The Evaluation of Shell Resources in Federal Waters, Offshore Mississippi

Prepared for
The U.S Minerals Management Service
Under Cooperative Agreement #14-35-0001-30733

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April 1, 1995

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INTRODUCTION

In March of 1994, the Continental Shelf Division (CSD) of the Marine Minerals Technology Center (MMTC) undertook an extensive study utilizing high-resolution seismic sub-bottom profiling, side-scan sonar, and geologic sample acquisition in an effort to locate fossil shell reserves in the waters of the Mississippi Exclusive Economic Zone (EEZ). Field work for this project, funded by the Minerals Management Service (MMS), was conducted adjacent to the Chandeleur Islands in the northern Gulf of Mexico (figure 1).

The dead shell, or mud shell, industry is an important industry in Gulf Coastal States. Oyster shell is used as construction aggregate, poultry feed, cattle roughage, in the cement and chemical industries, and in the preparation of lime (Arndt, 1976; Gulf Task Force, 1989). Although other substances such as limestone, caliche, gypsum, aragonite, clay, and shale are often used as shell substitutes (Arndt, 1976) none of these materials provides all the properties that make oyster shell desirable to so many different industries.

In Mississippi, however, there has been no commercial shell dredging since 1973 (Demoran, 1982). A 1982 shell survey, conducted by Demoran, identified over 1,870,000 cubic yards of potential shell reserves within the Mississippi Sound. These deposits have not been exploited because of environmental concerns regarding adverse ecological effects to fisheries, bottom geochemistry, and water chemistry. Due to the environmental concerns over dredging in estuarine waters with restricted circulation, the MMTC undertook this study with the intent of locating and mapping shell deposits in offshore federal waters. These offshore deposits are especially desirable in that they could be harvested without deleterious environmental affects to living oyster reefs and ecologically fragile estuarine systems.

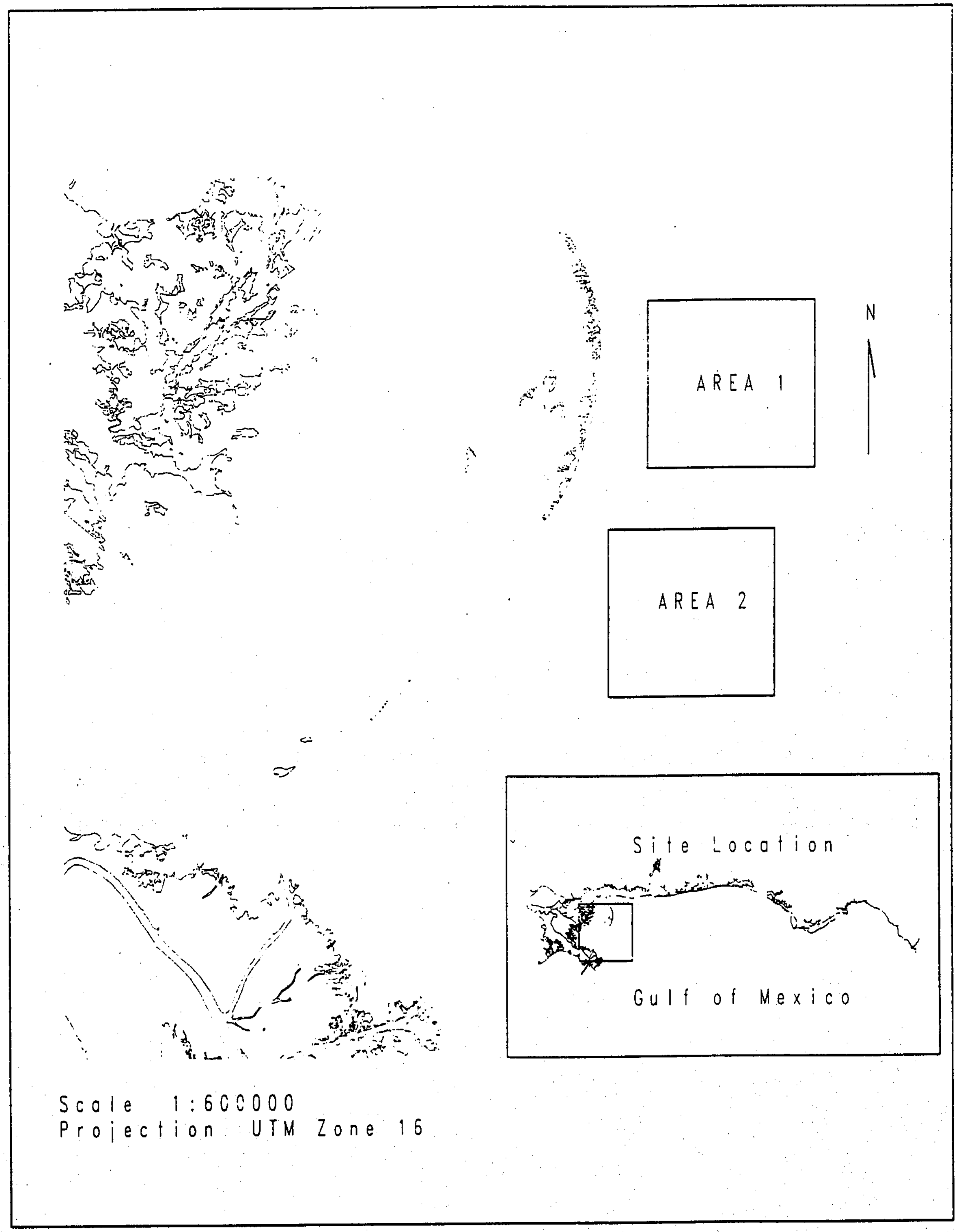


Figure 1. Site map of the study area.

METHODOLOGY

High Resolution Seismic Acquisition

A 1981 seismic survey, conducted for the Bureau of Land Management by the United States Geological Survey (USGS), collected over 3200 kilometers (km) of high resolution, seismic reflection data of the Louisiana and Mississippi continental shelf and slope (Kindinger, *et al.* 1982). A report based upon these tracklines identified the presence of extensive early Holocene oyster shell reefs adjacent to the Chandeleur Islands. The MMTC established two reconnaissance survey grids that occurred within areas identified by Kindinger *et al.* (1982) as having seismic signatures identifiable as oyster reefs (figure 2). To avoid duplication of existing seismic data the MMTC survey grid was designed to intersect Kindingers' tracklines at a 45° angle.

Reconnaissance Survey

Over 320 line kilometers of high-resolution, sub-bottom profile data were collected by MMTC personnel aboard the R/V Kit Jones, from March 11 to March 20, 1994 in two survey areas adjacent to the Chandeleur Islands in the Gulf of Mexico. Site I is approximately 8 kilometers (4.3 nautical miles) east of the Chandelier Islands and Site II is located 7.5 kilometers (4 nautical miles) to the southeast of the islands. The method of seismic data acquisition used in this study was a three system configuration consisting of a navigation and bathymetry package, a digital acquisition package, and an analog seismic source and receiver.

Navigation data were collected using a Magellan Model 1500 Global Positioning Receiver. Bathymetry data were collected with a Ratheon 719 fathometer and digitized by an

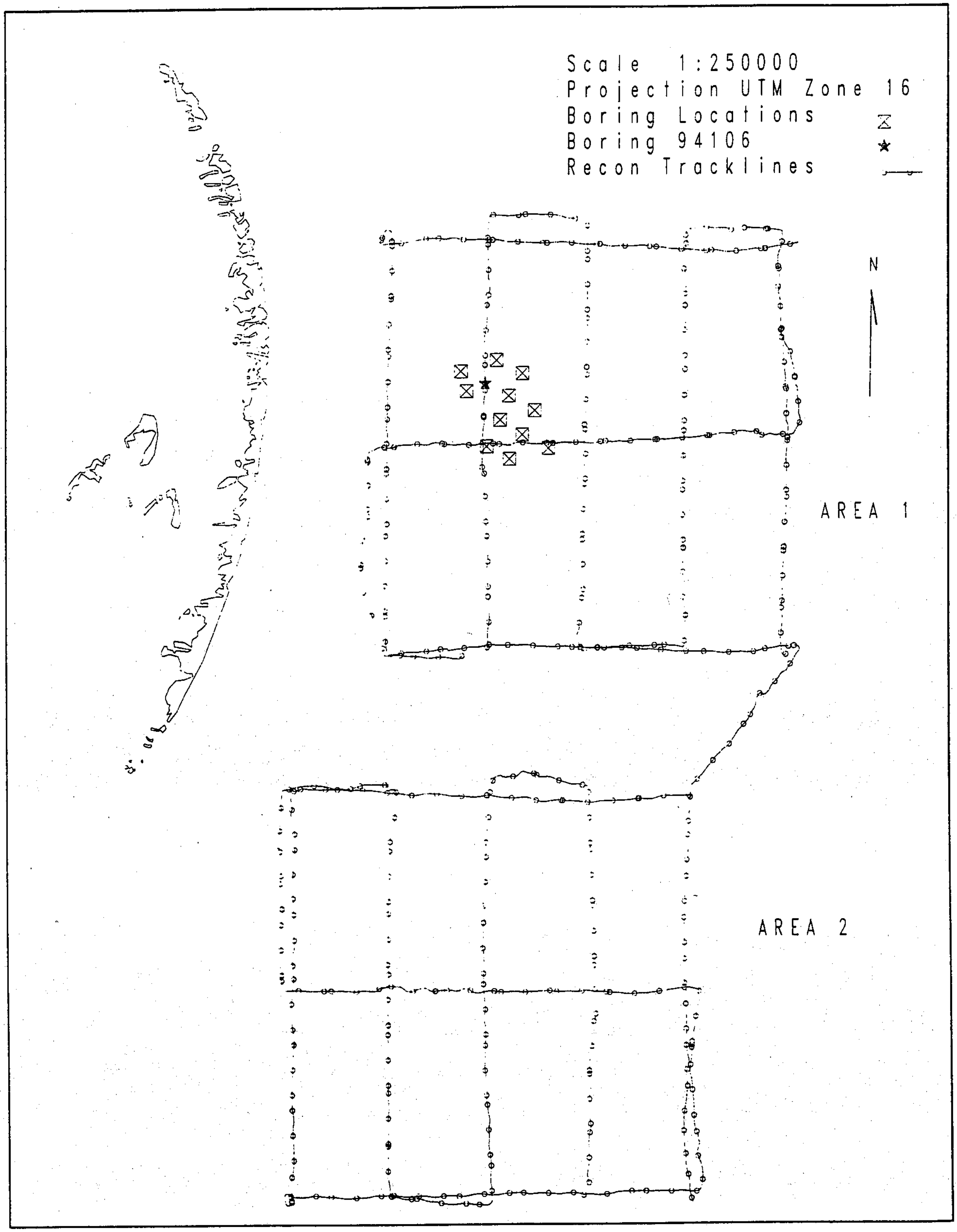


Figure 2. MMTC tracklines for 20 km^2 reconnaissance survey grids indicating boring locations.

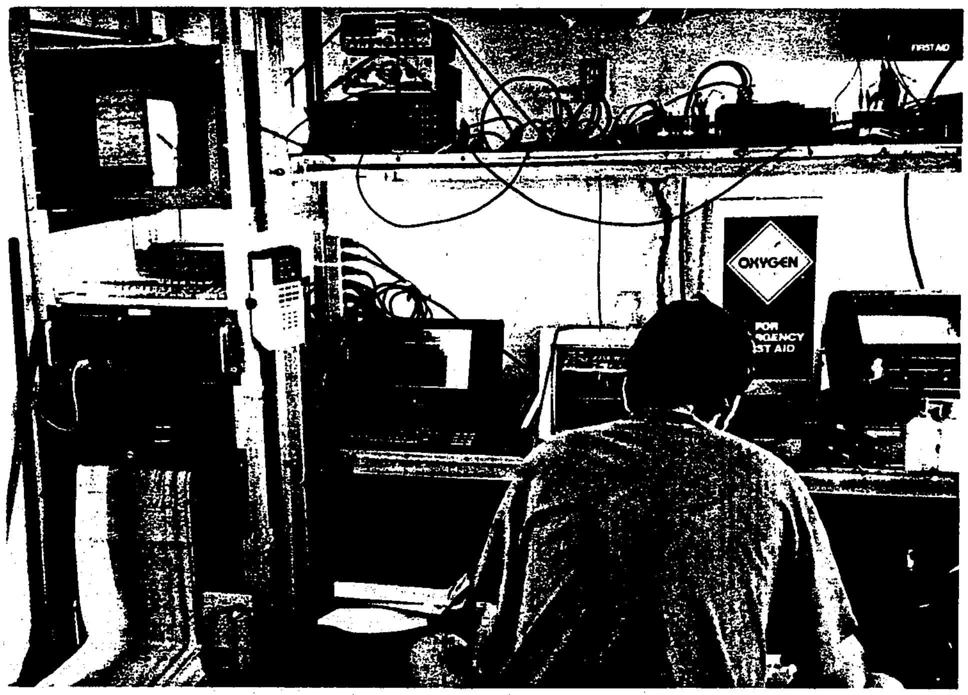
Odum Digitrace linked to a personal computer. GeoLink (GeoResearch, 1991), an application designed to interface navigation hardware with a Geographic Information System (GIS), was used to assist the boat crew with maintaining position on the tracklines. This application also interfaced with the seismic acquisition software to provide navigational fixes at one second intervals.

The digital seismic acquisition utilized ELICS Delph1 (Girault, 1992) software running on an 80486 personal computer. Raw data were stored on a 600 megabyte, rewritable magneto-optical disk and records were output to a Gulton Digital Plotter. This configuration, shown in figure 3, allowed data to be simultaneously stored in raw form, displayed on a monitor in real-time, and plotted as processed data on the Gulton Plotter.

The seismic system used an Innovative Transducers, Inc. (ITI) solid towed hydrophone array with a Datasonics Model BVP 520 Bubble Pulser sled as the sound source.

Production Survey

The MMTC planned to conduct high-resolution, sub-bottom profiles on two 5 km^2 grids during June, 1994. The proposed tracklines for the production grid in area 1 is shown in figure 4. This figure also includes boring locations for geologic sampling. The digital seismic acquisition system was identical to that utilized in the reconnaissance grid survey with the exception of an upgraded version of the ELICS Delph2 software (Girault, 1992). Tracklines for seismic data acquisition were constructed 5 km in length and 100 m apart. The smaller trackline interval necessitated higher resolution navigation, therefore an Acupoint Differential Receiver was acquired to provide fixes within five meters of accuracy. Side-scan



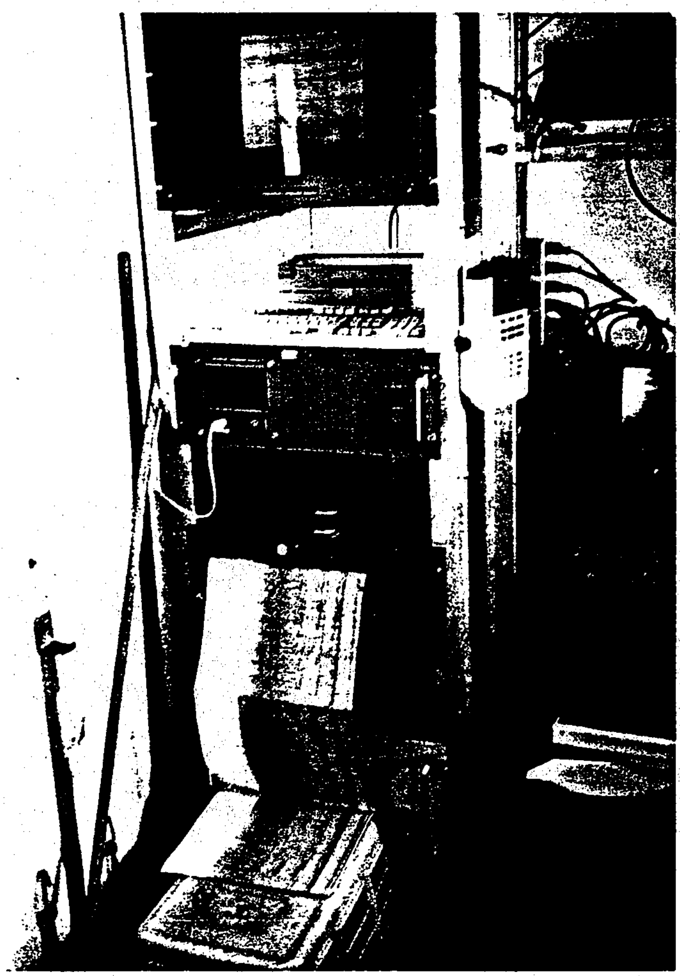


Figure 3. Photographs showing seismic acquisition setup during reconnaissance survey.

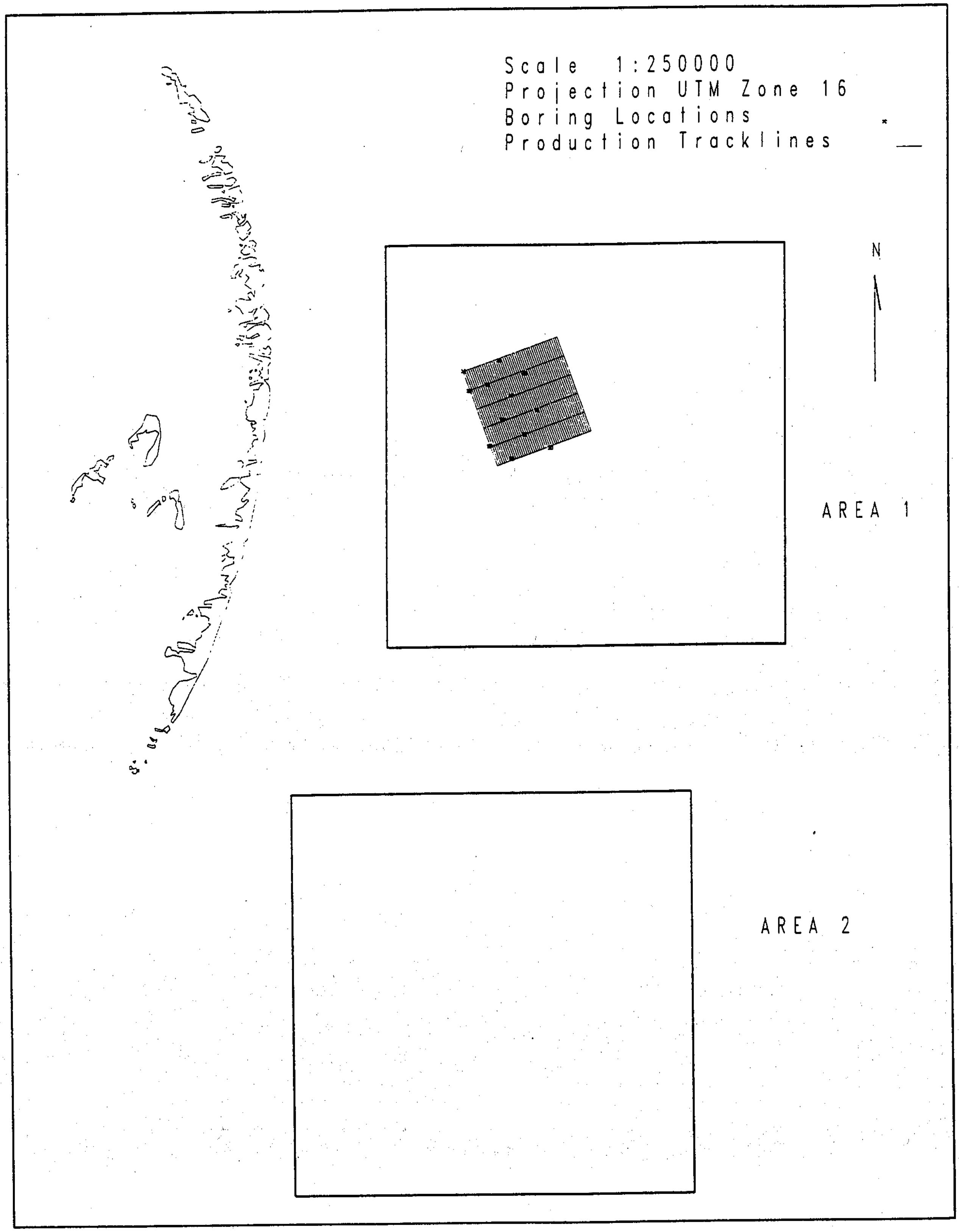


Figure 4. Proposed tracklines for 5 km^2 production grid in study area 1. Boring locations are also included.

sonar data were collected using an EG&G DF 1000 Towfish with a 256 topside unit provided by John E. Chance and Associates. A technician was also provided to assist in side-scan sonar data acquisition. The side-scan sonar was configured to obtain a 150 m swath so that a minimum of 50 meters would overlap on each trackline.

Geologic Sampling

Geologic sampling operations to ground-truth seismic data collected during previous surveys took place from June 16 to July 24, 1994 aboard the R/V Kit Jones. Two production sampling grids were established within the limits of the seismic surveys. The boring locations within the grids were designed to provide information to establish the areal distribution and volumetric estimates of encountered shell beds. These boring locations are shown in figure 2.

Geologic Sampling Methodology

Geologic sampling was accomplished utilizing a MMTC designed and constructed vibra-lift drill, comprised of a frame-supported pneumatic vibrator with a counter-flush system for sample recovery . This drill is capable of 7.5 meters of penetration and utilizes a 100 mm I.D. diameter casing (Woolsey, 1989). Drilling operations were initiated by anchoring the research vessel on the selected boring location. Bow and stern anchors were deployed to insure that the vessel remained stable during drilling operations. After the vessel was secured, the winch operator lowered the drill from the stern mounted A-frame. The air compressor was engaged to displace water from the casing prior to drill emplacement on the seafloor. When the drill was in contact with the bottom and the vibrator engaged, the winch cable was marked, and the winch operator allowed the drill to begin penetration into the bottom sediments. Penetration depth was measured on the winch cable using a meter stick. Samples were collected continuously over one meter intervals by MMTC personnel.

Sample slurry was pumped aboard into a cyclone dewatering cone to reduce slurry velocity prior to the sample collection in a 20 liter sample pail placed within a larger overflow container. Using of this "pail-within-a-tub" system, sample operations retained the fine grained sediments that would otherwise be lost.

At the end of each sample interval, as measured by the flagged winch cable, the winch operator continued to run air to the drill until the return lines were cleared of sample slurry. Once the sample was collected from an interval, the fines caught by the overflow container were placed into the sample bucket and new containers were emplaced. This process was repeated until refusal or total depth of the boring was reached, at which time all lines were cleared and the drill retrieved. After the drill frame was retrieved and secured on the stern, the boat crew retrieved the anchors and proceeded to the next boring location. While the vessel was underway, geologists determined the recovery volume per meter of sediment penetration. Each sample was then inspected, described, and logged. Records were also kept regarding position, water depth, time, total depth of the boring, and of any unusual circumstances for each boring. The boring logs are shown in Appendix A. After logging operations were complete, excess water from each sample was decanted and the sample placed into labeled polypropylene sample bags.

RESULTS

Reconnaissance Survey

Kindinger, *et al.* (1982) described the seismic signature of oyster reefs as having "hard jagged horizons with acoustic blank zones directly beneath them". Figure 5 shows a comparison of a seismic record from MMTC Site I near boring 94106 and a corresponding record from Kindinger, *et al.* (1982). Suter (1986) describes a similar seismic pattern with "high amplitude mounded reflection patterns", while Bouma (1976) refers to reefs appearing as "convex upward pinnacles or dome shapes having few or no internal reflectors". Based on these descriptions, the MMTC examined and interpreted the new seismic records from the reconnaissance sites and mapped those areas attributable to shell signatures. These mapped areas were compared with the results of Kindinger, *et al.* (1982) and a very strong correlation was noted as illustrated in figure 6. Based upon data from this survey, two smaller production survey grids were established in which to conduct further seismic studies.

Production Survey Results

Seismic and side-scan sonar surveys at Site I commenced on June 21, 1994. Deteriorating weather and navigation resolution problems during calibration efforts on the first trackline resulted in poor seismic and side-scan data acquisition. Due to these conditions the decision was made to abort further seismic acquisition within the production grids until after the completion of geologic sampling at Site I. Results from the geologic sampling conducted prior to the rescheduled seismic survey precluded further seismic data acquisition.

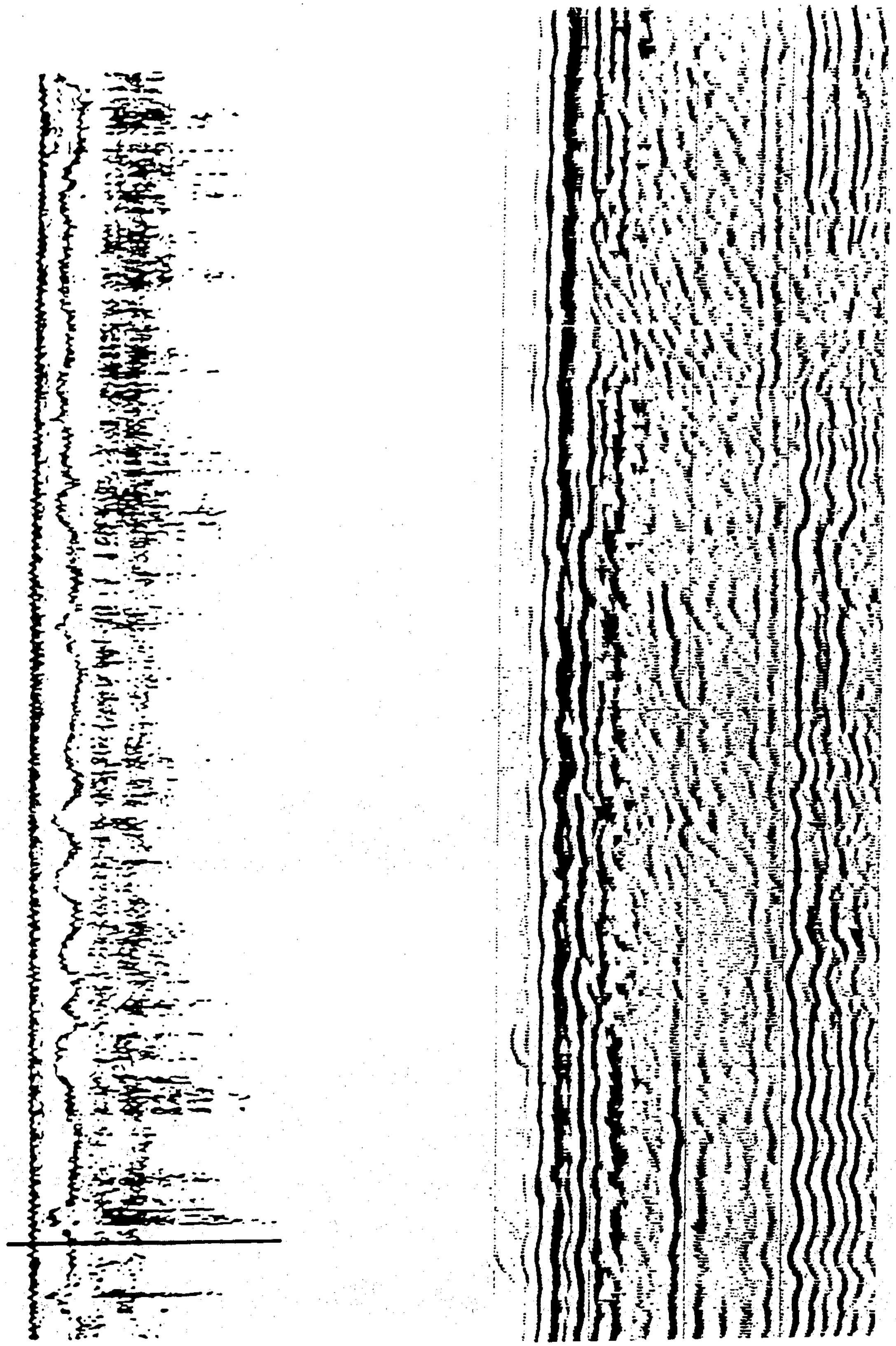


Figure 5. Kindinger's, et al. (1982) interpretation of oyster reef signature (left) compared to MMTC seismic data acquired near boring location 94106.

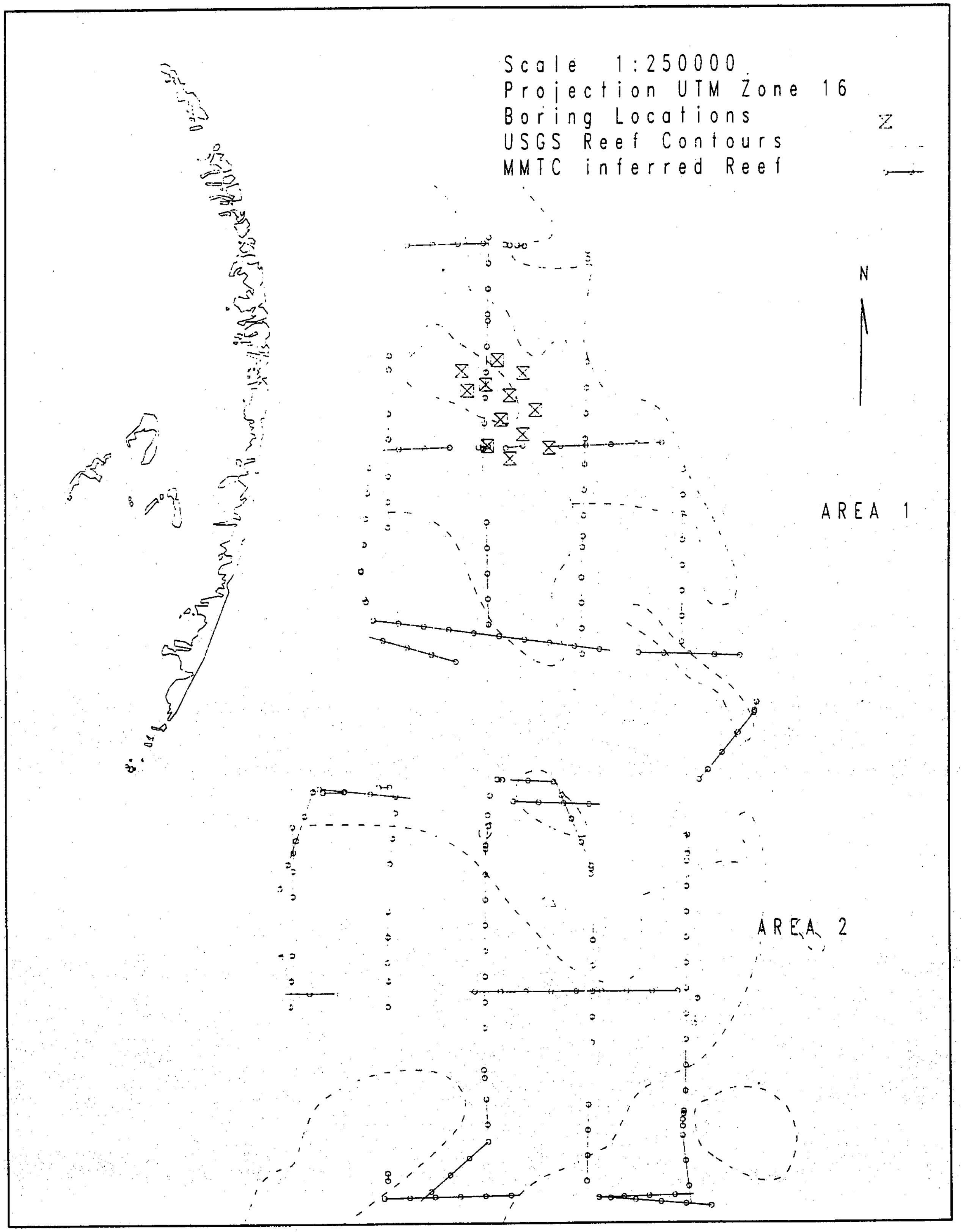


Figure 6. Inferred reef locations from MMTC seismic data superimposed on USGS reef contour map.

Geologic Sampling

Sampling operations were conducted in Site I over a nine day period. A total of 89 samples were collected during this phase of operations. Twelve borings were drilled to full penetration with an average sample recovery of 55.8 liters per site and 7.7 liters per meter. At site 94108, drilling was terminated due to mechanical problems after three meters of penetration. All samples are archived and available for inspection at the MMTC.

Although some small bivalve shell fragments were recovered in all of the borings, shell fragments were seldom found at sediment depths greater than 3 meters. There was no indication of the existence of any extensive shell deposits during drilling operations. Due to this lack of findings and deteriorating weather conditions (as a result of the presence of a tropical storm in the northern Gulf of Mexico), drilling operations were terminated after sampling at the twelfth boring in order to enable MMTC personnel to re-evaluate seismic data.

The sediment encountered in the borings consisted predominantly of dark gray, marine clay which is very cohesive and plastic. At borings 94113 and 94112 a dark brown, fine-grained, well-sorted, micaceous quartz sand was encountered at depths of five and two meters, respectively. Shell fragments were rare or absent in all the borings and, when present, never exceeded 24.5 mm in diameter.

Due to the fact that no oyster shell deposits were encountered during drilling operations the sampling crew did not conduct any operations utilizing a jet-probe.

SUMMARY AND RECOMMENDATIONS

Based upon the lack of shell deposits encountered during geologic sampling operations, the MMTC concluded that seismic signatures attributed as oyster reefs were in fact gas artifacts. This misinterpretation of seismic data by the MMTC and previous surveys is understandable due to the similar seismic signatures of buried shell deposits and gas pockets located in upper sediments. Bouma *et al.* (1973) addressed the tendency of gas to absorb energy which results in blank areas in the seismic record similar to the lack of internal reflectors created by shell deposits. These gas pockets are described by Kindinger *et al.*(1982) as "small areas with no acoustic returns" and are common in deltaic regions due to rapidly decomposing organic sediments such as those associated with the St. Bernard Delta sediments.

Prior to any additional field work being undertaken in the study area it is recommended by the MMTC that a thorough market analysis be conducted to determine the economic potential of shell resources located in these federal waters. This analysis should address the cost of dredging, maritime transport and of any subsequent overland transport. Additional factors to be determined as part of the production costs include the maximum operational water and overburden depths in which these deposits may be profitably dredged. This study should also access the current demand for shell resources in the Mississippi and northern Gulf Coastal region and compare the prices of materials now being utilized as shell substitutes.

In order to limit the area of future investigations a coastal model should be established using previous geophysical and geotechnical studies to identify likely estuarine environments during the Holocene lowstand. Seismic data, boring logs and well logs should be utilized to establish this model.

High resolution, multi-channel seismic data acquisition should be conducted over known shell deposits in order to establish clear models of the seismic signatures associated with both viable and buried reefs. Demoran (1979) identified many such reefs in the Mississippi Sound which may be investigated with minimal costs due to their proximity to shore.

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APPENDIX A

BORING LOG

Boring I.D.: 94101

Date: 6/29/94

Water Depth: 11.47 m

Time (CST): 1245

UTM Position:
X: 334142.5
Y: 3310733.3

Depth Interval (Meters below seafloor)	Sample Volume (Liters)	Sample Description
0-1	<1	Clay, dark grey, very cohesive, highly plastic, >95% clay, <5% silt, shell fragments rare, ≤1/2" diameter
1-2	0	No recovery
2-3	4	Clay, dark grey, very cohesive, highly plastic, >95% clay, <5% silt, shell fragments absent
3-4	4	Same as above (SAA)
4-5	9	SAA
5-6	6	SAA
6-7	5	SAA
7-7.5	10	SAA

Total depth: 7.5 meters

BORING LOG

Boring I.D.: 94107

Date: 6/29/94

Water Depth: 11.67 m

Time (CST): 1445

UTM Position:
X: 334421.8
Y: 3309754.1

Depth Interval (Meters below seafloor)	Sample Volume (Liters)	Sample Description
0-1	8	Clay, dark gray, very cohesive, highly plastic, >95% clay, <5% silt, shell fragments scattered to rare
1-2	4	SAA (same as above)
2-3	5	SAA
3-4	12	SAA except no shell fragments
4-5	8	SAA
5-6	13	SAA
6-7	5	SAA
7-7.5	0	No recovery

Total depth: 7 meters

BORING LOG

Boring I.D.: 94113

Date: 6/30/94

Water Depth: 12.08

Time (CST): 1545

UTM Position:
X: 335418.9
Y: 3306996.9

Depth Interval (Meters below seafloor)	Sample Volume (Liters)	Sample Description
0-1	8	Clay, dark grey, very cohesive, highly plastic, >95% clay, <5% silt, scattered shell fragments, ≤1/8" diameter
1-2	7	Same as above (SAA) except no shell fragments
2-3	13	SAA
3-4	12	SAA
4-5	11	SAA
5-5.25	10	SAA
5.25-6	5	Dark brown, highly rounded, very fine-grained , well-sorted sand, predominantly quartz and mica
6-7	4	Dark grey clay, very cohesive, highly plastic, >95% clay, <5% silt, shells absent
7-7.5	5	

Total depth 7.5 meters

BORING LOG

Boring I.D.: 94118

Date: 6/30/94

Water Depth: 12.70 m

Time (CST): 1815

UTM Position:
X: 336553.9
Y: 3306368.9

Depth Interval (Meters below seafloor)	Sample Volume (Liters)	Sample Description
0-1	3	Clay, dark grey, very cohesive, highly plastic, >95% clay, <5% silt, scattered to rare shell fragments, $\leq$1/4" diameter
1-2	9	Same as above (SAA) except no shell fragments
2-3	11	SAA
3-4	12	SAA
4-5	12	SAA
5-6	20	SAA

Total depth: 6 meters

BORING LOG

Boring I.D.: 94112

Date: 6/30/94

Water Depth: 12.29 m

Time (CST): 1910

UTM Position:
X: 336085.0
Y: 3308314.0

Depth Interval (Meters below seafloor)	Sample Volume (Liters)	Sample Description
0-1	6	Clay, dark grey, very cohesive, highly plastic, >95% clay, <5% silt, shell fragments rare, ≤1" diameter
1-2	8	Same as above (SAA) except shell fragments ≤1/8" diameter
2-3	1	Muddy sand, dark brown, very fine grained, well-sorted micaceous quartz sand, 60% sand, 30% clay, no shell fragments
3-3.25	2	SAA
3.25-4	5	Clay, dark grey, very cohesive, highly plastic, >95% clay, <5% silt, no shell fragments
4-5	11	SAA
5-6	9	SAA
6-7	14	SAA
7-7.5	4	SAA

Total depth: 7.5 meters

BORING LOG

Boring I.D.: 94106

Date: 7/1/94

Water Depth: 12.29 m

Time (CST): 0730

UTM Position:
X: 335339.0
Y: 3310054.3

Depth Interval (Meters below seafloor)	Sample Volume (Liters)	Sample Description
0-1	9	Clay, dark grey with dark brown mottling, very cohesive, highly plastic, >95% clay, <5% silt, shell fragments rare
1-2	5	Same as above (SAA) except no shell fragments
2-3	6	SAA except shell fragments rare, ≤ 1/8" diameter
3-4	3	SAA
4-5	3	SAA except no shell fragments
5-6	6	SAA
6-7	5	SAA
7-7.5	5	SAA

Total depth: 7.5 meters

BORING LOG

Boring I.D.: 94102

Water Depth: 12.70 m

Date: 7/1/94

UTM Position:
X: 335913.4
Y: 3311277.1

Time (CST): 0815

Depth Interval (Meters below seafloor)	Sample Volume (Liters)	Sample Description
0-1	13	Clay, dark grey, very cohesive, highly plastic, >95% clay, <5% silt, shell fragments rare, ≤ 1/8" diameter
1-2	10	Same as above (SAA)
2-3	6	SAA
3-4	9	SAA except no shell
4-5	9	SAA
5-6	6	SAA
6-7	12	SAA
7-7.5	1	SAA

Total depth: 7.5 meters

BORING LOG

Boring I.D.: 94105

Date: 7/1/94

Water Depth: 12.90 m

Time (CST): 0915

UTM Position:
X: 337200.3
Y: 3310622.4

Depth Interval (Meters below seafloor)	Sample Volume (Liters)	Sample Description
0-1	20	Clay, dark grey, very cohesive, highly plastic, >95% clay, <5% silt, shell fragments rare, ≤ 1/8" diameter
1-2	16	Same as above (SAA)
2-3	1	SAA except no shell
3-4	8	SAA
4-5	11	SAA
5-6	9	SAA
6-7	7	SAA

Total depth: 7 meters

BORING LOG

Boring I.D.: 94111

Date: 7/1/94

Water Depth: 13.31 m

Time (CST): 1000

UTM Position:
X: 337817.0
Y: 3308787.1

Depth Interval (Meters below seafloor)	**Sample Volume (Liters)**	**Sample Description**
0-1	4	Clay, dark grey, very cohesive, highly plastic, >95% clay, <5% silt, shell fragments rare, ≤ 3/8" diameter
1-2	12	Same as above (SAA) except shell fragments ≤ 1/8 diameter
2-3	6	SAA except no shell fragments
3-4	7	SAA except shell fragments rare, ≤1/8" diameter
4-5	6	SAA except no shell fragments
5-6	11	SAA except shell fragments rare, ≤1/8" diameter
6-7	8	SAA except no shell fragments
7-7.25	2	SAA

Total depth: 7.25 meters

BORING LOG

Boring I.D.: 94117

Date: 7/1/94

Water Depth: 13.72 m

Time (CST): 1100

UTM Position:
X: 338499.4
Y: 3306905.1

Depth Interval (Meters below seafloor)	Sample Volume (Liters)	Sample Description
0-1	8	Clay, dark grey, very cohesive, highly plastic, >95% clay, <5% silt, shell fragments rare, ≤ 1/4" diameter
1-2	20	Same as above (SAA) except no shell fragments
2-3	1	SAA except shell fragments rare, ≤ 1/8" diameter
3-4	4	SAA
4-5	20	SAA except no shell fragments
5-6	4	SAA
6-7	19	SAA
7-7.5	0	No recovery

Total depth: 7.5 meters

BORING LOG

Boring I.D.: 94114

Date: 7/1/94

Water Depth: 12.90 m

Time (CST): 1150

UTM Position:
X: 337189.5
Y: 3307579.6

Depth Interval (Meters below seafloor)	Sample Volume (Liters)	Sample Description
0-1	9	Clay, dark grey, very cohesive, highly plastic, >95% clay, <5% silt, no shell fragments
1-2	8	Same as above (SAA) except shell fragments rare, ≤ 1/4" diameter
2-3	10	SAA except no shell fragments
3-4	9	SAA
4-5	6	SAA
5-6	10	SAA
6-7	10	SAA

Total depth: 7 meters

BORING LOG

Boring I.D.: 94108

Date: 7/1/94

Water Depth: 12.49 m

Time (CST): 1345

UTM Position:
X: 336526.5
Y: 3309519.1

Depth Interval (Meters below seafloor)	Sample Volume (Liters)	Sample Description
0-1	1	
1-2	2	
2-3	1	Boring terminated due to mechanical problems
3-4		
4-5		
5-6		
6-7		
7-7.5		

Total depth 3 meters