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Potential Offshore Sand Resources in Northern Maryland Shoal Fields

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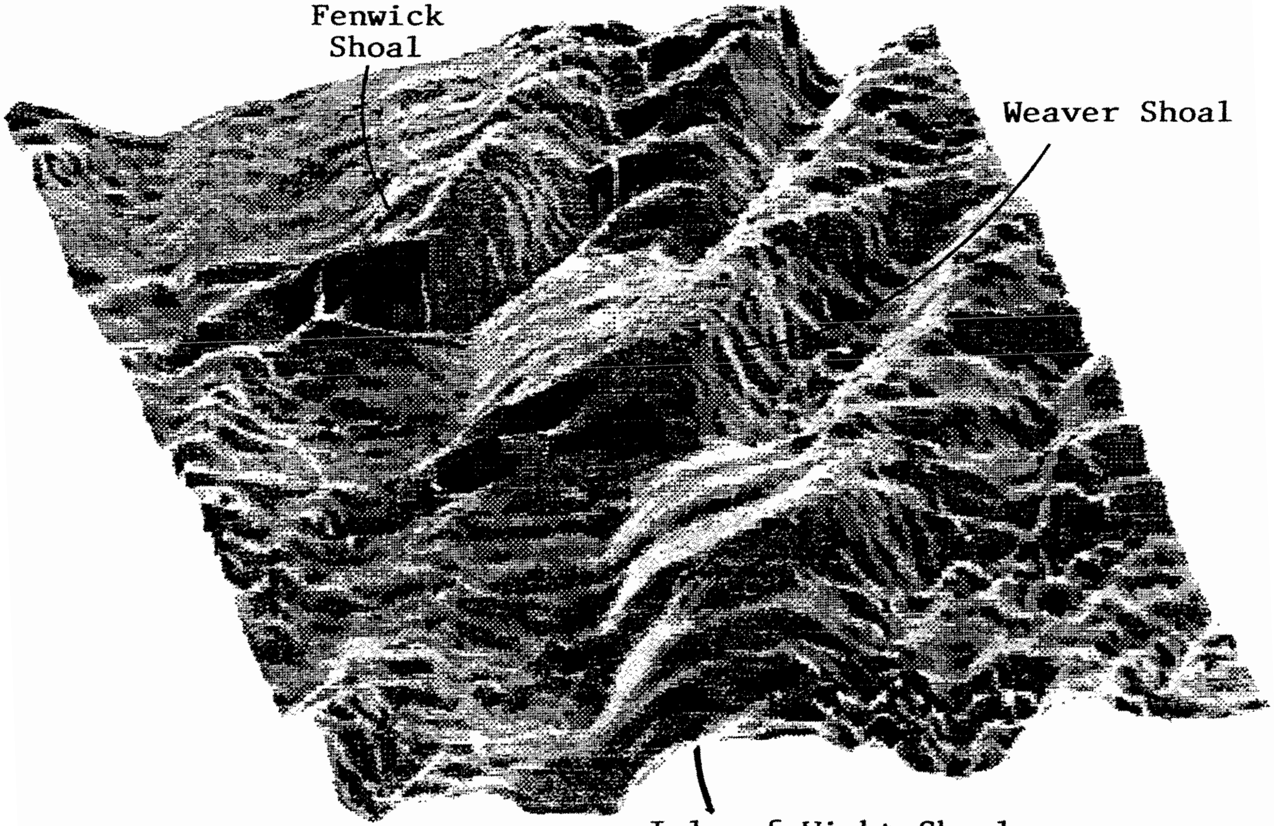
Figure 1



Rendered image of Shoal Field I

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Potential Offshore Sand Resources in Northern Maryland Shoal Fields

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Executive Summary

Extensive beach restoration projects on the Maryland coast are placing increased pressure on known offshore sand resources within State waters. Assessment of potential sand resources in Federal waters will encourage both the development of new resources and further restoration projects. Previous studies suggest that most usable sand deposits will occur within linear shoals on the inner continental shelf. A shoal field in Federal waters containing two linear shoals, Weaver and Isle of Wight Shoals, was examined for potential sand resources. The shoal field is located south of the Maryland-Delaware line, north of Ocean City Inlet, from four to nine miles offshore. Seismic surveys and vibracore sampling were used to estimate the quality and quantity of sediments contained within the shoals. Weaver Shoal was found to contain at least 45.4 million cubic yards of medium to coarse, moderately to well-sorted sands. Isle of Wight Shoal contains at least 28.1 million cubic yards of similar sands, but also was found to contain substantial amounts of fine sands and sediments.

INTRODUCTION

Atlantic coast beaches are primary economic and recreational resources in Maryland. Two barrier islands separated by the Ocean City Inlet comprise Maryland's coastline. Fenwick Island, to the north of the Inlet, is highly developed and is the site of the State's only coastal resort, Ocean City. The 8 miles of Fenwick Island within Maryland consist of public beaches fronting commercial and private real estate. South of the Inlet, the 32 miles of Assateague Island in Maryland are undeveloped state and Federal park lands. These islands and their coastal lagoons are readily accessible to nearly thirty-million people.

Although coastal lands are immensely valuable resources, they are also potentially an expensive liability. While barrier islands are ephemeral land forms, they are often developed as permanent features. Urbanization of these fragile islands may actually enhance their inherent instability. The natural migration of barrier island/inlet systems, exaggerated by development, poses a threat to regional economic and cultural commitments. In Maryland, rapid shoreward erosion of these islands jeopardizes both property and economy. A variety of shoreline stabilization and remediation schemes are available to protect established communities and investments. Beach nourishment is currently one of the most attractive options for barrier island protection.

Studies conducted by the U.S. Army Corps of Engineers in the 1980's indicated an immediate need for beach replenishment along the Ocean City shoreline (U.S. Army Corps of Engineers, 1980). There was also a projected need for beach nourishment on Assateague Island. The Army Corps study also examined alternate sand sources during the planning phase of Delmarva beach restoration projects. Beach nourishment projects demand that sand resources meet certain criteria. Sand used for replenishment must be of an optimum grain size, which is determined by kinetic factors specific for each region. The volume of sand required for restoration is also dependent on these factors. The proximity of sand sources to the target beach is an important economic factor. The Army Corps study concluded that offshore sands are the most desirable materials for beach nourishment. Factors considered included availability, cost, environmental, and social impact of onshore and offshore sand mining.

Currently utilized resources are located north of Ocean City Inlet, within the three-mile limit of state jurisdiction. These sands are committed to the reconstruction and periodic nourishment of Ocean City beaches. Demand for offshore sands is increasing as more shore communities opt for shoreline replenishment. An increase in the frequency of strong storms has accelerated erosion of the restored beaches. These factors place increasing demands on the sand resources within state waters. New sand sources must be found to meet increased demand. Access to aggregate resources in Federal waters would encourage the continuation of shoreline restoration projects. While the general distribution of offshore sand is understood, detailed information on potential resources is sparse. Site-specific data will encourage development of these resources.

The Maryland Geological Survey/Delaware Geological Survey Cooperative agreement was created to encourage and expedite an inventory of potential offshore sand resources for beach nourishment in the Delmarva region. Specifically, the cooperative agreement seeks to exchange field, laboratory, financial, and data resources for efficient production this information.

In Maryland, the objective of the first year of the cooperative was to identify potential sand resources for beach restoration projects in Ocean City, MD. We confined the initial study to Federal waters between Ocean City Inlet and the Maryland/Delaware border. This report presents the results of the first year's study.

Acknowledgements

The cooperative was funded by a grant from the U.S. Minerals Management Service, and contributions from Maryland Department of Natural Resources, and Delaware Geological

Survey. Kelvin Ramsey, Delaware Geological Survey's principal investigator in the cooperative, was of invaluable assistance. Brian Dolan, Rebecca Gast, and James Lowery performed sample preparation and laboratory analyses. I am grateful to Darlene Wells for her assistance in background preparation for this study. Special thanks to Richard Younger for his technical expertise in field data collection techniques. I also extend thanks to Randall Kerhin and Dr. Emery Cleaves for their suggestions and comments.

Previous Studies

Numerous scientists have investigated the Atlantic inner shelf. Comprehensive reviews of these works have been published by Duane and others (1972), Field (1976, 1980), Toscano and others (1989), McBride and Moslow (1991), and Wells (1994). Of primary interest to this study are the origins and morphology of linear shoals on the Atlantic inner shelf. Linear shoals have long been realized as important sand reservoirs on the Atlantic shelf. Linear shoals as a group share several common features. Duane and others (1972) characterized these features:

1) Linear shoal fields occur in clusters, or fields, from Long Island, New York, to Florida.
2) Shoals exhibit relief up to 30 ft, side slopes of a few degrees, and extend for tens of miles.
3) The long axes of linear shoals trend to the northeast and form an angle of less than 35° with the shoreline.
4) Shoals may be shoreface-attached, or detached. Shoreface-attached shoals may be associated with barrier island inlets.
5) Shoal sediments are markedly different from underlying sediments. Shoals are composed of sands that overlay fine, occasionally peaty, sediments.

With so many common characteristics, early researchers assumed a common origin for these features. Generally, it was assumed that linear ridges represented relict barriers or subaerial beaches, developed at a lower sea level stand, and preserved by the transgressive oceans (Veatch and Smith, 1939; Shepard, 1963; Emery, 1966; Kraft, 1971; and many others). Improvements in seismic data collection and reexamination of earlier data led to a new hypothesis of shoal evolution: linear shoals are post-transgressive expressions of modern shelf processes. In particular, Field's (1976, 1980) work on the Delmarva shelf could find no support for the theory of relict, submerged shorelines. Many investigators (including Field 1980; Swift and Field, 1981) concluded that ridge and swale topography developed by the interaction of storm-induced currents and sediments at the base of the shoreface. As the shoreface retreated during transgression, shoreface-attached shoals became detached, and isolated from their sand source. Once detached, the shoals continued to evolve within the modern hydraulic regime.

McBride and Moslow (1991) employed a statistical approach to analyze existing geomorphologic and sedimentologic data on linear shoals. They found a correlation between the distribution of shore-attached and detached shoals and the locations of historical and active inlets along the Atlantic coast. They described a model for the genesis and development of shoal fields, based on the formation and migration of ebb-tidal deltas. This model provides a source of sediment for shoal formation, and explains the orientation, shape, distribution and evolution of linear shoals. While these authors recognized that there are diverse mechanisms that can account for shoal formation, the ebb-tidal shoal model provides the first field-tested explanation for the formation of shoal fields.

A model of late Tertiary and Quaternary stratigraphy on the Maryland shelf has been published by Toscano and others (1989) and Toscano and Kerhin (1989). The model uses Field's (1976, 1980) framework, and clarifies spatial, temporal, and climatic relationships through extensive seismic, sedimentologic, and paleontologic investigations. Application of the model to further field investigations led Kerhin (1989) and Wells (1994) to conclude that sand resources off the Maryland coast are confined mainly to the linear shoal fields. It was Kerhin's (1989) preliminary assessment that any non-shoal sand resources within the explored Maryland shelf were limited to an area 12-15 km east of the Maryland-Virginia boundary. Wells (1994) found that significant sand sources within her study area were confined to shoal fields east of Ocean City, MD. Furthermore, she found that shore-attached shoals generally contained fine sands and muds, unsuitable for beach fill. Coarser sands were generally found in shore-detached shoals.

The Offshore Sand Resources Study employs the Toscano-Kerhin model of the Maryland Quaternary shelf to define shoal field structures. The McBride-Moslow shoal model is used here to classify the shoals as either ebb-tidal or non ebb-tidal in origin.

Study Area

The Offshore Sand Resources Study's first year study area was selected for its proximity to Ocean City, MD. A beach nourishment project for Ocean City was begun by the U.S. Army Corps of Engineers in 1988. Numerous studies were conducted before the Federal project to locate suitable sand resources within State waters. As resources are being depleted within the three-mile limit, new sand sources must be sought in Federal waters. A target shoal field was selected by examining NOS Bathymetric Map NJ 18-5. This field is located approximately five miles east of Fenwick Island, south of the Maryland-Delaware line, and north of Ocean City Inlet. The eastern edge of the shoal field extends to nine miles offshore. Included within the region designated Shoal Field 1 are the extreme southwestern crest of Fenwick Shoal in the north, a previously unnamed shoal referred to in this study as Weaver Shoal in the center, and Isle of Wight Shoal to the south. The study area encloses 25 square miles of ocean floor, from depths of -14 to -80 feet below NGVD.

The Maryland Department of Natural Resources has suggested practical some limits for offshore sand resource locations (J. Loran, pers. comm., 1992). Economical and mechanical limitations suggest that resources be located within a 15-mile radius from the point they are needed, and in waters less than 50 feet deep. Shoal Field 1 conforms to these suggested parameters. Figure 2 details the location of Shoal Field 1.

Study Methodology

Our goal in the first year of the Cooperative was to locate and evaluate potential sand resources within Shoal Field 1. To achieve this goal, we developed a plan of study that included seismic surveying of the shoal field, vibracore sampling of the shoal bodies, laboratory analysis of sediment and biologic samples, and digital analysis of seismic data. Seismic data provided a basis for stratigraphic and volumetric analysis of the shoals. Sediment data was required to determine the quality and quantity of sand/mud within the shoals. Biologic samples were collected for amino-acid age determinations, which assist in stratigraphic analyses. Based on this information, the shoals could be classified according to their resource potential. The data also contribute to a model of regional shoal classification.

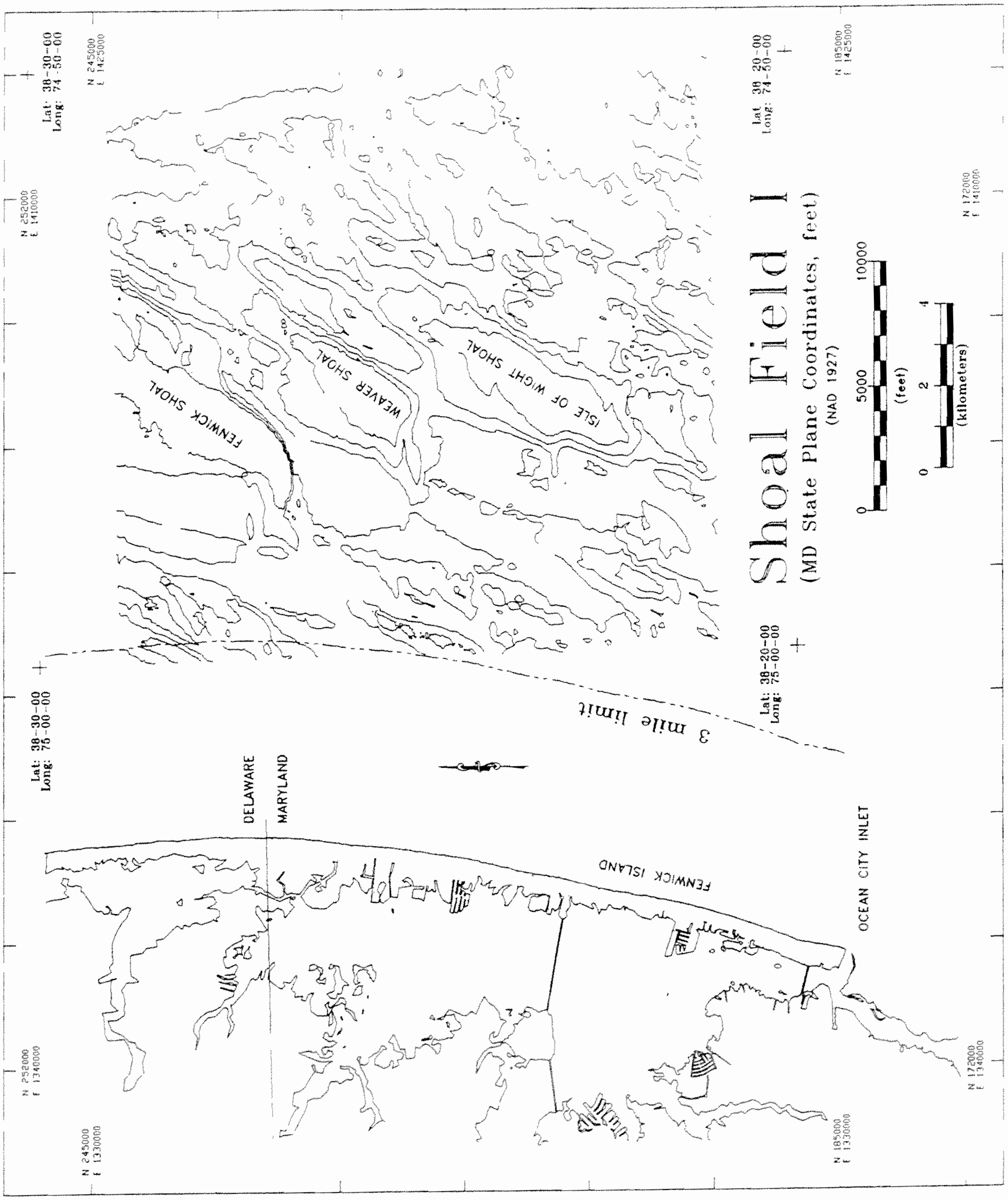
Previous studies by McBride and Moslow (1991), Toscano and Kerhin (1989a), Kerhin (1989b), and Wells (1994) show that significant sand deposits are most likely to be found in linear shoals. We therefore concentrated our data collection to the shoals and their flanks within the study area. Seismic lines were arrayed to provide cross-sections and axial profiles of the linear shoals, and the perimeter of the shoal field. Vibracore sites were located along the seismic tracklines. These sites were selected to provide representative sampling of shoals, and to penetrate the base of at least one shoal.

Funding for 10 vibracores was available for the Maryland portion of the Cooperative. Five cores per shoal were required to adequately characterize the sediments and stratigraphy. Shoal Field 1 fully encompasses Weaver and Isle of Wight Shoals and the southern extremity of Fenwick shoal.

Bathymetry and Subbottom Profiling

Bathymetry and subbottom structures were determined by high-resolution seismic profiling. We carried out the seismic survey on board Maryland Geological Survey's *R.V. Discovery* during joint field operations with Delaware Geological Survey. The survey took place in August 1992. Over 85 miles of seismic lines were recorded off the Maryland coast. We used a DataSonics acoustic profiling system for data collection. The best subbottom acoustic records were obtained at 3.5 kHz. While the DataSonics system can provide penetrations more than 300 feet, shallow water depths and a generally hard, sandy sea floor limited penetration to less than 90 feet. However, this limitation was not significant for the

Figure 2



Shoal Field I Index Map

study because our interests were in shallow and surficial sediments. Bathymetry was recorded at a frequency of 200 kHz. Trackline positioning was determined by a LORAN-C navigational unit, which provided fix marks at five minute intervals (Figure 3). Horizontal data are reported in Maryland State Plane Coordinates (NAD 27, feet). Conversion between Maryland State Plane Coordinates and geographic coordinates was performed by *CORPSCON* software.

Sediment sampling

Ten vibracores were obtained during the fall of 1992. Vibracore sampling stations were selected to fall on previously obtained seismic lines (Figure 4). Table 1 summarizes vibracore stations details. The stations were spaced on the shoals to provide optimum information. Three cores were taken on the northeast-trending, long axis of each shoal. Cores on the southwest crest, the center, and the northeast tail provide axial trend information. Cores from the west and east flanks provide cross-sectional data. We hoped to penetrate the lower boundary of the shoals on at least one flank.

Vibracoring was contracted to Ocean Surveys, Inc. of Old Saybrook, CT. Ocean Surveys provided a 110-foot vessel for the work. A custom drill rig, the OSI Model 1500, was outfitted to take 20 foot by 3⅝ inch Lexan lined vibracores. The rig was fitted with a penetrometer and a high pressure water pump for jet retries. When the penetrometer indicated penetration refusal of less than one foot in two minutes, the choice to retry in the same location would be made. During repenetration, the incomplete core is withdrawn and saved, and the corer is replaced on-station. The core barrel is jetted down to the depth of refusal, and vibracoring is continued until 20 feet or another refusal is encountered. One retry out of two refusals was attempted during our field work.

Coring station locations were provided by a three-range Racal "Micro-Fix" electronic positioning system. Location accuracies of ±6 feet were obtainable. Water depths from electronic soundings were corrected to NGVD based on NOAA predicted tides for the time of sampling. Upon retrieval, the 20 foot cores were cut into 5 foot sections and labeled for transportation to the laboratory.

Figure 3

Track Lines
and
Bathymetry
(feet below NVGD)
10 foot interval

Shoal Field I
(MD State Plane Coordinates, feet)
(NAD 27)

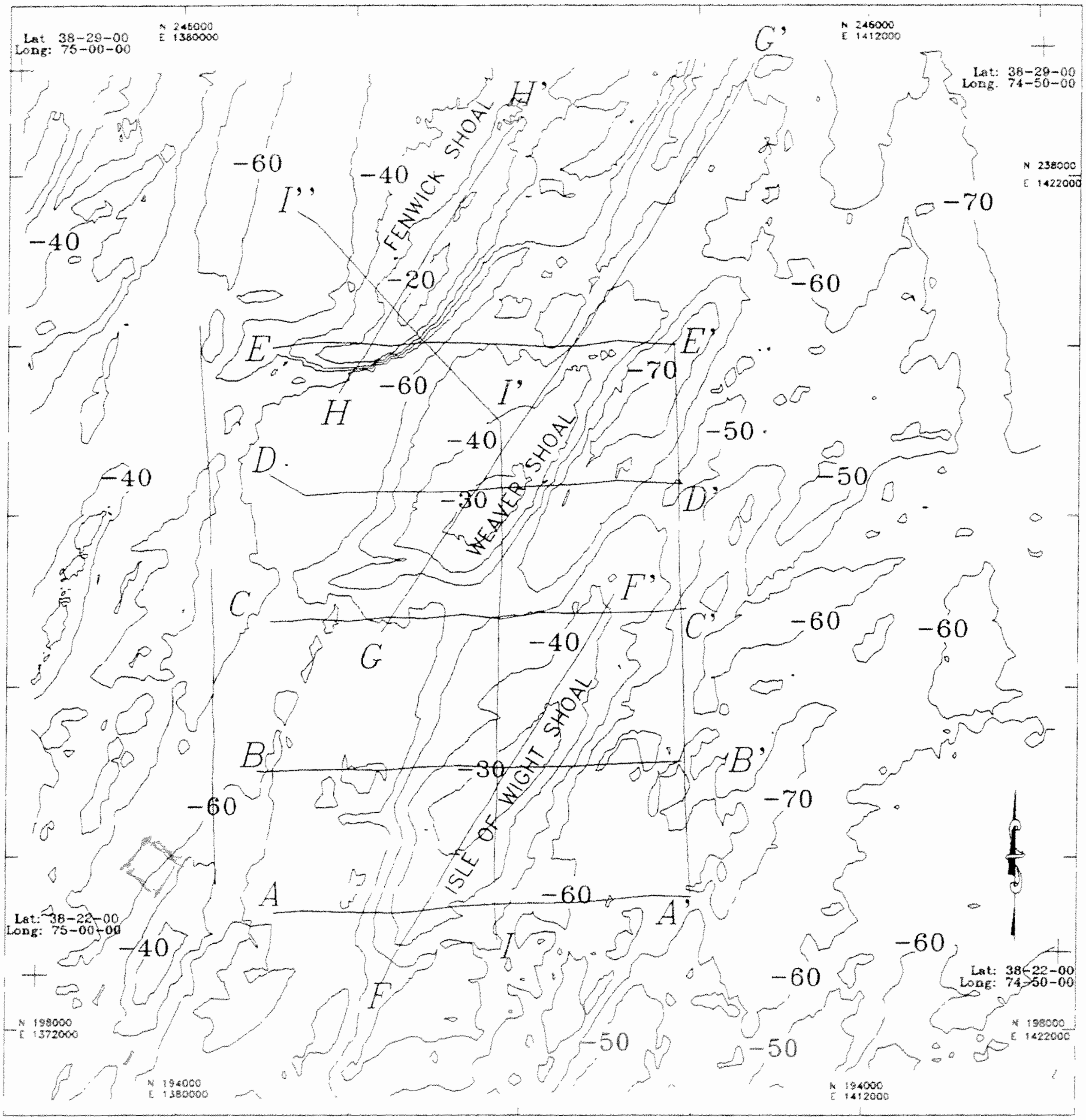
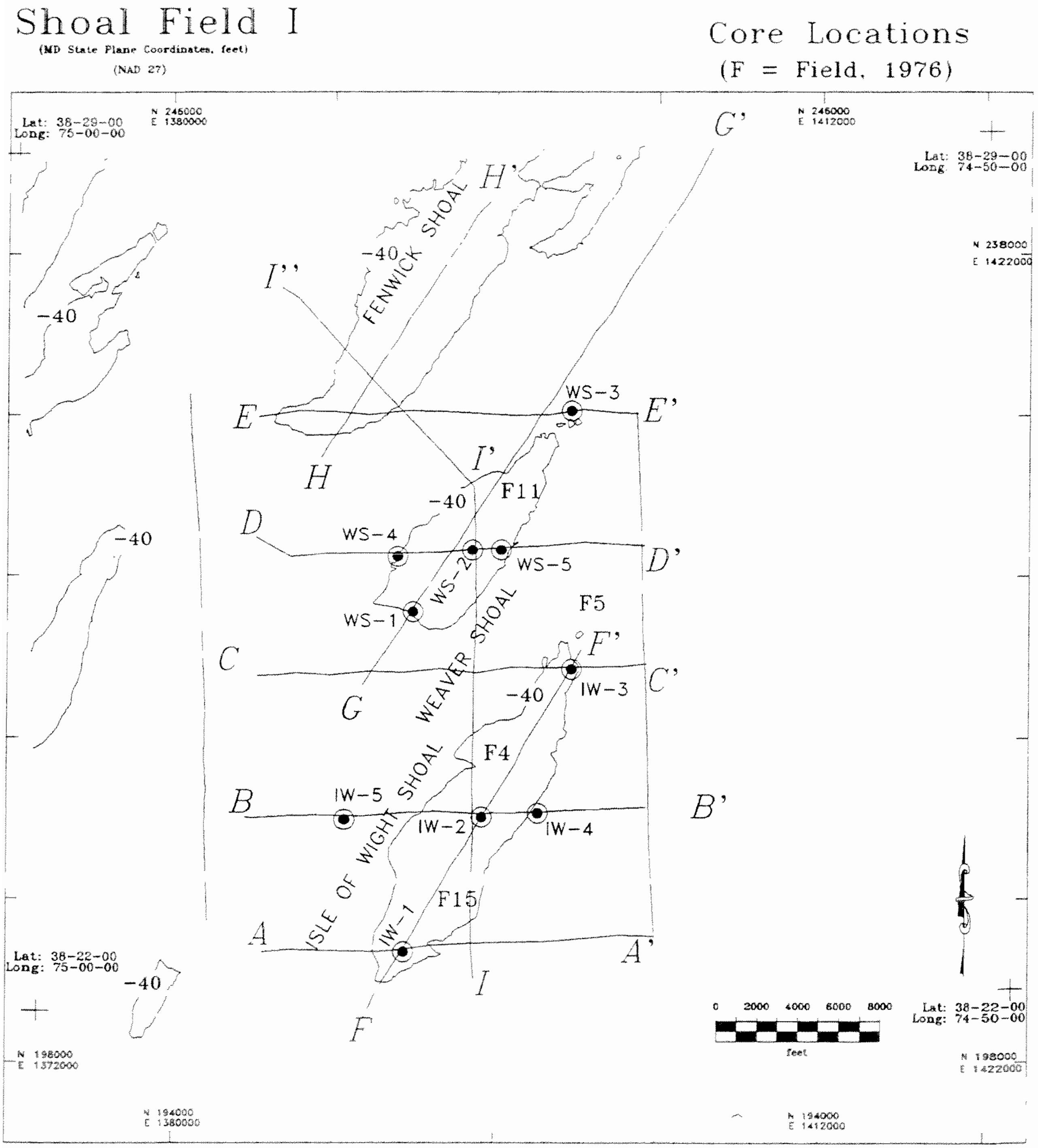


Figure 4


Shoal Field I
(MD State Plane Coordinates, feet)
(NAD 27)
Core Locations
(F = Field, 1976)
Lat: 38-29-00
Long: 75-00-00
N 246000
E 1380000
N 246000
E 1412000
Lat: 38-29-00
Long: 74-50-00
N 238000
E 1422000
Lat: 38-22-00
Long: 75-00-00
Lat: 38-22-00
Long: 74-50-00
N 198000
E 1372000
N 198000
E 1422000
N 194000
E 1380000
N 194000
E 1412000
0
2000
4000
6000
8000
feet
FENWICK SHOAL
WEAVER SHOAL
ISLE OF WIGHT SHOAL
-40
A
A'
B
B'
C
C'
D
D'
E
E'
F
F'
G
G'
H
H'
I
I'
I''
WS-1
WS-2
WS-3
WS-4
WS-5
IW-1
IW-2
IW-3
IW-4
IW-5
F4
F5
F11
F15

Core	Latitude[1]	Longitude[1]	Collection time[2] date	Water depth[3]	Top of core[3]	Penetration	Core length
WS-1	38°25.1811'	74°56.0132'	1154, 10/2/92	41.2'	39.4'	20'	18'11"
WS-2	38°25.6740'	74°55.3843'	1357, 10/2/92	34'	32.1'	14'	17'6"
WS-3	38°26.7994'	74°54.3306'	1635, 10/2/92	47'	46.5'	13'	17'5"
WS-4	38°25.6371'	74°56.1603'	1023, 10/2/92	44.5'	43.7'	20'	17'9"
WS-5	38°25.6714'	74°55.0844'	0938, 10/2/92	33'	32.9'	20'	14'10"
IW-1	38°22.4100'	74°56.1800'	0820, 11/17/92	41'	41.9'	10'	7'
IW-1 jet retry	38°22.4100'	74°56.1800'	0903, 11/17/92	41'	47.9'	8'	6'7"
IW-2	38°23.4931'	74°55.3439'	1620, 11/15/92	24'	24.9'	8'	0'
IW-3	38°24.6866'	74°54.3839'	1757, 10/2/92	41.5'	41.8'	16.5'	19'3"
IW-4	38°23.5137'	74°54.7627'	0629, 11/17/92	48'	49.4'	20'	19'8"
IW-5	38°23.4982'	74°56.7651'	1422, 11/6/92	73'	72.4'	20'	18'3"

[1] NAD 1983 [2] GMT [3] feet below NGVD

TABLE 1
Vibracore Locations and Parameters

Core Processing

Cores were further subdivided in the lab into 2½ foot sections and X-rayed. Xeroradiographs provide visual details of fine sedimentologic and biogenic structures that are otherwise not visible or destroyed during sampling procedures. The cores were X-rayed using a TORR-MED medical X-ray unit. Instrument settings varied depending on the composition of the cores. Settings generally ranged from 80 to 90 kV, at 5 mA, for 30 to 50 seconds. Latent X-ray images of the cores were developed using xeroradiographic procedures. Xeroradiography produces a crisper, more detailed radiography than conventional photographic techniques.

Core segments were then opened by cutting the Lexan liners along their length. An electro-osmotic knife (Strum and Matter, 1972) was used to split the sediment core lengthwise. This tool slices the sediment without smearing internal structures, thus providing a clear cross-section for photography. The cores were photographed and logged for sedimentary and biogenic structures, texture, color, approximate grain size and other features. Sediment, biologic, and age dating samples were removed for further analyses, and the remaining materials were sealed and archived for future work.

Textural Analysis

Sand, silt and clay contents were determined using the textural analysis detailed in Kerhin and others (1988). Sediment samples were first treated with 10% solution of hydrochloric acid to remove carbonate material such as shells and then treated with a 6 to 15% solution of hydrogen peroxide to remove organic material. The sediments were first passed through a 62-micron mesh sieve, then a 2-mm sieve, separating sands from mud and gravel fractions. Mud fractions were analyzed using a pipette technique to determine silt and clay contents. Weights of the sand, silt and clay fractions were converted to weight percentages. The sediments were categorized according to Shepard's (1954) classification based on percent sand, silt and clay components.

Sand fractions were analyzed using a rapid sediment analyzer (RSA) (Halka and others, 1980). Grain size analysis was conducted on the sand fraction only. Because the mud fraction was a minor component in shoal deposits, textural parameters for the entire distribution were not calculated. The RSA technique measured cumulative weight in ¼ ϕ (phi) intervals. Data were normalized to a 100% sand distribution, and the method of Folk and Ward (1957) was used to report graphic mean, sorting, skewness, and kurtosis.

Geochronology

Cores were sampled for biologic materials needed for age determinations. Both wood/peat material and calcareous shells were collected. Significant wood/peat was present in only one core. However, sufficient material for C^{14} could not be obtained. A variety of bivalves were recovered for amino acid dating.

Amino acid dating is increasingly accepted as a reliable method for age determination. Laboratory analyses were performed by the University of Delaware's Department of Geology, where the technique was developed by Wehmiller (1984, 1986). The method is based on the principle of amino acid racemization. Shell materials were identified and separated by species before analysis. Shell samples were analyzed for their D-alloisoleucine to L-isoleucine (A/I) ratio by high-pressure, liquid chromatography. These ratios are used to calculate numerical age assignments for each sample.

Digital analysis of Bathymetric and Subbottom Data

Seismic data were collected graphically on an analog strip chart recorder but were required in digital form. We developed a method of transferring the two- dimensional, graphic information into a three-dimensional, digital model. We used a Calcomp 9800, large format digitizer to enter the seismic data into *AutoCAD 12 DOS*. A program was developed for *AutoCAD* to calculate the three coordinates for each digitized point. Bathymetric and subbottom reflectors were digitized along each trackline to produce profiles of the bottom and subbottom.

We used a third party program, *Civil/Survey* (Softdesk) within the *AutoCAD* environment to generate surface models of the ocean floor and seismic reflectors. *Civil/Survey* uses triangular irregular networks, or TINs, to construct surface models. This is the most commonly employed method for constructing elevation models. TINs are generated by connecting elevation points with lines to form triangles. The network of inter-connected triangles forms an interpolated surface model. These models can be represented in several forms, including contour maps, cross-sections, and gridded and rendered models. Separate TINs are generated for bathymetric data and each digitized subottom horizon. The TIN surfaces derived from these data are then used to calculate a variety of parameters including area, volume, slope, intersecting surfaces and elevations. The initial bathymetric model based only on our 1992 seismic survey data, while generally accurate, was not detailed enough for volumetric analysis. Therefore, we obtained a digital bathymetric database of the Delmarva Atlantic shelf from the National Ocean Service. The bathymetric model generated from this database is accurate and highly detailed.

The surface models of subbottom reflectors are less detailed due to the limited amount of data points available from the digitized data. Because the shoals are usually acoustically opaque several feet below their surface, few data points for seismic reflectors under the shoals were obtained. The contours depicted under the shoals are extrapolated by the contouring program from data surrounding and under the thinner margins of the shoals. Seismic reflectors are subject to the phenomenon of 'pull-up'. This effect is seen as a change in depth of the reflector as it passes under a shoal. The density and thickness of shoal sediments change the two-way travel time of the acoustic signal and artificially warp the underlying seismic signatures. This causes anomalous contour highs or lows on reflector surfaces under ridges and swales. It is difficult to predict the net effect of this phenomenon on seismic reflectors. Although the pull-up effect causes inaccuracies in portions of the surface models, it is limited to a tolerance of several feet and has minimum influence on volumetric calculations. We assume that, while the contours under the shoals may not accurately reflect the surface geometry, they are a reasonable representation of the mean depth of these reflectors.

Volumetric determinations were carried out by *Civil/Survey*. This program offers several methods for volume determinations. The grid method is most appropriate for the type of data available. To determine shoal volumes, the upper and lower surfaces of the shoals, and their flanking boundaries must be defined. The upper surface is defined as the bathymetric surface, derived from the bathymetric TIN model. The lower surface is the surface upon which the shoal developed. The lower bounding surface is determined from seismic and core data which are in turn used to generate a TIN model of the subbottom reflectors. Shoal edges are defined by either pinch-out of shoal sediments, or a significant fining in flank sediment texture. Pinch-out was considered to occur where shoal sediments thin to one meter or less, which is the practical limit for dredging. These conditions were determined from seismic and core data. The volumetric program overlays grids on the upper and lower TINs, within the shoal boundaries. The three-dimensional coordinates for the corners, or nodes, of each grid cell on both surfaces are sampled. If any corner of any cell falls outside the boundary of either surface, the cell is discarded. The volume between each upper and lower cell is split vertically to produce two prisms. The volumes of both prism halves are summed to determine the cell volume. Cell volumes for the entire grid are summed to produce the total volume between the grids (Figure 5).

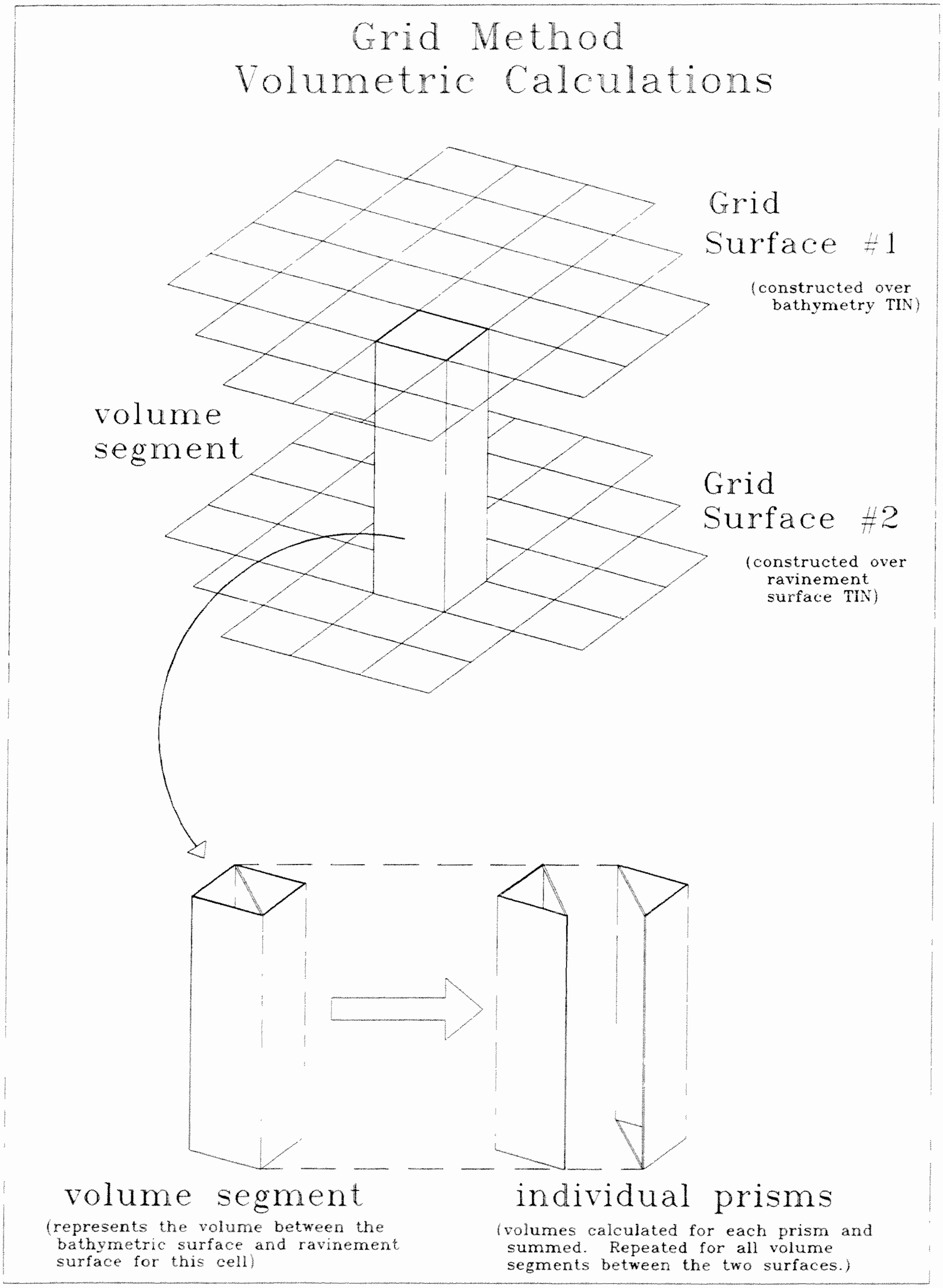
RESULTS

Shoal Field Structure

Shoal Field I encompasses the southern tip of Fenwick Shoal, Weaver Shoal and Isle of Wight Shoal. Depths range from a maximum of -20 ft. on the crest of Isle of Wight Shoal to a minimum of -75 ft. in a trough in the northeast corner of the field. The minimum depths for Fenwick and Weaver Shoals are -26 ft. and -25 ft., respectively. The mean depth of the shoal field is -53 ft. While each shoal possesses a unique shape, they all display the general morphologic characteristics associated with linear sand ridges:

elongated bodies with northeast axial trends;
an bathymetric high, or crest, proximal to the shore to the southwest;
depths increase to the northeast toward the shore distal end;
relief above surrounding terrain of tens of feet;
flank slopes between 0.2° and 7.0°;
seaward flanks steeper than landward flanks.

Figure 5


Grid Method
Volumetric Calculations
Grid
Surface #1
(constructed over bathymetry TIN)
volume
segment
Grid
Surface #2
(constructed over ravinement surface TIN)
volume segment
(represents the volume between the bathymetric surface and ravinement surface for this cell)
individual prisms
(volumes calculated for each prism and summed. Repeated for all volume segments between the two surfaces.)

The bathymetric map (Figure 3) shows the variations in form of these shoals. The proximal crest of Weaver Shoal is blunt and the distal portions display irregular topography. Isle of Wight Shoal has a more symmetrical appearance and a more elongated crest than Weaver Shoal. Fenwick Shoal has an arcuate crest that abruptly bends to the west at the proximal end. The seaward flank of Fenwick Shoal is the steepest slope in the shoal field. A summary of shoal geometry is presented in Table 2. Based on these parameters, these shoals fit the McBride/Moslow model for ebb tidal inlet shoal origins.

Seismic records reveal some of the shallow structure of Shoal Field I. The shoal bodies exhibit little internal structure. While this is in part due to the acoustic opacity of these sand bodies, it is also an indication of the massive, homogeneous structure characteristic of linear sand shoals.

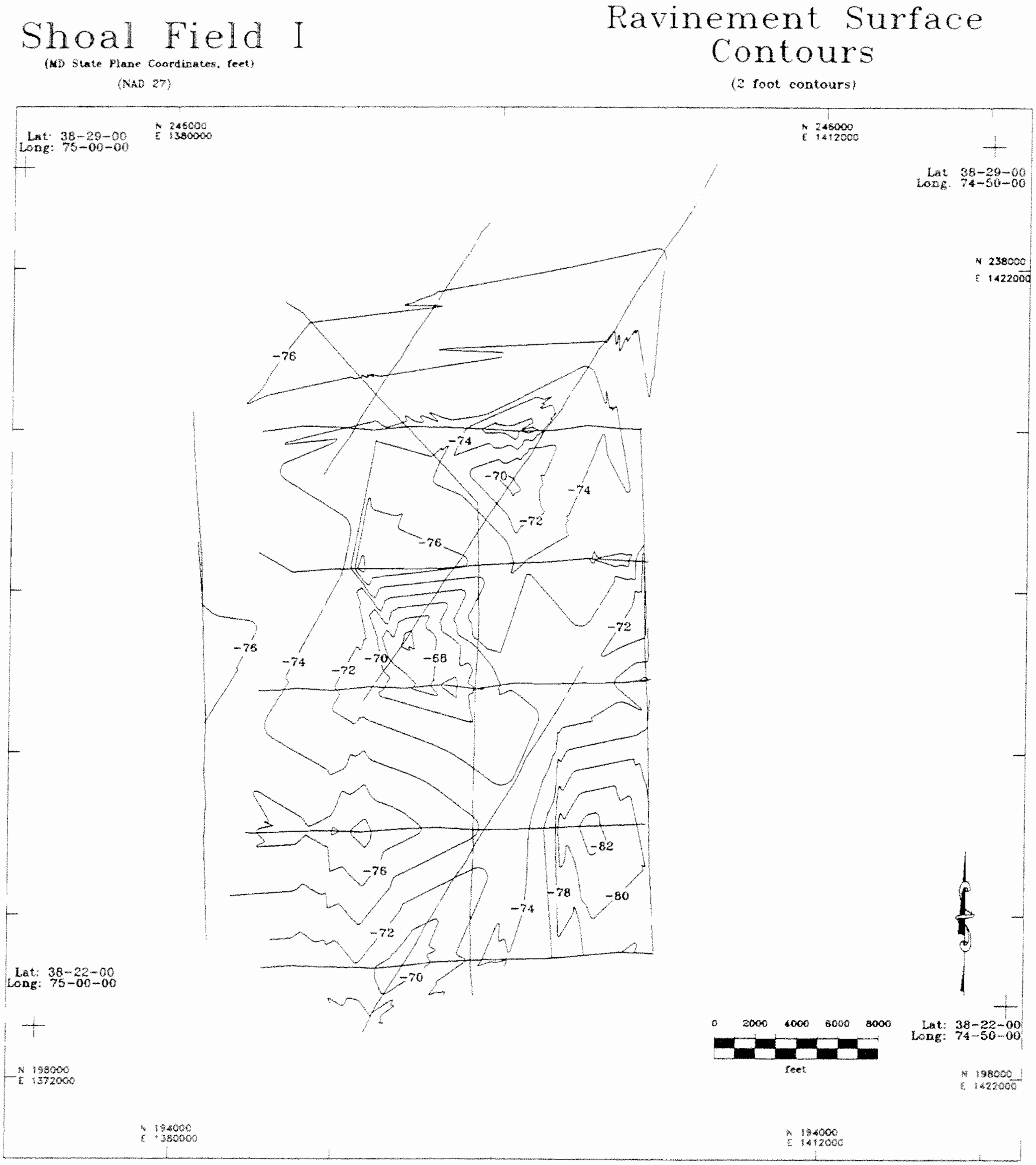
	Weaver Shoal	**Isle of Wight Shoal**
Parameter		
Area (miles^2)	2.9	4.3
Axis (° from north)	35	31
Length of base (ft)	16,000	20,000
Width (ft)	7,000	8,000
minimum depth (ft below NVGD)	-26	-20
depth of base (ft below [illegible]GD)	-60	-60

TABLE 2
Physical parameters of Weaver and Isle of Wight Shoals

Underlying the shoal field is a continuous, mappable reflector. This reflector has relatively flat relief, with a mean depth of -74 feet. A contour map of this surface (Figure 6) represented by the reflector shows irregular, low relief. The contours are based on a surface model derived from digitized seismic data. Two of Field's (1976) vibracores, 19 and 20, penetrated this reflector between -60 and -65 feet. Toscano and others (1989) described the reflector as evidence of a time-transgressive ravinement surface.

The ravinement surface developed as a result of erosional and depositional processes operating on the shoreface during the last Holocene transgression. As sea level rose, the base of the shoreface was eroded and the shoreface profile retreated landward and upward. The

Figure 6


Shoal Field I
(MD State Plane Coordinates, feet)
(NAD 27)
Ravinement Surface Contours
(2 foot contours)
Lat: 38-29-00
Long: 75-00-00
N 246000
E 1380000
N 246000
E 1412000
Lat: 38-29-00
Long: 74-50-00
N 238000
E 1422000
-76
-74
-70
-74
-72
-76
-72
-76
-74
-72
-70
-68
-76
-82
-78
-80
-74
-72
-70
Lat: 38-22-00
Long: 75-00-00
N 198000
E 1372000
0
2000
4000
6000
8000
feet
Lat: 38-22-00
Long: 74-50-00
N 198000
E 1422000
N 194000
E 1380000
N 194000
E 1412000

erosional surface created at the shoreface base followed the same retreat path. Shoreface sediments redeposited above the erosional surface were subsequently reworked by shelf processes into the modern sea floor. Thus the ravinement surface is both an erosional surface and a sediment transfer surface (Nummedal and Swift, 1987). Modern shelf sands that make up the sea floor, including the linear shoals, overlay the ravinement surface. The ravinement surface is not always apparent on seismic records due to several factors. Mixing of the bounding lithologies may occur during its formation (Toscano, *et al*, 1989) and prevent the appearance of an acoustically significant reflector. In some instances, the seismic signature is masked by the closeness of the ravinement surface to the ocean floor.

Shoal edges are usually observed in seismic records as a feathering out of shoal sediments over underlying units. However, shoal edges are not always this distinct, particularly where shoal sands have migrated over surrounding sediments. We have defined shoal edge boundaries for this study by the thickness of sediments, or abrupt changes in lithology. Additionally, we define the shoal edge where seismic records suggest shoal sediments abruptly become fine . These lithologies are not considered as potential beach fill material. As defined in these terms the shoals are outlined in Figure 7. Cross sections along the seismic track lines are shown in Figure 8. Vibracore locations and penetration depths are superimposed on the profiles.

Shoal Sediments

Weaver Shoal

Xeroradiographs and visual inspection of vibracores reveal a generally homogeneous structure within both shoals. Weaver Shoal cores show less internal structure than Isle of Wight Shoal cores. Core WS-1, from the south west flank, shows only very coarse, indistinct layering. Most shell material is randomly oriented. A single section, from -117 cm to -148 cm, shows a clam burrow - the only evidence of bioturbation within the core. WS-2, from the crest, displays almost no structure. Two layers, one from -211.5 cm to -220 cm and another from -375 cm to -385 cm, contain small, disarticulated clam valves in a horizontal orientation. All other shell material is randomly oriented. The vibracore stopped penetrating the subsurface at -438 cm and began pumping very coarse sand and shell material into the core barrel. WS-3, on the north east flank, has little discernible structure until -450 cm, where penetration stopped. Sixty cm of sediment was pumped into the core barrel and penetration resumed to -520 cm. The bottom section of the core, from -450 cm to -520 cm shows some fine bedding. WS-4, from the west flank, displays some bedding between -456 cm and -538 cm. WS-5 shows a section of alternating light and heavy mineral sands between -388 cm and -432 cm. While xeroradiographs showed bedding throughout the lower quarter of the core, visual inspection and grain size analyses did not reveal any structure other than the heavy mineral layering.

Figure 7

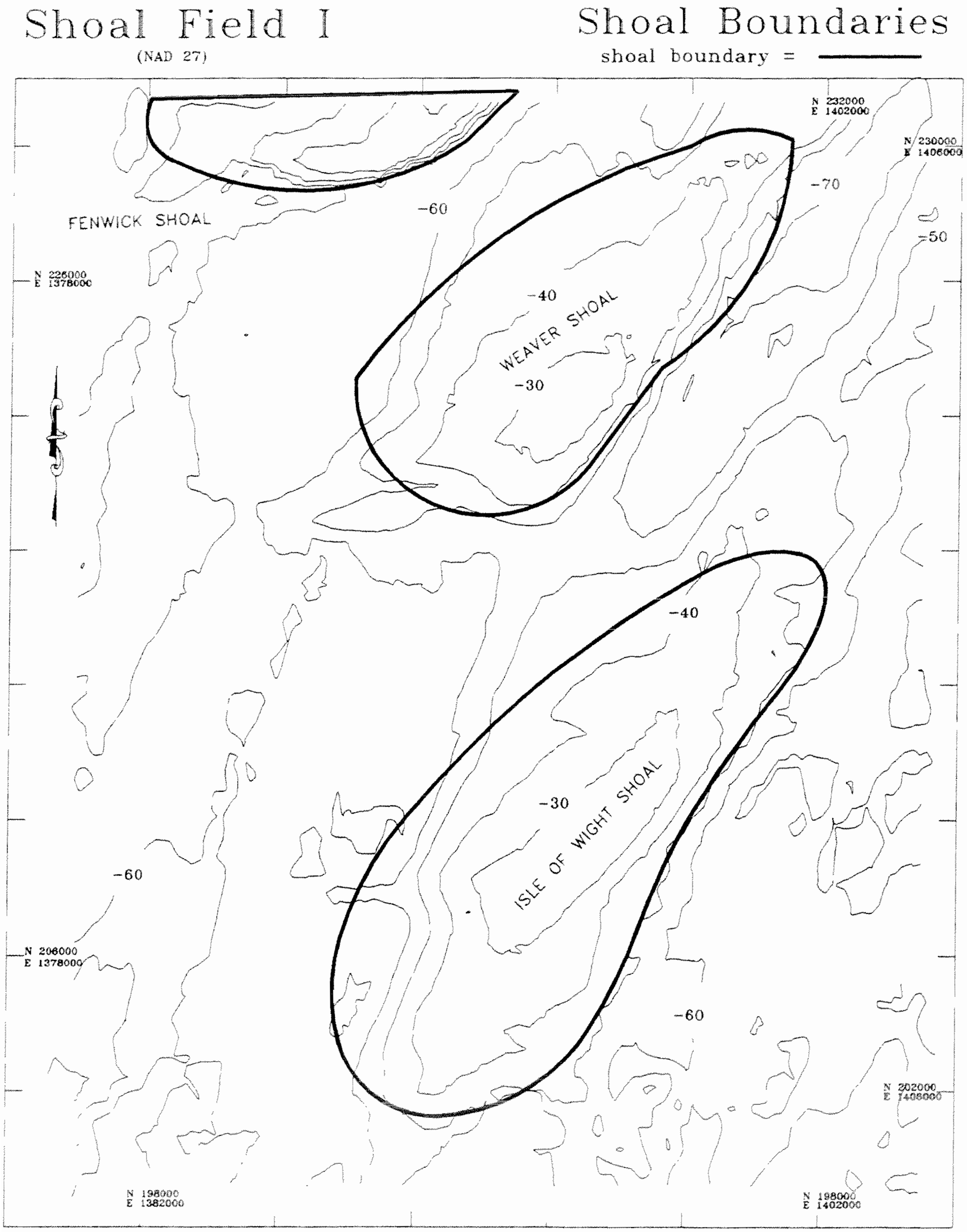
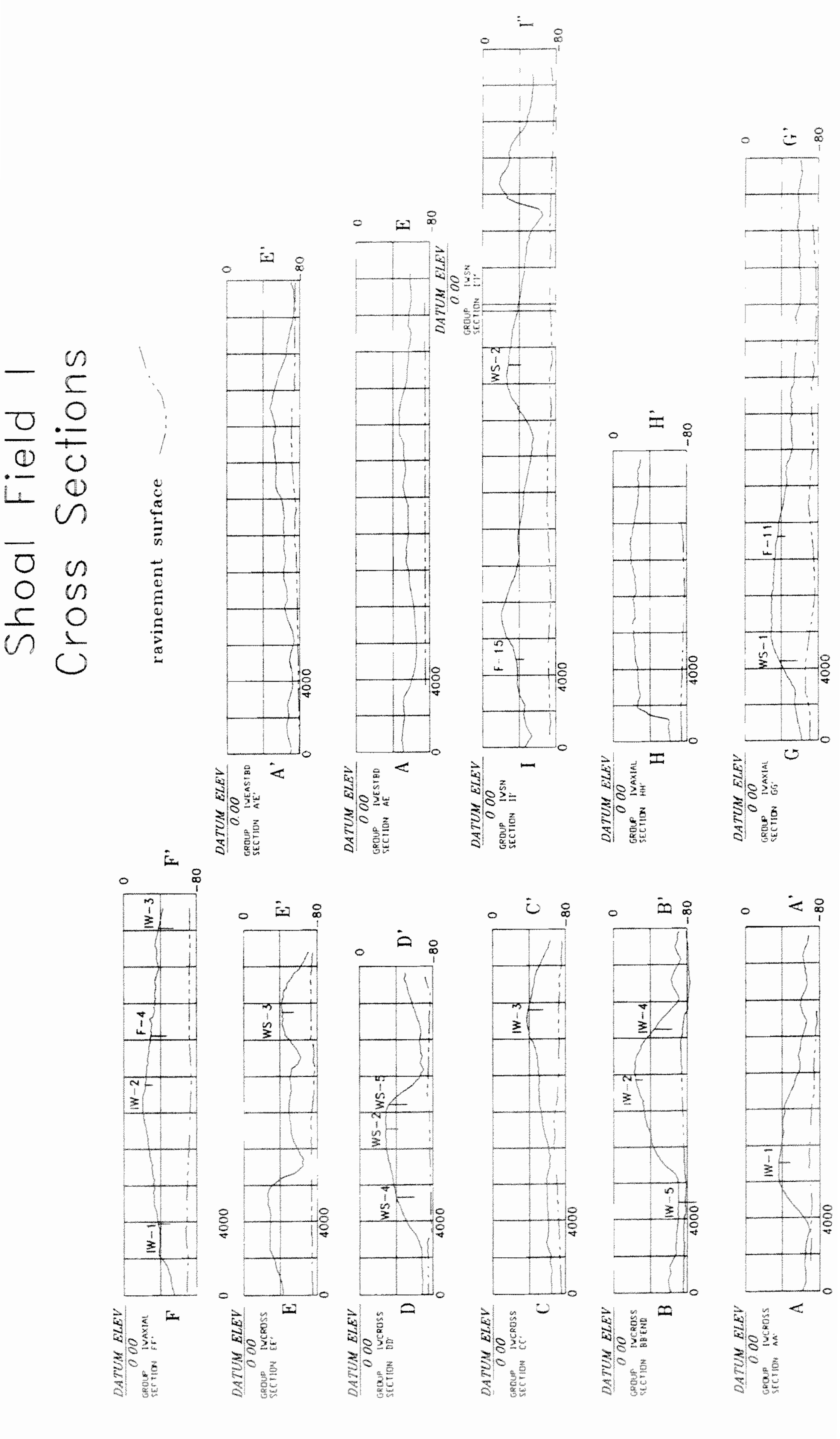

Shoal Field I
(NAD 27)
Shoal Boundaries
shoal boundary =
N 232000
E 1402000
N 230000
E 1406000
-70
-60
-50
FENWICK SHOAL
N 226000
E 1378000
-40
WEAVER SHOAL
-30
-40
-30
ISLE OF WIGHT SHOAL
-60
N 206000
E 1378000
-60
N 202000
E 1406000
N 198000
E 1382000
N 198000
E 1402000

Figure 8


Shoal Field I
Cross Sections
ravinement surface
DATUM ELEV 0.00 GROUP IWEASTBD SECTION AE'
A' E'
DATUM ELEV 0.00 GROUP IWESTBD SECTION AE
A E
DATUM ELEV 0.00 GROUP IWSN SECTION II'
I I'
F-15
WS-2
DATUM ELEV 0.00 GROUP IWAXIAL SECTION HH'
H H'
DATUM ELEV 0.00 GROUP IWAXIAL SECTION GG'
G G'
WS-1
F-11
DATUM ELEV 0.00 GROUP IWAXIAL SECTION FF'
F F'
IW-1
IW-2
F-4
IW-3
DATUM ELEV 0.00 GROUP IWCROSS SECTION EE'
E E'
WS-3
DATUM ELEV 0.00 GROUP IWCROSS SECTION DD'
D D'
WS-4
WS-2
WS-5
DATUM ELEV 0.00 GROUP IWCROSS SECTION CC'
C C'
IW-3
DATUM ELEV 0.00 GROUP IWCROSS SECTION BBEND
B B'
IW-5
IW-2
IW-4
DATUM ELEV 0.00 GROUP IWCROSS SECTION AA'
A A'
IW-1
0
4000
-80

Isle of Wight Shoal

Isle of Wight Shoal vibracores show more internal structure than Weaver Shoal cores. Core IW-1, from the south west flank, contains layers of horizontally oriented shell, several thin layers of heavy minerals, and alternating layers of coarse and fine material. Penetration stopped at -268 cm when a 17 cm thick layer of shells was encountered. Coring was resumed at this station with a jet retry, and continued to -380 cm. The abundance of shell material and medium-sized sand conspired to make vibracore penetration difficult at this station. At station IW-2, on the shoal crest, the vibracorer penetrated 244 cm into the bottom before first refusal. Due to severe weather, the core was lost during retrieval. We decided not to attempt further coring at this station due to poor sampling conditions and limited penetration. Fields collected a 9-foot core nearby, and we will use data from this core. IW-3, on the north east flank, is generally featureless, other than abundant, randomly oriented shell material, until -430 cm. A 2-cm thick muddy layer overlies a 5-cm thick layer of shell hash, small shell fragments, oyster shells and woody material in a fine sand matrix. Fine to medium sand continues down-hole until -549 cm, where the core ends in coarse sand, gravel and shell fragments. IW-4, obtained on the east flank, is topped with a 7 cm layer of 4 cm diameter gravel. The gravel overlays homogeneous sands that to -254 cm, where some bedding and cross-bedding become visible. Bedding ends at -374 cm, and only a few shelly layers are seen. The core bottoms out with a layer of fine sand interlayered with muds between -590 cm and -600 cm.

IW-5 is the only core to penetrate the ravinement surface. This core was taken to the west of the western flank. The top 130-cm of core contained fine, silty sand, mud, shell fragments, and some wood. This sequence abruptly ends with a layer of coarse gravel over peat. The transitional layer from basal gravel to peats and mud is interpreted to be the ravinement surface. The rest of the core contains alternating layers of mostly fine sands, silty sands and muds, with a few small wood fragments. Bedding is particularly evident from -460 cm to -540 cm. IW-5 is the only core collected for this study with significant organic content, and with almost no shell material.

The grain size analyses of cores collected on Weaver and Isle of Wight Shoals are presented in Appendix 1. Isle of Wight Shoal sediments are generally finer than Weaver Shoal material. Both shoals are essentially sand bodies and display similar grain size distribution patterns:

1) coarser, well-sorted materials are located in the crest regions;
2) finer, moderately sorted materials are found on the flanks;
3) surface sands tend to be coarser on the western flanks;
4) sediments tend to become finer and less well-sorted down-core.
5) flank sediments display greatest variation in grain size and sorting.

Isle of Wight Shoal sediments range from gravel to clay. Mean grain sizes for sampled intervals vary from 1.33 ϕ to 3.25 ϕ. Weaver Shoal sediments range from gravel to sand, with mean grain sizes for sampled intervals varying from 0.58 ϕ to 1.83 ϕ. Mean grain size and sorting versus depth for these shoals are depicted in Figures 9 to 13.

Amino Acid Dating

Twenty-three shell samples were collected from vibracores for amino acid dating. Results of the analysis are presented in Appendix 2.

SAND RESOURCE POTENTIAL OF SHOAL FIELD I

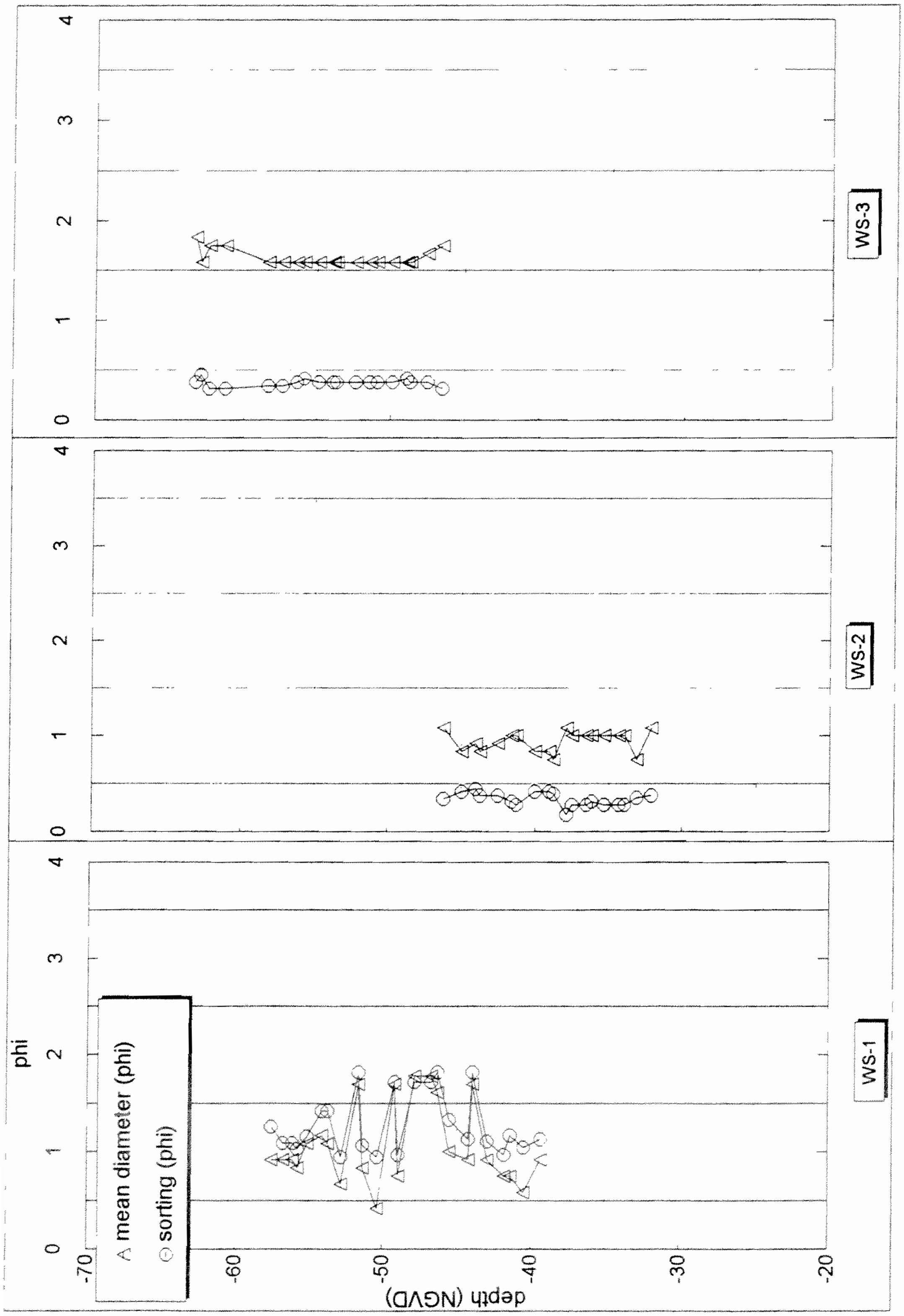
Criteria for estimating potential

Several factors were considered in determining the utility of a particular deposit for use as beach fill, including engineering, economic, and geologic elements. The U.S. Army Corps of Engineers and Maryland Department of Natural Resources have previously concluded that offshore deposits are the most desirable from economic and engineering standpoints (U.S. Army Corps of Engineers, 1980). Additionally, sand deposits within a 15-mile radius from the point of use are most desirable. Water depths of less than 50 feet are also advantageous for dredging technologies. This study has focused on the geologic factors deciding the value of particular deposits as potential sand sources.

Previous work on offshore sand resources in Maryland suggests that the most likely sites for suitable beach fill material will be found in linear, shore-detached sand ridges (Wells, 1994; Toscano and Kerhin, 1989). Both Isle of Wight and Weaver Shoals conform to the McBride/Moslow model for ebb-tidal shoal classification.

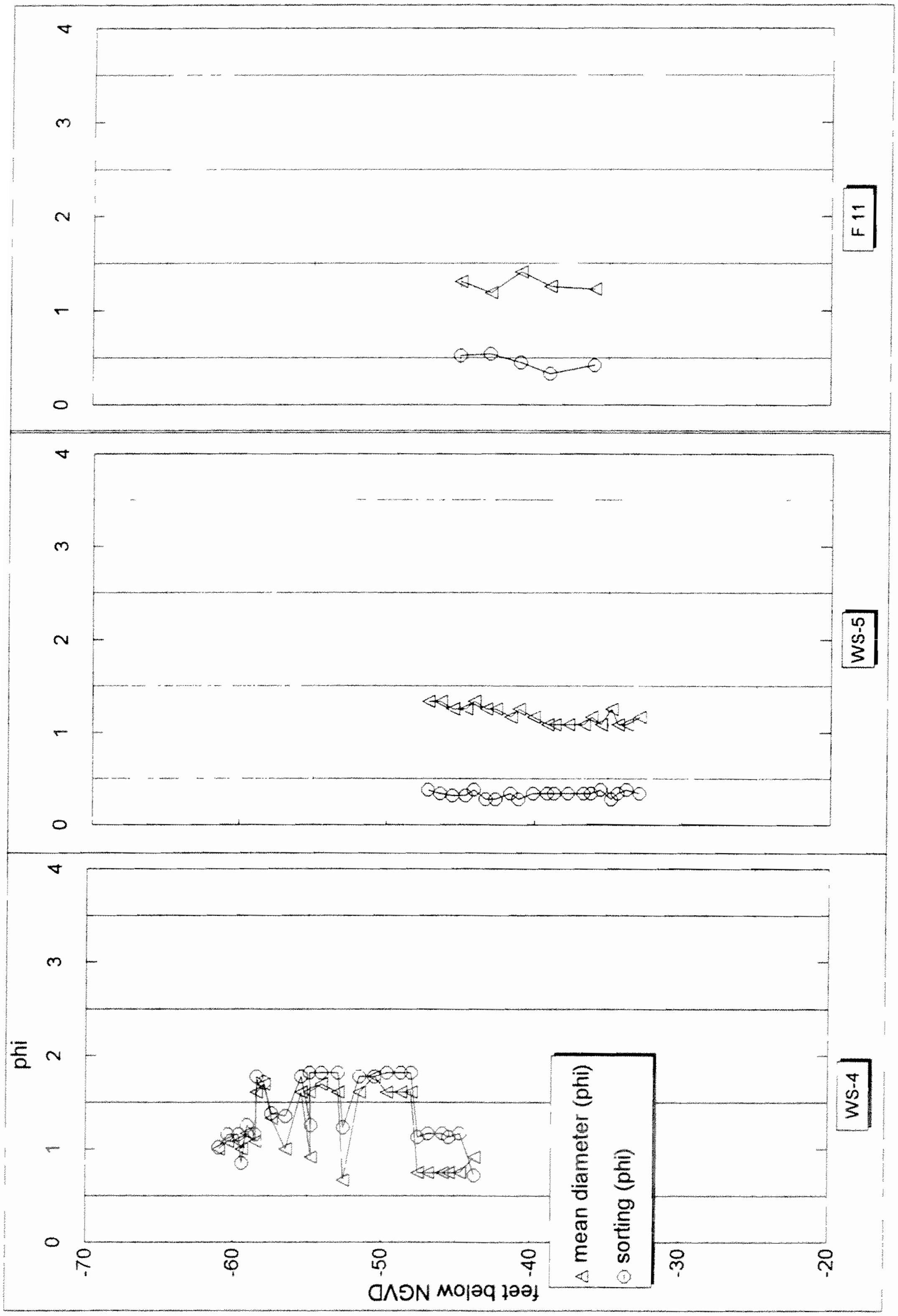
Potential beach fill material should exhibit textural parameters similar to the native sands they are intended to replenish. The Shore Protection Manual (U.S. Army Corps, 1984) describes methodologies to determine acceptable textural parameters for beach fill for any particular site. An important consideration is the overfill factor. The overfill factor is derived from the comparison of textural properties, such as composite graphic mean (Folk and Ward, 1957) and sorting of the potential borrow sediments to those of the native beach sand, using an overfill criteria developed by James (1975). The overfill factor considers the portion of borrow material expected to remain on the beach after equilibrium is achieved. High overfill factors indicate the borrow material will be unstable on the native beach. Thus, a larger volume of borrow material with a high overfill factor must be placed on the beach to maintain stability. Native Ocean City beach sands have a composite graphic mean of 1.84 ϕ and a sorting of 1.22 ϕ (Anders and others, 1987; Anders and Hansen, 1990).

Figure 9



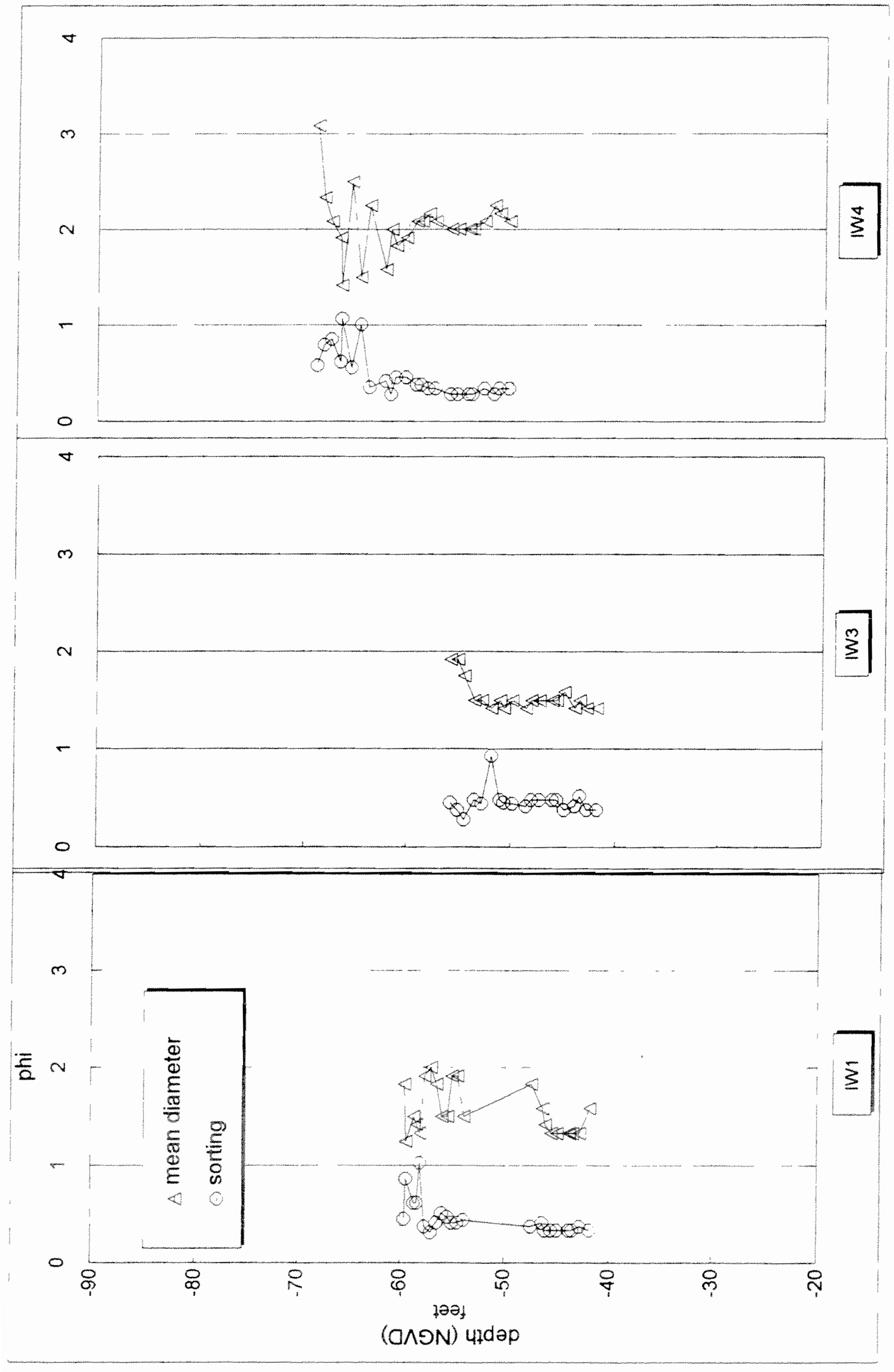
Mean Diameter and Sorting vs. Depth

Figure 10



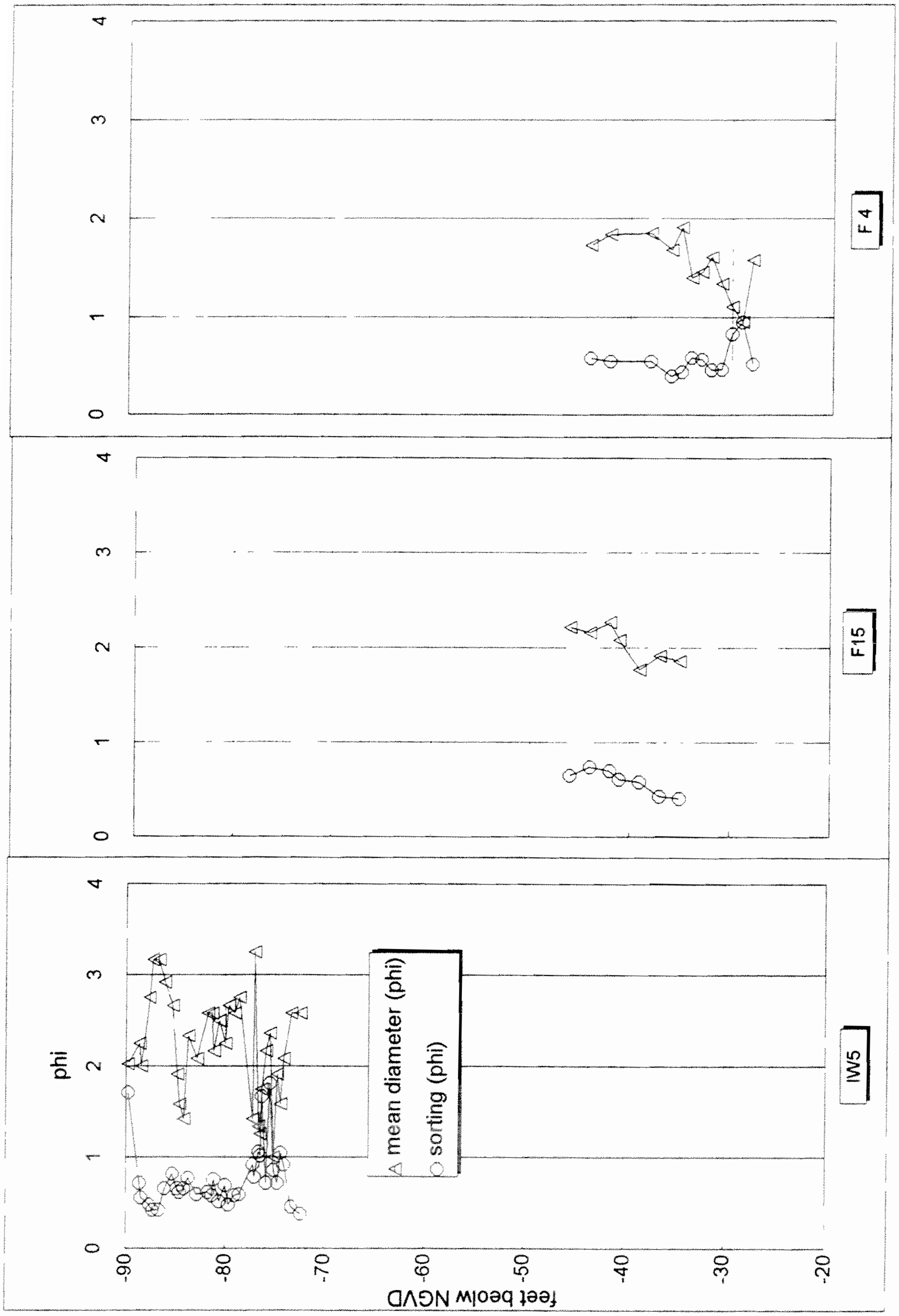
Mean Diameter and Sorting vs. Depth

Figure 11



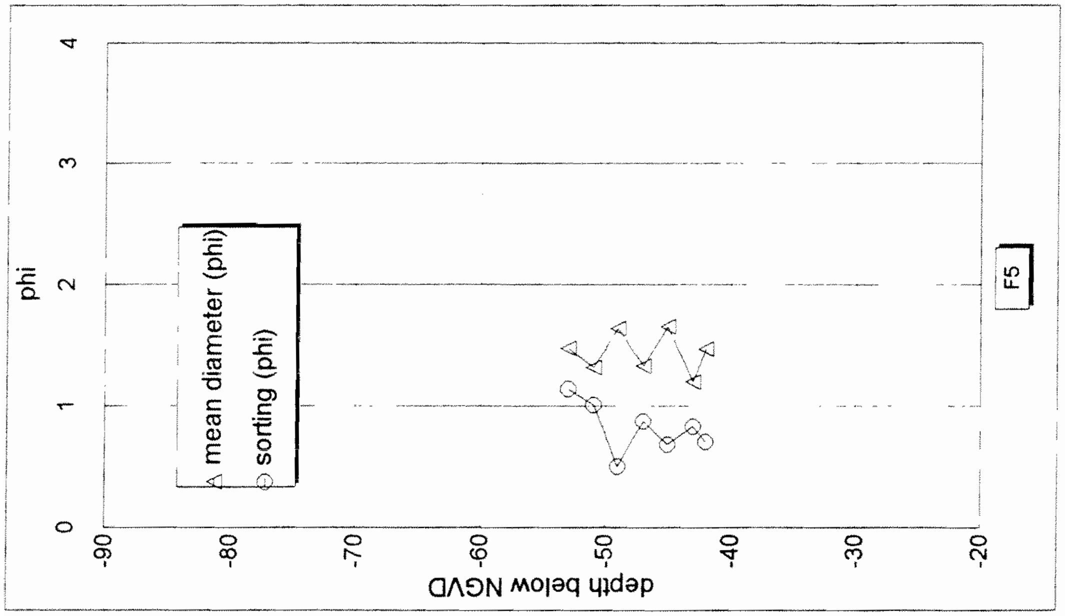
Mean Diameter and Sorting vs. Depth

Figure 12



Mean Diameter and Sorting vs. Depth

Figure 13



Mean Diameter and Sorting vs. Depth

Therefore, sand most suitable for beach fill should have a mean grain size coarser than 1.84 ϕ and have a sorting value less than 1.22 ϕ.

Sediment quality

Of the two shoals examined, Weaver Shoal has the coarsest sediment. No samples taken from Weaver Shoal had mean grain diameters finer than 1.84 ϕ. The majority of samples had sortings of less than 1.22 ϕ, which places the sands in sorting classes from poorly to very well sorted (Folk 1954). A few samples from WS-4 were poorly to very poorly sorted. However, these samples contained between 13% to 36% gravel rather than fines. The grain size and sorting parameters of Weaver Shoal sands meet or exceed those required for beach fill.

All samples obtained from the main body of Isle of Wight Shoal show sortings less than 1.1 ϕ, placing them in the moderately to very well sorted classes. Bulk grain sizes for these cores are less than 1.84 ϕ near the crest, but become finer toward the flanks. IW-5, which was taken off-shoal, is not characteristic of shoal sediments, and typifies material found between the shoals. Sands in the central region surrounding the shoal crest are well suited for beach fill. The flanks of Isle of Wight shoal have a lower potential for sand resources because the sands tend to become finer away from the crest.

Sediment volumes

The volume of sediment contained within the body of Weaver Shoal is about 92.7 million cubic yards. Based on our seismic data and vibracores, most of this volume is likely to be suitable beach fill material. Core data suggests some mixing of finer sediments down core on the flanks. This is often a characteristic of ebb-tidal linear shoals. No samples were obtained from the shoal deeper than -63 feet, 9 feet above the projected base. If we exclude the lower 9 feet of Weaver Shoal from our volume calculations, the potential quantity of sand available becomes 46.3 million cubic yards.

Isle of Wight Shoal contains about 136.4 million cubic yards of sediment. Not all of this material may be suitable for beach nourishment, based on our data. The region surrounding the crest has the highest potential for containing acceptable sand. In addition, there is a tendency toward mixing of finer sediments downward within this shoal. Our data suggest that the lower 12 feet of the shoal may be too fine for beach fill. Excluding the lower 12 feet of Isle of Wight shoal from volume calculations leaves us with 34.8 million cubic yards. If we further limit our volume to the center of the shoal, near the crest, we estimate 28.1 million cubic yards of potentially useful material.

SHOAL	REGION	VOLUME (million yds^3)
Weaver Shoal	total	92.7
	total (excluding lower 9 feet)	46.3
	high potential	82.8
	high potential (excluding lower 9 feet)	43.9
	moderate potential	9.9
	moderate potential (excluding lower 9 feet)	2.4
Isle Of Wight Shoal	total	136.4
	total (excluding lower 12 feet)	34.8
	high potential	71.2
	high potential (excluding lower 12 feet)	28.1
	moderate potential	65.2
	moderate potential (excluding lower 12 feet)	6.7
All shoals	**total high potential**	**154**
	total moderate potential	**75.1**
	total	**229.1**

Table 3
Sediment Volumes Within Shoal Field I

Resource Potential

A summary of resource potentials is presented as a map in Figure 14. This map shows the distribution of potential beach fill material within Shoal Field II. Areas of high potential contain sands

1) estimated to have mean grain sizes and sortings acceptable as beach fill;
2) in depths less than -50 ft ;
3) in deposits thicker than 1 meter.

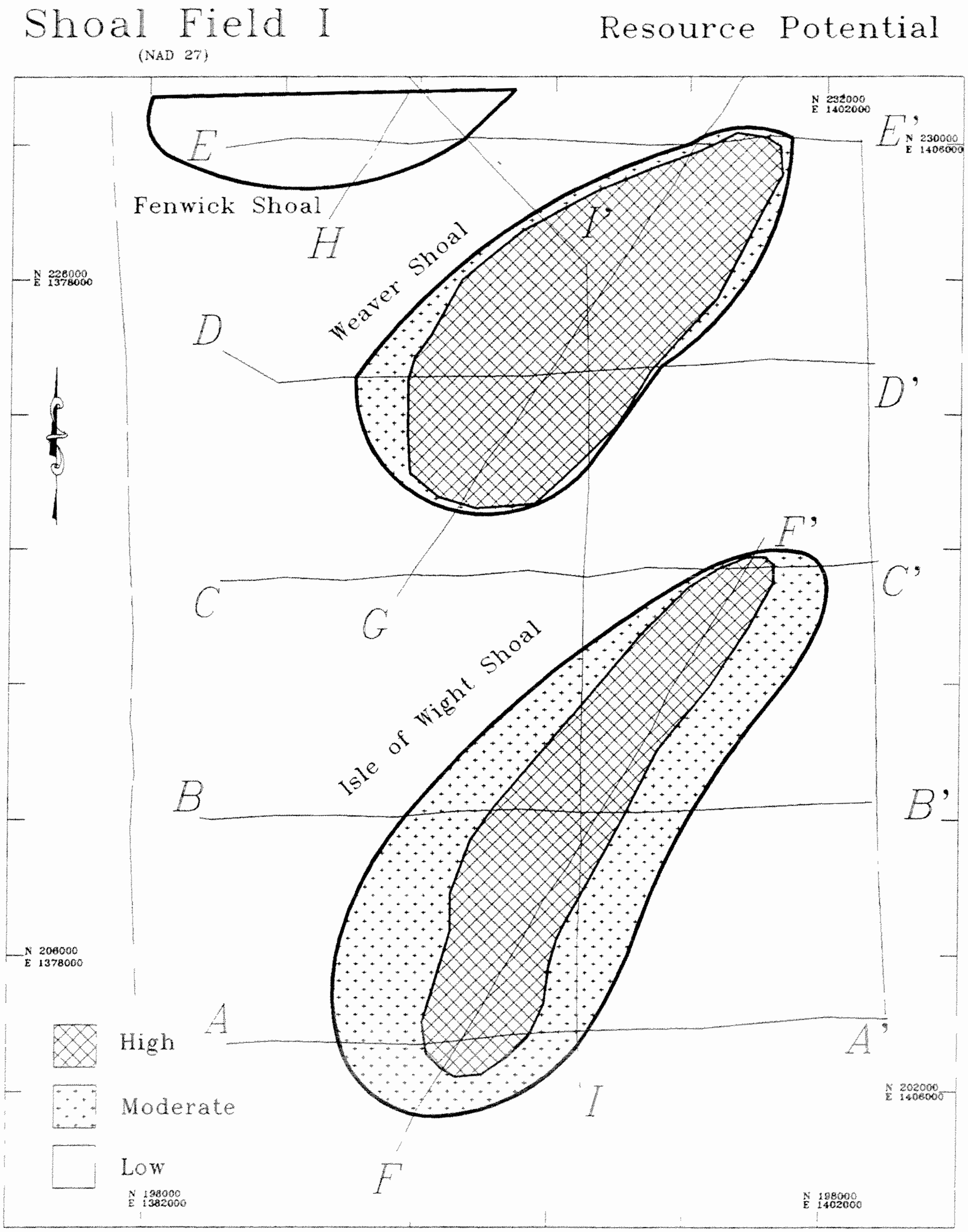
Areas of moderate potential contain sands

1) suspected to have mixed or marginal grain size parameters
2) in depth about -50 ft or less
3) in deposits thicker than 1 meter.

Areas of low potential are regions with fine sediment below -50 ft.

The map displays regions that are most likely to contain usable sand resources. A detailed sampling program which includes vibracoring capable of penetrating the shoals to at least -50 ft would be required to confirm these potentials.

Figure 14


Shoal Field I
(NAD 27)
Resource Potential
Fenwick Shoal
Weaver Shoal
Isle of Wight Shoal
E
E'
H
I'
D
D'
F'
C
C'
G
B
B'
A
A'
I
F
N 232000 E 1402000
N 230000 E 1406000
N 226000 E 1378000
N 206000 E 1378000
N 202000 E 1406000
N 198000 E 1382000
N 198000 E 1402000
High
Moderate
Low

CONCLUSION

Shoal Field I encompasses two shoals with a high potential for sand resources. Weaver Shoal has the highest potential for sand resources based on volume and quality of material. Isle of Wight also contains potentially useful sand deposits, but displays a more mixed textural environment, which limits the area and depth of potential resources. Both shoals are located within economical distances and depths for beach restoration. Extensive coring that penetrates the shoal bases will be required to fully determine the extent of useful deposits in the linear ridges of Shoal Field I.

The ocean floor between these two shoals has limited potential for sand resources. Relatively thin layers of fine sediment overlaying early and pre-Holocene sediments dominate the inter-shoal areas within Shoal Field I. These qualities and water depths of greater than 50 feet make non-shoal deposits less important as potential sand sources.

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Appendix 1

Grain Size Analyses and Sample Depths

Sample ID	Top interval (cm)	Bottom interval	Sample depth	% Gravel	% Sand	%Silt	% Clay	% Mud	Shepard's Classification	Graphic mean	Sorting	Skewness	Kurtosis	Median
ISLE OF WIGHT SHOAL														
IW-1C 0-4	0	4	-41.9	0.1%	99.0%	0.0%	0.0%	0.0%	SAND	1.58	0.34	0.09	0.20	1.50
IW-1C 30-34	30	34	-42.9	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.33	0.38	0.25	0.13	1.25
IW-1C 50-54	50	54	-43.5	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.33	0.34	0.34	0.10	1.25
IW-1B 60-64	60	64	-43.9	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.33	0.34	0.34	0.10	1.25
IW-1B 94-98	94	98	-45.0	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.33	0.34	0.34	0.10	1.25
IW-1B 112-116	112	116	-45.6	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.33	0.34	0.34	0.10	1.25
IW-1B 128-132	128	132	-46.1	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.42	0.34	-0.09	0.20	1.50
IW-1B 136-140	136	140	-46.4	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.58	0.41	0.09	0.31	1.50
IW-1B 170-174	170	174	-47.5	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.83	0.38	0.25	0.26	1.75
IW-1RB 183-187	183	187	-53.9	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.50	0.44	0.16	0.26	1.50
IW-1RB 202-206	202	206	-54.5	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.92	0.41	-0.47	0.46	2.00
IW-1RB 218-222	218	222	-55.1	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.92	0.41	-0.47	0.31	2.00
IW-1RB 230-234	230	234	-55.4	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.50	0.48	0.00	0.46	1.50
IW-1RB 246-250	246	250	-56.0	0.7%	99.3%	0.0%	0.0%	0.0%	SAND	1.50	0.52	-0.22	0.54	1.50
IW-1RB 262-266	262	266	-56.5	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.83	0.41	0.09	0.46	1.75
IW-1RA 277.5-281.5	277.5	281.5	-57.0	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	2.00	0.31	-0.16	0.26	2.00
IW-1RA 296-300	296	300	-57.6	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.92	0.38	-0.25	0.26	2.00
IW-1RA 310-314	310	314	-58.1	6.0%	94.0%	0.0%	0.0%	0.0%	SAND	1.33	1.03	2.50	2.22	1.50
IW-1RA 320-324	320	324	-58.4	0.8%	99.2%	0.0%	0.0%	0.0%	SAND	1.42	0.62	-0.66	0.82	1.50
IW-1RA 330-334	330	334	-58.7	0.4%	99.6%	0.0%	0.0%	0.0%	SAND	1.50	0.62	-1.47	0.61	1.75
IW-1RA 353-357	353	357	-59.5	4.6%	95.4%	0.0%	0.0%	0.0%	SAND	1.25	0.87	1.22	1.33	1.25
IW-1RA 357-361	357	361	-59.6	1.1%	98.9%	0.0%	0.0%	0.0%	SAND	1.83	0.45	-0.13	0.36	1.75
IW-1RA 374-378	374	378	-60.2	1.6%	98.4%	0.0%	0.0%	0.0%	SAND	1.50	0.52	-0.22	0.36	1.50
BULK										*1.57*				
IW-3D 0-4	0	4	-41.8	0.9%	99.1%	0.0%	0.0%	0.0%	SAND	1.42	0.38	-0.25	0.26	1.50
IW-3D 30-34	30	34	-42.8	0.3%	99.7%	0.0%	0.0%	0.0%	SAND	1.42	0.38	-0.25	0.26	1.50
IW-3D 50-54	50	54	-43.4	1.4%	98.6%	0.0%	0.0%	0.0%	SAND	1.50	0.52	-0.22	0.36	1.50
IW-3D 64.5-68.5	64.5	68.5	-43.9	0.8%	99.2%	0.0%	0.0%	0.0%	SAND	1.42	0.41	-0.09	0.31	1.50
IW-3D 94-98	94	98	-44.9	2.5%	97.5%	0.0%	0.0%	0.0%	SAND	1.58	0.38	0.25	0.26	1.50
IW-3D 116-120	116	120	-45.6	0.8%	99.2%	0.0%	0.0%	0.0%	SAND	1.50	0.48	0.00	0.31	1.50
IW-3C 129-133	129	133	-46.0	0.7%	99.3%	0.0%	0.0%	0.0%	SAND	1.50	0.48	0.00	0.31	1.50
IW-3C 165-169	165	169	-47.2	0.4%	99.6%	0.0%	0.0%	0.0%	SAND	1.50	0.48	-0.38	0.31	1.50

Appendix 1

Sample ID	Top interval (cm)	Bottom interval	Sample depth	% Gravel	% Sand	%Silt	% Clay	% Mud	Shepard's Classification	Graphic mean	Sorting	Skewness	Kurtosis	Median
IW-3C 129-133	129	133	-46.0	0.7%	99.3%	0.0%	0.0%	0.0%	SAND	1.50	0.48	0.00	0.31	1.50
IW-3C 165-169	165	169	-47.2	0.4%	99.6%	0.0%	0.0%	0.0%	SAND	1.50	0.48	-0.38	0.31	1.50
IW-3C 190-194	190	194	-48.0	1.1%	98.9%	0.0%	0.0%	0.0%	SAND	1.50	0.48	0.00	0.31	1.50
IW-3C 205.5-209.5	205.5	209.5	-48.5	1.9%	98.9%	0.0%	0.0%	0.0%	SAND	1.42	0.41	-0.09	0.31	1.50
IW-3C 245-249	245	249	-49.8	0.7%	99.3%	0.0%	0.0%	0.0%	SAND	1.50	0.44	0.16	0.26	1.50
IW-3C 270-274	270	274	-50.7	0.7%	99.3%	0.0%	0.0%	0.0%	SAND	1.42	0.45	-0.31	0.36	1.50
IW-3B 282-286	282	286	-51.0	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.50	0.48	0.00	0.31	1.50
IW-3B 306-310	306	310	-51.8	6.8%	93.2%	0.0%	0.0%	0.0%	SAND	1.42	0.93	3.07	1.25	1.50
IW-3B 335-339	335	339	-52.8	0.3%	99.7%	0.0%	0.0%	0.0%	SAND	1.50	0.44	0.16	0.26	1.50
IW-3B 357-361	357	361	-53.5	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.50	0.48	0.00	0.31	1.50
IW-3B 387-391	387	391	-54.5	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.75	0.28	0.00	0.20	1.75
IW-3B 405-409	405	409	-55.1	0.0%	98.2%	0.9%	0.9%	1.8%	SAND	1.92	0.38	-0.25	0.13	2.00
IW-3B 426 CLAY LAYER	426	426	-55.8	0.0%	68.0%	18.2%	13.8%	32.0%	SILTY SAND	1.92	0.45	0.13	0.36	2.00
IW-3A 428-432	428	432	-55.8	0.1%	99.3%	0.4%	0.1%	0.5%	SAND	1.83	0.41	0.09	0.31	1.75
IW-3A 432-436	432	436	-56.0	0.0%	94.2%	4.2%	1.6%	5.8%	SAND	2.25	0.47	1.41	0.46	2.25
IW-3A 470-474	470	474	-57.2	0.0%	99.5%	49.4%	0.0%	4.9%	SAND	1.91	0.34	-0.09	0.10	2.00
IW-3A 509-513	509	513	-58.5	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.67	0.34	-0.09	0.20	1.75
IW-3A 510.5-515	510.5	515	-58.5	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.67	0.38	-0.25	0.26	1.75
IW-3A 535-537	535	537	-59.3	0.1%	99.3%	0.6%	0.0%	0.6%	SAND	1.67	0.34	-0.09	0.20	1.75
IW-3A 557-561	557	561	-60.1	23.0%	77.0%	1.7%	0.0%	0.0%	SAND	1.86	1.81	7.17	3.96	1.25
BULK										*1.62*				
IW-4D 30-34	30	34	-50.4	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	2.08	0.34	0.09	0.10	2.00
IW-4D 58-62	58	62	-51.3	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	2.17	0.34	-0.34	0.10	2.25
IW-4D 72.5-76.5	72.5	76.5	-51.8	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	2.25	0.28	-0.25	0.10	2.25
IW-4D 102-106	102	106	-52.7	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	2.08	0.34	0.09	0.10	2.00
IW-4D 136-140	136	140	-53.9	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	2.00	0.28	0.00	0.20	2.00
IW-4C 146-150	146	150	-54.2	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	2.00	0.28	0.00	0.10	2.00
IW-4C 178-182	178	182	-55.2	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	2.00	0.28	0.00	0.20	2.00
IW-4C 198-202	198	202	-55.9	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	2.00	0.28	0.00	0.10	2.00
IW-4C 244-248	244	248	-57.4	0.9%	99.1%	0.0%	0.0%	0.0%	SAND	2.08	0.34	0.09	0.10	2.00
IW-4C 264-268	264	268	-58.1	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	2.17	0.34	-0.34	0.10	2.25
IW-4C 284-288	284	288	-58.7	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	2.08	0.38	-0.06	0.13	2.00
IW-4B 298-302	298	302	-59.2	0.5%	99.2%	0.3%	0.0%	0.0%	SAND	2.08	0.38	-0.06	0.26	2.00

Grain Size Analyses

Appendix 1

Sample ID	Top interval (cm)	Bottom interval	Sample depth	% Gravel	% Sand	%Silt	% Clay	% Mud	Shepard's Classification	Graphic mean	Sorting	Skewness	Kurtosis	Median
IW-4B 330-334	330	334	-60.2	0.3%	99.2%	0.5%	0.0%	0.5%	SAND	1.92	0.45	-0.75	0.36	2.00
IW-4B 360-364	360	364	-61.2	2.0%	98.0%	0.0%	0.0%	0.0%	SAND	1.83	0.45	-0.13	0.54	1.75
IW-4B 374-378	374	378	-61.7	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	2.00	0.28	0.00	0.20	2.00
IW-4B 389-393	389	393	-62.2	0.2%	99.5%	0.2%	0.0%	0.0%	SAND	1.58	0.41	0.09	0.46	1.50
IW-4B 436-440	436	440	-63.7	0.1%	97.5%	1.2%	1.2%	2.4%	SAND	2.25	0.35	0.00	0.31	2.25
IW-4A 462-468	462	468	-64.6	2.8%	95.2%	1.2%	0.8%	1.9%	SAND	1.50	1.01	3.94	2.31	1.25
IW-4A 490-494	490	494	-65.5	0.0%	96.3%	2.1%	1.7%	3.7%	SAND	2.50	0.55	0.00	0.41	2.50
IW-4A 521-525	521	525	-66.5	2.5%	94.8%	1.0%	1.7%	2.7%	SAND	1.42	1.07	3.78	1.92	1.25
IW-4A 525-529	524	529	-66.6	1.5%	89.7%	4.1%	4.7%	8.8%	SAND	1.92	0.62	-0.66	0.61	2.00
IW-4A 550-554	550	554	-67.4	0.6%	72.8%	17.3%	9.3%	26.6%	SILTY SAND	2.08	0.85	-2.81	1.41	2.50
IW-4A 572-576	572	576	-68.2	1.2%	51.2%	34.7%	14.0%	48.7%	SILTY SAND	2.33	0.79	-1.41	0.56	2.50
IW-4A 592-596	592	596	-68.8	0.0%	50.1%	39.6%	10.4%	49.9%	SILTY SAND	3.08	0.58	-0.06	0.54	3.00
BULK										*2.11*				
IW-5D 0-4	0	4	-72.4	0.0%	85.1%	7.0%	7.9%	14.9%	SAND	2.58	0.38	0.25	0.26	2.50
IW-5D 30-34	30	34	-73.4	0.0%	90.0%	4.5%	5.4%	10.0%	SAND	2.58	0.45	-0.13	0.18	2.50
IW-5D 53-57	53	57	-74.1	0.8%	65.9%	18.2%	15.1%	33.3%	SILTY SAND	2.08	0.92	-1.53	1.69	2.25
IW-5D 62-66	62	66	-74.4	3.1%	94.1%	1.2%	1.7%	2.8%	SAND	1.58	1.04	2.22	2.46	1.50
IW-5D 72-78	72	78	-74.8	0.2%	46.2%	25.6%	28.0%	53.6%	SAND/SILT/CLAY	1.92	0.72	0.66	1.15	1.75
IW-5D 83-87	83	87	-75.1	3.6%	94.5%	0.8%	1.1%	2.0%	SAND	1.00	0.86	4.00	0.82	1.00
IW-5D 95-99	95	99	-75.5	47.7%	50.9%	0.5%	0.9%	1.4%	SAND	2.36	1.81	-6.57	8.08	2.75
IW-5D 107-111	107	111	-75.9	0.6%	96.0%	1.5%	1.9%	3.4%	SAND	2.17	0.72	-1.59	0.70	2.50
IW-5D 120-124	120	124	-76.3	13.9%	83.7%	0.8%	1.6%	2.4%	SAND	1.75	1.67	8.64	3.46	1.00
IW-5D 125-129	125	129	-76.5	31.1%	56.5%	6.2%	6.3%	12.4%	SAND	1.25	1.02	1.59	2.15	1.00
IW-5D 130-133	130	133	-76.7	4.0%	14.0%	36.8%	45.1%	81.9%	SILTY CLAY	1.33	1.05	0.69	2.33	1.25
IW-5C 143-147	143	147	-77.1	0.0%	54.8%	31.5%	13.7%	45.2%	SILTY SAND	3.25	0.78	-2.06	1.38	3.50
IW-5C 148-153	148	153	-77.3	5.1%	83.3%	8.4%	3.2%	11.6%	SAND	1.42	0.92	1.53	1.97	1.25
IW-5C 189-193	189	193	-78.6	0.3%	80.3%	14.6%	4.7%	19.4%	SAND	2.75	0.59	-0.84	0.46	2.75
IW-5C 203-207	203	207	-79.1	0.0%	67.6%	24.6%	7.8%	32.4%	SILTY SAND	2.58	0.58	0.38	0.72	2.50
IW-5C 222-226	222	226	-79.7	0.0%	68.5%	23.6%	7.9%	31.5%	SILTY SAND	2.67	0.48	0.63	0.46	2.50
IW-5C 232-236	232	236	-80.0	0.6%	75.4%	14.3%	9.6%	23.9%	SAND	2.25	0.69	-1.72	0.51	2.50
IW-5C 250-254	250	254	-80.6	0.0%	68.5%	25.4%	6.2%	31.5%	SILTY SAND	2.50	0.52	0.22	0.36	2.50
IW-5C 266-269	266	269	-81.1	0.9%	83.4%	8.4%	7.3%	15.7%	SAND	2.17	0.75	-2.63	1.02	2.50
IW-5C 272-276	272	276	-81.3	0.0%	69.0%	22.9%	8.1%	31.0%	SILTY SAND	2.58	0.58	0.38	0.54	2.50
IW-5B 283.5-287.5	283.5	287.5	-81.7	0.0%	41.8%	45.1%	13.1%	58.2%	SANDY SILT	2.58	0.62	0.66	0.82	2.50

Grain Size Analyses

Appendix 1

Sample ID	Top interval (cm)	Bottom interval	Sample depth	% Gravel	% Sand	%Silt	% Clay	% Mud	Shepard's Classification	Graphic mean	Sorting	Skewness	Kurtosis	Median
IW-5B 317-321	317	321	-82.8	0.1%	87.6%	9.8%	3.3%	12.4%	SAND	2.08	0.59	-0.53	0.69	2.25
IW-5B 343-347	343	347	-83.7	0.0%	90.8%	6.7%	2.5%	9.2%	SAND	2.33	0.77	0.91	0.92	2.25
IW-5B 357-361	357	361	-84.1	0.1%	93.8%	4.3%	1.8%	6.1%	SAND	1.42	0.65	0.13	0.92	1.50
IW-5B 369-373	369	373	-84.5	0.0%	86.9%	9.2%	3.8%	13.1%	SAND	1.58	0.62	0.16	0.82	1.50
IW-5A 376-380	376	380	-84.7	0.0%	57.2%	32.6%	10.3%	42.8%	SILTY SAND	1.92	0.65	-0.44	0.69	2.00
IW-5A 391-395	391	395	-85.2	0.0%	62.9%	29.0%	8.0%	37.1%	SILTY SAND	2.67	0.82	-0.84	1.28	2.75
IW-5B 415-419	415	419	-86.0	0.0%	34.7%	52.2%	13.1%	65.3%	SILTY SAND	2.92	0.65	-1.00	0.92	3.00
IW-5A 433.5-438	433.5	438	-86.6	0.0%	35.5%	49.4%	15.1%	64.5%	SANDY SILT	3.17	0.41	-0.47	0.31	3.25
IW-5A 453-457	453	457	-87.3	0.0%	27.2%	54.7%	18.1%	72.8%	SANDY SILT	3.17	0.41	-0.47	0.31	3.25
IW-5A 463-467	463	467	-87.6	0.0%	72.7%	20.6%	6.7%	27.3%	SILTY SAND	2.75	0.48	0.00	0.46	2.75
IW-5A 489-493	489	493	-88.4	0.1%	92.1%	5.3%	2.5%	7.8%	SAND	2.00	0.55	0.00	0.41	2.00
IW-5A 495-499	495	499	-88.6	0.1%	66.8%	24.8%	8.4%	33.2%	SILTY SAND	2.25	0.72	-0.28	0.92	2.25
IW-5A 530-534	530	534	-89.8	16.8%	79.5%	2.3%	1.4%	3.6%	SAND	2.03	1.71	5.70	2.82	1.50
BULK										2.22				
WEAVER SHOAL														
WS-1D 0-4	0	4	-39.4	12.7%	87.3%	0.0%	0.0%	0.0%	SAND	0.92	1.13	8.15	1.88	0.50
WS-1D 35-39	35	39	-40.5	7.0%	93.0%	0.0%	0.0%	0.0%	SAND	0.58	1.04	6.99	0.99	0.50
WS-1D 62-66	62	66	-41.4	13.0%	87.0%	0.0%	0.0%	0.0%	SAND	0.75	1.17	7.49	1.48	0.50
WS-1D 74-78	74	78	-41.8	10.9%	89.1%	0.0%	0.0%	0.0%	SAND	0.75	0.97	7.68	1.33	0.50
WS-1D 109-113	109	113	-43.0	10.8%	89.2%	0.0%	0.0%	0.0%	SAND	0.92	1.11	6.00	1.48	0.75
WS-1D 140-144	140	144	-44.0	16.8%	83.2%	0.0%	0.0%	0.0%	SAND	1.69	1.81	11.75	2.97	0.75
WS-1C 148-152	148	152	-44.3	12.8%	87.2%	0.0%	0.0%	0.0%	SAND	0.92	1.13	8.15	1.41	0.50
WS-1C 188-192	188	192	-45.6	14.9%	85.1%	0.0%	0.0%	0.0%	SAND	1.00	1.33	6.13	2.08	0.75
WS-1C 212-216	212	216	-46.4	19.3%	80.7%	0.0%	0.0%	0.0%	SAND	1.61	1.81	14.04	2.97	0.50
WS-1C 224-228	224	228	-46.7	19.9%	80.1%	0.0%	0.0%	0.0%	SAND	1.78	1.71	12.19	2.82	0.75
WS-1C 259-263	259	263	-47.9	18.2%	81.8%	0.0%	0.0%	0.0%	SAND	1.78	1.71	12.19	2.35	0.75
WS-1C 292-296	292	296	-49.0	8.2%	91.8%	0.0%	0.0%	0.0%	SAND	0.75	0.97	7.68	1.33	0.50
WS-1B 300.5-304.5	300.5	304.5	-49.3	18.8%	81.2%	0.0%	0.0%	0.0%	SAND	1.69	1.71	14.36	1.41	0.50
WS-1B 335.5-339.5	335.5	339.5	-50.4	6.2%	93.8%	0.0%	0.0%	0.0%	SAND	0.42	0.94	8.45	1.41	0.25
WS1B 366-370	366	370	-51.4	8.1%	91.1%	0.0%	0.0%	0.0%	SAND	0.83	1.07	7.80	1.88	0.50
WS-1B 375-379	375	379	-51.7	20.5%	78.6%	0.0%	0.0%	0.0%	SAND	1.69	1.81	11.75	2.97	0.75
WS-1B 410-414	410	414	-52.8	6.7%	93.3%	0.0%	0.0%	0.0%	SAND	0.67	0.94	7.30	1.41	0.50
WS-1B 438-442	438	442	-53.8	15.0%	85.0%	0.0%	0.0%	0.0%	SAND	1.08	1.42	9.24	1.98	0.50

Sample ID	Top	Bottom	Sample	% Gravel	% Sand	%Silt	% Clay	% Mud	Shepard's	Graphic	Sorting	Skewness	Kurtosis	Median
	interval (cm)	interval	depth						Classification	mean				
WS-1A 450.5-455	450.5	455	-54.2	11.4%	84.8%	0.0%	0.0%	0.0%	SAND	1.17	1.42	7.35	3.96	0.75
WS-1A 480-484	480	484	-55.1	13.8%	85.9%	0.0%	0.0%	0.0%	SAND	1.08	1.16	7.13	2.22	0.75
WS-1A 500-504	500	504	-55.8	7.7%	92.0%	0.0%	0.0%	0.0%	SAND	0.83	1.03	7.96	0.89	0.50
WS-1A 509.5-513	509.5	513	-56.1	11.1%	88.4%	0.0%	0.0%	0.0%	SAND	0.92	1.09	8.30	1.77	0.50
WS-1A 530-534	530	534	-56.8	12.7%	87.0%	0.0%	0.0%	0.0%	SAND	0.92	1.09	8.30	1.77	0.50
WS-1A 555-559	555	559	-57.6	12.8%	86.5%	0.0%	0.0%	0.0%	SAND	0.92	1.26	8.46	2.35	0.50
BULK										*1.07*				
WS-2D 0-4	0	4	-32.1	0.8%	99.2%	0.0%	0.0%	0.0%	SAND	1.08	0.38	0.56	0.13	1.00
WS-2D 30-34	30	34	-33.1	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	0.75	0.35	0.38	0.31	0.75
WS-2D 56-60	56	60	-33.9	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.00	0.28	0.00	0.10	1.00
WS-2D 68-72	68	72	-34.3	0.3%	99.7%	0.0%	0.0%	0.0%	SAND	1.00	0.28	0.00	0.10	1.00
WS-2D 98-102	98	102	-35.3	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.00	0.28	0.00	0.20	1.00
WS-2D 124-128	124	128	-36.2	0.9%	99.1%	0.0%	0.0%	0.0%	SAND	1.00	0.31	0.16	0.26	1.00
WS-2C 135-139	135	139	-36.5	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.00	0.28	0.00	0.10	1.00
WS-2C 165-169	165	169	-37.5	0.4%	99.6%	0.0%	0.0%	0.0%	SAND	1.00	0.28	0.00	0.20	1.00
WS-2C 176-180	176	180	-37.9	0.3%	99.7%	0.0%	0.0%	0.0%	SAND	1.08	0.18	0.13	0.08	1.00
WS-2C 203-207	203	207	-38.8	2.0%	98.0%	0.0%	0.0%	0.0%	SAND	0.75	0.39	0.22	0.36	0.75
WS-2C 211.5-215.5	211.5	215.5	-39.0	3.4%	96.6%	0.0%	0.0%	0.0%	SAND	0.83	0.41	0.47	0.31	0.75
WS-2C 241.5-245.5	241.5	245.5	-40.0	1.6%	98.4%	0.0%	0.0%	0.0%	SAND	0.83	0.41	0.47	0.15	0.75
WS-2C 280-284	280	284	-41.3	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.00	0.28	0.00	0.10	1.00
WS-2B 288-292	288	292	-41.5	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.00	0.31	0.16	0.13	1.00
WS-2B 318-322	318	322	-42.5	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	0.92	0.38	0.06	0.13	1.00
WS-2B 355-359	355	359	-43.7	0.1%	99.6%	0.0%	0.0%	0.0%	SAND	0.83	0.38	0.56	0.13	0.75
WS-2B 363-367	363	367	-44.0	0.3%	99.2%	0.0%	0.0%	0.0%	SAND	0.92	0.44	0.72	0.26	0.75
WS-2B 393-397	393	397	-45.0	0.5%	99.1%	0.0%	0.0%	0.0%	SAND	0.83	0.41	0.47	0.46	0.75
WS-2B 430.5-434.5	430.5	434.5	-46.2	0.1%	99.5%	0.0%	0.0%	0.0%	SAND	1.08	0.34	0.34	0.10	1.00
BULK										*0.94*				
WS-3D 0-4	0	4	-46.5	0.2%	99.3%	0.0%	0.0%	0.0%	SAND	1.75	0.31	-0.16	0.26	1.75
WS-3D 30-34	30	34	-47.5	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.67	0.38	-0.25	0.26	1.75
WS-3D 66-70	66	70	-48.7	0.3%	99.7%	0.0%	0.0%	0.0%	SAND	1.58	0.38	0.25	0.26	1.50
WS-3D 73-77	73	77	-48.9	0.6%	99.4%	0.0%	0.0%	0.0%	SAND	1.58	0.41	0.09	0.46	1.50
WS-3C 103-107	103	107	-49.9	0.6%	99.4%	0.0%	0.0%	0.0%	SAND	1.58	0.38	0.25	0.13	1.50
WS-3C 134-138	134	138	-50.9	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.58	0.38	0.25	0.26	1.50
WS-3C 149-152	149	152	-51.4	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.58	0.38	0.25	0.26	1.50

Appendix 1

Sample ID	Top interval (cm)	Bottom interval	Sample depth	% Gravel	% Sand	%Silt	% Clay	% Mud	Shepard's Classification	Graphic mean	Sorting	Skewness	Kurtosis	Median
WS-3C 179-183	179	183	-52.4	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.58	0.38	0.25	0.26	1.50
WS-3C 218-222	218	222	-53.7	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.58	0.38	0.25	0.26	1.50
WS-3C 225-229	225	229	-53.9	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.58	0.38	0.25	0.38	1.50
WS-3B 255-259	255	259	-54.9	0.9%	99.1%	0.0%	0.0%	0.0%	SAND	1.58	0.38	0.25	0.26	1.50
WS-3B 285-289	285	289	-55.8	0.8%	99.2%	0.0%	0.0%	0.0%	SAND	1.58	0.41	0.09	0.31	1.50
WS-3B 301.5-305.5	301.5	305.5	-56.4	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.58	0.38	0.25	0.26	1.50
WS-3B 331.5-335.5	331.5	335.5	-57.4	0.4%	99.6%	0.0%	0.0%	0.0%	SAND	1.58	0.34	0.34	0.20	1.50
WS-3B 360-364	360	364	-58.3	0.3%	99.7%	0.0%	0.0%	0.0%	SAND	1.58	0.34	0.34	0.20	1.50
WS-3A 449.5-454	449.5	454	-61.2	0.0%	99.6%	0.0%	0.0%	0.0%	SAND	1.75	0.31	0.16	0.26	1.75
WS-3A 483-487	483	487	-62.3	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.75	0.31	0.16	0.26	1.75
WS-3A 499-503	499	503	-62.9	0.6%	99.4%	0.0%	0.0%	0.0%	SAND	1.58	0.45	-0.13	0.36	1.50
WS-3A 510-514	510	514	-63.2	0.0%	99.5%	0.0%	0.0%	0.0%	SAND	1.83	0.38	0.25	0.26	1.75
BULK										*1.63*				
WS-4D 0-4	0	4	-43.7	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	0.92	0.72	1.22	0.69	0.75
WS-4D 30-34	30	34	-44.7	7.8%	92.2%	0.0%	0.0%	0.0%	SAND	0.75	1.17	7.49	1.98	0.50
WS-4D 52-56	52	56	-45.4	8.0%	92.0%	0.0%	0.0%	0.0%	SAND	0.75	1.13	7.71	1.41	0.50
WS-4D 65-69	65	69	-45.8	6.9%	93.1%	0.0%	0.0%	0.0%	SAND	0.75	1.17	7.49	1.48	0.50
WS-4D 95-99	95	99	-46.8	9.4%	90.6%	0.0%	0.0%	0.0%	SAND	0.75	1.17	7.49	1.48	0.50
WS-4D 116-120	116	120	-47.5	9.4%	90.6%	0.0%	0.0%	0.0%	SAND	0.75	1.13	7.71	0.94	0.50
WS-4C 130-134	130	134	-48.0	17.0%	83.0%	0.0%	0.0%	0.0%	SAND	1.61	1.81	14.04	1.98	0.50
WS-4C 151-155	151	155	-48.7	21.1%	78.9%	0.0%	0.0%	0.0%	SAND	1.61	1.81	14.04	2.97	0.50
WS-4C 181-185	181	185	-49.6	26.8%	73.0%	0.0%	0.0%	0.0%	SAND	1.61	1.81	14.04	8.08	0.50
WS-4C 206-210	206	210	-50.5	36.3%	63.7%	0.0%	0.0%	0.0%	SAND	1.78	1.78	9.81	7.66	1.00
WS-4C 237-241	237	241	-51.5	17.3%	82.7%	0.0%	0.0%	0.0%	SAND	1.61	1.78	14.26	2.35	0.50
WS-4C 270-274	270	274	-52.6	6.4%	93.6%	0.0%	0.0%	0.0%	SAND	0.67	1.23	7.33	1.98	0.50
WS-4B 282-286	282	286	-52.9	17.7%	82.3%	0.0%	0.0%	0.0%	SAND	1.61	1.81	14.04	3.96	0.50
WS-4B 316-320	316	320	-54.1	18.4%	81.6%	0.0%	0.0%	0.0%	SAND	1.69	1.81	11.75	3.46	0.75
WS-4B 340-344	340	344	-54.9	24.0%	75.4%	0.0%	0.0%	0.0%	SAND	1.61	1.81	14.04	4.45	0.50
WS-4B 337-339	337	339	-54.8	13.3%	86.2%	0.0%	0.0%	0.0%	SAND	0.92	1.26	8.46	2.35	0.50
WS-4B 357.5-362	357.5	362	-55.4	21.9%	77.4%	0.0%	0.0%	0.0%	SAND	1.61	1.78	14.26	2.82	0.50
WS-4B 390-394	390	394	-56.5	14.8%	84.9%	0.0%	0.0%	0.0%	SAND	1.00	1.36	8.71	3.46	0.50
WS-4B 418-422	418	422	-57.4	15.5%	84.5%	0.0%	0.0%	0.0%	SAND	1.33	1.38	8.31	2.82	0.75
WS-4A 434-438	434	438	-57.9	18.0%	81.4%	0.0%	0.0%	0.0%	SAND	1.69	1.71	14.36	3.28	0.50
WS-4A 449-452	449	452	-58.4	17.8%	81.6%	0.0%	0.0%	0.0%	SAND	1.61	1.78	14.26	3.28	0.50
WS-4A 452-456	452	456	-58.5	7.9%	91.3%	0.0%	0.0%	0.0%	SAND	1.08	1.16	7.13	2.66	0.75

Appendix 1

Sample ID	Top interval (cm)	Bottom interval	Sample depth	% Gravel	% Sand	%Silt	% Clay	% Mud	Shepard's Classification	Graphic mean	Sorting	Skewness	Kurtosis	Median
WS-4A 468-471	468	471	-59.1	5.2%	92.1%	0.0%	0.0%	0.0%	SAND	1.17	1.26	7.31	3.75	0.75
WS-4A 479-482	479	482	-59.4	1.4%	97.3%	0.0%	0.0%	0.0%	SAND	1.00	0.85	1.69	1.13	0.75
WS-4A 486-490	486	490	-59.6	9.4%	90.0%	0.0%	0.0%	0.0%	SAND	1.08	1.16	7.13	2.66	0.75
WS-4A 508-512	508	512	-60.4	6.5%	93.0%	0.0%	0.0%	0.0%	SAND	1.08	1.16	7.13	2.66	0.75
WS-4A 527-531	527	531	-61.0	3.2%	96.4%	0.0%	0.0%	0.0%	SAND	1.00	1.02	2.34	2.15	0.75
BULK										*1.22*				
WS-5C 0-6	0	6	-32.9	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.17	0.34	-0.09	0.10	1.25
WS-5C 26-30	26	30	-33.8	0.3%	99.7%	0.0%	0.0%	0.0%	SAND	1.08	0.38	0.25	0.13	1.00
WS-5C 44-48	44	48	-34.3	0.3%	99.7%	0.0%	0.0%	0.0%	SAND	1.08	0.34	0.34	0.10	1.00
WS-5C 57-61	57	61	-34.8	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.25	0.28	0.00	0.20	1.25
WS-5C 80-84	80	84	-35.5	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.08	0.38	0.25	0.13	1.00
WS-5C 100-104	100	104	-36.2	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.17	0.34	-0.09	0.20	1.25
WS-5B 114.5-119	114.5	119	-36.7	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.08	0.34	0.34	0.10	1.00
WS-5B 148-152	148	152	-37.8	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.08	0.34	0.34	0.10	1.00
WS-5B 176-180	176	180	-38.7	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.08	0.34	0.34	0.10	1.00
WS-5B 190.5-195	190.5	195	-39.1	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.08	0.34	0.34	0.10	1.00
WS-5B 220-224	220	224	-40.1	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.17	0.34	-0.09	0.20	1.25
WS-5B 250-254	250	254	-41.1	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.25	0.28	0.00	0.20	1.25
WS-5A 266.6-270.5	266.5	270.5	-41.6	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.17	0.34	-0.09	0.10	1.25
WS-5A 296-300	296	300	-42.6	0.3%	99.7%	0.0%	0.0%	0.0%	SAND	1.25	0.28	0.00	0.10	1.25
WS-5A 316-320	316	320	-43.3	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.25	0.28	0.00	0.10	1.25
WS-5A 341-345	341	345	-44.1	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.33	0.38	0.25	0.26	1.25
WS-5A 357.5-361.5	357.5	361.5	-44.6	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.25	0.31	0.16	0.26	1.25
WS-5A 384-388	384	388	-45.5	0.1%	99.9%	0.0%	0.0%	0.0%	SAND	1.25	0.31	0.16	0.26	1.25
WS-5A 408-412	408	412	-46.3	0.0%	100.0%	0.0%	0.0%	0.0%	SAND	1.33	0.34	0.34	0.20	1.25
WS-5A 434-438	434	438	-47.1	0.2%	99.8%	0.0%	0.0%	0.0%	SAND	1.33	0.38	0.25	0.26	1.25
BULK										*1.19*				

Grain size analyses from Fields vibracores (1976)

Sample #	interval (ft)	Depth	Mean	Sorting
F4 0	0	-28.0	1.58	0.52
F4 -1	-1	-29.0	0.95	0.95
F4 -2	-2	-30.0	1.11	0.83
F4 -3	-3	-31.0	1.34	0.47
F4 -4	-4	-32.0	1.61	0.46
F4 -5	-5	-33.0	1.46	0.57
F4 -6	-6	-34.0	1.40	0.59
F4 -7	-7	-35.0	1.91	0.44
F4 -8	-8	-36.0	1.68	0.40
F4 -10	-10	-38.0	1.85	0.55
F4 -14	-14	-42.0	1.84	0.55
F4 -16	-16	-44.0	1.73	0.58
BULK			1.54	
F5A 0	0	-42.0	1.47	0.70
F5A -1	-1	-43.0	1.20	0.83
F5A -3	-3	-45.0	1.66	0.68
F5A -5	-5	-47.0	1.33	0.87
F5A -7	-7	-49.0	1.64	0.50
F5A -9	-9	-51.0	1.32	1.01
F5A -11	-11	-53.0	1.48	1.14
BULK			1.44	
F11 0	0	-36.0	1.23	0.42
F11 -3	-3	-39.0	1.26	0.33
F11 -5	-5	-41.0	1.41	0.45
F11 -7	-7	-43.0	1.19	0.54
F11 -9	-9	-45.0	1.31	0.52
BULK			1.28	
F15 0	0	-35.0	1.86	0.41
F15 -2	-2	-37.0	1.92	0.43
F15 -4	-4	-39.0	1.77	0.58
F15 -6	-6	-41.0	2.08	0.61
F15 -7	-7	-42.0	2.27	0.70
F15 -9	-9	-44.0	2.16	0.74
F15 -11	-11	-46.0	2.22	0.65
BULK			2.10	

Appendix 2

Geochronology

(Sample analyses have not yet been completed. Appendix 2 will be delivered when data is available)