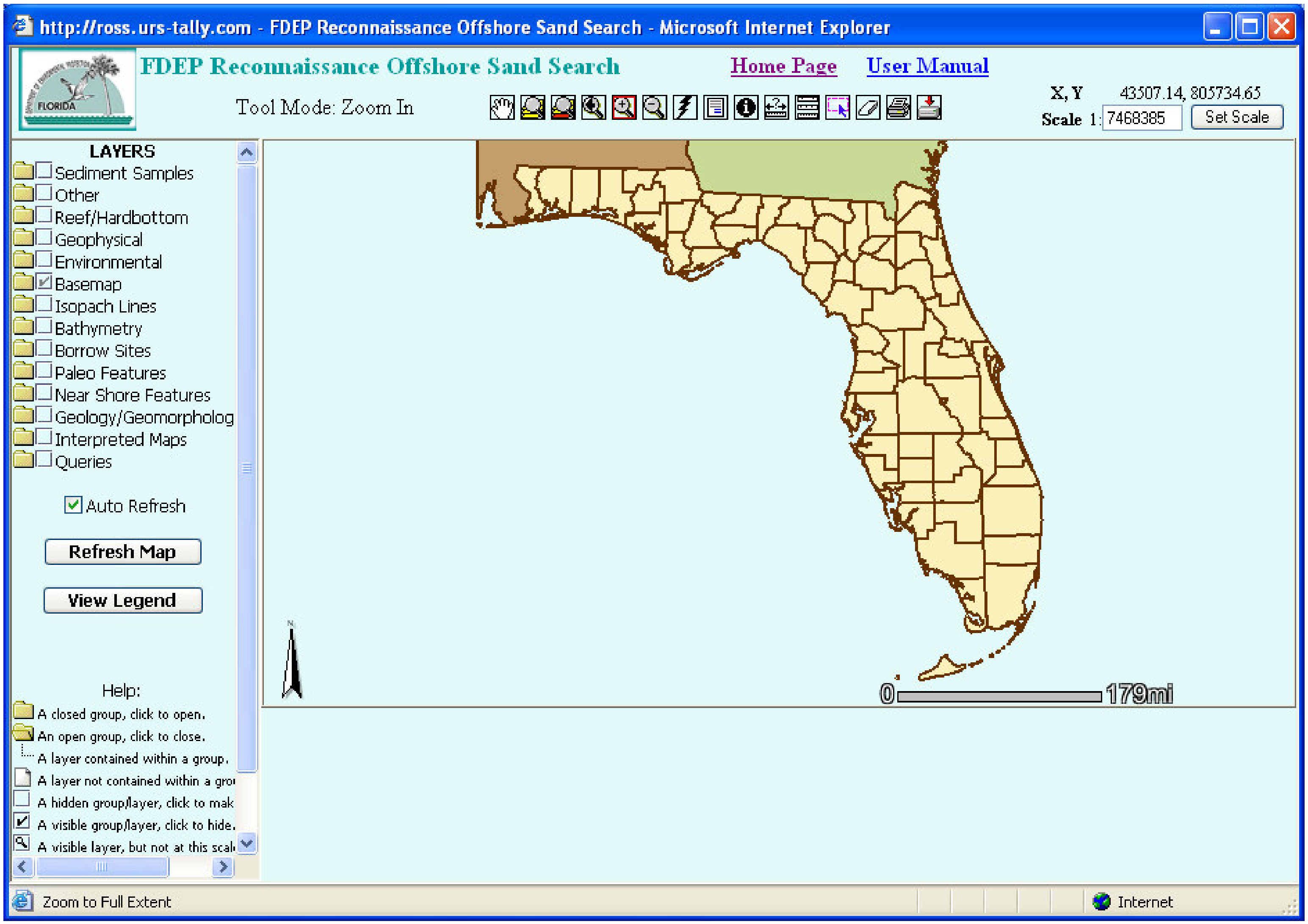


Figure 2-3. The ROSS on-line mapping page.

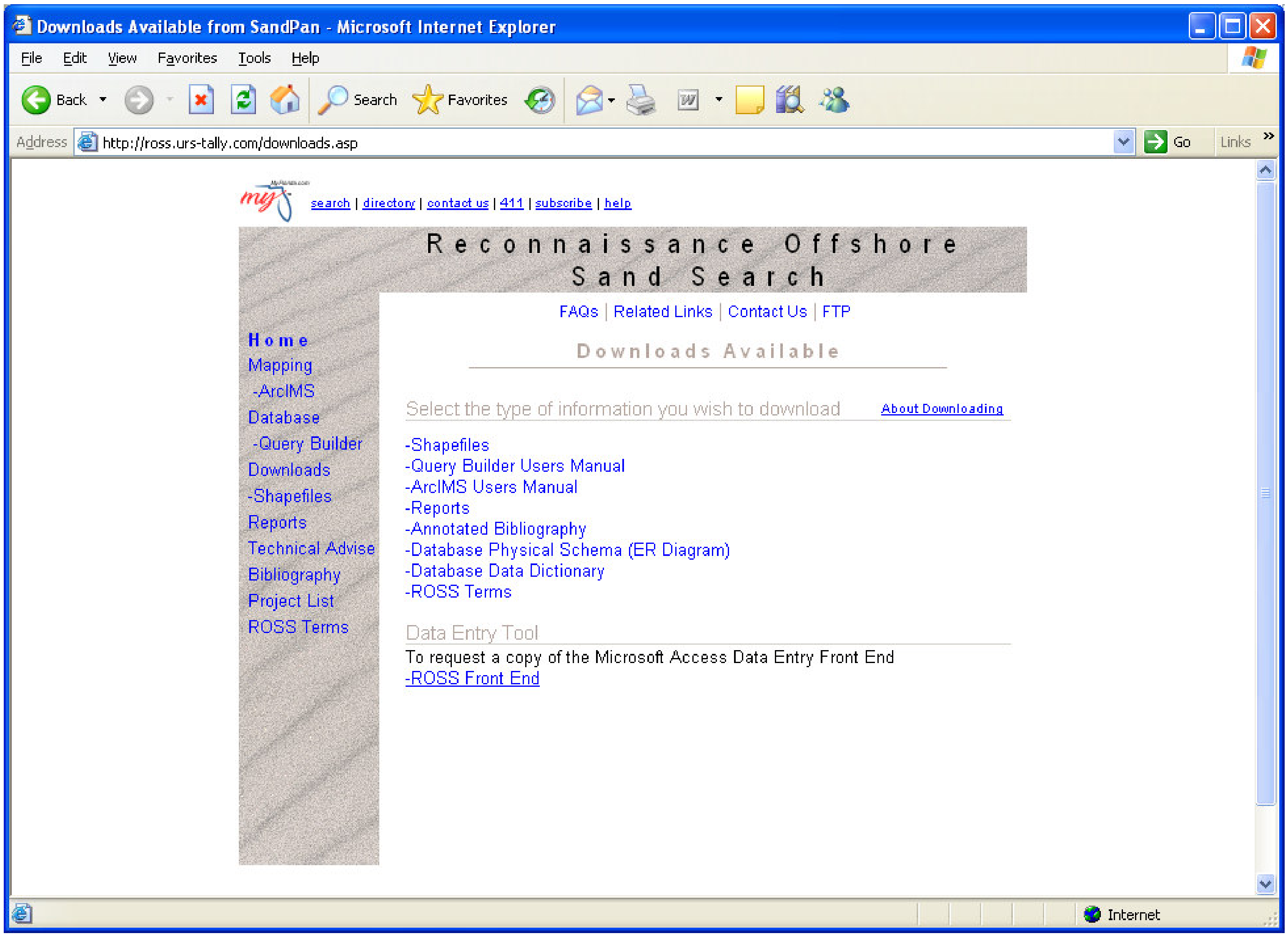


Figure 2-4. The ROSS Downloads page.

Figure 2-5. The ROSS Front End main page.

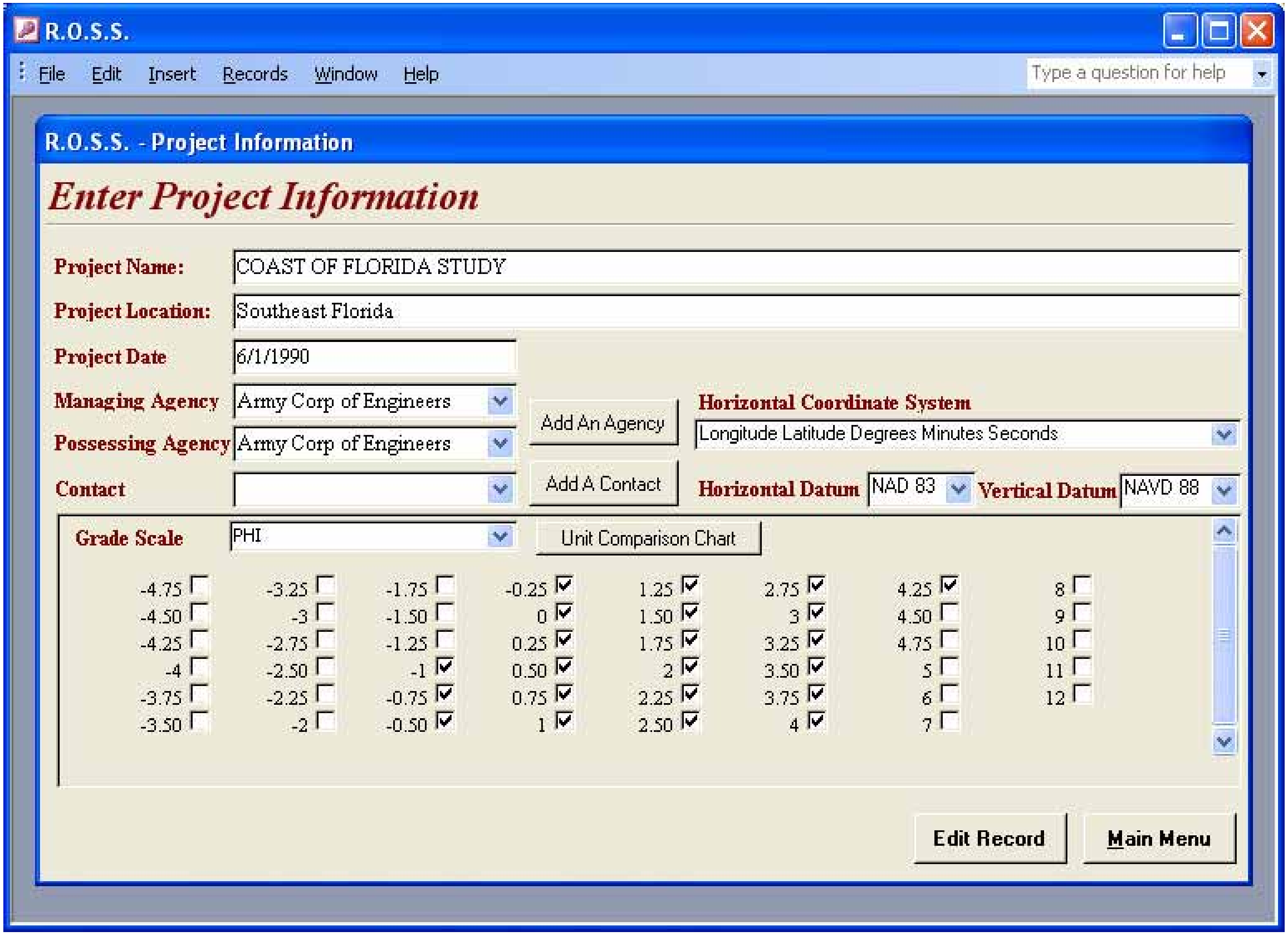


Figure 2-6. The ROSS Front End Project Information page.

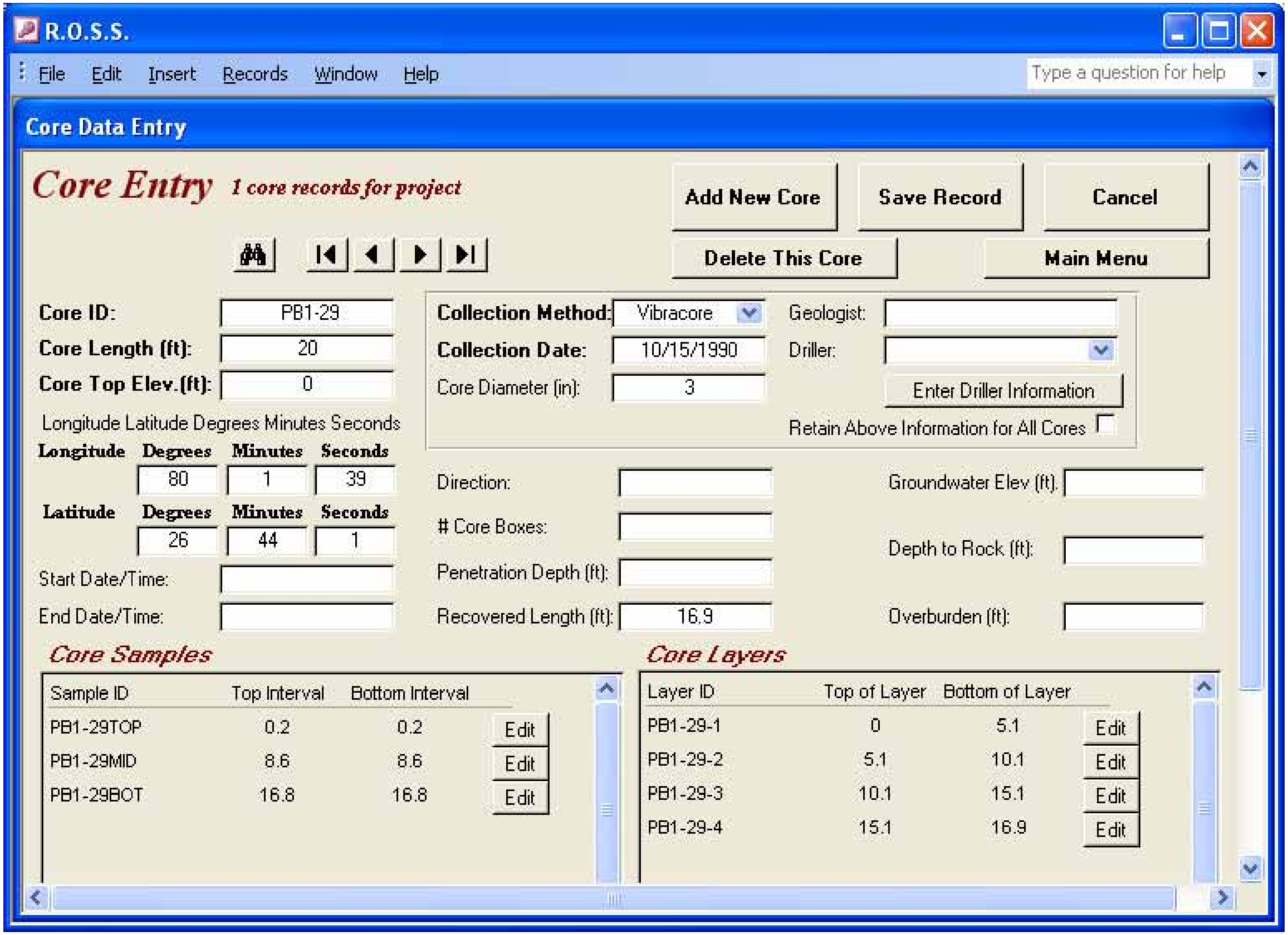


Figure 2-7. The ROSS core entry interface.

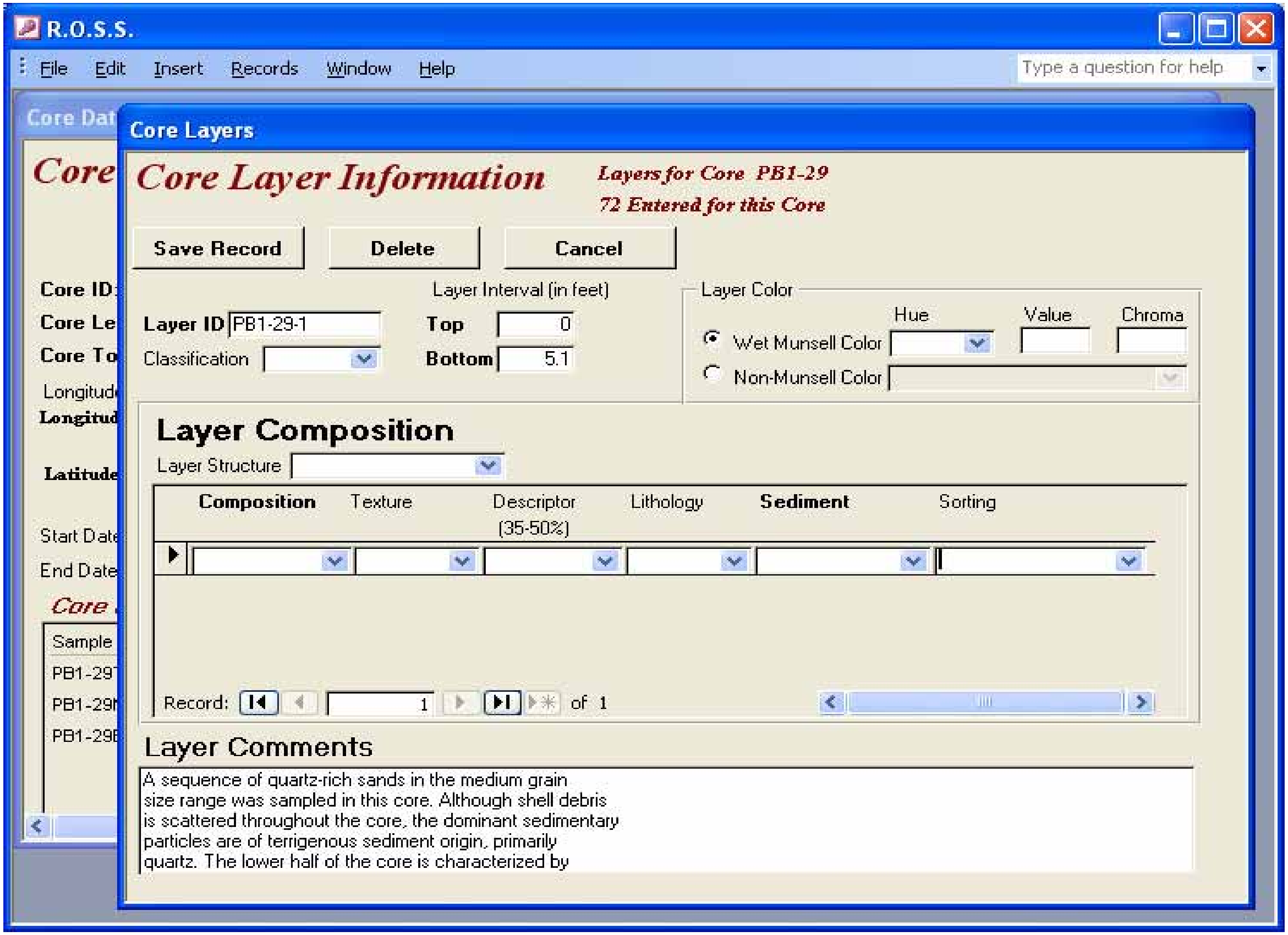


Figure 2-8. The ROSS core layer information interface.

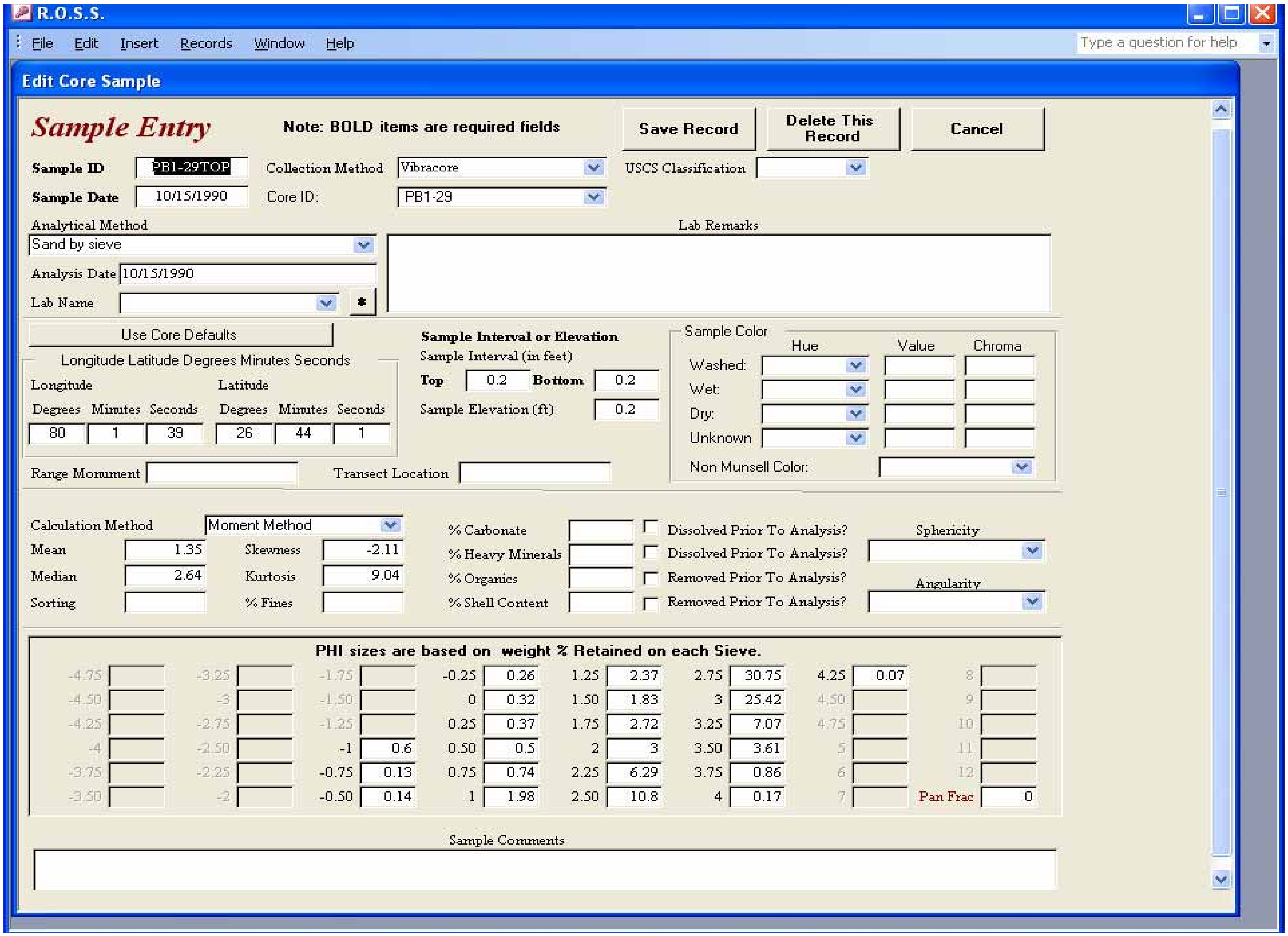


Figure 2-9. The ROSS sample information interface.

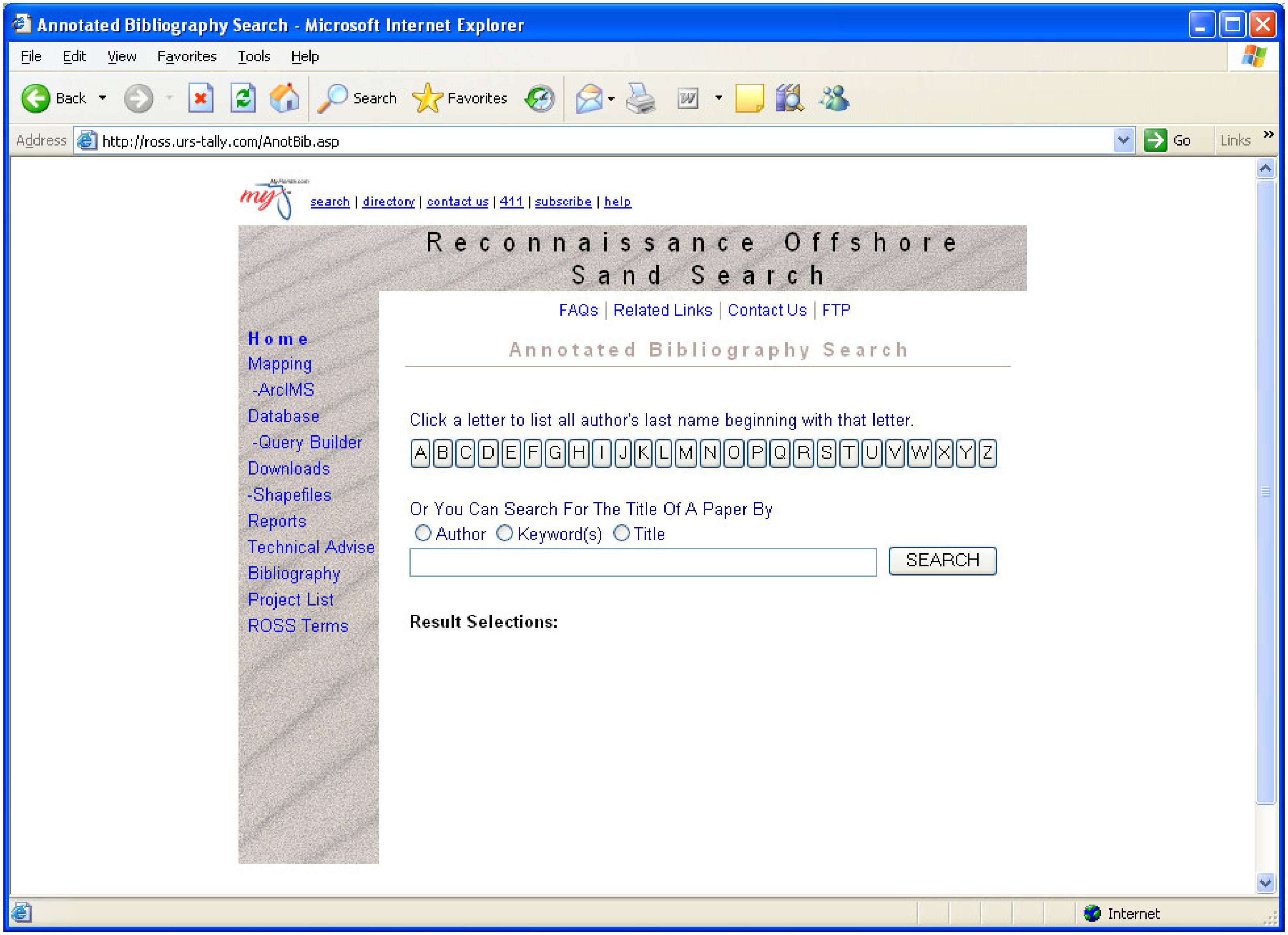


Figure 2-10. The Annotated Bibliography page.

3.1 PURPOSE, GOAL AND PROJECT DESIGN

The overall purpose of this reconnaissance-level project is to determine the sand resource potential on the continental shelf along the southeast coast of Florida. Results of the project will be incorporated into the ROSS (Reconnaissance Offshore Sand Search) database for the Bureau of Beaches and Coastal Systems (BBCS). Critical to this assessment of sand resource potential is the determination of areas related to prior investigations, areas actually exploited for sand as evidenced by borrow pits, areas that were investigated but not exploited, and areas that have not been investigated. In this way, a comprehensive overview of the status of sand resource investigations can be compiled and studied as guidance for future work. Development of a coastal geological framework is part of the scope of work because it facilitates comprehension of sediment distribution patterns, provides background for better understanding of the types of sedimentary bodies that occur in the study area, and indicates geological and geomorphological constraints on the evolution and maintenance of sedimentary basins on the shelf.

Key to this study was the availability of ALB (airborne laser bathymetry) data in the tri-county area of Palm Beach, Broward, and Miami-Dade counties in the form of LADS (Laser Airborne Depth Sounding) surveys. The LADS surveys provided a convenient basis for mapping seafloor topography, determining geomorphological units, and establishing a submarine land topology that could be related to sedimentary bodies. Analyses of sandy seafloor areas could thus be conducted in a GIS environment, based on iterative queries to ascertain specific types of sedimentary bodies by area. By assuming arbitrary depths of one, two, and three meters, it was possible to estimate potential sediment volumes by mapping the units and area within each county. Results of the study were to indicate potential sand resources by type of deposit and location on the continental shelf.

3.2 INTRODUCTION

The southeast coast of Florida has been widely studied in relation to biological resources associated with the barrier coral reef system (Florida Reef Tract), coastal hazards, storm impacts, and most extensively in terms of engineering structures (*e.g.* jetties, seawalls, groins, beach renourishment), offshore sand sources, and littoral sediment budgets. Aside from the general knowledge regarding the presence of coral reefs, hardgrounds (exposure of bedrock on the seafloor) and extensive sandy bottom areas, little information is known concerning the spatial distribution patterns, the continuity or connectivity, and volumes of specific lithologic units and potential sediment resources.

The absence of information pertaining to morpho-sedimentary features in this region stimulated our interest to attempt a study for ROSS that would comprehensively focus on the identification, description, and delineation of unconsolidated sedimentary deposits. This paper reports the results of detailed mapping (2001-2006) on the continental shelf based on interpretation of airborne laser bathymetry in the form of LADS (Laser Airborne Depth Sounding) in the tri-county area of southeast Florida.

The purpose of seafloor characterization is to determine the presence of potential sand resources for beach nourishment. Clark (1993) has summarized the condition of Florida beaches in terms of “indices of erosion”. Eroded areas often require remediation in the form of beach nourishment to maintain important habitats and to protect shoreline infrastructure. In this context, all major seafloor features had to be determined since the distribution patterns of sedimentary bodies is complicated by rock outcrops and the presence of coral reefs or other sensitive habitats. Because nearshore rock outcrops and offshore coral reefs frame sedimentary deposits, they are identified here as spatial placeholders but are not the subject of this report. The regional context of the southeastern coastal segment of the Florida peninsula and its morphological expression from the shore to the seaward margin of the offshore barrier reef system are briefly described here as a prologue to the description of sedimentary deposits in the study area.

From a physiographic point of view for the southeastern-most quadrant of North America, the southeast part of the Florida peninsula belongs to the Atlantic and Gulf Coastal Province (Walker and Coleman, 1987). The subaerial portion is referred to as the Coastal Plain, whereas the suboceanic portion encompasses part of the North American Continental Shelf. Most of the current subocean portion of the province was subaerially exposed as recently as 18,000 years ago, during the last glacial maximum (LGM), but the interface between the two divisions has been near its present elevation for the last 5,000 to 6,000 years, when initial phases of rapid Holocene sea-level rise decelerated. The eastern Florida Shelf is extremely narrow and merges southward with the Florida Reef Tract (FRT), which is most extensive and best developed offshore from the Florida Keys (Lighty, 1977; Lidz *et al.*, 1985, 1997; Lidz, 2006). The FRT is flanked on its seaward margin by the shelf break, a rather steep and abrupt slope that forms the western edge of the Straits of Florida. The active reef tract is composed of a series of complex reefal facies. During the LGM when sea level was lowered by about 120 m (Bloom, 1983; Shennan, 1993), many of the reef facies were exposed and dissolution of carbonate lithologies under subaerial conditions resulted in the formation of an irregular topography upon which many modern reefal facies became established. There is much debate as to just how many times and at what rates sea level rose and fell during the Quaternary, but it is clear from subaerial karst topography (now drowned) that the continental shelf was exposed to subaerial weathering at different intervals. Since the beginning of the most recent deglaciation, episodic rises in sea level sequentially drowned the subaerial landscape and approximated the position of the present shoreline about 3,000 years ago.

3.2.1 Study Area and Coastal Geological Framework

The study area is a 160-km long coastal strip along the southeast coast from the Martin County – Palm Beach County line to 13 km south of the Port of Miami navigational entrance (Figure 3-1). Widths of the study area reach a maximum of 10 km and 8.5 km offshore of northern Palm Beach County and southern Miami-Dade County, respectively. The LADS survey generally extends to water depths of about 55 m seaward of the FRT at the shelf break. Portions of the Florida east coast differ markedly in shoreline configuration and are influenced by the tectonic setting of the continental margin, regional bedrock geology, nearshore sediment supply, and relative sea-level fluctuations during the Quaternary (*e.g.* Duane and Meisburger, 1969; Brown, 1998). Mainland coastal segments characterize the southeastern Florida coast, stretching from approximately northern Palm Beach County to Key West. This stretch of coast is often mistaken for natural barrier islands, but many are former barrier spits that were detached by the cutting of inlets. The detached spits were destabilized and migrated landward, eventually becoming welded to the mainland (Finkl, 1993). Because the present coastal barriers are underlain by the

Anastasia Formation (Lovejoy, 1983), they cannot migrate as most sandy barrier islands do in response to changes in relative sea level (Finkl, 1993).

An important aspect of the southeast Florida coast is the way in which morphology is affected by underlying bedrock. The bedrock control here is related to exposures of the Anastasia Formation (formed during the Sangamon high sea-level stand, about 100,000 to 120,000 years ago) and to Pleistocene coral reefs. The pre-Holocene bedrock structure strongly influences morphological evolution of the shore (as described elsewhere by Evans *et al*., 1985; Riggs *et al*., 1995), because these structures not only provided a base on which sediment could accumulate but also created topographic lows between lithified paleo-shorelines (Finkl, 1993). Sands accumulate (to depths of 15 m) between the shore-parallel submerged paleo-shorelines to form inter-reefal sands (*e.g.* Duane and Meisburger, 1969; Finkl, Andrews and Benedet, 2003). Paleo-marine abrasion surfaces are variably covered by sand where the depth of cover is insufficient to mask bedrock structure (Finkl and Warner, 2004).

3.2.2 Prior Differentiation of Seafloor Morphologic Types

Recognition of bottom types along the southeast Florida coast goes back to early studies of the coral reefs (e.g. Agassiz, 1852), the extent of which was appreciated at that time. Subsequent studies of the coral reef system (e.g. Lighty, 1977; Lidz et al., 1991a,b) eventually resulted in the formalization of the so-called Florida Reef Tract (FRT) and its recognition as the third largest barrier reef system in the world. Although the descending staircase model of deeper reefs lying farther offshore was well known to the research community, little progress was made in the characterization of bottom types across the Johnson (upper) shoreface (i.e. less than 20 m depth), as discussed by Wright and Short (1984) and Short (1999), on the inner shelf until Duane and Meisburger (1969) clearly identified (using seismic survey techniques) the boundaries of reef tracts and inter-reefal sand flats. The same broad-scale features were also remotely sensed using the Thematic Mapper (Landsat 7) satellite platform (Finkl and DaPrato, 1993) and integrated into a GIS framework. Much previous work was brought together by Finkl, Benson and Yuhr (1997) in their development of a comprehensive geomorphological model that incorporated a wide range of bottom types that included coral reefs, hardgrounds (rock reefs), and sedimentary features. Overviews by Hoffmeister (1974) provided a general coastal geological framework whereas more recent studies by Lidz et al. (1991a,b) and Lidz (2006) on the southern portion of the FRT offered descriptions of reef and backreef environments. Coastal morphologies along the Broward coast were interpreted in terms of morphodynamic zones (Finkl and Khalil, 2000) that were based on the classification and distribution of bottom types. The present study extends and intensifies study of seafloor features (e.g. Finkl et al., 2005a,b) from the beachface to the shelf break.

3.3 CONCEPTUAL GEOLOGICAL MODEL

The coastal geological framework along the southeast coast of Florida is based on interpretation of seafloor topography as displayed in LADS imagery. The detailed LADS imagery provided a basis for mapping the seafloor surficial units in terms of landforms that were in turn interpreted in terms of geomorphological units. Each geomorphological unit represents an assemblage of individual landforms that together make up a cohesive mapping unit. The geomorphological mapping units make up a topology (study of the anatomical or geometric structure of topographic forms in relation to their geometry, connectivity, and regional history) for the continental shelf off the southeast coast of Florida. The basic rationale for the topological development is provided in Finkl and Warner (2004). Geomorphological maps of the seafloor in the study area were prepared by county. Figures 3-2A and 3-2B, (Palm Beach County), Figure 3-3, (Broward County), and Figure 3-4 (Miami-Dade County) show color-ramped LADS imagery in one panel and the interpreted geomorphological units in another panel. These figures are used as base maps to show a range of other types of features that impact potential sand resources areas viz. bottom restrictions and infrastructures such as sewage outfall corridors, artificial reefs, and wrecks. The conceptual geological model sets the stage for interpretation of potential sand resources by displaying spatial distributions of various bottom types. Most of the sedimentary features are framed by exposure of bedrock on the seafloor or barrier coral reefs.

3.3.1 Methodology

Acquired along the Florida southeast coast in 2001 (Broward County) and 2003 (Palm Beach and Miami-Dade counties), the LADS data comprise millions of points in a bathymetric database for a coastal segment that spans 160 km alongshore and up to 6 km offshore to cover nearly 600 km^2 of seabed. When this detailed coverage is printed at a nominal map scale of about 1:800, it provides convenient handling capabilities for sheets laid end to end that stretch 16 m in a long continuous map sheet. Continuous map sheets are an advantage because patterns become recognizable for the first time viz. extent and continuity of rock outcrop, reef tracts, sand flats, etc. Where there is rapid change in depth, well-defined dark shadows emphasize closely spaced isobaths. Shadows are especially useful for subtle features as they may otherwise go unnoticed. Shaded relief bathymetric maps with about a tenfold exaggeration of vertical scale produce discrete sounding patterns that can be interpreted in terms of topographic units. The LADS high-density bathymetric datasets provide good discrimination of geomorphological units and this cognitive recognition of various geomorphological units leads to the development of a seafloor topology. Validation of typologies is achieved by seatruthing, supported by side scan sonar (SSS) and sub-bottom survey (SBS) geophysical surveys, by geotechnical (vibracore) surveys, and by bottom samples retrieved by divers.

3.3.2 Characterization of Seafloor Mapping Units

Morphological units comprised by combinations of depth, shape, and arrangement of soundings, and shadow patterns were drawn in the paper charts (at a scale of 1:800) by freehand and then digitized on screen. This dual procedure was followed, as it is easier to identify and follow patterns on large charts than on the computer screen. Screen resolution was better than print resolution and patterns marked on the bathymetric charts could be modified on screen during digitizing phases in ArcView (ArcGIS). The final digital product is thus compiled in a spatial context that facilitates analysis and computation of selected parameters, such as areas for inter-reefal sand flats of coral reef crests, spur and groove topography, backreef debris fields, etc.

Prior to embarking on the actual mapping process based on image interpretation, each chart in the series was visually inspected and partially mapped in an effort to ascertain the range of features that could be identified in the study area (Finkl, Benedet and Andrews, 2004, 2005a,b). A list of features that occurred on each chart was compiled to a master list to make a comprehensive legend. More than thirty major landform features were found in the ALB survey area, which appear similar to those described by Finkl and Warner (2004). These features are organized in terms of a geomorphological classification scheme. There are many possibilities for interpretation of features and the orientation depends on the purpose, which in this case was the production of a geomorphological map. The classification scheme adopted here is summarized by Finkl and Warner (2004) and applies to the 64-km long Palm Beach County coastline.

Because the development of a morphological classification scheme can be an endless task, it is necessary to focus on the purpose of the survey and to rationalize procedures for consistently recognizing features that are identifiable at specific scales of observation. The nominal scale of observation for the southeast coast of Florida was determined for ease of handling of paper copy (at a scale of 1:800 there were 9 sheets for Miami-Dade County, 6 sheets for Broward County, and 11 sheets for Palm Beach County). More detail can be observed on computer monitors to the point where the image disintegrates by pixilation. For large-scale mapping purposes, however, the printed map sheets provided sufficient detail for feature recognition but still showed general spatial trends. It was thus possible to identify a range of features while not becoming overwhelmed with too much detail. The other point to consider is the balance between what can be seen, what can be mapped, and what is useful or practical to delineate. The natural spatial heterogeneity of morphological units on the seafloor determines to a large extent what should be mapped. In a sense, then, most natural units are predetermined and they reflect the units that have been mapped and described by other researchers working elsewhere.

Some of the morphological units in the study area originated as terrestrial features (*e.g.* karst nu, bare terrestrial karst – exposed limestone with karst features) that were subsequently drowned by sea-level rise viz. to become karst noye (drowned, subaqueous karst). Ample evidence throughout the study area suggests karstic origin in the form of solution pits, dolines, and sink holes. Most other features are, however, marine in origin (e.g. the Florida Reef Tract) except for the coastal channels. The main morphological features occurring in the study area are summarized by Finkl and Warner (2004) in terms of sandy bottom types, rock hardgrounds (exposed bedrock, usually as karst noye), coral reefs and related features (see Tables 3-1A,B; 3-2A,B; 3-3A,B). For the Palm Beach County sector of the overall study area, 269 km^2 were mapped with continental slope, ridge fields, and sand flats respectively, making up 15.6%, 27.4% and 30.6% of the total area (Tables 3-1A and 3-1B). Diabathic channel fields comprising 19.2 km^2 accounted for 7.1% of the survey area. Other units of lesser extent individually accounted for less than 2% of the survey area except for deepwater reefs, forereef rubble slopes, backreef overwash deposits, and sand waves, each of which accounted for about 2%.

3.3.3 Rock and Unconsolidated Sediments

Seafloor mapping units are described by county, from north to south. The study area shows an amazingly diverse range of bedrock morphological features that includes drowned karst features (e.g. beach ridges, sink holes) and submerged paleo inlets in Palm Beach and Broward counties to extensive unconsolidated sedimentary features such as tidal sand flats and sand ridges (referred to as linear shoals by Duane et al., 1972) in Miami-Dade County. About thirty distinct types of submarine geomorphological units were identified and mapped offshore of the tri-county area. Each county is thus generally characterized by distinct submarine physiographic units, not the least of which are sedimentary bodies that support exploitation of sand resources for beach nourishment.

3.4 PALM BEACH COUNTY SEAFLOOR FEATURES AND SAND RESOURCES

Seafloor features in Palm Beach County are shown diagrammatically in Figures 3-2A and 3-2B, where 1 cm on the map equals approximately 830 m on the ground. These maps contain two panels, the lower showing the color-ramped LADS bathymetry and the upper showing the interpreted features. The purpose of the two-paneled maps is to show how the LADS bathymetry was interpreted into geomorphological units. The maps also contain ancillary information that is referred to throughout this report. More detailed larger-scale maps (Figures 3-5A, 3-5B and 3-5C) are subdivisions of these smaller scaled maps. The maps can be used in conjunction to show general along- and cross-shore trends and details of landform assemblages.

The continental shelf here ranges up to 10 km in width in the northern part of the county but narrows to about 2 km in the south. Hardbottom features take up approximately 47% of the mapped area (284 km^2), with the Ridge Field mapping unit of outcropping limestone bedrock, occupies nearly half of the total hardbottom area (48.7%) (Table 3-1A). Other bedrock features include Rock Ridges (3.8%), Structural Troughs (3.7%), Ridge and Valley (3.2%), and Arcuate structures (1.2%) in hardbottom areas. Although not defined here (see Finkl and Warner, 2004; Finkl *et al.*, 2005, for descriptions), suffice it to say that these bedrock features are defined on the basis of the shape and arrangement of topographic expression on the seafloor and represent non-sediment areas. Coral reefs (Figure 3-5B, 3-5C), although environmentally important, take up a small part of the total survey area (1.6% comprised by the FRT) or approximately 3% of hardbottom features in the area.

3.4.1 Bedrock Features Exposed on the Seafloor

Part of the continental shelf is covered by sediments, but significant portions lack sedimentary cover and limestone bedrock is exposed on the seafloor. From central Broward County northward along the nearshore zone, bedrock outcrops are facies of the Anastasia Formation (a 100,000 – 120,000 year-old coquinoid bank deposit that formed when sea level was higher than present) (Lovejoy, 1983). The limestone outcrops are formed by a wide range of structural features that have variable topographic expression. Resistant layers in the limestone deposits formed positive relief under subaerial weathering when sea level was lower. The drowned karst topography is interpreted in general terms, as the purpose of this report is to focus on sand resources. Hard bottom features are reported because they constrain sediment distribution patterns and broadly define depositional areas containing potential sand resources.

Rock Ridge

This mapping unit occurs in the northern part of the county about 3 km offshore from monuments R005 to R039. The unit occupies 5.1 km^2 (3.8% of hardbottoms and 1.8% of the total area mapped) (Table 3-1A) and is bounded by the Structural Trough mapping unit on its seaward margin and by the Offshore Sand Flat mapping units landward. The distinctive topography of this drowned karst topography defines the unit in terms of numerous linear shore-parallel ridges with transverse gaps.

Ridge and Valley Topography

A complicated series of low-relief ridges and valleys occurs south of the Ridge Field mapping unit. The small area occupies about 4.3 km^2 and is bounded in a landward direction by the Offshore Sand Flat mapping unit and seaward by the Ridge Field mapping unit. The unit contains broad valleys with a sand cover. The ridges are karstified limestone facies of the Anastasia Formation.

Ridge Field

This large mapping unit makes up the outer portion of the continental shelf. Covering an area of about 65.8 km^2, the ridge fields extend from R120 in Martin County to R095 in Palm Beach County. The unit comprises about 48.7% of the hardbottom area and about 23% of the total area mapped (Table 3-1A). The ridge field is buried by sand designated as the Sedimentary Cover Over Ridge Fields mapping unit on the Martin County – Palm Beach County border. To the south, the ridge fields pinch out at the northern-most extension of coral reefs about 1.4 km offshore from R095. These ridge fields are interpreted as drowned beach ridge systems where the ridges were lithified during subaerial exposure. The paleo-swales contain unconsolidated sediments.

Continental Slope

The continental slope mapping unit occurs seaward of the FRT at about 50 m depth and makes up about 30% of the mapped area (Table 3-1A). It occurs throughout the study area and often contains older coral reef systems (identified as Deepwater Reefs) at the base of the FRT, for example, as in the vicinity of R110 intermittently southward.

Nearshore Rock

This mapping unit includes exposed facies of the Anastasia Formation that generally occur landward of the surf zone. Small patches of rock occur sporadically alongshore and may be exposed or covered by moving sand, depending on the season (winter vs. summer). Some outcrops occur within the Nearshore Sand Flat mapping unit, for example in the range R203 to R212. Small cliffs (< 2 m) occur sporadically alongshore but are especially prominent north of the Jupiter Inlet. Though minor in areal extent comprising only 0.1% of total hardbottom occurrences (Table 3-1A), nearshore rock has important morphodynamic implications for shoreline stability and planform configuration.

Structural Trough

Subaerial weathering of coquinoid bank deposits of the Anastasia Formation formed large troughs in otherwise more resistant layers. This mapping unit, lying 4.5 km offshore from monuments R005 to R040, occupies an area of about 4.9 km^2 or about 3.7% of the hardbottom area (Table 3-1A). The unit lies shoreward of the drowned beach ridges and is transitional to the Rock Ridge mapping unit, from which it differs by having wider valleys between ridges.

Coral Reefs and Related Features

The FRT, the main coral reef system on the continental shelf, is comprised of a series of shore-parallel barrier reefs that are separated from one another longitudinally by sand flats that are best developed in Broward County. In Palm Beach County, there is a single, wide (up to 1.5 km in width at R165) sand flat that lies between the shore and barrier reef. The barrier is disjointed with sections of the reef separated from one another by reef gaps, which often form conduits for sand transport from the sand flats offshore beyond the barrier reef (Finkl, 2004). Rubble accumulates on the shoreward side of the barrier reefs due to overwash during storms. The Backreef Apron mapping unit identifies these rubble accumulations that spill into the Nearshore Sand Flat mapping unit. The seaward margins of the barrier reefs are characterized by a series of benches that step down into deeper water. The benches are comprised by undifferentiated Marine Terrace mapping units. Patch reefs occur sporadically shoreward of the barrier reefs.

Coral Reef (Florida Reef Tract)

Barrier coral reefs comprising the FRT tend to occur about 1 to 1.5 km offshore and occupy about 4.2 km^2 or about 3% of the total hardbottom area (Table 3-1A). The barrier reefs in Palm Beach County are the areally constricted northern extension of the FRT, which is thoroughly described in the Florida Keys (*e.g*. Lidz, Robbin and Shinn, 1985; Lidz, Hine and Shinn, 1991; Lidz, Hine, Shinn and Kindinger, 1991; Lidz, Shinn, Hine and Locker, 1997; Lidz, 2006). Hoffmeister (1974) and Lighty (1977) include descriptions of the more northerly portions of the FRT, as it occurs in Palm Beach County. Gaps between the barrier reefs are mentioned by these authors and described as "leaky sediment valves" by Finkl (2004). The barrier reefs act as sills that retain sediments in the trough between the coral reefs and the shore. Reef gaps and reef gap ramps contain sand spills through the FRT from offshore sand flats. Submarine deltas often occur seaward of the gap in the FRT and obscure deepwater marine terraces in the vicinity offshore from R173 and R181.

Marine Terraces

The Marine Terrace mapping unit occurs along the seaward margin of the barrier coral reefs, but in deeper water beginning at 35 m and stepping downwards as marine terraces on the continental rise. The terraces appear to be discontinuous as a whole, but they are well developed offshore from monuments R110 to R135, R140 to R188, and from R195 to Broward County. They make up about 5 km^2 or nearly 4% of the hardbottom area (Table 3-1A).

Nearshore Reef

The Nearshore Reef mapping unit is caused by exposure of the Anastasia Formation alongshore. Normally masked by a thin sedimentary cover that is transitory in nature, moving with the seasons and energy conditions (e.g. quiescent phases punctuated by storms), these rock reefs (hardbottom) are prominently displayed between monuments R086 to R095. The units make up about 1 km^2 or about 0.8% of the hardbottom area (Table 3-1A). Smaller rock reefs occur sporadically throughout the nearshore zone, but they are not mapped at the scale of this reconnaissance survey.

Patch Reef

In terms of reef geomorphology (shape, form, distribution of reef building corals), a patch reef is defined as an isolated coral growth forming a small platform in a lagoon, barrier reef, or atoll. Patch reefs may occur as isolated features or in clusters of variable density. They tend to occur inshore of the main reef line. For instance, most of the Florida Keys' main reef is 10 km offshore. But the patch reefs are small, isolated, and scattered anywhere between dry land and the deeper water. Most patch reefs in Palm Beach County occur landward of the barrier reefs as isolated features that collectively account for 0.2% of the hardground area (0.281 km^2) or 0.1% of the total mapping area (Table 3-1A). These features, though areally restricted, require environmental buffers that restrict exploitation of sand resources in their vicinity.

Sedimentary Features

Sediments make up the rest of the survey area in Palm Beach County. Sandy sediments occur alongshore but are interrupted on the beachface and shoreface by sporadic outcrops of facies of the Anastasia Formation. In the northern part of the county where the continental shelf widens, sedimentary deposits cover partly submerged beach ridges and collect in various types of basins or troughs within karstified hardbottom areas (see types described above). Sedimentary areas, which are more extensive in the northern part of the county, become restricted by a narrow shelf and the presence of coral reefs in the south.

Diabathic Channels

This mapping unit, a prominent feature of nearshore sand flats, extends nearly continuously for the length of the county. Diabathic channels make up about 18 km^2 (6.6% of the mapped area) and comprise about 15% of the sand resources in the county (Table 3-1B). They were first recognized as displayed in the LADS imagery. In the Palm Beach County seabed classification system (Finkl *et al*., 2005a,b), these cross-shore channels were mapped as ‘Diabathic Channel Fields’ alongshore for a continuous distance of approximately 70 km. The channel fields average about 300 m in width but show variability ranging from 100 m to 600 m. Based on measurements of the LADS imagery, the diabathic channels occur in water depths of 7.5 to 10.5 m and have an azimuth orientation ranging from 70 to 90 degrees. Channel lengths average about 300 m but show variation on the order of ±60 m. Alongshore wavelengths range from 75 m in the south to 150 m in the north, ±15 m in both areas, and show an average local relief of 1 m ±0.3 m. The landward boundary of the diabathic channel field lies about 400 m offshore from the present shoreline. The channels are associated with inter-reefal sand flats (Nearshore Sand Flat mapping unit), sedimentary accumulations in backreef troughs where sandy materials accumulate up to 10 m in thickness. The contiguous nature of the diabathic channels suggests that they are unrelated to the barrier coral reefs and reef gaps farther offshore in deeper water.

Ebb-Tidal Deltas

Small deltas are associated with Jupiter Inlet, Boynton (South Palm Beach) Inlet, and Boca Raton Inlet. The Palm Beach Inlet is dredged as a deep draft navigation channel. The Boynton ebb-tidal delta is shown on the map because it is morphologically distinctive. It occupies an area of about 0.1 km^2 and accounts for 0.1% of the sand resource area.

Nearshore Sand Flat

Sand flats occurring in the nearshore zone occupy about 70 km^2 (about 25% of the total area mapped) and account for about 57% of the sand resource area (Table 3-1B). Sedimentary flats, a characteristic feature of the seafloor, occur shoreward of barrier reefs in the FRT. Many sedimentological studies on the southeastern Florida shelf continental shelf describe sedimentary infills in the nearshore zone as being composed mainly of sand-sized clastics and carbonates (Duane and Meisburger, 1969). The sandy deposits in the study area are mostly sheet formations that overlie karstified bedrock depressions as basinal infills. Although wide ranges of seafloor patterns are associated with this unit, they are grouped into one category for mapping purposes. One notable variation within the Nearshore Sand Flat mapping unit includes diabathic channels. Other variations include ripples and planar bed forms. Sediments comprising this mapping unit fill former backreef areas to depths of 7 to 10 m. Study of sediment stratigraphy in the sand flat unit indicates mostly sandy facies, but there may be lenses of fine-grained materials or coarse limestone rubble derived from storm overwash of barrier reefs (CPE, 1985, 1996; Finkl, 2004). These areas have been extensively used as sources of sand for beach nourishment. The sand resource potential of this unit lies in a large volume (about 210 x 10^6 m^3) that occurs extensively in the nearshore zone.

Offshore Sand Flat

Along the northern part of the county where the shelf widens, an Offshore Sand Flat mapping unit is recognized as occurring seaward of diabathic channels, which tend to occur on the seaward margin of the Nearshore Sand Flat mapping unit. This sedimentary unit is flanked on seaward margins by hardbottom mapping units viz. Ridge Fields, Ridge and Valley, and Rock Ridge. On the northeastern extension of the unit, it merges with Sand Waves and Sediment Covered Ridge Field mapping units. Offshore sand flats make up about 25 km^2 (about 9% of the total area mapped) and account for about 21% of the sand resource area (Table 3-1b). To a depth of 3 m, these sediments comprise about 76 x 10^6 m^3 making them a potential sand resource of note.

Sand Waves

Large sand waves occur near the northern margin of the study area about 2 km offshore from monuments R117 (Martin County) to R007 (Palm Beach County). The mapping unit is differentiated from the Nearshore Sand Flat mapping unit by the presence of large sand waves (800 m to 1 km wavelength and more than 3 km in length). On its seaward flank, the unit overlaps the Ridge Field mapping unit and merges with the Sediment Covered Ridge Field mapping unit. Shoreward, the unit merges into nearshore sand flats. The Sand Waves mapping unit takes up about 5.6 km^2 (2% of the total area mapped) and accounts for nearly 5% of the sand resource area (Table 3-1B). There is a volume of about 17 x 10^6 m^3 in the unit to a 3 m depth. The northwestern margin of the unit contains a borrow area that was used for a previous beach nourishment project.

Morphosedimentary Environments

Morphosedimentary subprovinces in Palm Beach County included shoreface sands, inter-reefal sedimentary infills (sandy deposits with thin intercalations of finer-grained materials overlying coral rubble in basal sequences and near reef gaps), and finer-grained materials seaward of coral reefs. The parabathic sedimentary subprovinces can be further divided into diabathic facies that include cross-shore channels in shoreface sand deposits. The channels, identified in the LADS imagery and by shore-parallel seismic reflection profiling, range up to 100 m wide by 3 m deep by 300 m in length. These deposits constitute a valuable, newly-identified sand source (Finkl *et al.*, 2006).

3.4.2 Potential Sand Resources

Sand resources in Palm Beach County are represented by diabathic channels, ebb-tidal deltas, nearshore sand flats, offshore sand flats, and sand waves (ridges) (Table 3-1b). Seafloor sedimentary features make up about 43% of the mapped area. Of the sediment bottom types, the Nearshore Sand flat mapping unit covers the largest area at 57%, followed by the Offshore Sand flat mapping unit (21%) and diabathic channels (15%). Borrow extraction of sand in the sediment areas amounts to about 2% of the area. Table 3-1b shows total volumes of sediment based on depth calculations for mapped areas. Based on a 3 m depth, the Nearshore Sand flat mapping unit contains about 200 x 10^6 m^3 followed by 76 x 10^6 m^3 in the Offshore Sand flat mapping unit and 56 x 10^6 m^3 of sediment in the diabathic channels. Significantly, the Sand Waves mapping units contain about 17 x 10^6 m^3 of sediment. Ebb-tidal deltas contain about 300 x 10^3 m^3 of sand. Collectively, submarine sand resources on the continental shelf in Palm Beach County amount to something on the order of 360 x 10^6 m^3 of sediment to 3 m depth.

3.5 BROWARD COUNTY SEAFLOOR FEATURES AND SAND RESOURCES

In contrast to Palm Beach and Miami-Dade counties, offshore Broward County is characterized by a relatively narrow continental shelf (Figures 3-3, 3-6A and 3-6B), as measured about 2 km wide in the vicinity of the Port Everglades entrance channel. Most of the shelf area is occupied by sediment areas in the north but there is considerably more exposure of bedrock surfaces in the southern part of the county. Of the total area mapped (112 km^2), major hardbottom features comprise about 40% of the area. Exposure of the Anastasia Formation on the seafloor accounts for most of the hardgrounds. Of the hardbottom features, the Nearshore Reef mapping unit accounts for nearly half of the rock (47%) and 19% of the total area mapped. Coral Reef marine terrace mapping units (coral reefs making up the FRT, Marine Terrace I, Marine Terrace II) make up nearly a third (29%) of the hardbottom area and about 12% of the total area mapped (Table 3-2A).

3.5.1 Bedrock Features Exposed on the Seafloor

The continental shelf in Broward County contains extensive exposure of limestone bedrock (Anastasia Formation to the north and Miami Limestone to the south). Nearly half of the shelf area contains hardbottom in the form of bedrock exposure or coral reefs (barrier and patch) (Table 3-2A). The continental slope contains forereef rubble that has moved down slope by gravity flow to form talus and scree deposits. The forereef rubble partly covers proximal portions of deeper water marine terraces.

Continental Slope

The continental slope occupies an area of about 10 km^2 or about 23% of the hardbottom area and 9.4% of the total mapped area (Table 3-2A). Forereef rubble accumulates near the base of the seaward margin of the FRT and partly mantles the upper (shallower) marine terrace, identified here as Marine Terrace I (Figures 3-6A and 3-6B). This terrace, which tends to occur in water depths of about 29 m to 37 m, occupies an area of about 69 hectares. The Marine Terrace II occurs in about 38 to 46 m of water and occupies about 118 hectares. Identification of the marine terraces was problematic in some areas because they occur near the instrumental depth limit of the LADS technology. Nevertheless, their distribution was very clear in some areas and here they were mapped with confidence. It is not known whether the marine terraces are rock cut surfaces or whether they contain Pleistocene coral reefs under a surficial cover of sedimentary debris derived from the FRT or sandy deposits. More investigation is required to ascertain the true nature of these deposits.

Nearshore (Rock and Coral) Reef

The Nearshore Reef mapping unit (Figures 3-3, 3-6A and 3-6B) is comprised by limestone bedrock and coral reef. Because there were numerous, thin shore-parallel stringers that appeared to have undifferentiated surface expression in the LADS imagery, it was not possible to consistently distinguish one unit from the other. They were thus mapped as a complex unit containing both types of hardground. This complex mapping unit accounts for about 47% of the hardbottom occurrence on the Broward County continental shelf.

Spatial distribution patterns of the Nearshore Reef mapping unit become spatially more complex south of Port Everglades where they tend to break up the nearshore Sand Flat mapping unit into long narrow segments of both units. That is, the nearshore reefs (rock plus coral reef) and the sand flats tend to become long narrow stringers.

Coral Reefs and Related Features

The FRT, the main coral reef system on the continental shelf, is comprised by a series of shore-parallel barrier reefs that are separated from one another longitudinally by sand flats, a sequence that is best developed in Broward County (*cf*. Figures 3-3, 3-6A and 3-6B). Between R020 and R030 the crest of the barrier reef ranges between 153 m and 255 m in width and lies in about 18 to 24 m water depth. The seaward margins of the barrier reefs are characterized by a series of benches that step down into deeper water. The benches are comprised of undifferentiated Marine Terrace mapping units. Marine terraces occur seaward of the barrier reef system where the Marine Terrace I mapping unit is continuous along the FRT seaward margin. Discontinuous segments of the Marine Terrace II mapping unit occur seaward of R049 to R059, 096 to R101, and R104 to 108.

The barrier coral reef is disjointed with sections of the reef separated from one another by reef gaps, which often form conduits for sand transport from the sand flats offshore beyond the barrier reef (Finkl, 2004). Reef Gap Ramps descend seaward across the shelf break, cutting through the marine terraces (Figures 3-3, 3-6A and 3-6B). The ramps, cutting through the marine terraces to the upper margins of the continental slope, comprise the deep portions of reef gaps. The barrier reefs act as a sill or lip that retains sediments in the trough between the coral reefs and the shore. Reef gaps and reef gap ramps contain sand leaking from the offshore sand flats. Submarine deltas often occur seaward of the gap in the FRT and obscure deepwater marine terraces in the vicinity offshore from R003, R017, R035, R043, R057, R103, and R124.

Rubble accumulates on the shoreward side of the barrier reefs due to overwash during storms. The Backreef Apron mapping unit identifies these rubble accumulations that spill shoreward into the Nearshore Sand Flat mapping unit. Patch reefs occur sporadically shoreward of the barrier reefs.

Coral Reef

Barrier coral reefs comprising the FRT tend to occur about 2 to 3 km offshore and occupy about 5 km^2 or about 11.2% of the total hardbottom area and 4.5% of the total mapping area (Table 3-2A). The barrier reefs in Broward County are the areally constricted northern extension of the FRT, which is thoroughly described in the Florida Keys (Lidz, Robbin and Shinn, 1985; Lidz, Hine and Shinn, 1991; Lidz, Hine, Shinn and Kindinger (1991); Lidz, Shinn, Hine and Locker, 1997; Lidz, 2006). Hoffmeister (1974) and Lighty (1977) include descriptions of the more northerly portions of the FRT, as that occuring in Broward County. Gaps between the barrier reefs, mentioned by these authors and described in terms of leaky sediment valves by Finkl (2004), are identified here as Reef Gap and Reef Gap Ramp mapping units. The barrier reefs act as a sill or lip that retains sediments in the trough between the coral reefs and the shore.

Marine Terraces I and II

The Marine Terrace I and II mapping units occur along the seaward margin of the barrier coral reefs, but in deeper water beginning at 35 m and stepping downwards as marine terraces along the shelf break (Figures 3-3, 3-6A and 3-6B). Marine terraces make up about 7 km^2 or nearly 15% of the hardbottom area (6% of the total mapped area) and 1 km^2 or about 48% of the hardbottom area (about 1% of the total mapped area) for Marine Terrace I and Marine Terrace II, respectively (Table 3-2A). There are typically more than two marine terraces, four being a common occurrence. The Marine Terrace I and II mapping units are wider and more contiguous than the other deeper terraces. A good example of multiple terraces centers offshore from the reef gap at R120.

Nearshore Reef

Nearshore coral-algal reefs are not easily interpreted in the LADS imagery and they are consequently mapped together with rock outcrops, mostly Anastasia Formation from central Broward northwards and Miami Limestone southwards. The nearshore mapping unit is thus comprised of rock reef and coral reef. This complex unit significantly accounts for about 21 km^2 of mapped shelf area, about 47% of the hardbottom and 19% of the total area mapped (Table 3-2A). The nearshore reefs tend to occur as elongate stringers that trend parallel to the shore. They are surrounded by sand flats in the northern part of offshore Broward but become progressively and spatially involved with the Structural Sand Flat mapping unit south of Port Everglades. The seaward-most occurrence of the Nearshore Reef mapping unit rests in about 12 to 18 m water depth and separates nearshore sand flats from offshore sand flats. Sand flat corridors occurring between nearshore reefs and/or structural sand flats are of variable widths ranging up to 375 m wide but commonly narrow to several tens of meters in width.

Patch Reef

A patch reef is an isolated coral growth forming a small platform in a lagoon, barrier reef, or atoll. Patch reefs may occur as isolated features or in clusters of variable density. Most patch reefs in Broward County occur landward of the barrier reefs as isolated features that together collectively account for about 14,000 m^2 (Table 3-2A). Because of their small size and scalar considerations in the production of maps showing submarine geomorphological features, most patch reefs are not shown. They are mentioned because of their environmental significance and relevance to buffers for dredging. These features, though areally restricted, require environmental buffers that restrict exploitation of sand resources near them. Because of their small size, they are normally precluded from the mapping. Some of the more prominent strings of patch reefs occurring in offshore sand flats are shown offshore from monuments R003, R012-R016, R025-R028, R030-R032, R033, R038-R039, R052-R054, R067, and R117-R122. Mapping more detailed than this reconnaissance survey (e.g. sidescan sonar or multibeam with bottom reflection) is required to show the positions of patch reefs.

3.5.2 Sedimentary Features and Sand Resources

The wide range of sedimentary deposits mapped in Broward County include nearshore bar and trough systems, nearshore troughs, nearshore sand flats, offshore sand flats, structural sand flats, and coral reef overwash deposits. Sand resources for beach renourishment are associated with nearshore and offshore sand flats. The other types of sedimentary deposits occur too close to shore (e.g. sand bars), are too thin (e.g. structural sand flats), or contain rock fragments (e.g overwash deposits) that are unsuitable for placement on the shore.

Sand resources in Broward County are represented by Nearshore Sand Flat and Offshore Sand Flat mapping units, which together make up 95% of the unconsolidated sediment areas and about one-third (35%) of the total area mapped (Table 3-2B). About 5% of the sediment area (and about 1.7% of the total area mapped) has been dredged to renourish beaches. Large sand resource volumes occur in the inter-reefal sand flats, over 100 x 10^6 m^3 to a depth of 3 m (Table 3-2B). This estimate is conservative considering that sediments in the inter-reefal sand flats are often more than 7 m thick. These potential sand resources are limited by sensitive marine habitats, proximity to bedrock and coral reefs, artificial reefs, and other factors. About 5% of the sediment area has been exploited for beach nourishment.

Sedimentary Features

Because bar and trough systems, nearshore troughs, structural sand flats, and coral reef overwash deposits are not suitable for beach nourishment, they are not described here. Descriptions of these types of features may be found in Finkl and Warner (2004), as detailed for shelf areas in Palm Beach County. Relevant to beach nourishment are sand sources found in nearshore and offshore sand flats.

Nearshore Sand Flat

Extending seaward from the Bar and Trough, Nearshore Trough, Structural Sand Flat, and Nearshore Reef mapping units, the nearshore sand flats occupy an area of about 22 km^2 or about 54% of the sand resource area (about 20% of the total mapped area) (Table 3-2B). The sand flats range in width from about 800 m along the northern portion of the county to about 1 km in the south (Figures 3-3, 3-6A and 3-6B). Along the northern segment of the county shore, the nearshore sand flats lie about 200 m offshore but become progressively displaced seaward by intervening structural sand flats that may range up to 1.5 km in width. Beginning at the Hillsboro Inlet (R025), the nearshore sand flats become fragmented from contiguous belts up to about 1 km wide (at about R024) to narrower sand corridors that are flanked by rock, coral reef, or structural sand flats. Some of these corridors eventually pinch out to form complex distribution patterns between R045 and R100. The Nearshore Sand Flat mapping unit is separated from the Offshore Sand Flat mapping unit by coral reefs. Gaps in this "3rd reef" occur at R087 to R088, R089 to R090, R108 to R113, and R124 to R125. At these reef gaps the two sand flats merge and morphodynamically interact, but they are cartographically separated to provide closed polygons in the GIS.

Offshore Sand Flat

Lying seaward of the Nearshore Sand Flat and Nearshore Reef mapping units, Offshore Sand Flats take up about 17 km^2 of the sand resource area in Broward County (Table 3-2B). Although more contiguous and less fragmented by rock outcrops and coral reefs, the offshore sand flats make up about 41% of the sand resource area (about 15% of the total mapped area). The offshore sand flats are slightly more than 1 km wide in the northern part of the offshore area but narrow to about 0.5 km in width starting at R057 and extending to about R090 south of the Port Everglades entrance channel. Southwards the offshore sand flats average between 0.50 and 1 km in width.

Morphologically, the offshore sand flats are flanked on their seaward margins by the barrier coral reefs (Figures 3-3, 3-6A and 3-6B). The FRT acts as a physical barrier that retains sand deposits on the continental shelf, except at reef gaps. The general morphology of reef gaps is described by Finkl *et a*l (2005) who reports that they function as leaky sediment valves that control the level of sand behind the barrier coral reefs. Reef gaps offshore Broward County are often associated with Reef Gap Ramps, a mapping unit that extends the reef gap through the shelf break to the continental slope. Examples occur at R017, R035, R042, R049, R056, R103, and R125 (Figures 3-5A and 3-5B). Sometimes there are wide reef gaps that are open for 5 km or more, such as occurs between R107 to R128. In this location, there is no reef gap ramp and the gap is closed at depth by a marine terrace (Marine Terrace I mapping unit). The seaward margin of the Offshore Sand Flat mapping unit is mostly bounded by reef overwash deposits that stratigraphically interdigitate with sediments in the flats. The overwash deposits (see previous descriptions) contain coarse-grained, coral fragment clasts that are unsuitable as beach fill materials.

3.5.3 Potential Sand Resources

About 95% of the sand resources in Broward County are comprised by nearshore and offshore sand flats (Figures 3-3, 3-6A and 3-6B). These deposits together take in about 40 km^2 of the continental shelf area and comprise significant potential volumes of sandy sediments. Based on arbitrary, but very conservative depths, the potential volume ranges from about 40 x 10^6 m^3 (1 m depth assumption) to about 110 x 10^6 m^3 (3 m depth assumption) (Table 3-2B). The nearshore and offshore sand flats are about equally divided in spatial terms with the nearshore sand flats occupying slightly more area (20% vs. 15%) and potentially slightly greater volume. Based on measurements of borrows shown in the LADS imagery and assuming 3 m depths of cut, about 6 x 10^6 m^3 of sediments have been extracted from nearshore and offshore sand flats. Better estimates of total dredging volumes, which are available locally and summarized in Finkl, Benedet and Campbell (2006), can be accessed for comparative purposes. The volumes estimated here from the LADS imagery are supplied in an effort to indicate the extent to which potential sand resources have been exploited.

3.6 MIAMI-DADE COUNTY SEAFLOOR FEATURES AND SAND RESOURCES

About one-third (30%) of the hardbottom shelf area is comprised by the Nearshore Reef mapping unit with about another third (32%) being taken up by the FRT (Coral Reef, Marine Terraces I and II, Forereef Rubble, Patch Reef, Reef Crest mapping units) (Table 3-3A). The continental slope takes up the remainder, but it lies seaward of the FRT (Figure 3-4). Seafloor exposure of bedrock is significant in the northern part of the county but decreases southward and is largely replaced by sediments south of the navigational entrance to the Port of Miami. Overall, hardbottom features make up 20% of the total area mapped.

Sedimentary features cover about 63% of the total area mapped (Figures 3-7A 3-7B and 3-7C). The Sand flat with Sand Ridges mapping unit occupies the largest area of sediment cover (about 40%) followed by Tidal Sand Flat (19%) and Nearshore Sand Flat - Sandsheet (22%) mapping units (Table 3-3B). Offshore sand flats make up about 10% of the sediment area and 6% of the total area mapped. Assuming a 3 m thickness for all sand bodies, there is a potential sand resource of about 470 x 10^6 m^3 . However, that volume will undoubtedly be reduced by proximity to environmentally sensitive areas and other types of hazards to dredging. In the mapped sediment area, about 2.4% has been exploited by dredging for beach nourishment.

3.6.1 Bedrock Features Exposed on the Seafloor

Limestone outcrops on the continental shelf in Miami-Dade County are contained within the Structural Sand Flat and Sand Flat with Sand Ridges mapping units (Figures 3-4, 3-7A, 3-7B and 3-7C). Sand cover is generally only a few centimeters thick over the limestone bedrock permitting structural features to be seen in the LADS imagery. Placement of the Structural Sand Flat mapping unit in a hierarchical classification is problematic because it is transitional from bedrock features to sedimentary seafloor features. When structures are clearly evident in the bathymetric imagery, the unit characterizes rocky seafloor with a thin sediment cover. In any case, the unit eventually becomes obscured by thicker sediment accumulations occurring, for example, in the Nearshore Sand Flat (R037 southwards) and Nearshore Sand Sheet (R075 to R090) mapping units (Figures 3-7A, 3-7B, and 3-7C). Bedrock is sporadically exposed in Tidal Sand Flat and Sand Flat with Ridges mapping units, depending on the thickness of sediment cover. Sand ridges are typically separated by sediment troughs that may contain patches of exposed limestone bedrock.

Continental Slope

The continental slope occurs about 5 km offshore in the northern part of the county but lies nearly 10 km offshore in southern Miami-Dade County (Figures 3-7A, 3-7B, and 3-7C). It accounts for about 38% of the hardbottom area and about 8% of the total area mapped. The slope lies seaward of marine terraces fronting the FRT and occurs in about 50 m water depth.

Nearshore Reef

The Nearshore Reef mapping unit (Figures 3-4, 3-7A, 3-7B, and 3-7C), which includes both rock and coral reef, separates structural sand flats from nearshore sand flats in the nearshore zone and also separates nearshore sand flats from offshore sand flats in the offshore zone. There are, however, gaps in the latter separation as occur, for example, offshore from R002-R004, R009, R027-R036, R038, R045-R060, and southwards (Figures 3-4, 3-7A and 3-7B). Nearshore reefs take up about 15 km^2 and account for about 30% of hardbottom occurrences or 6% of the total area mapped (Table 3-3A).

Coral Reefs and Related Features

Coral reefs comprising the FRT become more spatially extensive from north to south, the variation ranging from 100 m in the north (*e.g.* R030) to over 800 m (south of R112) in the south (Figures 3-4, 3-7A, 3-7B, and 3-7C). The coral reef area covers about 8.6 km^2 and accounts for about 16% of the hardbottom area (about 3% of the total area mapped) (Table 3A). Patch reefs, that are large enough to map, cover about 200,000 m^2 of area, and account for about 0.4% of the hard bottom. The Reef Crest mapping unit was introduced for Miami-Dade County because the FRT increases in width compared to Palm Beach and Broward counties.

Barrier Coral Reef

The barrier coral reefs in Miami-Dade County lie nearly 4 km offshore in the northern part of the county and about 8 km offshore in the south (Figure 3-4). The barriers are broken by reef gaps centered on R009, R027, R034, R038, R055, 068, R090105, and southward from R112 (Figures 3-7A, 3-7B, and 3-7C). In the northern and central parts of the mapping area, the barrier reefs are backed by offshore sand flats and reef overwash units, but south of R112 they are backed by the Sand Flats with Sand Ridges mapping unit. This basic change in the character of the submarine topography occurs south of the navigational entrance to the Port of Miami in the general offshore vicinity of R095 (Figures 3-4 and 3-7C).

Marine Terraces

The Marine Terrace mapping units occur along the seaward margin of the barrier coral reefs, but in deeper water beginning at 35 m and stepping downwards as marine terraces along the shelf break. The terraces make up about 6 km^2 or about 12% of the hardbottom area (2% of the total mapped area) (Table 3-3a). There are typically more than two marine terraces but they are mapped here as a complex single unit for simplicity. The Marine Terrace mapping units tend to become wider and more contiguous south of R095 where three combined terraces are nearly 800 m wide (Figure 3-7C).

Forereef Rubble

Scree (talus, rubble) deposits occur along the seaward base of the FRT and sometimes accumulate as coarse-grained deposits in reef gaps (*e.g*. R003). Because the deposits tend to be narrow, elongated gravity accumulations at the base of spur and groove topography in the reef face, they are not extensively mapped. However, they should be noted as an important feature of reef topography.

Nearshore Reef

Complex limestone bedrock and coral reef mapping units tend to occur about 0.5 to 1 km offshore in northern and central segments of the continental shelf area, except southwards from the navigational entrance to the Port of Miami where they lie about 5 km offshore. The Nearshore Reef mapping unit separates structural sand flats from nearshore sand flat units. On the northern part of the shelf in Miami-Dade County (Figure 3-7A), nearshore reefs also occur as elongated, shore-parallel hardbottoms surrounded by structural sand flats. The Nearshore Reef mapping unit takes in about 15 km^2 and accounts for about 30% of hardbottom occurrences (6% of the total shelf mapping area) (Table 3-3A).

3.6.2 Sedimentary Features

As the continental shelf area widens south of the entrance to the Port of Miami (Figure 3-4), the topographic expression and the nature of the sedimentary cover contrasts with characterizations of shelves in Broward and Palm Beach counties. With a broader shelf area and tidal influences on the shallow flats, the new mapping units include Channel Bar, Nearshore Sand Sheet, Tidal Sand Flat, Tidal Sand Ridges, Tidal Channel, Tidal Channel Bar, and Sand Flat with Sand Ridges (Figures 3-7B and 3-7C). This wide range of sedimentary deposits in the southern Miami-Dade County shelf mapping segment forms spatially-complex depositional environments that are described below in terms of mapping units that were interpreted from the LADS imagery.

Diabathic Channels

Shore normal ridge and valley topography was described in this report as occurring within Nearshore Sand Flat mapping units in Palm Beach County. These features were also detailed by Finkl, Benedet and Andrews (2006) as having formed by processes associated with high energy events effecting offshore sand transport from the beach to nearshore sand flats. In contradistinction to the cross-shore (diabathic) channels in Palm Beach County, those in Miami-Dade County occur in offshore sand flats mostly shoreward of reef gaps (Figures 3-7B and 3-7C). Strong tidal current flows cause the channeling effect (ridge and valley topography) on the sand seafloor. This mapping unit comprises approximately 2 km^2 or 1.4% of the sand resources (0.9% of the total mapping area) (Table 3-3B).

Ebb-Tidal Delta

The single ebb-tidal delta in the Miami-Dade mapping area occurs at Haulover Inlet (Figure 3-7A) and extends between R025 and R028. Sands comprising the shoal cover a small portion of the Structural Sand Flat mapping unit.

Nearshore Sand Flats, Sand Flats with Ridges and Tidal Sand Flats

The Nearshore Sand Flat mapping unit, which is fragmented in Broward County, becomes displaced alongshore by structural sand flats. These sand flats take about 30 km^2 of shelf area and account for about 19% of the sand resource base (Table 3-3B). The unit occurs continuously along the seaward margin of structural sand flats and averages about 1 km in width in northern segments of the shelf. It narrows offshore at about R050, where it is marginal to offshore sand flats, to about 200-300 m wide before termination at the navigational entrance to the Port of Miami (offshore from R074) (Figure 3-7B). At about R038, the unit occurs alongshore to about R074 where it becomes partially replaced by a distinctive rippled surface topography that reflects strong tidal currents. A series of transverse bars occurs alongshore between R038 and R053 (Figure 3-7A). For example, some of the transverse bars range up to 1 km in length at R052. The transition is gradual and the boundary between the Tidal Sand Flat mapping unit and nearshore sand flats is diffuse. The unit is further differentiated from more or less featureless sandy seafloor by distinct sand ridges that may range up to about 2 m or more in height and up to 2 km in length. The Sand Flat with Sand Ridges mapping unit has a northern boundary offshore from about R093 (Figure 3-7C). This unit takes up about 64 km^2 and accounts for about 39.5% of the sand resource base (25% of the mapping area) in Miami-Dade County (Table 3-3B). Tidal sand flats take up about 31 km^2 (12% of the mapped shelf area) or about 19% of the sand resource base (Table 3-3B).

Nearshore Sand Sheet

From R075 on Fisher Island southwards to R103 on Key Biscayne there is a nearshore sand sheet that is topographically distinct from the tidal sand flat offshore (Figures 3-7B and 3-7C). The shoreface-attached sand sheet is comprised by tidal sediments that have been redistributed by alongshore currents. Seafloor topography in this unit is modified by tidal currents flowing through Government Cut (R075), Norris Cut (R085), and Bear Cut (R112). The sand sheet flanks black mangrove forest on Virginia Key and Key Biscayne. The nearshore sand sheet takes about 5 km^2 or nearly 4% of the sand resource base on the continental shelf mapping area (Table 3-3B).

Offshore Sand Flat

Offshore sand flats occur as sedimentary units confined between the FRT and Nearshore Reef and Structural Sand Flat mapping units in the northern part of the study area (Figures 3-7A and 3-7B). South of the navigational entrance channel to the Port of Miami at about the latitude of R095, the offshore sand flats merge shoreward with nearshore sand flats and sand flats with tidal sand ridges (Figure 3-7C). Offshore from Bear Cut, which separates Virginia Key from Key Biscayne (south of R112), offshore sand flats occur on both sides of the FRT. Offshore sand flats comprise about 16 km^2 or about 10% of the sand resources area (6% of the total shelf area mapped).

Structural Sand Flat

Structural sand flats extend southwards from Broward County in Miami-Dade County (Figure 3-4). In the northern part of the shelf area, the unit occurs alongshore from the Bar and Trough mapping unit to Nearshore Reef and Nearshore Sand Flat mapping units. Structural sand flats average about 0.5 to 1 km in width from R001 to about R035 but are interspersed by nearshore reefs. At about R035, nearshore sand flats cover the structural sand flat units up to 2 km offshore north of the entrance channel to the Port of Miami (about the latitude of R070). Limestone bedrock units making up the structural sand flat units are buried by sediment (nearshore sand sheets, tidal sand flats, nearshore sand flats, sand flats with tidal ridges) south of the latitude of Fisher Island (R075).

Tidal Channels and Bars

Tidal channels and bars, as well as ebb-tidal shoals, are mapped in Bear Cut and where they cross the Nearshore Sand Sheet mapping unit between R083 and R090 (Figure 3-4). Tidal channels and bars take about 3 km^2 and account for about 2% of the sand resource base (1% of the mapped area).

Transverse Bars

Sand bars that are oblique to the shoreline occur in the central part of the study area from R038 to R073 (Figure 3-4). The bars, which can range up to 4 km in length, occupy nearly 2 km^2 of shelf area and account for about 1% of the sand resource base (Table 3-3B). The transverse bars occur within the Nearshore Sand Flat mapping unit.

3.6.3 Potential Sand Resources

The sand resource potential in Miami-Dade County is more varied than in areas to the north with various subdivisions of sand flat mapping units making up the total sand resource base: Nearshore Sand Flats (18%), Offshore Sand Flats (10%), Sand Flats with Sand Ridges (40%), and Tidal Sand Flats making up the bulk (68%)(Table 3-3B). Potential volumes associated with these mapping units for an assumed 3 m thickness, summarized in Table 3B, show 195 x 10^6 m^3 in Sand Flats with Sand Ridges and 92 x 10^6 m^3 in Nearshore Sand Flats. Tidal Sand Flats contain about 92 x 10^6 m^3 and Offshore Sand Flats about 48 x 10^6 m^3.

Perusal of Table 3-3B thus indicates that there are large potential volumes of sandy deposits on the continental shelf. Tidal Sand Ridges contain nearly 11 x 10^6 m^3 of sediment that may have potential for beach nourishment. Diabathic Channels offer an additional sand source in central and southern parts of the shelf (Figures 3-7B and 3-7C). These cross-shore channels differ from the ones mapped in Palm Beach County in that they occur farther offshore. Their location thus suggests that they form in response to tidal currents in the vicinity of reef gaps.

3.7 PREVIOUS BEACH NOURISHMENT PROJECTS: STATEWIDE PERSPECTIVE IN RELATION TO THE SOUTHEAST COAST

Because there have been numerous beach renourishment projects in Florida, a brief overview is presented to put efforts along the southeast coast into perspective. The purpose here is to indicate coastal segments where beach nourishment has occurred, not to detail every episode. Project dates and other details area available in the ROSS database and from the Florida Department of Environment Protection, Bureau of Beaches and Coastal Systems (Tallahassee, Florida). Locations of previous beach nourishments are indicated by a green colored bar along the shore on the left panel of the series of maps provided for each county (Figures 3-5A, 3-5B, 3-5C, 3-6A, 3-6B, 3-7A, 3-7B and 3-7C). This information was acquired online from Todd Walton, Florida State University - Beaches and Shores Resource Center (Beach Erosion Control Project Monitoring Database Information System) website. According to the metadata file, the digitized data represents the results of data collection/processing for a specific activity and indicates the general existing conditions at the time of collection, but no acquisition dates are given in the file. For ease of reference, approximate place names are associated with coastal segments that contain renourished stretches as indicated below by county.

Palm Beach County contains several coastal segments with beach nourishments (Figures 3-5A, 3-5B and 3-5C). Although present in the northern part of the county, renourished segments become more common southward. In northern Palm Beach County, beach renourishment segments occur from R013 to R019 (Jupiter/Carlin) and between R026 and R038 (Juno Beach) (Figure 3-5A). Central Palm Beach County contains one coastal segment with beach renourishment from R090 to R101 (Midtown Palm Beach) (Figure 3-5B). Southern Palm Beach County contains several beach nourishment segments as follows: R116 to R33 (Phipps Ocean Park), R152 to R159 (Ocean Ridge), R180 to R188 (Delray Beach), R205 to R212 (Boca Raton North), R216 to 222 (Boca Raton Central), and R223 to R001 (Boca Raton South).

Broward County contains three main coastal segments with renourished beaches (Figures 3-6A and 3-6B). In the northern part of the county, renourished segments occur from R006 to R012 (Hillsboro Beach) and from R025 to R051 (Pompano Beach) (Figure 3-6A). In the southern part of the county, renourished segments occur from R086 to R098 (John U. Lloyd State Beach Park) and from R101 to R001 (Hollywood/Hallandale) (Figure 3-6B).

Coastal segments in Miami-Dade County containing renourished beaches are from R007 to R020 (North of Haulover Canal, Sunny) R031 to R036 and from R027 to R074 (Miami Beach) in the northern part of the county (Figure 3-7A). Renourished segments in the central part of the county are located from R075 to R077 (Fisher Island) (Figure 3-7B) and between R101 to R113 (Key Biscayne) (Figure 3-7C).

Introductory background information regarding previous beach nourishment projects in southeast Florida, within the overall Florida context, is summarized from Finkl *et al*. (2005) and Finkl, Benedet and Campbell (2006), who consider volumes and costs by regional areas. This kind of information is relevant to considerations of potential sand volumes and new areas that can be exploited to meet the needs of established projects that require maintenance.

3.7.1 Total Volumes

According to Finkl, Benedet and Campbell (2006), prior to the early 1970s, less than 2 x 10^6 m^3 of sand are used every year in Florida beach nourishment projects. On average, about 4.5 x 10^6 m^3 of sand have been placed annually on Florida beaches (Atlantic and Gulf coasts) since the 1980s. Figure 3-8 shows the trend in renourishment cycles (every four or five years) of Florida beaches and includes peaks ranging from 4 to 7 x 10^6 m^3 of sand, except for the Miami Beach project that reached an exceptional 12 x 10^6 m^3.

3.7.2 Nourishment Cycles and Costs

This same nourishment cycle shows an increase in total expenses every four years (Finkl, Benedet and Campbell, 2006). Since the late 1960s, costs of beach nourishment have increased. Up to mid-1980s, restoration of Atlantic beaches comprised much of the total amount. However, total annual costs to nourish Gulf beaches have been almost twice the total costs of beach restoration on Atlantic beaches. In general, annual costs of beach nourishment are less than $ 10 million along the east coast and about $ 20 million along the west coast. Average costs for the State for the 1970-1997 period are about $ 37 million per year. Projects along the Atlantic coast were more expensive than along the Gulf coast before 1985, although prices on the east and west coasts are similar in recent years.

Nourishment of the southeast coast (tri-county area of this study) is the most expensive along the Atlantic, having the highest unit price per kilometer in Florida ($ 2.7 million) (Finkl, Benedet and Campbell, 2006). In this segment, average cost per episode and average unit costs are above the state average (Table 3-4). Average cost per episode is 50% above the state average and average unit cost per length and per volume are respectively 33% and 12% higher. Considering that restored beaches along the Southeast segment have average length and placed sand densities near mean values for the State, the high costs are probably due to the scarcity of suitable sand sources that result in extraction from deeper and distant waters. Other major nourishment programs on the Florida southeast coast include Jupiter Island, Delray Beach, Boca Raton (North and South) beaches, Pompano Beach/Lauderdale-by-the-Sea, *etc.*

Atlantic beaches, comprising 55% of Florida's restored beaches, received about 61% of the total placed sand volume, and accounted for 59% of total expenses. Florida, the most southern U.S. state, has successful beach nourishment programs on both Atlantic and Gulf coasts. The Atlantic coast has about fifty nourished areas that together received up to 65 x 10^6 m3 of sediments since the mid 1940s. Miami Beach, built from 1978 to 1982, was the largest single construction event in the history of beach nourishment on the U.S. East Coast. The Miami Beach project consumed about 9.2 x 10^6 m^3 of sediments (construction density of 543 m^3 m^{-1}) that were dredged from several different borrow areas located in inter-reefal sediment troughs along 17 km of shoreline. The Miami Beach nourishment project demonstrates excellent performance relative to other U.S. projects (NRC, 1995; Wiegel, 1992). The success of the Miami Beach project may be attributed to the long extent of the nourished area (17 km) that reduces fill spreading rates (*e.g*. Dean, 2002), a relatively low wave energy, relatively high construction density, and the fact that the project ends at a very long downdrift jetty where the sand accumulates. An example of a successful project that combines use of groins with nourishment of headland bay-beach planforms occurs on Fisher Island (Bodge and Olsen, 1992), south of Miami Beach. In contrast to the large Miami Beach project, the Fisher Island experiment used small aragonite fill volumes over short distances between groins.

Along Atlantic shores, episodes are more evenly distributed: 41 (30%) in the Northeast segment, 44 (32%) along the Central East, and 53 (38%) along the Southeast. Beach nourishment in the Southeast coastal segment occurred in 25 locations, representing 50% of the total nourished places on the east coast.

The east coast of Florida has numerous inlets (both natural and man-made) some of which have been jettied. The jetties at Hillsboro Inlet are short and parallel to the inlets entrance. In addition, a curved detached breakwater has been placed off the center of the entrance and, in essence, serves as a hard-structure downdrift spit. The zone between the northern jetty and the detached breakwater serves as a conduit at high water (through a weir jetty) and allows sediment to pass into a sand trap instead of accumulating as an updrift fillet.

An 18.5-km long beach system lies between Hillsboro Inlet and Port Everglades Inlet. The northern part of this beach segment has been twice artificially renourished with federal funds, first in 1970 with 0.8 x 10^6 m^3 along 5.1 km of beach and then in 1983 with 1.46 x 10^6 m^3 along a 5.1 km section (Lin *et al*., 1996). Borrow areas for these two renourishment projects were offshore, seaward of bedrock exposures of the Anastasia Formation (Finkl, 1993). In addition, 2.28 x 10^6 cubic meters were used along another 11-km stretch shoreline in Broward County.

Although the official inlet dredging project was initiated in 1931, dredge materials from Hillsboro Inlet were not bypassed to the beach south of the inlet until 1947. From 1948 to 1993, 2.33 x 10^6 m^3 of sand (averaging 52,000 m^3 a^{-1}) were bypassed. The volume was increased after 1980 in response to improved dredging capabilities. The pre-1993 sediment budget indicates that bypassing made 52,800 m^3 a^{-1} (*i.e.* 60,400 m^3 minus the 7600 m^3 washed into the inlet from the south) available to southern beaches.

The pre-1993 sediment budget also shows that 27,000 m^3 were lost to the sea. A 1995 inlet management plan calls for the establishment of a 40,000 m^2 fan-shaped sand trap offshore of the navigation channel to trap sand that is usually jetted offshore by strong ebb-tidal currents. Such sand trapping would increase the volume of sand available for mechanical bypassing. The plan calls for increasing the amount by-passed to 89,000 m^3 a^{-1}. It is contended that the "...already successful bypassing program at Hillsboro Inlet, once further improved, is expected to completely eliminate the need for continuous renourishment of the Pompano/Lauderdale-by-the-Sea area" (Lin *et al*., 1996:157).

3.7.3 Selected Examples from the Southeast Coast

Delray Beach is an example of a successful and well-monitored beach nourishment program. Delray has been maintained since 1973 with five periodic beach nourishments. Pertinent data for Delray Beach nourishment projects is summarized in Table 3-5. Sand placed along this coastal segment has stabilized the shore with periodic renourishment.

Since inception, about 4.5 x 10^6 m^3 (5.9 x 10^6 yd^3) of sediment were placed on Delray Beach. The project employed an initial construction density of 293 m^3 m^{-1} (Table 3-5), but from 1978 to 2001 the program was maintained with an average volume of about 10 x 10^5 m^3 a^{-1} or about 24 m^3 m a^{-1} (using the maximum project length of 4.2 km). Delray is an example of a successful beach nourishment program (Fernandez, 1999; Dean, 2002; Benedet *et al*., 2005) and currently contains a healthy restored beach-dune system. Renourishment intervals have been gradually increasing from five (initial renourishment) to 10 years (last renourishment).

The town of Delray Beach, about 80 km north of Miami, Florida, is separated from the Atlantic Ocean by a beach and coastal a road, both of which were subject to heavy erosion prior to 1970 (Beachler, 1993). The revetment that the city constructed earlier increased erosion so that, in 1971, it was decided to renourish the beach. In 1973, 1.22 x 10^6 m^3 (1.6 x 10^6 yd^3) of sand was placed along 4.34 km of the city's shoreline. By 1992 (*i.e.* within a 19-year period) the beach was renourished an additional three times with a total of 3.5 x 10^6 m^3 (4.6 x 10^6 yd^3) of sand of which 0.75 x 10^6 m^3 (0.98 x 10^6 yd^3) was added in the 1992 project.

Because the Delray Beach shoreline was surveyed every year after 1973, good data about sand loss from the system is available. These data show that 1.15 x 10^6 m^3 (1.5 x 10^6 yd^3) of sand was lost between 1973 and 1990. This amount represents a 41% loss from the beach prior to the 1992 renourishment. These data also show that 0.51 x 10^6 m^3 (0.66 x 10^6 yd^3) (or 45%) of the sand was transferred to adjacent beaches widening them in the process. North of the renourished area, the beach widened by an average of 18.6 m whereas to the south it averaged 16.8 m wide. Textural differences, *i.e*. finer-grained to the south, produced a flatter southern profile. The Delray Beach renourishment project, where fill was placed along a 4.34 km stretch of beach, actually benefited an 11.3 km stretch of the coastline (Beachler, 1993).

3.7.4 Contextual Summary

The beach nourishment experience in Florida, as acquired over the last half century (1944 – 1997), is an evolutionary process that identifies improved methods for locating beach-quality sediments offshore, placing them onshore as fill, and monitoring project performance under ambient and energetic (storm) environmental conditions over time. Beach erosion along developed shorelines necessitates beach nourishment, which is a shore protection measure that also provides habitat and recreational possibilities. In the last half century, about 251 projects were conducted along 91 different locations. The total sand volume used in these renourishment activities was about 115 x 10^6 m^3 and total costs amounted to approximately $ 1.02 billion. Costs for beach nourishment in Florida, however, are under reported because costs were available for about half of all projects. Atlantic beaches, comprising 55% of Florida's restored beaches, received about 61% of the total placed sand volume, and accounted for 59% of total expenses. Since 1969, about 2 x 10^6 m^3 of offshore sand resources were exploited for beach nourishment in Florida. Based on a renourishment cycle of four to five years, the annual volume of sand used as beach fill increases by 3 to 8 x 10^6 m^3 (Finkl *et al*., 2005).

3.8 AREAS NOT TESTED ENOUGH TO DETERMINE SAND RESOURCE POTENTIAL

This category in the analysis phase of this study relates to perception of reconnaissance and detailed surveys to find sand bodies that are compatible with beach nourishment activities. Borrow areas are delineated on the LADS interpretive maps (see summary Figures 3-2A, 3- 2B, 3-3, and 3-4) but this does not necessarily mean that the area has been completely or thoroughly investigated. Rather, it means that a particular borrow area was selected for dredging, without implying that immediately adjacent areas are unsuitable or that they have been comprehensively studied. Borrows are selected on the basis of numerous criteria, but the best or most obvious good quality sand of sufficient quantity for the project is targeted first. If sufficient volume occurs in the area studied, exploration is focused on the target with the remainder of the area left for future investigation. Borrows thus indicate areas that have been dredged for beach nourishment and it is logical to assume that immediately adjacent areas have good potential as sand resources. Another consideration is that all available sand in a borrow area may not have been extracted for the project and consequently, old borrows should be subject to further consideration as sand sources. Perusal of vibracore logs and collateral data such as seismic reflection profiles will indicate the depth of quality sand or presence of undesirable materials that are either too coarse or too fine grained.

For purposes of this analysis, the positions of vibracores have been surrounded by a 300 m (1,000 foot) sphere of influence. This industry standard for vibracore spacing (Finkl and Khalil, 2005) provides a fair estimate of sediment properties over relatively large areas in sand search investigations. Individual vibracore locations are thus circled in red outline on the maps to show where sediment data is available (see summary Figures 3-2A, 3- 2B, 3-3, and 3-4). Where there are clusters of vibracores spaced 300 m apart or less, the area is bounded by the outer limits of combined spheres of influence. Areas so delineated on the maps show where there have been previous investigations of offshore sand deposits. Examples of large vibracore clusters in Palm Beach County (Figures 3-5A, 3-5B and 3-5C) include R001 to R015, R075 to R094, R097 to R137, R150 to R165, R175 to R190, and R204 to R218 in the Nearshore Sand Flat mapping unit; in Broward County (Figures 3-6A and 3-6B) R001 to R023, R028 to R034, in the Nearshore Sand Flat mapping unit; R041 to R053 and R115 to R124 in Offshore Sand Flat mapping units; and in Miami-Dade County (Figures 3-7A, 3-7B and 3-7C) R003 to R018, R036 to R054, and R095 to R099 in the Offshore Sand Flat mapping unit. Levels of investigation range from detailed studies where borrows were eventually established to outlier lone vibracores of reconnaissance survey.

Summarized in Table 3-6 are the results by county of a GIS analysis ring where areas were calculated for the following categories: borrows (used), zones that were investigated but not exploited (not dredged), and segments that were not investigated at all. Table 3-6 shows the total area of sand in each county by summarizing the mapping units that are characterized by the sedimentary units that were described above in terms of mapping units for the interpreted LADS imagery.

Perusal of Table 3-6 shows that about 8.4 km^2 of borrow area has already been exploited on the tri-county continental shelf. Interestingly, about 100 km^2 has been explored but not exploited (not dredged). The calculated difference between ‘exploited’ plus ‘explored but not exploited’ values gives the total area not investigated or explored, about 200 km^2 for the study area. Broward County has the least area left for future investigation, about 23 km^2 of potential sand resource area. Palm Beach County has about twice (49 km^2) the area of Broward County not investigated and Miami-Dade County has several times the area not explored.

A percentage comparison of potential sand resource areas is summarized in Table 4-1 for the same areas. Perusal of this table shows that (used) borrows account for relatively small percentages of the potential sand resource area by county, respectively 2.2%, 4.7%, and 2.4% for Palm Beach, Broward, and Miami-Dade counties. Miami-Dade County has the least area (12%) that is ‘explored but not exploited’ whereas Palm Beach County has the most (58%). The converse is true for percent of the potential sand resource area that is ‘not investigated or explored’ where Miami-Dade County has the most (87%) and Palm Beach County the least (40%).

Table 3-1A. Hardbottom features in Palm Beach County based on percent of Anastasia Formation outcrops and coral reefs.

Feature	Area (m^2)	% Hardbottom	% Total Area
Arcuate Structural Feature	1,655,503	1.2%	0.6%
Structural Basin	1,382,271	1.0%	0.5%
Continental Slope	40,663,357	30.1%	14.3%
Coral Reef (FRT)	4,236,229	3.1%	1.5%
Marine Terraces (Deepwater)	5,164,588	3.8%	1.8%
Forereef Platform	174,116	0.1%	0.1%
Nearshore Reef	1,101384	0.8%	0.4%
Nearshore Rock	200,458	0.1%	0.1%
Patch Reef	281,587	0.2%	0.1%
Ridge and Valley	4,351,019	3.2%	1.5%
Ridge Field	65,834,775	48.7%	23.1%
Rock Ridge	5,130,592	3.8%	1.8%
Structural Trough	4,973,126	3.7%	1.7%
Total	135,149,004	100%	47%

Table 3-1B. Sand resources in Palm Beach County by percent of sedimentary features (sand resources) and total area mapped.

Feature	Area (m^2)	Volume* (1 m depth)	Volume* (2 m depth)	Volume* (3 m depth)	% Sand Resources	% Total Area
Borrows	2,646,919	2,646,919	5,293,838	7,940,756	2.2%	0.9%
Diabathic Channels	18,782,027	18,782,027	37,564,054	56,346,082	15.3%	6.6%
Ebb-Tidal Delta	104660	104,660	209,321	313,981	0.1%	0.0%
Nearshore Sand Flat	69,998,023	69,998,023	139,996,045	209,994,068	57.0%	24.6%
Offshore Sand Flat	25,578,298	25,578,298	51,156,597	76,734,895	20.8%	9.0%
Sand Waves	5669179	5,669,179	11,338,358	17,007,537	4.6%	2.0%
Total	122,779,106	122,779,106	245,558,212	368,337,318	100.0%	43.1%

* Based on cubic meters for arbitrary depths of 1, 2, and 3 m.

Table 3-2A. Hardbottom features in Broward County based on percent of Anastasia Formation outcrops and coral reefs.

Feature	Area (m^2)	% Hardbottom	% Total Area
Continental Slope	10,500,158	23.3%	9.4%
Coral Reef	5,056,462	11.2%	4.5%
Marine Terrace I	6,948,949	15.4%	6.2%
Marine Terrace II	1,182,334	2.6%	1.1%
Nearshore (Rock -Coral) Reef	21,370,767	47.4%	19.2%
Patch Reef	14,006	0.0%	0.0%
Total	45,072,676	40%	40%

Table 3-2B. Sand resources in Broward County by percent of sedimentary features and total area mapped.

Feature	Area (m^2)	Volume (1 m depth)	Volume (2 m depth)	Volume (3 m depth)	% Sand Resources	% Total Area
Borrow	1,937,181	1,937,181	3,874,362	5,811,544	4.7%	1.7%
Nearshore Sand Flat	22,238,766	22,238,766	44,477,531	66,716,297	54.4%	19.9%
Offshore Sand Flat	16,680,968	16,680,968	33,361,937	50,042,905	40.8%	15.0%
Total	40,856,915	40,856,915	81,713,831	122,570,746	100.0%	36.6%

Table 3-3A. Hardbottom features in Miami-Dade County based on bedrock exposure on the seafloor and coral reefs (FRT).

Feature	Area (m^2)	% Hardbottom	% Total Area
Continental Slope	19,839,568	38.3%	7.6%
Coral Reef	8,564,472	16.5%	3.3%
Marine Terraces	6,409,339	12.4%	2.4%
Forereef Rubble	267,056	0.5%	0.1%
Nearshore Reef	15,396,396	29.7%	5.9%
Patch Reef	208,620	0.4%	0.1%
Reef Crest	1,139,580	2.2%	0.4%
Total	51,825,030	100%	20%

Table 3-3B. Sand resources in Miami-Dade County by percent of sedimentary features and total area mapped.

Feature	Area (m^2)	Volume (1 m depth)	Volume (2 m depth)	Volume (3 m depth)	% Sand Resources	% Total Area
Borrow	3,912,838	3,912,838	7,825,675	11,738,513	2.4%	1.5%
Diabathic Channel	2,314,697	2,314,697	4,629,395	6,944,092	1.4%	0.9%
Ebb-Tidal Delta	1,271,090	1,271,090	2,542,181	3,813,271	0.8%	0.5%
Nearshore Sand Flat	30,624,413	30,624,413	61,248,826	91,873,239	18.7%	11.7%
Nearshore Sand Sheet	6,039,622	6,039,622	12,079,244	18,118,866	3.7%	2.3%
Offshore Sand Flat	16,068,630	16,068,630	32,137,259	48,205,889	9.8%	6.1%
Sand Flat With Sand Ridges	64,820,833	64,820,833	129,641,665	194,462,498	39.5%	24.8%
Tidal Channel Bar	3,116,615	3,116,615	6,233,230	9,349,846	1.9%	1.2%
Tidal Sand Flat	30,809,649	30,809,649	61,619,298	92,428,947	18.8%	11.8
Tidal Sand Ridges	3,535,247	3,535,247	7,070,494	10,605,741	2.2%	1.4%
Transverse Bar	1,662,482	1,662,482	3,324,964	4,987,446	1.0%	0.6%
Total	164,176,116	164,176,116	328,352,232	492,528,348	100.0%	62.7%

Table 3-4. Average values of volume, length, and costs calculated for beach nourishment episodes implemented in Florida coastal segments. Note the higher-than-state average for the southeast coast (tri-county area) (ased on Finkl, Benedet and Campbell, 2006).

	Volume (10^6 m^3)	Length (km)	Sand Density (m^3 km^{-1})	Average Cost (in 1996 US$)		
				Episode	m^3	km
Panhandle	1,027,774	6,87	302,368	23,708,236	4.97	899,560
Lower Gulf	305,154	2,89	139,441	6,345,999	17.02	1,942,373
Gulf	439,759	3,66	173,907	8,015,445	15.79	1,805,161
Northeast	547,155	4,53	155,403	8,289,379	13.04	1,081,008
Central-East	425,989	3,15	236,957	2,616,242	8.30	1,998,018
Southeast	666,609	3,40	212,840	12,258,805	15.81	2,718,596
Atlantic	558,963	3,64	203,316	8,296,351	12.87	2,198,128
Florida	505,635	3,65	191,988	8,179,494	14.12	2,037,561

Table 3-5. Renourishment cycles for Delray Beach (southern Palm Beach County) (Figure 6C) showing volumetric trends of sand placed on the beach since 1973. (Based on Finkl, Benedet and Campbell, 2006).

Year	Volume (m^3)	Length (m)	Density (m^3 m^{-1})
1973	1,250,000	4,270	293
1978	536,000	2,890	185
1984	994,000	4,270	233
1992	914,500	2,730	334
2002	940,000	3,000	313

Table 3-6. Summary of areas that have been exploited for sand, 'explored but not exploited', and areas that have not been investigated.

County	Sand Area (m^2)	Borrow Area Exploited (m^2)	Explored but Not Exploited (m^2)	Not Investigated, Explored (m^2)
Palm Beach	122,779,106	2,646,919	70,711,731	49,420,456
Broward	40,856,915	1,937,181	15,798,977	23,120,758
Dade	164,176,116	3,912,838	19,677,493	140,585,785

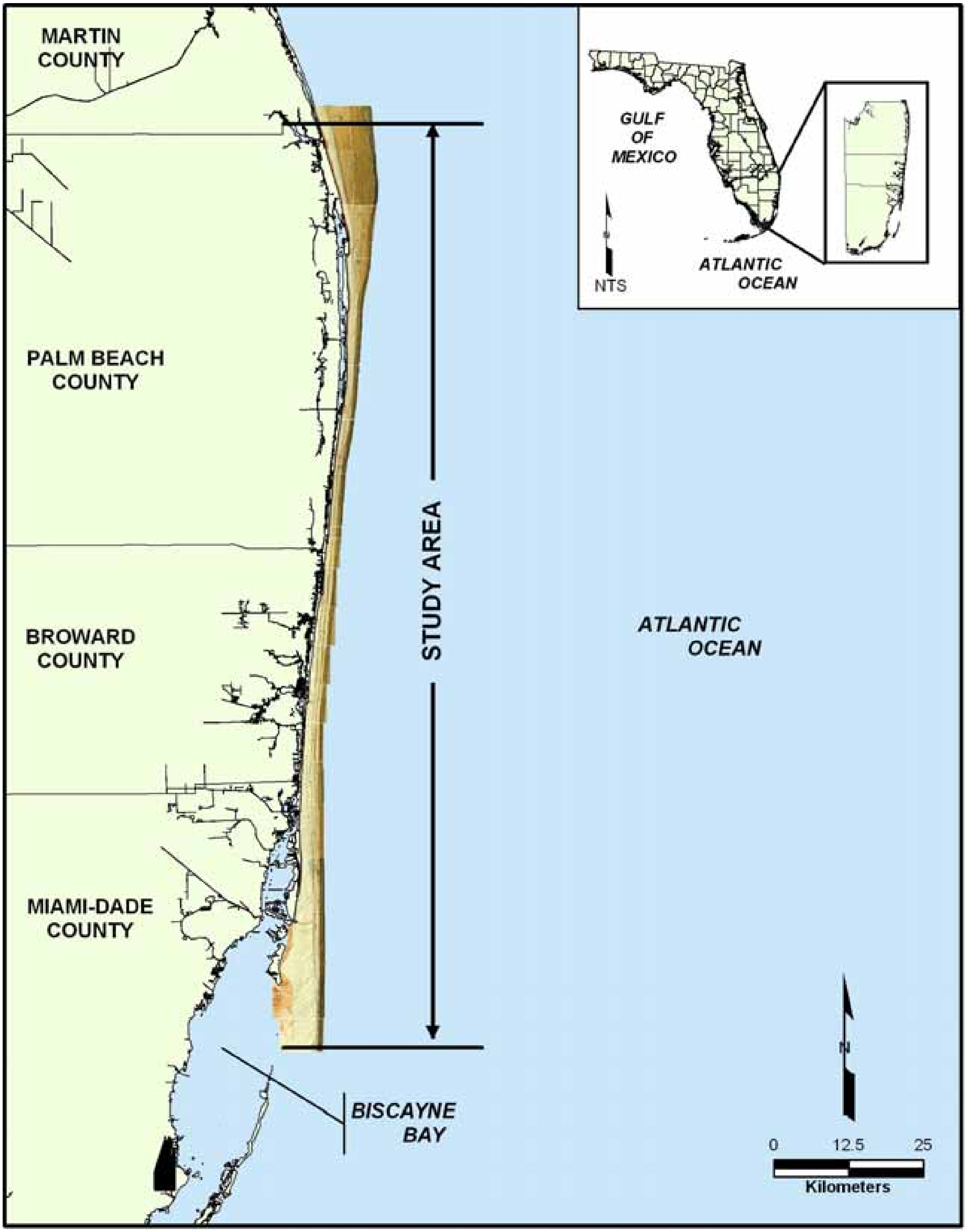
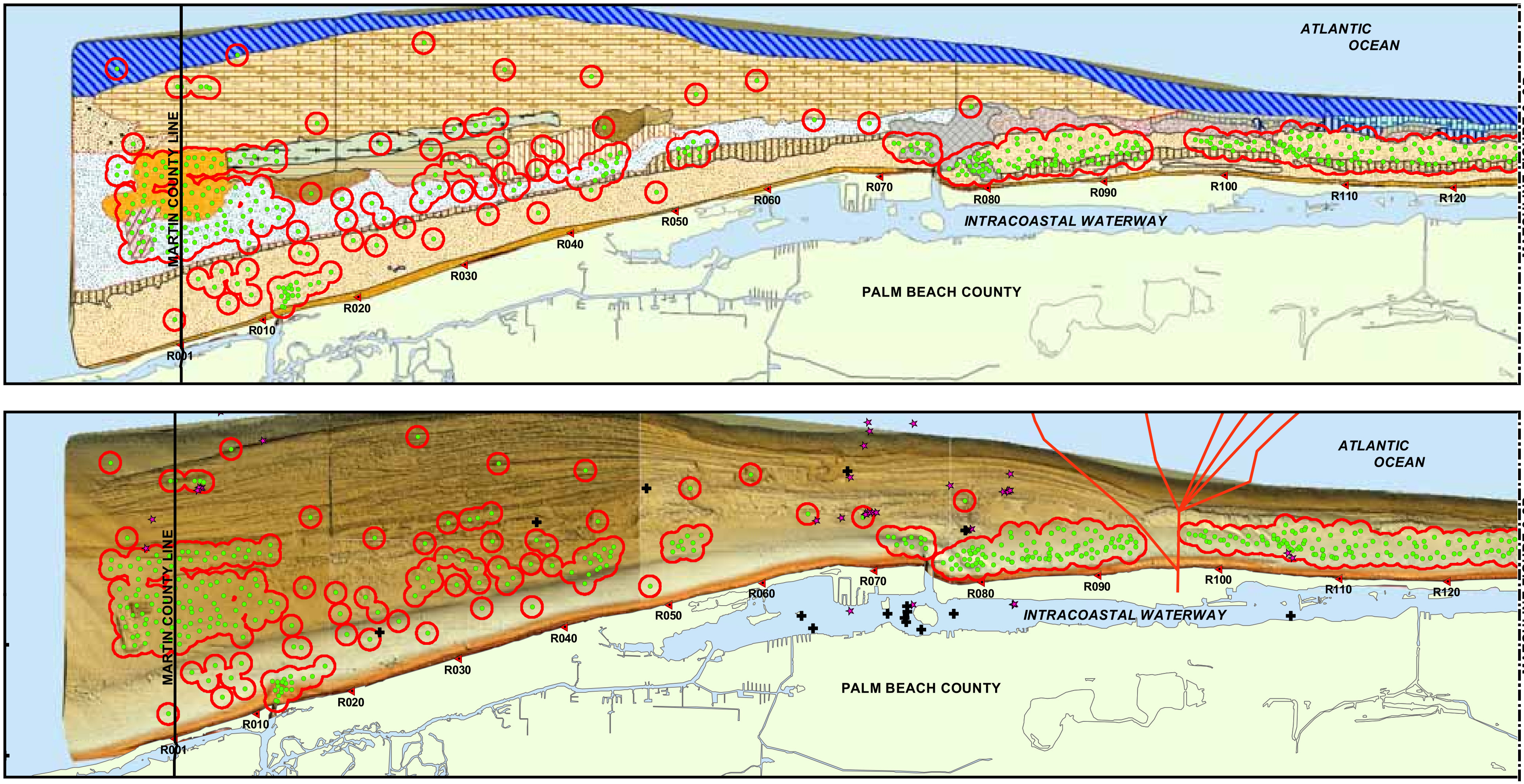


Figure 3-1. Location of study along the southeast coast of Florida. The brownish and tan-colored tones mark the actual area of the LADS imagery between the northern and southern limits of study on the continental shelf.



LEGEND

- WRECK
- ARTIFICAL REEFS
- VIBRACORES
- VIBRACORE BUFFERS
- CABLE LOCATIONS
- LAND
- FLORIDA MONUMENTS
- BACKREEF APRON
- BAR AND TROUGH
- BORROW AREA
- CONTINENTIAL SLOPE
- CORAL REEF
- MARINE TERRACE 1
- DIABATHIC CHANNEL
- DREDGE SPOIL
- FOREREEF RUBBLE
- NEARSHORE REEF
- NEARSHORE SAND FLAT
- OFFSHORE SAND FLAT
- REEF GAP
- RIDGE FIELD
- RIDGE AND VALLEY
- ROCK RIDGE
- ROCK RUBBLE
- SAND WAVES
- SEDIMENT COVERED RIDGE VALLEY
- STRUCTURAL TROUGH

N

0 1.5 3
Kilometers

TITLE:

PALM BEACH COUNTY
SAND RESOURCE AVAILABILITY

CPE

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 02/15/07	BY: HMV	COMM NO: 7849.27	FIGURE 3-2A

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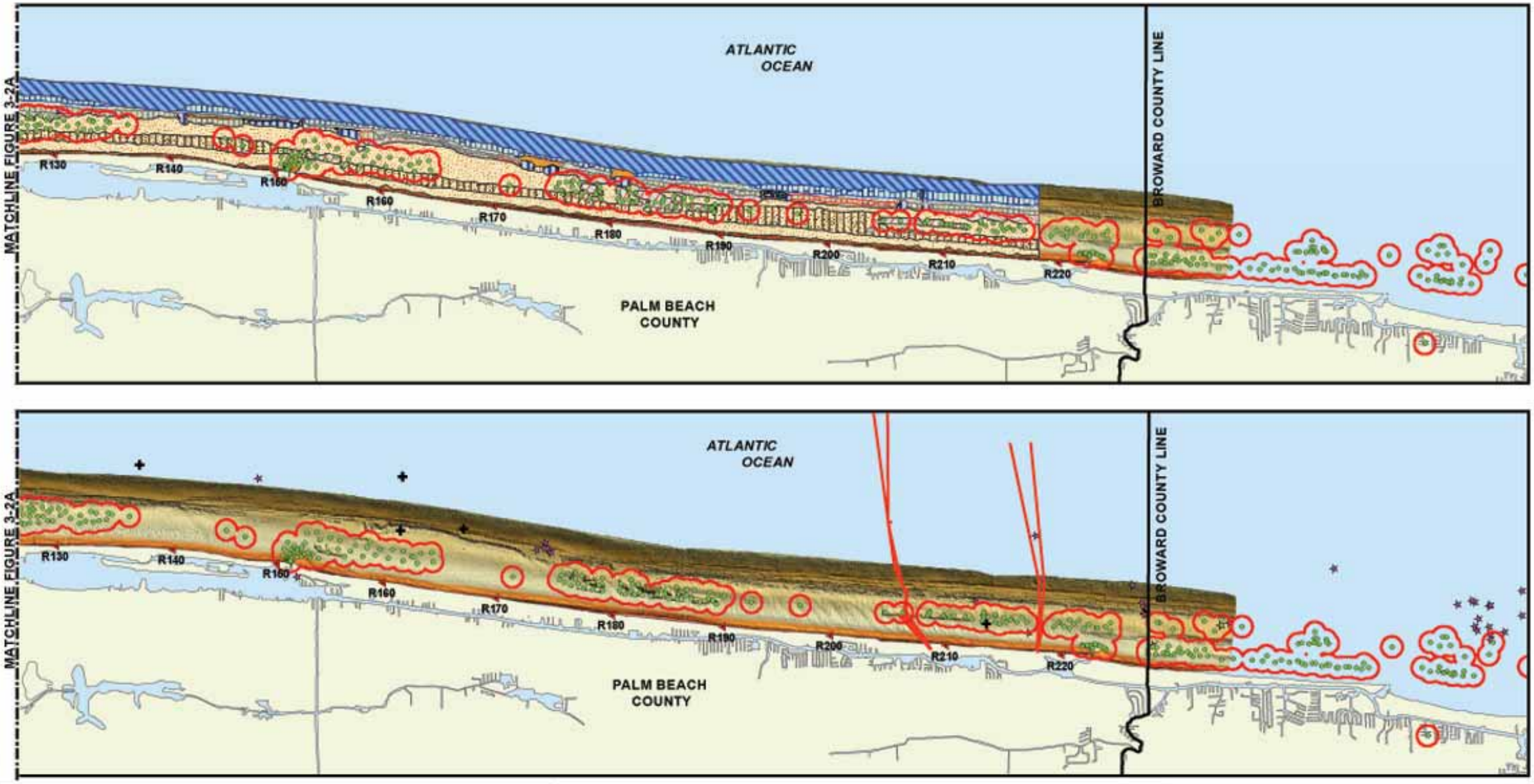

LEGEND

- WRECK
- ARTIFICAL REEFS
- VIBRACORES
- VIBRACORE BUFFERS
- CABLE LOCATIONS
- LAND
- FLORIDA MONUMENTS
- BACKREEF APRON
- BORROW AREA
- CONTINENTIAL SLOPE
- CORAL REEF
- MARINE TERRACE 1
- DIABATHIC CHANNEL
- FOREREEF PLATFORM
- FOREREEF RUBBLE
- NEARSHORE REEF
- NEARSHORE ROCK
- NEARSHORE SAND FLAT
- PATCH REEF
- REEF GAP
- REEF GAP RAMP

0 1.5 3
Kilometers

TITLE:

PALM BEACH COUNTY
SAND RESOURCE AVAILABILITY

COASTAL PLANNING & ENGINEERING, INC
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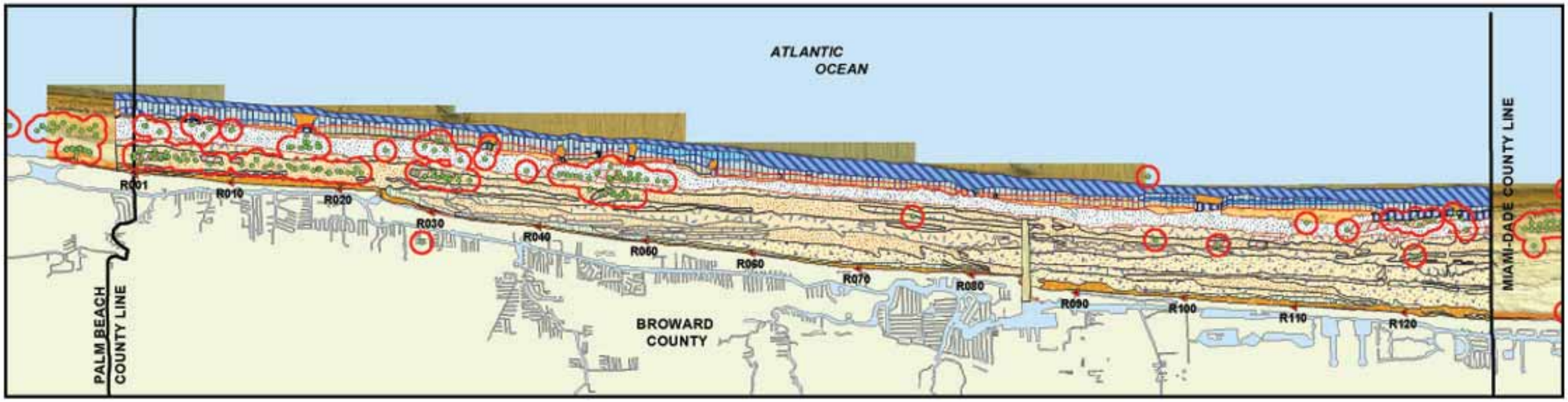
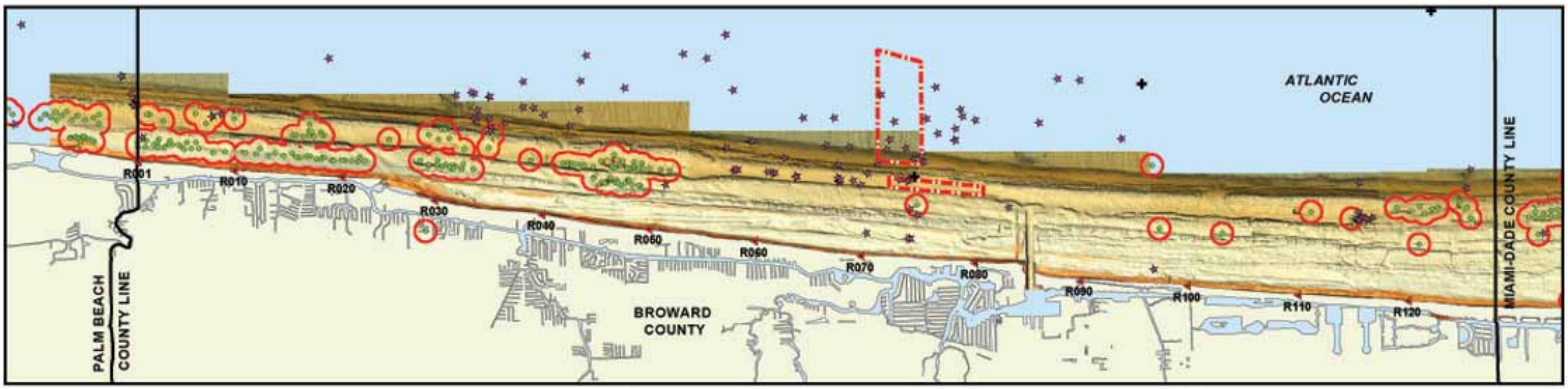
DATE: 02/15/07	BY: HMV	COMM NO: 7849.27	FIGURE 3-2B





LEGEND

- WRECK
- ARTIFICAL REEFS
- PORT EVERGLADES ANCHORAGE AREA
- BOTTOM RESTRICTIONS
- VIBRACORES
- VIBRACORE BUFFERS
- LAND
- FLORIDA MONUMENTS
- BAR AND TROUGH
- BORROW AREA
- CONTINENTIAL SLOPE
- CORAL REEF
- MARINE TERRACE 1
- MARINE TERRACE 2
- DREDGED CHANNEL
- NEARSHORE BAR
- NEARSHORE REEF
- NEARSHORE SAND FLAT
- NEARSHORE TROUGH
- OFFSHORE SAND FLAT
- PATCH REEF
- REEF GAP
- REEF GAP RAMP
- REEF OVERWASH
- STRUCTURAL SAND FLAT

N

0 1.5 3
Kilometers

TITLE:

BROWARD COUNTY
SAND RESOURCE AVAILABILITY

CPE
COASTAL PLANNING & ENGINEERING, INC
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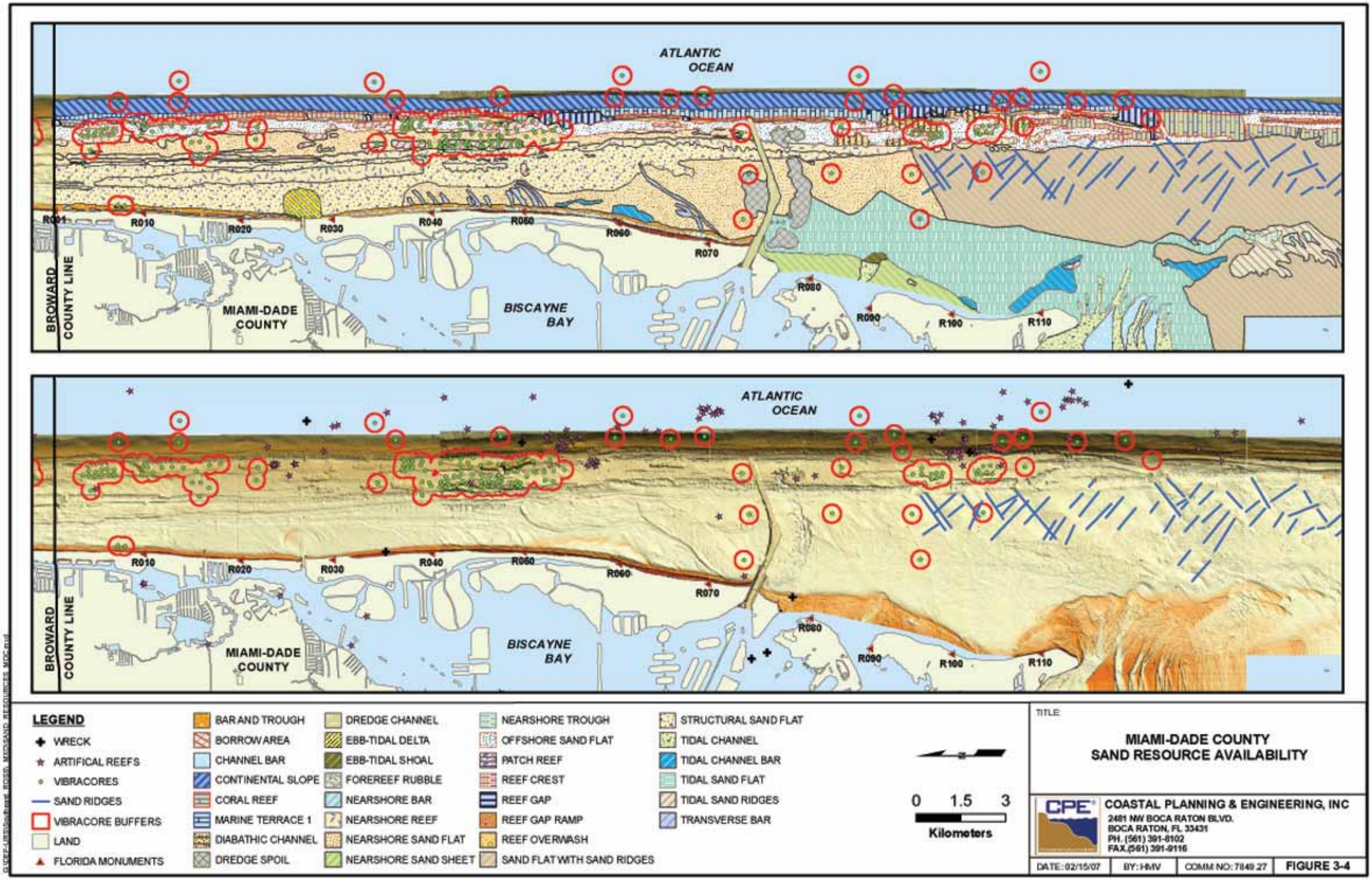
DATE: 02/15/07	BY: HMV	COMM NO: 7849.27	FIGURE 3-3



ATLANTIC OCEAN
BROWARD COUNTY LINE
MIAMI-DADE COUNTY
BISCAYNE BAY
R001
R010
R020
R030
R040
R050
R060
R070
R080
R090
R100
R110
ATLANTIC OCEAN
BROWARD COUNTY LINE
MIAMI-DADE COUNTY
BISCAYNE BAY
R010
R020
R030
R040
R050
R060
R070
R080
R090
R100
R110
LEGEND
WRECK
ARTIFICAL REEFS
VIBRACORES
SAND RIDGES
VIBRACORE BUFFERS
LAND
FLORIDA MONUMENTS
BAR AND TROUGH
BORROW AREA
CHANNEL BAR
CONTINENTAL SLOPE
CORAL REEF
MARINE TERRACE 1
DIABATHIC CHANNEL
DREDGE SPOIL
DREDGE CHANNEL
EBB-TIDAL DELTA
EBB-TIDAL SHOAL
FOREREEF RUBBLE
NEARSHORE BAR
NEARSHORE REEF
NEARSHORE SAND FLAT
NEARSHORE SAND SHEET
NEARSHORE TROUGH
OFFSHORE SAND FLAT
PATCH REEF
REEF CREST
REEF GAP
REEF GAP RAMP
REEF OVERWASH
SAND FLAT WITH SAND RIDGES
STRUCTURAL SAND FLAT
TIDAL CHANNEL
TIDAL CHANNEL BAR
TIDAL SAND FLAT
TIDAL SAND RIDGES
TRANSVERSE BAR
0 1.5 3
Kilometers
TITLE:
MIAMI-DADE COUNTY
SAND RESOURCE AVAILABILITY
CPE
COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116
DATE: 02/15/07
BY: HMV
COMM NO: 7849.27
FIGURE 3-4

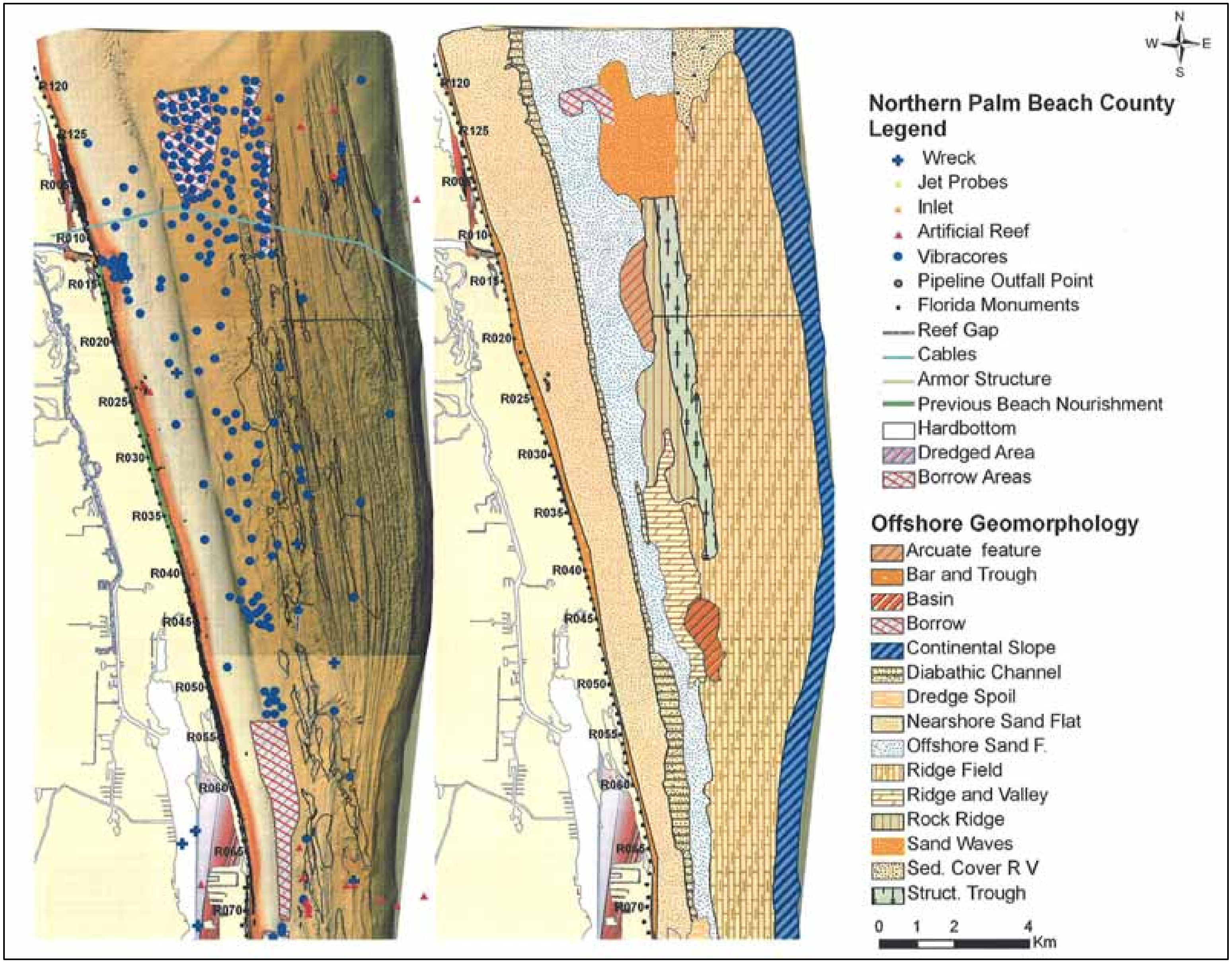


Figure 3-5A. Detailed view of submarine geomorphic units on the continental shelf off northern Palm Beach County, Florida, showing uninterpreted LADS bathymetry (left panel) and spatial distribution patterns of bottom types in the right panel. Note the extensive occurrence of the Nearshore Sand Flat and Offshore Sand Flat mapping units (right panel), a sand resource for beach nourishment.

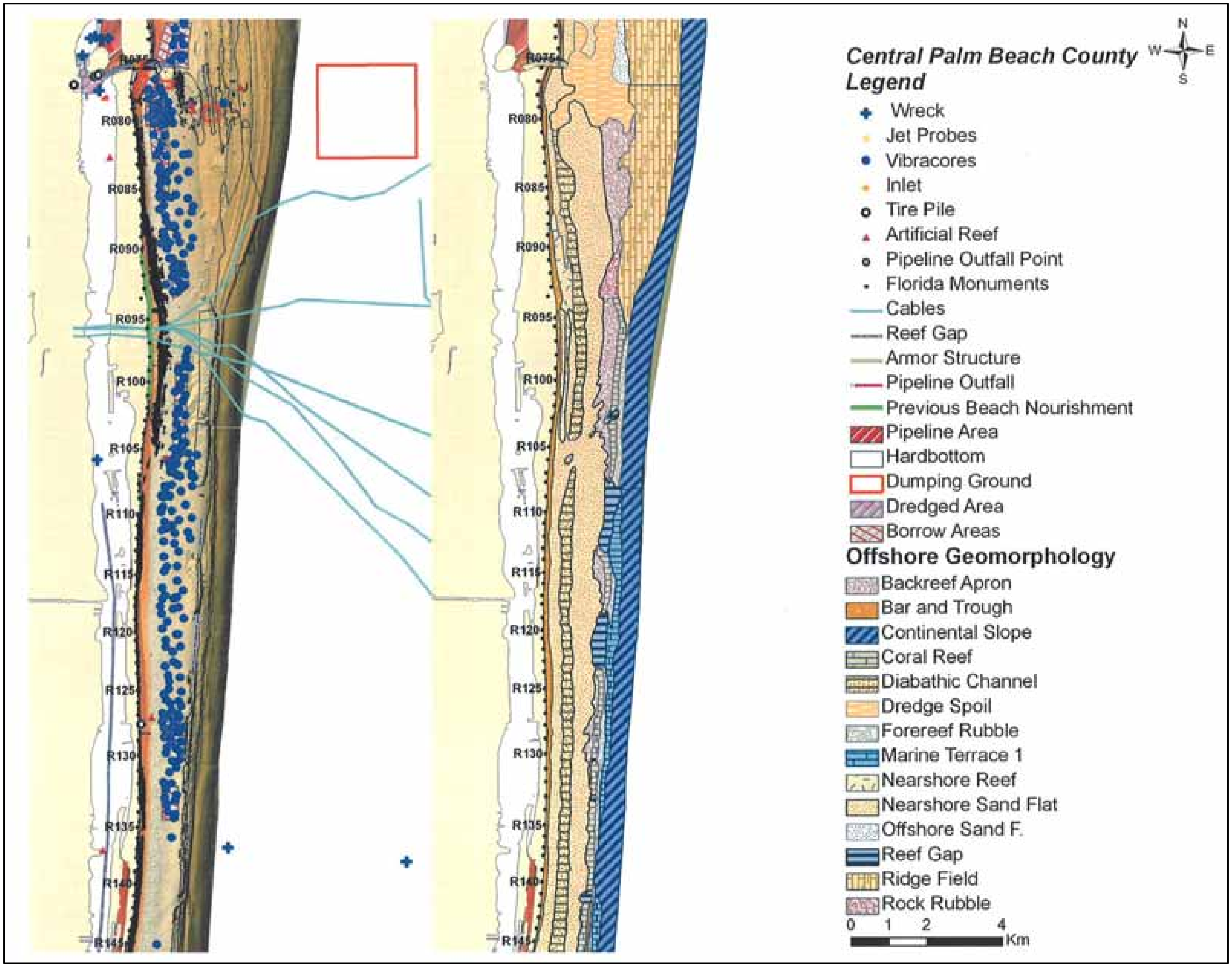


Figure 3-5B. Detailed view of submarine geomorphic units on the continental shelf off central Palm Beach County, Florida, showing un-interpreted LADS bathymetry (left panel) and spatial distribution patterns of bottom types in the right panel. Note the extensive occurrence of the Nearshore Sand Flat mapping unit (right panel), a sand resource for beach nourishment, decrease in area of bedrock outcrops (Ridge Field mapping unit), and presence of barrier coral reefs along the edge of the shelf.

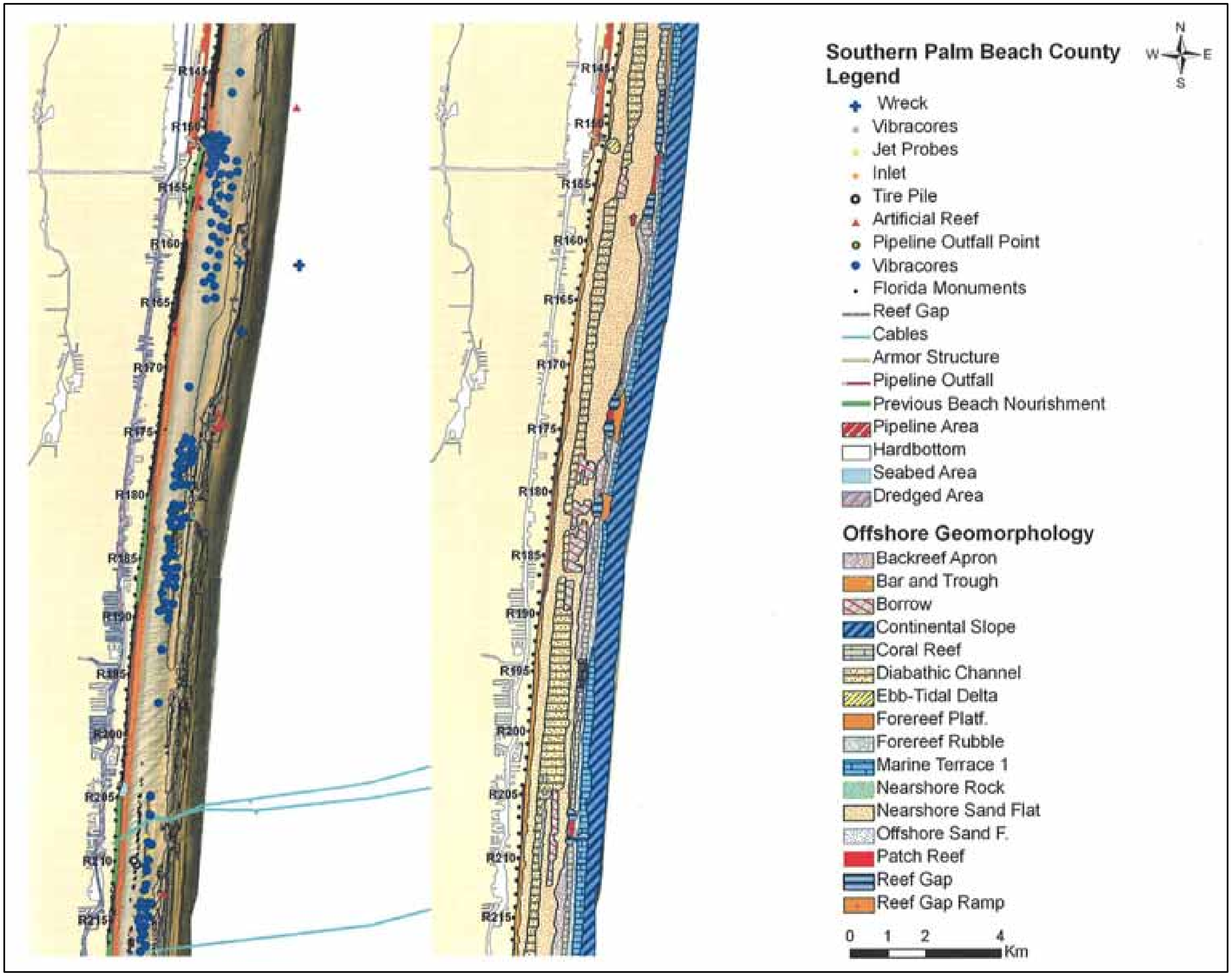


Figure 3-5C. Example of submarine geomorphic units on the continental shelf off southern Palm Beach County, Florida, showing uninterpreted LADS bathymetry (left panel) and spatial distribution patterns of bottom types in the right panel. Note the extensive occurrence of the Nearshore Sand Flat mapping unit (right panel), a sand resource for beach nourishment, that contains diabathic channels.

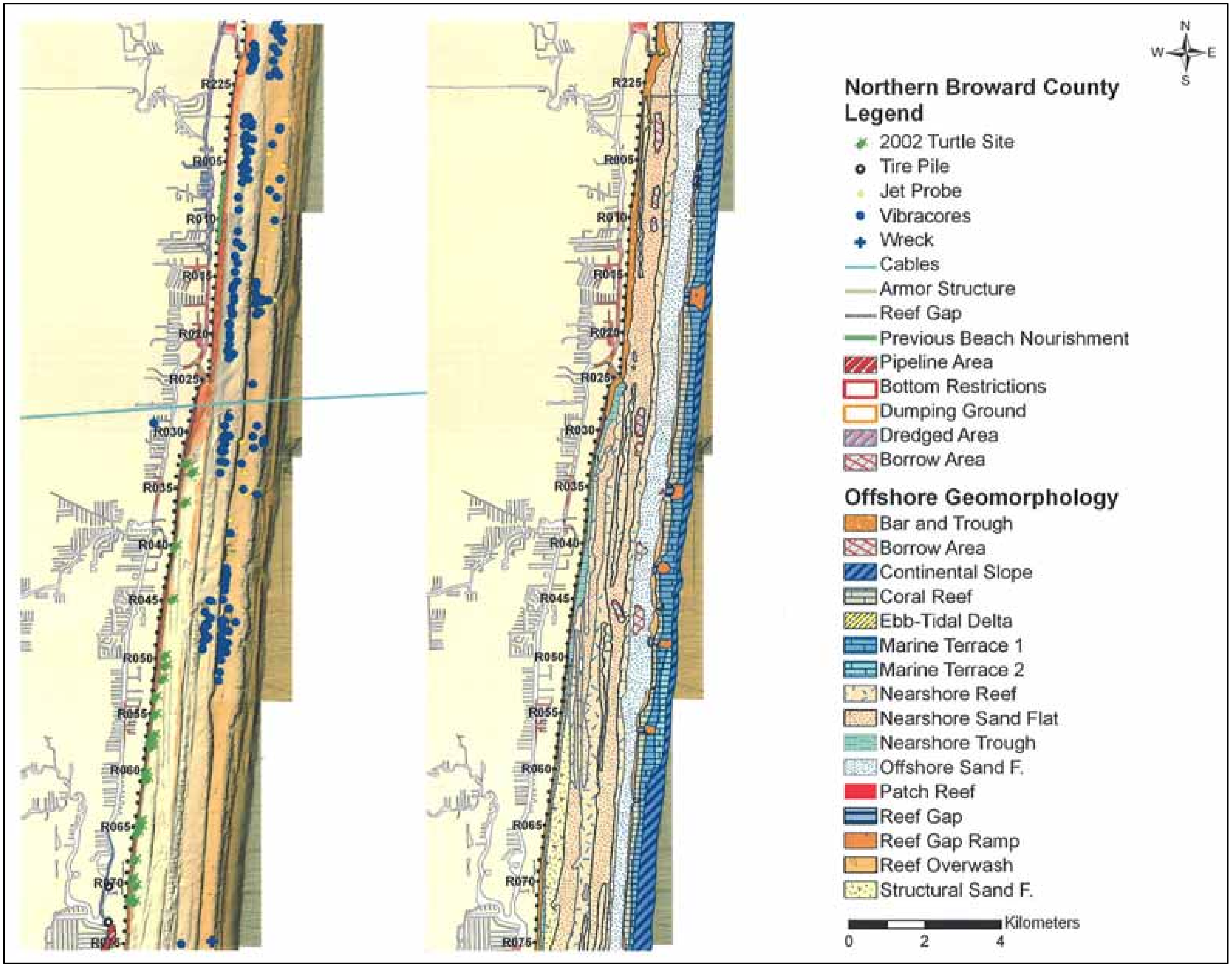


Figure 3-6A. Submarine geomorphic units on the continental shelf off northern Broward County and showing uninterpreted LADS bathymetry (left panel) and spatial distribution patterns of bottom types (right panel). Note the areal increase of nearshore reefs as they fragment and constrict the Nearshore Sand Flat mapping unit. Note also the more or less uninterrupted extent of the Offshore Sand Flat mapping unit.

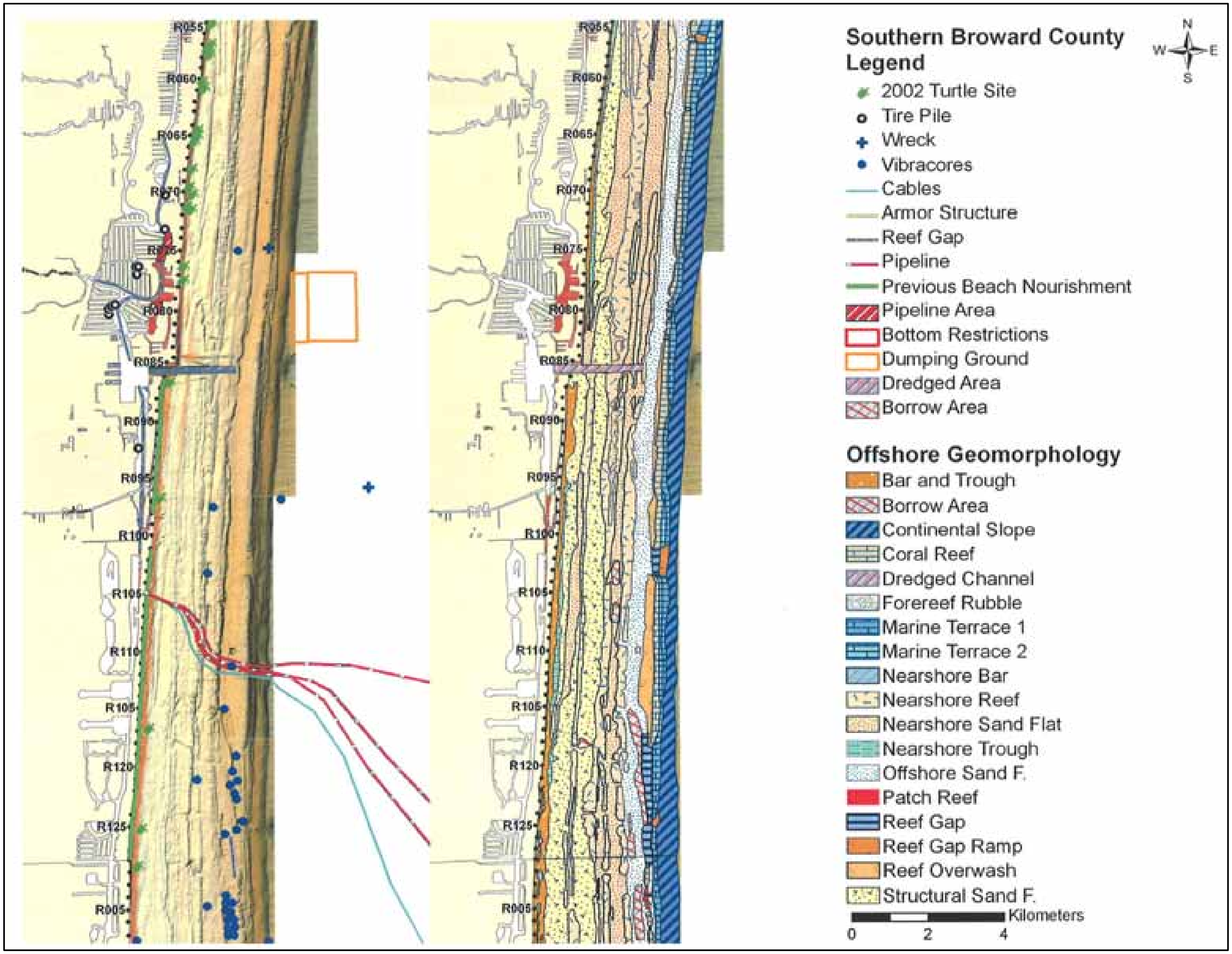


Figure 3-6B. Submarine geomorphic units on the continental shelf off southern Broward County showing uninterpreted LADS bathymetry (left panel) and spatial distribution patterns of bottom types (right panel). Note the areal increase of the Structural Sand Flat mapping units that fragment and constrict the Nearshore Sand flat mapping unit. Note also the decrease in width of offshore sand flat areas.

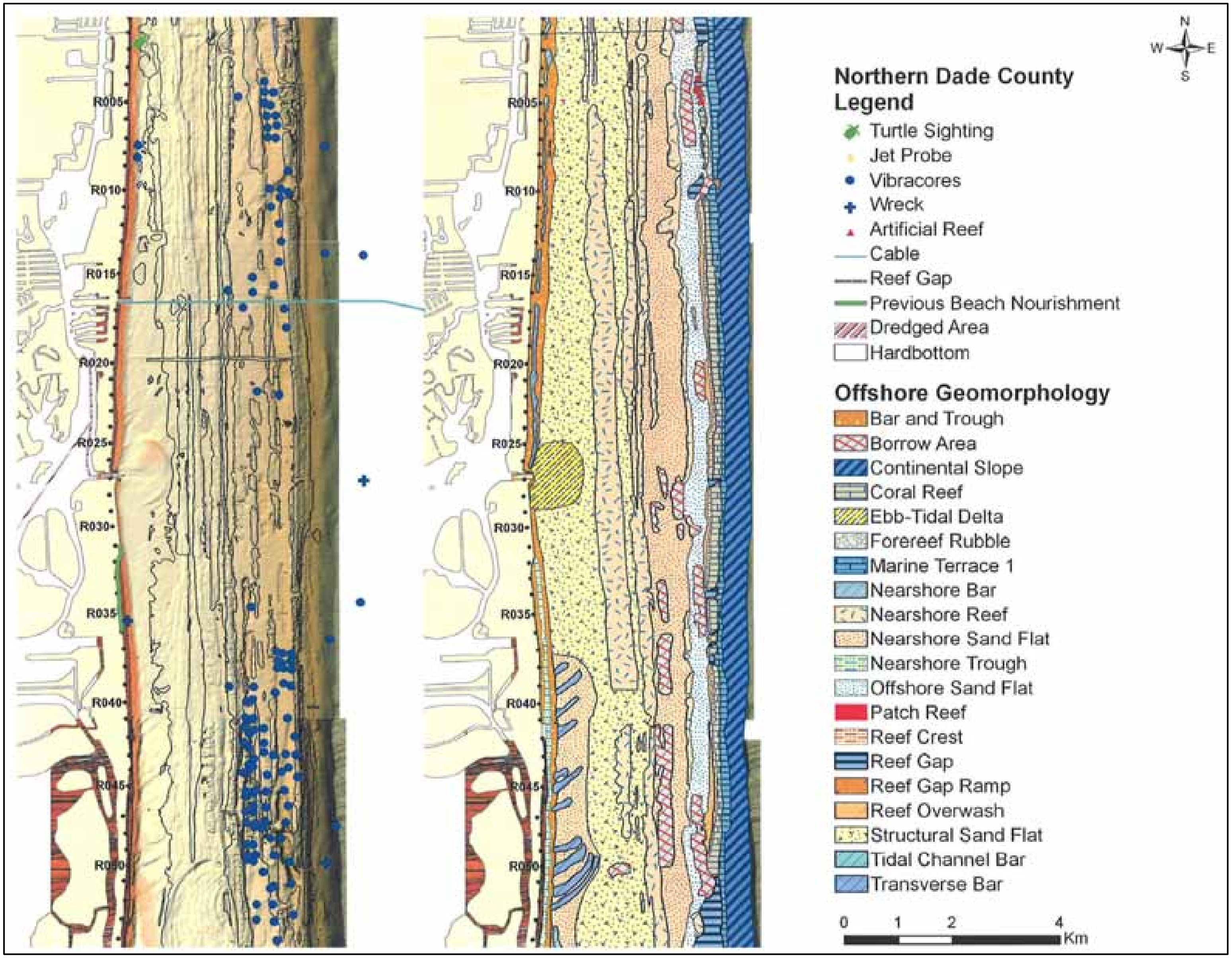


Figure 3-7A. Submarine geomorphic units on the continental shelf off northern Miami-Dade County, Florida, showing uninterpreted LADS bathymetry (left panel) and spatial distribution patterns of bottom types (right panel). Note the extensive occurrence of structural sand flats that are fragmented by nearshore reefs. The expanse of structural sand flats is interposed between the shore and nearshore reefs.

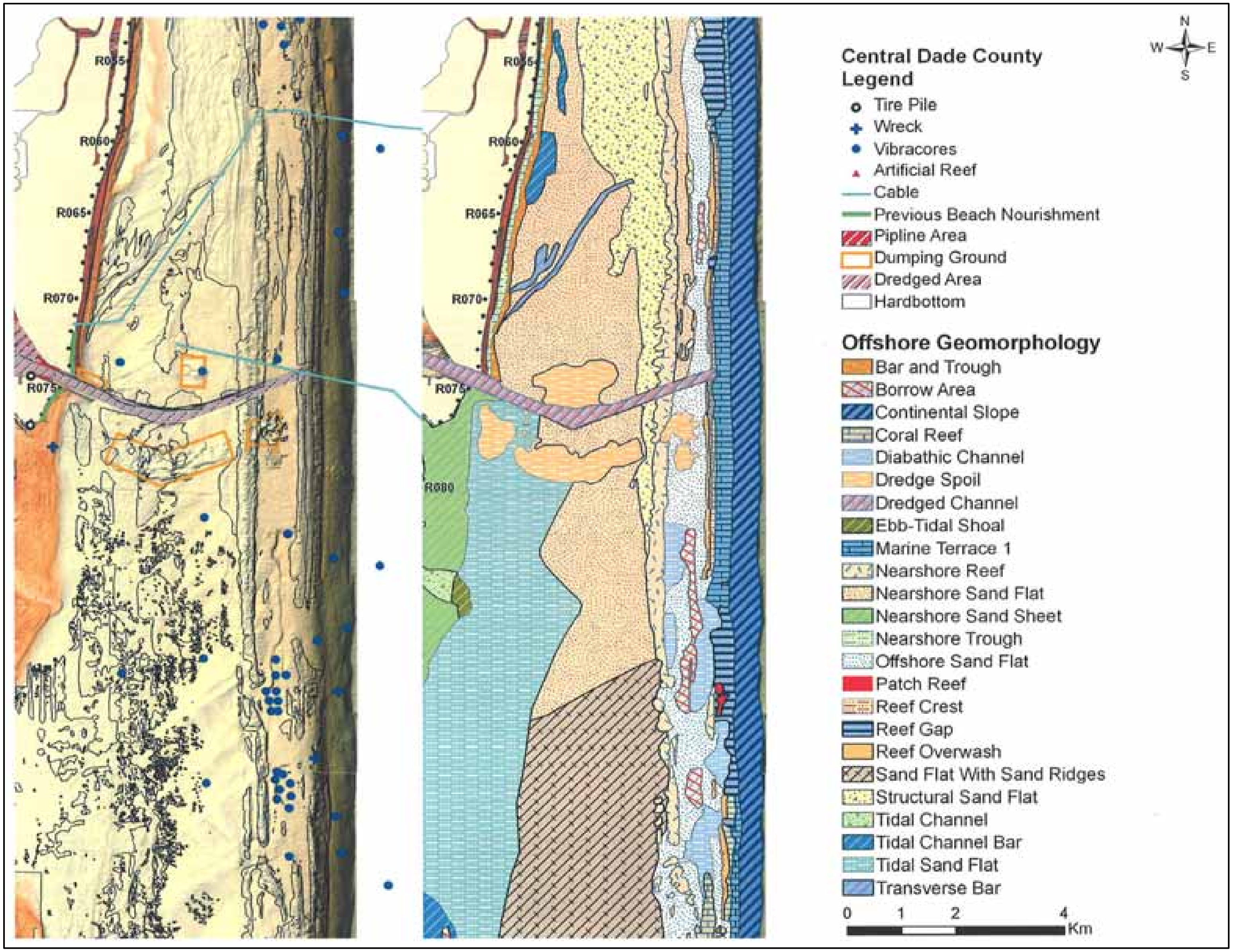


Figure 3-7B. Submarine geomorphic units on the continental shelf off central Miami-Dade County, Florida, showing uninterpreted LADS bathymetry (left panel) and spatial distribution patterns of bottom types (right panel). Note the extensive occurrence of unconsolidated sediments comprising the surface of seafloor in the form of tidal sand flats, nearshore sand flats, and offshore sand flats.

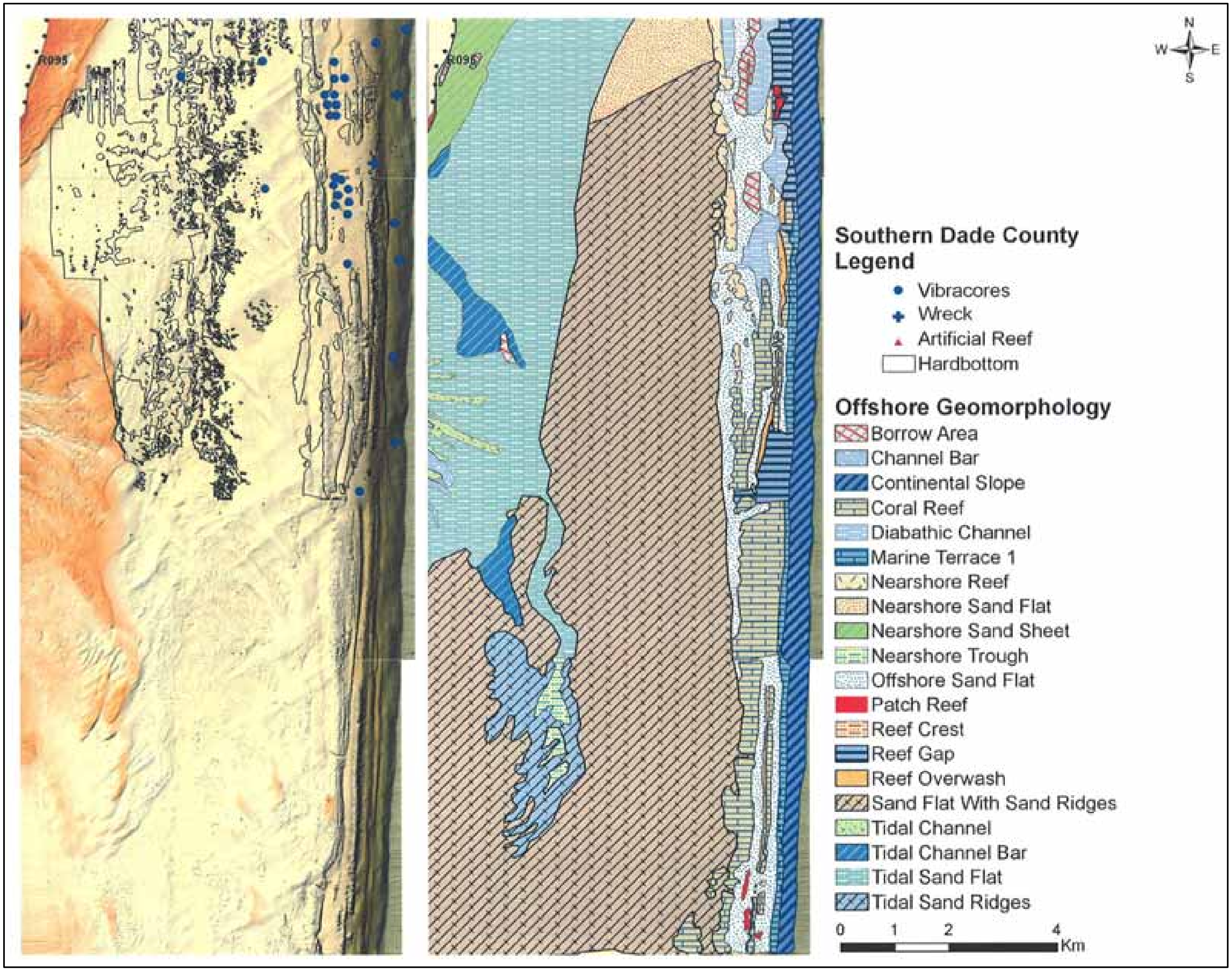


Figure 3-7C. Submarine geomorphic units on the continental shelf off southern Miami-Dade County, Florida, showing uninterpreted LADS bathymetry (left panel) and spatial distribution patterns of bottom types (right panel). Note the extensive occurrence of unconsolidated sediments comprising the surface of seafloor in the form of tidal sand flats and sand flats with sand ridges. Nearshore sand flats and offshore sand flats are limited in areal extent.

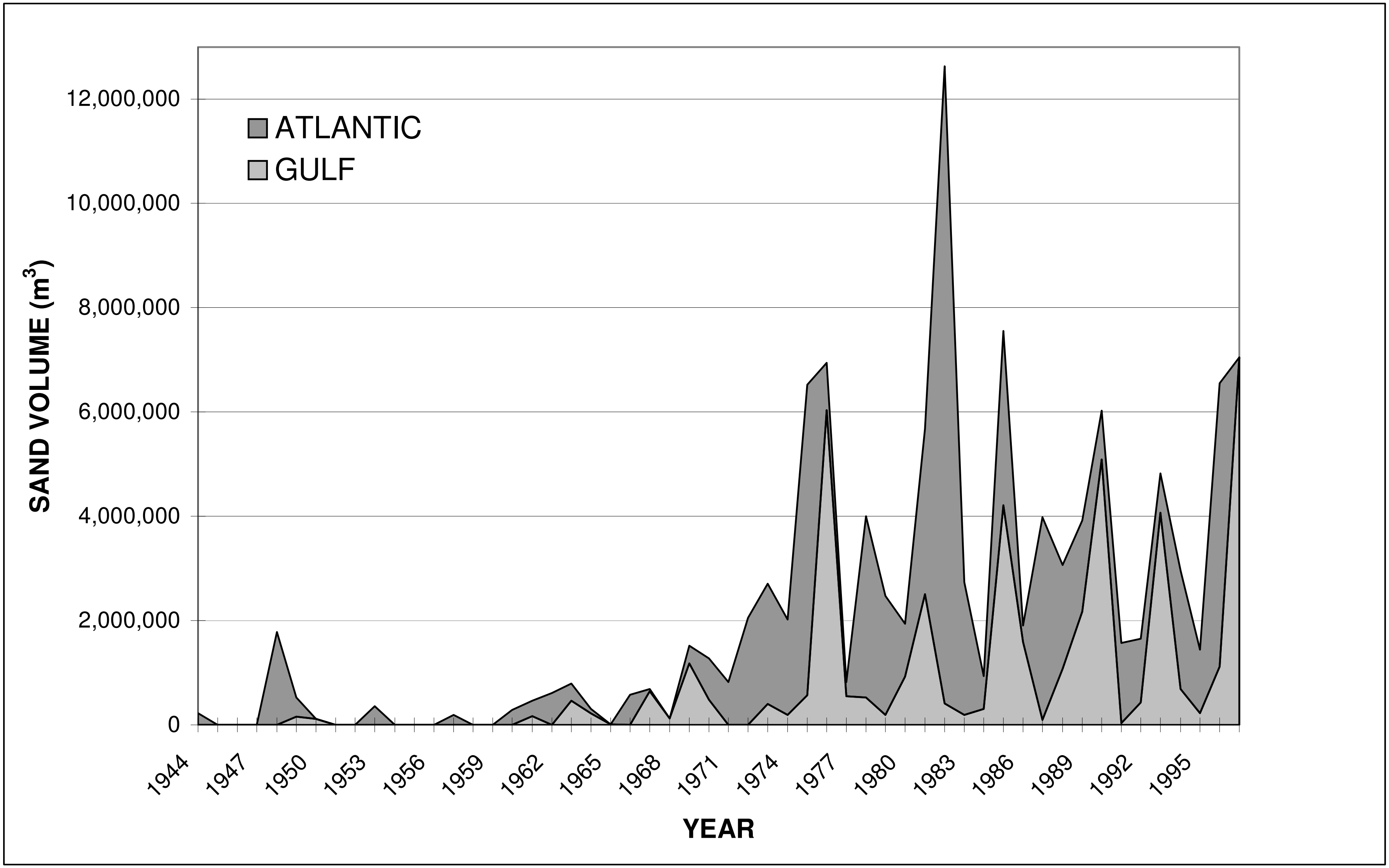


Figure 3-8. Evolution (1944 to 1997) of total sand volume used to nourish Florida beaches (Gulf and Atlantic coasts). Note the replenishment cycle by high peaks every four or five years (based on Esteves, 1997; Finkl, Benedet and Campbell, 2006).

Areas not previously investigated offer promise as potential sand resource areas. These areas differ from those that have been exploited as borrows and are distinct from areas not tested adequately, which may contain some widely spaced vibracores. Perusal of Table 4-1 shows significant areas of bottom sediment that have not been investigated viz. 40% in Palm Beach County, 57% in Broward County, and 86% in Miami-Dade County.

A total of thirteen potential sand source areas have been identified in the Phase I southeast region. Five sources are located in the nearshore waters off Palm Beach County, four off Broward County and four off Dade County (Figure 4-1). Several of these areas have been selected for further analysis using the data and information found in the ROSS database. This analysis will make use of geophysical data along with vibracores, jet probes and grab sample information where available. The outcome of this analysis will show what is known about the sand resources in each of these areas. Table 4-2 is a summation of the data for each of these areas currently available in ROSS. Additionally, sand volumes for each of these potential areas are presented based on 3 ft., 6 ft., and 9 ft cuts. The following sections will discuss in greater detail each of the potential sand source borrow areas identified as part of this study.

The process for this analysis will be the same for each of the areas selected and will be accomplished by using the data and information residing in the ROSS database. From the ROSS website, users can activate various layers on the IMS site, utilize images on the associated ftp site, and access the data in the Oracle database through the Enhanced Query Builder (EQB). This analysis will follow five steps by showing; 1) the location of the potential sand source areas, 2) the location of the geophysical tracklines, 3) the geophysical images (from the ftp site), 4) the vibracore and/or jet probe and grab sample locations and 5) the data pertaining to each core layer or sand sample from the Oracle database.

4.1 PALM BEACH COUNTY

Nearshore sand flats in Palm Beach County that may represent potential sand resource areas include segments offshore from R050 to R071, R094 to R097, R137 to R152, and R161 to R175 (Figure 4-2). An interesting new potential sand resource occurring in nearshore sand flats are diabathic channels, as reported by Finkl, Benedet and Andrews (2006), that extend more or less continuously alongshore. Coastal segments that have not been studied for this specific type of seabed feature include those between R055 to R070, R094 to R104, R130 to R145, R165 to 175, and R193 to R217. Some of the diabathic channels fall within the 300 m sphere of influence of vibracores but they really are not represented by the vibracore due to distinct sedimentary boundaries between the storm deposits with channels and sand flat units. Of the five areas identified off Palm Beach County, only two have both geophysical data and cores. These are PB-1 and PB-5 which will be discussed here.

PB-1 lies offshore between Palm Beach range monuments R055 and R071. This area has been described as diabathic channels (described in Section 3) occurring in the nearshore sand flats physiographic zone. Figure 4-3 shows this zone overlaying the gray scale image. Data in ROSS shows that three studies have been conducted in this area. These are the 1990 USACE Coast of Florida Study (USACE, 1990), the 2004 Palm Beach County Singer Island Vibracore Study (Zarillo, 2004) and the 2005 Palm Beach County Singer Island Vibracore Study (Zarillo, 2006). These studies have resulted in the collection of geophysical and vibracore data in this area.

Figure 4-4 shows the locations of geophysical tracklines in this area collected as part of the USACE Coast of Florida Study.

A total of 13 vibracores from the Palm Beach Singer Island study are located within Area PB-1. Figure 4-5 shows the locations of these cores and Table 4-3 contains the related data stored in ROSS. The data shows that the majority of these cores contain almost identical layer descriptions, showing mostly fine- to medium-grained quartz and carbonate sands. The associated samples taken from these cores show mean grain size ranging from 0.09 to 3.05 phi. Only two samples out of seventy-one fall below the 1.0 phi value (cores S104-3 and S104-6). This range places the majority of the sand analyzed from all these cores in the fine to medium grain size category using the Unified Soils Classification System (USCS).

Several geophysical tracklines, taken for the USACE 1990 Coast of Florida Study cross this feature. These are lines 57, 62 and 66, and the related images are shown in Figures 4-6, 4-7 and 4-8. These images have been annotated to show the extent of diabathic channels within the approximate location of Area PB-1 and the extent of the potential sand source related to the diabathic channel.

PB-5 is located between Palm Beach county range monuments R-195 and R-217. This area is south of PB-1 and is a continuation of the nearshore sand flats physiographic zone (Figure 4-9). This area is also characterized as including the diabathic channels. An extensive geophysical survey, the 2004 North Boca Raton Seismic Study has been conducted in this area. This study was concentrated mostly in the center of this area leaving the northern and southern portions candidates for further investigation.

Data in the ROSS database shows a total of 19 vibracores located within the boundary of the PB-5 area. Twelve of these are from the Palm Beach County 2004 Highlands (Zarillo, 2004) vibracore study and 5 from the 2004 North Boca Raton Seismic Study(CPE, 2004) (Figure 4-10). The data contained in ROSS relating to these cores is found in Table 4-4a. As in area PB-1 these cores show that the majority of the sediments in this area to be mostly fine quartz sand with some medium to fine carbonate sands. The mean grain size ranges from 1.32 to 2.49 phi which falls within the fine sand category using the USCS. Two additional cores also found in the PB-5 area are Cores BR-1 and #22, (Figure 4-10), from the 1984 North Boca Raton Sand Search (CPE, 1984) and the 1969 Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Florida study (Duane & Meisberger, 1969) respectively. The granulametric data for these cores show mean grainsize is slightly larger, 0.27 to 0.38 phi, corresponding to medium sand using the USCS.

Analysis for this study also includes descriptions and granulometry for composite samples (highlighted in Table 4-4b) extracted from the cores taken as part of the Palm Beach County 2004 Highlands (Zarillo. 2004) vibracore study. As would be expected, the range of means for these composites is 1.61 to 2.36 phi, falling within the fine sand category on the USCS.

Geophysical data collected during the CPE 2005 North Boca Raton Beach Nourishment Project (Finkl, Andrews and Benedet, 2005), covers the central portion of area PB-5. Five of these lines are presented here as representative of this dataset. These are lines 4, 19, 32, 56 and 72. Figure 4-11 shows the location of the selected tracklines and Figures 4-12 and 4-13 are the images from these tracklines. These images have been annotated to show the extent of area PB-5 within PB-5 extents, various reflectors and the location of potential sand sources.

4.2 BROWARD COUNTY

Broward County contains sand flat areas that may contain potential sand resources that are suitable for beach renourishment. Both nearshore and offshore sand flats have already been exploited (4.7% of the sand resource area) (Table 4-1) via borrows and good sand may reside in adjacent units. Gaps in offshore sand flat areas previously studied include those offshore from R011 to R027 and R053 to R105 as well as gaps in nearshore sand flats from R050 to R070 and R086 to R120.

As part of this study, four areas have been designated as potential sand source locations. These are shown on Figure 4-14. This figure also shows the extent of the Coast of Florida Study geophysical lines for Broward County. A review of the ROSS database shows that two of these areas, B-1 and B-3, have sufficient data on which to perform an analysis.

B-1 is found offshore Broward County between Range Monuments R-011 and R-027. This area is designated as the Offshore Sand Flat physiographic zone and is situated between the nearshore reef and coral reef physiographic zones (Figure 4-15). Data from ROSS shows that there have been eight vibracores taken in this region from the Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida, (CPE, 1996). These core locations are seen in Figure 4-16. Additionally five jet probes were collected for this same study. The locations for the jet probes may be seen in Figure 4-17. The only geophysical data shown in this area was collected for the USACE 1990 Coast of Florida Study (USACE, 1990) (Figure 4-14).

A review of the vibracore data shows that the majority of these cores maintain a general pattern of finer sand, coarsening down core. Several cores, VC96-18, VC96-48 and VC96-51, show thin layers (½ to 1 ft thick) composed predominantly of rock fragments approximately 4 feet below the top of the core (Table 4-5).

Jet probes taken by CPE for the Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida, (CPE, 1996) also show mostly sand at the top with increasing rock fragments and shell hash at depth (Table 4-6).

Geophysical data for B-1 was collected during the USACE 1990 Coast of Florida Study (USACE, 1990). Lines B-4, B-5 and B-6 traverse this area. Figures 4-18 through 4-20 clearly show the extent of the Offshore Sand Flats physiographic zone between the nearshore reef and the seaward coral reef.

B-3 is an area located between Broward County Range Monuments R-054 and R-104 (Figure 4-21). This area is also part of the Offshore Sand Flat physiographic zone. B-3 lies between the Nearshore Reef and Coral Reef physiographic zones. The ROSS database contains jet probe data and geophysical information from three studies that provide data for this area. These are the Broward County, Florida Bathymetric and Sand Inventory Survey, 1967 (Ocean Science and Engineering, 1967), the Broward County Erosion Prevention District – Core Boring Analysis for Zone II and Zone IV, 1976 (D.E. Britt and Assoc, 1976) and the Coast of Florida Study (USACE, 1990).

Jet probes A-1 through A-11 for the Broward County Erosion Prevention District – Core Boring Analysis for Zone II and Zone IV, 1976 (D.E. Britt and Assoc, 1976) were taken on a west to east trending transect in a location that essentially bisects area B-3 (Figure 4-22). Data from all probes indicate that the majority of the sediment is medium to coarse sand with traces of rock and/or gravel (Table 4-7). The average depth of these probes was approximately 6 feet with maximum penetration to 10 feet below the surface (Table 4-7). Jet probes P-9, P-16, P-17, and P-23 from the Broward County, Florida Bathymetric and Sand Inventory Survey, 1967 (Ocean Science and Engineering, 1967), were taken on the western edge of area B-3 just on the fringe of the inner nearshore reef (Figure 4-22). These probes also show that the majority of sediments are medium sand (Table 4-7).

Geophysical data was collected in this area as part of the USACE 1990 Coast of Florida Study (USACE, 1990). Lines B-13 through B-24 zigzag across area B-3 (Figure 4-23). Figures 4-24 through 4-29 show the images of these sub-bottom profiles. These images have been annotated to show the locations of the inner and outer reefs, as well as the extent of the Offshore Sand Flats physiographic zone. Each line is annotated with ship direction for better understanding.

4.3 DADE COUNTY

About 86% of the sand resource area in Miami-Dade County has not been previously investigated (Table 4-1). Potential sand resource areas in Miami-Dade County for nearshore sand flats include segments offshore from R001 to R032 and from R037 to R095. Gaps in areas previously studied in offshore sand flats include those offshore from R023 to R033 and R055 to 070. Extensive areas of tidal sand flats, sand flats with sand ridges, and tidal sand ridges have not been studied and offer potential as a sand resource.

Four areas have been designated as potential sand sources offshore of Dade County. These are D-1 through D-4 (Figure 4-30). D-1 and D-4 are located in the nearshore sand flats, D-2 and D-3 are in the offshore sand flats. Of these four, only D-2 has had geophysical data added to the ROSS database. All of the other three areas have vibracore information only. Each of these areas will be discussed below. Additionally an area south of D-4 will also be discussed.

D-1 is located offshore of the northern end of Dade County between Range Monuments R001 and R032 (Figure 4-31). This potential sand source is situated within the nearshore sand flats physiographic area and is bounded on the west and east by the nearshore reef. Data residing in ROSS for this area includes 12 vibracores and one grab sample (Figure 4-32). These include one vibracore from the Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Florida project (Duane & Meisburger, 1969), two vibracores from the Beach Erosion Control and Hurricane Protection Study for Dade County, Florida North of Haulover Beach Park (USACE, 1988), three from the North Dade County Beach Erosion Control (1978) project (USACE, 1978) and seven from the Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida (USACE, 1974) study. This data is presented in Table 4-8a. There is also one grab sample from the 1964 USGS / Woods Hole Oceanographic Institution (Hathaway, J., 1994) study of the Atlantic Continental Margin (Table 4-8b).

A review of the vibracore data from this area shows sediments are comprised mostly of medium to coarse carbonate sands (Table 4-8a). This information is taken from descriptions from the core logs. However, analytical data from only one core was received and entered into the database. This includes four sample descriptions from core #12 from the Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Florida (Duane & Meisburger, 1969). From this core, four samples were taken from the 0 to 0.5, 0.5 to 2.0, 2.0 to 5.0 and the 5.0 to 7.5 core depth intervals. The samples show mean grain sizes of 0.26, 0.36, 0.46 and 0.56 phi respectively. Using the USCS classification scheme, this places the sediments within the medium sand range.

The only grab sample shown in this area was collected for the 1964 USGS / Woods Hole Oceanographic Institution (Hathaway, J., 1994) study of the Atlantic Continental Margin. In addition to the sample identification and location information, the data includes the mean grain size of 1.26 phi (Table 4-8b), which places this sample exactly between the medium to fine category using the USCS classification scheme.

D-2 is located approximately 2 miles off the coast of Dade County between Range monuments R-022 and R-033 (Figure 4-33). It is found between the nearshore reef and coastal reef physiographic units. The data residing in ROSS for this area was collected during the USACE 1990 Coast of Florida Study (USACE, 1990), and the Geomorphology and Sediments of the Nearshore Continental Shelf, Miami to Palm Beach, Florida study (Duane & Meisburger, 1969).

Only one vibracore and one grab sample are shown to have been taken from this area (Figure 4-34). Core # 11 was collected as part of the Geomorphology and Sediments of the Nearshore Continental Shelf, Miami to Palm Beach, Florida study (Duane & Meisburger, 1969).

A review of the ROSS database shows that 3 sediment samples were taken from the core and analyzed (Table 4-9a). The descriptions for each of these samples are identical and show that they are made up of mostly medium to coarse carbonate sand with some shell fragments. The mean grain size for these three samples ranges from 0.21 to 0.62 phi. This corresponds to medium sand using the USCS classification. The grab sample was collected as part of the USGS/Woods Hole Oceanographic Institution study (Hathaway, J., 1994). The only data for the grab sample shows a mean grain size of 1.85 phi, placing it in the fine sand range using the USCS (Table 4-9b).

Geophysical data, in the form of sub-bottom profiles, was collected in this area for the USACE 1990 Coast of Florida Seismic Survey and Seismic Coring Study (USACE, 1990). Two tracklines cross area D-2 (Figure 4-35). These are lines D-35 and D-36, which are shown in Figure 4-36. These images have been annotated to show the Offshore Sand Flats, Nearshore Reef and Coral Reef physiographic zones.

D-3 area is also located in the Offshore Sandflats physiographic zone due south of the D-2 area, between Range Monuments R-055 and R-072 (Figure 4-37). As with the other potential borrow sites identified in the Tri-County area, this site is located between the nearshore reef and the more seaward Coral Reef. Data residing in ROSS for this area comes from the USACE 1974 study "Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida".

There are a total of 5 vibracores in the D-3 area (Figure 4-38). The associated data from the ROSS database is presented in Table 4-10. The core descriptions show the sediments in the D-3 area are mostly made up of medium-grained, carbonate sands.

Currently there is no geophysical data in ROSS for D-3.

D-4 is the largest of the potential areas in Dade County. It is also the area with the least amount of data. Located between Range Monuments R037 and R101, this area is primarily in the Near Shore Sand Flats physiographic region and includes the Transverse Bars and Structural Sands physiographic zones (Figure 4-39). One other prominent feature shown on Figure 4-39 is the location of dredge spoils proximate to the Macarthur Causeway.

The ROSS database contains information on seven vibracores taken in this area as part of two different studies (Figure 4-40). Five cores come from the Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (Duane & Meisburger, 1969) and two are from the Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida (USACE, 1974). These cores are located in the lower portion of the study area and are too widely spaced to give much more than a cursory look at the actual bottom sediment characteristics. Descriptive core layer information indicates that shallow sediments in these cores are mostly carbonate sands ranging from fine to coarse. Corresponding records for mean grain size show a range from 0.17 to 0.53 phi (Table 4-11). These values fall within the medium grain size category using the USCS classification.

Sand Ridge Area Sand ridges (see Sand Flat with Sand Ridges mapping unit in Figure 4-41), constitute a potential sand resource that should be investigated in Miami-Dade County.

These types of features have been described for the central-west coast of Florida (Finkl *et al.*, 2007) and their occurrence along the southeast coast is worthy of note. The locations of these sand ridges are shown as blue lines on Figure 4-41 for easy reference. Results of the west coast study concluded that widely-spaced sediment ridges, interspersed by karstified limestone seafloor (hardgrounds), offer potential as sand resources that can be exploited by dredging to renourish eroded beaches for shore protection. The sand ridges, late Holocene in age, are generally shoreface-detached, sediment-starved, and occurring in clusters identified as ridge fields. The ridge fields are now recognized as important sand resources on the sediment-starved continental shelf off the central-west coast of Florida. Although the shelf has traditionally supplied beach-quality sediments from ebb-tidal shoals and nearshore sand sheets, sand searches increasingly need to look to offshore resources as these supplies dwindle. The same situation occurs along the southeast coast where sand ridges should be regarded as potential sand resources worthy of investigation for use in beach renourishment activities in Miami-Dade County.

Table 4-1. Companion to Table 3-6 showing the same information but in terms of percentage of the total potential sand resource area by borrow, explored but not exploited, and areas not investigated or explored.

County	Sand Area (m^2)	Borrow Area Exploited (%)	Explored but Not Exploited (%)	Not Investigated, Explored (%)
Palm Beach	122,779,106	2.2%	57.6%	40.3%
Broward	40,856,915	4.7%	38.7%	56.6%
Dade	164,176,116	2.4%	12.0%	85.6%

Figure 4-2. A Listing of the Potential Borrow Sites with Volume Calculations, and Available Data From ROSS

Potential Area	Areal Extent (sq.ft)	Areal Extent (acres)	Total Volume (3 ft cut) with setbacks	Total Volume (6 ft cut) with setbacks	Total Volume (9 ft cut) with setbacks	# of Vibracores	# of Jet Probes	# of Grab Samples	# of Geophysical Tracklines
PB-1	30911421.06	711.00	3,434,616	6,869,232	10,303,848	13	0	0	7
PB-2	18641201.01	428.70	2,071,253	4,142,506	6,213,759	1	0	0	3
PB-3	25321323.27	582.40	2,813,492	5,626,983	8,440,475	2	0	0	34
PB-4	16147766.58	371.40	1,794,203	3,588,407	5,382,610	11	0	0	0
PB-5	41709134.59	959.30	4,634,367	9,268,734	13,903,100	10	0	0	79
BROW-1	29874179.34	687.10	3,319,367	6,638,733	9,958,100	8	5	0	3
BROW-2	27919640.81	642.20	3,102,195	6,204,389	9,306,584	0	0	0	0
BROW-3	137317883.80	3158.30	15,257,604	30,515,207	45,772,811	0	15	0	12
BROW-4	56518557.84	1299.90	6,279,865	12,559,730	18,839,595	2	0	0	0
DADE-1	99087582.80	2279.00	11,009,775	22,019,551	33,029,326	12	0	1	0
DADE-2	14305756.98	329.00	1,589,535	3,179,070	4,768,605	1	0	1	2
DADE-3	27992859.22	643.80	3,110,330	6,220,660	9,330,990	5	0	0	0
DADE-4	359957191.76	8279.10	39,995,404	79,990,807	119,986,211	7	0	0	0

Note: Volume calculations incorporate 400-ft environmental setbacks, established by the NMFS and adopted by FDEP

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-3	-62.12	94	1.3	0	10YR 6/1	mostly Medium To Fine Sand; some Fine To Coarse Shell Fragments; trace Medium Gravely Whole Shell	SI04-3 #1.0	1	1.5	2.27
Palm Beach County Vibracore 2004 - Singer Island	SI04-3	-62.12	95	2.6	1.3	10YR 7/2	mostly Medium To Fine Sand; some Medium Gravely Whole Shell; little Fine To Coarse Shell Fragments	SI04-3 #1.0	1	1.5	2.27
Palm Beach County Vibracore 2004 - Singer Island	SI04-3	-62.12	96	2.8	2.6	10YR 7.5/1	mostly Rock Fragments				
Palm Beach County Vibracore 2004 - Singer Island	SI04-3	-62.12	97	9.9	2.8	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Shell Fragments; little Medium Peaty Whole Shell	SI04-3 #4.0	4	4.5	1.64
Palm Beach County Vibracore 2004 - Singer Island	SI04-3	-62.12	97	9.9	2.8	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Shell Fragments; little Medium Peaty Whole Shell	SI04-3 #8.0	8	8.5	1.74
Palm Beach County Vibracore 2004 - Singer Island	SI04-3	-62.12	98	13	9.9	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Medium To Fine Gravely Whole Shell; little Fine To Medium Gravely Shell Fragments	SI04-3 #11.0	11	11.5	0.9
Palm Beach County Vibracore 2004 - Singer Island	SI04-3	-62.12	99	13.6	13	10YR 7.5/2	mostly Rock Fragments; some Shell Fragments				

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-3	-62.12	100	14.2	13.6	10YR 5.5/1	mostly Fine Quartz Sand; some Fine Carbonate Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-3	-62.12	101	17.5	14.2	10YR 6.5/1	mostly Medium To Fine Carbonate Sand; some Medium To Fine Quartz Sand; some Fine To Coarse Gravely Shell Fragments; little Fine To Coarse Gravely Whole Shell				
Palm Beach County Vibracore 2004 - Singer Island	SI04-3	-62.12	102	18.2	17.5	10YR 6.5/1	mostly Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-3	-62.12	103	20.2	18.2	10YR 8/2	mostly Carbonate Sand; some Silt; some Rock Fragments	SI04-3 #Comp	19		1.36
Palm Beach County Vibracore 2004 - Singer Island	SI04-5	-52.95	109	1	0	10YR 7/2	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; trace Fine Gravely Shell Fragments				
Palm Beach County Vibracore 2004 - Singer Island	SI04-5	-52.95	110	5.2	1	10YR 7/2	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Rock Fragments	SI04-5 #2.0	2	2.5	1.87
Palm Beach County Vibracore 2004 - Singer Island	SI04-5	-52.95	111	11.1	5.2	10YR 7/1	mostly Fine Quartz Sand; some Fine Carbonate Sand; little Fine To Medium Gravely Whole Shell; little Fine To Medium Gravely Shell Fragments	SI04-5 #8.0	8	8.5	2.23
Palm Beach County Vibracore 2004 - Singer Island	SI04-5	-52.95	112	15.2	11.1	10YR 7/1	mostly Fine Quartz Sand; some Fine Carbonate Sand; little Fine To Coarse Gravely Shell Fragments	SI04-5 #13.0	13	13.5	1.98

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-5	-52.95	113	20.1	15.2	1OYR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Coarse To Fine Gravely Shell Fragments	SI04-5 #Comp	19		1.95
Palm Beach County Vibracore 2004 - Singer Island	SI04-5	-52.95	113	20.1	15.2	1OYR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Coarse To Fine Gravely Shell Fragments	SI04-5 #18.0	18	18.5	1.81
Palm Beach County Vibracore 2004 - Singer Island	SI04-6	-66.07	114	1.8	0	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Fine Gravely Shell Fragments				
Palm Beach County Vibracore 2004 - Singer Island	SI04-6	-66.07	115	3	1.8	10YR 7/2	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Fine Gravely Shell Fragments	SI04-6 #2.0	2	2.5	1.42
Palm Beach County Vibracore 2004 - Singer Island	SI04-6	-66.07	116	8.4	3	10YR 6.5/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Fine To Coarse Gravely Shell Fragments	SI04-6 #7.0	7	7.5	1.3
Palm Beach County Vibracore 2004 - Singer Island	SI04-6	-66.07	117	8.9	8.4	10YR 7/1	mostly Coarse To Fine Carbonate Sand; some Fine Quartz Sand; some Shell Fragments; little Rock Fragments; little Fine To Coarse Gravely Whole Shell				
Palm Beach County Vibracore 2004 - Singer Island	SI04-6	-66.07	118	9.1	8.9	10YR 7.5/1	mostly Rock Fragments; some Shell Fragments				

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-6	-66.07	119	11.2	9.1	10YR 6.5/1	mostly Fine Carbonate Sand; trace Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-6	-66.07	120	18.6	11.2	10YR 7/2	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; trace Fine To Medium Gravely Shell Fragments	SI04-6 #18.0	18	18.5	1.47
Palm Beach County Vibracore 2004 - Singer Island	SI04-6	-66.07	120	18.6	11.2	10YR 7/2	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; trace Fine To Medium Gravely Shell Fragments	SI04-6 #13.0	13	13.5	0.85
Palm Beach County Vibracore 2004 - Singer Island	SI04-6	-66.07	121	19.5	18.6	10YR 7/1	mostly Fine Quartz Sand; some Fine Carbonate Sand	SI04-6 #Comp 1	19		1.31
Palm Beach County Vibracore 2004 - Singer Island	SI04-6	-66.07	122	19.9	19.5	10YR 6.5/1	mostly Coarse To Fine Carbonate Sand; some Fine Gravely Shell Fragments				
Palm Beach County Vibracore 2004 - Singer Island	SI04-6	-66.07	123	20.2	19.9	10YR 7/2	mostly Fine Carbonate Sand	SI04-6 #Comp 2	20		1.21
Palm Beach County Vibracore 2004 - Singer Island	SI04-7	-51.02	124	1	0	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Medium To Coarse Gravely Whole Shell; little Medium To Coarse Gravely Shell Fragments	SI04-7 #0.5	0.5	1	1.32

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-7	-51.02	124	1	0	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Medium To Coarse Gravely Whole Shell; little Medium To Coarse Gravely Shell Fragments	SI04-7 #1.0	1	1.5	1.54
Palm Beach County Vibracore 2004 - Singer Island	SI04-7	-51.02	125	1.9	1	10YR 6/1	mostly Fine Quartz Sand; trace Carbonate Sand	SI04-7 #0.5	0.5	1	1.32
Palm Beach County Vibracore 2004 - Singer Island	SI04-7	-51.02	125	1.9	1	10YR 6/1	mostly Fine Quartz Sand; trace Carbonate Sand	SI04-7 #1.0	1	1.5	1.54
Palm Beach County Vibracore 2004 - Singer Island	SI04-7	-51.02	126	2.4	1.9	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Medium Gravely Shell Fragments; little Fine To Medium Gravely Whole Shell				
Palm Beach County Vibracore 2004 - Singer Island	SI04-7	-51.02	127	6.7	2.4	10YR 7.5/2	mostly Medium To Fine Sand; some Medium Carbonate Sand; little Medium To Fine Gravely Whole Shell; little Medium To Fine Gravely Shell Fragments	SI04-7 #4.0	4	4.5	1.4
Palm Beach County Vibracore 2004 - Singer Island	SI04-7	-51.02	128	11	6.7	10YR 6.5/1	mostly Fine Quartz Sand; trace Medium To Fine Carbonate Sand; trace Fine To Medium Gravely Shell Fragments; trace Fine To Medium Rock Fragments	SI04-7 #9.0	9	9.5	2.12
Palm Beach County Vibracore 2004 - Singer Island	SI04-7	-51.02	129	17.2	11	10YR 7.5/1	mostly Fine Quartz Sand; trace Carbonate Sand	SI04-7 #14.0	14	14.5	2.24

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-7	-51.02	130	19.1	17.2	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	SI04-7 #Comp	19		1.89
Palm Beach County Vibracore 2004 - Singer Island	SI04-8	-31.61	131	2.9	0	10YR 7/1	mostly Fine Quartz Sand	SI04-8 #0.5	0.5	1	2.95
Palm Beach County Vibracore 2004 - Singer Island	SI04-8	-31.61	132	3.5	2.9	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Coarse To Fine Gravely Shell Fragments; some Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-8	-31.61	133	4.7	3.5	10YR 7/1	mostly Fine Quartz Sand; little Medium To Fine Carbonate Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-8	-31.61	134	5.5	4.7	10YR 7.5/2	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand	SI04-8 #5.0	5	5.5	1.24
Palm Beach County Vibracore 2004 - Singer Island	SI04-8	-31.61	135	9.2	5.5	10YR 7/1	mostly Fine Quartz Sand	SI04-8 #5.0	5	5.5	1.24
Palm Beach County Vibracore 2004 - Singer Island	SI04-8	-31.61	135	9.2	5.5	10YR 7/1	mostly Fine Quartz Sand	SI04-8 #7.0	7	7.5	2.58

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-8	-31.61	136	9.5	9.2	10YR 7/2	mostly Coarse To Fine Carbonate Sand; some Rock Fragments; some Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-8	-31.61	137	11.6	9.5	10YR 6.5/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand	SI04-8 #11.0	11	11.5	1.97
Palm Beach County Vibracore 2004 - Singer Island	SI04-8	-31.61	138	15.6	11.6	10YR 6.5/1	mostly Coarse To Fine Carbonate Sand; some Coarse To Medium Gravely Shell Fragments; some Fine Sand	SI04-8 #14.0	14	14.5	1.55
Palm Beach County Vibracore 2004 - Singer Island	SI04-8	-31.61	139	16.3	15.6	10YR 6.5/1	mostly Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-8	-31.61	140	16.8	16.3	10YR 6.5/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-9	-58.6	141	1.6	0	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand	SI04-9 #1.0	1	1.5	1.66
Palm Beach County Vibracore 2004 - Singer Island	SI04-9	-58.6	142	2.5	1.6	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Coarse To Medium Gravely Shell Fragments				

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-9	-58.6	143	11.5	2.5	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Coarse To Fine Gravely Shell Fragments	SI04-9 #4.0	4	4.5	1.81
Palm Beach County Vibracore 2004 - Singer Island	SI04-9	-58.6	143	11.5	2.5	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Coarse To Fine Gravely Shell Fragments	SI04-9 #7.0	7	7.5	1.72
Palm Beach County Vibracore 2004 - Singer Island	SI04-9	-58.6	143	11.5	2.5	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Coarse To Fine Gravely Shell Fragments	SI04-9 #11.0	11	11.5	1.51
Palm Beach County Vibracore 2004 - Singer Island	SI04-9	-58.6	144	14.6	11.5	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Coarse To Medium Gravely Shell Fragments	SI04-9 #11.0	11	11.5	1.51
Palm Beach County Vibracore 2004 - Singer Island	SI04-9	-58.6	144	14.6	11.5	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Coarse To Medium Gravely Shell Fragments	SI04-9 #13.0	13	13.5	1.72
Palm Beach County Vibracore 2004 - Singer Island	SI04-9	-58.6	145	14.8	14.6	10YR 7.5/1	mostly Rock Fragments				
Palm Beach County Vibracore 2004 - Singer Island	SI04-9	-58.6	146	16.6	14.9	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine To Medium Gravely Shell Fragments; some Fine Quartz Sand; trace Rock Fragments				

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-10	-54.92	8	0.9	0	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine To Coarse Gravely Shell Fragments; some Whole Shell; some Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-10	-54.92	9	1.5	0.9	1OYR 7.5/1	mostly Rock Fragments	SI04-10 #1.0	1	1.5	1.42
Palm Beach County Vibracore 2004 - Singer Island	SI04-10	-54.92	10	5.4	1.5	10YR 7/2	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Fine To Coarse Gravely Shell Fragments; trace Fine To Coarse Gravely Rock Fragments	SI04-10 #1.0	1	1.5	1.42
Palm Beach County Vibracore 2004 - Singer Island	SI04-10	-54.92	10	5.4	1.5	10YR 7/2	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Fine To Coarse Gravely Shell Fragments; trace Fine To Coarse Gravely Rock Fragments	SI04-10 #4.0	4	4.5	1.07
Palm Beach County Vibracore 2004 - Singer Island	SI04-10	-54.92	11	10.3	5.4	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand	SI04-10 #8.0	8	8.5	2.17
Palm Beach County Vibracore 2004 - Singer Island	SI04-10	-54.92	12	14.6	10.3	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Coarse Carbonate Sand	SI04-10 #12.0	12	12.5	2.12
Palm Beach County Vibracore 2004 - Singer Island	SI04-10	-54.92	13	18.8	14.6	10YR 7/1	mostly Fine Quartz Sand; some Fine Carbonate Sand				

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-10	-54.92	14	19.3	18.8	10YR 8/1	mostly Rock Fragments; some Medium To Fine Sand	SI04-10 #Comp	19		1.69
Palm Beach County Vibracore 2004 - Singer Island	SI04-11	-34	15	5.9	0	10YR 7.5/1	mostly Fine Quartz Sand	SI04-11 #1.0	1	1.5	2.85
Palm Beach County Vibracore 2004 - Singer Island	SI04-11	-34	15	5.9	0	10YR 7.5/1	mostly Fine Quartz Sand	SI04-11 #4.0	4	4.5	1.42
Palm Beach County Vibracore 2004 - Singer Island	SI04-11	-34	16	8.2	5.9	10YR 7.5/1	mostly Medium To Fine Carbonate Sand; some Whole Shell; some Fine Quartz Sand; some Shell Fragments	SI04-11 #8.0	8	8.5	1.43
Palm Beach County Vibracore 2004 - Singer Island	SI04-11	-34	17	9.1	8.2	10YR 7.5/1	mostly Fine Quartz Sand	SI04-11 #8.0	8	8.5	1.43
Palm Beach County Vibracore 2004 - Singer Island	SI04-11	-34	18	9.5	9.1	10YR 7.5/3	mostly Fine To Coarse Sand; some Whole Shell; little Shell Fragments				
Palm Beach County Vibracore 2004 - Singer Island	SI04-11	-34	19	10.9	9.5	10YR 7/2	mostly Fine Quartz Sand; some Fine Carbonate Sand				

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-11	-34	20	12.3	10.9	10YR 7.5/1	mostly Fine Quartz Sand; trace Fine Carbonate Sand	SI04-11 #12.0	12	12.5	1.4
Palm Beach County Vibracore 2004 - Singer Island	SI04-11	-34	21	16.2	12.3	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Shell Fragments	SI04-11 #12.0	12	12.5	1.4
Palm Beach County Vibracore 2004 - Singer Island	SI04-11	-34	22	18.9	16.2	10YR 7/2	mostly Fine Quartz Sand; little Medium To Fine Carbonate Sand; little Rock Fragments				
Palm Beach County Vibracore 2004 - Singer Island	SI04-16	-29.36	50	2.1	0	10YR 7/1	mostly Fine Quartz Sand; trace Medium To Fine Carbonate Sand	SI04-16 #1.0	1	1.5	3.05
Palm Beach County Vibracore 2004 - Singer Island	SI04-16	-29.36	51	3.4	2.1	10YR 7/1	mostly Medium To Fine Quartz Sand; some Fine Quartz Sand; trace Fine Gravely Shell Fragments				
Palm Beach County Vibracore 2004 - Singer Island	SI04-16	-29.36	52	3.8	3.4	10YR 7/1	mostly Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-16	-29.36	53	4.4	3.8	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand	SI04-16 #4.0	4	4.5	1.27

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-16	-29.36	54	6	4.4	10YR 7.5/2	mostly Coarse To Fine Carbonate Sand; some Coarse To Medium Shell Fragments; some Fine Quartz Sand	SI04-16 #4.0	4	4.5	1.27
Palm Beach County Vibracore 2004 - Singer Island	SI04-16	-29.36	55	6.9	6	10YR 7.5/1	mostly Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-16	-29.36	56	8.2	6.9	10YR 7/1	mostly Fine Quartz Sand; trace Shell Fragments	SI04-16 #8.0	8	8.5	2.76
Palm Beach County Vibracore 2004 - Singer Island	SI04-16	-29.36	57	8.9	8.2	10YR 7.5/2	mostly Coarse To Fine Carbonate Sand; some Fine Quartz Sand; some Fine To Medium Gravely Shell Fragments	SI04-16 #8.0	8	8.5	2.76
Palm Beach County Vibracore 2004 - Singer Island	SI04-16	-29.36	58	10.1	8.9	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-16	-29.36	59	11	10.1	10YR 7.5/1	mostly Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-16	-29.36	60	14.1	11	10YR 7.5/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand	SI04-16 #13.0	13	13.5	1.77

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-16	-29.36	61	14.7	14.1	10YR 7/1	mostly Fine Quartz Sand; some Rock Fragments				
Palm Beach County Vibracore 2004 - Singer Island	SI04-16	-29.36	62	17	14.7	10YR 7/1	mostly Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-17	-52.45	63	1.2	0	10YR 7/2	mostly Medium To Fine Carbonate Sand; some Medium To Coarse Gravely Rock Fragments; some Fine Quartz Sand; little Medium To Fine Gravely Whole Shell; little Medium	SI04-17 #0.5	0.5	1	1.67
Palm Beach County Vibracore 2004 - Singer Island	SI04-17	-52.45	64	5.7	1.2	10YR 7.5/3	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Coarse To Medium Gravely Shell Fragments	SI04-17 #4.0	4	4.5	1.85
Palm Beach County Vibracore 2004 - Singer Island	SI04-17	-52.45	65	6.8	5.7	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-17	-52.45	66	7	6.8	10YR 5.5/1	mostly Silt; some Clay				
Palm Beach County Vibracore 2004 - Singer Island	SI04-17	-52.45	67	10.1	7	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Coarse Carbonate Sand; some Fine Quartz Sand	SI04-17 #8.0	8	8.5	1.46

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-17	-52.45	68	10.6	10.1	10YR 7.5/2	mostly Coarse To Fine Carbonate Sand; some Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-17	-52.45	69	14.2	10.6	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand	SI04-17 #12.0	12	12.5	1.8
Palm Beach County Vibracore 2004 - Singer Island	SI04-18	-30.85	70	1.6	0	10YR 7.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	SI04-18 #1.0	1	1.5	3.03
Palm Beach County Vibracore 2004 - Singer Island	SI04-18	-30.85	71	4.6	1.6	10YR 7/1	mostly Fine Quartz Sand; some Coarse Carbonate Sand; little Fine To Medium Gravely Shell Fragments; little Fine To Medium Gravely Whole Shell	SI04-18 #4.0	4	4.5	2.34
Palm Beach County Vibracore 2004 - Singer Island	SI04-18	-30.85	72	5.2	4.6	10YR 8/2	mostly Medium To Coarse Carbonate Sand; some Fine To Medium Gravely Whole Shell; some Fine To Medium Gravely Shell Fragments				
Palm Beach County Vibracore 2004 - Singer Island	SI04-18	-30.85	73	5.7	5.2	10YR 8/2	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-18	-30.85	74	7.8	5.7	10YR 7/1	mostly Fine Sand; some Coarse To Fine Carbonate Sand; little Fine To Medium Gravely Shell Fragments	SI04-18 #7.0	7	7.5	2.88

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-18	-30.85	75	8.4	7.8	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand				
Palm Beach County Vibracore 2004 - Singer Island	SI04-18	-30.85	76	9.1	8.4	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Coarse Gravely Shell				
Palm Beach County Vibracore 2004 - Singer Island	SI04-18	-30.85	77	9.5	9.1	10YR 7.5/1	mostly Rock Fragments				
Palm Beach County Vibracore 2004 - Singer Island	SI04-18	-30.85	78	11.5	9.5	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand	SI04-18 #11.0	11	11.5	1.45
Palm Beach County Vibracore 2004 - Singer Island	SI04-18	-30.85	79	13.5	11.5	10YR 7/2	mostly Fine Quartz Sand; some Rock Fragments; some Coarse To Fine Carbonate Sand	SI04-18 #11.0	11	11.5	1.45
Palm Beach County Vibracore 2004 - Singer Island	SI04-18	-30.85	80	16.8	13.5	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	SI04-18 #15.0	15	15.5	3.2
Palm Beach County Vibracore 2004 - Singer Island	SI04-18	-30.85	81	17.9	16.8	10YR 7/1	mostly Fine Carbonate Sand; some Fine Quartz Sand				

Table 4-3. PB-1 results from ROSS vibracore query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original (phi)
Palm Beach County Vibracore 2004 - Singer Island	SI04-19	-50.54	82	2.8	0	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; little Fine To Coarse Gravely Shell Fragments	SI04-19 #0.5	0.5	1	2.05
Palm Beach County Vibracore 2004 - Singer Island	SI04-19	-50.54	83	4.5	2.8	10YR 7.5/2	mostly Coarse To Fine Carbonate Sand; some Fine Quartz Sand; little Fine To Medium Gravely Shell Fragments; little Rock Fragments; little Fine To Medium Gravely Whole	SI04-19 #4.0	4	4.5	1.36
Palm Beach County Vibracore 2004 - Singer Island	SI04-19	-50.54	84	4.8	4.5	10YR 7.5/1	mostly Rock Fragments	SI04-19 #4.0	4	4.5	1.36
Palm Beach County Vibracore 2004 - Singer Island	SI04-19	-50.54	85	6.2	4.8	10YR 7.5/2	mostly Coarse To Fine Carbonate Sand; some Fine Quartz Sand; little Fine To Medium Gravely Whole Shell; little Rock Fragments; little Fine To Medium Gravely Shell				
Palm Beach County Vibracore 2004 - Singer Island	SI04-19	-50.54	86	10.4	6.2	10YR 7.5/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand; trace Fine To Medium Gravely Shell Fragments	SI04-19 #8.0	8	8.5	1.49
Palm Beach County Vibracore 2004 - Singer Island	SI04-19	-50.54	87	18.9	10.4	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand	SI04-19 #16.0	16	16.5	2.04
Palm Beach County Vibracore 2004 - Singer Island	SI04-19	-50.54	87	18.9	10.4	10YR 7/1	mostly Medium To Fine Carbonate Sand; some Fine Quartz Sand	SI04-19 #12.0	12	12.5	1.85

Table 4-4a. PB-5 results from ROSS vibracore query.

	A	B	C	D	E	F	G	H	I	J	K	L
1	**Sand Query Results/Project Name**	**Core Identifier**	**Core Top Elevation**	**Core Layer Identifier**	**Bottom of Layer Interval**	**Top of Layer Interval**	**Core Layer Munsell**	**Core Layer Qualifiers**	**Sample Identifier**	**Top Of Sample Interval**	**Bottom Of Sample Interval**	**Mean Original**
2	Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Top of Layer Interval	Bottom of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
3	North Boca Raton Sand Search - Vibracores (1984)	BR1	-41	BR1-A	0	20		mostly Medium Sand	BR1-1	12	15.25	0.27
4	North Boca Raton Sand Search - Vibracores (1984)	BR1	-41	BR1-A	0	20		mostly Medium Sand	BR1-2	15.25	20	0.33
5	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	25	0	3.8	10YR 7.5/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand; some Fine Shell Fragments	HB04-44 #0.5	0.5	1	2.03
6	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	26	3.8	5.1	10YR 7.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-44 #4.0	4	4.5	1.73
7	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	29	7.9	8.3	10YR 6.5/1	mostly Fine Quartz Sand; some Rock Fragments; some Medium To Fine Carbonate Sand	HB04-44 #8.0	8	8.5	1.92
8	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	30	8.3	8.8	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-44 #8.0	8	8.5	1.92
9	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	33	10	15	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Medium Shell Fragments; little Fine To Medium Whole Shell	HB04-44 #12.0	12	12.5	1.71
10	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	34	15	18	10YR 6.5/2	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Coral	HB04-44 #16.0	16	16.5	1.48
11	Palm Beach County Vibracore 2004 - Highlands	HB04-45	-40.81	36	0.4	1.5	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-45 #0.5	0.5	1	2.16
12	Palm Beach County Vibracore 2004 - Highlands	HB04-45	-40.81	38	2.5	11.6	10YR 6/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand; little Fine To Medium Shell Fragments	HB04-45 #4.0	4	4.5	1.5

Table 4-4a. PB-5 results from ROSS vibracore query.

	A	B	C	D	E	F	G	H	I	J	K	L
1	**Sand Query Results/Project Name**	**Core Identifier**	**Core Top Elevation**	**Core Layer Identifier**	**Bottom of Layer Interval**	**Top of Layer Interval**	**Core Layer Munsell**	**Core Layer Qualifiers**	**Sample Identifier**	**Top Of Sample Interval**	**Bottom Of Sample Interval**	**Mean Original**
13	Palm Beach County Vibracore 2004 - Highlands	HB04-45	-40.81	38	2.5	11.6	10YR 6/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand; little Fine To Medium Shell Fragments	HB04-45 #8.0	8	8.5	2.01
14	Palm Beach County Vibracore 2004 - Highlands	HB04-45	-40.81	39	11.6	13.9	10YR 6/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand	HB04-45 #12.0	12	12.5	1.61
15	Palm Beach County Vibracore 2004 - Highlands	HB04-45	-40.81	40	13.9	17.9	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Fine Shell Fragments	HB04-45 #16.0	16	16.5	2.14
16	Palm Beach County Vibracore 2004 - Highlands	HB04-47	-31.14	49	0	0.9	10YR 7.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-47 #0.5	0.5	1	1.78
17	Palm Beach County Vibracore 2004 - Highlands	HB04-47	-31.14	50	0.9	4.3	10YR 6.5/2	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Medium Shell Fragments	HB04-47 #0.5	0.5	1	1.78
18	Palm Beach County Vibracore 2004 - Highlands	HB04-47	-31.14	50	0.9	4.3	10YR 6.5/2	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Medium Shell Fragments	HB04-47 #4.0	4	4.5	1.56
19	Palm Beach County Vibracore 2004 - Highlands	HB04-47	-31.14	51	4.3	10.8	10YR 6.5/2	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-47 #4.0	4	4.5	1.56
20	Palm Beach County Vibracore 2004 - Highlands	HB04-47	-31.14	51	4.3	10.8	10YR 6.5/2	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-47 #8.0	8	8.5	1.5
21	Palm Beach County Vibracore 2004 - Highlands	HB04-47	-31.14	53	11.9	15.4	10YR 6/2	mostly Fine Quartz Sand; some Medium To Fine Quartz Sand	HB04-47 #12.0	12	12.5	1.72
22	Palm Beach County Vibracore 2004 - Highlands	HB04-48	-41.27	54	0	1.4	10YR 7.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-48 #0.5	0.5	1	1.99
23	Palm Beach County Vibracore 2004 - Highlands	HB04-48	-41.27	56	1.7	7.8	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-48 #4.0	4	4.5	1.86

Table 4-4a. PB-5 results from ROSS vibracore query.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
24	Palm Beach County Vibracore 2004 - Highlands	HB04-48	-41.27	57	7.8	8.5	10YR 6.5/1	mostly Fine Quartz Sand; some Fine Shell Fragments; some Coarse To Fine Carbonate Sand	HB04-48 #8.0	8	8.5	1.78
25	Palm Beach County Vibracore 2004 - Highlands	HB04-48	-41.27	58	8.5	16.8	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Fine Shell Fragments	HB04-48 #16.0	16	16.5	2.02
26	Palm Beach County Vibracore 2004 - Highlands	HB04-48	-41.27	58	8.5	16.8	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Fine Shell Fragments	HB04-48 #8.0	8	8.5	1.78
27	Palm Beach County Vibracore 2004 - Highlands	HB04-48	-41.27	58	8.5	16.8	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Fine Shell Fragments	HB04-48 #12.0	12	12.5	1.64
28	Palm Beach County Vibracore 2004 - Highlands	HB04-49	-55.92	59	0	2.4	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Fine Shell Fragments	HB04-49 #0.5	0.5	1	2.38
29	Palm Beach County Vibracore 2004 - Highlands	HB04-49	-55.92	61	4.2	6.9	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Medium Shell Fragments	HB04-49 #6.0	6	6.5	2.47
30	Palm Beach County Vibracore 2004 - Highlands	HB04-49	-55.92	62	6.9	12.9	10YR 7/1	mostly Fine Quartz Sand; little Fine To Coarse Whole Shell; little Fine To Coarse Shell Fragments	HB04-49 #11.0	11	11.5	2.37
31	Palm Beach County Vibracore 2004 - Highlands	HB04-49	-55.92	62	6.9	12.9	10YR 7/1	mostly Fine Quartz Sand; little Fine To Coarse Whole Shell; little Fine To Coarse Shell Fragments	HB04-49 #8.0	8	8.5	2.49
32	Palm Beach County Vibracore 2004 - Highlands	HB04-49	-55.92	63	12.9	13.7	10YR 7/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand; some Fine To Coarse Shell Fragments; some Coarse To Fine Rock Fragments				
33	Palm Beach County Vibracore 2004 - Highlands	HB04-49	-55.92	64	13.7	19.3	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Coarse Shell Fragments; little Fine To Coarse Rock Fragments; little Fine To Coarse Whole Shell				

Table 4-4a. PB-5 results from ROSS vibracore query.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
34	Palm Beach County Vibracore 2004 - Highlands	HB04-50 R2	-32.19	65	0	7.1	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Coarse To Fine Shell Fragments	HB04-50 R2 #0.5	0.5	1	1.79
35	Palm Beach County Vibracore 2004 - Highlands	HB04-50 R2	-32.19	65	0	7.1	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Coarse To Fine Shell Fragments	HB04-50 R2 #4.0	4	4.5	2.08
36	Palm Beach County Vibracore 2004 - Highlands	HB04-50 R2	-32.19	66	7.1	8.1	10YR 7/1	mostly Fine Quartz Sand; some Fine Shell Fragments; some Coarse To Fine Carbonate Sand	HB04-50 R2 #8.0	8	8.5	1.39
37	Palm Beach County Vibracore 2004 - Highlands	HB04-50 R2	-32.19	67	8.1	10.5	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-50 R2 #8.0	8	8.5	1.39
38	Palm Beach County Vibracore 2004 - Highlands	HB04-50 R2	-32.19	68	10.5	18	10YR 5.5/1	mostly Fine Quartz Sand; little Fine To Coarse Shell Fragments; trace Medium To Fine Sand	HB04-50 R2 #12.	12	12.5	1.68
39	Palm Beach County Vibracore 2004 - Highlands	HB04-50 R2	-32.19	68	10.5	18	10YR 5.5/1	mostly Fine Quartz Sand; little Fine To Coarse Shell Fragments; trace Medium To Fine Sand	HB04-50 R2 #16.	16	16.5	2.11
40	Palm Beach County Vibracore 2004 - Highlands	HB04-51	-42.42	69	0	4.8	10YR 6.5/1	mostly Fine Quartz Sand; some Coarse To Medium Carbonate Sand; some Medium To Fine Carbonate Sand	HB04-51 #0.5	0.5	1	2.43
41	Palm Beach County Vibracore 2004 - Highlands	HB04-51	-42.42	69	0	4.8	10YR 6.5/1	mostly Fine Quartz Sand; some Coarse To Medium Carbonate Sand; some Medium To Fine Carbonate Sand	HB04-51 #4.0	4	4.5	1.32
42	Palm Beach County Vibracore 2004 - Highlands	HB04-51	-42.42	71	5.7	9.8	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-51 #8.0	8	8.5	1.97
43	Palm Beach County Vibracore 2004 - Highlands	HB04-51	-42.42	73	10.1	14.7	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; some Fine Shell Fragments	HB04-51 #12.0	12	12.5	1.56
44	Palm Beach County Vibracore 2004 - Highlands	HB04-51	-42.42	74	14.7	17	10YR 6/1	mostly Fine Quartz Sand; some Carbonate Sand; some Rock Fragments	HB04-51 #16.0	16	16.5	1.68

Table 4-4a. PB-5 results from ROSS vibracore query.

	A	B	C	D	E	F	G	H	I	J	K	L
1	**Sand Query Results/Project Name**	**Core Identifier**	**Core Top Elevation**	**Core Layer Identifier**	**Bottom of Layer Interval**	**Top of Layer Interval**	**Core Layer Munsell**	**Core Layer Qualifiers**	**Sample Identifier**	**Top Of Sample Interval**	**Bottom Of Sample Interval**	**Mean Original**
45	Palm Beach County Vibracore 2004 - Highlands	HB04-52	-58.25	75	0	6.4	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-52 #0.5	0.5	1	1.86
46	Palm Beach County Vibracore 2004 - Highlands	HB04-52	-58.25	75	0	6.4	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-52 #4.0	4	4.5	2.08
47	Palm Beach County Vibracore 2004 - Highlands	HB04-52	-58.25	77	7	13.4	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-52 #12.0	12	12.5	2.08
48	Palm Beach County Vibracore 2004 - Highlands	HB04-52	-58.25	77	7	13.4	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-52 #8.0	8	8.5	2.08
49	Palm Beach County Vibracore 2004 - Highlands	HB04-52	-58.25	78	13.4	14.1	10YR 6.5/1	some Carbonate Sand; some Quartz Sand; some Large Rock Fragments				
50	Palm Beach County Vibracore 2004 - Highlands	HB04-52	-58.25	79	14.1	17.6	10YR 6.5/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand; little Rock Fragments				
51	Palm Beach County Vibracore 2004 - Highlands	HB04-53	-36.48	80	0	1.5	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-53 #0.5	0.5	1	2.17
52	Palm Beach County Vibracore 2004 - Highlands	HB04-53	-36.48	81	1.5	11.3	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-53 #8.0	8	8.5	1.74
53	Palm Beach County Vibracore 2004 - Highlands	HB04-53	-36.48	81	1.5	11.3	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-53 #4.0	4	4.5	1.57
54	Palm Beach County Vibracore 2004 - Highlands	HB04-53	-36.48	82	11.3	18.5	10YR 6/1	mostly Fine Quartz Sand; trace Carbonate Sand	HB04-53 #12.0	12	12.5	1.86
55	Palm Beach County Vibracore 2004 - Highlands	HB04-53	-36.48	82	11.3	18.5	10YR 6/1	mostly Fine Quartz Sand; trace Carbonate Sand	HB04-53 #16.0	16	16.5	2.04
56	Palm Beach County Vibracore 2004 - Highlands	HB04-54	-53.29	83	0	2	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; some Fine Shell Fragments	HB04-54 #0.5	0.5	1	2.17

Table 4-4a. PB-5 results from ROSS vibracore query.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
57	Palm Beach County Vibracore 2004 - Highlands	HB04-54	-53.29	85	2.8	4.6	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Fine Shell Fragments	HB04-54 #4.0	4	4.5	2.24
58	Palm Beach County Vibracore 2004 - Highlands	HB04-54	-53.29	87	6.7	10.5	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Fine Shell Fragments	HB04-54 #8.0	8	8.5	1.85
59	Palm Beach County Vibracore 2004 - Highlands	HB04-54	-53.29	88	10.5	14.7	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments; trace Fine To Medium Rock Fragments	HB04-54 #12.0	12	12.5	1.8
60	Palm Beach County Vibracore 2004 - Highlands	HB04-54	-53.29	89	14.7	20	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Medium Shell Fragments; little Coarse Rock Fragments				
61	Palm Beach County Vibracore 2004 - Highlands	HB04-55	-35.79	90	0	2.1	10YR 7/1	mostly Fine Quartz Sand; some Carbonate Sand	HB04-55 #0.5	0.5	1	2.06
62	Palm Beach County Vibracore 2004 - Highlands	HB04-55	-35.79	92	2.6	9.9	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Coarse To Fine Shell Fragments	HB04-55 #4.0	4	4.5	1.89
63	Palm Beach County Vibracore 2004 - Highlands	HB04-55	-35.79	92	2.6	9.9	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Coarse To Fine Shell Fragments	HB04-55 #8.0	8	8.5	1.77
64	Palm Beach County Vibracore 2004 - Highlands	HB04-55	-35.79	93	9.9	14.1	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Coarse To Fine Shell Hash	HB04-55 #12.0	12	12.5	1.69
65	Palm Beach County Vibracore 2004 - Highlands	HB04-55	-35.79	94	14.1	17	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-55 #16.0	16	16.5	2.16
66	Palm Beach County Vibracore 2004 - Highlands	HB04-56	-51.17	95	0	4.1	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-56 #0.5	0.5	1	2.13
67	Palm Beach County Vibracore 2004 - Highlands	HB04-56	-51.17	95	0	4.1	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-56 #4.0	4	4.5	2.17

Table 4-4a. PB-5 results from ROSS vibracore query.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
68	Palm Beach County Vibracore 2004 - Highlands	HB04-56	-51.17	96	4.1	4.8	10YR 7/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand; some Fine Shell Fragments; some Fine Coral	HB04-56 #4.0	4	4.5	2.17
69	Palm Beach County Vibracore 2004 - Highlands	HB04-56	-51.17	97	4.8	8	10YR 7/1	mostly Fine Sand; some Medium To Fine Carbonate Sand; some Fine Shell Fragments	HB04-56 #8.0	8	8.5	2.04
70	Palm Beach County Vibracore 2004 - Highlands	HB04-56	-51.17	98	8	17.9	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Medium Shell Fragments; little Medium Rock Fragments	HB04-56 #8.0	8	8.5	2.04
71	Palm Beach County Vibracore 2004 - Highlands	HB04-56	-51.17	98	8	17.9	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Medium Shell Fragments; little Medium Rock Fragments	HB04-56 #12.0	12	12.5	2.08
72	Palm Beach County Vibracore 2004 - Highlands	HB04-56	-51.17	98	8	17.9	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Medium Shell Fragments; little Medium Rock Fragments	HB04-56 #16.0	16	16.5	1.87
73	Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	22	-40	22a	0	10.3		mostly Medium Quartz Sand	22-1	0	0.5	0.33
74	Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	22	-40	22a	0	10.3		mostly Medium Quartz Sand	22-7	8.5	10.3	0.28

Table 4-4a. PB-5 results from ROSS vibracore query.

	A	B	C	D	E	F	G	H	I	J	K	L
1	**Sand Query Results/Project Name**	**Core Identifier**	**Core Top Elevation**	**Core Layer Identifier**	**Bottom of Layer Interval**	**Top of Layer Interval**	**Core Layer Munsell**	**Core Layer Qualifiers**	**Sample Identifier**	**Top Of Sample Interval**	**Bottom Of Sample Interval**	**Mean Original**
75	Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	22	-40	22a	0	10.3		mostly Medium Quartz Sand	22-6	5.5	8.5	0.31
76	Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	22	-40	22a	0	10.3		mostly Medium Quartz Sand	22-5	3.5	5.5	0.32
77	Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	22	-40	22a	0	10.3		mostly Medium Quartz Sand	22-4	2.5	3.5	0.36
78	Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	22	-40	22a	0	10.3		mostly Medium Quartz Sand	22-3	1.5	2.5	0.38
79	Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	22	-40	22a	0	10.3		mostly Medium Quartz Sand	22-2	0.5	1.5	0.32
80	North Boca Raton Sand Search (2004)	NBVC-04-01A	-41.2	1	0	2	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-01A #1	0	2	2.6
81	North Boca Raton Sand Search (2004)	NBVC-04-01A	-41.2	1	0	2	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-01A #2	2	8.5	1.76

Table 4-4a. PB-5 results from ROSS vibracore query.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
82	North Boca Raton Sand Search (2004)	NBVC-04-01A	-41.2	2	2	14.4	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-01A #1	0	2	2.6
83	North Boca Raton Sand Search (2004)	NBVC-04-01A	-41.2	2	2	14.4	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-01A #2	2	8.5	1.76
84	North Boca Raton Sand Search (2004)	NBVC-04-01A	-41.2	2	2	14.4	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-01A #3	8.5	14.4	2.04
85	North Boca Raton Sand Search (2004)	NBVC-04-01A	-41.2	3	14.4	20			NBVC-04-01A #3	8.5	14.4	2.04
86	North Boca Raton Sand Search (2004)	NBVC-04-02	-38.1	4	0	2	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-02 #1	0	2	2.12
87	North Boca Raton Sand Search (2004)	NBVC-04-02	-38.1	4	0	2	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-02 #2	2	8.8	1.53
88	North Boca Raton Sand Search (2004)	NBVC-04-02	-38.1	5	2	8.8	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-02 #1	0	2	2.12
89	North Boca Raton Sand Search (2004)	NBVC-04-02	-38.1	5	2	8.8	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-02 #2	2	8.8	1.53
90	North Boca Raton Sand Search (2004)	NBVC-04-02	-38.1	5	2	8.8	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-02 #3	8.8	17.1	2
91	North Boca Raton Sand Search (2004)	NBVC-04-02	-38.1	29	8.8	17.1	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-02 #2	2	8.8	1.53
92	North Boca Raton Sand Search (2004)	NBVC-04-02	-38.1	29	8.8	17.1	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-02 #3	8.8	17.1	2
93	North Boca Raton Sand Search (2004)	NBVC-04-02	-38.1	6	17.1	19			NBVC-04-02 #3	8.8	17.1	2

Table 4-4a. PB-5 results from ROSS vibracore query.

	A	B	C	D	E	F	G	H	I	J	K	L
1	**Sand Query Results/Project Name**	**Core Identifier**	**Core Top Elevation**	**Core Layer Identifier**	**Bottom of Layer Interval**	**Top of Layer Interval**	**Core Layer Munsell**	**Core Layer Qualifiers**	**Sample Identifier**	**Top Of Sample Interval**	**Bottom Of Sample Interval**	**Mean Original**
94	North Boca Raton Sand Search (2004)	NBVC-04-03	-40.6	7	0	16.5	5Y 5/1	mostly Fine Sand; trace Shell Hash; trace Silt	NBVC-04-03 #1	0	6.5	2.04
95	North Boca Raton Sand Search (2004)	NBVC-04-03	-40.6	7	0	16.5	5Y 5/1	mostly Fine Sand; trace Shell Hash; trace Silt	NBVC-04-03 #2	6.5	11.3	2.01
96	North Boca Raton Sand Search (2004)	NBVC-04-03	-40.6	7	0	16.5	5Y 5/1	mostly Fine Sand; trace Shell Hash; trace Silt	NBVC-04-03 #3	11.3	16.5	1.89
97	North Boca Raton Sand Search (2004)	NBVC-04-03	-40.6	8	16.5	20			NBVC-04-03 #3	11.3	16.5	1.89
98	North Boca Raton Sand Search (2004)	NBVC-04-04	-39.5	9	0	12.5	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash; trace Shell Fragments	NBVC-04-04 #1	0	6.5	1.7
99	North Boca Raton Sand Search (2004)	NBVC-04-04	-39.5	9	0	12.5	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash; trace Shell Fragments	NBVC-04-04 #2	6.5	12.5	1.48
100	North Boca Raton Sand Search (2004)	NBVC-04-04	-39.5	9	0	12.5	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash; trace Shell Fragments	NBVC-04-04 #3	12.5	18.9	1.92
101	North Boca Raton Sand Search (2004)	NBVC-04-04	-39.5	30	12.5	18.9	5Y 5/1	mostly Fine Sand; trace Shell Hash; trace Shell Fragments; trace Silt	NBVC-04-04 #2	6.5	12.5	1.48
102	North Boca Raton Sand Search (2004)	NBVC-04-04	-39.5	30	12.5	18.9	5Y 5/1	mostly Fine Sand; trace Shell Hash; trace Shell Fragments; trace Silt	NBVC-04-04 #3	12.5	18.9	1.92
103	North Boca Raton Sand Search (2004)	NBVC-04-04	-39.5	10	18.9	20			NBVC-04-04 #3	12.5	18.9	1.92
104	North Boca Raton Sand Search (2004)	NBVC-04-05	-54.4	11	0	9.8	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-05 #1	0	5.5	2.25
105	North Boca Raton Sand Search (2004)	NBVC-04-05	-54.4	11	0	9.8	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-05 #2	5.5	9.8	1.63

Table 4-4a. PB-5 results from ROSS vibracore query.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
106	North Boca Raton Sand Search (2004)	NBVC-04-05	-54.4	11	0	9.8	5Y 5/1	mostly Fine Sand; trace Silt; trace Shell Hash	NBVC-04-05 #3	9.8	14.9	1.62
107	North Boca Raton Sand Search (2004)	NBVC-04-05	-54.4	12	9.8	14.9	5Y 5/1	mostly Fine Sand; trace Shell Fragments; trace Shell Hash; trace Silt	NBVC-04-05 #2	5.5	9.8	1.63
108	North Boca Raton Sand Search (2004)	NBVC-04-05	-54.4	12	9.8	14.9	5Y 5/1	mostly Fine Sand; trace Shell Fragments; trace Shell Hash; trace Silt	NBVC-04-05 #3	9.8	14.9	1.62
109	North Boca Raton Sand Search (2004)	NBVC-04-05	-54.4	13	14.9	20			NBVC-04-05 #3	9.8	14.9	1.62

Table 4-4b. PB-5 results from ROSS vibracore query- composite samples.

	A	B	C	D	E	F	G	H	I	J	K	L
1	**Sand Query Results/Project Name**	**Core Identifier**	**Core Top Elevation**	**Core Layer Identifier**	**Bottom of Layer Interval**	**Top of Layer Interval**	**Core Layer Munsell**	**Core Layer Qualifiers**	**Sample Identifier**	**Top Of Sample Interval**	**Bottom Of Sample Interval**	**Mean Original**
2	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	25	0	3.8	10YR 7.5/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand; some Fine Shell Fragments	HB04-44 #Comp	0	16	1.74
3	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	26	3.8	5.1	10YR 7.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-44 #Comp	0	16	1.74
4	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	27	5.1	7.2	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Coarse Rock Fragments	HB04-44 #Comp	0	16	1.74
5	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	28	7.2	7.9	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-44 #Comp	0	16	1.74
6	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	29	7.9	8.3	10YR 6.5/1	mostly Fine Quartz Sand; some Rock Fragments; some Medium To Fine Carbonate Sand	HB04-44 #Comp	0	16	1.74
7	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	30	8.3	8.8	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-44 #Comp	0	16	1.74
8	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	31	8.8	9.1	10YR 6.5/1	mostly Fine Quartz Sand; some Fine To Medium Rock Fragments; some Medium To Fine Carbonate Sand	HB04-44 #Comp	0	16	1.74
9	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	32	9.1	10	10YR 6.5/2	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-44 #Comp	0	16	1.74
10	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	33	10	15	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Medium Shell Fragments; little Fine To Medium Whole Shell	HB04-44 #Comp	0	16	1.74
11	Palm Beach County Vibracore 2004 - Highlands	HB04-44	-29.33	34	15	18	10YR 6.5/2	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Coral	HB04-44 #Comp	0	16	1.74

Table 4-4b. PB-5 results from ROSS vibracore query- composite samples.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
12	Palm Beach County Vibracore 2004 - Highlands	HB04-45	-40.81	35	0	0.4	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Medium To Coarse Whole Shell; little Medium To Coarse Shell Fragments; little Medium To Coarse Coral	HB04-45 #Comp	0	16	1.87
13	Palm Beach County Vibracore 2004 - Highlands	HB04-45	-40.81	36	0.4	1.5	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-45 #Comp	0	16	1.87
14	Palm Beach County Vibracore 2004 - Highlands	HB04-45	-40.81	37	1.5	2.5	10YR 6/1	mostly Fine Quartz Sand; some Fine To Medium Shell Fragments; some Coarse To Fine Carbonate Sand; some Fine To Medium Whole Shell	HB04-45 #Comp	0	16	1.87
15	Palm Beach County Vibracore 2004 - Highlands	HB04-45	-40.81	38	2.5	11.6	10YR 6/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand; little Fine To Medium Shell Fragments	HB04-45 #Comp	0	16	1.87
16	Palm Beach County Vibracore 2004 - Highlands	HB04-45	-40.81	39	11.6	13.9	10YR 6/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand	HB04-45 #Comp	0	16	1.87
17	Palm Beach County Vibracore 2004 - Highlands	HB04-45	-40.81	40	13.9	17.9	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Fine Shell Fragments	HB04-45 #Comp	0	16	1.87
18	Palm Beach County Vibracore 2004 - Highlands	HB04-47	-31.14	49	0	0.9	10YR 7.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-47 #Comp	0	16	1.61
19	Palm Beach County Vibracore 2004 - Highlands	HB04-47	-31.14	50	0.9	4.3	10YR 6.5/2	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Medium Shell Fragments	HB04-47 #Comp	0	16	1.61
20	Palm Beach County Vibracore 2004 - Highlands	HB04-47	-31.14	51	4.3	10.8	10YR 6.5/2	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-47 #Comp	0	16	1.61
21	Palm Beach County Vibracore 2004 - Highlands	HB04-47	-31.14	52	10.8	11.9	10YR 6.5/1	mostly Fine Quartz Sand; some Fine To Medium Shell Fragments; some Coarse To Fine Carbonate Sand	HB04-47 #Comp	0	16	1.61

Table 4-4b. PB-5 results from ROSS vibracore query- composite samples.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
22	Palm Beach County Vibracore 2004 - Highlands	HB04-47	-31.14	53	11.9	15.4	10YR 6/2	mostly Fine Quartz Sand; some Medium To Fine Quartz Sand	HB04-47 #Comp	0	16	1.61
23	Palm Beach County Vibracore 2004 - Highlands	HB04-48	-41.27	54	0	1.4	10YR 7.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-48 #Comp	0	16	1.89
24	Palm Beach County Vibracore 2004 - Highlands	HB04-48	-41.27	55	1.4	1.7	10YR 7.5/1	mostly Coarse To Fine Carbonate Sand; some Fine Shell Fragments; some Fine Sand	HB04-48 #Comp	0	16	1.89
25	Palm Beach County Vibracore 2004 - Highlands	HB04-48	-41.27	56	1.7	7.8	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-48 #Comp	0	16	1.89
26	Palm Beach County Vibracore 2004 - Highlands	HB04-48	-41.27	57	7.8	8.5	10YR 6.5/1	mostly Fine Quartz Sand; some Fine Shell Fragments; some Coarse To Fine Carbonate Sand	HB04-48 #Comp	0	16	1.89
27	Palm Beach County Vibracore 2004 - Highlands	HB04-48	-41.27	58	8.5	16.8	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Fine Shell Fragments	HB04-48 #Comp	0	16	1.89
28	Palm Beach County Vibracore 2004 - Highlands	HB04-49	-55.92	59	0	2.4	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Fine Shell Fragments	HB04-49 #Comp	0	11	2.36
29	Palm Beach County Vibracore 2004 - Highlands	HB04-49	-55.92	60	2.4	4.2	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Whole Shell; some Medium To Fine Shell Fragments; some Medium To Fine Carbonate Sand	HB04-49 #Comp	0	11	2.36
30	Palm Beach County Vibracore 2004 - Highlands	HB04-49	-55.92	61	4.2	6.9	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Medium Shell Fragments	HB04-49 #Comp	0	11	2.36
31	Palm Beach County Vibracore 2004 - Highlands	HB04-49	-55.92	62	6.9	12.9	10YR 7/1	mostly Fine Quartz Sand; little Fine To Coarse Whole Shell; little Fine To Coarse Shell Fragments	HB04-49 #Comp	0	11	2.36
32	Palm Beach County Vibracore 2004 - Highlands	HB04-50 R2	-32.19	65	0	7.1	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Coarse To Fine Shell Fragments	HB04-50 R2 #Com	0	16	1.74

Table 4-4b. PB-5 results from ROSS vibracore query- composite samples.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
33	Palm Beach County Vibracore 2004 - Highlands	HB04-50 R2	-32.19	66	7.1	8.1	10YR 7/1	mostly Fine Quartz Sand; some Fine Shell Fragments; some Coarse To Fine Carbonate Sand	HB04-50 R2 #Com	0	16	1.74
34	Palm Beach County Vibracore 2004 - Highlands	HB04-50 R2	-32.19	67	8.1	10.5	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-50 R2 #Com	0	16	1.74
35	Palm Beach County Vibracore 2004 - Highlands	HB04-50 R2	-32.19	68	10.5	18	10YR 5.5/1	mostly Fine Quartz Sand; little Fine To Coarse Shell Fragments; trace Medium To Fine Sand	HB04-50 R2 #Com	0	16	1.74
36	Palm Beach County Vibracore 2004 - Highlands	HB04-51	-42.42	69	0	4.8	10YR 6.5/1	mostly Fine Quartz Sand; some Coarse To Medium Carbonate Sand; some Medium To Fine Carbonate Sand	HB04-51 #Comp	0	17	1.81
37	Palm Beach County Vibracore 2004 - Highlands	HB04-51	-42.42	70	4.8	5.7	10YR 7.5/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand; some Fine Shell Fragments	HB04-51 #Comp	0	17	1.81
38	Palm Beach County Vibracore 2004 - Highlands	HB04-51	-42.42	71	5.7	9.8	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-51 #Comp	0	17	1.81
39	Palm Beach County Vibracore 2004 - Highlands	HB04-51	-42.42	72	9.8	10.1	10YR 7.5/1	mostly Coarse To Fine Carbonate Sand; some Fine Quartz Sand; some Fine Shell Fragments	HB04-51 #Comp	0	17	1.81
40	Palm Beach County Vibracore 2004 - Highlands	HB04-51	-42.42	73	10.1	14.7	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; some Fine Shell Fragments	HB04-51 #Comp	0	17	1.81
41	Palm Beach County Vibracore 2004 - Highlands	HB04-51	-42.42	74	14.7	17	10YR 6/1	mostly Fine Quartz Sand; some Carbonate Sand; some Rock Fragments	HB04-51 #Comp	0	17	1.81
42	Palm Beach County Vibracore 2004 - Highlands	HB04-52	-58.25	75	0	6.4	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-52 #Comp	0	12	2.14
43	Palm Beach County Vibracore 2004 - Highlands	HB04-52	-58.25	76	6.4	7	10YR 6/1	mostly Fine Quartz Sand; some Large Rock Fragments	HB04-52 #Comp	0	12	2.14
44	Palm Beach County Vibracore 2004 - Highlands	HB04-52	-58.25	77	7	13.4	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-52 #Comp	0	12	2.14

Table 4-4b. PB-5 results from ROSS vibracore query- composite samples.

	A	B	C	D	E	F	G	H	I	J	K	L
1	**Sand Query Results/Project Name**	**Core Identifier**	**Core Top Elevation**	**Core Layer Identifier**	**Bottom of Layer Interval**	**Top of Layer Interval**	**Core Layer Munsell**	**Core Layer Qualifiers**	**Sample Identifier**	**Top Of Sample Interval**	**Bottom Of Sample Interval**	**Mean Original**
45	Palm Beach County Vibracore 2004 - Highlands	HB04-53	-36.48	80	0	1.5	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-53 #Comp	0	16	1.79
46	Palm Beach County Vibracore 2004 - Highlands	HB04-53	-36.48	81	1.5	11.3	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-53 #Comp	0	16	1.79
47	Palm Beach County Vibracore 2004 - Highlands	HB04-53	-36.48	82	11.3	18.5	10YR 6/1	mostly Fine Quartz Sand; trace Carbonate Sand	HB04-53 #Comp	0	16	1.79
48	Palm Beach County Vibracore 2004 - Highlands	HB04-54	-53.29	83	0	2	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; some Fine Shell Fragments	HB04-54 #Comp	0	12	1.94
49	Palm Beach County Vibracore 2004 - Highlands	HB04-54	-53.29	84	2	2.8	10YR 6.5/1	mostly Fine Quartz Sand; some Coarse Rock Fragments	HB04-54 #Comp	0	12	1.94
50	Palm Beach County Vibracore 2004 - Highlands	HB04-54	-53.29	85	2.8	4.6	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Fine Shell Fragments	HB04-54 #Comp	0	12	1.94
51	Palm Beach County Vibracore 2004 - Highlands	HB04-54	-53.29	86	4.6	6.7	10YR 6.5/1	mostly Fine Quartz Sand; some Fine Shell Fragments; some Medium To Fine Carbonate Sand; little Coarse Coral; little Coarse Whole Shell	HB04-54 #Comp	0	12	1.94
52	Palm Beach County Vibracore 2004 - Highlands	HB04-54	-53.29	87	6.7	10.5	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Fine Shell Fragments	HB04-54 #Comp	0	12	1.94
53	Palm Beach County Vibracore 2004 - Highlands	HB04-54	-53.29	88	10.5	14.7	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments; trace Fine To Medium Rock Fragments	HB04-54 #Comp	0	12	1.94
54	Palm Beach County Vibracore 2004 - Highlands	HB04-55	-35.79	90	0	2.1	10YR 7/1	mostly Fine Quartz Sand; some Carbonate Sand	HB04-55 #Comp	0	16	1.87
55	Palm Beach County Vibracore 2004 - Highlands	HB04-55	-35.79	91	2.1	2.6	10YR 7.5/1	mostly Coarse To Fine Carbonate Sand; some Fine Quartz Sand; some Fine Shell Fragments	HB04-55 #Comp	0	16	1.87

Table 4-4b. PB-5 results from ROSS vibracore query- composite samples.

	A	B	C	D	E	F	G	H	I	J	K	L
1	Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
56	Palm Beach County Vibracore 2004 - Highlands	HB04-55	-35.79	92	2.6	9.9	10YR 6.5/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; trace Coarse To Fine Shell Fragments	HB04-55 #Comp	0	16	1.87
57	Palm Beach County Vibracore 2004 - Highlands	HB04-55	-35.79	93	9.9	14.1	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Coarse To Fine Shell Hash	HB04-55 #Comp	0	16	1.87
58	Palm Beach County Vibracore 2004 - Highlands	HB04-55	-35.79	94	14.1	17	10YR 6/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand	HB04-55 #Comp	0	16	1.87
59	Palm Beach County Vibracore 2004 - Highlands	HB04-56	-51.17	95	0	4.1	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine Shell Fragments	HB04-56 #Comp	0	16	2.04
60	Palm Beach County Vibracore 2004 - Highlands	HB04-56	-51.17	96	4.1	4.8	10YR 7/1	mostly Fine Quartz Sand; some Coarse To Fine Carbonate Sand; some Fine Shell Fragments; some Fine Coral	HB04-56 #Comp	0	16	2.04
61	Palm Beach County Vibracore 2004 - Highlands	HB04-56	-51.17	97	4.8	8	10YR 7/1	mostly Fine Sand; some Medium To Fine Carbonate Sand; some Fine Shell Fragments	HB04-56 #Comp	0	16	2.04
62	Palm Beach County Vibracore 2004 - Highlands	HB04-56	-51.17	98	8	17.9	10YR 7/1	mostly Fine Quartz Sand; some Medium To Fine Carbonate Sand; little Fine To Medium Shell Fragments; little Medium Rock Fragments	HB04-56 #Comp	0	16	2.04

Table 4-5. B-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Sample Date	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in	VC96-13	-74	13a	1.2	0	5Y 6/2	mostly Fine Sand; some Silt	VC96-13-1	9/1/1996	0	1.2	0.21
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in	VC96-13	-74	13a	1.2	0	5Y 6/2	mostly Fine Sand; some Silt	VC96-13-2	9/1/1996	1.2	4	0.75
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in	VC96-13	-74	13b	4	1.2	5Y 5/1	mostly Coarse Sand; some Shell Hash	VC96-13-1	9/1/1996	0	1.2	0.21
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-13	-74	13b	4	1.2	5Y 5/1	mostly Coarse Sand; some Shell Hash	VC96-13-2	9/1/1996	1.2	4	0.75
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-13	-74	13c	5.1	4		mostly Rock Fragments	VC96-13-2	9/1/1996	1.2	4	0.75
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-13	-74	13c	5.1	4		mostly Rock Fragments	VC96-13-3	9/1/1996	5.1	9.2	0.38

Table 4-5. B-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Sample Date	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-13	-74	13d	9.2	4.1	5Y 7/2	mostly Medium Sand; some Shell Hash	VC96-13-3	9/1/1996	5.1	9.2	0.38
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-15	-66	15a	2.2	0	5Y 5/1	mostly Fine Sand	VC96-15-1	9/1/1996	0	2.2	0.21
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-15	-66	15b	4.4	2.2	5Y 5/1	mostly Fine Sand; some Shell Hash	VC96-15-1	9/1/1996	0	2.2	0.21
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-15	-66	15b	4.4	2.2	5Y 5/1	mostly Fine Sand; some Shell Hash	VC96-15-2	9/1/1996	4.4	7	0.24
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-15	-66	15c	7	4.4	5Y 5/1	mostly Fine Sand	VC96-15-2	9/1/1996	4.4	7	0.24

Table 4-5. B-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Sample Date	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-16	-72.5	16a	10.9	0	5Y 4/1	mostly Medium Sand; some Shell Hash	VC96-16-1	9/1/1996	0	2.5	0.37
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-16	-72.5	16a	10.9	0	5Y 4/1	mostly Medium Sand; some Shell Hash	VC96-16-2	9/1/1996	2.5	7.7	0.41
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-16	-72.5	16a	10.9	0	5Y 4/1	mostly Medium Sand; some Shell Hash	VC96-16-3	9/1/1996	7.7	10.9	0.24
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-18	-72	18a	4.3	0	5Y 7/2	mostly Medium Sand; some Shell Fragments; some Boulder	VC96-18-1	9/1/1996	0	2.5	0.44
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-18	-72	18a	4.3	0	5Y 7/2	mostly Medium Sand; some Shell Fragments; some Boulder	VC96-18-2	9/1/1996	2.5	4.3	0.4

Table 4-5. B-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Sample Date	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-18	-72	18b	5.1	4.3		mostly Rock Fragments	VC96-18-2	9/1/1996	2.5	4.3	0.4
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-18	-72	18c	7	5.1	5Y 7/2	mostly Medium Sand; some Boulder; some Shell Fragments	VC96-18-3	9/1/1996	7	9.4	0.26
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-18	-72	18d	9.4	7	5Y 6/2	mostly Medium Sand; some Shell Hash; some Silt	VC96-18-3	9/1/1996	7	9.4	0.26
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-18	-72	18e	10.4	9.4	5Y 6/2	mostly Fine Sand; some Boulder; some Shell Fragments	VC96-18-3	9/1/1996	7	9.4	0.26
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-48	-72	48a	0.7	0	5Y 5/2	mostly Fine Sand; some Silt	VC96-48-1	10/1/1996	0.7	2.5	0.48

Table 4-5. B-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Sample Date	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-48	-72	48b	4.8	0.7	5Y 5/1	mostly Medium Sand; some Shell Hash	VC96-48-1	10/1/1996	0.7	2.5	0.48
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-48	-72	48b	4.8	0.7	5Y 5/1	mostly Medium Sand; some Shell Hash	VC96-48-2	10/1/1996	2.5	4.8	0.48
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-48	-72	48c	5.8	4.8		mostly Rock Fragments	VC96-48-2	10/1/1996	2.5	4.8	0.48
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-49	-70	49a	5.8	0	5Y 6/2	mostly Medium Sand	VC96-49-1	10/1/1996	0	5.8	0.33
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-49	-70	49a	5.8	0	5Y 6/2	mostly Medium Sand	VC96-49-2	10/1/1996	5.8	11	0.38

Table 4-5. B-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Sample Date	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-49	-70	49b	11	5.8	5Y 5/1	mostly Medium Sand; some Shell Hash	VC96-49-1	10/1/1996	0	5.8	0.33
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-49	-70	49b	11	5.8	5Y 5/1	mostly Medium Sand; some Shell Hash	VC96-49-2	10/1/1996	5.8	11	0.38
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-49	-70	49b	11	5.8	5Y 5/1	mostly Medium Sand; some Shell Hash	VC96-49-3	10/1/1996	11	13.4	0.44
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-49	-70	49c	13.4	11	5GY 5/1	mostly Medium Sand; some Fine Sand	VC96-49-2	10/1/1996	5.8	11	0.38
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-49	-70	49c	13.4	11	5GY 5/1	mostly Medium Sand; some Fine Sand	VC96-49-3	10/1/1996	11	13.4	0.44

Table 4-5. B-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Sample Date	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-49	-70	49d	14.2	13.4	5Y 6/2	mostly Silty Sand	VC96-49-3	10/1/1996	11	13.4	0.44
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-50	-71	VC96-50a	4	0	5Y 6/2	mostly Coarse Sand; some Shell Hash; trace Shell Fragments; trace Boulder	VC96-50 1	########	0	4	0.72
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-50	-71	VC96-50a	4	0	5Y 6/2	mostly Coarse Sand; some Shell Hash; trace Shell Fragments; trace Boulder	VC96-50 2	########	4	6.7	0.48
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-50	-71	VC96-50b	10.2	4	5Y 6/2	mostly Medium To Coarse Sand; some Shell Hash; trace Boulder; trace Silt; trace Shell Fragments	VC96-50 1	########	0	4	0.72
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-50	-71	VC96-50b	10.2	4	5Y 6/2	mostly Medium To Coarse Sand; some Shell Hash; trace Boulder; trace Silt; trace Shell Fragments	VC96-50 2	########	4	6.7	0.48

Table 4-5. B-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Sample Date	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-50	-71	VC96-50b	10.2	4	5Y 6/2	mostly Medium To Coarse Sand; some Shell Hash; trace Boulder; trace Silt; trace Shell Fragments	VC96-50 3	########	6.7	10.2	0.63
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-51	-74	51a	0.3	0	5Y 6/2	mostly Fine Sand	VC51-1	10/1/1996	0	3.5	0.61
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-51	-74	51b	8	0.3	5Y 7/1	mostly Medium To Coarse Sand; some Shell Hash	VC51-1	10/1/1996	0	3.5	0.61
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-51	-74	51b	8	0.3	5Y 7/1	mostly Medium To Coarse Sand; some Shell Hash	VC96-51-2	10/1/1996	3.5	8	0.5
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	VC96-51	-74	51c	8.6	8		mostly Rock Fragments	VC96-51-2	10/1/1996	3.5	8	0.5

Table 4-6. B-1 results from ROSS jetprobe query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	JP96-38	-71	JP96-38-a	8	0		mostly Sand				
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	JP96-38	-71	JP96-38 b	13	8		some Shell Hash; mostly Sand				
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	JP96-38	-71	JP96-38-c	15	13		some Shell Hash; little Rock Fragments; mostly Sand				
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	JP96-40	-76	JP96-40 a	3	0		mostly Sand				
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	JP96-40	-76	JP96-40 b	5	3		mostly Sand; some Rock Fragments				

Table 4-6. B-1 results from ROSS jetprobe query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	JP96-44	-74	JP96-44 a	2	0		mostly Sand				
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	JP96-44	-74	JP96-44 b	5.5	2		mostly Sand; some Rock Fragments				
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	JP96-44	-74	JP96-44 c	20	5.5		mostly Sand				
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	JP96-45	-69	JP96-45 a	14	0		some Shell Hash; mostly Sand				
Geotechnical Study of Offshore Sand Deposits for Beach Renourishment in Broward County Florida (1996)	JP96-47	-68.5	JP96-47 a	9	0		some Shell Hash; mostly Sand				

Table 4-7. B-3 results from ROSS jetprobe query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Broward County, Florida Bathymetric and Sand Inventory Survey	P9	0	P9a	6	0		mostly Sand				
Broward County, Florida Bathymetric and Sand Inventory Survey	P16	0	P16a	3	0		mostly Sand; some Organics; trace Boulder; trace Rock Fragments				
Broward County, Florida Bathymetric and Sand Inventory Survey	P17	0	P17a	10	0		mostly Sand				
Broward County, Florida Bathymetric and Sand Inventory Survey	P23	0	P23a	5	0		mostly Coarse Shelly Sand; trace Rock Fragments; trace Boulder				
Broward County Erosion Prevention District- Core Boring Analysis for Zone II and Zone IV	A1	-80	A1a	2	0		mostly Coarse To Medium Sand; little Rock Fragments; trace Boulder				
Broward County Erosion Prevention District- Core Boring Analysis for Zone II and Zone IV	A2	-85	A2a	4	0		trace Boulder; mostly Coarse To Medium Sand; some Shell				
Broward County Erosion Prevention District- Core Boring Analysis for Zone II and Zone IV	A3	-83	A3a	7	0		mostly Medium Sand; trace Rock Fragments; trace Gravel; trace Silt				
Broward County Erosion Prevention District- Core Boring Analysis for Zone II and Zone IV	A4	-78	A4a	10	0		little Silt; trace Rock Fragments; trace Gravel; mostly Coarse To Medium Sand				
Broward County Erosion Prevention District- Core Boring Analysis for Zone II and Zone IV	A5	-73	A5a	5	0		mostly Medium Sand; trace Gravel; trace Rock Fragments				

Table 4-7. B-3 results from ROSS jetprobe query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Broward County Erosion Prevention District- Core Boring Analysis for Zone II and Zone IV	A6	-75	A6a	10	0		trace Gravel; trace Silt; trace Rock Fragments; mostly Medium Sand				
Broward County Erosion Prevention District- Core Boring Analysis for Zone II and Zone IV	A7	-75	A7a	8	0		trace Gravel; trace Silt; mostly Medium Sand; little Rock Fragments				
Broward County Erosion Prevention District- Core Boring Analysis for Zone II and Zone IV	A8	-75	A8a	3	0		trace Rock; little Rock Fragments; mostly Medium Sand				
Broward County Erosion Prevention District- Core Boring Analysis for Zone II and Zone IV	A9	-75	A9a	5	0		mostly Medium Sand; trace Rock				
Broward County Erosion Prevention District- Core Boring Analysis for Zone II and Zone IV	A10	-73	A10a	9	0		mostly Medium Shelly Sand; trace Silt; trace Gravel				
Broward County Erosion Prevention District- Core Boring Analysis for Zone II and Zone IV	A11	-71	A11a	5	0		mostly Medium Silty Sand; trace Rock Fragments				

Table 4-8a. D-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	12	-54	12a	1	0	10YR 7/2	mostly Fine To Medium Carbonate Sand	1-Dec	0	0.5	0.26
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	12	-54	12a	1	0	10YR 7/2	mostly Fine To Medium Carbonate Sand	2-Dec	0.5	2	0.36
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	12	-54	12b	3	1	10YR 7/2	mostly Fine To Medium Carbonate Sand; little Shell Fragments	2-Dec	0.5	2	0.36
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	12	-54	12b	3	1	10YR 7/2	mostly Fine To Medium Carbonate Sand; little Shell Fragments	3-Dec	2	5	0.46
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	12	-54	12c	6	3	10YR 6/1	mostly Medium To Coarse Carbonate Sand	3-Dec	2	5	0.46

Table 4-8a. D-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	12	-54	12c	6	3	10YR 6/1	mostly Medium To Coarse Carbonate Sand	4-Dec	5	7.5	0.56
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	12	-54	12d	7.5	6	10YR 7/1	mostly Medium To Coarse Carbonate Sand; trace Shell Fragments	4-Dec	5	7.5	0.56
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	12	-54	12e	8	7.5	10YR 7/2	mostly Medium To Coarse Carbonate Sand; trace Shell Fragments	4-Dec	5	7.5	0.56
Beach Erosion Control and Hurricane Protection Study for Dade County, Florida North of Haulover Beach Park	CB-DAC-2	-36.7	CB-DAC-2A	14	0		mostly Carbonate Sand; some Coarse Shell Fragments; some Medium To Very Coarse Shell; little Fine To Medium Cobble				
Beach Erosion Control and Hurricane Protection Study for Dade County, Florida North of Haulover Beach Park	CB-DAC-2	-36.7	CB-DAC-2B	18	14		trace Silt; mostly Fine Cobble				

Table 4-8a. D-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
Beach Erosion Control and Hurricane Protection Study for Dade County, Florida North of Haulover Beach Park	CB-DAC-2	-36.7	CB-DAC-2C	19.8	18		mostly Silt				
Beach Erosion Control and Hurricane Protection Study for Dade County, Florida North of Haulover Beach Park	CB-DAC-5	-42.9	CB-DAC-5A	10	0		trace Silt; mostly Carbonate Sand; isolated Medium To Very Coarse Silty Shell; isolated Boulder; some Fine To Coarse Shell Fragments				
Beach Erosion Control and Hurricane Protection Study for Dade County, Florida North of Haulover Beach Park	CB-DAC-5	-42.9	CB-DAC-5B	18.8	10		little Rock Fragments; trace Silt; mostly Fine To Medium Quartz Sand				
North Dade County Beach Erosion Control (1978)	CB-ND-22	-44.5	CB-ND-22A	13.5	0		mostly Medium To Coarse Shelly Sand; trace Silt				
North Dade County Beach Erosion Control (1978)	CB-ND-23	-45	CB-ND-23A	2.8	0		mostly Fine To Coarse Sand; some Shell; trace Silt	CB-ND-23-1	0	2.8	
North Dade County Beach Erosion Control (1978)	CB-ND-24	-44	CB-ND-24A	12.7	0		mostly Medium To Coarse Shelly Sand; little Silt				

Table 4-8a. D-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-DAC-3	-44.2	CB-3A	3.7	0		mostly Fine To Coarse Carbonate Sand; little Boulder; little Shell Fragments; trace Silt				
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-DAC-4	-40.4	CB-4A	11	0		mostly Fine To Coarse Carbonate Sand; trace Boulder; trace Shell Fragments; trace Silt				
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-DAC-4	-40.4	CB-4B	19.8	11		mostly Fine Quartz Sand; little Rock Fragments; trace Silt				
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-DAC-6	-53.2	CB-6A	19.8	0		mostly Carbonate Sand; some Coarse Shell Fragments; some Fine To Medium Cobble; trace Silt; isolated Shell				

Table 4-8a. D-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-DAC-7	-44.7	CB-7A	15	0		mostly Fine Carbonate Sand; some Medium To Coarse Shell Fragments; trace Silt				
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-DAC-7	-44.7	CB-7B	19.6	15		mostly Silty Sand; trace Boulder; trace Shell				
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-27	-42.8	CB-27A	19.8	0		mostly Silty Carbonate Sand; little Coarse Shell Fragments; little Fine To Medium Cobble; trace Boulder				
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-28	-53.6	CB-28A	9.2	0		mostly Carbonate Sand; some Shell Fragments; little Fine Cobble; isolated Boulder; isolated Medium To Very Fine Shell				

Table 4-8a. D-1 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-28	-53.6	CB-28B	16	9.2		mostly Fine To Medium Sand; trace Silt; isolated Medium To Very Fine Shell; isolated Rock Fragments				

Table 4-8b. D-1 results from ROSS grab sample query.

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean
USGS / Woods Hole Oceanographic Institution								U01344			1.26

Table 4-9a. D-2 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Length	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	11	-55	1.7	11a	1.7	0	10YR 7/3	mostly Medium To Coarse Carbonate Sand; some Shell Fragments	1-Nov	0	0.4	0.46
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	11	-55	1.7	11a	1.7	0	10YR 7/3	mostly Medium To Coarse Carbonate Sand; some Shell Fragments	2-Nov	0.4	1.3	0.62
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	11	-55	1.7	11a	1.7	0	10YR 7/3	mostly Medium To Coarse Carbonate Sand; some Shell Fragments	3-Nov	1.3	1.7	0.21

Table 4-9b. Results from ROSS grab sample query

Sand Query ResultsProject Name	Core Identifier	Core Top Elevation	Core Length	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean
USGS / Woods Hole Oceanographic Institution									U01343			1.85

Table 4-10. D-3 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Length	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Color	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-22B	-45.8	17.6	CB-22B-A	17.6	0	LIGHT GRAY	mostly Fine To Medium Silty Carbonate Sand; little Coarse Shell Fragments; trace Shell; isolated Rock Fragments				
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB23	-47.2	15	CB-23A	15	0	LIGHT TANISH GRAY	mostly Fine To Coarse Carbonate Sand; some Shell Fragments; trace Silt; isolated Boulder; isolated Shell				
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-24	-48.7	10.9	CB-24A	10.9	0	TANISH GRAY	mostly Medium To Coarse Carbonate Sand; little Shell Fragments; isolated Shell; isolated Boulder				
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-25	-47.7	16.9	CB-25A	16.9	0	TANISH GRAY	mostly Medium Carbonate Sand; some Coarse Shell Fragments; trace Silt; trace Boulder; isolated Shell				
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-26	-49	14.8	CB-26A	9	0	LIGHT BEIGEISH	mostly Fine To Medium Carbonate Sand; little Coarse Shell Fragments; little Boulder; isolated Shell				
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-26	-49	14.8	CB-26B	14.8	9	LIGHT GRAY	mostly Fine Quartz Sand; little Rock; trace Silt; trace Shell Fragments				

Table 4-11. D-4 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	1A	-30	1A-a	1	0	10YR 7/2	mostly Fine To Medium Carbonate Sand	Data from these cores	0	0.5	0.17
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	1A	-30	1A-a	1	0	10YR 7/2	mostly Fine To Medium Carbonate Sand	2-Jan	0.5	1.5	0.53
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	1A	-30	1A-b	2	1		mostly Fine To Coarse Carbonate Sand; little Cobble; trace Shell Fragments	2-Jan	0.5	1.5	0.53
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	1A	-30	1A-c	3	2	10YR 8/1	mostly Fine To Medium Silty Carbonate Sand; some Medium To Very Coarse Rock	3-Jan	2.5	3.25	0.39
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	1A	-30	1A-d	3.5	3	10YR 7/2	mostly Fine To Medium Carbonate Sand; some Medium To Very Coarse Rock	3-Jan	2.5	3.25	0.39
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	1A	-30	1A-d	3.5	3	10YR 7/2	mostly Fine To Medium Carbonate Sand; some Medium To Very Coarse Rock	4-Jan	3.25	3.5	0.34

Table 4-11. D-4 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	2	-30	2a	1	0	10YR 7/2	mostly Medium To Coarse Carbonate Sand; trace Shell Fragments	1-Feb	0	1	0.44
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	2	-30	2a	1	0	10YR 7/2	mostly Medium To Coarse Carbonate Sand; trace Shell Fragments	2-Feb	1	2.5	0.49
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	2	-30	2b	3.4	1	10YR 8/2	mostly Medium To Coarse Carbonate Sand	1-Feb	0	1	0.44
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	2	-30	2b	3.4	1	10YR 8/2	mostly Medium To Coarse Carbonate Sand	2-Feb	1	2.5	0.49
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	2	-30	2c	4	3.4	10YR 7/3	mostly Medium Carbonate Sand				
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	3	-27	3a	1.5	0	10YR 6/1	mostly Medium To Coarse Carbonate Sand	1-Mar	0	1	0.4

Table 4-11. D-4 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	3	-27	3a	1.5	0	10YR 6/1	mostly Medium To Coarse Carbonate Sand	2-Mar	1	2	0.51
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	3	-27	3b	2	1.5	10YR 6/1	mostly Medium To Coarse Carbonate Sand	2-Mar	1	2	0.51
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	4	-28	4a	1	0	10YR 7/4	mostly Fine To Medium Carbonate Sand; trace Limestone	1-Apr	0	1	0.24
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	10	-36	10a	1.2	0	10YR 8/2	mostly Medium Carbonate Sand	1-Oct	0	0.5	0.39
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	10	-36	10a	1.2	0	10YR 8/2	mostly Medium Carbonate Sand	2-Oct	0.5	1.5	0.44
Geomorphology and Sediments of the Nearshore Continental Shelf Miami to Palm Beach, Fl (1969)	10	-36	10b	2	1.2		some Fine Carbonate Sand; some Rock	2-Oct	0.5	1.5	0.44

Table 4-11. D-4 results from ROSS vibracore query.

Sand Query Results/Project Name	Core Identifier	Core Top Elevation	Core Layer Identifier	Bottom of Layer Interval	Top of Layer Interval	Core Layer Munsell	Core Layer Qualifiers	Sample Identifier	Top Of Sample Interval	Bottom Of Sample Interval	Mean Original
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-DAC-32	-11.8	CB-32A	12.8	0		mostly Fine To Coarse Carbonate Sand; trace Silt; isolated Shell				
Environmental Impact Statement Beach Erosion Control and Hurricane Surge Protection Project Dade County, Florida	CB-DAC-33	-17.9	CB-33A	1.1	0		mostly Rock				

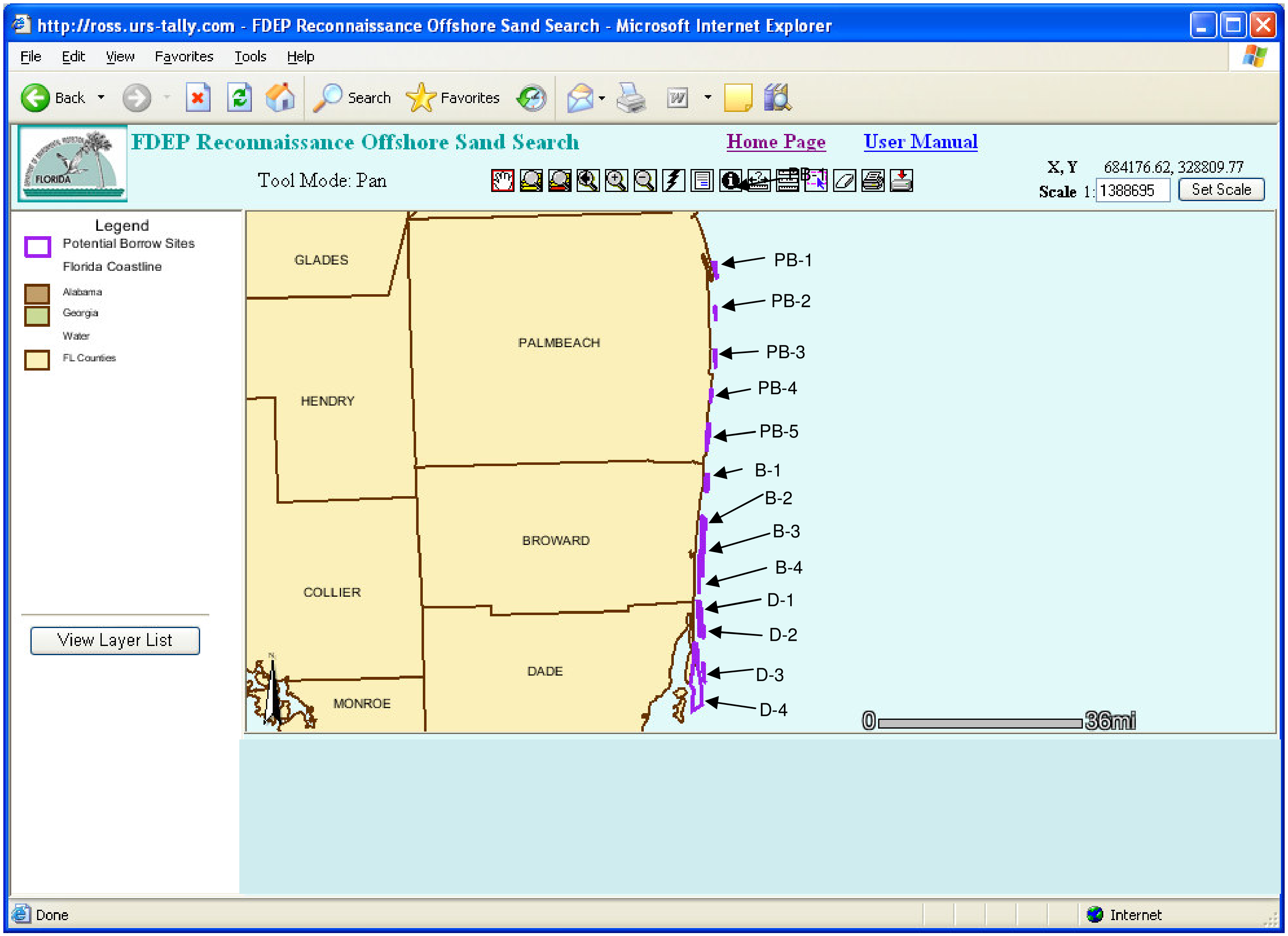


Figure 4-1. Potential Sand Source Areas for the Southeast Phase I Region.

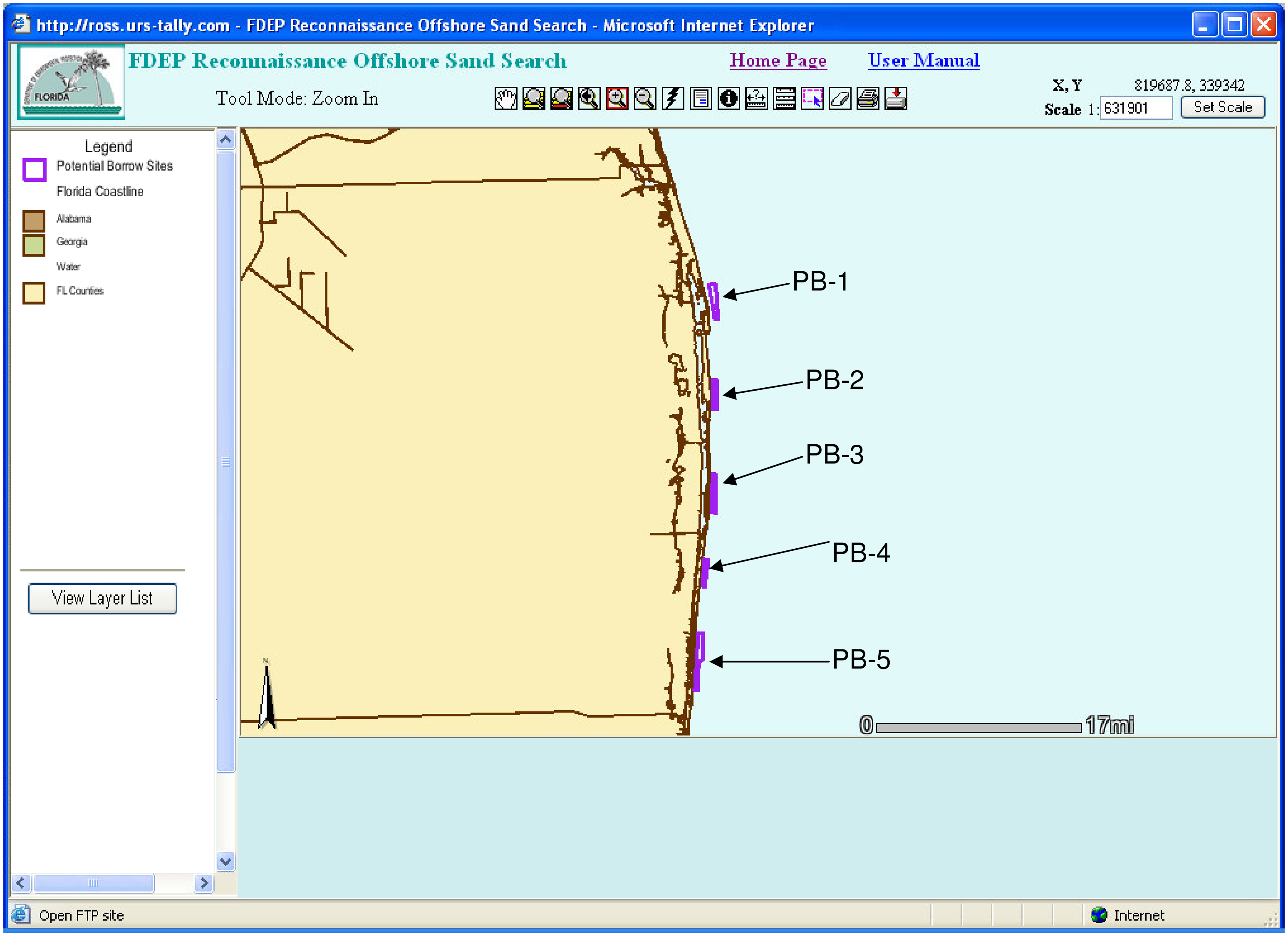


Figure 4-2. Palm Beach County Nearshore Potential Borrow Areas.

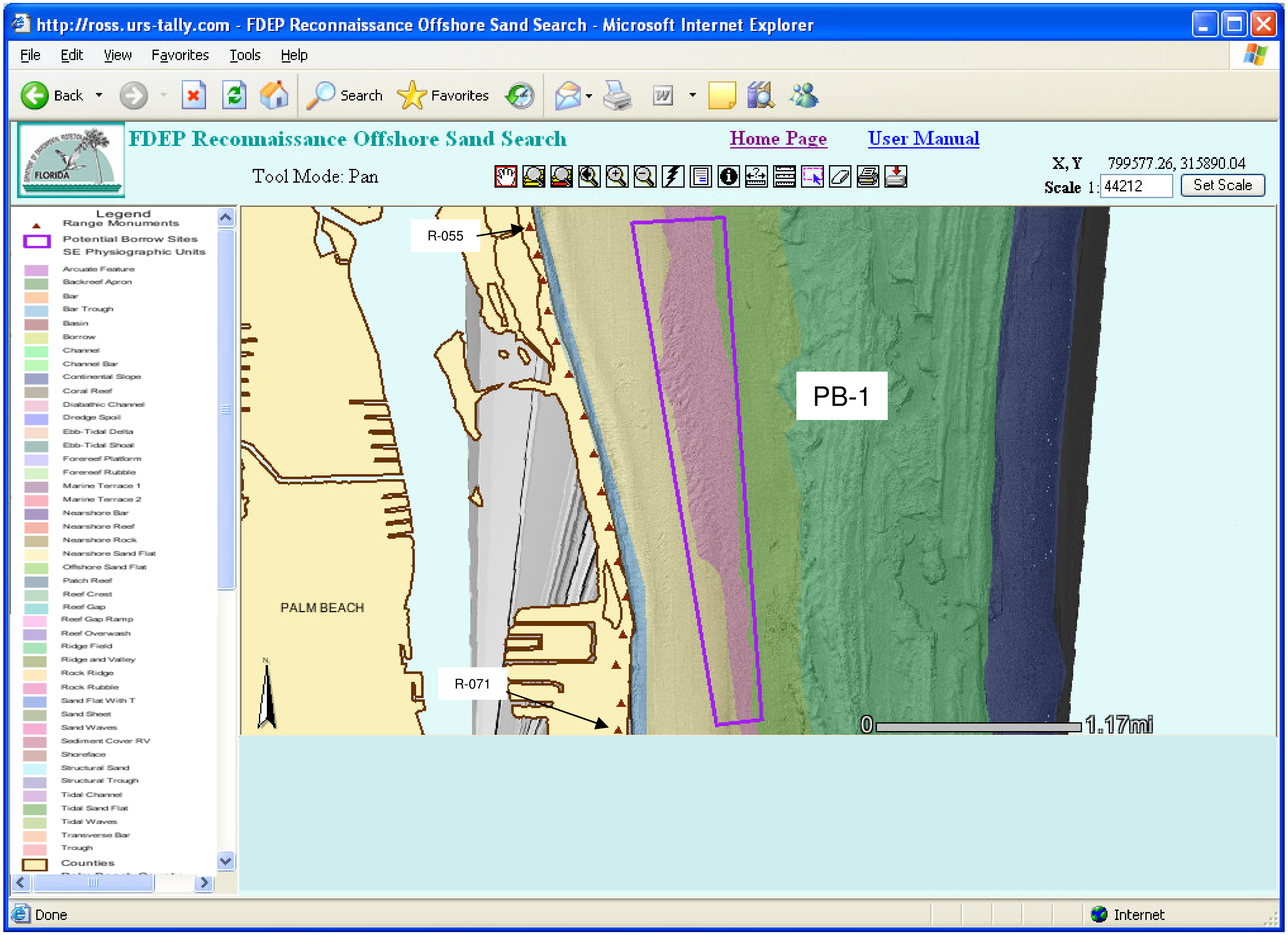


Figure 4-3. Palm Beach County Area PB-1 showing physiographic zones overlaying the gray scale image.

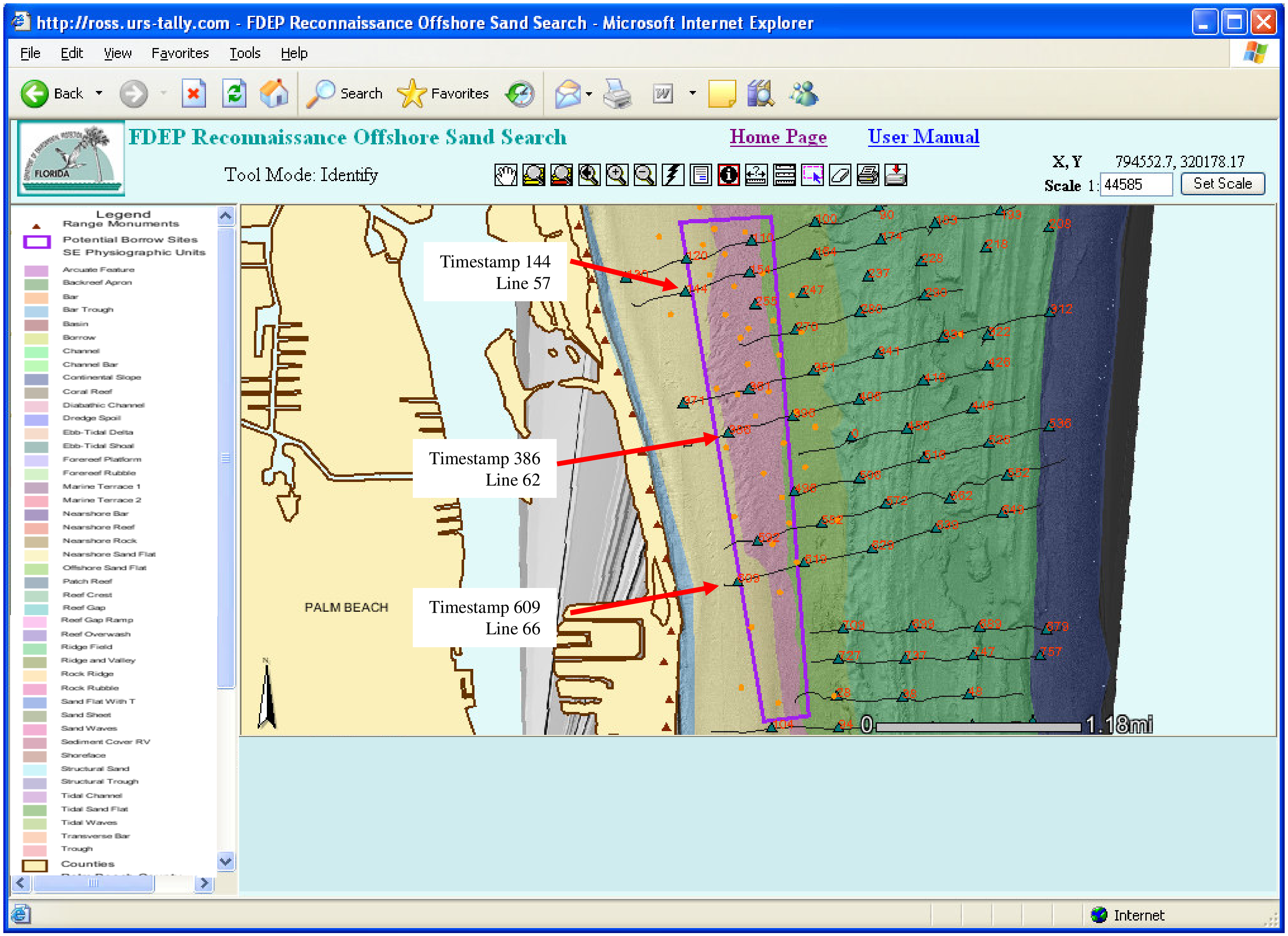


Figure 4-4. Palm Beach County Area PB-1 showing selected trackline locations.

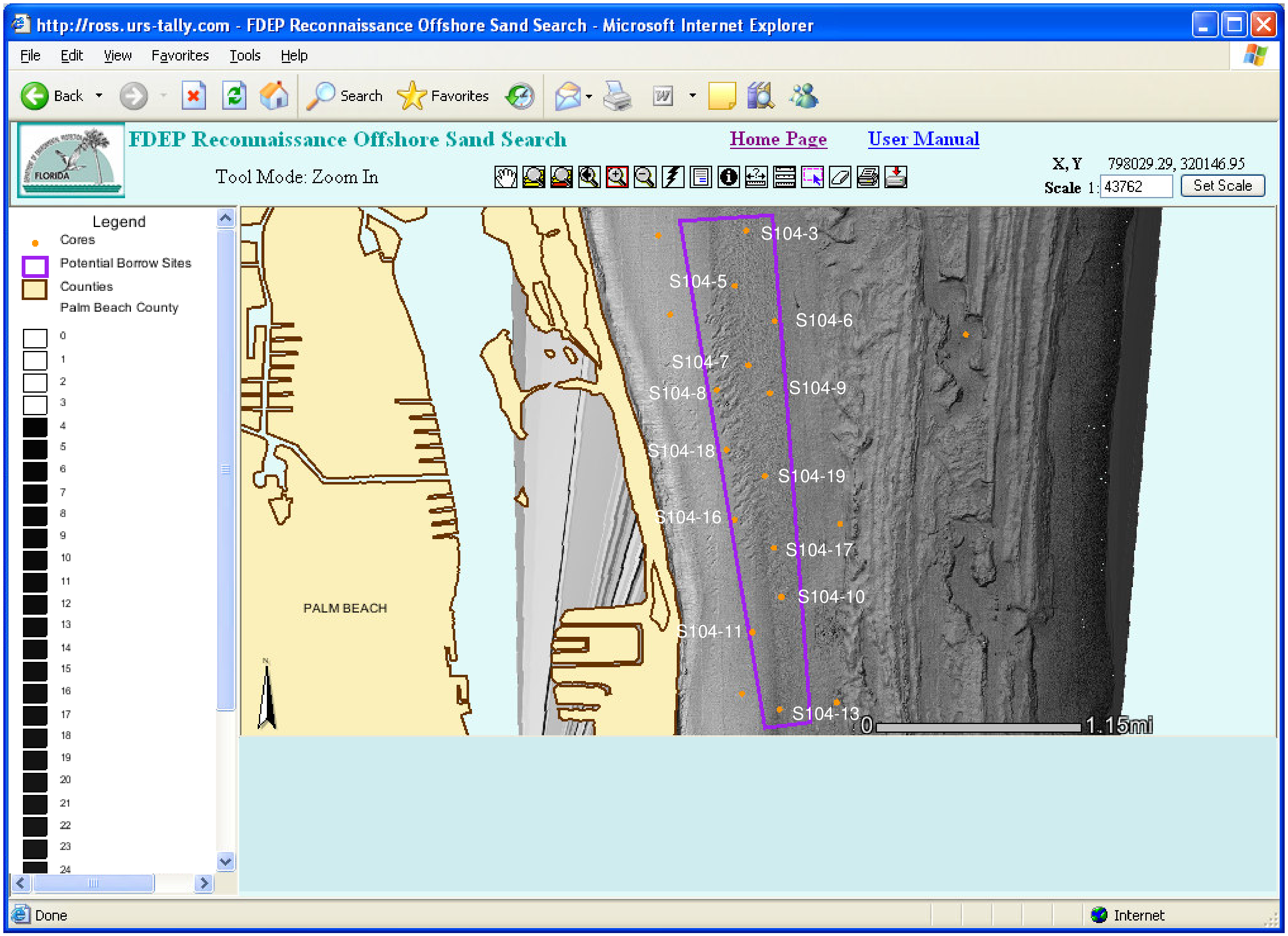


Figure 4-5. Palm Beach County Area PB-1. Locations of cores.

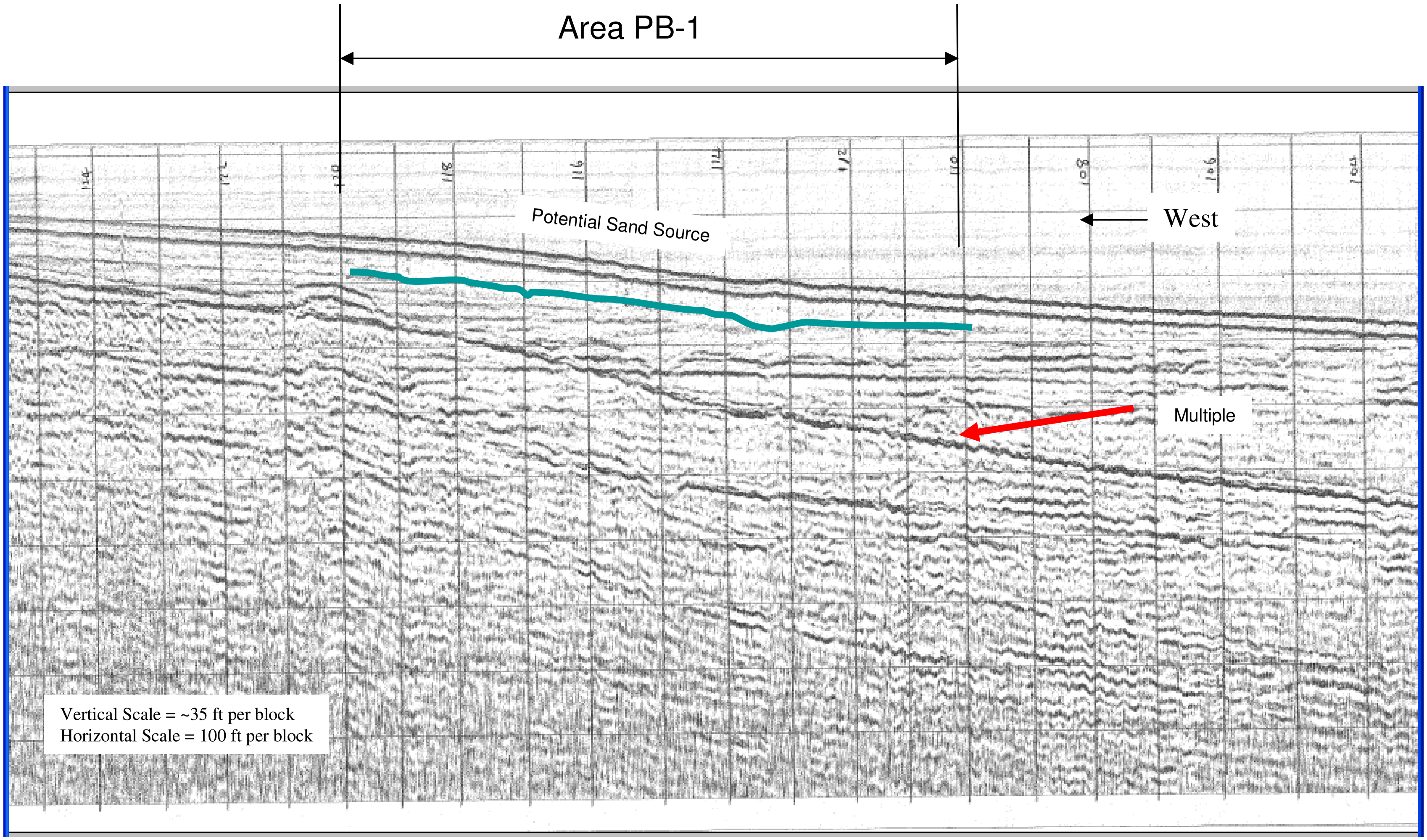


Figure 4-6. Palm Beach County Area PB-1. Line 57 between timestamp 104 and 124.

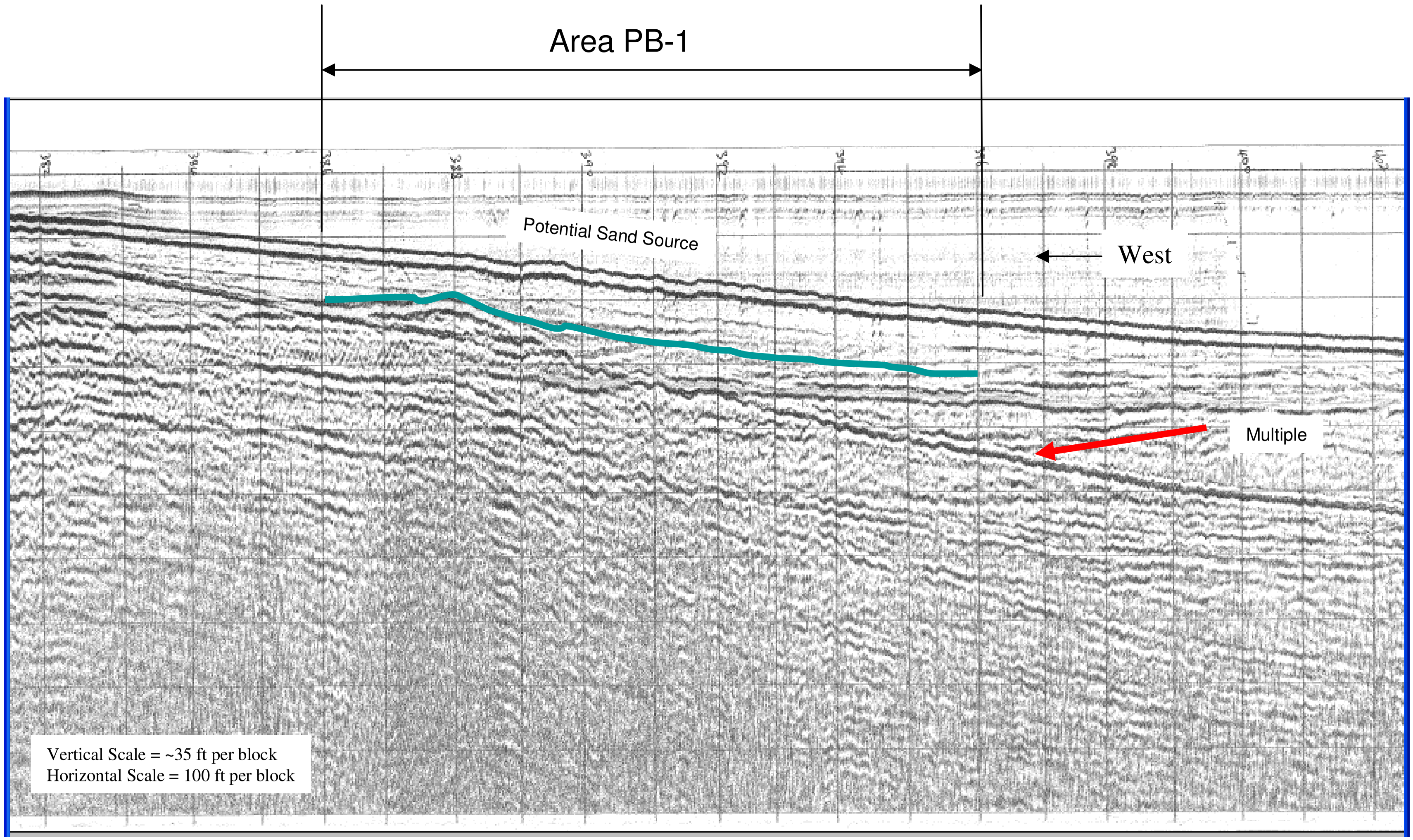


Figure 4-7. Palm Beach County Area PB-1. Line 62. Area is between timestamp 386 and 396.

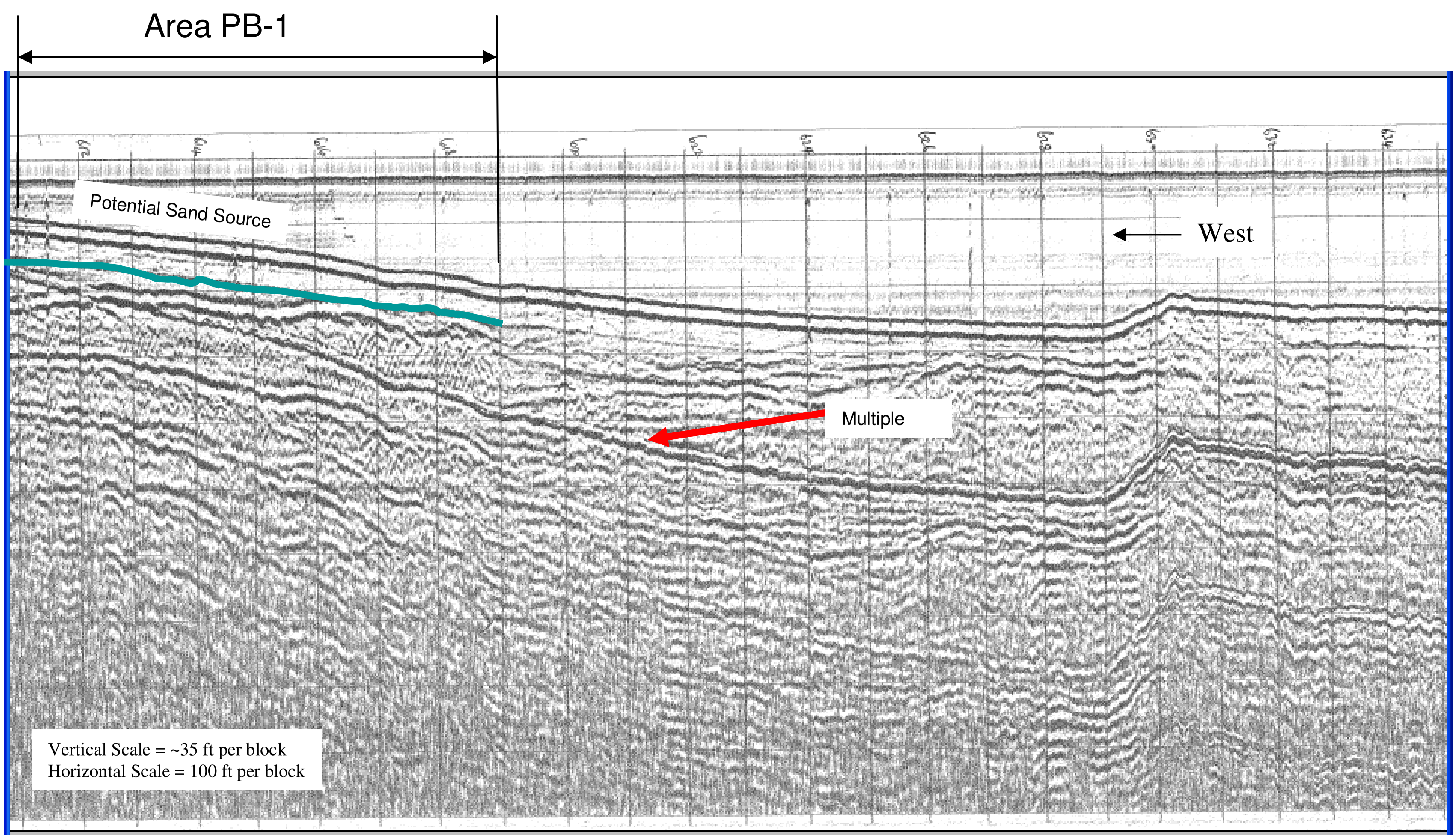


Figure 4-8. Palm Beach County Area PB-1. Line 66. Area PB-1 is between timestamp 609 and 619.

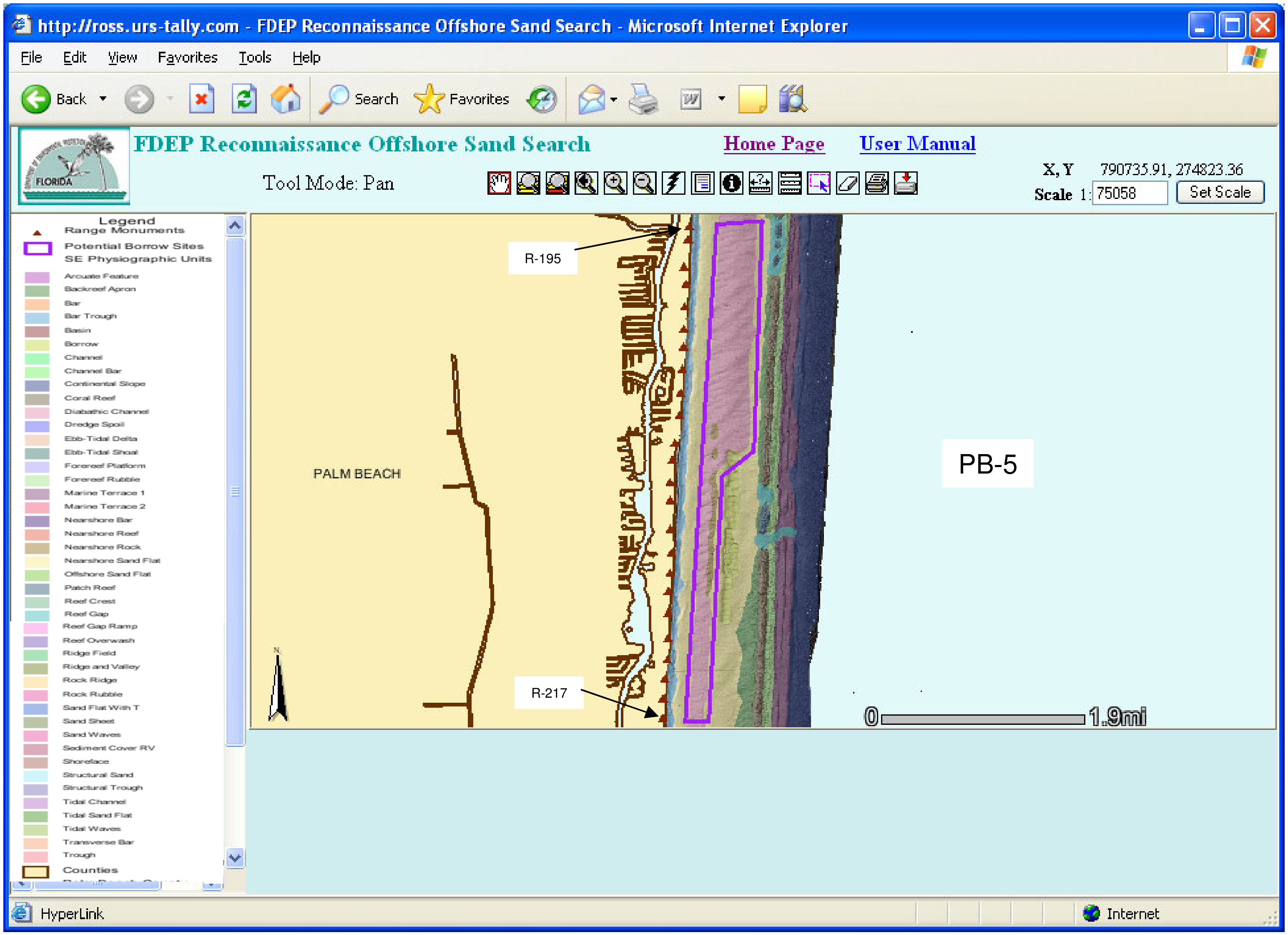


Figure 4-9. Palm Beach County Area PB-5 showing physiographic zone overlaying the gray scale image.

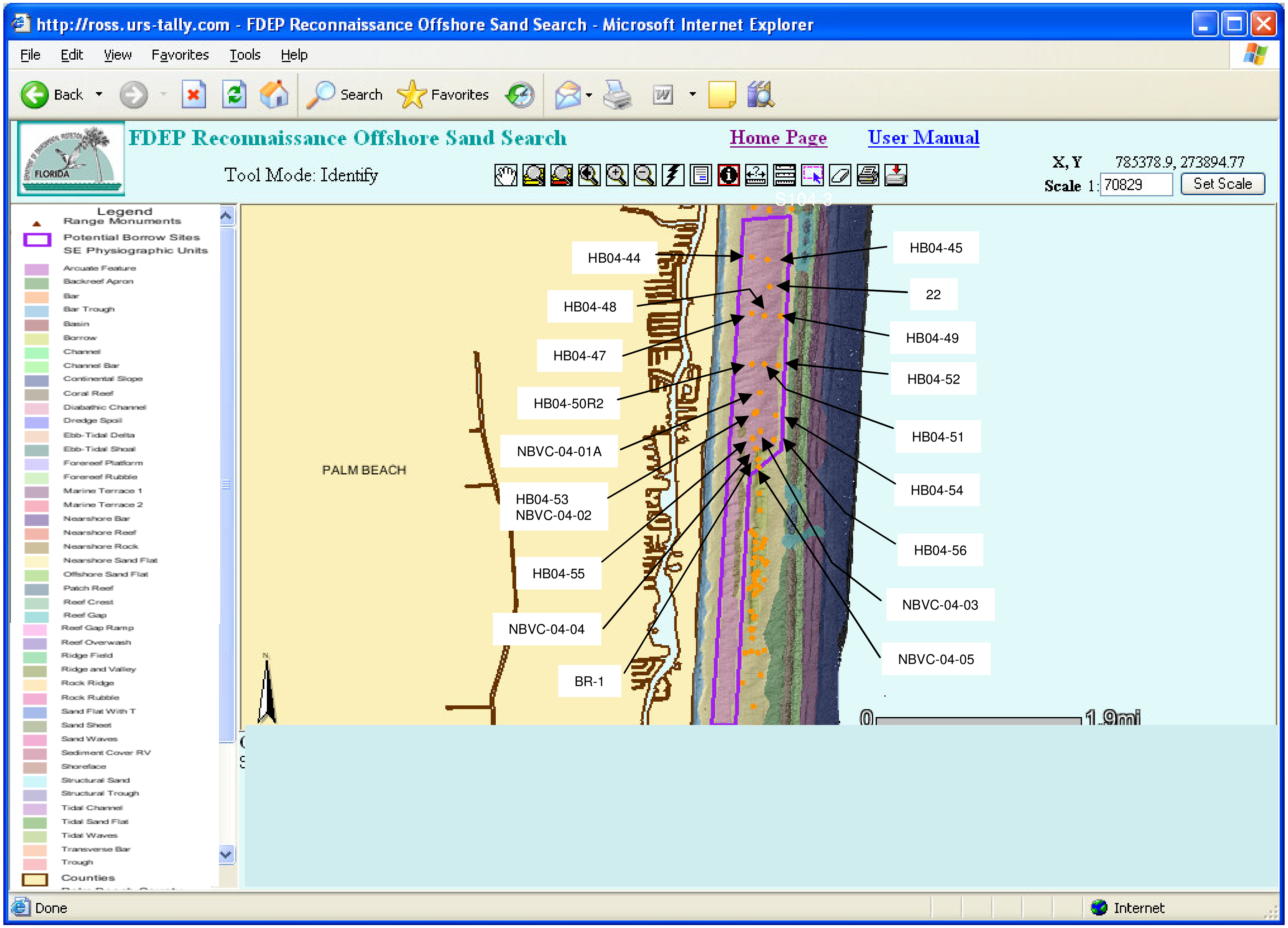


Figure 4-10. Palm Beach County Area PB-5. Vibracore locations.

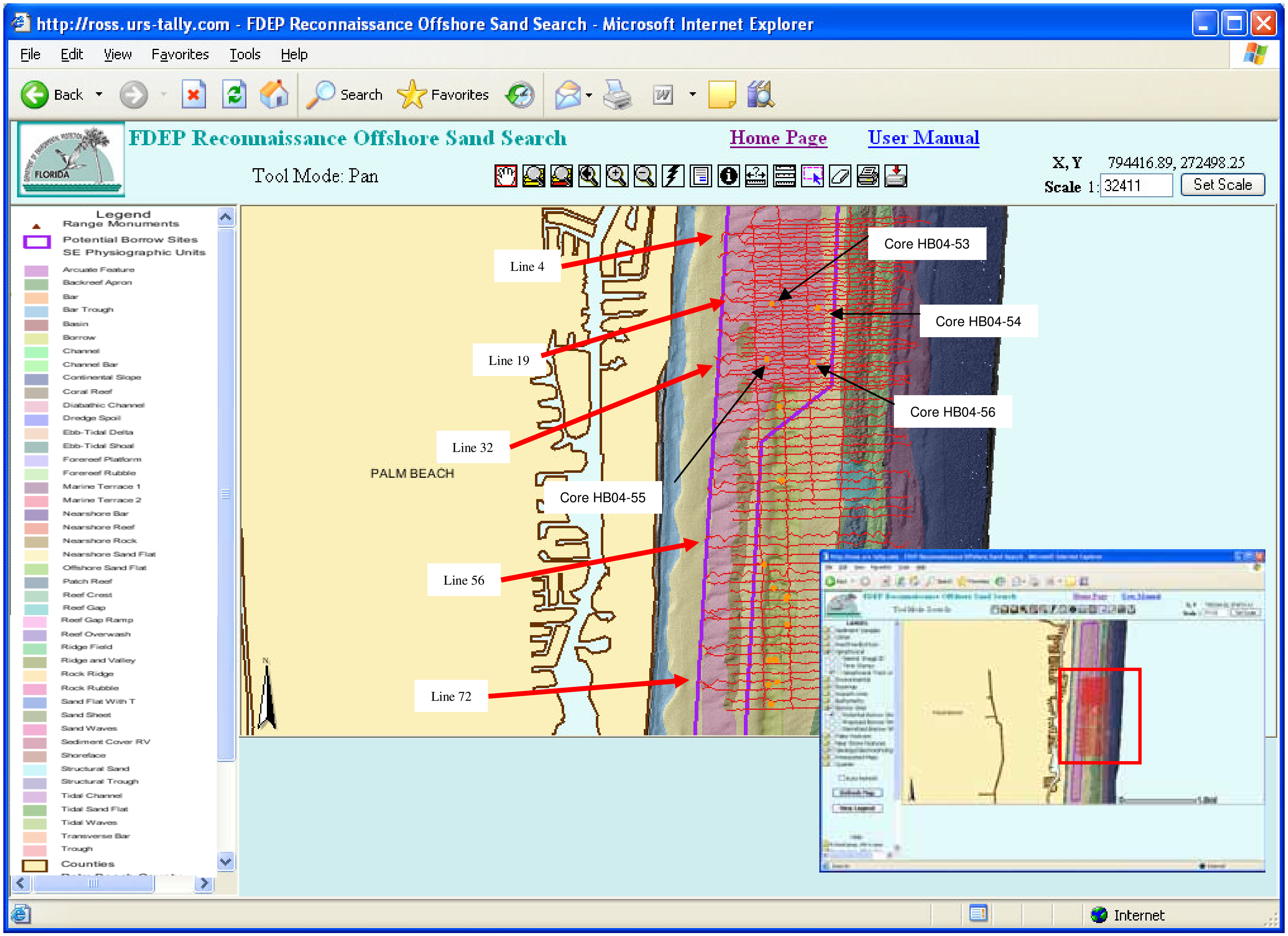


Figure 4-11. Palm Beach County Area PB-5. Select geophysical trackline locations with vibracore locations.

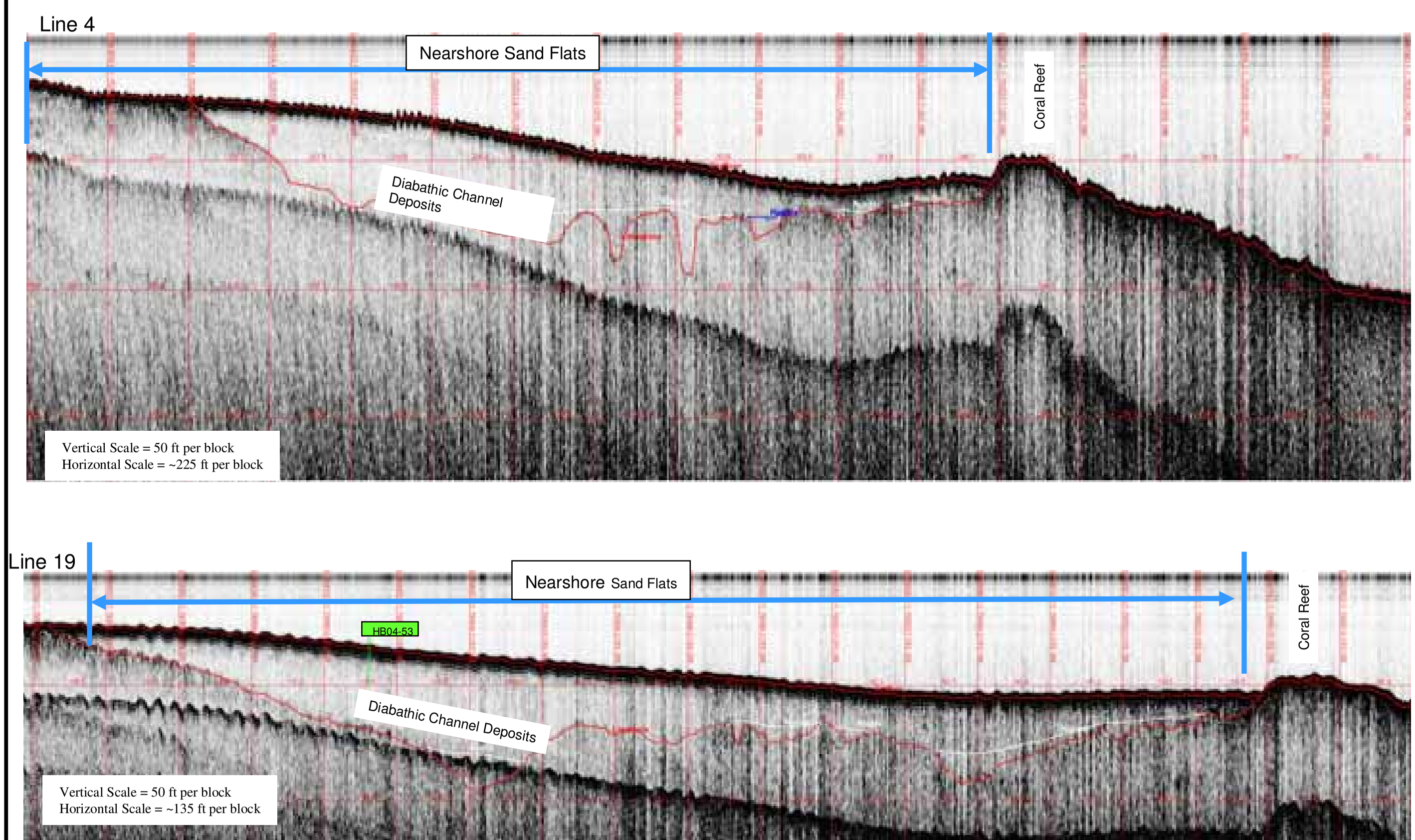


Figure 4-12. Palm Beach County Area PB-5. Line 4 (above) and Line 19 (below). Showing Nearshore Sand Flats and extent of Diabathic Channels. The location of Vibracore HB04-53 also shown on Line 19.

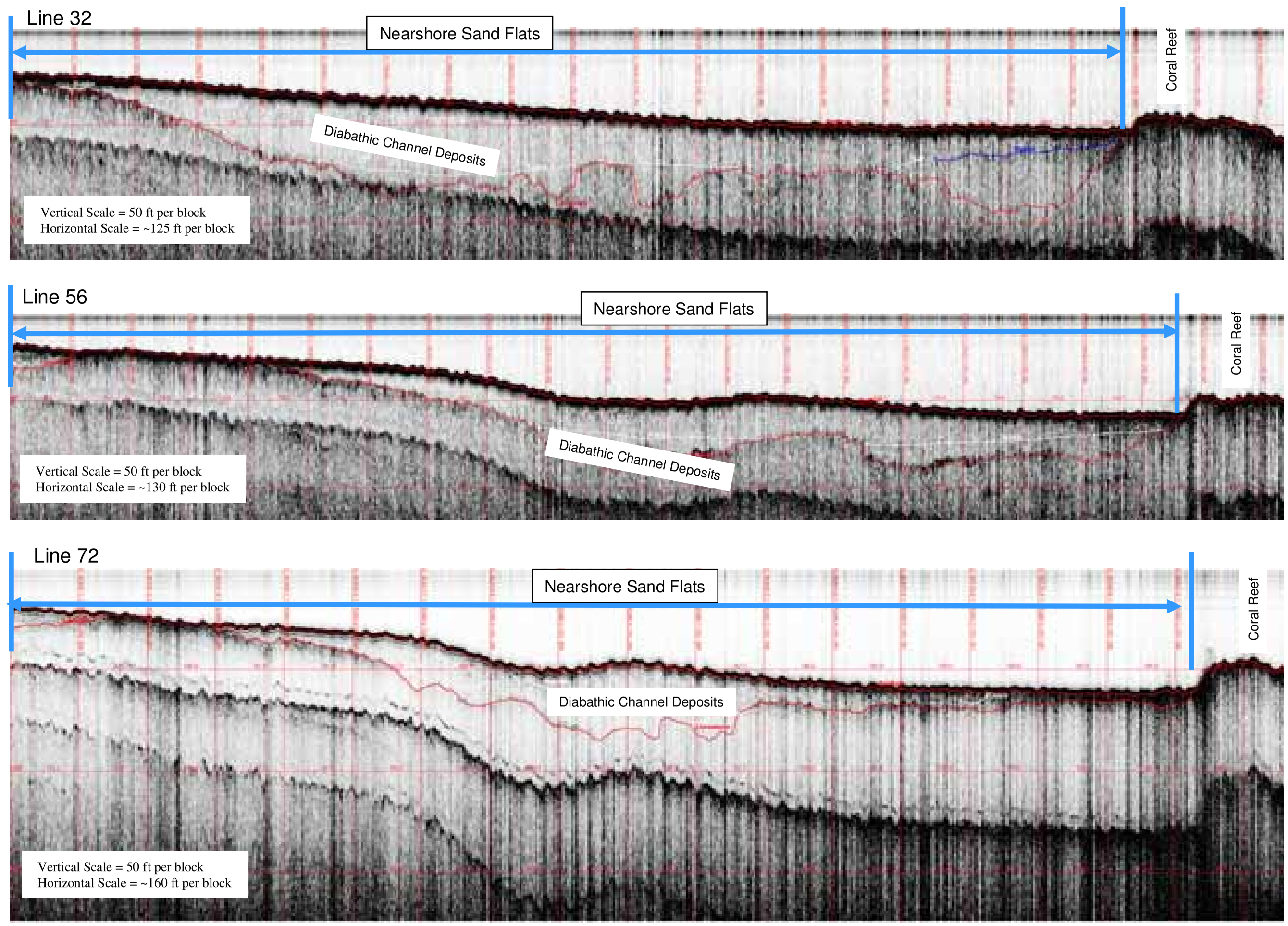


Figure 4-13. Palm Beach County Area PB-5. Sub-bottom images from Line 32, Line 56 and Line 72 with annotations.

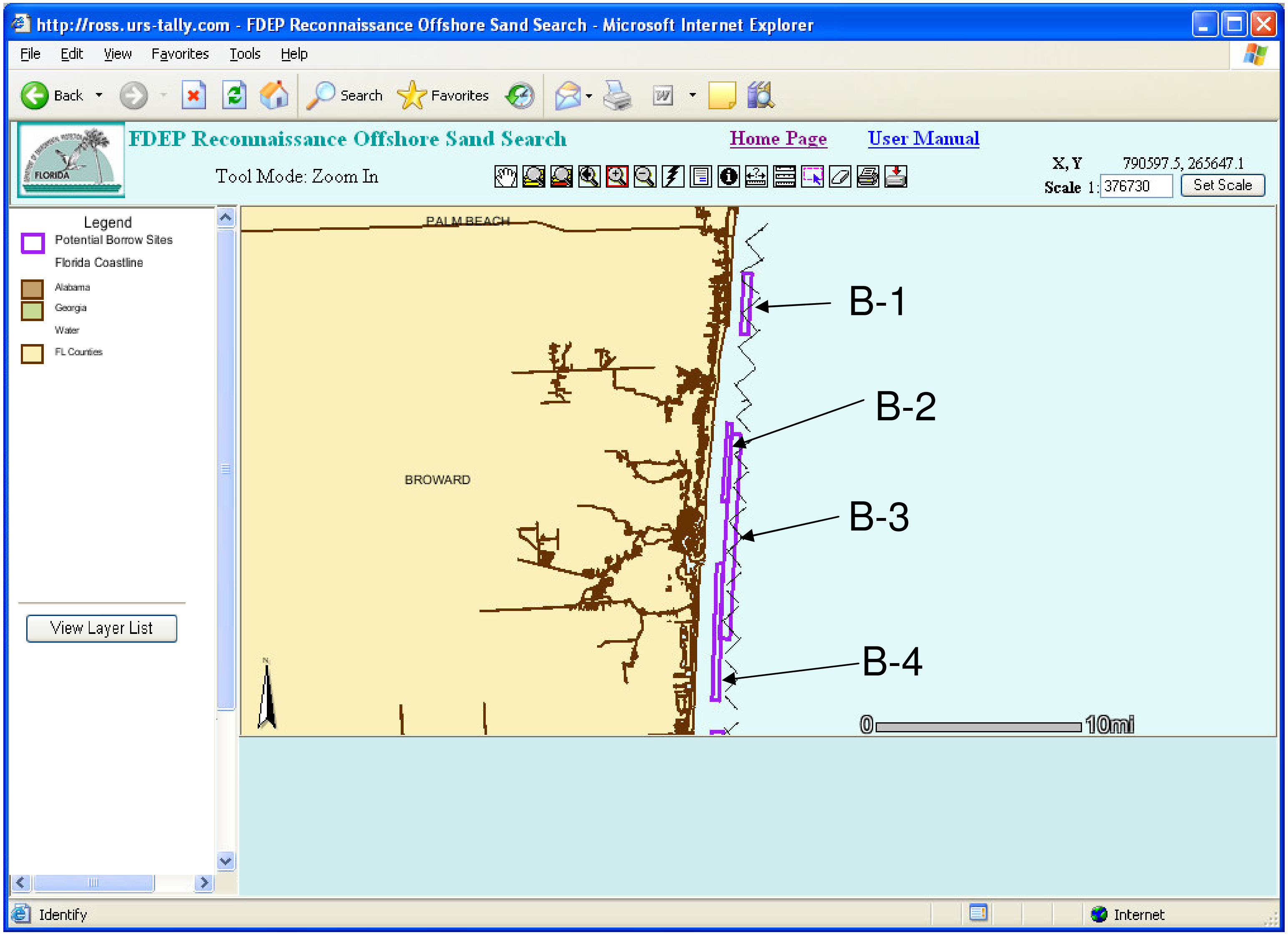


Figure 4-14. Broward County Nearshore Potential Borrow Areas and Geophysical Trackline Locations.

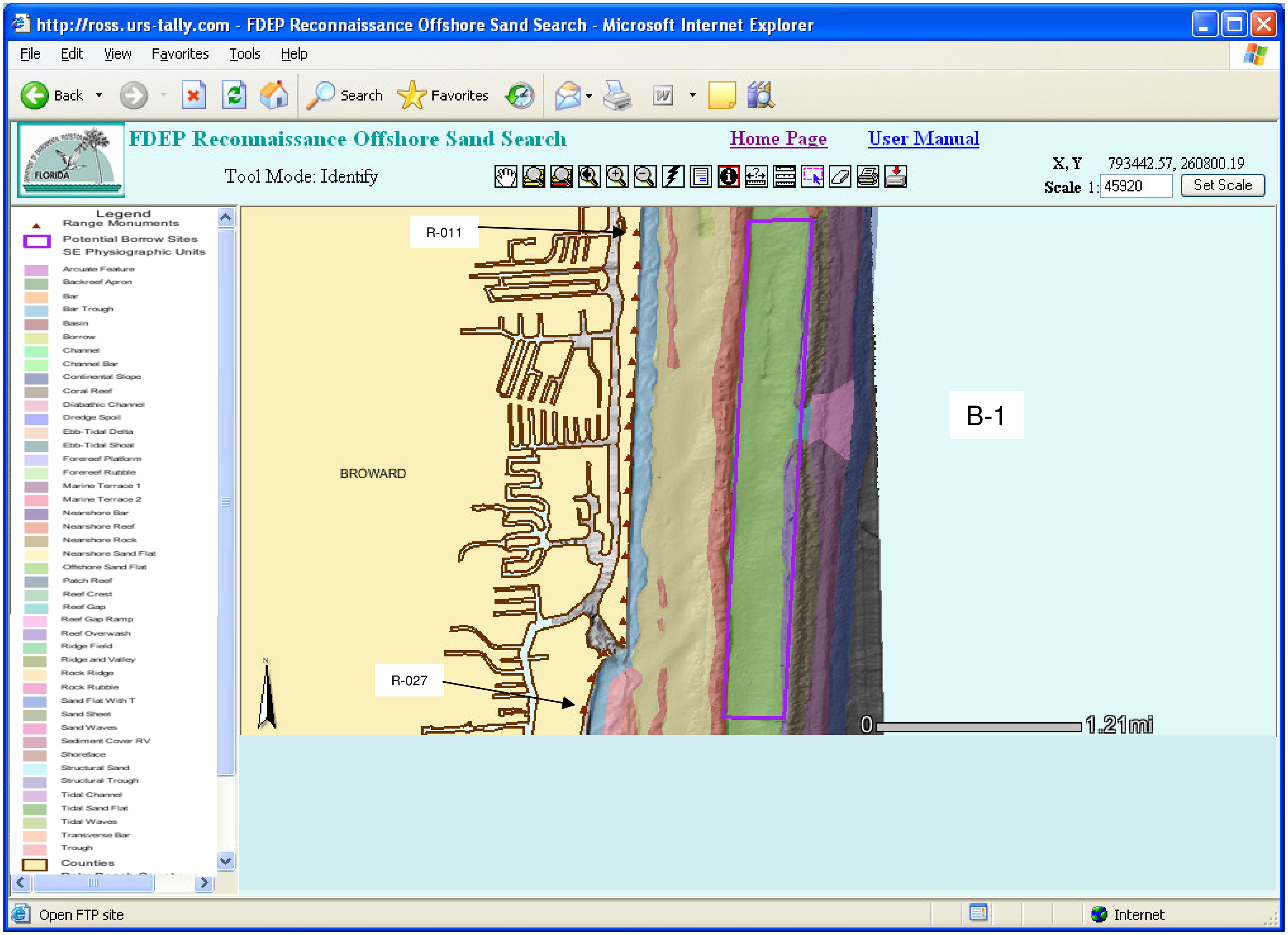


Figure 4-15. Broward County Area B-1 showing physiographic zone overlaying the gray scale image.

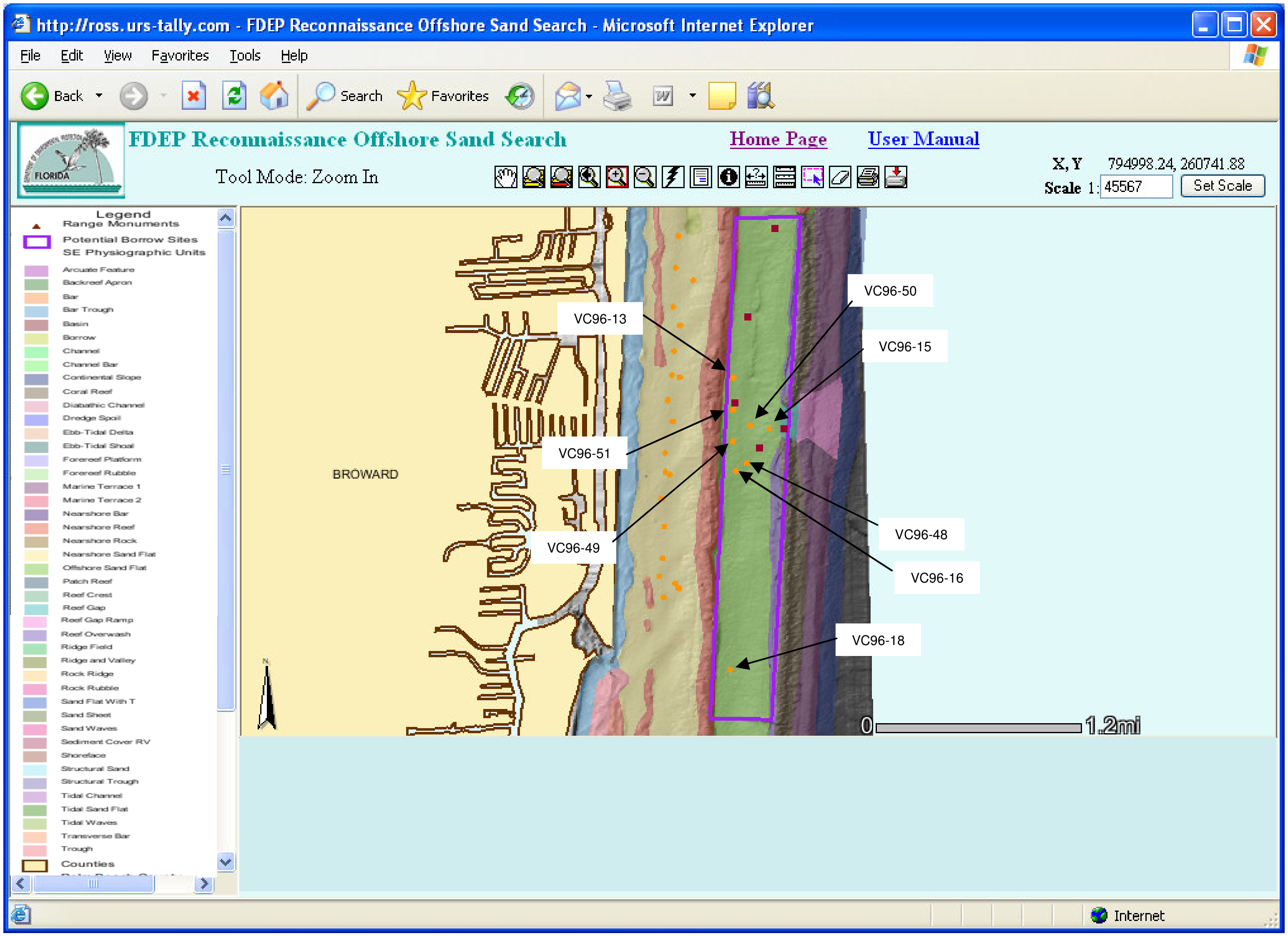


Figure 4-16. Broward County Area B-1 showing vibracore locations.

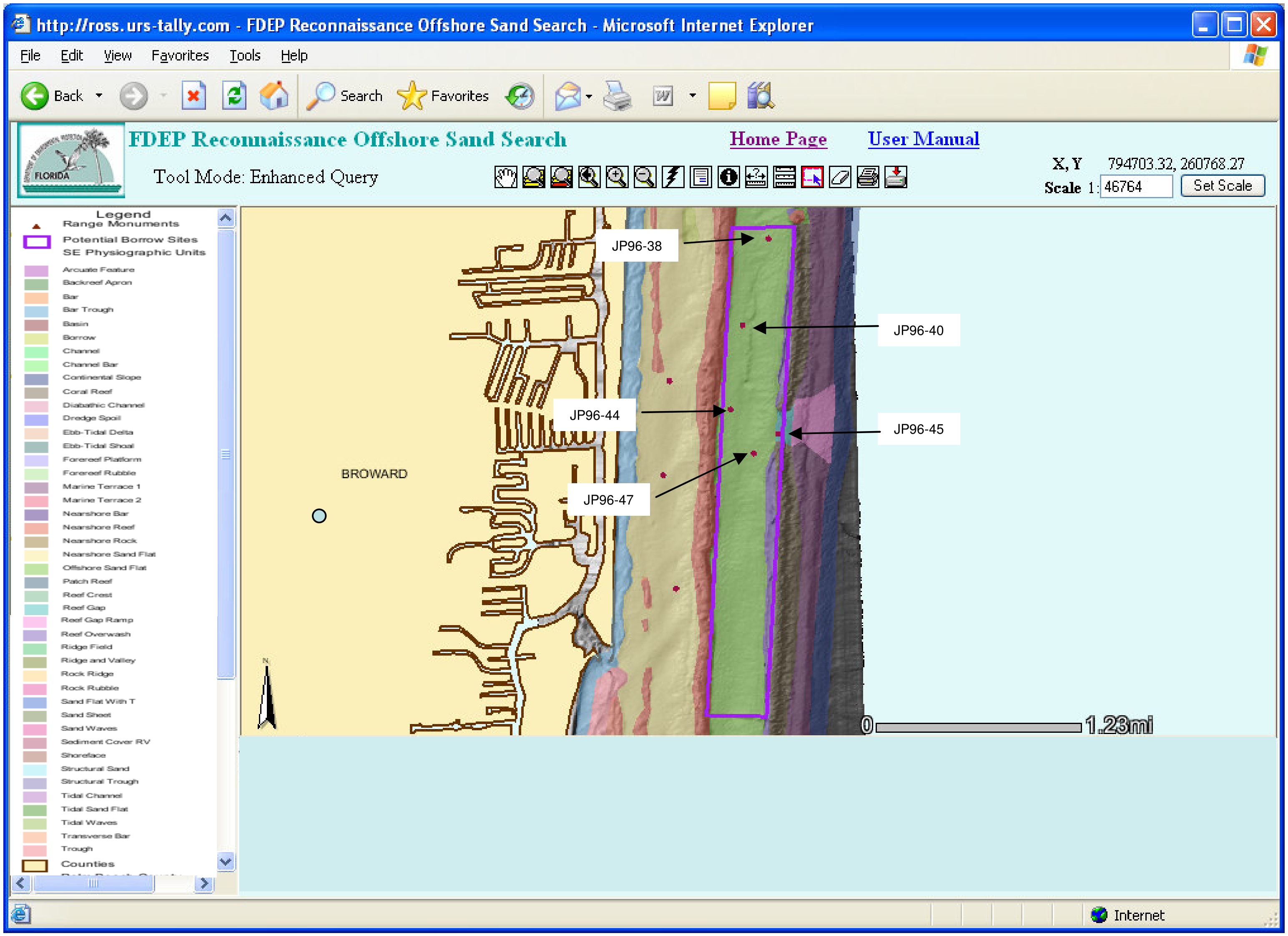


Figure 4-17. Broward County Area B-1 showing jet probe locations.

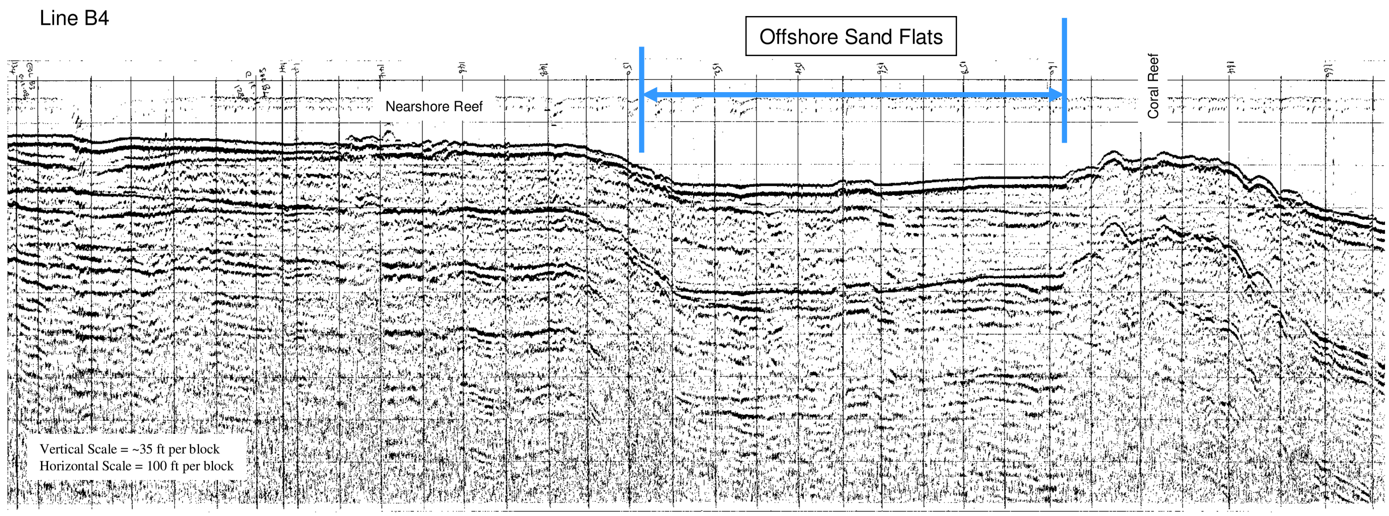


Figure 4-18. Broward County Area B-1. Sub-bottom images from Line B4, between Timestamps 144 to 164.

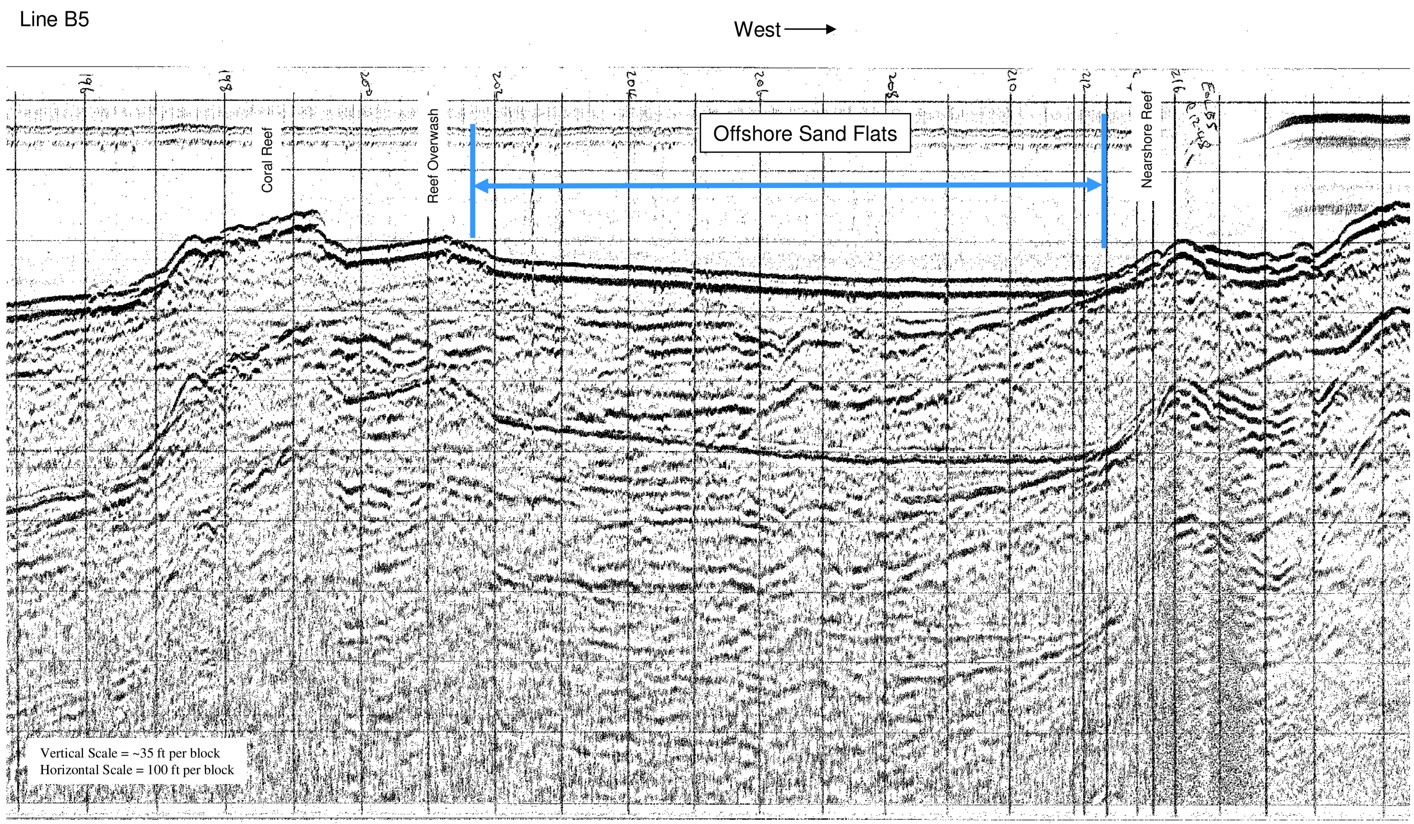


Figure 4-19. Broward County Area B-1. Sub-bottom images from Line B5, between Timestamps 199 to 209.

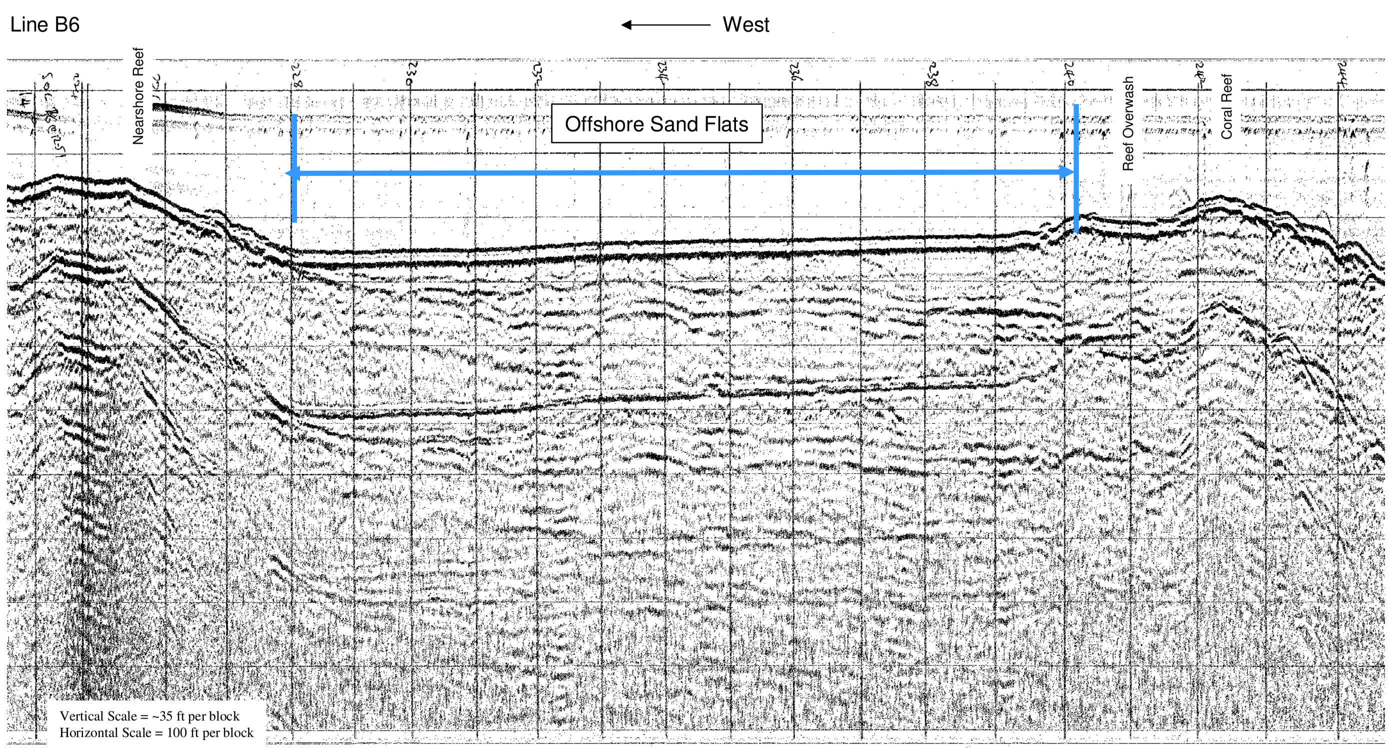


Figure 4-20. Broward County Area B-1. Sub-bottom images from Line B6, between Timestamps 209 to 240.

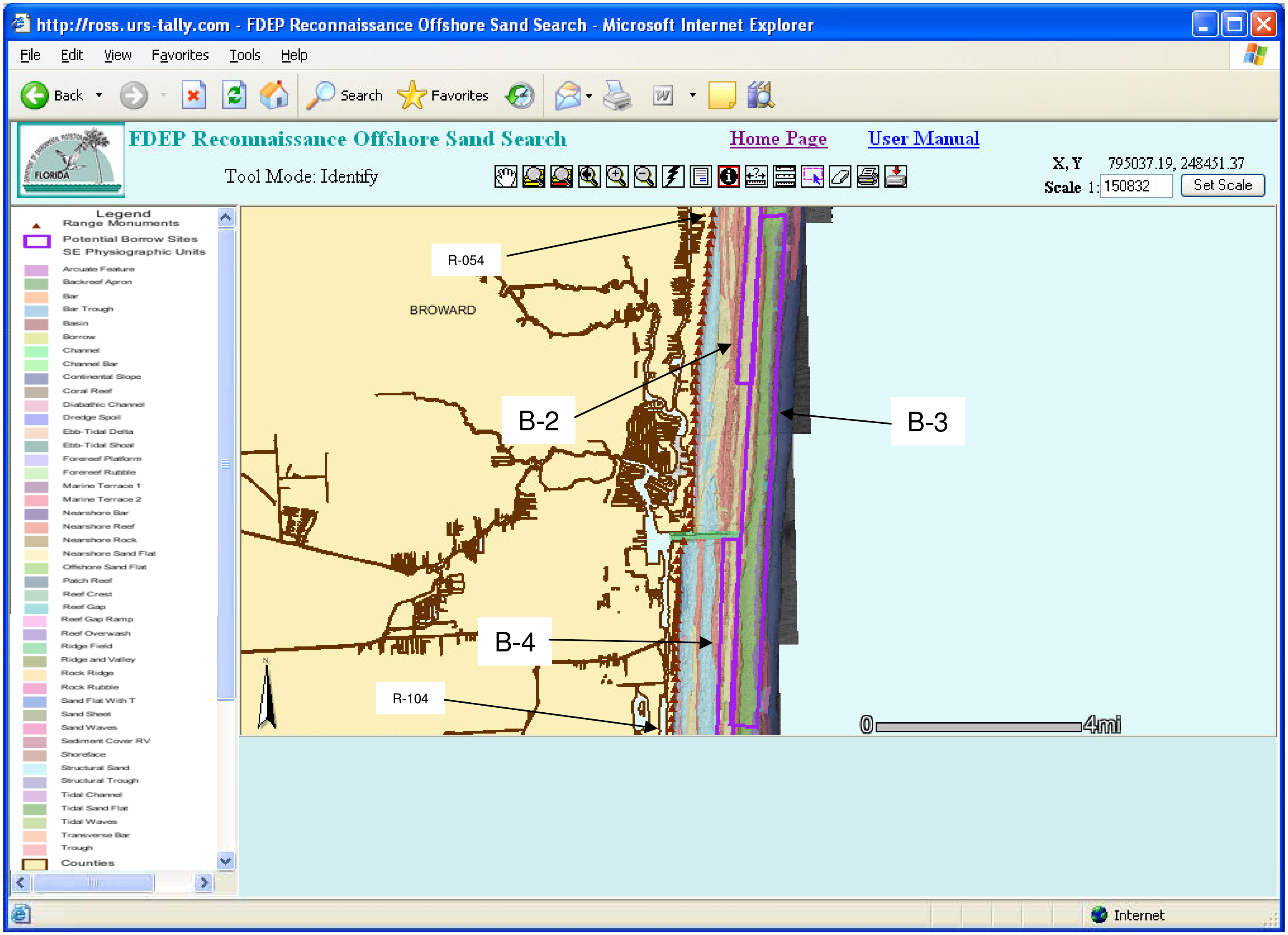


Figure 4-21. Broward County Area B-3 showing physiographic zone overlaying the gray scale image.

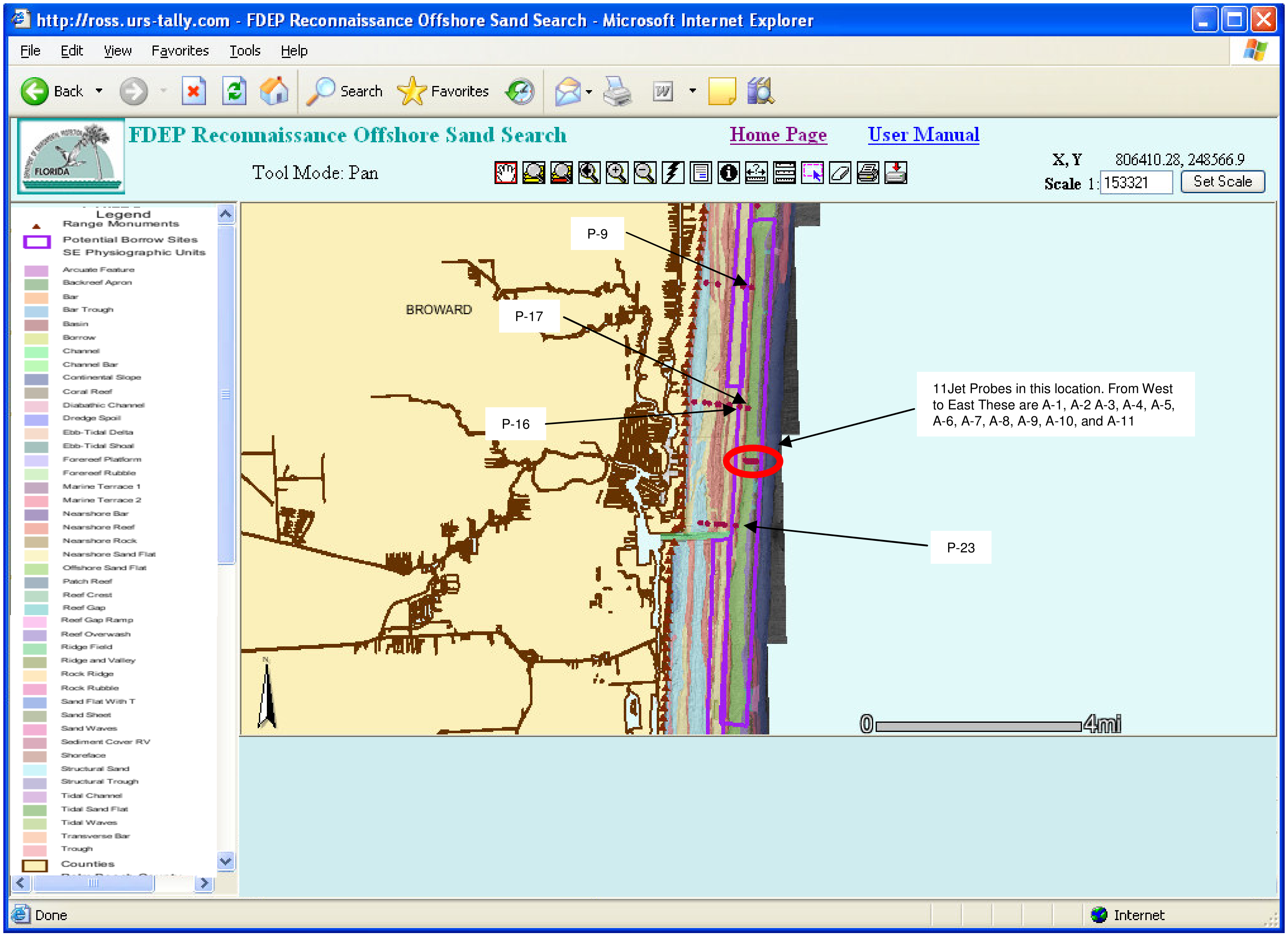


Figure 4-22. Broward County Area B-3 showing jet probe locations.

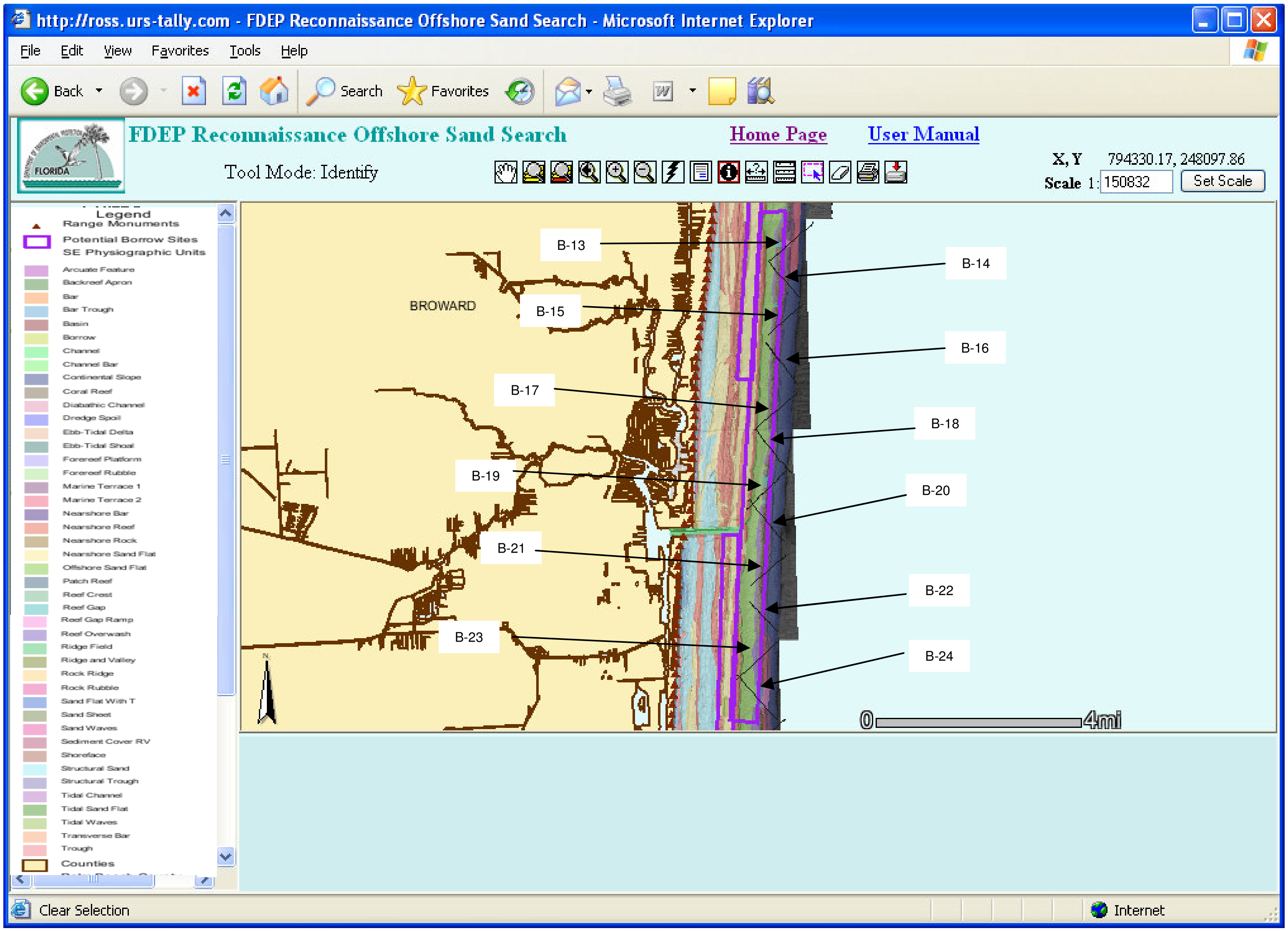


Figure 4-23. Broward County Area B-3 showing geophysical trackline locations.

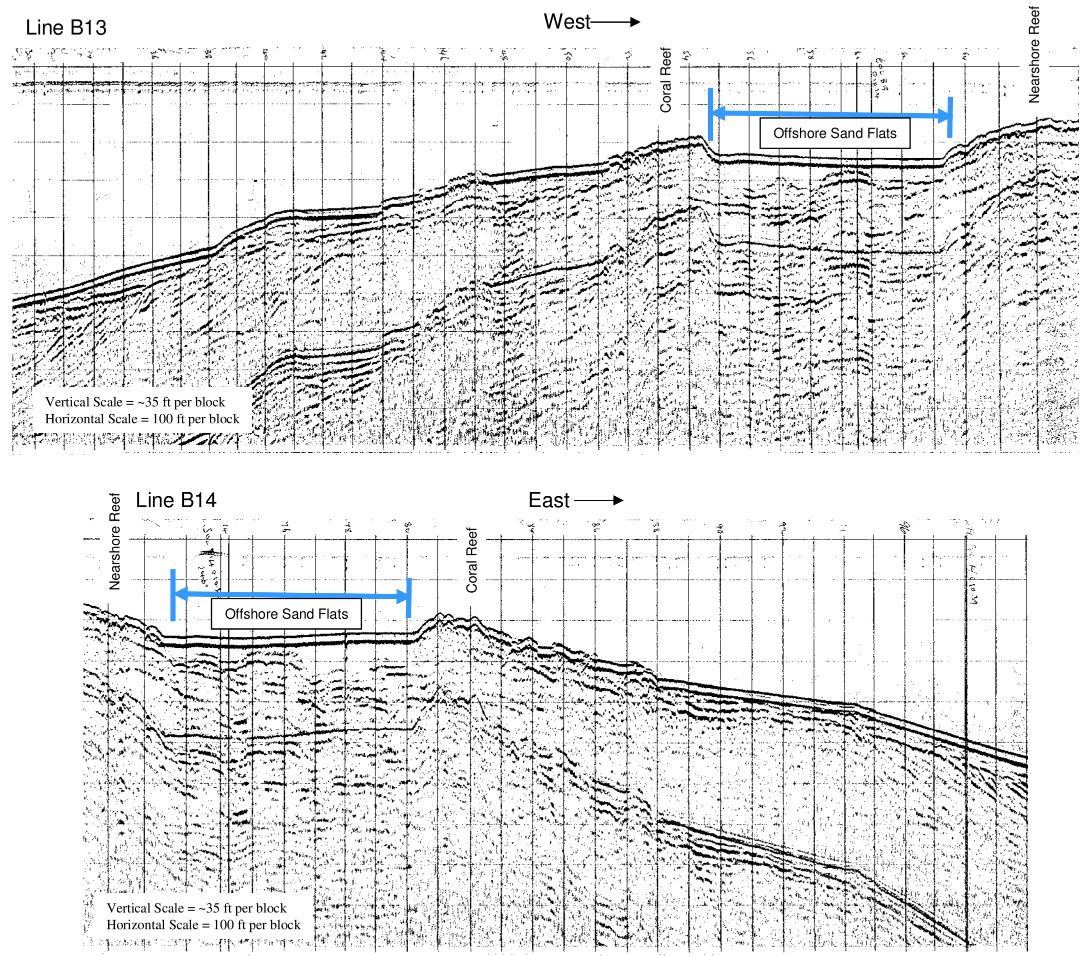


Figure 4-24. Broward County Area B-3. Sub-bottom images from Lines B13 and B14.

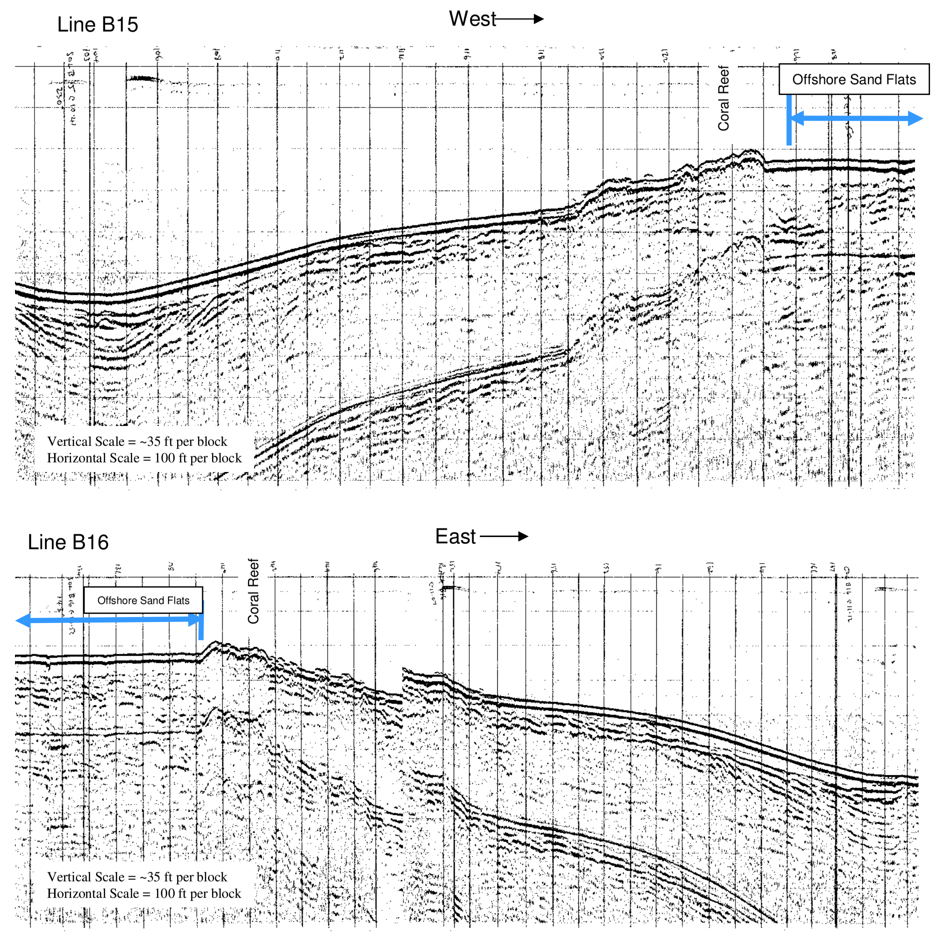


Figure 4-25. Broward County Area B-3. Sub-bottom images from Lines B15 and B16.

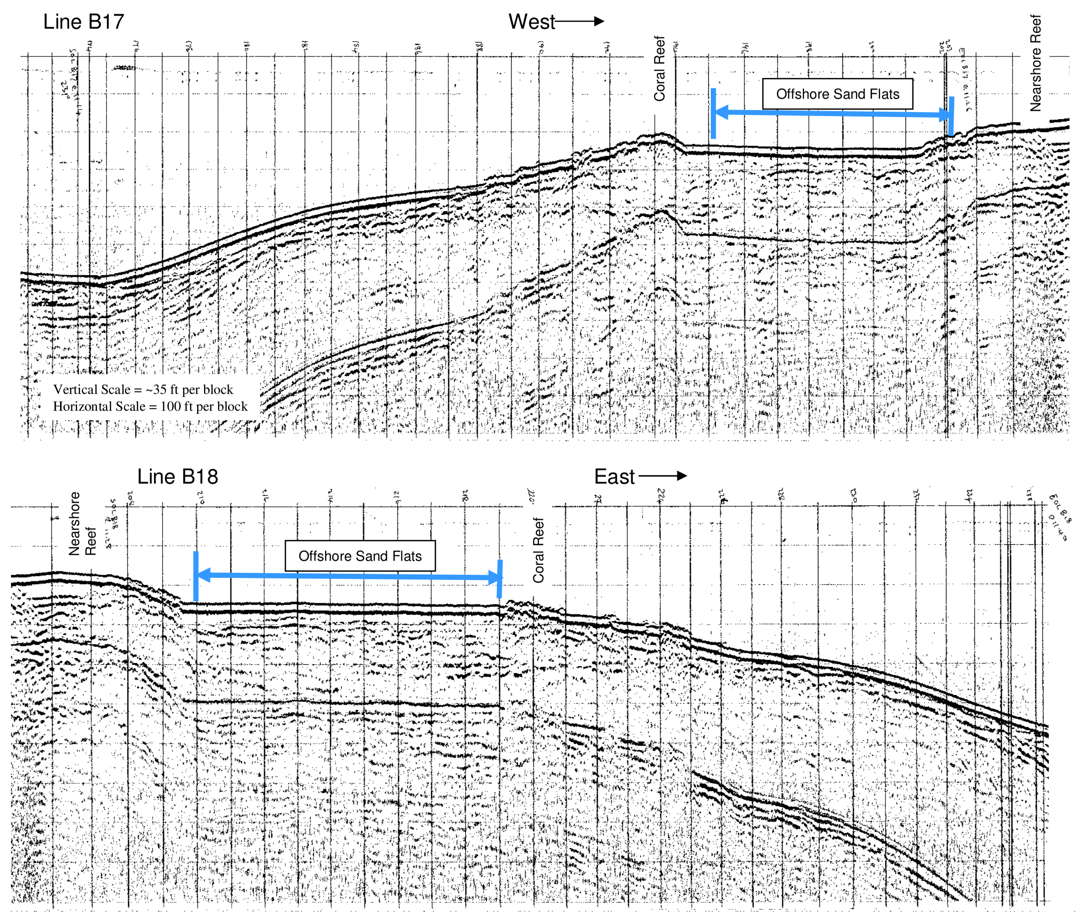


Figure 4-26. Broward County Area B-3. Sub-bottom images from Lines B17 and B18.

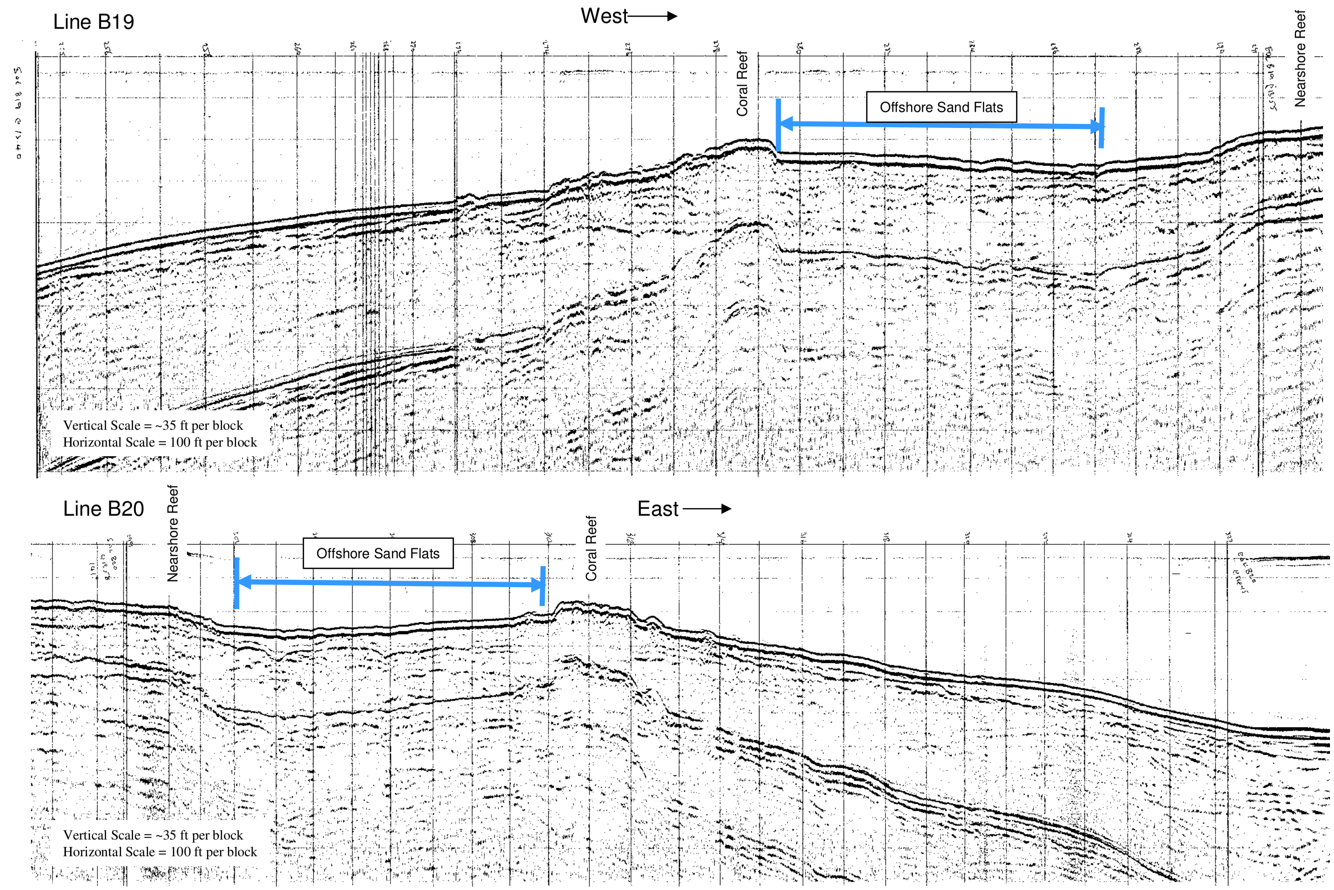


Figure 4-27. Broward County Area B-3. Sub-bottom images from Lines B19 and B20.

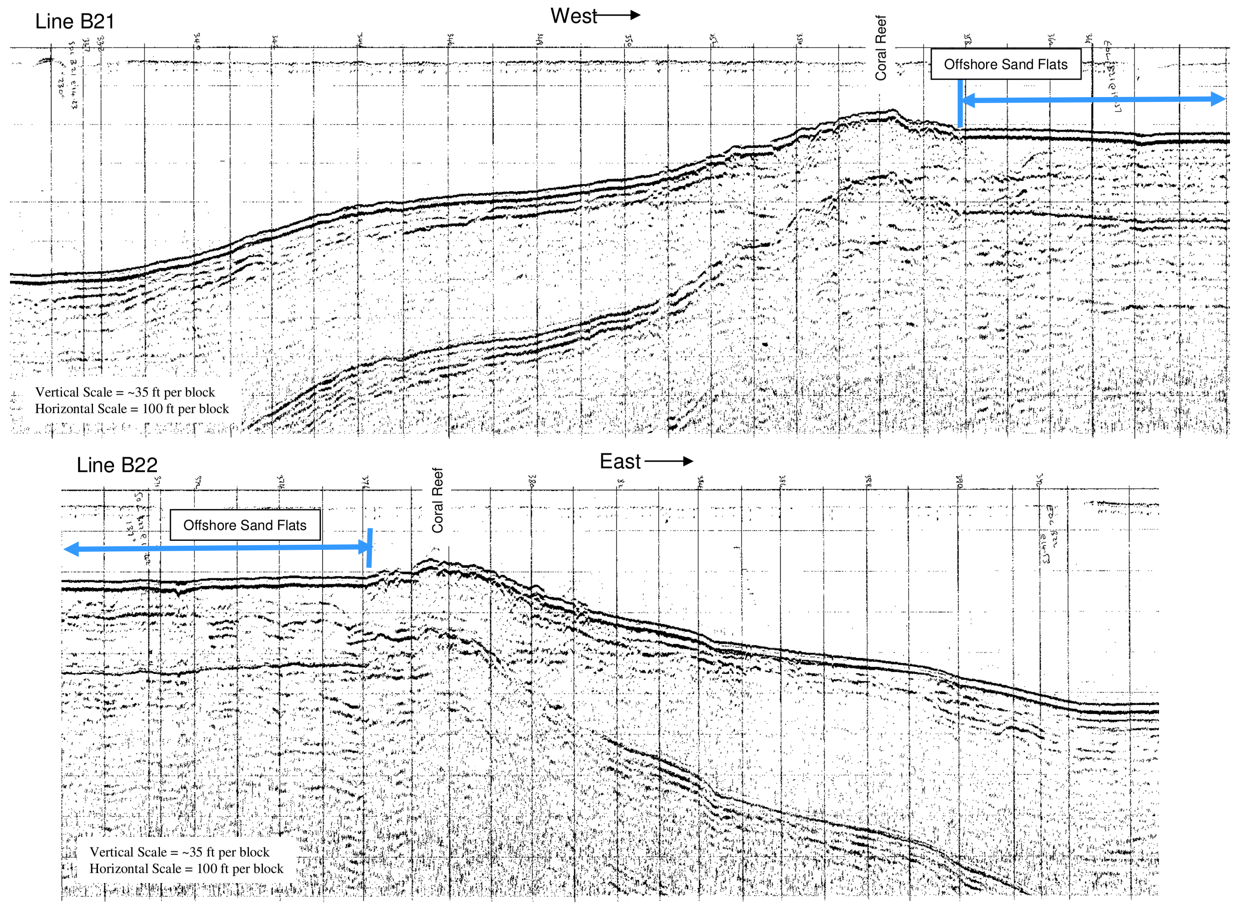


Figure 4-28. Broward County Area B-3. Sub-bottom images from Lines B21 and B22.

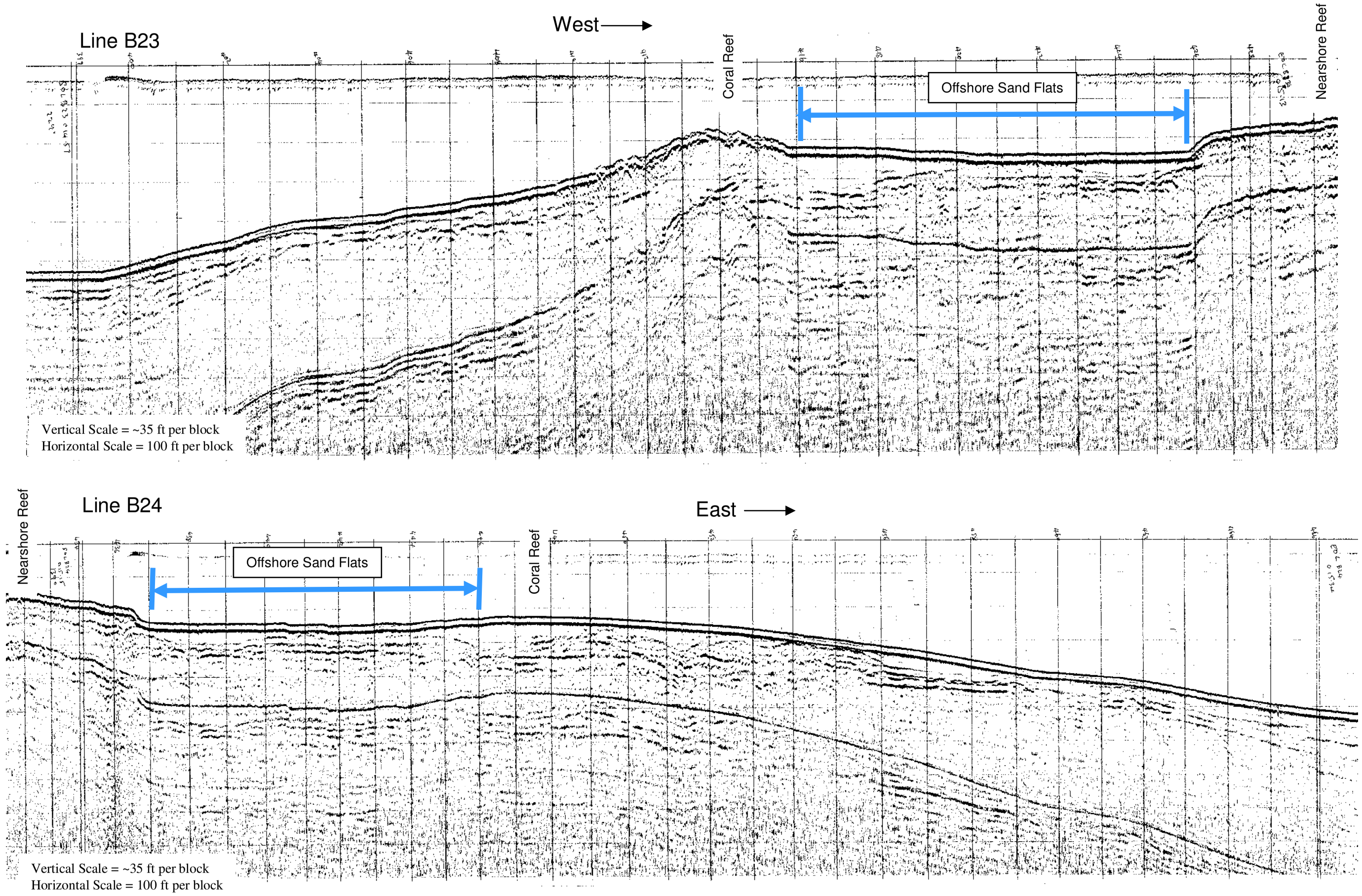


Figure 4-29. Broward County Area B-3. Sub-bottom images from Lines B23 and B24.

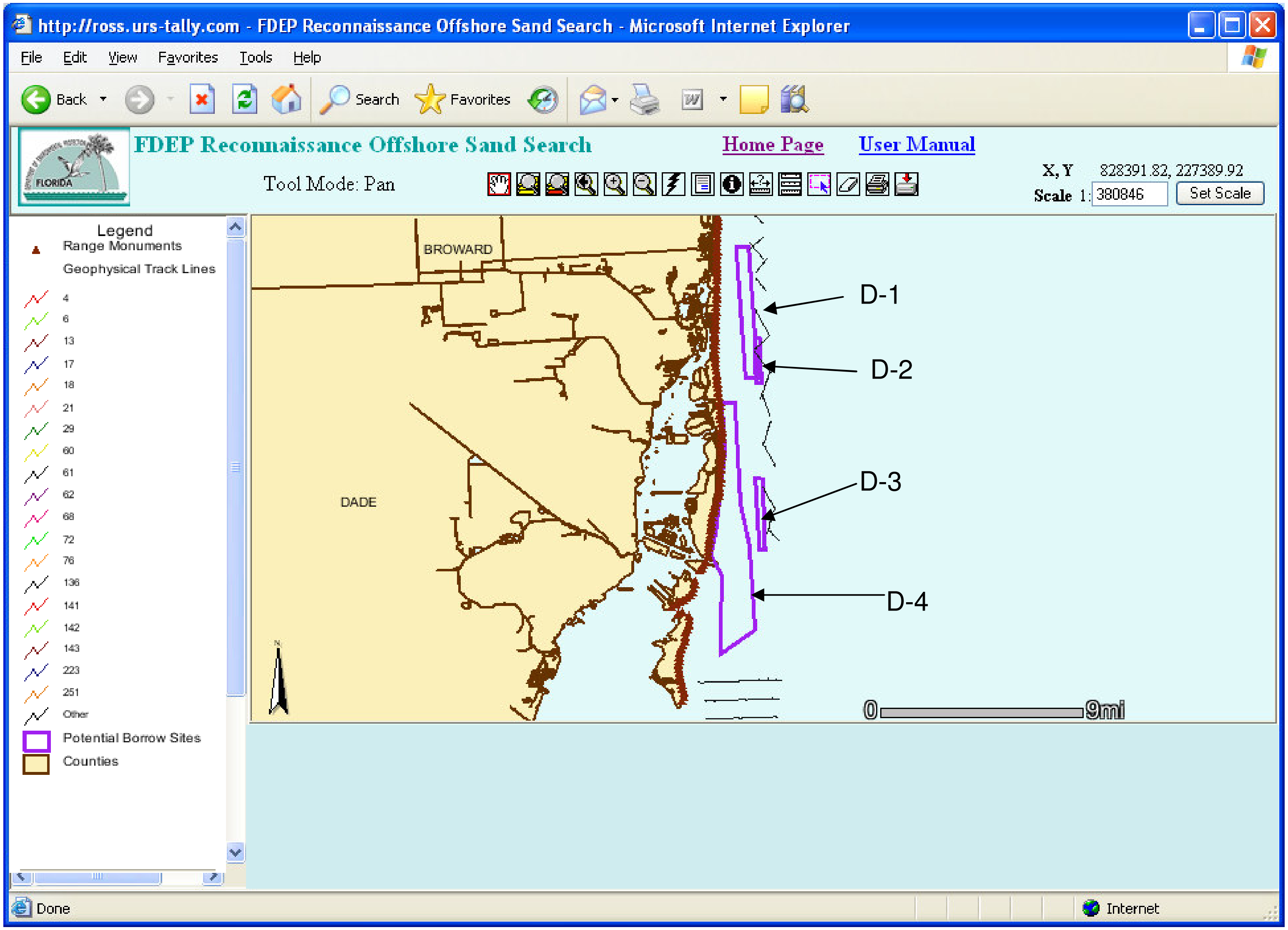


Figure 4-30. Dade County Nearshore Potential Borrow Areas and Geophysical Trackline Locations.

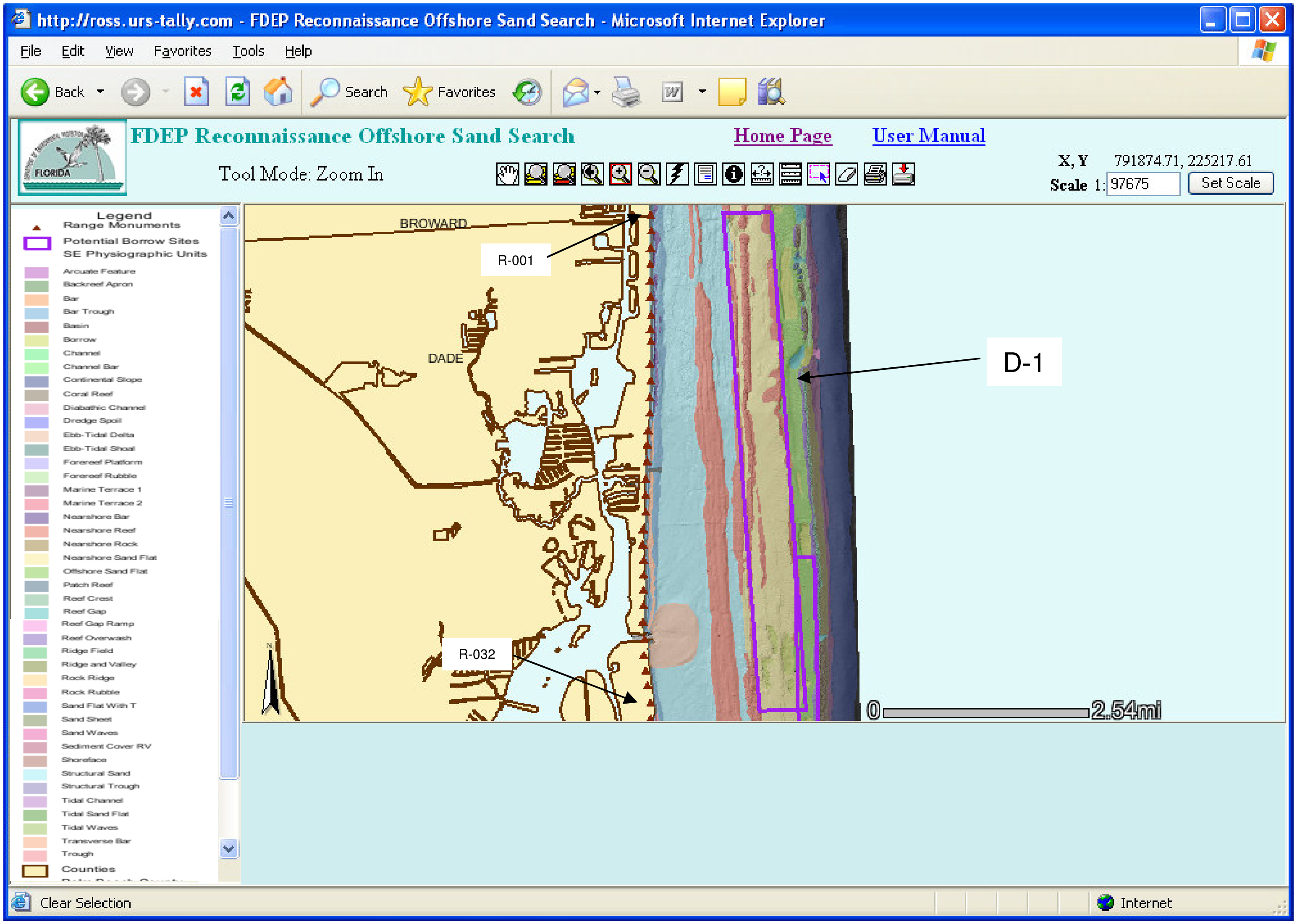


Figure 4-31. Dade County Area D-1 showing physiographic zones overlaying the gray scale image.

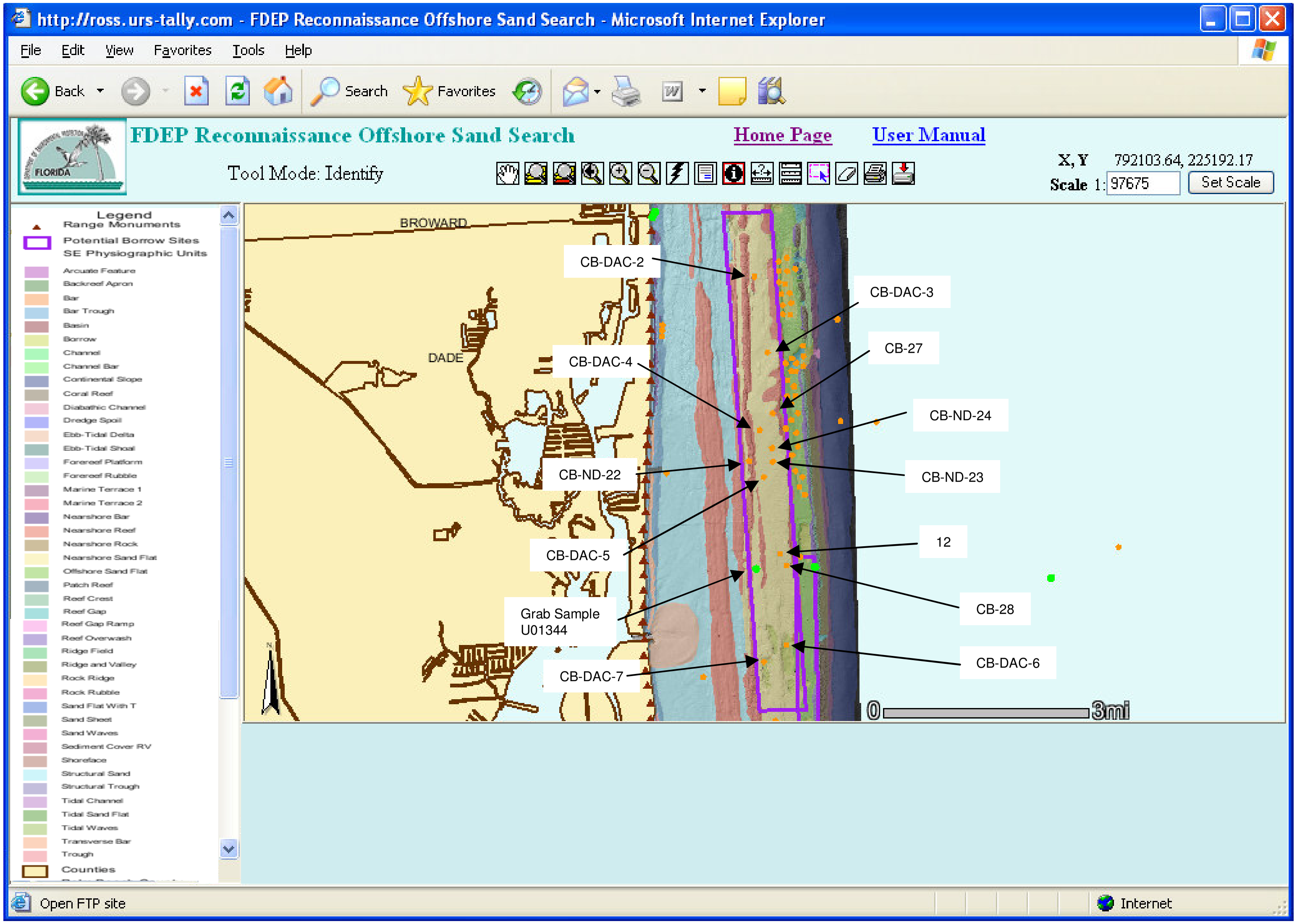


Figure 4-32. Dade County Area D-1 showing vibracore and grab sample locations.

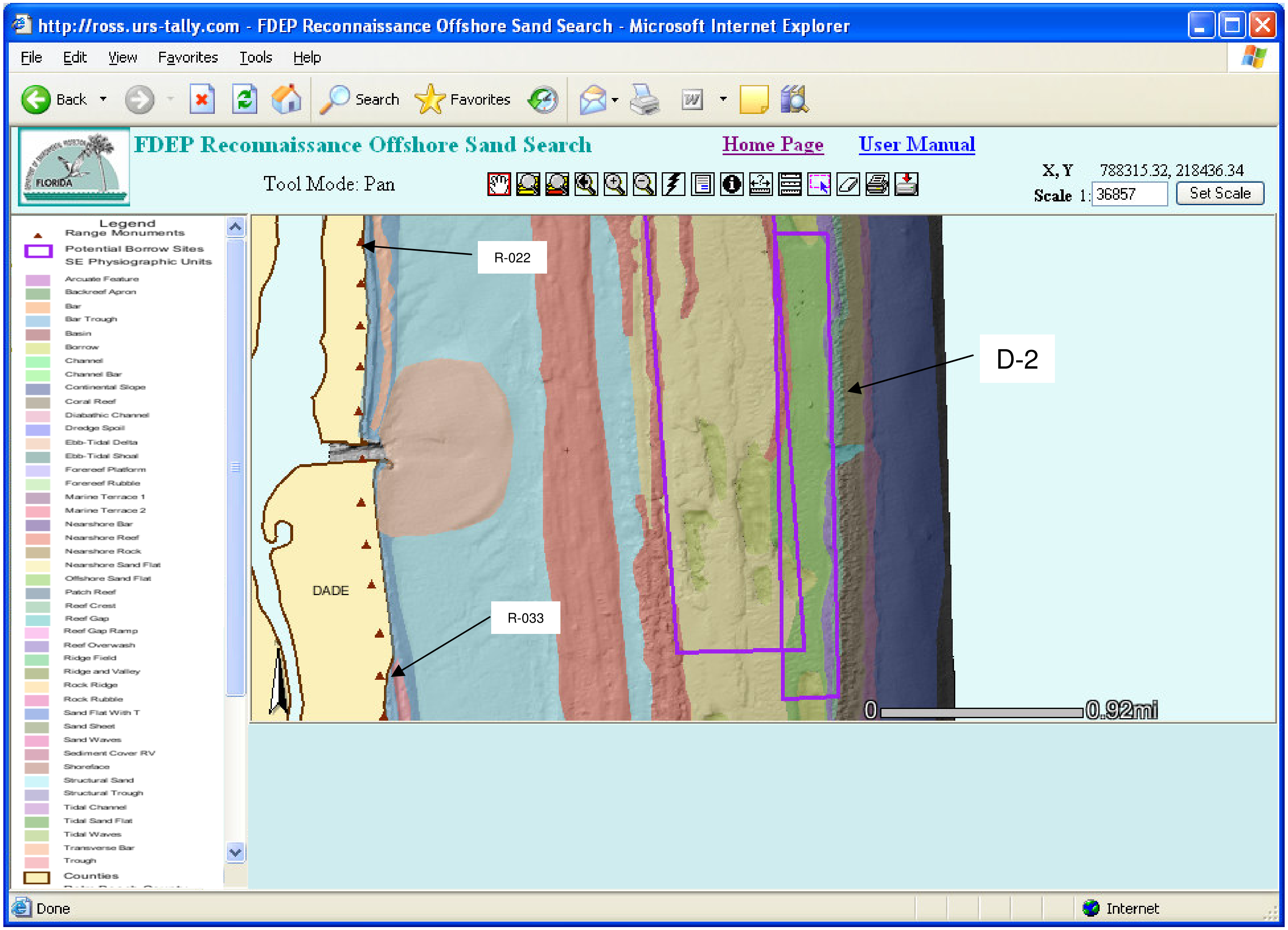


Figure 4-33. Dade County Area D-2 showing physiographic zones overlaying the gray scale image.

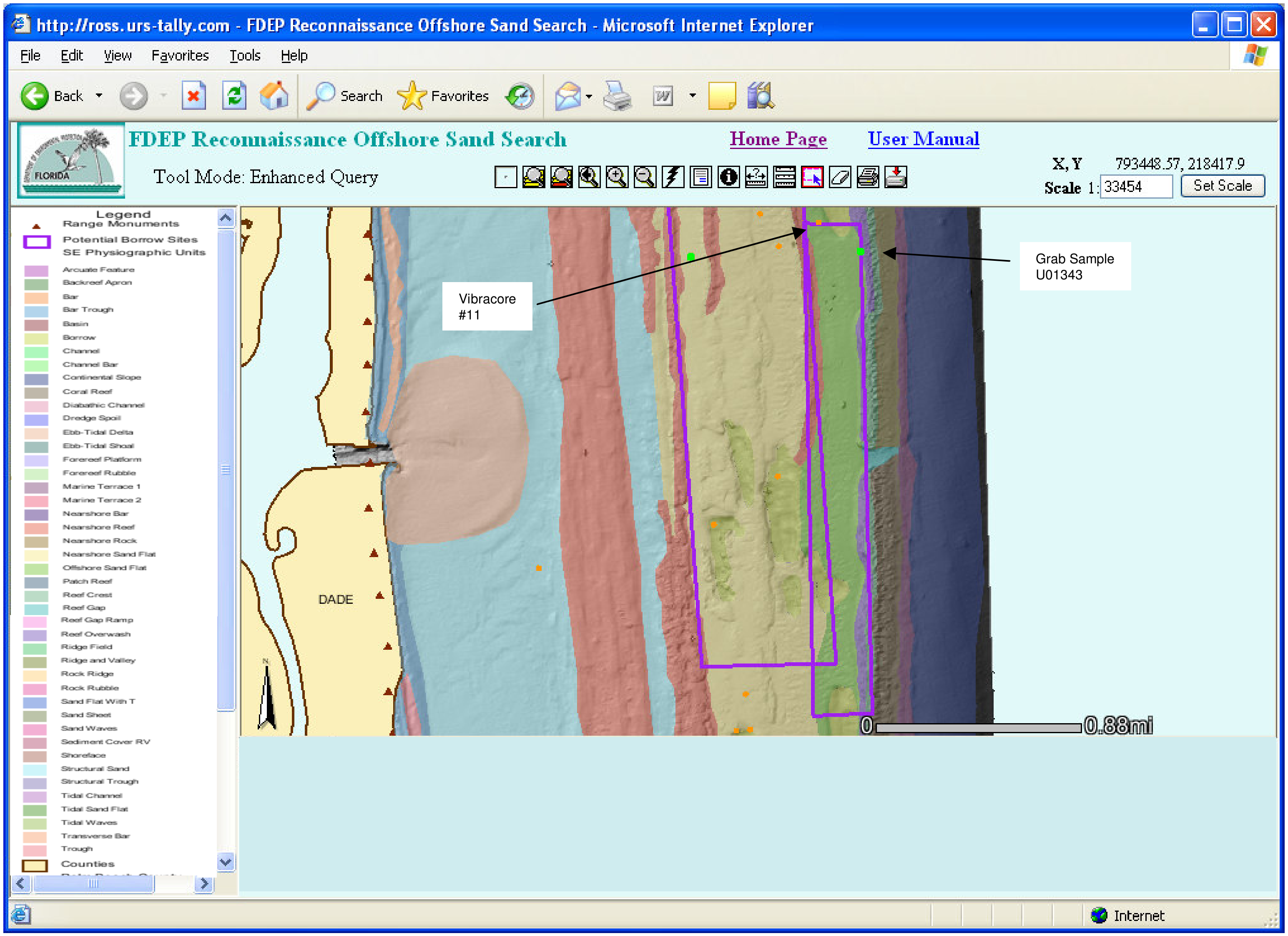


Figure 4-34. Dade County Area D-2 showing Vibracore and Grab Sample locations.

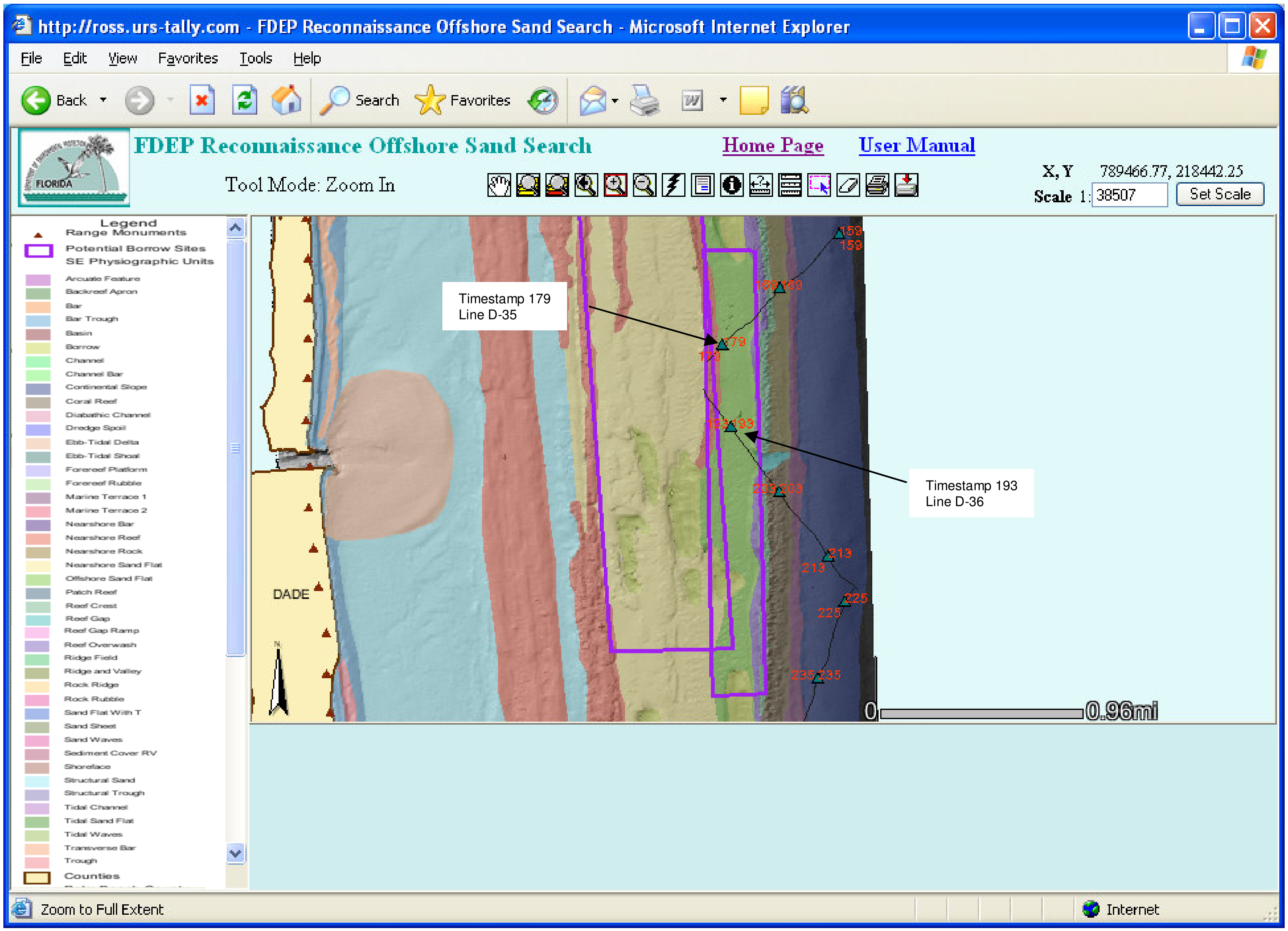


Figure 4-35. Dade County Area D-2 showing selected trackline locations.

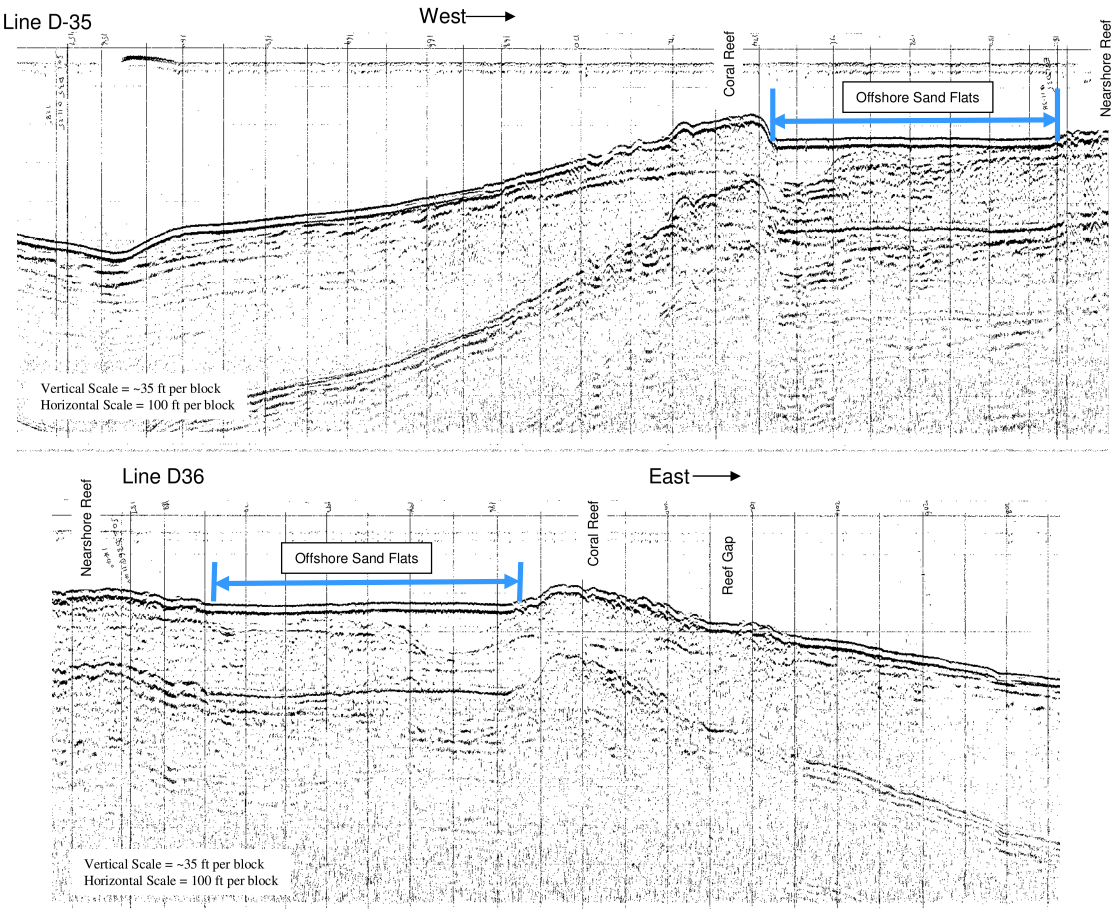


Figure 4-36. Dade County Area D-1. Sub-bottom images from Lines D35 and D-36.

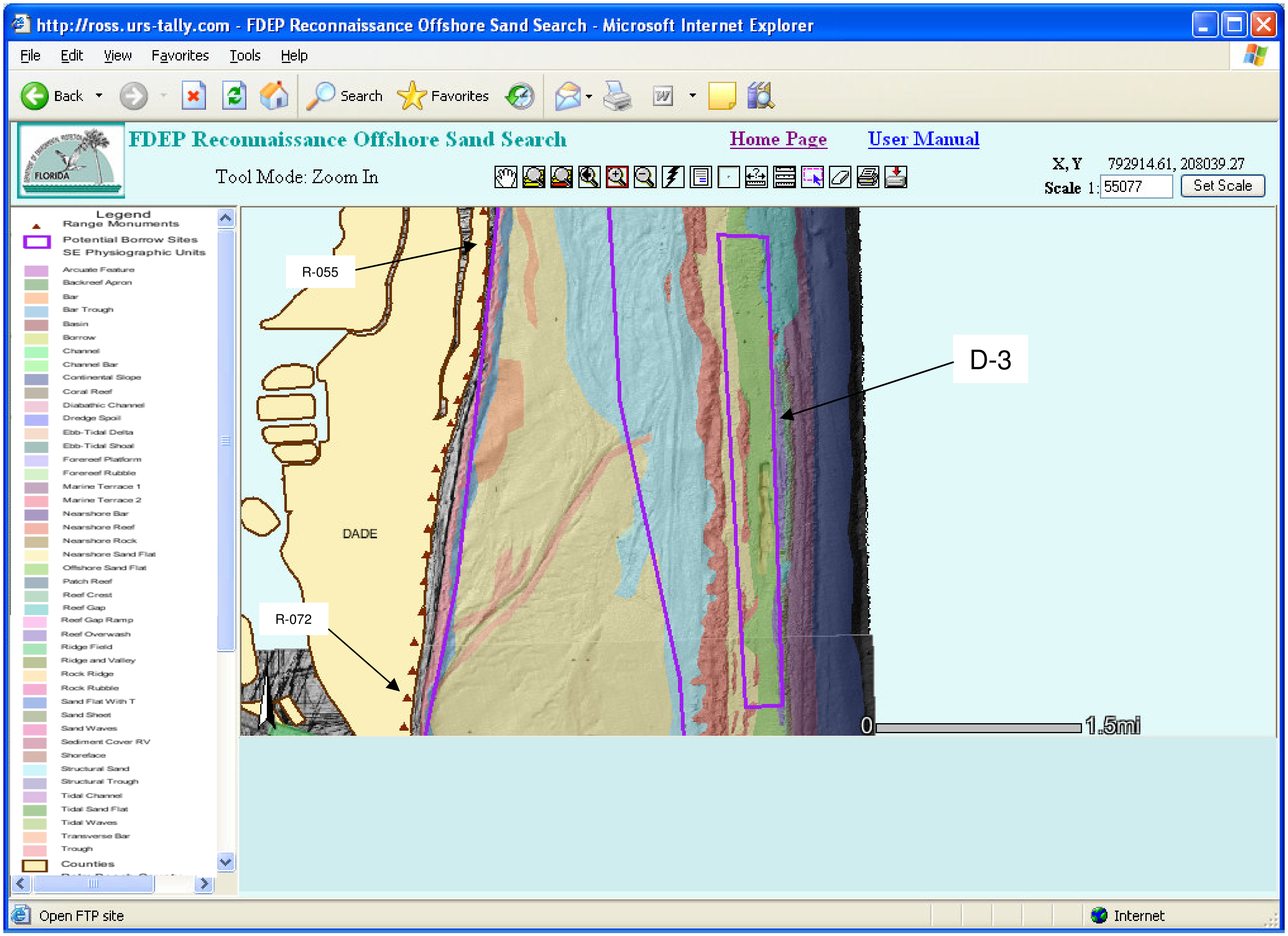


Figure 4-37. Dade County Area D-3 located in the Offshore Sand Flat Physiographic mapping unit.

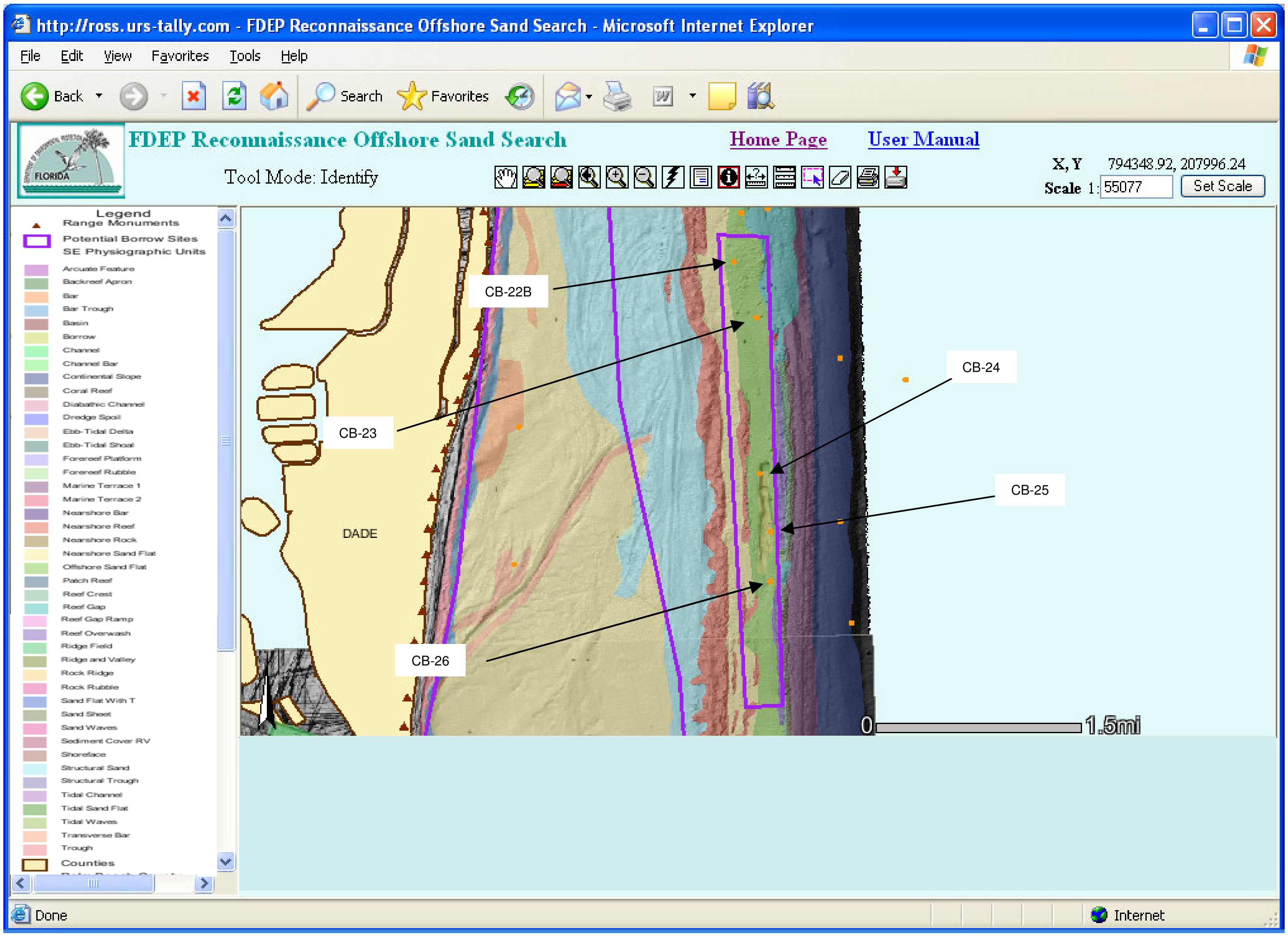


Figure 4-38. Dade County Area D-3 showing Vibracore locations.

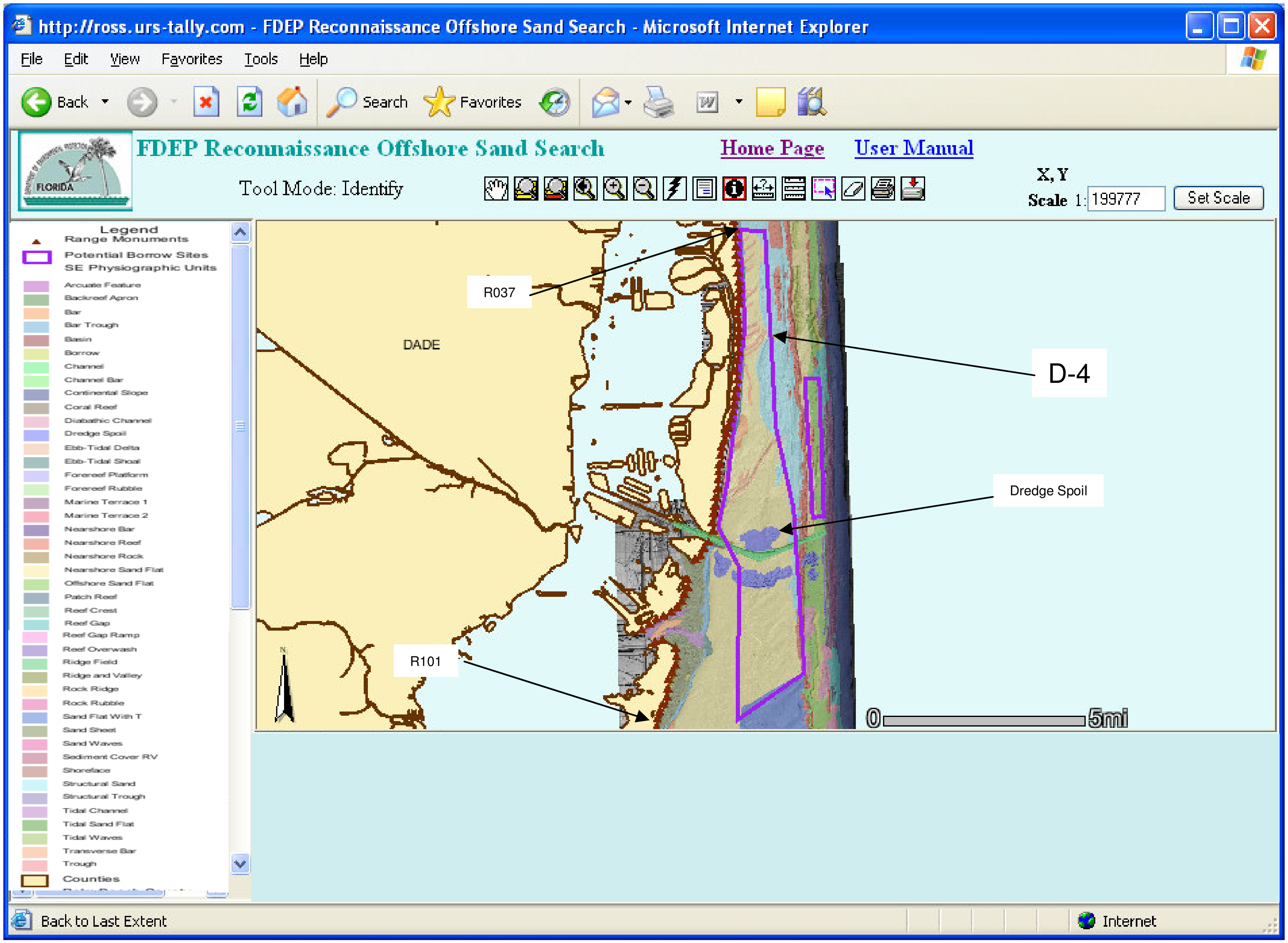


Figure 4-39. Dade County Area D-4 located in the Nearshore Sand Flat Physiographic mapping unit.

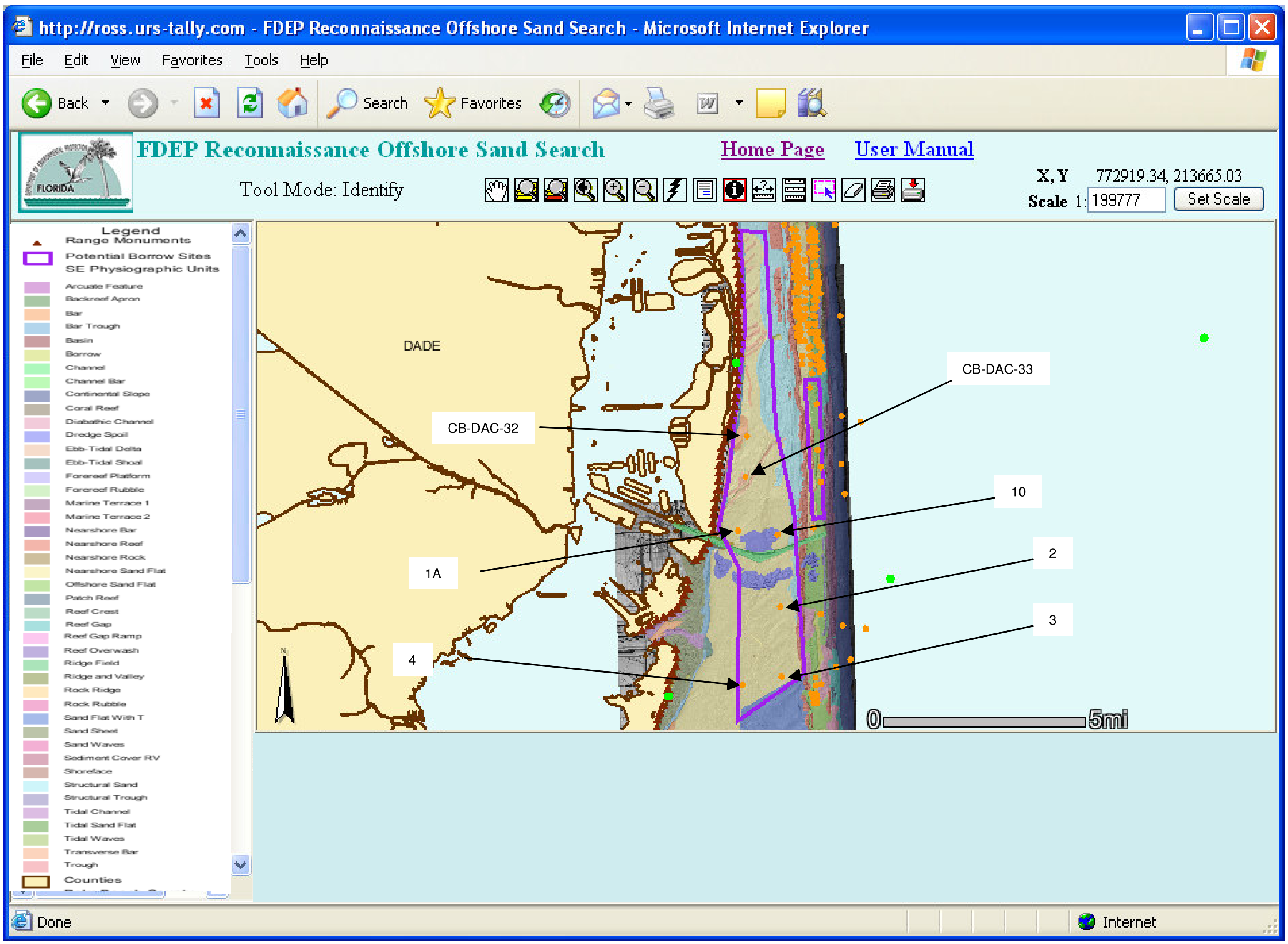


Figure 4-40. Dade County Area D-4 showing vibracore locations.

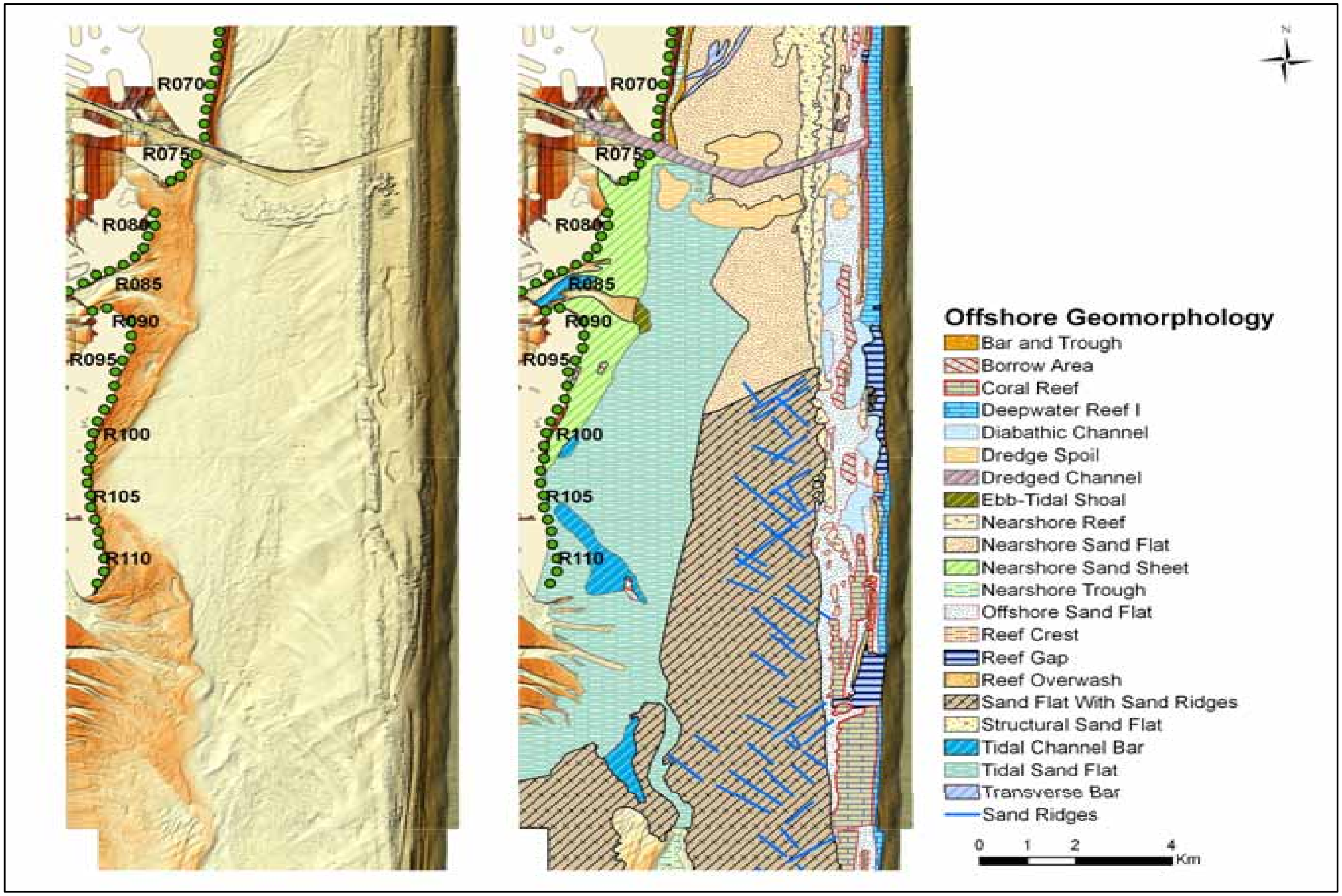


Figure 4-41. Sand ridges within the Sand Flat with Sand Ridge mapping unit. Crests of the major ridges are highlighted by the blue color. The ridges trend NNE and NNW and may be up to several kilometers in length.

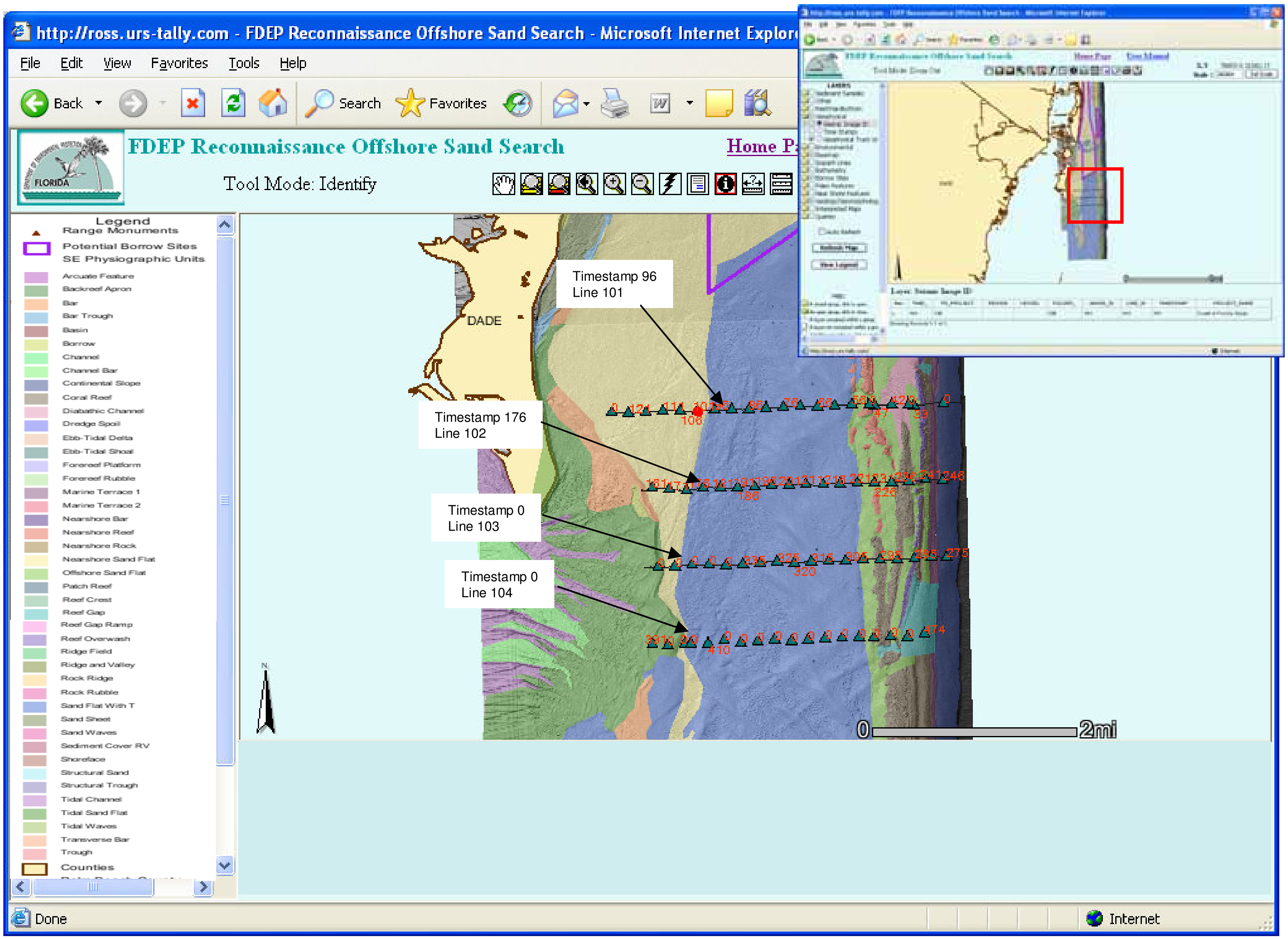


Figure 4-42. Southern Dade County region showing locations of tracklines in the area of sand ridges.

5.1 LIMITATIONS OF SAND RESOURCE POTENTIALS

Although the total area of unexplored, potential sand resources seems encouraging, there are several caveats that limit their potential. Significant among these are restrictions of potential sand resource areas adjacent to sensitive marine habitats such as coral reefs, hardgrounds, and seagrass meadows. Other factors that limit or preclude exploration and exploitation of sand resources include areas of seafloor that have restricted access and use, such as pipeline corridors, cable routes, sewage outfall pipes, artificial reefs, and wrecks. Last, but not least, are dredging setbacks that specify minimum distances that dredges may approach coral reefs, hardgrounds, artificial reefs, and wrecks. At the present time, dredging setbacks have been established managerially as 122 m (400 feet), as suggested by guidelines from the National Marine Fisheries Service (NMFS) which were adopted by FDEP. The impacts of these factors limiting the potential of sand resources are discussed in the next section.

Dredging buffers take up significant space, depending on the shape of the potential sand resource area. Compact circular, ovid, or rhomb (quadrilateral) shaped zones are least affected by 122-m (400 foot) buffers whereas long and narrow (rectangular) areas can be severely impacted. In order to estimate the effects of dredging setbacks on potential sand resource areas, mapping units comprised of sedimentary bodies were grouped together in a GIS platform and then subdivided by zones where polygons distally terminated. Buffer notations in the table accompanying the maps (Figures 5-1A, 5-1B, 5-1C, 5-2A, 5-2B, 5-3A and 5-3B) identify the county (PBC, Palm Beach County; BC, Broward County, and MDC, Miami-Dade County) and sedimentary feature where SW indicates sand waves, OS indicates offshore sand flats, NS indicates nearshore sand flats, SS means structural sand flats, SFR locates sand flats with sand ridges, and TSF shows tidal sand flats. Segments within these units are further subdivided by number for geographic reference and area calculations. The series of maps produced at a scale of 16 cm per kilometer (1 inch equals 6000 feet, 12 inches equals 1 nautical mile) are grouped in Figures 5-1A, 5-1B and 5-1C (Palm Beach County), 5-2A and 5-2B (Broward County), and 5-3A and 5-3B (Miami-Dade County). Point source areas (*e.g.* artificial reefs, wrecks), although important locally, were ignored in the calculations because they are minor compared to the large areas covered by buffer zones.

Mapping units included in the Palm Beach County sand resource availability maps include Nearshore Sand Flats, Offshore Sand Flats, and Sand Waves. In the northern part of the county (Figure 5-1A), the buffer zones do not present problems where reduction of sand resources is concerned. In the central part of the county, the buffer zones become problematic offshore from R080 to R093 and R096 to R106 (Figure 5-1B). Buffer zones offshore from about R187 to R211 (Figure 5-1C) on the landward side of barrier coral reefs preclude use of potential sand resources in nearshore sand flats because those segments of the sand flats are narrow. Perusal of Table 5-1 shows that total loss of potential sand resource areas in Palm Beach County due to 122-m buffer zones amounts to about 10%. The range of loss extends from 100% in feature PBC-NS3 (Figures 5-1A, 5-1B and 5-1C) to 17% and 28% in features PBC-NS4 and PBC-NS2, respectively. Still, the average loss of potential sand resource area is rather minimal because the sand bodies tend to be equant in shape or robust rhombi.

The same procedure applied in Broward County produced dramatically different results due to the nature of sand body geometry where barrier coral reefs and outcrops of the Anastasia Formation and Miami Limestone confined sediments to long narrow troughs. Although relatively large volumes of sediment occur in the troughs that have a surface geomorphic expression as sand flats (Tables 3-2b and 3-6), the long narrow configuration of the mapping units drastically reduced the areas of potential sand resources. Buffers were applied to the following mapping units: Nearshore Sand Flat, Offshore Sand Flat, and Structural Sand Flats. Several features had 100% reduction in area: BC-NS4, BC-NS-6, and BC-NS7 (Table 4-2). Near complete loss of area also occurred in features BC-NS2 (98%) and BC-NS8 (96%) with half or more of the area lost in BC-NS1 (73%), BC-NS3 (46%), BC-OS1 (57%), BC-SS1 (46%), and BC-SS3 (70%). The main areas where sand resource potential was most severely reduced occur in nearshore sand flats offshore from R001 to R015, R021 to R061, and R070 to the county line (Figures 5-2A and 5-2B). The average area loss in sand resource availability in Broward County amounted to nearly half the area (46%) (see Figures 5-2A and 5-2B for a visual impression of area lost).

Additional area of continental shelf, shelf break, and continental slope is lost to 'Bottom Restrictions,' anchorages, cable routes, and sewage outfalls. Refer to red-boxed areas in Figures 3-4, 3-7A and 3-7B for locations of various types of bottom restrictions (undifferentiated in the map units). Total area covered by bottom restrictions amounts to 7,206 ha (Note: bottom restrictions extend beyond the mapping area) but the really critical issues for Broward County are areas of bottom restrictions in nearshore and offshore sand flats because these sedimentary units host potential sand resources for beach nourishment activities. Total area of bottom restrictions in the nearshore sand flats region amounts to about 1,900 ha. Offshore sand flat segments sequestered by bottom restrictions amount to 1,738 ha. Bottom restricted areas in Broward County mostly include artificial reefs and wrecks, but they are not broken out separately due to the overlap in coverage. In any case, the total area occupied by artificial reefs and wrecks is minimal in the overall scheme of sand resource areas. The total sand area for Broward is about 5,200 ha and the sand area that intersects bottom restrictions amounts to 3,644 ha, creating a loss of 70%. The major bottom restricted areas occur offshore from R001 to R010, R025 to R027 (cross-shore corridor), R033 to R034 (cross-shore corridor), R032 to R047, R052 to R074, R071 to R074, R074 to R080 (Port Everglades Anchorage, 439 ha), R086 to R110 (U.S. Navy cable field), R117 to R116 (cross-shore corridor), and R120 to R125 (see Figures 3-4, 3-5A and 3-5B).

Thus, nearly two-thirds (64%) of the potential sand resource area in Broward County is lost to dredging setbacks. Bottom restrictions decrease potential sand resource areas by 69%. It should be noted however, that dredging setbacks and bottom restrictions overlap in many areas. Thus, the point can be made that at least two-thirds of the sand areas in Broward County are lost to dredging setbacks and bottom restrictions. Still more area in nearshore sand flats is lost indirectly due to dredging setbacks because the remaining areas are too small to be efficiently dredged, for example: nearshore segments of BC-NS1 between R001 and R015, R021 to R022 and R025, R025 to R043, R050 to about R055, and R070 to R128. All of BC-NS2, BC-NS6, BC-NS7, and BC-NS8 is lost to dredging setbacks (Figures 5-2A and 5-2B). Exploitation of BC-OS1 becomes problematic from R055 to R075 and is completely precluded in numerous other areas such as R095 to R097, R105 to R110, and in the vicinity of R115 to R120. Some of these areas are overlapped by bottom-restricted areas and so the area loss due dredging setbacks becomes moot.

Miami-Dade County showed about 20% loss of sand resource availability due to dredging buffers (Table 5-3) (Figures 5-3A and 5-3B). Because sand bodies in Miami-Dade County tended to be more or less equant in shape or at least robust rhombi, losses were minimized. Mapping units included in the Miami-Dade calculations include: Nearshore Sand Flat, Nearshore Sand Sheet, Offshore Sand Flat, Sand Flats with Sand Ridges, Structural Sand Flat, Tidal Sand Flat, and Tidal Sand Ridges. The largest losses tended to occur in offshore sand flats [MDC-OS1, 66% (R010 to R026, R038 to R045, R060 to R072) (Figure 5-3A); MDC-OS2, 45% (R085 to R090); MDC-OS3, 60% (R095 southwards of R110) (Figure 5-3B); MDC-OS4, 96% (R106 southward beyond R110) (Figure 5-3B); MDC-OS5, 96% (southwards of R110] with some large percentage loss of area (but small total area) in the nearshore zone (MDC-NS5, 91%).

Although potential sand resource area lost to dredging setbacks is minimal (Table 4-2), sensitive marine habitats in southern Miami-Dade County must be considered in evaluation of sand deposits. Discontinuous or sporadic seagrass meadows occur in the study area south of the navigational entrance to the Port of Miami, specifically offshore from Fisher Island, Virginia Key, and Key Biscayne from R075 to R110. Figure 5-4 shows seagrass locations determined by the Florida Fish and Wildlife Conservation Commission and the Fish and Wildlife Research Institute's Center for Spatial Analysis. Continuous or dense seagrass beds flourish offshore Key Biscayne from R100 to R110 and southwards. The seagrass meadows extend from the nearshore zone to about 2000 m offshore at about the latitude of R115.

The total area of seagrass beds in the study area south of the navigational entrance to the Port of Miami amounts to about 5000 hectares. Of this area, discontinuous seagrass beds make up about 1,840 ha and continuous seagrass beds take in about 3,165 ha. The breakdown of total seagrass beds (discontinuous plus continuous) by submarine geomorphic feature, as shown in Figure 5-4, is: Nearshore Sand Sheet, 426 ha; Offshore Sand Flat, 13 ha; Sand Flat with Sand Ridges, 2,578 ha; Tidal Sand Flat, 1,655 ha; and Tidal Sand Ridges, 332 ha. Clearly, tidal flats with sand ridges are most heavily impacted.

Potential sand resource areas in the same zone that are not impacted by seagrass beds are as follows: Nearshore Sand Sheet, 178 ha; Offshore Sand Flat, 1,594 ha; Sand Flat with Sand Ridges, 3,904 ha; Tidal Sand Flat, 1,426 ha; and Tidal Sand Ridges, 22 ha. Figure 5-4 shows the distribution of seagrass beds in relation to potential sand resource areas. It is worth noting that the following mapping units do not host seagrass beds: offshore sand flats, structural sand flats, and nearshore sand flats. Tidal sand flats and sand flats with sand ridges are impacted by the presence of seagrass beds. Note, however, that most of the sand resource area associated with sand flats with sand ridges is not affected by seagrass beds offshore Key Biscayne and Biscayne Bay.

5.2 DISCUSSION

Application of airborne laser bathymetry (ALB) technology to the continental shelf off southeast Florida in the form of LADS imagery permits interpretation of bathymetry as sequences of landforms. The resulting interpretive maps that depict seafloor features present a rational basis for delineating bottom types, particularly hardgrounds (bedrock and corals) and sediments. LADS provides useful imagery for interpretive purposes and the results can be dramatic and useful, but caveats are associated with training and experience of the interpreter. This reconnaissance survey of sand resources required comprehensive mapping of all seafloor features in order to evaluate modes of occurrence for various types of sedimentary bodies. The present reconnaissance mapping scale (1:800 operation scale for hard copy maps) precludes detailed investigation of many types of features but has the advantage of providing an overview of general relationships between mapping units.

These geospatial relationships combined with collateral data (e.g. vibracore logs, seismic reflection profiles) were used to build a model of the coastal surficial geological framework. The geological model is essentially comprised of two overarching types of units, hardgrounds and sediments. Perusal of the LADS geomorphological units in a GIS platform showed that areal distributions of sedimentary bodies are constrained by bedrock (Anastasia Formation and Miami Limestone) and barrier coral reefs with minor occurrences of patch reefs. Without interpretation of the LADS bathymetry, these relationships could not be established on a regional basis. Prior work identified general bottom types for localized study areas, but there was no integrated interpretation of trends or geospatial variation within and between the counties along the southeast coast. The gradation of bottom types from northern Palm Beach County to the general latitude of Biscayne Bay in Miami-Dade County is pronounced and heretofore generally unappreciated. Seafloor geomorphological units in northern Palm Beach County are gradational to reefless shelf areas (drowned coastal plains) that are characterized by rock outcrop and the presence of sand sheets and sand ridges, whereas the southern part of the study area in Miami-Dade County grades to Florida Keys environments. Seafloor in Broward County is transitional to both extremes and best represents the model that is most familiar in the literature, several reef tracts separated by sedimentary corridors. The interpreted LADS maps show that this well-known geological model for Broward County is only partially applicable in modified form to Palm Beach and Miami-Dade counties. The comprehensive geological model developed in this study incorporates intra-county variation in seafloor geomorphological units as well as gradation in distal northern and southern parts of the study area to different geomorphological regimes.

Incorporation of the LADS imagery and interpreted units in a GIS platform such as ArcView permitted quantification of mapping units and investigation of areal relationships between units. Prior to this study, it was impossible to quantify sand resources along the southeast coast because seafloor geomorphological features were generally unknown and the few features that were known were not integrated along the continental shelf. This study thus, for the first time, quantifies sand resource areas along the southeast coast of Florida. Because the system is not perfect due to interpretive difficulties in some areas where sediments thinly covered bedrock (*e.g*. Structural Sand Flat mapping unit), areas so determined are not finite but representative of extent conditions at the time of the LADS surveys (2001 for Broward County and 2003 for Palm Beach and Miami-Dade counties). Nevertheless, areas derived from spatial analyses in GIS provided the basis for estimating sand volumes from arbitrary depth assumptions of 1, 2, and 3 m for conservative estimates. Inspection of some vibracore logs showed these depth assumptions to be very conservative but generally indicative of maximum volumes based on the 3 m depth assumption. Although acceptable for reconnaissance-level studies, the vibracore logs show that some areas contain two or three times this assumed thickness of sediments in nearshore and offshore sand flats, for example. More detailed study of sedimentary mapping units would improve volume estimates, although it may be unlikely that areal distribution patterns would be substantially modified by a more intensive study.

Although estimates of sand volumes were conservative, the potential of sand resource areas was drastically reduced by dredging setbacks from hardgrounds (bedrock and coral reefs) and areas of bottom restrictions, so much so that 70% of the Broward County continental shelf area is eliminated from consideration. It may be possible to reposition some artificial reefs to open up some additional areas on sand flats, but this possibility requires investigation. Without the LADS interpretive maps in a GIS platform where dredging setbacks could be superimposed as a layer, it would be impossible to estimate potential sand resource availability due to areal losses. Additional comprehension of the magnitude of areal losses in Broward County could only be achieved from study of polygon shapes for sediment mapping units. Long, narrow sediment corridors buffered away because the remaining unbuffered areas were too narrow or too small to be economically dredged. Potential sand resource availability was less encumbered by dredging buffers in Palm Beach and Miami-Dade counties because the shapes of sedimentary bodies were equant rather than rectangular. An added benefit of mapping seafloor bottom types, as in the case of LADS geomorphological units, is that it becomes possible to not only quantify sedimentary areas but also to determine spatial geometries that are important to dredging.

Comparison of geomorphological seafloor units in Miami-Dade County with spatial distributions patterns for seagrasses was instructive. Because seagrass meadows constitute sensitive marine environments, they should be avoided by activities that disturb the environment. Although a large sand resource was mapped from the LADS imagery on the continental shelf seaward of Biscayne Bay, it was suspected that perhaps seagrasses would encumber the potential sand resource availability. By overlying a coverage of seagrass distribution patterns on top of the geomorphological units, it became apparent that the seagrasses were mostly restricted to nearshore occurrences and that they did not seriously impact offshore sand flats and sand ridges. The advantage of seafloor mapping at different levels in a GIS framework, in terms of geomorphological units and biological habitats, is that intersection of spatial distribution patterns becomes known, can be quantified, and not guessed at or alluded to.

Coastal segments with previous beach nourishments were compiled from DEP databases and CPE's corporate knowledge. Offshore borrows that serviced these renourished segments are indicated on the interpretive geomorphological maps as well as being mostly evident in the color ramped LADS imagery. Total sand volumes as well as nourishment cycles and general costs were indicated for the tri-county study area, as compared to other regions along the Florida coast. Delray Beach was cited as an example of a renourished coastal segment that exemplifies the history and success of beach restoration by placement of offshore fill on the beach. This analysis was not perfect because it is difficult to ascertain exact sand volumes placed on beaches. The values reported are, however, representative of the best data in hand.

Because restored beaches require maintenance, there is a need to continually evaluate sand resource potential in the offshore zone. Interpretation of the LADS imagery included a prominent subdivision of the Nearshore Sand Flat mapping unit where diabathic channels extended alongshore for many kilometers in Palm Beach County. Recognition of beach sand in channel fills after hurricanes Frances and Jeanne suggested the potential of these deposits as a new sand source. Had the interpretive geomorphological maps based on LADS bathymetry not been prepared, this sand source would have remained unknown. Now being studied for potential development by the Town of Palm Beach, discovery of this sand resource may soon pay dividends for beach restoration because the sand is beach-quality and lies close to shore.

Study of seafloor mapping units comprised by sand in a GIS framework permitted quantification of total sand resource potential by county. In Palm Beach County, about 58% of the offshore sand resource areas were explored (investigated) but not exploited (developed); about 40% of the sand resource area was not explored. The remainder (about 2%) represents sand resource areas that were exploited as borrows for beach restoration projects. Miami-Dade County contains extensive sand resource areas that have not been explored (about 86% of the sand resource area). On the other hand, about 12% of the area was explored but not exploited. Broward County is a bit of an enigma because there are significant areas with potential as sand resources, but they are compromised by managerial restrictions such as dredging setbacks and offshore anchorages (for Port Everglades). Nearly 5% of the potential sand resource base in Broward County has already been exploited with less than one-third of the sediment area remaining unexplored (not investigated). These kinds of results coming from the GIS analyses are enlightening because they provide for the first time a sense of offshore sediment areas that have been studied versus those areas that need further evaluation. Without seafloor mapping efforts, this kind of insight is only attainable on a limited basis using other remote sensing techniques such as side scan sonar and seismic reflection profiling. Geomorphological interpretation of the LADS imagery thus provides a rational and comprehensive basis for assessing offshore sand resource potential.

5.3 CONCLUSION

Results of this study indicate that there are more offshore sand resources than originally perceived. These results would not have been possible without geomorphological interpretation of LADS bathymetry in terms of sedimentary and hardground mapping units. Development of a surficial geological model for the coastal framework of southeast Florida provides a logical basis for sand searches that are cognizant of spatial distribution patterns for sediments and hardgrounds. Incorporation of submarine geomorphological mapping units in a GIS framework permitted recognition and analysis of sediment corridors that lie between bedrock outcrops and barrier coral reefs. Quantitative study would not have been possible without geomorphological interpretation of LADS bathymetry in a GIS environment.

The total sand resource areas for Palm Beach, Broward, and Miami-Dade counties are 123 km^2 (12,300 ha, 47 mi^2), 41 km^2 (4,100 ha, 15 mi^2), and 164 km^2 (164,000 ha, 63 mi^2), respectively. Volumes that are potentially available for beach nourishment depend on deposit thickness, homogeneity of the sedimentary bodies, sedimentary architecture, and numerous grain-size parameters. However, they are primarily limited by managerial constraints related to dredging setbacks and restricted seafloor areas. Potential volumes, based on average 3 m depth assumptions, are great: 368×10^6 m^3, 122×10^6 m^3, 492×10^6 m^3 for Palm Beach, Broward, and Miami-Dade counties. Areas that are available for exploitation are constrained by dredging setbacks and infrastructure so that approximately 70% of the sand resource area in Broward County may be unavailable. Resource availability in Palm Beach and Miami-Dade counties is much better, where the loss of sand resource availability is only about 20%. About 40% (49.42 km^2) of the continental shelf area in Palm Beach County has not been explored and about 58% of the area has been explored but not exploited. There is clearly potential for further investigation of offshore sand resources in Palm Beach County. In Miami-Dade County, about 87% (140 km^2) of the LADS survey area has not been investigated. Although partly compromised by the presence of seagrass meadows, tidal and flats and sand ridges remain good potential sand resources.

Table 5-1. Area lost in potential sand resource areas in Palm Beach County due to 122 m (400 foot) buffers.

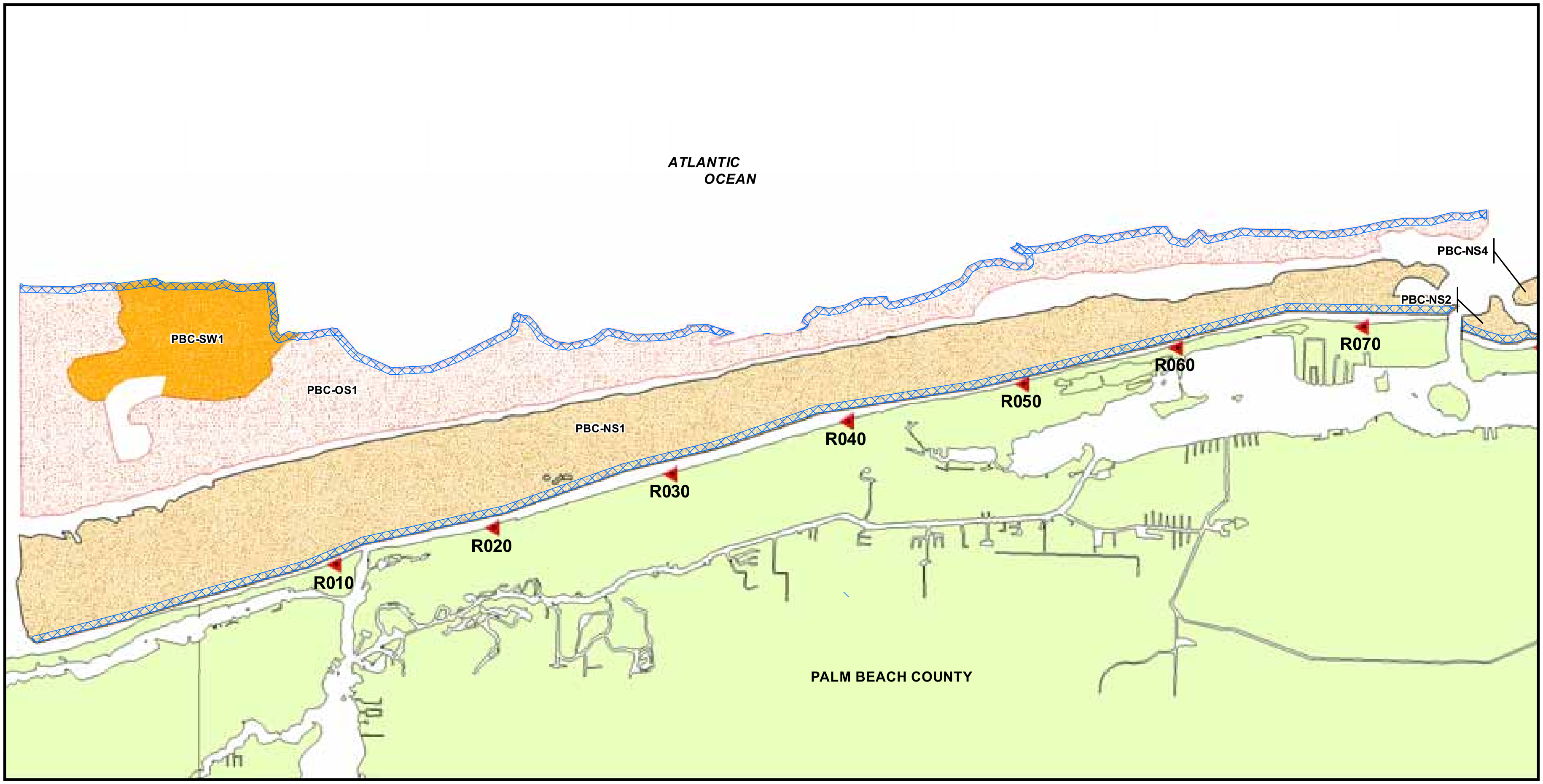
FEATURE	ORIGINAL HECTARES	HECTARES LOST	NEW HECTARES	PECENTAGE LOST
PBC-SW1	567	25	542	4
PBC-OS1	2558	144	2414	6
PBC-NS1	3282	156	3126	5
PBC-NS2	121	34	87	28
PBC-NS3	1	1	0	100
PBC-NS4	3596	611	2985	17
TOTAL	10125	971	9154	10

Table 5-2. Area lost in potential sand resource areas in Broward County due to 122 m (400 foot) buffers.

FEATURE	ORIGINAL HECTARES	HECTARES LOST	NEW HECTARES	PERCENTAGE LOST
BC-NS1	1155	840	315	73
BC-NS2	207	203	4	98
BC-NS3	304	139	165	46
BC-NS4	43	43	0	100
BC-NS5	141	54	87	38
BC-NS6	9	9	0	100
BC-NS7	5	5	0	100
BC-NS8	361	346	15	96
BC-OS1	1668	959	709	57
BC-SS1	251	116	135	46
BC-SS2	68	6	62	9
BC-SS3	220	153	67	70
BC-SS4	767	451	316	59
TOTAL	5199	3324	1875	64

Table 5-3. Area lost in potential sand resource areas in Miami-Dade County due to 122 m (400 foot) buffers.

FEATURE	ORIGINAL HECTARES	HECTARES LOST	NEW HECTARES	PERCENTAGE LOST
MDC-NS1	1073	565	508	53
MDC-NS2	607	249	358	41
MDC-NS3	596	59	537	10
MDC-NS4	775	29	746	4
MDC-NS5	11	10	1	91
MDC-OS1	644	427	217	66
MDC-OS2	174	79	95	45
MDC-OS3	482	289	193	60
MDC-OS4	82	79	3	96
MDC-OS5	224	216	8	96
MDC-SF1	2284	772	1512	34
MDC-SF2	60	37	23	62
MDC-SFR1	6482	193	6289	3
MDC-TSF1	3081	52	3029	2
MDC-TSR1	354	96	258	27
TOTAL	16929	3152	13777	19



FEATURE	ORIGINAL HECTARES	HECTARES LOST	NEW HECTARES	PECENTAGE LOST
PBC-SW1	567	49	518	9
PBC-OS1	2558	285	2273	11
PBC-NS1	3282	312	2970	10
PBC-NS2	121	64	57	53
PBC-NS3	1	1	0	100
PBC-NS4	3596	1172	2424	33
TOTAL	10125	1883	8242	19

Legend

- NEARSHORE SAND FLAT
- OFFSHORE SAND FLAT
- SAND WAVES
- PALM BEACH COUNTY
- 400' BUFFER
- FLORIDA MONUMENTS

N

0 3,000 6,000 Feet

1 inch equals 6,000 feet

TITLE:

PALM BEACH COUNTY SAND RESOURCE AVAILABILITY 400 FOOT BUFFER

CPE
COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 01/26/07 | BY: HMV | COMM NO: 7849.27 | FIGURE 5-1A

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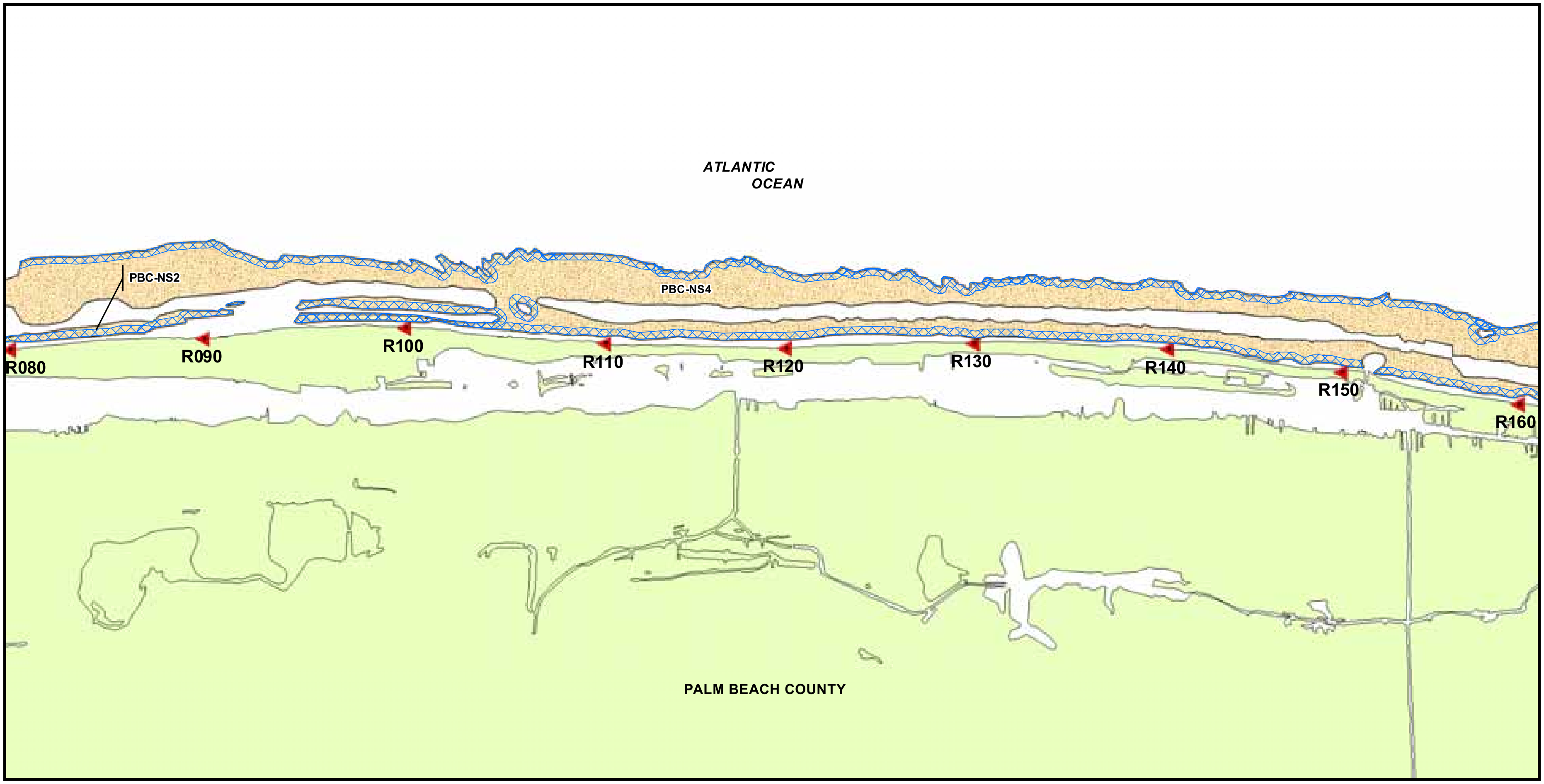

FEATURE	ORIGINAL HECTARES	HECTARES LOST	NEW HECTARES	PECENTAGE LOST
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PBC-OS1	2558	285	2273	11
PBC-NS1	3282	312	2970	10
PBC-NS2	121	64	57	53
PBC-NS3	1	1	0	100
PBC-NS4	3596	1172	2424	33
TOTAL	10125	1883	8242	19

Legend

- NEARSHORE SAND FLAT
- OFFSHORE SAND FLAT
- SAND WAVES
- PALM BEACH COUNTY
- 400' BUFFER
- FLORIDA MONUMENTS

N

0 3,000 6,000 Feet

1 inch equals 6,000 feet

TITLE:

PALM BEACH COUNTY
SAND RESOURCE AVAILABILITY
400 FOOT BUFFER

CPE
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BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 01/26/07 | BY: HMV | COMM NO: 7849.27 | **FIGURE 5-1B**

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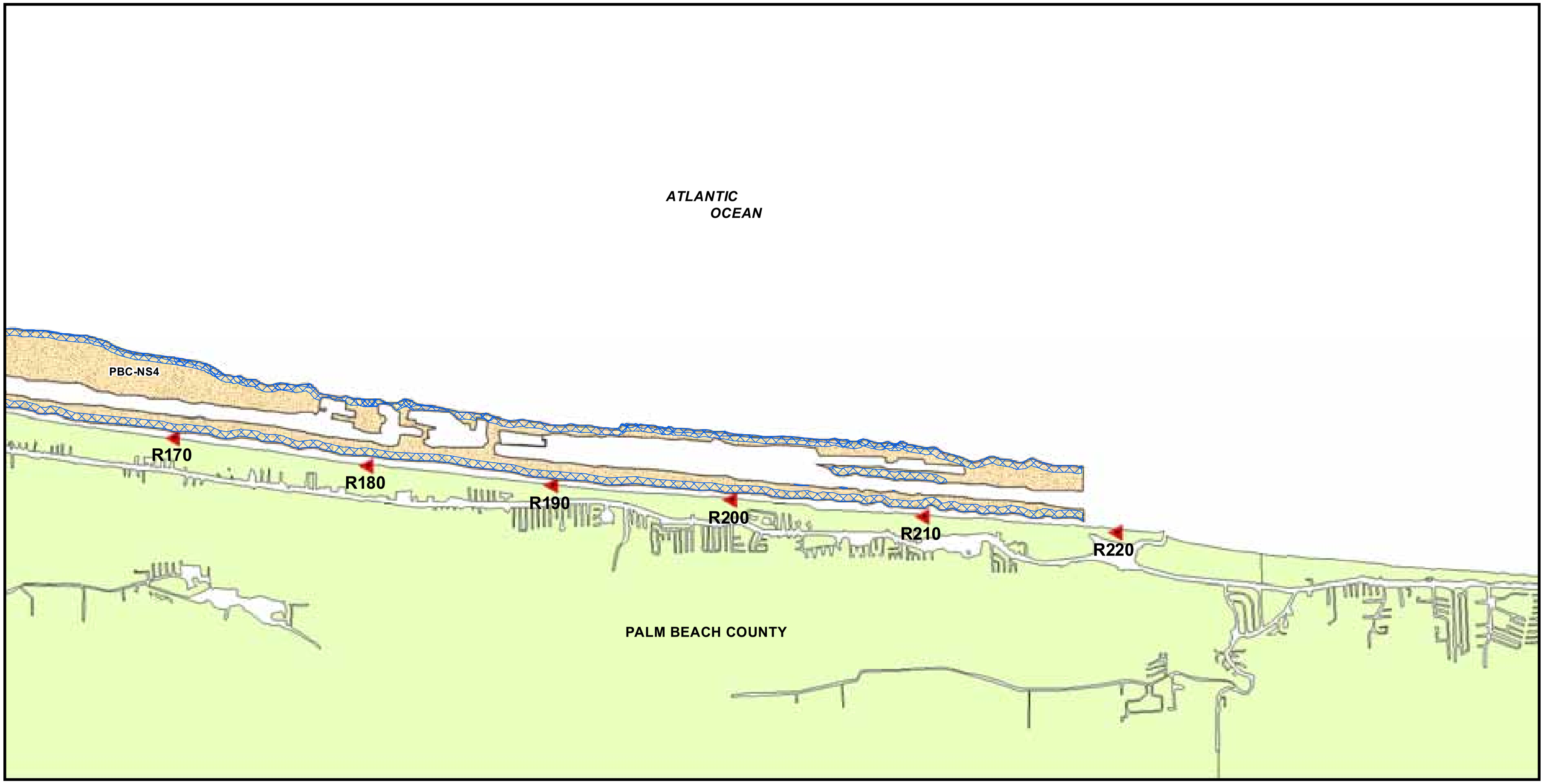

FEATURE	ORIGINAL HECTARES	HECTARES LOST	NEW HECTARES	PECENTAGE LOST
PBC-SW1	567	49	518	9
PBC-OS1	2558	285	2273	11
PBC-NS1	3282	312	2970	10
PBC-NS2	121	64	57	53
PBC-NS3	1	1	0	100
PBC-NS4	3596	1172	2424	33
TOTAL	10125	1883	8242	19

Legend

- NEARSHORE SAND FLAT
- OFFSHORE SAND FLAT
- SAND WAVES
- 400' BUFFER
- PALM BEACH COUNTY
- FLORIDA MONUMENTS

N

0 3,000 6,000 Feet

1 inch equals 6,000 feet

TITLE:

PALM BEACH COUNTY
SAND RESOURCE AVAILABILITY
400 FOOT BUFFER

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
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FAX.(561) 391-9116

DATE: 01/26/07	BY: HMV	COMM NO: 7849.27	FIGURE 5-1C

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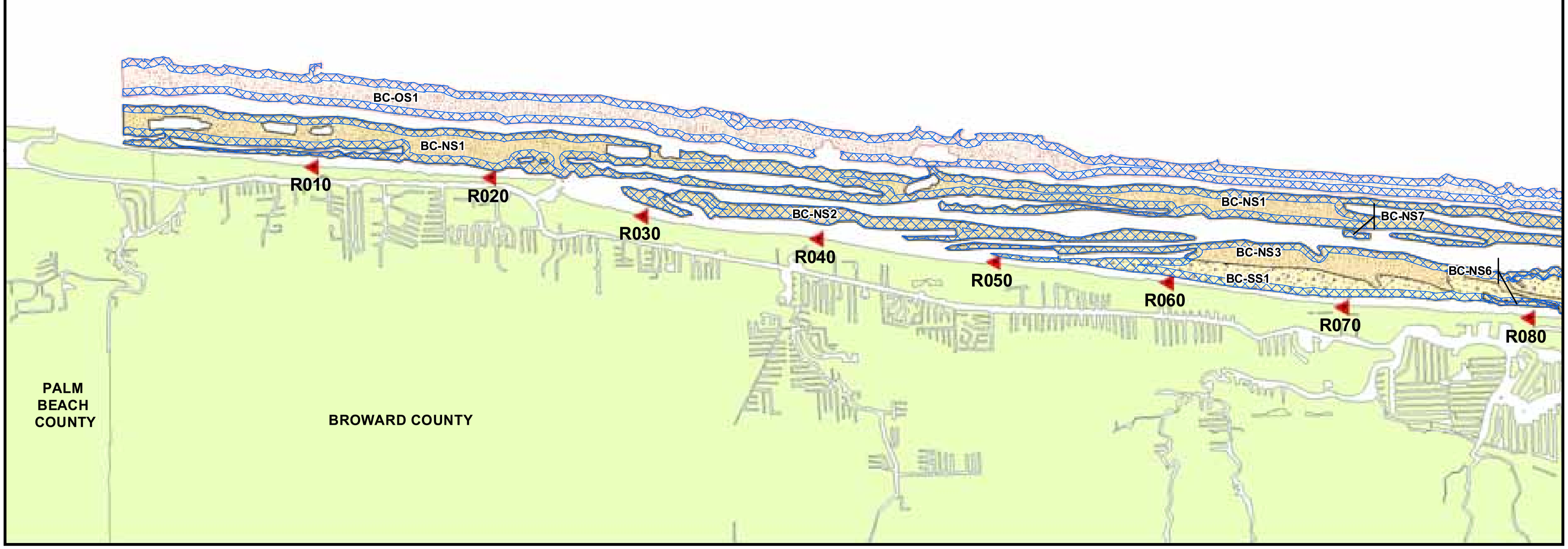
FEATURE	ORIGINAL HECTARES	HECTARES LOST	NEW HECTARES	PERCENTAGE LOST
BC-NS1	1155	840	315	73
BC-NS2	207	203	4	98
BC-NS3	304	139	165	46
BC-NS4	43	43	0	100
BC-NS5	141	54	87	38
BC-NS6	9	9	0	100
BC-NS7	5	5	0	100
BC-NS8	361	346	15	96
BC-OS1	1668	959	709	57
BC-SS1	251	116	135	46
BC-SS2	68	6	62	9
BC-SS3	220	153	67	70
BC-SS4	767	451	316	59
TOTAL	5199	3324	1875	64



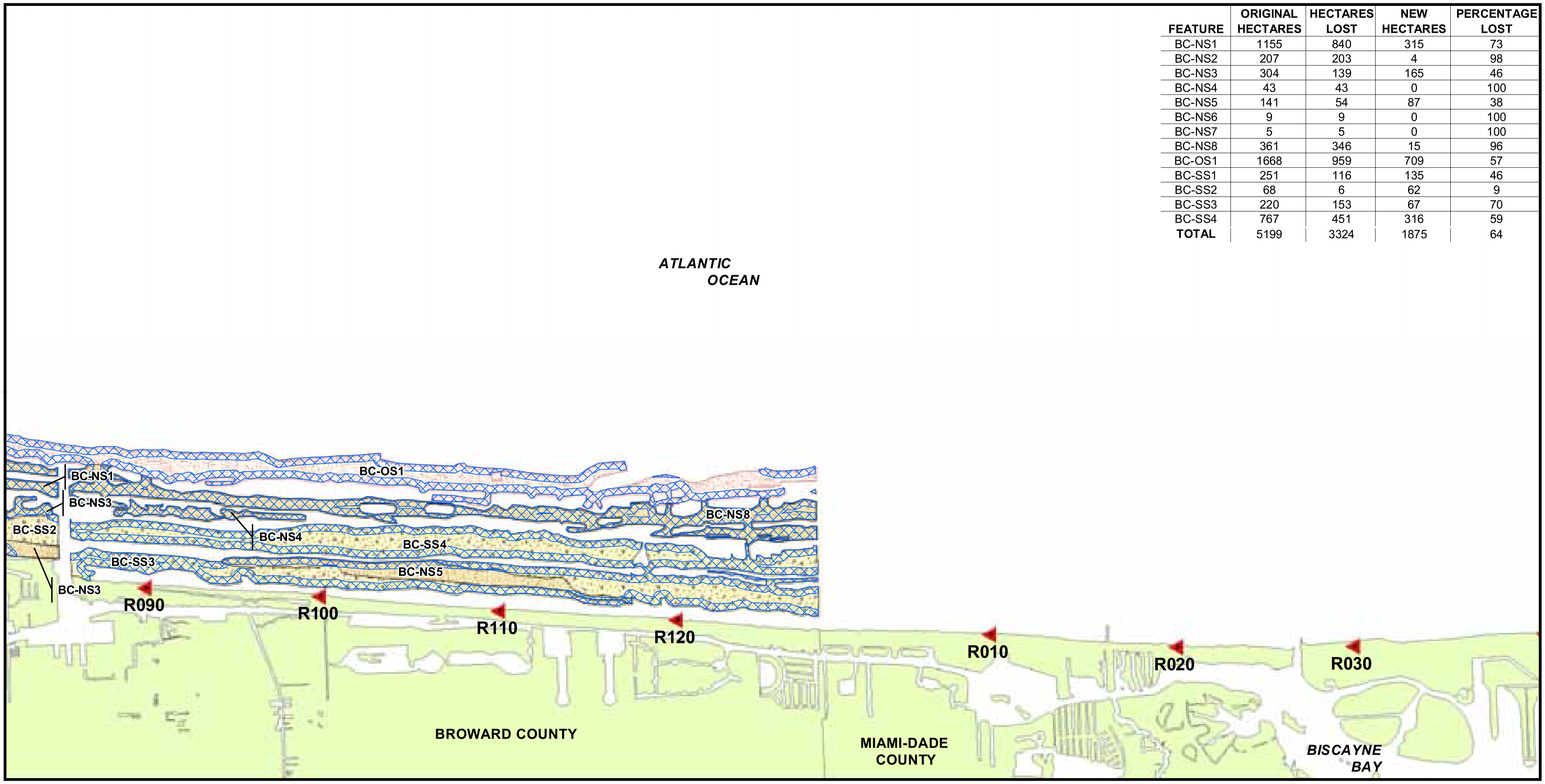
TITLE:

BROWARD COUNTY SAND RESOURCE AVAILABILITY 400 FOOT BUFFER

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 01/26/07 | BY: HMV | COMM NO: 7849.27 | **FIGURE 5-2A**

G:\DEP-URS\Southeast_ROSS_MXD\SAND_RESOURCES_400_FT_BUFFER_BC.mxd



FEATURE	ORIGINAL HECTARES	HECTARES LOST	NEW HECTARES	PERCENTAGE LOST
BC-NS1	1155	840	315	73
BC-NS2	207	203	4	98
BC-NS3	304	139	165	46
BC-NS4	43	43	0	100
BC-NS5	141	54	87	38
BC-NS6	9	9	0	100
BC-NS7	5	5	0	100
BC-NS8	361	346	15	96
BC-OS1	1668	959	709	57
BC-SS1	251	116	135	46
BC-SS2	68	6	62	9
BC-SS3	220	153	67	70
BC-SS4	767	451	316	59
TOTAL	5199	3324	1875	64

TITLE:

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SAND RESOURCE AVAILABILITY
400 FOOT BUFFER

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2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 01/26/07 | BY: HMV | COMM NO: 7849.27 | **FIGURE 5-2B**

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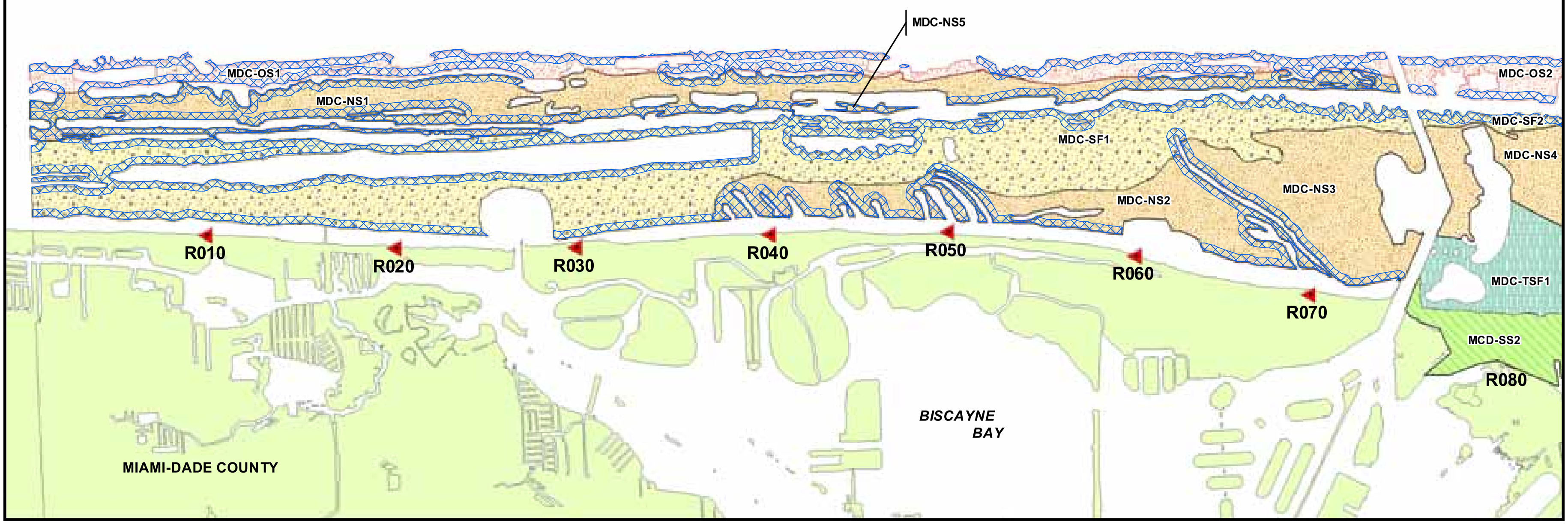
FEATURE	ORIGINAL HECTARES	HECTARES LOST	NEW HECTARES	PERCENTAGE LOST
MDC-NS1	1073	565	508	53
MDC-NS2	607	249	358	41
MDC-NS3	596	59	537	10
MDC-NS4	775	29	746	4
MDC-NS5	11	10	1	91
MDC-OS1	644	427	217	66
MDC-OS2	174	79	95	45
MDC-OS3	482	289	193	60
MDC-OS4	82	79	3	96
MDC-OS5	224	216	8	96
MDC-SF1	2284	772	1512	34
MDC-SF2	60	37	23	62
MDC-SFR1	6482	193	6289	3
MDC-TSF1	3081	52	3029	2
MDC-TSR1	354	96	258	27
TOTAL	16929	3152	13777	19



Legend

- NEARSHORE SAND FLAT
- NEARSHORE SAND SHEET
- OFFSHORE SAND FLAT
- SAND FLAT WITH SAND RIDGES
- STRUCTURAL SAND FLAT
- TIDAL SAND FLAT
- TIDAL SAND RIDGES
- 400' BUFFER
- MIAMI DADE COUNTY
- FLORIDA MONUMENTS

N

0 3,000 6,000 Feet

1 inch equals 6,000 feet

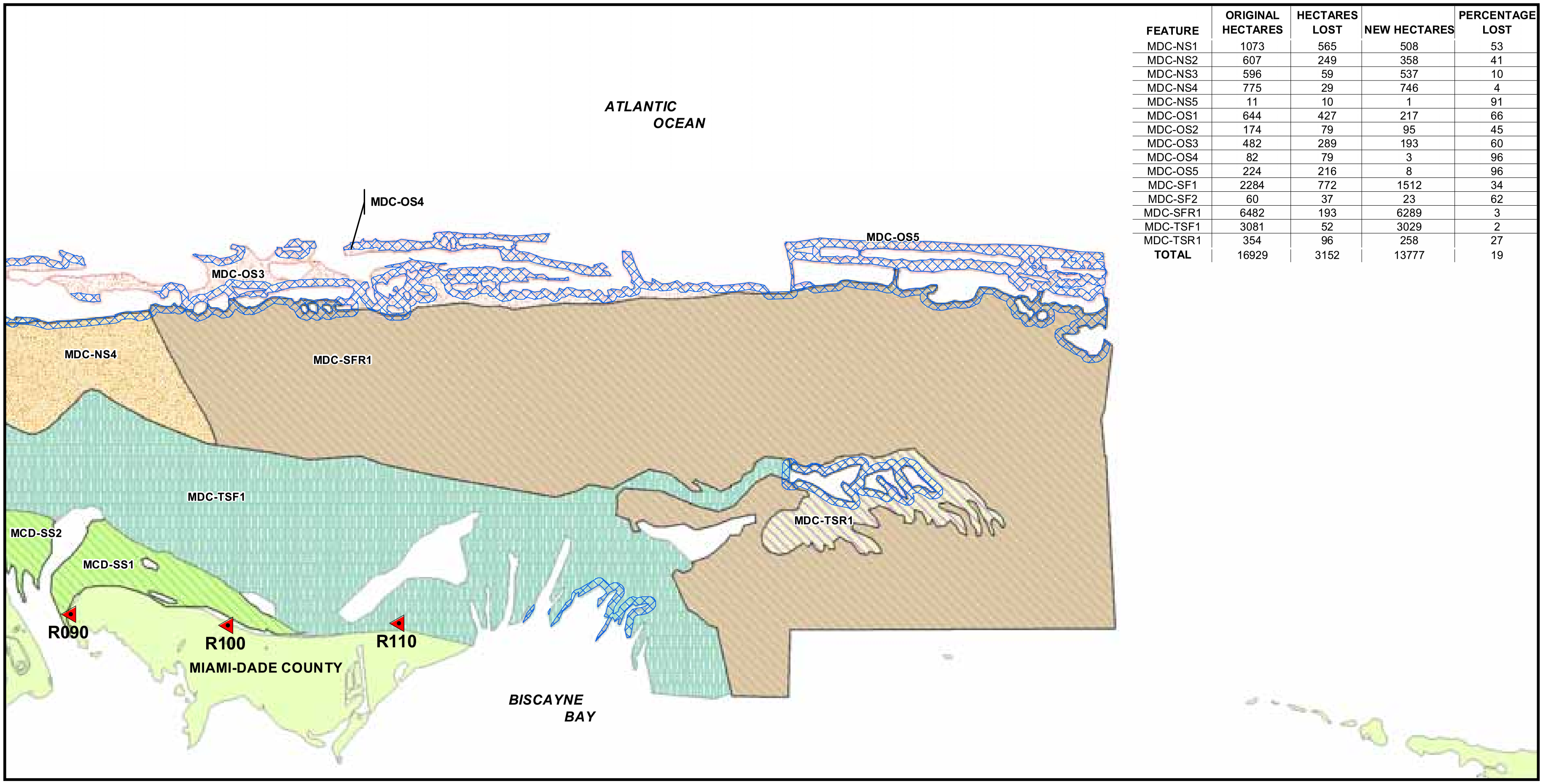
TITLE:

MIAMI-DADE COUNTY
SAND RESOURCE AVAILABILITY
400 FOOT BUFFER

COASTAL PLANNING & ENGINEERING, INC
2481 NW BOCA RATON BLVD.
BOCA RATON, FL 33431
PH. (561) 391-8102
FAX.(561) 391-9116

DATE: 01/26/07	BY: HMV	COMM NO: 7849.27	**FIGURE 5-3A**

G:\DEP-URS\Southeast_ROSS_MXD\SAND_RESOURCES_400_FOOT_BUFFER_MDC.mxd



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Legend

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DATE: 01/26/07 | BY: HMV | COMM NO: 7849.27 | **FIGURE 5-3B**

G:\DEP-URS\Southeast_ROSS_MXD\SAND_RESOURCES_400_FOOT_BUFFER_MDC_2.mxd

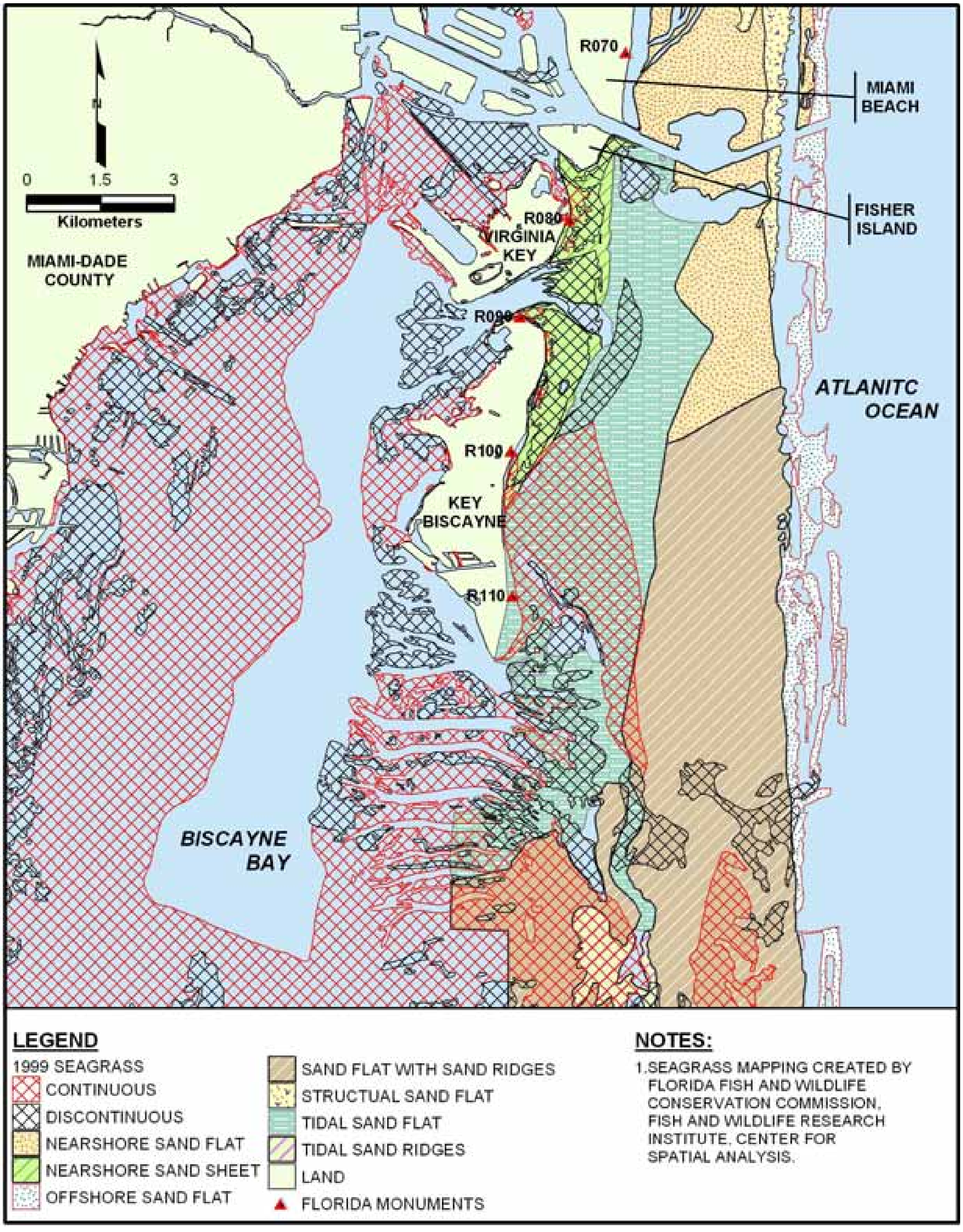

Figure 5-4. Seagrass beds in relation to sand resource areas south of the navigational entrance to the Port of Miami. Note that offshore sand flats, nearshore sand flats, and sand flats with sand ridges are unaffected by seagrass beds whereas tidal sand flats, nearshore sand flats, and tidal sand ridges are impacted.

6.1 METHODOLOGICAL APPROACH FOR SAND SEARCHES ON THE SOUTHEAST FLORIDA ATLANTIC COAST

Offshore sand resources along the southeast Florida Atlantic coast occur in four main depositional settings: (1) nearshore sand flats, (2) offshore sand flats, (3) sand ridge fields (northern Palm Beach County), (4) tidal sand flats (Southern Miami-Dade County), (5) tidal sand ridges (Southern Miami-Dade County), and (6) reef gaps and reef gap ramps (Finkl, Andrews and Benedet, 2007). Interreefal sand flats accumulate sandy sediments between nearshore rock reefs and offshore coral reefs. The long, narrow rectangular basins provide potential for large volumes of sand resources that may be suitable for beach renourishment.

Ridge fields are an alternative sediment resource to sand flats. These bathymetrically-positive features, known as sand ridges, are a prominent but under-used, offshore sand deposit. These offshore sand ridges are “mounds of sand” anchored in hardbottom that are generally composed of admixed silicates (quartz) and carbonates (shell fragments, shell hash). Generally, silt content increases with depth and rock fragments are encountered in the boundary between the ridge’s sandy sediments and the underlying hardbottom, but sediment thickness and specific composition varies between ridges within the same field and between ridges located in different geographic locations along the coast.

Reef gaps, reef gap ramps, and associated deepwater submarine deltas may represent a new sand source for beach renourishment. The barrier reef along the southeast coast is disjointed with reef sections separated from one another by gaps, which often form conduits for sand transport from the sand flats offshore beyond the barrier reef (Finkl, 2004).

Searches for beach quality sand in sand flats, on sand ridges, or in reef gaps should be based on investigations that feature a logical sequence of steps (Figure 6-1). Sand search procedures developed, for example, by Finkl, Khalil and Andrews (1997), Benedet *et al*. (2004), Finkl and Khalil (2005), and Finkl *et al*. (2006) follow strategic sand search protocols that are widely accepted in the industry. The three-phased protocol suggests that, in areas where bathymetrically positive features (*e.g.* sand ridges, bars, shoals) occur, reconnaissance investigations should concentrate on bathymetric data (preferably recently obtained) and reconnaissance sand samples (Phase I), followed by jet probes (Phase II), and finally seismic reflection (sub-bottom) profiles and vibracores (Phase III).

A logical sequence of offshore sand searches targeting sand resources along the central Florida Atlantic coast should approximate the following steps. These suggested procedures can be adapted to individual survey requirements, but they nevertheless provide a basic framework for sequencing steps in a logical cost-effective progression.

6.1.1 Review of Historical Data

Using the ROSS database, the investigator should download historical datasets containing seabed relief information, description of geotechnical data (vibracore logs, jet probe logs, grain size data) and geophysical data (sidescan sonar and seismic reflection profiles) to identify initial target areas for more detailed investigation. The gray scale shaded relief image available from ROSS should be used to identify offshore morphosedimentary features (sand ridges, bars, shoals, sand flats) occurring near a project area. The geotechnical and geophysical layers should then be turned on to see if available sediment data overlie morphosedimentary features of interest. These data may provide initial information regarding deposit thickness and sediment textural properties. After target ridges are identified and data availability checked, the investigator can design a reconnaissance survey plan.

6.2 RECONNAISSANCE SURVEY PLAN

The reconnaissance survey plan should focus on obtaining better definition of seafloor geomorphology and morphosedimentary properties. Commonly, a few (more than five) offshore morphosedimentary features are selected on the basis of the Phase I analyses. These potential sand targets typically are then narrowed down to one or two features for more detailed field investigations that may define final borrow areas.

The bathymetric data that is used to define the morphosedimentary features of interest in Phase I most likely will consist of historical NOAA-NOS data that may be several decades old. Because morphosedimentary features tend to be modified by tidal currents and wave action, an updated bathymetric survey is required to determine whether seafloor features changed shape or migrated over time. A reconnaissance seismic reflection profile survey can be conducted simultaneously with the bathymetric survey to determine sediment thickness. Bathymetric data and seismic records can be used to determine sediment thickness and presentation of results in an isopachous map. Undesirable materials such as rubble layers or presence of fine-grained sediments can normally be identified in seismic records if calibration data (*i.e.* historical vibracores) are available. Line spacing in reconnaissance surveys depends on the survey area, but generally ranges from 1000 to 2000 feet.

Traditionally, sand quality and thickness are investigated during preliminary sampling surveys using surface grab samples and jet probes. Because vibracores are more expensive and time-consuming, they are reserved for detailed phases of offshore investigation after the search area has been narrowed to target areas using other methods.

Sand quality and thickness may be investigated during preliminary sampling surveys using surface samples, jet probes or widely-spaced vibracores. Surface grab samples can be deceiving because they only sample the upper few inches of seafloor sediments (generally sediment transported by modern processes) and do not show the characteristics of deeper lying sediments. Jet probes are a cost-effective method to estimate sediment thickness and broadly indicate sediment quality in deeper layers. Because sediment samples extracted from jet probes are disturbed by the water jet, silt content may be underestimated.

One important consideration of sediment variability is that sand quality on the surface, as indicated by surface samples and widely spaced jet probes, may not always be the most effective procedure to select morphosedimentary features for further investigation during reconnaissance efforts. It may be found, for example, that relict sediments underlying the surface of the feature contain cleaner sandy sediments (*e.g.* fewer shell and rubble fragments) than surface sediments. This occurs because modern sedimentation processes that are linked to the upper layers of sedimentation on a sand ridge, for example, may be significantly different from relict sedimentation processes that formed the ridge. Evidence of relict processes is normally found in deeper subsurface layers that have been unaffected by subsequent events. Thus, it is suggested that during reconnaissance investigations of offshore morphosedimentary features on the central Florida Atlantic coast, at least one undisturbed sample (vibracore) be acquired to supplement jet probe and surface sample data for each sedimentary feature that is under investigation. The purpose of this suggestion is to provide better insight into the nature of sediments comprising the core of the feature under study.

Reconnaissance sampling plans should be designed to target the crests or divides of the main morphosedimentary features. Spacing between samples will thus span a range depending on the size of the area under investigation, the total volume targeted, and the project budget.

6.3 DETAILED SURVEY PLAN AND PRELIMINARY BORROW AREA DESIGN

Following analysis of the data collected in Phase II, a plan to conduct detailed investigations over a smaller area should be prepared. Detailed investigation plans should strive to obtain enough information to define sand quality for specific quantities and to map the vertical and horizontal continuity of sand layers. This level of investigation also provides sufficient information to identify layers or zones of undesirable sediments that should be avoided during borrow area design. The detailed investigations usually consist of detailed bathymetry, sidescan sonar and seismic reflection profile surveys on 200 to 300 foot grids with vibracores obtained on 1,000 foot centers. Analysis of the information obtained in detailed surveys permits preliminary design of offshore borrow areas and mapping of surface features (*i.e.* environmental resources, possible obstructions to dredging) that occur in or near the borrow area. Tools that assist in the visualization of deposit morphology, sediment thickness, and general characteristics of the borrow area include geological cross-sections and fence diagrams, three-dimensional isopach maps and bathymetric charts, color-coded interpretation of seismic records, etc.

Although these detailed investigations allow for preliminary borrow area design, they are usually not adequate to meet final engineering requirements of complete borrow area design. It must be appreciated that characteristics of sand resources, even in geologically well-known sites, are still subject to interpretive errors that are linked to spatial and temporal variability of natural environments.

6.3.1 Cultural Resource Investigations

Detailed geophysical investigations are required to determine whether cultural resources occur within the boundary limits of a proposed borrow area. Geophysical surveys are usually conducted on a grid with tracklines spaced 30 m (98 feet) apart (Note: Cultural resource surveys are conducted on metric grids). The cultural resource surveys generally consist of magnetometer, sidescan sonar and seismic reflection profile surveys. Because these investigations must be conducted at 30 m intervals, other geophysical Phase III investigations are generally conducted along multiple trackline spacings at 60 m (196 feet) and 90 m (294 ft). These multiple-spaced grids are so spaced so that cultural resource investigations can make use of data from Phase III by nesting additional tracklines between lines of prior Phase III geophysical surveys. It is desirable that the cultural resource investigations be conducted using the same type of geophysical equipment deployed in other Phase III geophysical surveys. In this way, borrow area design can be refined using the additional (cultural resource) data obtained, making for efficient use of separate surveys. Presence of cultural resources (i.e. shipwrecks, large cultural artifacts, etc.) requires modification of the borrow area design to avoid disturbing the mapped features. The addition of 200-foot no-dredge buffers around the cultural resource feature usually satisfies this requirement. The margins of the borrow area (when the cultural resource features occur near the borders of the borrow area) may also be modified to meet cultural resource requirements.

6.3.2 Borrow Area Impact Analysis (Environmental Investigation and Numerical Modeling)

Data from Phases III and IV may be used to map sensitive environmental resources (e.g. hardbottoms) occurring near the proposed borrow site. If sensitive environmental resources occur near the proposed dredge site, the borrow area design is modified.

In addition to cultural resources and consideration of environmental impacts, there is a need to evaluate whether the proposed borrow sites will adversely affect the nearshore wave climate to cause additional erosion of adjacent beaches. This evaluation is preferably accomplished by using a range of numerical models that simulate wave transformation over the borrow sites. These models can also simulate wave-induced currents, sediment transport, shoreline change, and variation in beach morphology. Several wave models evaluate borrow area impacts on nearshore wave climates. In order to properly evaluate borrow area impact on nearshore waves, spectral wave models that incorporate most of the relevant physical processes of wave transformation (e.g. wave refraction, bottom friction and to a lesser extent diffraction) are recommended. Even though proposed borrow areas may induce changes in the nearshore wave climate, these changes may not necessarily cause additional erosion of adjacent beaches. To evaluate whether the impacts of borrow areas on nearshore waves is significant in terms of beach erosion and deposition patterns, shoreline change models or beach morphology change models can be used.

These models can be either empiric (i.e. sediment transport is calculated based on the output of a wave transformation model that feeds empirical sediment transport formulas) or process-based (output from a wave transformation model is used to calculate wave-induced currents and these are in turn used to calculate bed-load and suspended load sediment transport). Simulations are run for scenarios with and without the proposed dredging. By comparing the with/without dredging scenarios, the investigator can evaluate the impact of dredging on the beach deposition and erosion patterns. If numerical modeling indicates that significant undesirable impacts are expected on adjacent beaches due to borrow area dredging, borrow area design modifications may be required.

6.3.3 Final Borrow Area Design

Final borrow area designs, plans, and specifications are prepared when all concerns regarding sediment quality, cultural resource potential, environmental impacts, and physical considerations are addressed. Due to implementation of no-dredge buffers that reduce negative impacts from dredging, final shape and cut depths may differ significantly from the design prepared at the end of Phase III.

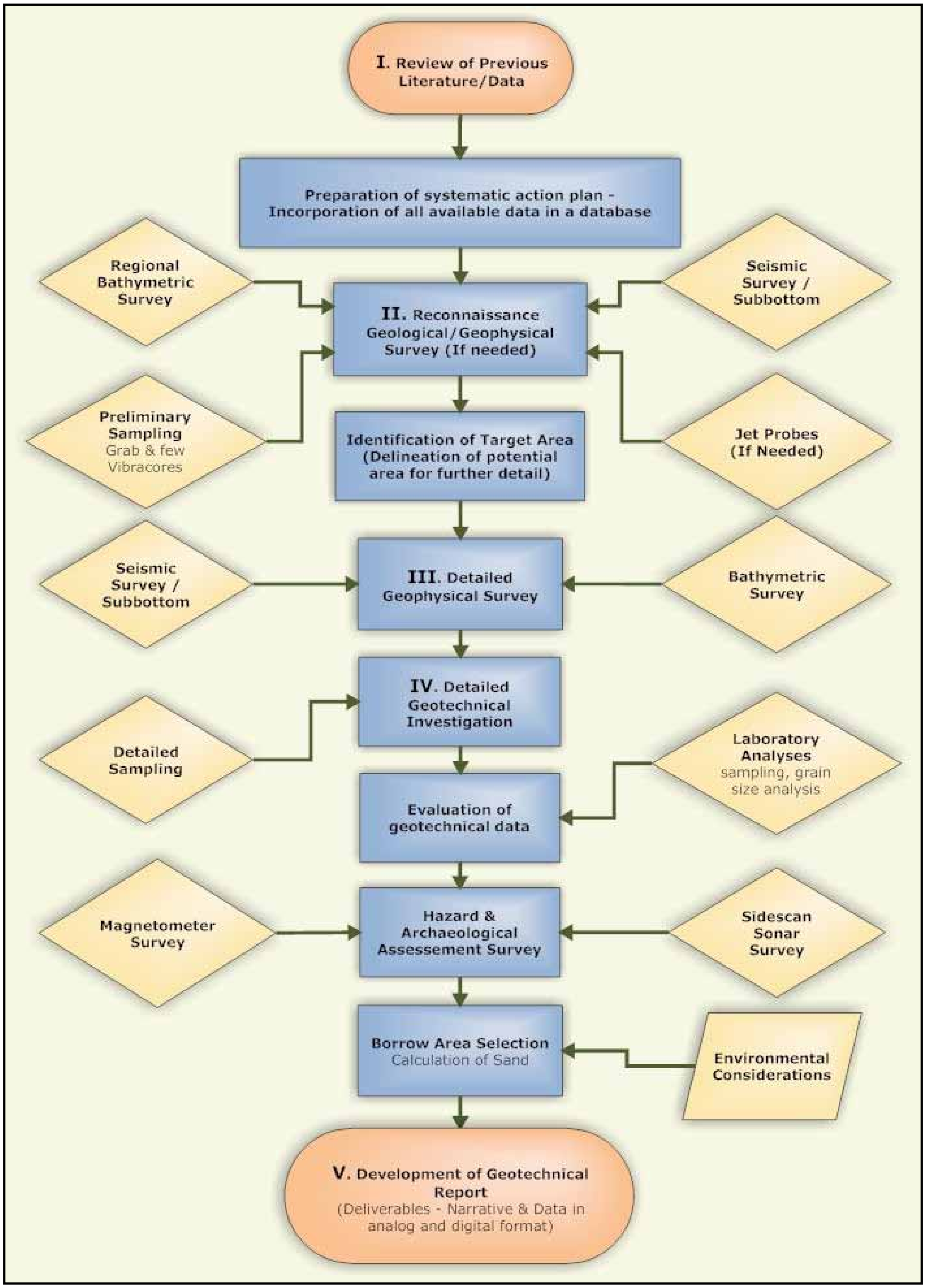

Figure 6-1. Flow diagram showing systematic approaches to offshore sand searches, based on major steps that incorporate a range of subset activities that are restrained by local circumstances. Each task is meant to direct the course of subsequent actions so that sand searches along sandy coasts proceed following a logical strategy that produces an efficient exploration methodology.

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Walker, H.K. and Coleman, J.M., 1987. Atlantic and Gulf coastal province. In: Graf, W.L., (ed.), Geomorphic Systems of North America. Boulder, Colorado: Geological Society of America, Centennial Special Volume 2, pp. 51-110.

Wiegel, R.L., 1992. Dade County, Florida, beach nourishment and hurricane surge protection Project. Shore and Beach , October 1992, pp. 2-28.

Wright, L.D. and Short, A.D., 1984. Morphodynamic variability of surf zones and beaches: A synthesis. Marine Geology, 56, 93-118.

Zarillo, G.A., 2004. Final Report Geotechnical Investigation Palm Beach County Reconnaissance Vibracores: 2004 Prepared for Palm Beach County Department of Environmental Resource Management: Revised November 2004. Scientific Environmental applications, Inc. Melbourne, Florida

Zarillo, G.A., 2006. Final Report Geotechnical Investigation Palm Beach County Singer Island Vibracores: 2005. October 2005: Revised January 2006. Scientific Environmental Applications, Inc. Melbourne, Florida.

Appendix A

Online Query Builder Users Manual

Reconnaissance Offshore Sand Search

Online Database Query Builder

Building a Custom Query

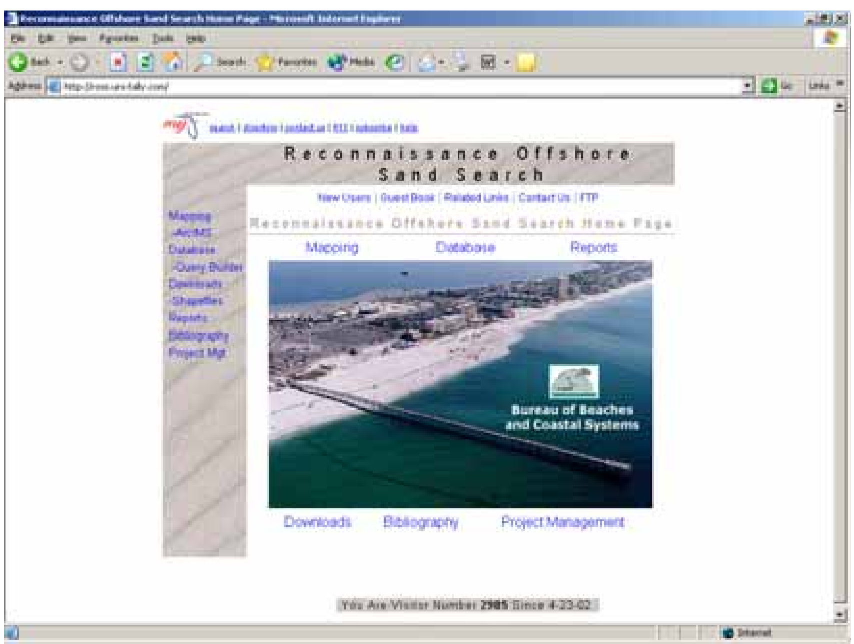
Introduction:

The query builder works by allowing you to create a "where" clause that is added to an SQL (Structured Query Language) selection statement. This selection statement tells the database to retrieve rows where the conditions you have set are true.

The query is made against one of two database views that join together data from several different database tables. Because of the structure of the database, you must specify whether the query should be run against the samples or core view. The sample view includes all data in the samples data, plus related data in the core table. The core view includes all data in the core table plus related data in the samples table. They appear to be very similar, but they are different representations of the data.

Creating a custom query

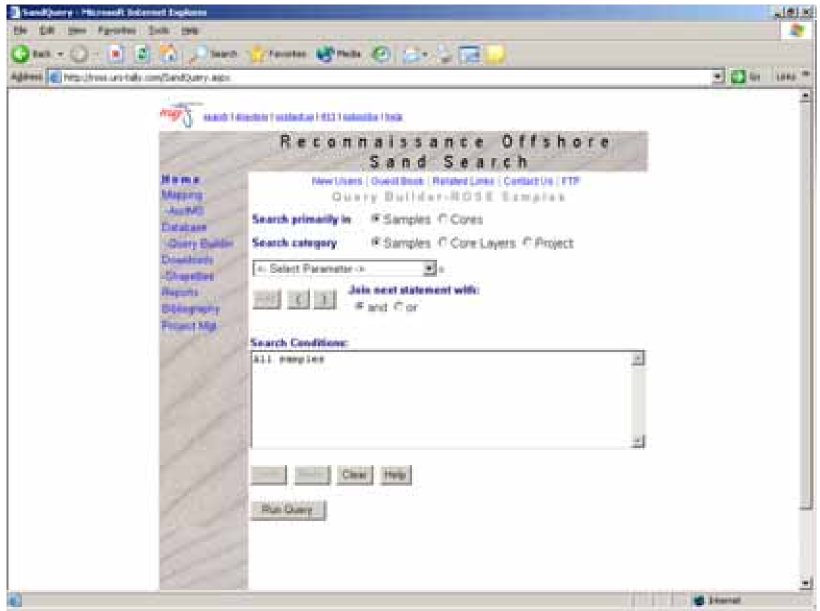
First you need to get to the Query Builder page.



Click on the link titled 'Query Builder' on the ROSS Main page.

You should now see the Online Query Builder page. From this page you can select the query criteria you want to use to filter the data.

The query parameters are categorized into three different groups. The Sample group, which provides parameters associated with the samples table. The Cores group, which provides parameters associated with the cores and core layers tables, and the Project group, which provides parameters associated with the project table.



Depending on which parameter you choose, the screen will change to allow you to enter an appropriate value.

If you choose a numeric or date parameter (such as Mean Grain Size, or Sample Date), the screen will change to show you a drop-down list of relational operators ("=", ">", "<", etc.) and a text box into which you can enter a number or date, as appropriate.

If you choose a text parameter, the screen will change to show you a different set of relational operators ("=", "<>", "like" and "not like"). The first two operators allow you to search for a specific text value, while the latter two operators allow you to search using a wildcard character ("*") to represent any text. The following examples demonstrate the difference between the relational operators:

For example, searching for a sample record that contains the word "island" in the project location field yields the following results based on the relational operator

- The "=" operator requires an EXACT match to return any results
- The "like" and "not like" require the use of the 'wildcard character' ('*', an asterisk) placed in the appropriate location within the search criteria for example
    - Choose "like" then enter "*island*" this will return ANY Project location that has the word island anywhere in the location
        - Captiva **Island**

    - Sanibel and Captiva **Island**s
    - Captiva **Island**, Lee County, Florida
- Choose "like" then enter "*island" this will return results where the word "island" is at the end of the project location.
    - Captiva **Island**
- Choose "like" then enter "island*" this will return results where the word "island" is at the beginning of the project location.
    - Currently there are no Project Locations that begin with the word "island"

There are several parameters (such as Layer Structure) you can use that provide you with a lookup list. If you choose one of these parameters, a drop-down list containing the acceptable values will appear.

There are other parameters that provide an even more customized query interface. These include Munsell color, named descriptive color, and core layer qualifiers. These screens are described in more detail below.

Search by range of dates or numbers

If you choose one of the numeric or date parameters, you will see the "between" relational operator appear in the drop-down list. This allows you to enter two values in the textbox and return records whose values fall between the two numbers (or dates). For example, to search for samples with a mean grain size greater or equal to -1 and less than or equal to 2, you would select the "between" relational operator and enter "-1 and 2" in the textbox.

Acceptable date formats

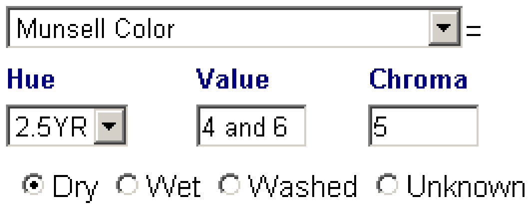
The query builder allows you to enter a date in a variety of formats, including:

Format	Example
mm/dd/yyyy	12/31/2003
mm dd yyyy	12 31 2003
mm-dd-yyyy	12-31-2003
mm.dd.yyyy	12/31/2003
mm/dd/yyyy	12/31/2003
dd month yyyy	3 May 2004
month dd yyyy	May 3 2004
dd mon yyyy	3 Jan 2006
mon dd yyyy	Jan 3 2006

If you leave the year off, it will assume you mean the current year. Enter the date in whatever format you are most comfortable with, and the query builder will reformat the date into a standard MM/DD/YYYY format for you.

Searching by Munsell color

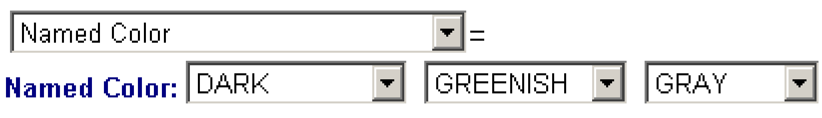
If you choose the Munsell color parameter, the screen will change to show a drop-down list and two textboxes. To enter a Munsell color, select the hue from the drop-down list, and enter numbers in the value and chroma text boxes.



You can also search by a range of Munsell values or chromas. To do this, enter the lower and upper limits of the range you wish to search in the value or chroma textboxes. For example, to search for Munsell colors with a range of values between 2 and 5, enter "2 and 5" in the value textbox.

Searching by named color

If you choose Named Color as the parameter, the screen will display three drop-down lists. These allow you to enter a descriptive color name.



Undo and Redo

If you make a mistake and enter a query condition accidentally, you can "undo" the mistake simply by clicking the Undo button. You can undo as many changes as you like. If you undo one too many changes, hit the Redo button to reapply the last change.

Joining Query Conditions

The conditions you enter must be joined together by a combinatorial operator, either "and" or "or". "And" signifies that all conditions must be true to return a record, while "or" signifies that only one must be true. You can group conditions together to clarify how the "or" operator is to be applied. For example, to search for samples with a mean grain size of -1 phi with a color of 2.5yr 5/6 or 5yr 5/6, you should group the color conditions together within parentheses. To do this:

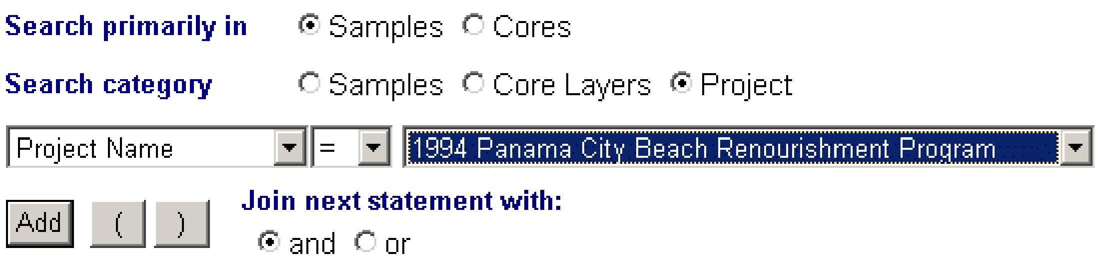
1. Enter the grain size condition
2. Change the join operator to "and"
3. Click the "(" button
4. Enter the first color
5. Change the join operator to "or"
6. Enter the second color
7. Click the ")"

Example

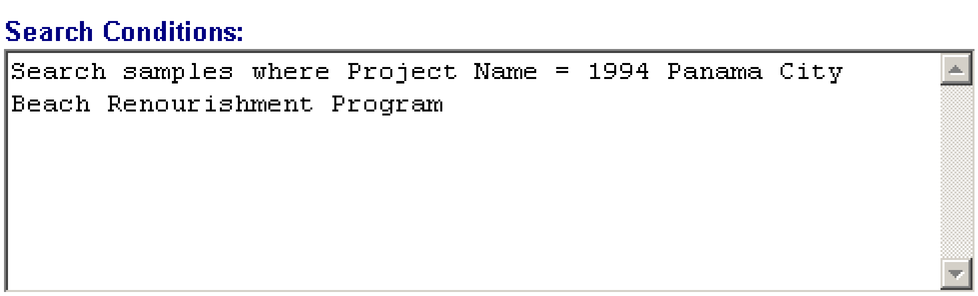
Now that you know how to provide the information to the Query Builder, Its time to put that knowledge to the test and create a query. Let's say that you want to run a query for All Samples in the 1994 Panama City Beach Renourishment Program that contain at least 80% Fine Sand (as determined by the Unified Soils Classification) that are found within 2 feet of the bottom*. You would open the Query Builder page and select the following:

Part 1: Add project condition

1. Select the Project search category.
2. Select the Project Name parameter.
3. Select 1994 Panama City Beach Renourishment Program from the drop-down list that appears after you select the project name.
4. Click the Add button.

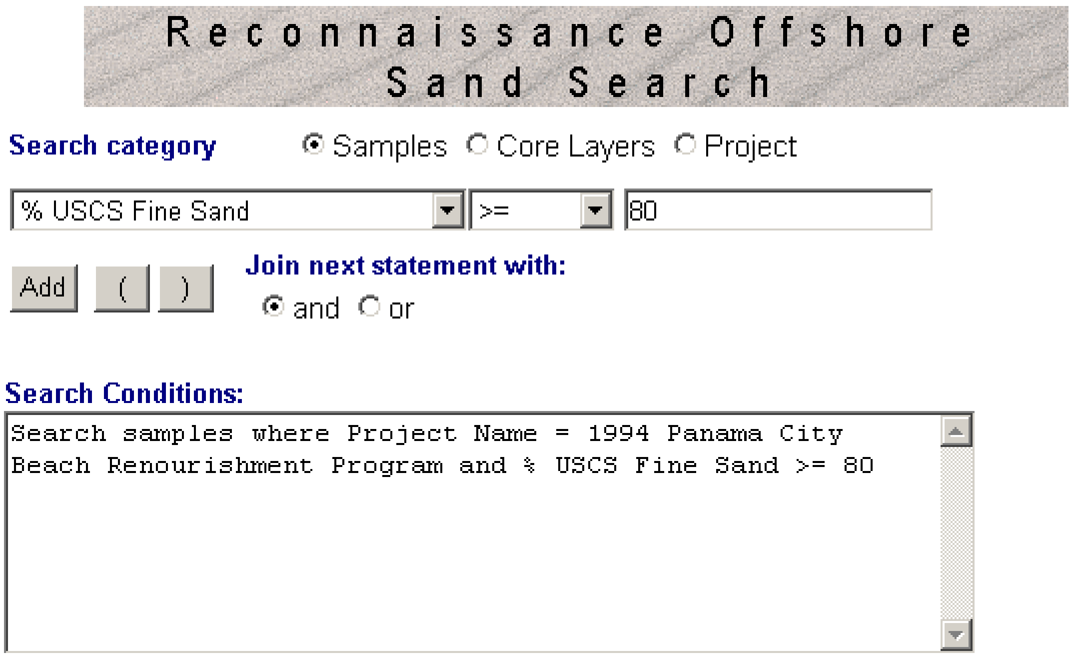


You will see the first query condition appear in the Search Conditions textbox.



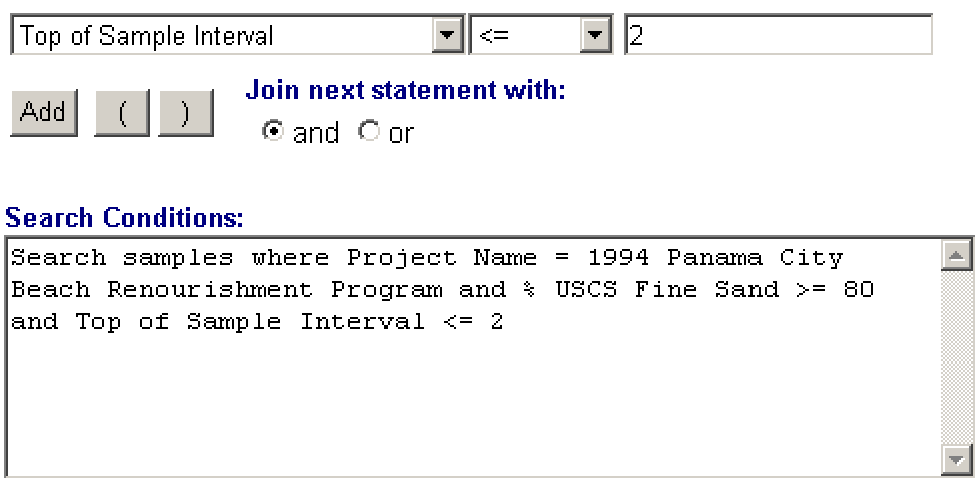
Part 2: Add the USCS Find Sand condition

1. Select the Samples search category
2. Select the % USCS Fine Sand parameter
3. Change the relational operator to ">="
4. Enter 80 in the text box.
5. Click the Add button.



Part 3: Add the depth condition

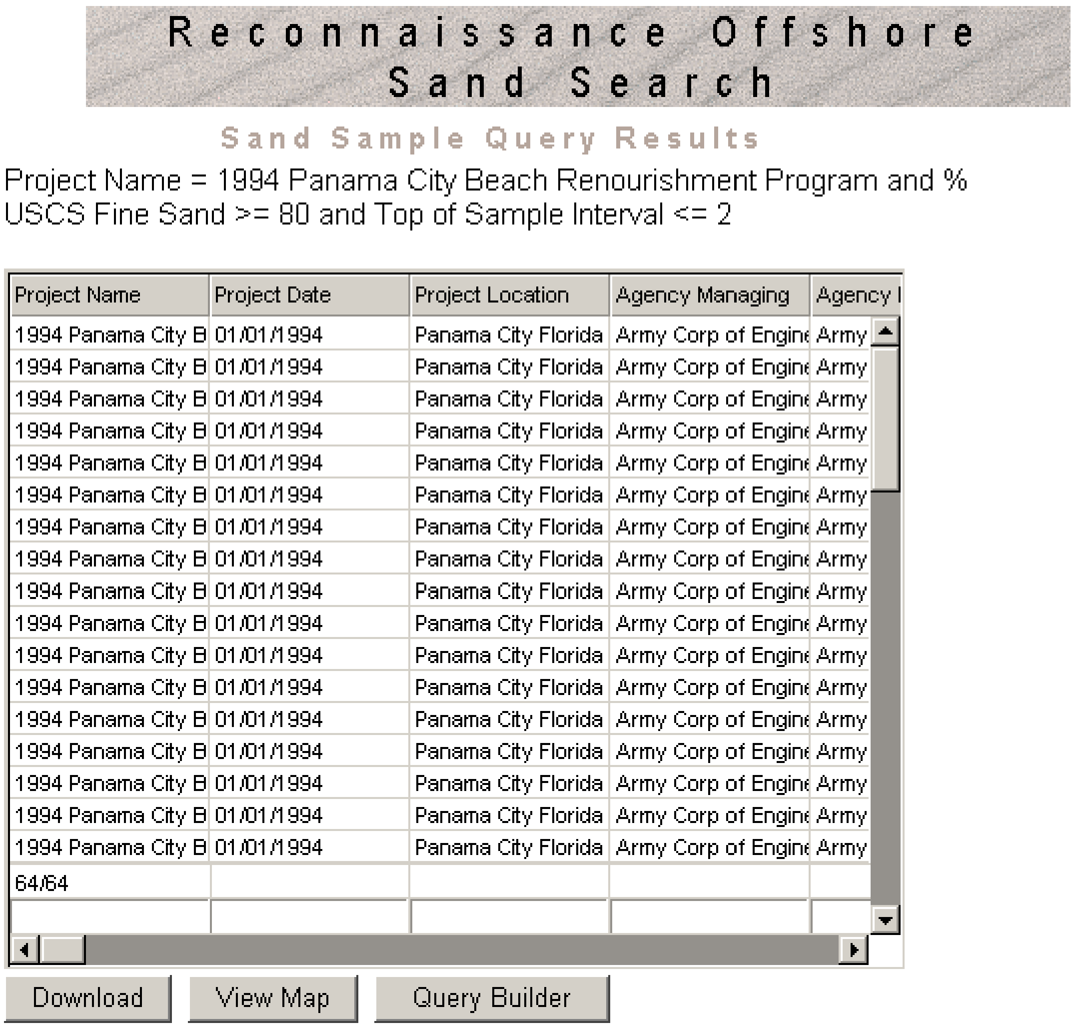
1. Select the Top of Sample Interval parameter
2. Enter 2 in the text box.
3. Click the Add button.



Now that you have entered all of the search conditions, click the Run Query button.

Query Results

The next screen that appears shows you a table of the results of your query.


Reconnaissance Offshore Sand Search

Sand Sample Query Results

Project Name = 1994 Panama City Beach Renourishment Program and % USCS Fine Sand >= 80 and Top of Sample Interval <= 2

Project Name	Project Date	Project Location	Agency Managing	Agency I
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
1994 Panama City B	01/01/1994	Panama City Florida	Army Corp of Engine	Army
64/64				

Download | View Map | Query Builder

Sorting Query Results

You can sort the results that appear in this table by clicking on one of the column headings Click the column heading again to reverse the sort order.

ate	Range Monument	Collection Method	Core ID	Core Identifier	Core
		Vibracore	170	S-2-94	-
		Vibracore	173	S-37-94	-
		Vibracore	174	S-39-94	-
		Vibracore	174	S-39-94	-
		Vibracore	176	S-52-94	-
		Vibracore	177	S-7-94	-
		Vibracore	179	V-10-94	-
		Vibracore	179	V-10-94	-
		Vibracore	181	V-13-94	-
		Vibracore	181	V-13-94	-
		Vibracore	181	V-13-94	-
		Vibracore	182	V-14-94	-
		Vibracore	183	V-16-94	-
		Vibracore	183	V-16-94	-
		Vibracore	183	V-16-94	-
		Vibracore	184	V-17-94	-
		Vibracore	184	V-17-94	-

Filtering Query Results

You can further narrow the results of your search by either clicking the Query Builder button to go back to the query builder, or you can filter the results on the fly using the filter bar.

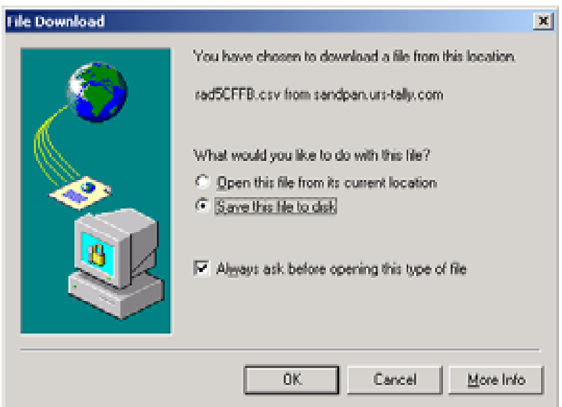
ent	Collection Method	Core ID	Core Identifier	Core Top Elevation	Co
	Vibracore	183	V-16-94	-39.90	11
	Vibracore	183	V-16-94	-39.90	11
	Vibracore	183	V-16-94	-39.90	11
			V-16		

To query using the filter bar, simply start typing a pattern in the column of data you want to filter. In this example, only samples from cores with a core identifier like "V-16" are shown. It's important to note that the filter bar does not requery the database, so you cannot use it to add results to your output.

Downloading Query Results

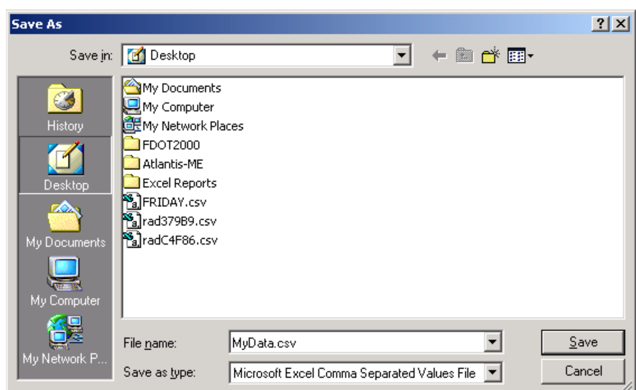
To export the filtered data from the table into a tab-delimited format suitable for import into a spreadsheet program, click the Download button. This will open up a new browser window.

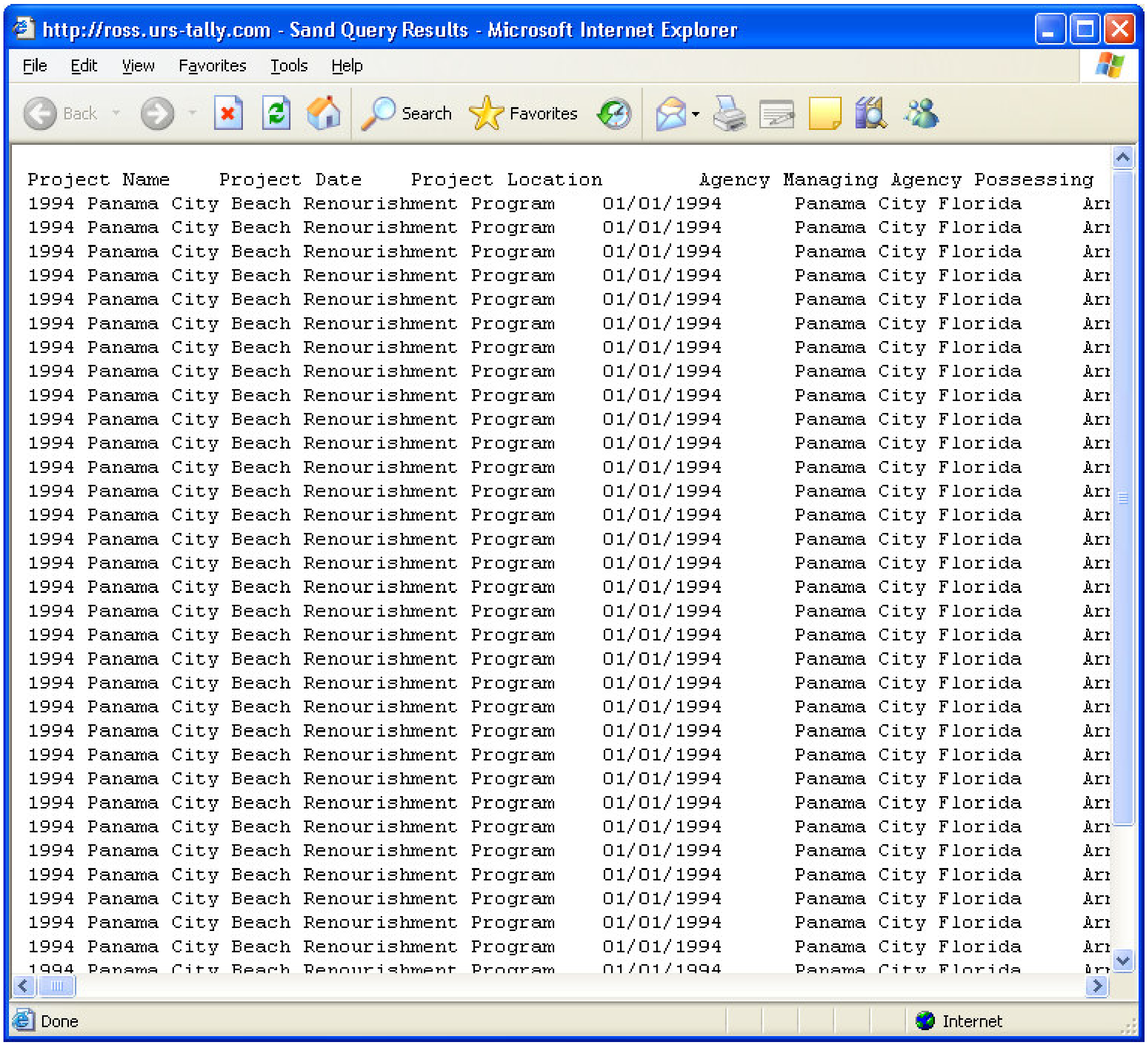
Most browsers, however, will show the data as text in the window. Simply select all of the text and copy and paste it into a blank spreadsheet page. (Hit Ctrl-A, Ctrl-C, switch to your spreadsheet program and hit Ctrl-V).



On some browsers you will be prompted to save the data, or it may open up directly in your spreadsheet program. You may see a window that looks like the one to the left. Select 'Save this file to disk' and click 'OK'

You should see a window that looks like the one to the right. Select the location where you wish to save the file. Rename the file if you wish. Now click 'Save' and the download will begin.





Saving the downloaded File as a .dbf File to use with ArcView

After you download the file, open it using Microsoft Excel. To properly save the file as a .dbf that can be used in ARCview, you will need to format each of the columns for the data type that the column contains. For example, format the State_X and State_Y columns as number columns that have 6 or 8 decimal places. If you do not reformat EVERY COLUMN, the process of saving the file as a .dbf will concatenate each column to 10 characters and you will lose valuable information.

View in ArcView

If you would like to graphically see where the samples you have queried for lie on a map, click the 'View In ArcIMS' button at the bottom of the page. An ArcIMS window will load that will display the area your samples exist and highlight the samples within that area that meet the query criteria you specified.

Appendix B

Interactive Mapping Users Manual

Reconnaissance Offshore Sand Search

New Users | Guest Book | Related Links | Contact Us | FTP

Interactive Mapping

Internet Map Services

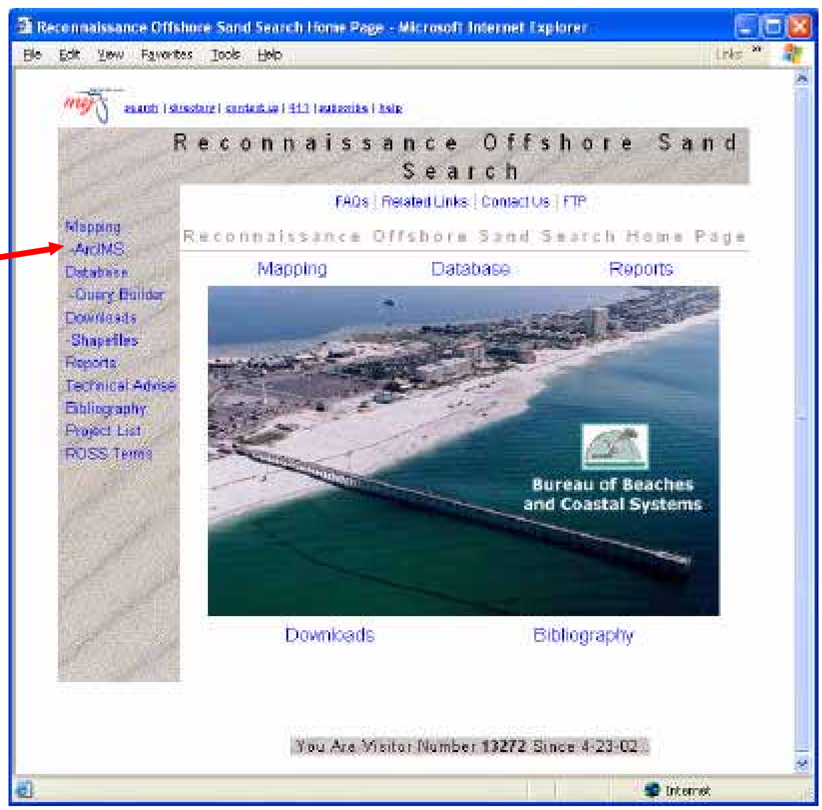
What does an Internet Map Service do?

An Internet Map Service (IMS) displays a map image based on an underlying database of spatial information. The map service allows the user to interact with the map display and query the underlying spatial data. The technology used to coordinate the database and map display is ArcIMS. More information on ArcIMS can be found on the web at http://www.esri.com/software/arcims .

Creating an Interactive Map

First you need to get to the Interactive Mapping page.

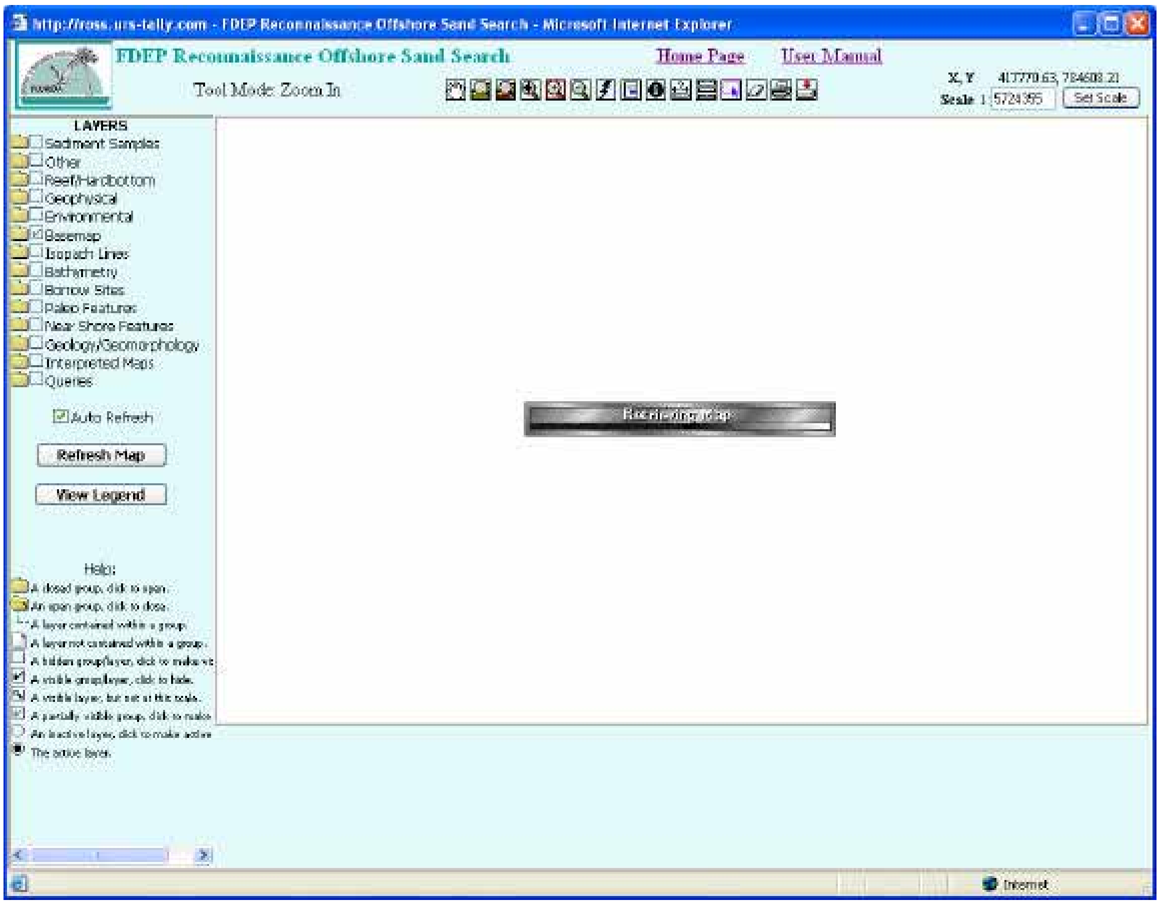
Click on the link titled 'ArcIMS' on the navigation bar of the BBCS Reconnaissance Offshore Sand Search web page.



You should now see the Interactive Mapping page in a new browser window. From this page you can use a variety of tools to navigate the map and query the underlying data.

The map image displays the full extent of the spatial data contained in the database. You may navigate through any part of the map shown in this initial extent. Below the map is an area for displaying responses from the database to your requests.

When you make requests of the map service, a response to your request is generated by the server and sent to your browser for display. The response may be a new map or the results of a query for tabular information. A response may take anywhere from a few seconds to a couple of minutes to process, depending on its complexity. During this processing time, the ArcIMS map viewer will be in Retrieving mode, preventing it from producing further requests until a reply from the server is received.



Navigating an Interactive Map

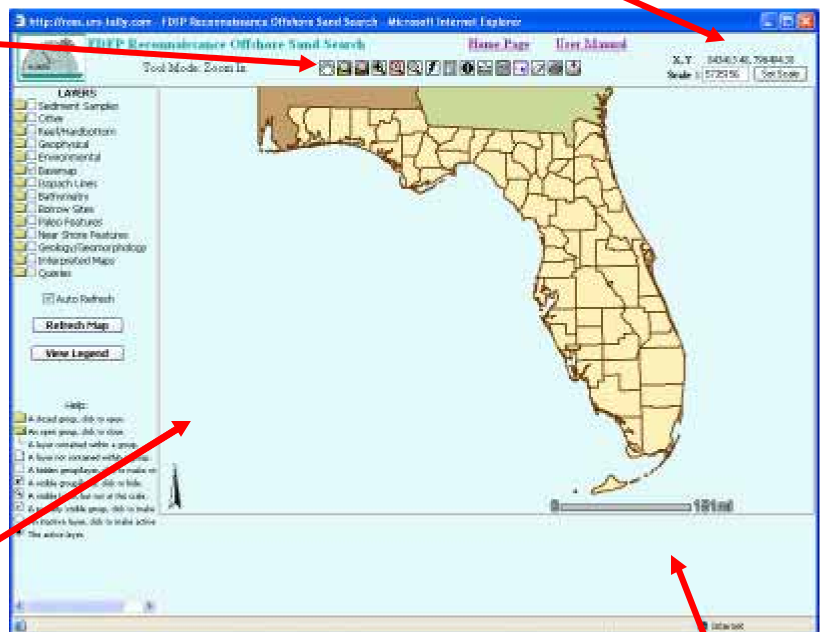
The interactive map page has a variety of tools for manipulating the map and querying the underlying spatial data. Here is a general overview of the Interactive Map page.

Across the top of the interactive map is a toolbar that includes tools for navigating, querying, and printing. A tool mode message next to the tool bar indicates the currently selected tool.

As the mouse cursor moves over the map, the map coordinates under the cursor are displayed in the top right frame, along with the current reference scale.

Appearing in the left-hand frame is the Table of Contents (TOC).

The map frame displays the interactive map.

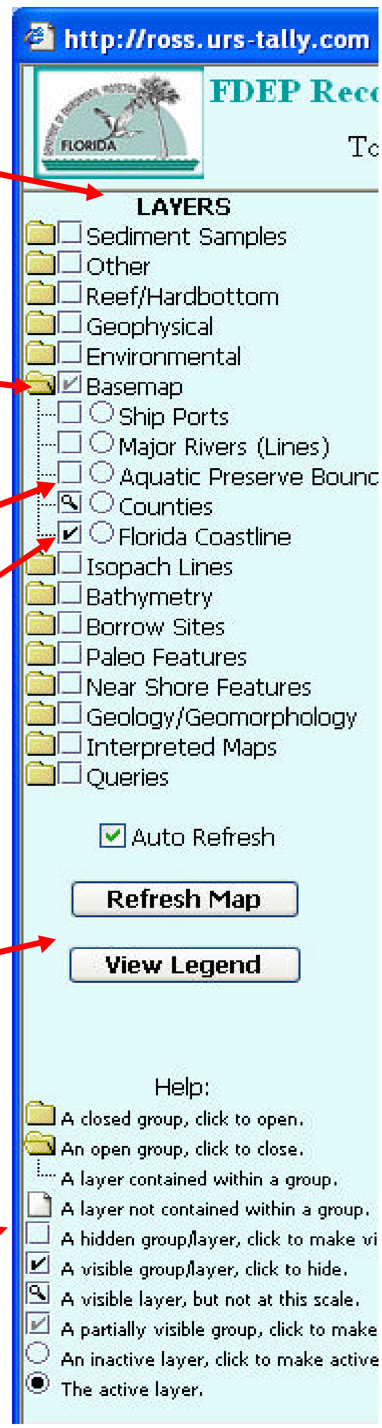


The results frame below the map displays the records associated with the results of queries and selections, as well as various messages.

Next we will examine in detail the various frames that make up the interactive mapping website.

Table of Contents Frame

The Table of Contents (TOC) contains a list of all the data sets, or layers, that can be viewed and queried in the ROSS database. The data sets and queries are organized in category folders.



The first section of the TOC is the Layer List, which displays all of the spatial data sets that are potentially visible.

Each of the category folders contains a list of layers. Next to the folder icon is a check box for making all of the layers in the folder visible.

Each layer name appears next to a check box and radio button. The check box indicates if the layer is currently visible on the map, and the radio button indicates if the layer is activated for use with the query, select, and identify tools.

A magnifying glass symbol in the checkbox lets you know that the layer is not visible at the present scale. To improve performance by reducing the map drawing speed, some very detailed layers can only be displayed when the map area is small.

Below the Layer List is the Refresh Map and View Legend buttons. Use the Refresh Map buttons to apply changes to the visible layers. The View Legend button loads a map legend that shows the meaning of all the symbols in the map.

At the bottom of the frame is a Help section that describes all of the icons used in the TOC.

Results Frame

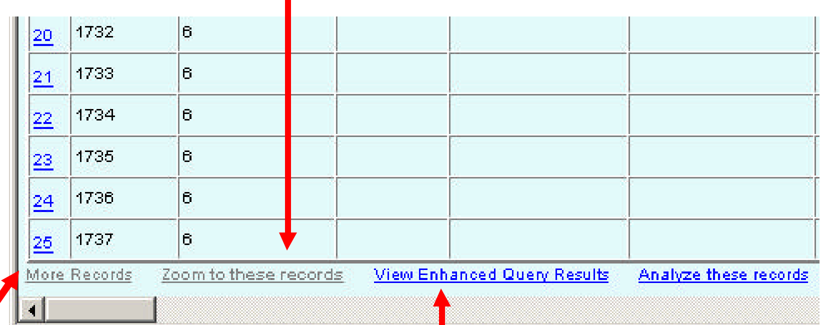
The Results Frame is the area below the map image that is used to display several kinds of textual information, such as:

- Diagnostic messages
- Tabular results from identifying, selecting, and querying features
- Forms for user input
- Hyperlinks to related documents

Below is a screen capture of the results from a selection by rectangle on the All Sand Samples layer. The Select By Rectangle tool is described in detail in the Toolbar Frame section.

Each record has a number that can be used to highlight the feature on the map.

Use the 'Zoom to these records' link to focus the map on the results of the selection.



Identify, query, and selection results records are displayed in the results frame in sets of 25; If there are more than 25 records, a link below the records retrieves the next/previous 25 records.

Features from any of the Sand Samples layers can be analyzed in more depth once they are identified, selected, or returned by a query. See the section on Additional Tools for more details.

Toolbar Frame

The toolbar buttons that appear near the top of the window are used to navigate around the map and query the database for more information about the visible features on the map.

Important Notes:

- Many tools are dependent on whether or not a layer is Visible and/or Active. To make layers visible, check the box next to the layer name, and then click the Refresh Map button at the bottom of the TOC. To make a layer active, click the radio button next to the layer name. Only one layer can be active at a time.

- Tool icons with a red outline are persistent, which means these tools remain enabled until another tool is selected. The name for the currently enabled tool, or Tool Mode, is displayed to the left of the toolbar. When the map page first loads, the Zoom In tool is automatically selected.

Next is a description of how each toolbar button operates.

Pan: Select the pan tool, and then hold the mouse cursor over any part of the map. The mouse cursor will appear as a pair of arrows. By clicking and holding down the left mouse button, you can drag the map image around the map frame. Release the mouse button to re-center the map in a new position.

Zoom to Full Extent: Clicking this button returns the map image to the initial statewide view of Florida.

Zoom to Active Layer: Each spatial data set occupies some region, or extent, on the map. For example, potential borrow areas have been identified off the Florida Panhandle. Clicking the Zoom to Active Layer button will produce the map with the smallest scale at which the selected layer is entirely visible.

Back to Last Extent: This tool returns the map to the previous spatial extent and scale. This button will cycle back through all of the map images that have been viewed, ending with the statewide view of Florida.

Zoom In: There are two ways to use this tool to zoom in on the map:

- **Zoom to Point**: Click anywhere on the map image to re-center the view on that point, and zoom in by a factor of two.

- **Zoom to Box**: Use this mode to define a rectangular region to zoom in on. Hold the mouse cursor over the map image at the top left corner of the new viewing rectangle. Click and hold down the left mouse button, then drag the cursor across the map to create a zoom box. Release the mouse button to complete the rectangle and produce a new map image.

Zoom Out: This button works similarly to the Zoom In tool, allowing you instead to zoom out.

Hyperlink: The hyperlink tool allows you to view documents related to features in some designated layers on the map. There are currently two layers with hyperlinks, Core Locations and Data Buoys. One of these layers must be visible and active to use this tool.

- *Core Locations*: Select the hyperlink tool, and then click on any core location (represented by an orange dot). If there are core logs or photos for that core location, links to these documents will be presented below the map. Click on the links to open these documents.

- *Data Buoys*: Select the hyperlink tool, and then click on the data buoy location (represented by a yellow triangle). If available, a link to the National Data Buoy Center website for the selected buoy will be presented below the map. Click on the link to open the web page containing statistics for the selected buoy.

View Metadata: This button opens a document describing in detail the currently active layer. This document, referred to as the metadata, is presented in Federal Geographic Data Committee (FGDC) format. The information in the metadata file includes a general description of the data set, a description of all the attribute columns that are associated with the data set features, and information about the data set's spatial projection, just to name a few of the available items.

Identify: More than just graphics, features on the map are related to a database record of attribute information. This information can be displayed by using the Identify tool. Any visible map features that are part of the currently active layer can be identified by selecting the identify tool and clicking on a map feature that belongs to the active layer. The database record for that feature will be retrieved and displayed in below the map.

Measure: The measure tool is used to determine the distance along a line segment or series of connected line segments, or path. Select the Measure tool and click once on the map to create a starting point. A new map image will be retrieved showing this starting point. On the new map, click again to mark the ending point of the line segment. A new map will again be retrieved showing the line segment. Continue this process of adding points to create a path. Near the top of the map are two boxes showing the length of the current path, as well as the distance from the last point added to the position of the mouse cursor. The current path may be cleared at any time using the Clear Selection tool, described below.

Set Units: The map units can be changed to feet, miles, meters, or kilometers by selecting this tool and completing the Set Units dialog that appears. A drop-down menu provides the various options for units, and a submit button is provided to apply the changes to the map display units.

Enhanced Query: Use this tool to select points from any of the Sand Samples layers and send the area of interest to the advanced Query Builder. The advanced Query Builder can be used to refine the query, sort the results, and download them for further study. See the section on Additional Tools for more information.

Clear Selection: This button clears the current selected features and compound select areas from the map image, resets the measure tool, and clears any buffers from the map.

Print: Opens the print dialog for printing the current map image. A title can be added before creating the print page. The print page opens in a new browser window, and the File menu of the new window may be used to print the map image.

FTP link: Opens the Regional Offshore Sand Search FTP site in a separate browser window. The FTP site contains the seismic images and GIS shape files for download.

Additional Tools

Enhanced Query

The results from selecting by rectangle or querying can be viewed in the Interactive Query Builder portion of the Sand Search website.

Select the enhanced query tool and draw a rectangle around features of interest on the map. Make sure the sand samples layer you want to query is visible and active.

-OR-

Identify, select, or query any Sand Sample layer, as described in the Toolbar Frame section. Click on the 'View Enhanced Query Results' Link that appears below the table in the Results Frame.