GULF SHORES, ALABAMA
BEACH RESTORATION PROJECT

Sand Search Investigation

Prepared for:
The City of Gulf Shores, AL

Prepared by:
olsen associates, inc.

June 2001

City of Gulf Shores, Alabama

olsen
associates, inc.
coastal engineering

City of Gulf Shores, AL
Beach Restoration Project

Sand Search Investigation

Report Submitted To:

City of Gulf Shores, Alabama
P.O. Box 266
Gulf Shores, AL

Report Submitted By:

Olsen Associates, inc.
4438 Herschel St.
Jacksonville, FL

June 2001

1.0 INTRODUCTION

This report documents the findings of a comprehensive investigation to identify a suitable source of beach quality material for purposes of constructing the Gulf Shores, AL, Beach Restoration Project. The restoration project was constructed between January and March 2001 along a 3.1-mile segment of Gulf Shores in Baldwin County, AL. The borrow site for the project was located approximately 1.5 miles offshore of the eastern end of the project limits. Olsen Associates, inc., of Jacksonville, FL, was contracted by the City of Gulf Shores, AL, to conduct this and other investigations pursuant to the project and to permit, design, and oversee construction by the selected contractor. This report presents the findings of the native beach characterization, the geophysical exploration and core-boring program, and the analysis of the core-boring logs and sediment sampling. Details of the other engineering analyses and the construction of the project may be found in the companion to this report (Olsen Associates, 2001).

2.0 STUDY SCOPE

Gulf Shores lies on the Gulf of Mexico shoreline of Baldwin County, AL, on the Morgan Point Peninsula, approximately 20 miles east of the entrance to Mobile Bay (Figures 2.1 and 2.2). The eastern 3.1 miles of Gulf Shores are intensively developed with hotels, businesses, and condominiums and represent a heavily visited tourist destination. The remainder of the Gulf Shores beach is fronted principally by private homes and condominiums. State Route 182 is the primary east-west road through the area. Highway 59 intersects the project shoreline at the main city beach park The project discussed herein encompasses the eastern 3.1 miles of Gulf Shores adjacent to Gulf State Park.

The primary components of the Sand Search Investigation for the Gulf Shores, AL, Beach Restoration Project were:

- Literature survey of relevant previous investigations,
- Native beach sediment sample collection (December 1999),
- Seismic sub-bottom survey (November 1999),
- Sediment core-boring collection (November 1999),
- Logging, sampling, and analysis of collected cores.

All geophysical data acquisition was performed by Alpine Ocean Seismic Survey (AOSS), Inc., of Norwood, N.J., under the guidance of Olsen Associates, inc. The logging, sampling, and analysis of the collected cores was performed by Scientific Environmental Applications, Inc., of Melbourne, FL. Native beach surface samples were collected by Dr. Scott L. Douglass. Grain size analyses of the native sediments were conducted by Ellis and Associates, Inc., of Jacksonville, FL. Data from the native beach sampling and Vibracore logging and analyses are provided in Portable Document Format (*.PDF) on the attached CD-ROM disc. The disc contains a map (Figure 2.3) of all core locations and native beach transects and can be 'searched' by clicking on the map on the desired core or beach profile.

Figure 2.1 Location map - southeastern U.S.

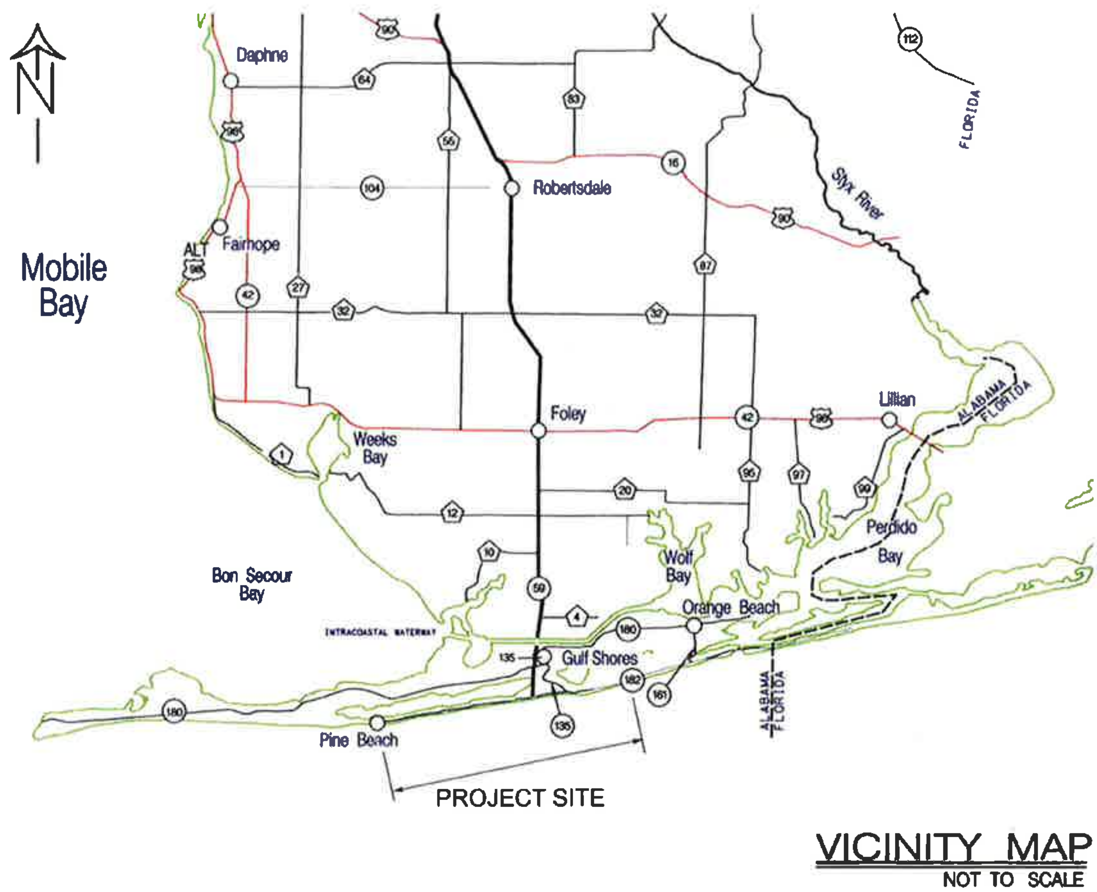


Figure 2.2 Location Map - Baldwin County, Alabama, and Gulf Shores.

Figure 2.3 presents a map of the project baseline and nearshore area. Four beach profile transects were identified for native sediment characterization. These transects are identified in Table 2.1. Along each profile, between seven and ten surface samples were collected, extending from the back of the dry beach berm seaward beyond the crest of the primary nearshore bar feature. In total, 36 surface samples were collected.

Table 2.1 Location of Native Beach Sampling Transects:

Line #	Location	Nearest Reference Monument
1	Gulf State Park Convention Center	ADEM B-24
2	Holiday Inn White Sands Resort	GS-25
3	City Park (Highway 182 and Highway 59)	GS-23
4	Edgewater Condominiums	GS-17

In November 1999, AOSS and OA conducted approximately 80 miles of seismic sub-bottom survey along roughly five-mile transects in the region immediately offshore of the project area. The seismic survey consists of the measurement of pulses of sound directed into the seabed. The time of return of various frequencies of the reflected sound pulse provides information regarding changes in density of the material in the upper 50 ft (approximate) of the seabed. In this manner, areas characterized by multiple layers of sediment can be distinguished from areas containing little or no layering. In general, areas containing potential volumes of sandy-type sediments are those that are essentially featureless in the upper roughly 20 ft of the seabed. Areas with significant layering generally have alternating layers of mud or silt with layers of dense sand or clay (obviously undesirable material for a beach). The survey indicated that the crests of two large transverse ridges may contain a consistent lense of potentially beach-compatible material. To develop a suitable borrow site, 47 Vibracores were collected, principally in the vicinity of these ridges (Figure 2.3).

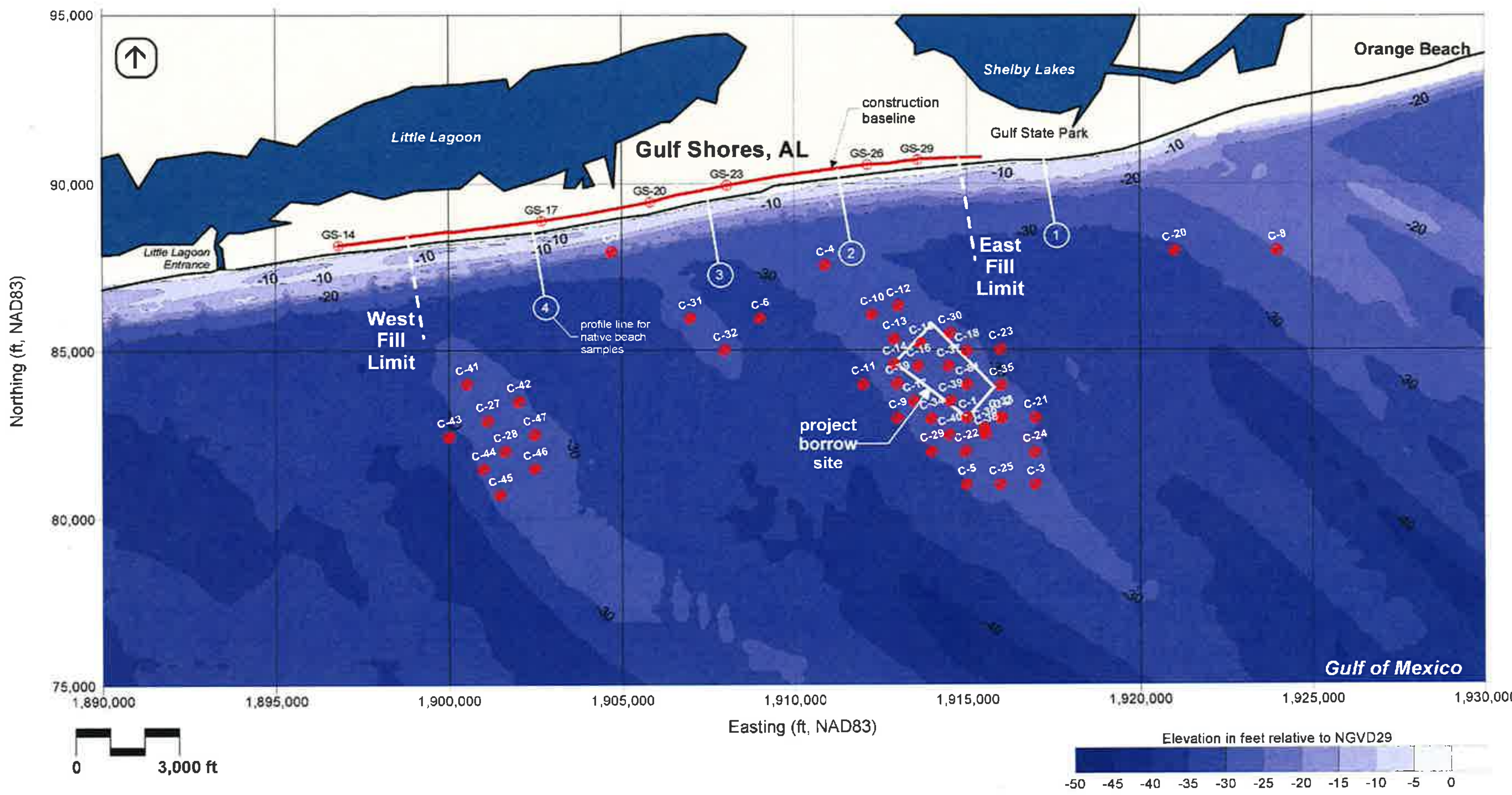


Figure 2.3 Location of Gulf Shores, AL, Beach Restoration Project construction baseline, native sampling transects, borrow site, and Vibracore locations.

3.0 NATIVE BEACH CHARACTERISTICS

Figure 3.1 presents a comparison of the composite grain size distributions generated from each cross- shore position of 35 of 36 collected samples (one sample was primarily peat and was excluded from the calculation). The sediments demonstrate a pattern of offshore fining (Table 3.1). All samples can be generally classified as quartz, medium- to fine-grained sand (Unified Soils Classification) or coarse- to fine-grained sand (Wentworth scale) with very low percentages of shell content (generally less than one percent, estimated). Data for each sample can be found on the attached CD-ROM disc. Sediment grain sizes are typically described in either phi units, ϕ, or millimeters, *mm*. Phi units are commonly used to relate various properties of a sediment sample (e.g. sorting, skewness, etc.). The relationship between diameter in phi units and diameter in mm is given in Equation 3.1.

$$d = 2^{-\phi} \tag{3.1}$$

The median diameter, D_{50}, of a sediment sample is that diameter for which 50% of the sample by weight is coarser (or finer). Median diameters for all the composite samples fall within a range of 0.27 mm to 0.39 mm (1.889 ϕ to 1.351 ϕ), and the composite median diameter is 0.31 mm (1.667 ϕ). All native samples contain a very low percentage of fine material (only one sample, collected in a small muddy patch, had a fine fraction, smaller than a #200 sieve, greater than 2.2% by weight). The sorting of a sediment sample describes the degree to which all sediments are similarly sized. This value is represented by the standard deviation/sorting coefficient of the sample, given by

$$\sigma_\phi = \frac{(\phi_{84} - \phi_{16})}{2} \tag{3.2}$$

The average sorting coefficients for the native beach is 0.49, indicating a well-sorted sample ($\sigma_\phi < 0.50$), meaning most of the grain sizes in the sample are fairly similar[1].

---

[1]A perfectly sorted sample would be a sample in which all the sediment grains are the same size ($\sigma_\phi = 0$).

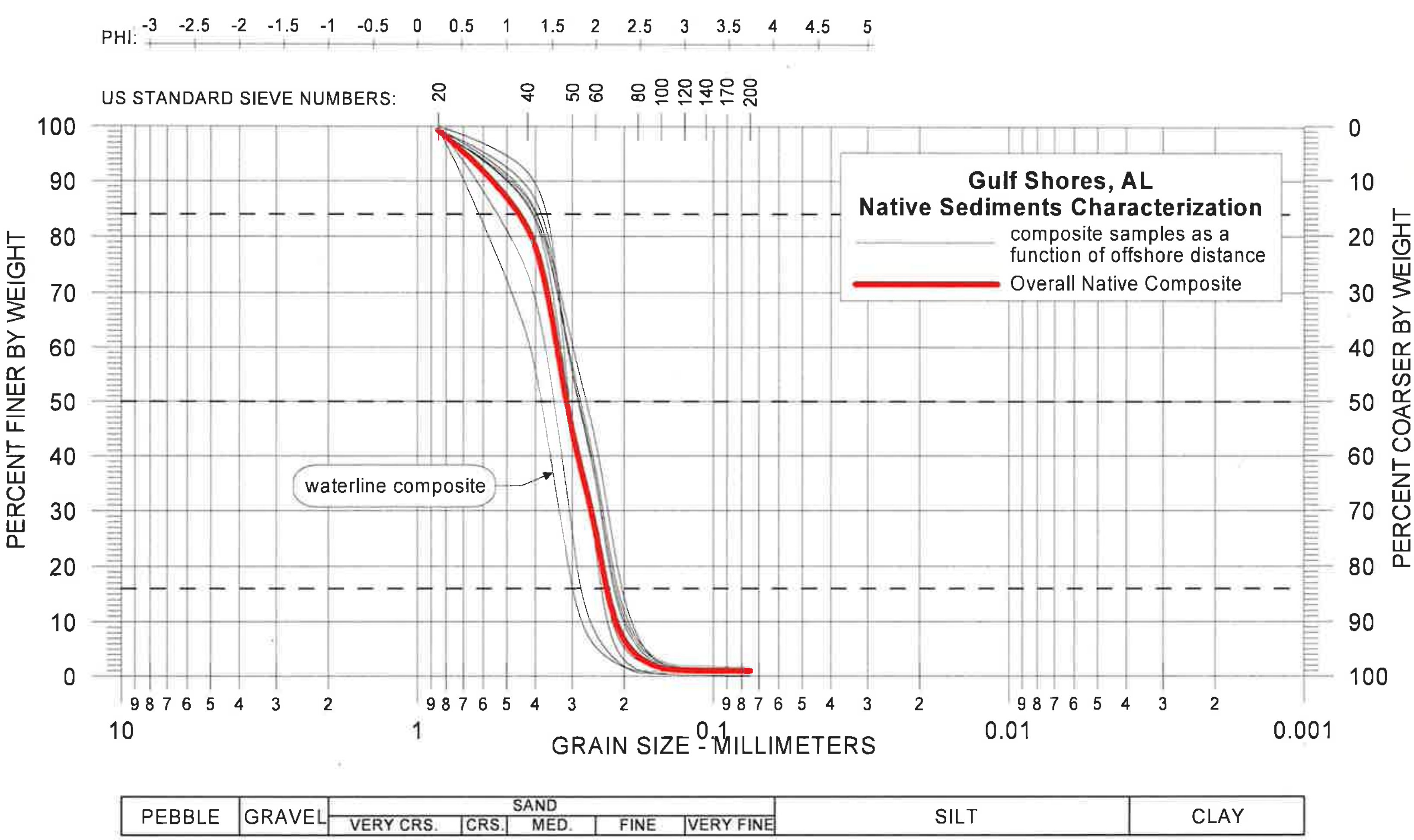


Figure 3.1 Comparison of overall composite grain size distribution to composites generated at each cross-shore station on the beach profiles at Gulf Shores, AL. The composites indicate the fining of sediments in the offshore direction (Table 3.1). The waterline composite is the coarsest sample.

Table 3.1 Median Diameter of Gulf Shores Native Beach Composite Samples

Cross-Shore Location	**D_{50} (mm)**
Back of Berm (toe of dune)	0.38
Top of Berm (berm break)	0.36
Waterline	0.39
-3.0-ft depth	0.31
-6.0-ft depth	0.29
Trough	0.29
Bar Crest	0.28
Gulfward of Bar Crest	0.27
Profile Average	0.31 - 0.32

**NOTE: data collected by S. Douglass, December 1999.

Native Sediment Color Native sediment samples were roughly graded for color by Ellis and Associates, Inc., of Jacksonville, FL. The samples were classified as tan or light tan in color. Informal color grading by Olsen Associates, inc., staff suggests that the native beach color can initially be characterized by use of the standard Munsell Soils Color Charts. Use of the 10 YR Hue in that reference classifies the native sediment as a 10YR 8.0/2.0 (Very Pale Brown), where the 8 refers to the Value (how light or dark a color is on a scale of 0-10), and the 2 refers to the Chroma (how vivid a particular color is on a scale in which 0.0 indicates a grayscale color between pure black and pure white), in this case Yellow-Red (YR)). The "standard" Munsell Soils Color Chart only extends upward to a Value of 8.0. The native material may actually exceed that Value. Using a specific Munsell product, the 10YR Hue Page, the scale can be refined and extended to a Value of 9.0. Application of the 10YR Hue Page to the Gulf Shores native sediments suggests that a large percentage of the native sands may be classified as a 10YR 9.0/1.5. The Chroma of 1.5 indicates a slight tan or orange cast to the native sands.

4.0 GEOPHYSICAL INVESTIGATION & CORE-BORING COLLECTION

The nearshore region seaward of Gulf Shores, AL, was searched to identify the highest-quality sediment source in an area of sufficient volume to cost-effectively construct a beach restoration project. Quality in the present context refers to grain size distribution, shell content, and color. In addition to the characterization of the native sediments, the offshore sand search consisted of:

- Literature survey of relevant previous investigations,
- Seismic sub-bottom survey (November 1999),
- Sediment core-boring collection (November 1999),
- Logging, sampling, and analysis of collected cores.

The required volume of sand identified to properly construct the project was approximately 1.5 million cubic yards (Mcy). To provide a sense of scale, 1.5 Mcy is translated into several different terms for the layman:

- If 1.5 Mcy of sand were delivered to Gulf Shores by dump-truck, approximately 100,000 dump-truck loads would be required (a dump-truck typically carries up to 15 cubic yards per load).
- If 1.5 Mcy of sand were placed on a football field, the pile of sand would be roughly 850 ft in height.
- A cube of sand occupying 1.5 Mcy would be 343 ft on a side.

4.1 Previous Investigations

Various investigators have studied the geologic makeup of the seabed in the vicinity of Gulf Shores, AL. Locker et al. (1988) conducted a Panhandle survey of sub-bottom structure and surface sediment sampling, primarily offshore of Florida. While their study covers an extensive area westward to Gulf State Park in Alabama, the density of data in the area of Gulf Shores is insufficient to gain any useful information regarding the development of a borrow site suitable for beach restoration.

McBride et al. (1999) conducted numerous studies in the Pensacola Pass, FL, to Mobile Bay, AL, area, collecting sediment samples and core borings out to the edge of the continental shelf at DeSoto Canyon. Several of the cores collected in this study were taken in the nearshore region offshore of Gulf Shores, all below 30 ft MSL. The cores reveal several differing sediment types, but generally revealed a thin lense of marine sands overlying relict estuarine silty clays and marine shell beds. The authors present information detailing the shift in shelf sediments between the Mobile subprovince and the Apalachicola subprovince to the east. The Mobile subprovince receives finer sediments from Mobile Bay and thus has a distinctly finer nature than the Apalachicola subprovince. The boundary between the two intersects the shoreline east of Gulf Shores in the West Orange Beach area.

Parker et al. (1997) present an investigation of nearshore leasable sand deposits for potential beach nourishment use. The authors characterize the area offshore of Shelby Lakes (Figure 2.3, generally south of the cores shown in Figure 2.3) at the eastern end of Gulf Shores as potentially containing 160 Mcy of clean sand. The sediments are characterized as having clean medium sand with a mean grain diameter of 1.99 ϕ and an average sorting coefficient of 0.86 ϕ. While these values are finer and more widely distributed than the native Gulf Shores sands, in all likelihood, some fraction of that 160 Mcy deposit is compatible with the Gulf Shores beaches.

While it is *unlikely* that the entire area and 160 Mcy are composed entirely of truly "beach compatible" materials, Parker et al. do identify the coarser sediments on the crests of transverse ridges in the area. It is the crest of one of these ridges that was ultimately identified as the borrow site for the beach restoration project (see below).

Hummell (1999) prepared a study of offshore sand resources in the Morgan Point Peninsula area. The study, sponsored by the Minerals Management Service of the U.S. Department of the Interior, focused on lands lying in Federal waters, more than 3.0 miles offshore. Hummell identifies the area as a Holocene transgressive fluvial-deltaic and marine fill sequence overlying older estuarine and fluvial deltaic deposits. The author describes the genesis of the NW-SE oriented transverse ridges also described by Parker et al. (1997). The author discusses the composition of additional core borings taken during the study, and identifies potential beach nourishment borrow materials south of the Morgan Point Peninsula. Hummell generally describes the surficial sand sheet as an excellent source of borrow materials, but he does recognize that project distances, lense thickness, and other issues may limit the usefulness of some areas. Similar to the Parker study, it is unlikely that the entire surficial sand sheet is "beach compatible." Project-specific geotechnical analysis would be required to establish an area's viability as a borrow site.

4.2 Seismic Sub-Bottom Survey

To identify potential areas for detailed investigation via sediment core-boring, an acoustic/seismic sub-bottom survey was conducted along approximately 80 miles of offshore tracklines at Gulf Shores, AL. The acoustic survey, performed by Alpine Ocean Seismic Survey, Inc., Norwood, NJ, consists of the measurement of pulses of sound directed into the seabed. The time of return of various frequencies of the reflected sound pulse provides information regarding changes in density of the material in the upper 50 ft (approximate) of the seabed. In this manner, areas characterized by multiple layers of sediment can be distinguished from areas containing little or no layering. In general, areas containing potential volumes of sandy-type sediments are those that are essentially featureless in the upper roughly 20 ft of the seabed. Areas with significant layering generally have alternating layers of mud or silt with layers of dense sand or clay (obviously undesirable material for a beach). The findings of the subbottom survey, along with the subsequent core-boring efforts, are described in AOSS (2000). A copy of that report is included as Appendix A. Full scale maps produced by AOSS are included on the attached CD-ROM disc.

4.3 Vibracore Collection

Using the results of the subbottom seismic survey, areas were identified for further investigation via core-boring. The sediment core-borings were collected using a vibrating pneumatic rig (Vibracore) set to collect a 20-ft core sample (Figure 4.1). Referring to Figure 2.3, 47 cores were collected. The coring efforts centered principally on the crests of two prominent transverse sand ridges. These features are similar to those identified by Parker et al. (1997), and Hummell (1999). Guided by field inspection of the sediment quality and color, a potential borrow site was identified on the eastern ridge, located approximately 1.5 miles offshore of the eastern end of the restoration project. All vibracores were prioritized for logging by a professional geologist for sediment composition and color. Composite sediment samples of each core were analyzed for grain size distribution, color, and shell content. All logs, core photographs, and grain-size data are provided on the attached CD-ROM disc.

Figure 4.1 Pneumatic core boring rig (left) on the Research Vessel Atlantic Twin, owned and operated by Alpine Ocean Seismic Survey, Inc., of Norwood, NJ. Twenty-foot sediment core ready for labeling and cutting (right).

Once in the laboratory, the cores are split and examined for logging (Figure 4.2). The logging describes the various layers present within the core. The sediments classifications are based on the Unified Soils Classification System (USCS). Generally, in the USCS system, beach quality sediments will have an SP rating. Several cores collected outside of the borrow site areas were rated as SM or ML sediments. These sediments have noticeably higher percentages of fine particles or muds and, for that reason, are not analyzed for grain size distribution. These muddy sediments are typically much darker in color than the sandy materials. Individual samples are taken from various elevations in the core and analyzed for grain size distribution, shell content, percentage of fine material, etc. These procedures were conducted by Scientific Environmental Applications, Inc., of Melbourne, FL.

The reader is referred to Appendix A and the attached CD-ROM for further information regarding the geophysical survey and the Vibracore analysis.

Figure 4.2 Segment of Vibracore Core C-37 collected in the borrow site. The figure shows the white sands in the split core between 10 and 11 feet below the seabed.

5.0 BORROW SITE ANALYSIS

Having identified the general location of the project borrow site, the Vibracore and laboratory data were analyzed to refine the area and to compare the borrow sediments with the native. This comparison consists of the analysis of the grain size distributions, percent fines content, shell content, and sediment color. The native beach sediments are described in detail in Chapter 3. This chapter focuses on the borrow sediments and their similarity to the native beach. The cores that define the selected borrow site are shown in Figure 2.3. The borrow site[2] occupies an area of approximately 100 acres in water depths of approximately 26 to 29 ft. Inspection of the Vibracores and the subbottom survey results indicated that a 15 ft lense of desirable sediment could be reliably excavated throughout the borrow area. The discussion of the borrow site analysis in this report focuses on the geotechnical aspects of the site. A separate analytical study was performed to model and predict the potential changes to the nearshore wave and littoral transport climate resulting from the excavation area subsequent to construction. That report, and a summary of it, can be found in the companion engineering report, Olsen Associates (2001).

5.1 Grain Size Distributions

Figure 5.1 plots the composite grain size distributions of the cores typifying the borrow area. For comparison, the native beach composite distribution is shown. The core composites compare quite well to the native beach distribution. Some core composites do indicate a higher fraction of coarser material, reflecting the slightly higher shell content of the borrow area. Inspection of the borrow area grain size distributions reveals an average grain size of 0.32 mm and an average sorting coefficient of 0.94. A quantitative comparison of the native and borrow sediments in terms of overfill ratios follows.

2

As described in the companion engineering report, during construction, the borrow site was expanded slightly, by way of an approved permit modification, to provide additional fill material. The site was expanded by approximately 17 acres along the southwestern border of the site (expanded from 83 to 100 acres). The reader is referred to the engineering report for additional details of the project construction.

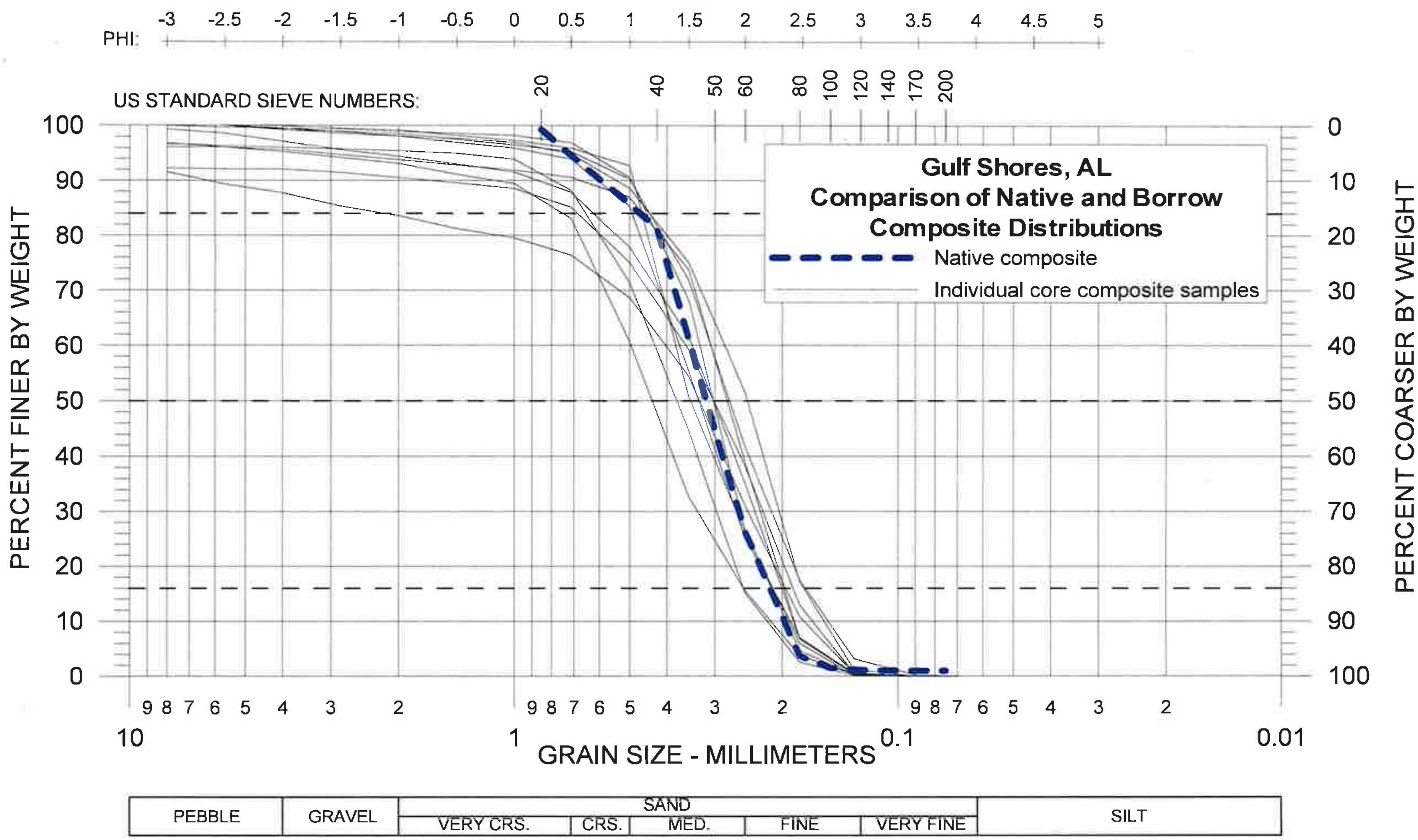


Figure 5.1 Comparison of native beach composite grain size distribution to composite distributions within the borrow site at Gulf Shores, AL.

5.2 Overfill Ratios

Rarely if ever are sediment samples composed entirely of material of the exact same size (hence the sorting coefficient term introduced earlier) and rarely if ever are two sediment composites typifying beach or borrow areas composed of the same distribution of sediments. The concept of an overfill ratio is therefore used to describe the additional volume (or reduced volume) of sand necessary to account for differences between the native beach and the proposed borrow sediments. In so doing, each native beach or borrow "composite" is made up of numerous individual samples. Dean (2000) provides an overview of the overfill ratio history and methods, as well as the look-up charts used in the methods. The Shore Protection Manual (USACE, 1984) also provides an overfill ratio calculation discussion.

Based upon the distributions shown in Figure 5.1, overfill ratios for the offshore borrow site were computed using two methods. The first method is that of Dean, which is a modification of the work of Krumbein and James. These methods assume a particular shape of the distribution of sediment sizes within a sample. The methods then seek ways to discount the portion of the borrow material that is not entirely similar to the native beach. Dean assumed that any portion of the borrow material that was finer than the native distribution would be washed away by the energy in the wave climate[3]. That loss of the finer fraction of the borrow material forms the basis for the overfill ratio of Dean.

James modified the Krumbein-James method to only include the loss of the finer fraction of the fill. While both methods consider only the finer fraction of the borrow material, the James method is typically the more conservative of the two methods (i.e., it yields a higher overfill ratio for the same sediments). In addition to the overfill ratio, James presents a renourishment factor that is intended to describe the performance of a beach fill based on the fraction of the fill remaining after the finer fraction winnows out. The methods

3

In comparison the original Krumbein-James method (1965) discounted both the finer and coarser excess fractions of the borrow material.

of James are presented in the Shore Protection Manual. Figure 5.2 presents a graphic example of two very different sediment samples. The figure illustrates the effect of the difference in sorting coefficient and the effect of a significant difference in mean grain size. The shaded area of the borrow sample curve represents that portion of the beach fill that would be expected to winnow out of the beach fill more rapidly. That volume, therefore, needs to be 'discounted' in the prediction of the performance of the pumped fill.

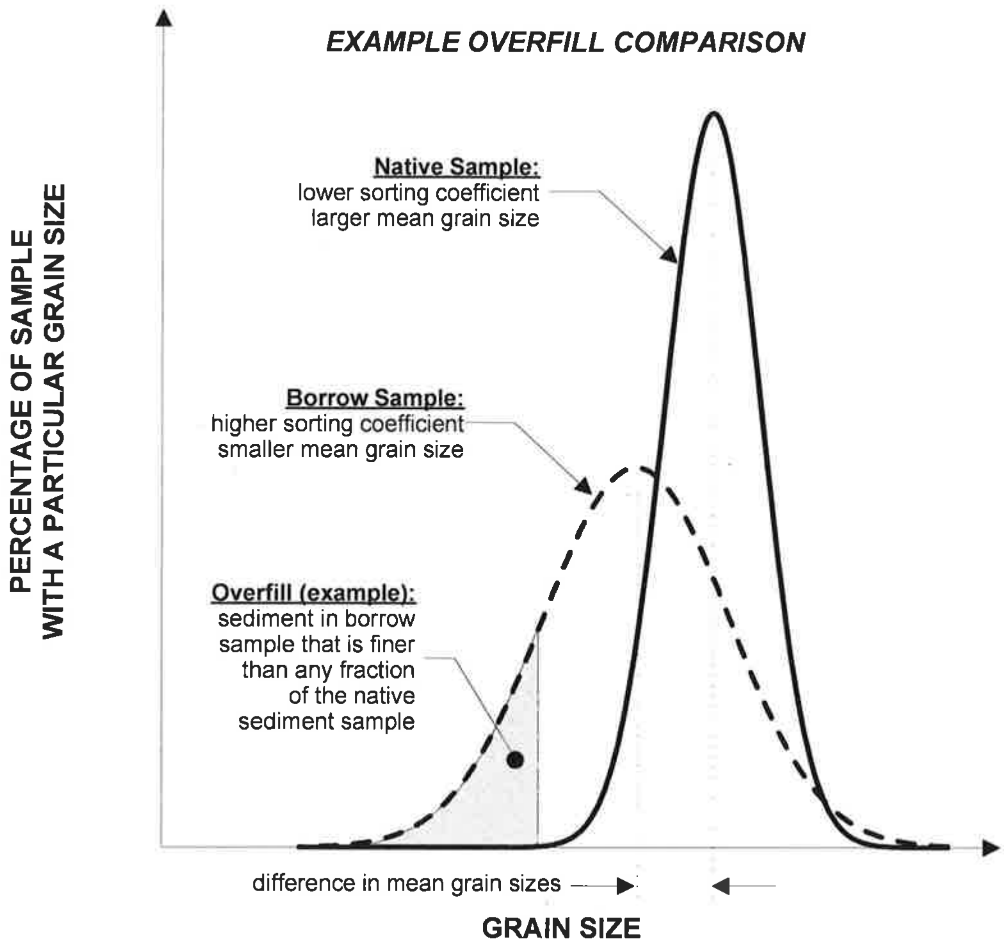


Figure 5.2 Illustrative example of borrow and native sediment comparison and overfill ratio origin.

Using the Dean method, the average computed overfill ratio is 1.0 (the look-up chart presents values as low as one). Using the James method, the computed overfill ratio is 1.2. The computed renourishment factor is 0.4. The two James numbers may seem initially to contradictory (e.g. "*More fill is required but it is predicted to last longer?*"). This issue is discussed in the Shore Protection Manual and can be understood by inspection of the sorting coefficient and the distributions themselves. In cases where the borrow sediments are more poorly sorted (higher sorting coefficient) but the mean diameters are reasonably similar (as in the present case), the finer fraction dictates that a larger fill volume is required. However, once that finer fraction is winnowed out of the beach fill, the excess coarse fraction theoretically produces extended longevity of the beach fill. For the project under consideration, Olsen Associates, Inc., has recommended an overfill ratio of 1.0.

5.3 Percent Fines and Heavy Mineral Content

The cores in the borrow area were evaluated for the percentage of fine materials and heavy minerals present. These constituents can produce a darker colored component to the fill material, and only the organic portion of the fine fraction might be expected to lighten significantly over time (these and other fine particles typically wash out during the dredging and beach construction process or oxidze once exposed to sunlight). Inspection of the fines fraction (those particles passing a #200 standard sieve, smaller than 0.075 mm) from the cores in the borrow area reveals a maximum in-situ fines percentage of 1.53% by weight. This compares extremely well to the native beach samples. A table containing the mud and sand percentages for each core collected can be found on the attached CD-ROM disc.

Microscopic examination of several samples from the borrow area by a professional geologist (SEA, Inc.) revealed trace amounts of some heavy minerals. The primary trace mineral is feldspar, which contains some potassium. The trace amounts do not contribute significantly to the color of the sediment, which is predominantly clear quartz.

Throughout most of the borrow site Vibracores, both pieces of shell fragments and whole shells were observed during the logging process. These shells and shell pieces account for a very small percentage of the borrow site by weight. As expected, they are visually apparent in the constructed project beach.

5.4 Sediment Color

The beaches of the northeast Gulf of Mexico panhandle shoreline east of Mobile Bay are well known for their nearly white color and coarse composition. Sediment color, therefore, is a primary element in the selection of a suitable borrow site. This presents several engineering challenges, because the sediments found in the submerged nearshore region will not immediately resemble those on the native beach, even if the sediments are identical. The submerged sediments are typically mixed with a slightly greater fraction of fine material, which is frequently organic and darker in color. Much of these fine materials tend to disperse easily (i.e., washout) during the hydraulic dredging and placement process. The fine sediments that do remain within the fill berm are then subjected to weathering by sunlight, rain, and wave action. These processes tend to lighten/fade the materials. The difficulty lies in recognizing how, and if, borrow material obtained within a Vibracore will ultimately match the native beach in appearance.

The Vibracores were graded for color during the logging process by the professional geologist (SEA, Inc.). The color scale was the 'standard' Munsell Soil Color Charts, which extend upward to a Value of 8.0, and downward to a Chroma of 1.0. Using the limited color scale, the average color grading of the borrow site cores was a 7.0/1.5 (Value/Chroma). Inspection of the photographs of the cores suggests that many of the segments of the cores that were graded with Values of 8.0 were actually lighter in Value, approaching 9.0. It is hypothesized that had the cores been graded on the complete Munsell scale, the average color grading would approach a 10YR 8.0/1.5. This value is still lower in Value than the native beach sediments. However, the gradings were made on the cores without benefit of weather exposure (see below).

Weather Exposure To attempt to gage the impact of weather exposure on the sediments in the borrow site cores, composite samples were set out for limited solar exposure testing during the design phase of the project. SEA, Inc., graded the samples for color at approximately two-week intervals for a roughly six-week period. During that time, most of the samples demonstrated an increase in color value of 1 Value point (generally from 7.0 to 8.0, again using the limited scale). Tables of color exposure testing can be found on the attached CD-ROM disc. This increase suggests that the bulk of the borrow material would be expected to lighten considerably in the first few weeks of exposure to the elements. Inspection of the in-place borrow material over the first three months of the project indicates that this phenomenon has in fact occurred. Based on the limited exposure testing conducted for this project and for the Pensacola Beach, FL, Beach Restoration project, in design phase at the time of this writing (Browder and Olsen, 2001), the lightening/fading of the borrow material utilized occurs rather rapidly. This has also been the authors' observation of the Panama City Beach project, where some areas of very dark material were placed to significant depths. This dark material, once it reaches the surface, lightens up rapidly over a period of weeks.

Observation of the Gulf Shores Beach Restoration Project sands following completion of the project suggests that the borrow material has lightened to as much as a 9.0 or 9.25 in Value (10 YR Hue). The Chroma of the borrow material appears to be lower than the native, which had a distinct tan or light orange tint. The borrow material is much closer to a true light-gray/white with a Chroma at or below 1.0.

6.0 REFERENCES

Alpine Ocean Seismic Survey, Inc. (AOSS, 2000), "*Subsurface Investigation by Subbottom Profiler and Vibracore for Gulf Shores, Alabama, Beach Restoration Project,*" Report submitted to Olsen Associates, inc.
Report in Appendix A and in PDF format on attached CD-ROM disc.

Browder, A.E., and Olsen, E.J. (2001), "*Pensacola Beach, FL, Feasibility Study for Beach Restoration,*" Report submitted to the Santa Rosa Island Authority and the Florida Department of Environmental Protection Office of Beaches and Coastal Systems.

Dean, R.G., 2000, "*Beach Nourishment Design: Consideration of Sediment Characteristics*" Coastal and Oceanographic Engineering Department, University of Florida, Gainesville, FL. UFL/COEL -2000/002.

Hummell, Richard, 1999, "*Geologic and Economic Characterization and Near-term Potential of Sand Resources of the east Alabama Inner Continental Shelf offshore of Morgan Peninsula, Alabama,*" Open File Report 99-01, Geological Survey of Alabama, Tuscaloosa, Alabama, 231 p.

Locker, S.D., Logue, K.T., and Doyle, L.J., 1998. "*Neogene Stratigraphy, Bedforms, and Surface Sediments: NW Florida State Waters,*" Report submitted to GECO Geophysical Company. The Center for Nearshore Marine Science, University of South Florida, Tampa, FL.

McBride, R.A., Anderson, L.C., Tudoran, A., and Roberts, H.H., 1999, "*Holocene Stratigraphic Architecture of a Sand-Rich Shelf and the Origin of Linear Shoals: Northeastern Gulf of Mexico.*" In: Bergman, K.M., and Snedden, J.W., (editors), *Isolated Shallow Marine Sandbodies: Sequence Stratigraphic Analysis and Sedimentologic Interpretation*, Society of Sedimentary Geology Special Publication #64, Tulsa, OK. PP 95-126

Munsell Color, 1998, "Munsell® Soil Color Charts, 1998 Revised Washable Edition," Munsell® Color, GretagMacBeth, New Windsor, NY

Munsell Color, 1998, "Munsell® Color, Nearly Whites™ Fandeck," Munsell® Color, GretagMacBeth, New Windsor, NY

Olsen Associates, 2001. "*Gulf Shores, AL, Beach Restoration Project – Report of Project Construction and Supporting Analyses,*" Report submitted to the City of Gulf Shores, Alabama.

Parker, S.J., Davies, D.J, and Smith, W.E., 1997, "*Geological, Economic And Environmental Characterization Of Selected Near-Term Leasable Offshore Sand Deposits And Competing Onshore Sources For Beach Nourishment,*" Alabama Geological Survey Circular 190, 173p.

SEA, 2000, "*City of Gulf Shores, Alabama, Beach Renourishment Project: 1999-2000 Offshore Geotechnical Investigation Core Boring Logs and Photographic Records Cores C-1 - C-81,*" reports submitted to Olsen Associates, Inc., by Scientific Environmental Applications, Inc. (SEA), Melbourne Village, FL.
Data report provided on CD-ROM (attached).

U.S. Army Corps of Engineers, 1984, "*Shore Protection Manual,*" U.S. Army Corps of Engineers, Department of the Army, Washington, D.C.

APPENDIX A

FINAL REPORT

SUBSURFACE INVESTIGATION BY SUBBOTTOM PROFILER AND VIBRACORE FOR GULF SHORES, ALABAMA BEACH RESTORATION PROJECT

Prepared for:

Olsen Associates
4438 Herschel Street
Jacksonville, Florida 32210

Submitted by:

Alpine Ocean Seismic Survey, Inc.
70 Oak Street
Norwood, New Jersey 07648

March 22, 2000

TABLE OF CONTENTS

1.0 INTRODUCTION

This project was conducted by Alpine Ocean Seismic Survey, Inc. (Alpine) under subcontract to Olsen Associates, Jacksonville, Florida, for the town of Gulf Shores, Alabama. The purpose of the project was to identify potential offshore sand borrow areas which could be used as sources of sand for beach reconstruction along the coast of Gulf Shores. The regional setting of the survey area is shown in Figure 1.

The project was conducted in two parts, consisting of approximately 66 nautical miles of bathymetry-subbottom seismic survey and 47 cores obtained using the Alpine 20 foot Vibracore sampler. The two parts were conducted consecutively in November 1999. The R/V Atlantic Twin was used as the support vessel for both the seismic survey and the Vibracore sampling.

2.0 GEOLOGIC SETTING

The sediments of the Alabama inner continental shelf consist of Holocene transgressive fluvial-deltaic and marine-fill sequences overlying estuarine and fluvial-deltaic sediments of late Pleistocene age.[1] An erosional disconformity, formed at the time of the most recent sea level transgression, separates these two sediment units. In addition, the sediments in the study area include recent sediments typical of coastal barrier island sequences, such as lagoonal clays and sand units deposited in areas where inlets have eroded channels through the barrier islands and subsequently migrated along the barrier coast. These sediments have been reworked by waves and currents to form the coastal barrier beaches and the series of offshore transverse sand bars present in the study area. A contoured plot of water depth data collected in the study area by National Ocean Survey indicates that the ocean bottom topography is dominated by a series of transverse sand bars or ridges and troughs, oriented in a northwest-southeast direction. These ridges are shown on Figure 2, Survey Grid and Core Locations.

Morgan Peninsula, located adjacent to the eastern side of the mouth of Mobile Bay, has been formed by the western movement of sediment along the coastline. Along the southern side of Morgan Peninsula are various narrow, shallow coast-parallel lagoons. One of these is known as Little Lagoon, which is located to the west of Gulf Shores. Two others, known collectively as Shelby Lakes, are located to the east of Gulf Shores. Little Lagoon is connected to the ocean by a narrow, man-made inlet.

Review of aerial photos of the coastline within the study area, along with the local marine charts, indicates that there is a complex set of low ridges and swales present on land behind the barrier island in the vicinity of Romar Beach. These ridges clearly curve to the southwest at an angle to the present coastline. Some of the ridges are located on the southeast side of the eastern Shelby Lake, while some are located on the north side of that lake. These ridges, and the shallow marsh environments between them, may extend under the barrier beach, and the variations in sediment grain size may control local beach erosion rates.

It appears from local maps that Shelby Lakes were once connected to the ocean by an inlet, but that inlet has apparently closed due to natural sediment migration. There is a moderate bump out in the coastline direction at this location, and that may be controlled by the remnants of the former barrier inlet.

Just to the east of this postulated former inlet location, one of the transverse sand ridges is virtually attached to the beach face. The 20-foot depth contour is extended over 1500 feet offshore around this feature, whereas in the remainder of the study area, the contour is generally less than a few hundred feet from the beach, and is relatively straight along the beach face. The presence of this large sand bar may also be indicative of a former active inlet, supplying a significant sand supply to an ebb tidal delta.

Work by Swift and Field[2] on the evolution of similar sand ridges along the Maryland coastline indicate that the ridges in that area are formed and move in response to storm generated currents moving in a southerly direction. In the Maryland area, the coastline runs more north-south and the axes of the ridges are aligned in a northeast-southwest direction, approximately 35 degrees away from the coast. In the Gulf shores area, the coastline is approximately east-west in direction while the ridge crests are aligned in a southeast-northwest direction, also about 35 degrees to the coast. The storm currents in the Gulf area would be generated by hurricanes moving up from the south, such that the currents would be moving to the west along the beach in response to the counter-clockwise motion of the winds around the approaching hurricane.

Where the sand input is large enough, the ridges are composed completely of sand. Where the sand input is not adequate to support the ridge form, the currents will erode the existing bottom to create the sand form, capping the ridge areas with the available sand. This erosional wave form seems to be the case in the study area.

Farther to the east is Perdido Pass, which connects Bayou St. John to the ocean. The location of this inlet is artificially maintained by a set of stone jetties. The shape of the inlet, along with westerly extension of beach on the east of the inlet, indicates that the inlet would migrate to the west if not artificially stabilized. Sediment dredged from the inlet has been stockpiled on the beach on the west side of the inlet to offset local beach erosion in the lee of the down drift jetty.

3.0 PREVIOUS WORK IN THE PROJECT AREA

The beaches of the area were severely eroded by hurricane George and others in the 1990s. Various projects have been undertaken to determine the location of potential sand sources for use in beach renourishment projects in the impacted area. Parker and others published Alabama Geological Survey Circular No. 190, entitled Geological, Economic and Environmental Characterization of Selected Near-term Leasable Offshore Sand Deposits and Competing Onshore Sources for Beach Nourishment.[3] That study concentrated on five blocks, two of which are located offshore of Gulf Shores, Alabama. The inshore edges of these blocks are 2 to 2.5 miles offshore, and extend five to six miles farther out from those starting points, as shown on Figure 3, adopted from Hummel. Parker's eastern block included portions of the area of transverse sand bars.

The most recent publication summarizing the available information was conducted by the Geological Survey of Alabama, which published Open-File Report 99-01, entitled "Geologic and Economic Characterization and Near-term Potential of Sand Resources of the East Alabama Inner Continental Shelf Offshore of Morgan Peninsula, Alabama" by Richard L. Hummel. The project was funded by Minerals Management Services, U. S. Dept. of the Interior. The Hummel project, being funded by federal funds, concentrated in the area beyond three miles from the coastline, known as the Exclusive Economic Zone. Hummel determined that, although sources of sand were present in sand ridges and transverse bars, a greater volume of sand was present in the form of a "geographically extensive shelf sand sheet." Hummel concentrated on mapping the shelf sand sheet in the area south of Morgan Peninsula.

Hummel presents descriptions of nine Holocene and one pre-Holocene lithofacies, each representing one or more depositional environments. The descriptions of these cores, as presented in Hummel, are included in this report for reference. These lithofacies descriptions are used in the latter parts of this report to refer to sediments in the Alpine cores.

Figure 3 includes the locations of core samples obtained by Parker and by Hummel. One of Parker's cores (SR-45) and three of Hummel's cores (SR-110, 111 and 112) were found to be within the bounds of Alpine's project and they are located as shown on Figure 2. Two other cores which were included in Hummel and were shown as being within the Alpine study area, namely G-12 and G-13, may have been miss-located, as the water depths given for these cores (10.3 and 11.7 feet) do not correspond to the water depths at the locations given in the text for these cores (30 and 26 feet).

Cores SR-110 and SR-111 were collected in locations not sampled by Alpine. According to the stratigraphic log in Hummel for SR-110, there was a basal shell layer between 4.5 and 5.8 feet below ocean bottom. The sediments above this layer were described as being sand, fining upward. The sediments below the shell layer were sand, but with wood debris and abundant bioturbation. The sand above the shell layer is taken as representing the surficial sand sheet, while the silty sediments with wood fragments are described by Hummel as being part of the Holocene marsh and peat lithofacies.

In core SR-111, the sand layer above the shells is less than two feet thick, and there was a gray clay layer present at about 8 feet below bottom. Between the shell layer at 2 feet and the clay layer at 8 feet was a unit of silty sand with frequent burrows and shell debris, somewhat similar to the lower sand unit in SR-110.

Core SR-112 was located in the vicinity of several cores collected by Alpine during the present study. This core contained over ten feet of sand above a basal shell layer, and the sand below the shell layer contained silt and evidence of burrows as found in cores SR-110 and SR-111. Core SR-112 was located near the crest of one of the transverse shoals present in the study area, while SR-111 was located between transverse ridges, corresponding to the difference in sand thickness at these two locations. SR-110 was located on the side of a ridge, with a sand thickness between the other two cores.

Core SR-45, obtained by Parker, was located on a transverse ridge, and contains approximately 8.5 feet of sand over a basal shell layer. The sediments below the shell layer contained increasing amounts of silt and mud-filled burrows below the shell layer, typical of the marsh lithofacies.

Hummel concluded, based on the thickness of the surficial sands described in the cores, that there were approximately 176 million cubic yards of sand in the surficial sand sheet within Parker's Area 1 and approximately 206 million cubic yards in Area 2. Constraints against use of some of this sand, as listed by Hummel, include the economics of a specific beach nourishment project, ship and gas industry infrastructure, historical and archaeological sites, sites of unexploded military ordinance, dredge material disposal sites, areas where the surficial sand sheet lithofacies deposit is too thin, environmental concerns and areas where a borrow site would not alter the wave climate and thereby cause or aggravate shoreline erosion and compromise shoreline storm protection.

Olsen Associates has been collecting beach profiles at several points of interest within the study area. Surficial sediment samples obtained along some of these profiles have shown that very fine sediments, including organic silts and clays are present in the shallow beach face in some portions of the project. This indicates that the sand wedge forming the barrier island in these locations is very thin in locations and, therefore, subject to rapid erosion.

4.0 METHODS

Methods used to determine the location of potential borrow areas in the study site included a Subbottom seismic survey to detect and map subsurface reflectors and Vibracore sampling to obtain a continuous twenty foot sequence of the sediments at selected core sites. The cores were subsequently split, described, and sampled by others to determine the grain size distribution of the various sediment layers.

The seismic data and core sediment data were mapped to provide a basis for estimating volumes of borrow sands available in the project area. The major reflectors on those seismic lines that passed through or near the cores were digitized and plotted for convenient geographic referencing. The cores were plotted on the digitized sections for comparison. The grain size distribution data were plotted adjacent to the cores, so that areas where the sediments most suitable for use as beach fill could be outlined on the map.

4.1 Survey Vessel

The R/V Atlantic Twin, a 90 foot steel catamaran hull research vessel with a seven-has ample laboratory and deck space, anchoring system, hydraulic crane, deck winches and A-frame capability for vibracoring. The navigational equipment and echo sounder, with associated computes, printer and display units were mounted in the pilothouse. The vessel has sleeping facilities to accommodate the crew and survey staff during the project.

4.2 Navigation

Navigation procedures for the seismic survey and Vibracoring operations were based on Trimble 4000 Series Differential Global Positioning System (DGPS). The Trimble unit received differential corrections from US Coast Guard base stations through a Trimble NavBeacon XL receiver. The NavBeacon XL system automatically locks onto the strongest Coast Guard signal, which results in optimal horizontal positioning during vessel operations. During the seismic survey, the navigation data from the Trimble DGPS was acquired and logged by the Hypack Software package, which logged positions and graphically displayed the vessel location in relation to the pre-plotted survey lines. The DGPS data are referred to WGS 84, and the software converted the Latitude-Longitude information into Alabama West state grid, NAD 83. Navigation fix positions were obtained at distance intervals of 200 feet.

The Sextant software package was used during the coring for ease of locating the vessel and core rig relative to pre-determined core sites. The actual location of the core rig was logged at the moment the coring rig was located on the ocean bottom at each site. The navigation antenna is located on the top of the A-frame that is used to lower the Vibracore to the ocean bottom.

4.3 Seismic Survey

A continuous Subbottom seismic reflection was completed using a DataSonics 6600 Chirp System. This system transmitted an output pulse that sweeps from 2 to 10 kHz frequency. The signal was transmitted through a set of four parallel- connected transducers mounted in a tow fish. The pulse length was 0.05 milliseconds at a one-quarter second repetition rate. The data were displayed on a video monitor and simultaneously recorded on an Alden thermal recorder and on a magneto-optical disk. The Alden recorder was set to 40 meters full scale, based on a speed of sound of 1500 m/sec.

Water depths were recorded using an Innerspace 448 digital echo sounder, with a 200 kHz, 9-degree beam width transducer. Hydrographic sounding were reduced to MLW using predicted tides for the entrance to Mobile Bay, as actual tidal data were not available for that location.

4.4 Vibracores

A Model 217B Alpine Pneumatic Vibracore configured to take cores 20 feet in length was used to collect 47 cores in the study area. The model 271-B consists of an air-driven vibratory hammer assembly, an aluminum H-beam which acts as a vertical guide for the vibrator, a set of four steel support pads and legs to hold the beam upright, a 4-inch diameter steel coring pipe, a cutting edge a core retainer, and a plastic core liner fitted into the core pipe. During operation, an air hose array provided passage of compressed air from a deck-mounted air compressor to drive the vibrator. A penetrometer was used to record the rate and depth of penetration by the core pipe into the seafloor.

In cases where the Vibracore did not penetrate to a full 20 feet, a jetting technique was used to increase core penetration and retrieval of sediments. Once the Vibracore penetrated to refusal at a site, the equipment was returned to the support vessel deck, the core liner removed and measured, and the Vibracore was re-deployed for a second run with a new liner installed. During the second run, a water jet pump was used to jet the core pipe to the depth achieved by bottom of the core from the previous run. At that depth, the jet was turned off and the air was turned on to the Vibracore, commencing core sampling on the second run. Once each core was on deck, the core liner was marked appropriately and cut into five-foot sections. Each section was then capped and taped for storage.

4.5 Operations

Field operations consisted of the following:

- The seismic survey commenced on November 21 and was completed on November 23, 1999. Seismic data were collected along sixteen pre-plotted track lines, spaced at 1000-foot intervals in an east-west direction.

- Vibracore sampling commenced on November 24, 1999. Core locations were initially determined based on a proposed grid established on a central transverse sand ridge. The proposed core locations were subsequently modified in the field based on the grain size distributions observed in the cores. Cores location which were observed to contain significant amounts of coarser grain sediments were used as the starting points for a grid of additional sample locations, while those core locations which contained significant concentrations of fine grained sediments were abandoned. Coring operations were completed on November 28, 1999.

4.5.1 Summary Log of Operations

20 November 1800 R/V Atlantic Twin arrives Pensacola, FL.
Commence seismic equipment mobilization.
21 November 0600 Dense fog
1000 Depart Fuel Dock in Pensacola for site
1600 Arrive at site, conduct bar check, deploy seismic profiler and commence survey on line 16, outermost survey line.
1900 Docked at Orange Beach, AL, inside Perdido Pass
22 November 0700 Depart dock for site

	0815	On site, deploy gear, commence survey
	1800	Return to dock at Orange Beach
23 November	0700	Depart dock for site
	1600	Finish survey, return to dock to mobilize for coring

24 November 0600- Dense fog; client,
0925- Depart harbor for work site
1020- Near work area; stop to set out legs on Vibracore and conduct bar check
1045- Anchored on site for first core
1700- Depart work area for dock, having completed 9 cores
1800- Docked at Orange Beach, AL
25 November 0600- Dense fog
0830- Depart harbor for work site
0955- Anchored on first site
1730- Depart work area for dock, having completed 10 cores
1845- Docked at Orange Beach, AL

26 November 0615- No fog, underway to site
0730- Anchored on first site
1600- Depart work area, having completed 11 cores
1715- Docked at Orange Beach, AL

27 November 0600- Underway to site
0715- Anchored on first site
1500- Depart work area, having completed 10 cores
1610- Docked at Orange Beach, AL

28 November 0615- Underway to site
0740- Anchored on first site
1300- Depart work site, having completed 8 cores, for a total of 47
1415- Docked at Orange Beach, AL; demobilize geophysical and Vibracore equipment and make vessel ready for travel

29 November Complete demobilization; vessel departs for Tampa, FL

4.5.2 Personnel

The following personnel were involved in the project:

Captain R/V Atlantic Twin	Darren McClave
Field Manager/Geophysicist	Charles Dill
Electronics Technician	Terry Snyder
Navigator/Geologist	Maurizzio Rossi
Technician	Andrew Asbury
Technician	Ovidio Hernandez
Client	Erik Olsen

5.0 DATA PRESENTATION

Published bathymetric data for the site were used to present the water depth contours presented on Figure 2. The track lines surveyed during the seismic data collection portion of this project with fix number annotations are overlain on the bathymetric data. Vibracore locations are indicated on the chart and are tabulated in Table 1. The penetrations graphs and field data for the cores were presented under separate cover. The cores were logged and described by others, but that descriptive sedimentological data has been referred to in the preparation of this report. Figure 4 (Geological Features and Isopach of Surficial Sand Sheet) summarizes the seismic and sedimentological data for the site.

Sections of various seismic survey lines were selected for profiling to show the distribution of significant reflectors in the areas where Vibracore samples were collected. The significant stratigraphic changes in the cores are shown on the sections for comparison to the seismic reflectors. The total core length is based on the penetration depth recorded in the field when the core was collected. The horizontal scale of the sections is the same as that used for the track lines shown on Figure 2. The vertical scale is equivalent to that displayed on the seismic sections. The depths to reflectors were determined using a speed of sound of 5000 ft/sec. These selected sections are shown on Figures 5 and 6, Geologic Cross Sections.

The depth below the ocean bottom to the first major continuous reflector is shown on several of the seismic sections. The sediments above this reflector consist mostly of sands that may be useful for beach nourishment. The mean grain size data, in millimeters, and the thickness of the sand unit, are shown adjacent to the cores on Figure 4. Alpine has prepared an isopach map of the thickness of this sediment unit, based on the seismic data. The north side of the isopach contour area ends as a dashed line because the reflectors could not be consistently followed outside of the contoured area. However, based on the cores, the useful sediment unit does continue to the north outside of the contoured area. The sediment thickness has been contoured at a 2-foot contour interval.

5.1 Discussion

The seismic data showed that there are a number of distinct subbottom reflection characteristics within the survey area. The most distinct sections are those portions that contained numerous parallel reflectors in the upper twenty feet of the section. This type of section is most noticeable in portions of the project close to the beach. This pattern does not correlate with the bathymetric topography, but occurs on both the ridges and the troughs. Cores obtained in these areas show the sediments to consist of numerous closely spaced silt and sand layers not suitable for beach borrow material. Therefore, the areas where this type of seismic section was found were avoided after the initial cores were collected.

The cores collected during the project were concentrated on two of the transverse sand ridges, as shown on Figure 2. The seismic data obtained across these two transverse ridges did not appear to display an obvious consistent basal reflector that could be used as a basis for determining the thickness of a surficial sand unit, although portions of the ridge to the east of the main ridge do show a basal reflector, as plotted on seismic lines 8 and 11.

The most promising sediment unit for use as borrow material was found under portions of both the central and western transverse shoal, but below the finer grained unit described above. This unit, which is characterized by the presence of well-sorted, white, medium grain size sand, lies below a finer grained, medium gray sand. After all the cores were collected and analyzed, plotting of the grain size data on the seismic sections confirmed the initial field interpretation that the white sand unit is not directly correlated with a given reflector or set of reflectors. Therefore, it is not possible to accurately determine the extent of that unit beyond the core locations.

At the bottom of the white sand unit in some of the cores was a dense orange-brown sandy clay layer. This unit is the upper surface of the pre-Holocene sediments in the study area. Review of the geophysical data did not indicate a constant relationship between the depth to this sediment change, as defined in the cores, and a significant seismic reflector. The bottom of the white sand unit appears to be approximately 18 feet below the ocean floor, based on the core samples. Additional work in these areas would be required to define the extent and thickness of the white sand unit.

The seismic sections show the depth to the first significant continuous reflector, where such a reflector exists. The thickness of the sediments above this reflector is displayed as Figure 4. Based on the available core data within the contoured area, the sediments above this reflector are sand. The sand unit is known from the cores to extend to the north of the contoured area, but the seismic data are not as distinct in this area. The sediments apparently are less consistent in the area to the north of the contoured section.

This inconsistency is demonstrated by the changes in sediments between the area of cores 10 and 12, along seismic line 6, and cores 13, 15 and 30, which are located approximately 500 feet south of seismic line 6. The short seismic section from line 6, showing cores 10 and 12, indicates that the significant seismic reflector corresponds well with the depth to a clay layer. The clay layer was found at between 11 and 13 feet on cores 10 and 12, and the depths to that clay layer are shown on Figure 4. However, cores 13, 15 and 30 all contained approximately 20 feet of sand. Seismic line 7 does not contain a significant consistent reflector through this area. For these reasons, the contoured area does not extend north of the area shown.

A portion of the study area to be avoided is located in the northwest portion of the survey area, where an area of gray organic silt and clay was found. This fine sediment unit, best shown in core 41, appears to have been deposited in a bay or lagoonal environment which may have formed in a valley eroded into the Pre-Holocene land surface. The orientation of the valley cannot be determined from the data. The extent of this silt-clay unit does correspond in some areas to a seismic reflector, which correlates with the depth to the bottom of this unit. Initially the valley trend appeared to be north-south, based on the seismic data. The reflector is best observed at the western ends of seismic lines 7 and 8.

However, the reflector could not be definitively followed on lines 9 or 10. Cores 41 and 42, collected on the north side of the western ridge, were mostly organic silt, as was core 47, on the east side of the ridge. However, cores 27, 28, 43, 45 and 46, located to the south and west of the silty cores, contained significant quantities of sand usable as beach fill. This suitable sand appears to be very similar in texture and color to the white sand unit found in the contoured portion of the central sand ridge. However, no distinct change was observed on the seismic data between core 27 and the area between cores 42 and 47. Due to the lack of sediment continuity, the depth to the first significant reflector was not contoured on the western ridge.

Figure 4 shows the average mean grain size for the sand units sampled on the sand ridges. The total thickness of the sand is also shown on this figure. The data show that, based on the average grain size data, there is a significant quantity of sand suitable for use as beach nourishment material in the study area.

References

1. Hummel, Richard, 1999, Geologic and Economic Characterization and Near-term Potential of Sand Resources of the east Alabama Inner Continental Shelf offshore of Morgan Peninsula, Alabama; Open File Report 99-01, Geological Survey of Alabama, Tuscaloosa, Alabama, 231 p.

2. Swift, D.J.P., Field, M.E., 1981, Evolution of a Classic Sand Ridge Field: Maryland Sector, North American Inner Shelf; Sedimentology; vol. 28, pp 461-482.

3. Parker, S.J., Davies, D.J, and Smith, W.E., 1997, Geological, Economic And Environmental Characterization Of Selected Near-Term Leasable Offshore Sand Deposits And Competing Onshore Sources For Beach Nourishment; Alabama Geological Survey Circular 190, 173p.

TABLES

Table 1 – Core Locations, Gulf Shores, Alabama

			WGS-84		AL West, NAD 83		Depth
Date	Time	Number	Latitude	Longitude	Easting	Northing	MLLW
11/24/99	13:07	C-1	30°13’41.312”	87°40’09.692”	1915015.1	83008.4	27.17
11/24/99	13:35	C-2	30°13’31.356”	87°39’58.298”	1916013.2	82001.1	27.99
11/24/99	14:00	C-2a	30°13’31.306”	87°39’58.459”	1915999.0	81996.1	27.94
11/24/99	14:37	C-3	30°13’21.612”	87°39’47.214”	1916984.1	81015.4	27.82
11/24/99	11:04	C-4	30°14’26.406”	87°40’56.688”	1910899.6	87570.2	26.66
11/26/99	11:15	C-5	30°13’21.603”	87°40’10.020”	1914983.4	81017.4	28.78
11/26/99	11:34	C-5a	30°13’21.630”	87°40’09.935”	1914990.8	81020.1	28.83
11/24/99	16:44	C-6	30°14’10.589”	87°41’18.162”	1909013.5	85975.4	31.76
11/25/99	11:26	C-7	30°14’30.392”	87°42’07.237”	1904712.3	87983.4	22.09
11/25/99	13:44	C-8	30°14’30.936”	87°38’27.626”	1923975.0	88009.3	24.82
11/25/99	14:25	C-8a	30°14’30.833”	87°38’27.156”	1924016.2	87998.8	24.74
11/26/99	13:27	C-9	30°13’41.196”	87°40’32.788”	1912989.0	82999.7	29.37
11/24/99	11:38	C-10	30°14’11.697”	87°40’41.251”	1912251.4	86082.2	26.53
11/27/99	07:45	C-11	30°13’15.045”	87°40’44.052”	1912002.4	83996.2	29:05
11/24/99	16:16	C-12	30°14’11.233”	87°40’32.568”	1913013.0	86034.1	26.66
11/27/99	09:00	C-13	30°14’04.373”	87°40’33.824”	1912901.7	85341.3	25.48
11/27/99	09:18	C-13a	30°14’04.191”	87°40’33.932”	1912892.2	85322.9	25.46
11/24/99	15:06	C-14	30°13’56.959”	87°40’33.873”	1912896.3	84592.3	26.43
11/24/99	16:31	C-14a	30°13’56.968”	87°40’33.690”	1912912.3	84593.2	26.44
11/27/99	09:49	C-15	30°14’03.021”	87°40’25.025”	1913673.4	85203.5	26.15
11/27/99	10:08	C-15a	30°14’02.798”	87°40’25.159”	1913661.6	85181.0	26.20
11/24/99	12:10	C-16	30°13’56.443”	87°40’25.964”	1913590.0	84539.1	26.43
11/27/99	08:13	C-17	30°13’46.105”	87°40’27.184”	1913481.4	83494.9	27.14
11/27/99	08:33	C-17a	30°13’46.120”	87°40’27.067”	1913491.6	83496.4	26.14
11/26/99	15:38	C-18	30°14’00.852”	87°40’09.946”	1914995.8	84982.4	28.04
11/26/99	13:56	C-19	30°13’51.257”	87°40’21.506”	1913980.8	84014.6	26.33
11/26/99	14:48	C-19b	30°13’51.172”	87°40’21.341”	1913994.7	84006.1	26.20
11/25/99	13:16	C-20	30°14’30.873”	87°39’01.498”	1921004.0	88006.7	30.08
11/26/99	07:36	C-21	30°13’41.234”	87°39’47.200”	1916988.3	82997.6	29.02
11/26/99	08:49	C-22	30°13’31.505”	87°40’10.230”	1914966.4	82017.7	27.72
11/26/99	09:09	C-22a	30°13’31.577”	87°40’10.233”	1914966.2	82025.0	26.78
11/27/99	11:34	C-23	30°14’01.428”	87°39’58.772”	1915976.0	85039.1	30.18
11/26/99	09:38	C-24	30°13’31.249”	87°39’47.540”	1916956.9	81989.0	28.47
11/26/99	10:27	C-25	30°13’21.648”	87°39’58.743”	1915972.7	81020.5	28.20
11/26/99	10:49	C-25A	30°13’21.655”	87°39’58.839”	1915984.1	81015.4	28.18
11/25/99	10:54	C-27	30°13’40.320”	87°42’47.977”	1901129.4	82931.5	27.60
11/25/99	10:02	C-28	30°13’31.430”	87°42’42.213”	1901633.4	82032.5	27.59
11/25/99	10:22	C-28a	30°13’31.544”	87°42’42.209”	1901633.8	82044.8	27.59
11/26/99	11:58	C-29	30°13’31.415”	87°40’21.491”	1913978.5	82010.1	29.49
11/26/99	12:15	C-29a	30°13’31.303”	87°40’21.255”	1913999.2	81998.8	29.46
11/27/99	10:39	C-30	30°14’06.109”	87°40’15.512”	1914508.3	85514.2	28.53
11/27/99	11:01	C-30a	30°14’05.976”	87°40’15.534”	1914506.4	85500.8	27.31
11/25/99	11:55	C-31	30°14’10.529”	87°41’41.198”	1906992.8	85972.8	27.26
11/25/99	12:20	C-32	30°14’00.996”	87°41’29.761”	1907994.4	85008.0	29.03
11/26/99	08:01	C-33	30°13’41.310”	87°39’58.792”	1915971.3	83006.8	27.07
11/26/99	08:20	C-33a	30°13’41.187”	87°39’58.644”	1915984.3	82994.3	27.24
11/25/99	16:31	C-34	30°13’41.003”	87°40’21.593”	1913971.0	82978.8	26.82
11/25/99	16:49	C-34a	30°13’41.075”	87°40’21.676”	1913963.8	82986.0	26.73

11/25/99	15:29	C-35	30°13'50.705"	87°39'58.581"	1915991.2	83955.9	28.95
11/25/99	16:04	C-35a	30°13'50.987"	87°39'58.824"	1915969.9	83984.4	28.79
11/27/99	13:12	C-36	30°13'38.266"	87°40'04.166"	1915499.4	82700.1	27.19
11/27/99	13:28	C-36a	30°13'38.295"	87°40'04.302"	1915487.5	82702.9	27.17
1127/99	12:43	C-37	30°13'56.397"	87°40'15.946"	1914468.8	84533.1	27.02
11/27/99	13:54	C-38	30°13'36.384"	87°40'03.713"	1915538.9	82509.8	27.56
11/27/99	14:16	C-39	30°13'46.128"	87°40'15.293"	1914524.5	83495.6	26.65
11/27/99	14:44	C-39a	30°13'45.822"	87°40'15.398"	1914515.2	83465.4	26.59
11/28/99	07:46	C-40	30°13'36.268"	87°40'15.560"	1914499.6	82499.6	26.31
11/28/99	08:05	C-40a	30°13'36.296"	87°40'15.518"	1914503.3	82502.4	26.39
11/28/99	09:09	C-41	30°13'50.996"	87°42'54.784"	1900534.3	84011.2	27.78
11/28/99	09:36	C-42	30°13'45.953"	87°42'37.836"	1902020.1	83498.9	28.67
11/28/99	10:08	C-43	30°13'35.612"	87°43'00.731"	1900009.7	82458.0	29.16
11/28/99	10:25	C-43a	30°13'36.266"	87°40'00.680"	1900014.3	82524.1	29.22
11/28/99	11:00	C-44	30°13'26.147"	87°42'49.422"	1901000.0	81500.0	28.10
11/28/99	11:32	C-45	30°13'18.457"	87°42'43.805"	1901491.3	80722.2	27.96
11/28/99	11:59	C-46	30°13'26.311"	87°42'32.350"	1902497.7	81513.8	27.69
11/28/99	12:26	C-46a	30°13'26.314"	87°42'32.350"	1902497.7	81513.8	27.71
11/28/99	12:51	C-47	30°13'36.360"	87°42'32.500"	1902486.4	82528.9	28.83
11/26/99	15:11	C-81	30°13'50.972"	87°40'09.790"	1915007.9	83984.3	28.53

FIGURES

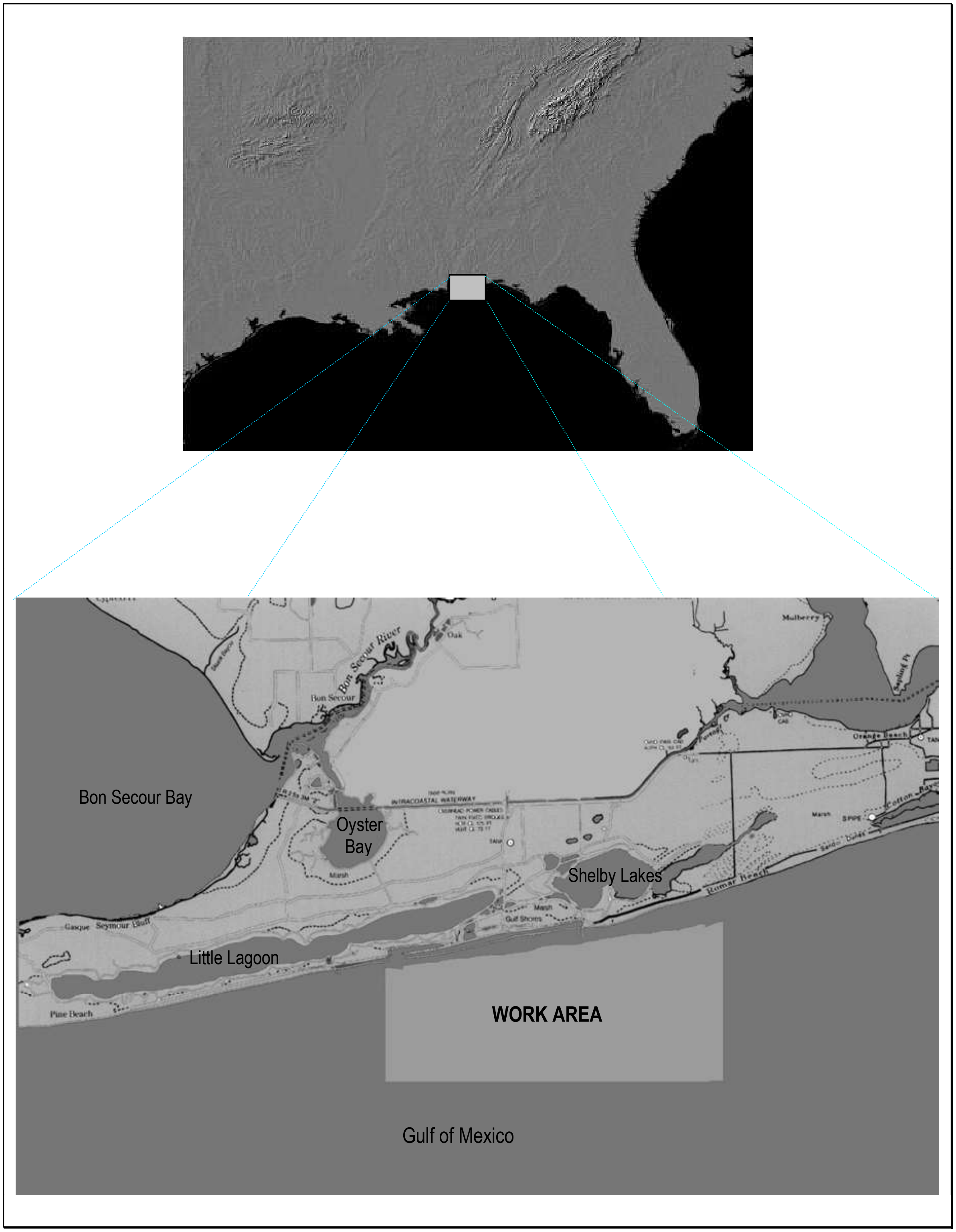
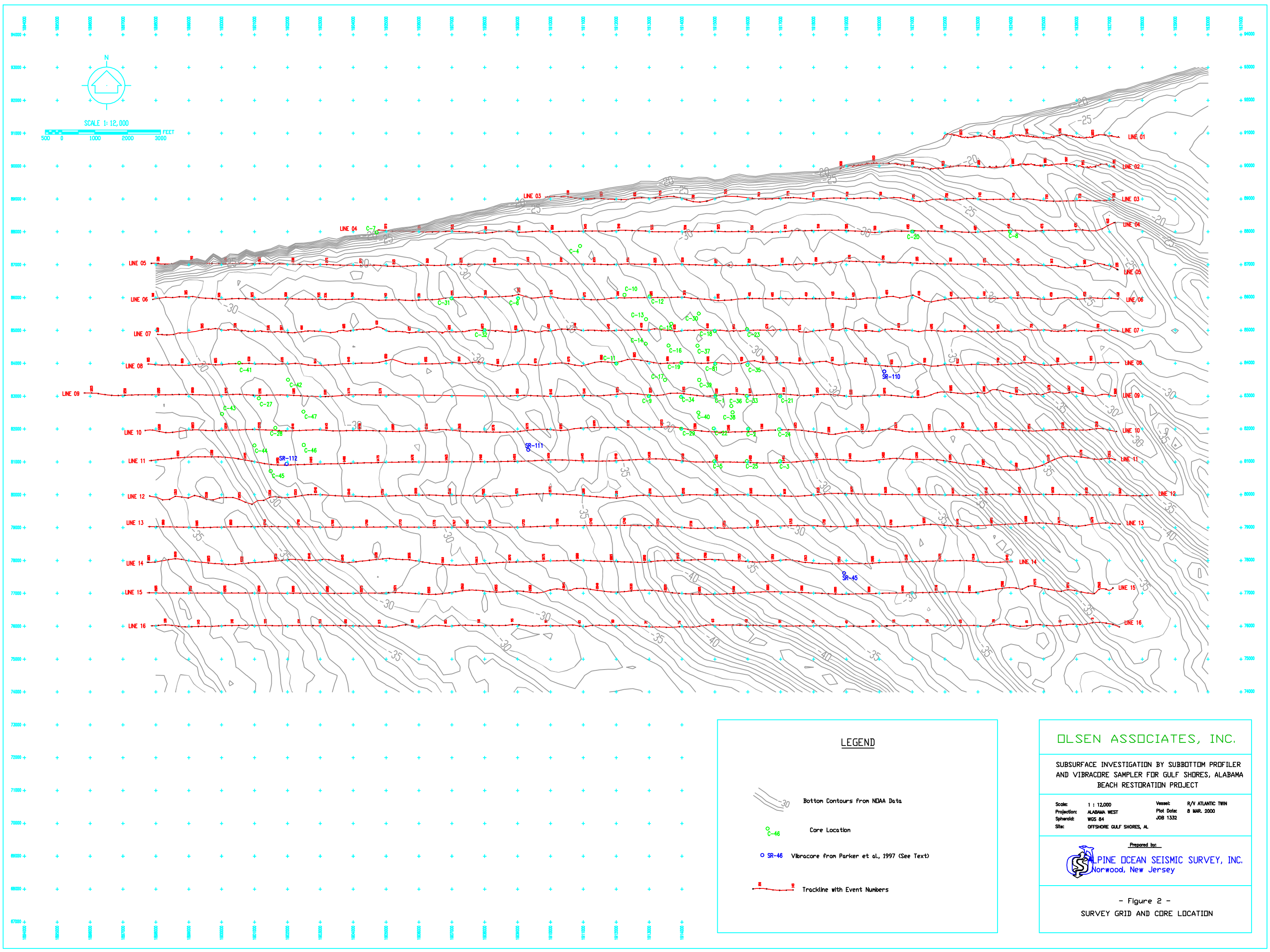


Figure 1: Regional Setting



- Figure 2 -

SURVEY GRID AND CORE LOCATION

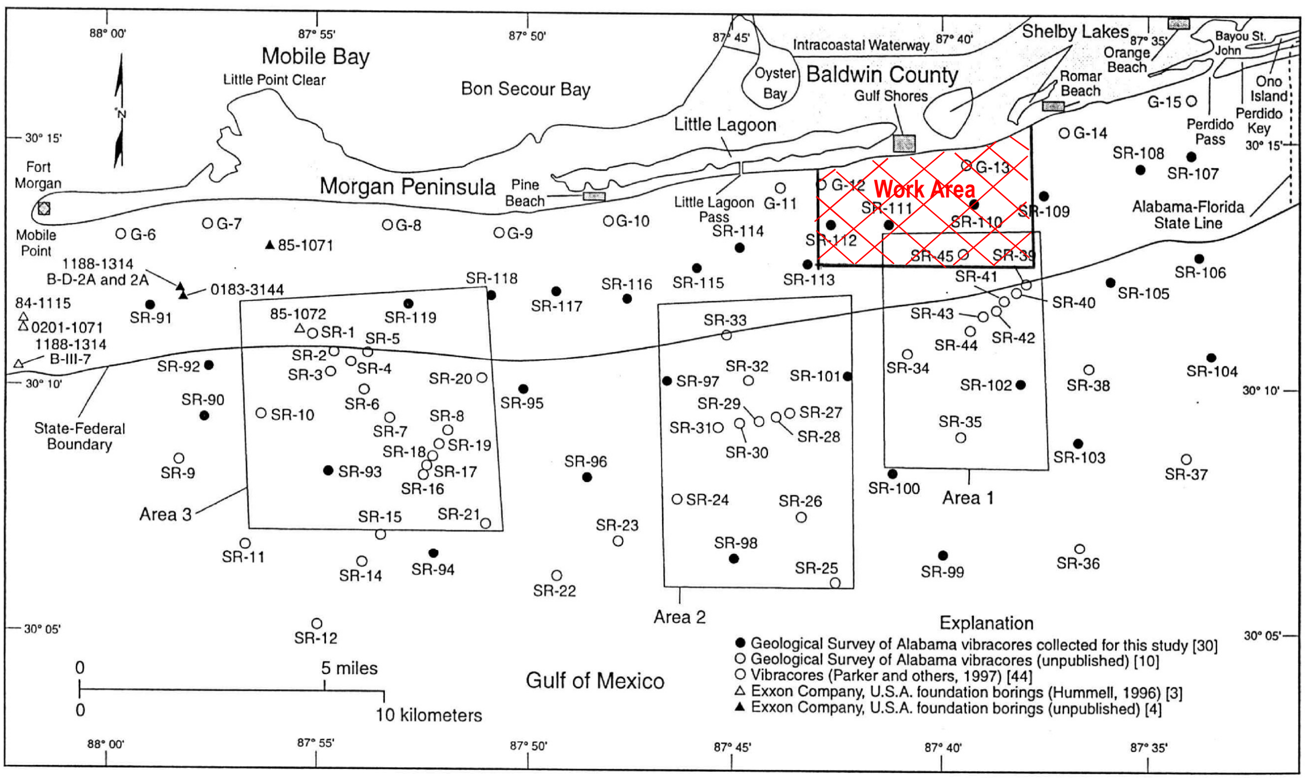
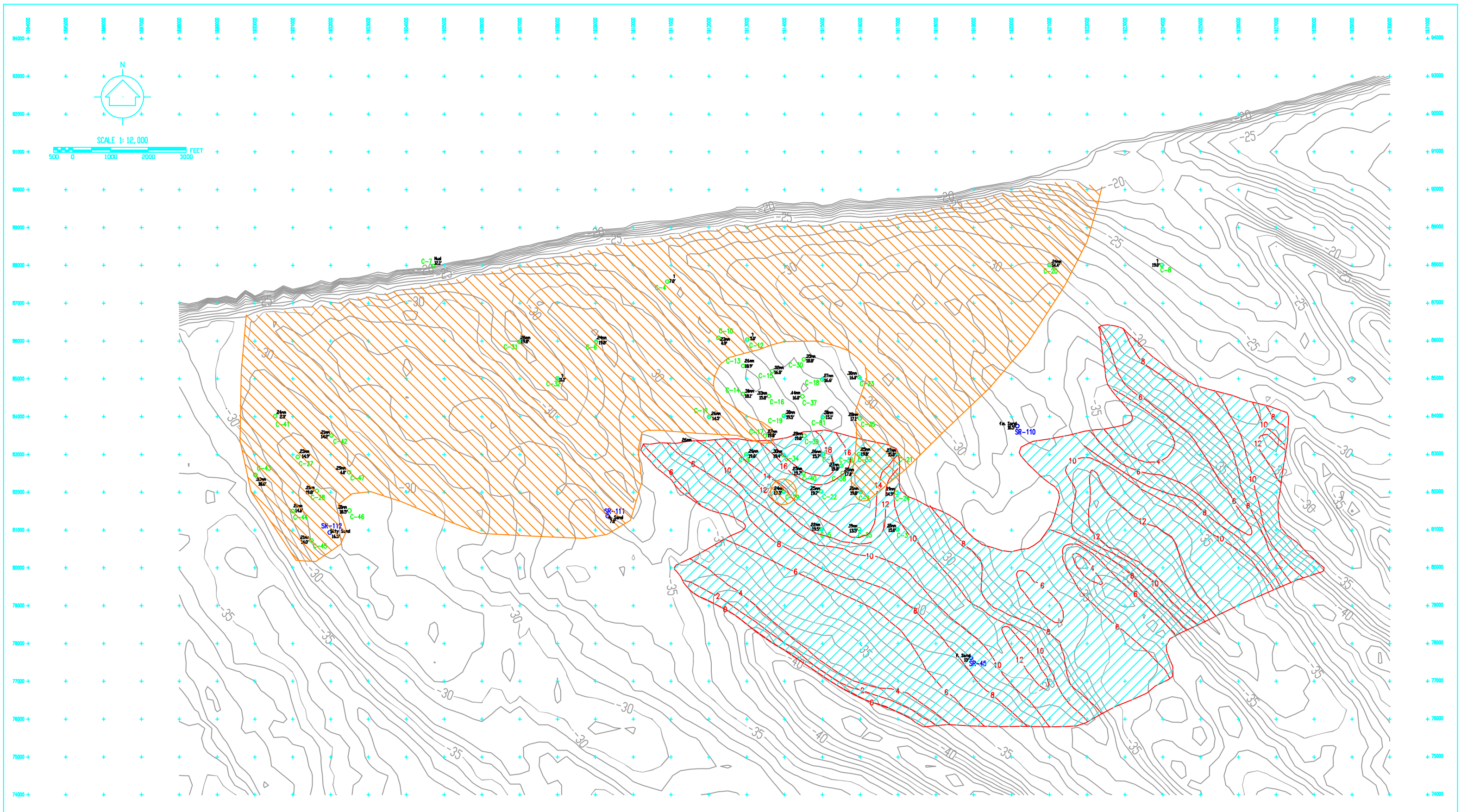


Figure 3: Core Locations and Work Areas, from Hummel, 1999



LEGEND

Bottom Contours from NOAA Data

Core Location with:
- .31mm Median Grain size Composite Sample
- 18.5' Thickness of Composite Sample, Feet
- C-46 Core Number

Isopach of First Prominent and Continuous Reflector. Two (2) Foot Thickness Interval (Assumed to be Surficial Sand Sheet)

Outlines Area where Silty Sand or Clay (Mud) is encountered within 20' of bottom

SR-46 Vibracore from Parker et al., 1997 (See Text)

OLSEN ASSOCIATES, INC.

SUBSURFACE INVESTIGATION BY SUBBOTTOM PROFILER AND VIBRACORE SAMPLER FOR GULF SHORES, ALABAMA BEACH RESTORATION PROJECT

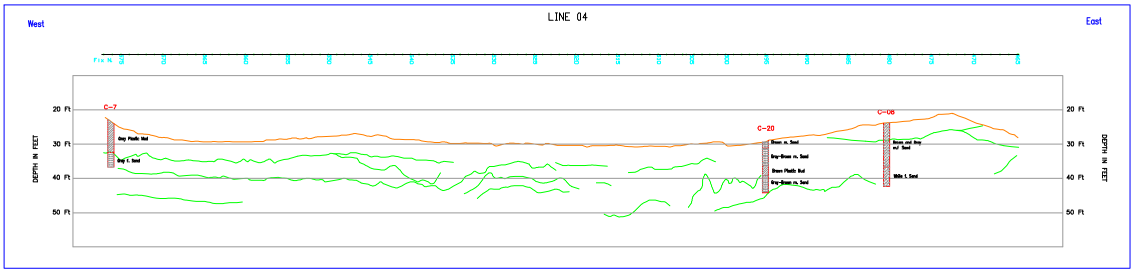
Scale:	1 : 12,000	Vessel:	R/V ATLANTIC TWIN
Projection:	ALABAMA WEST	Plot Date:	8 MAR. 2000
Spheroid:	WGS 84	JOB 1332	
Site:	OFFSHORE GULF SHORES, AL		

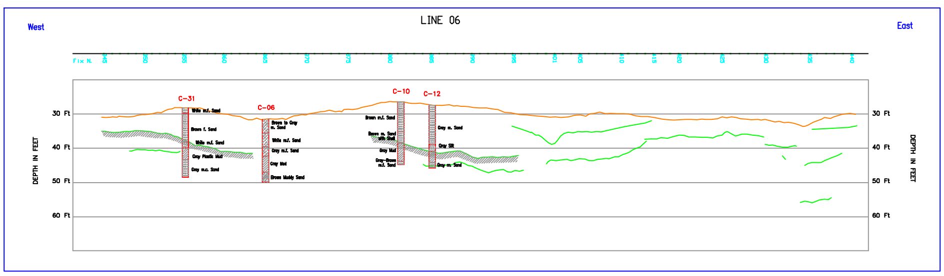
Prepared by:

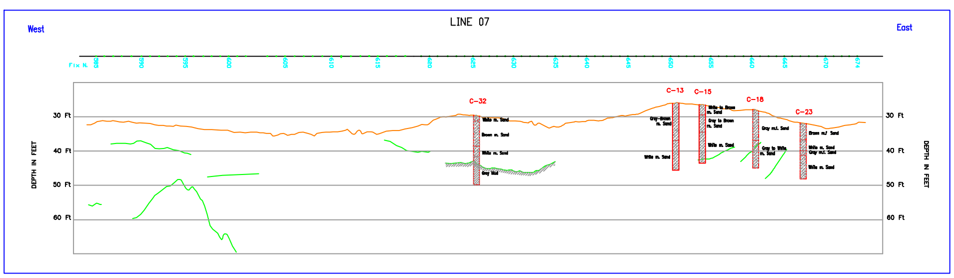
ALPINE OCEAN SEISMIC SURVEY, INC.
Norwood, New Jersey

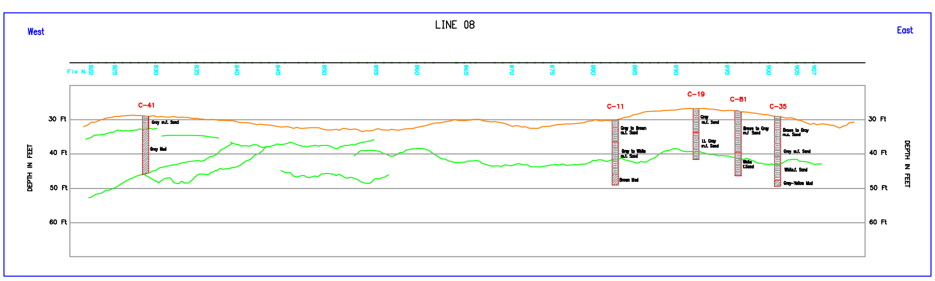
- Figure 4 -

GEOLOGIC FEATURES AND ISOPACH OF SURFICIAL SAND SHEET









OLSEN ASSOCIATES, INC.

SUBSURFACE INVESTIGATION BY SUBBOTTOM PROFILER AND VIBRACORE SAMPLER FOR GULF SHORES, ALABAMA BEACH RESTORATION PROJECT

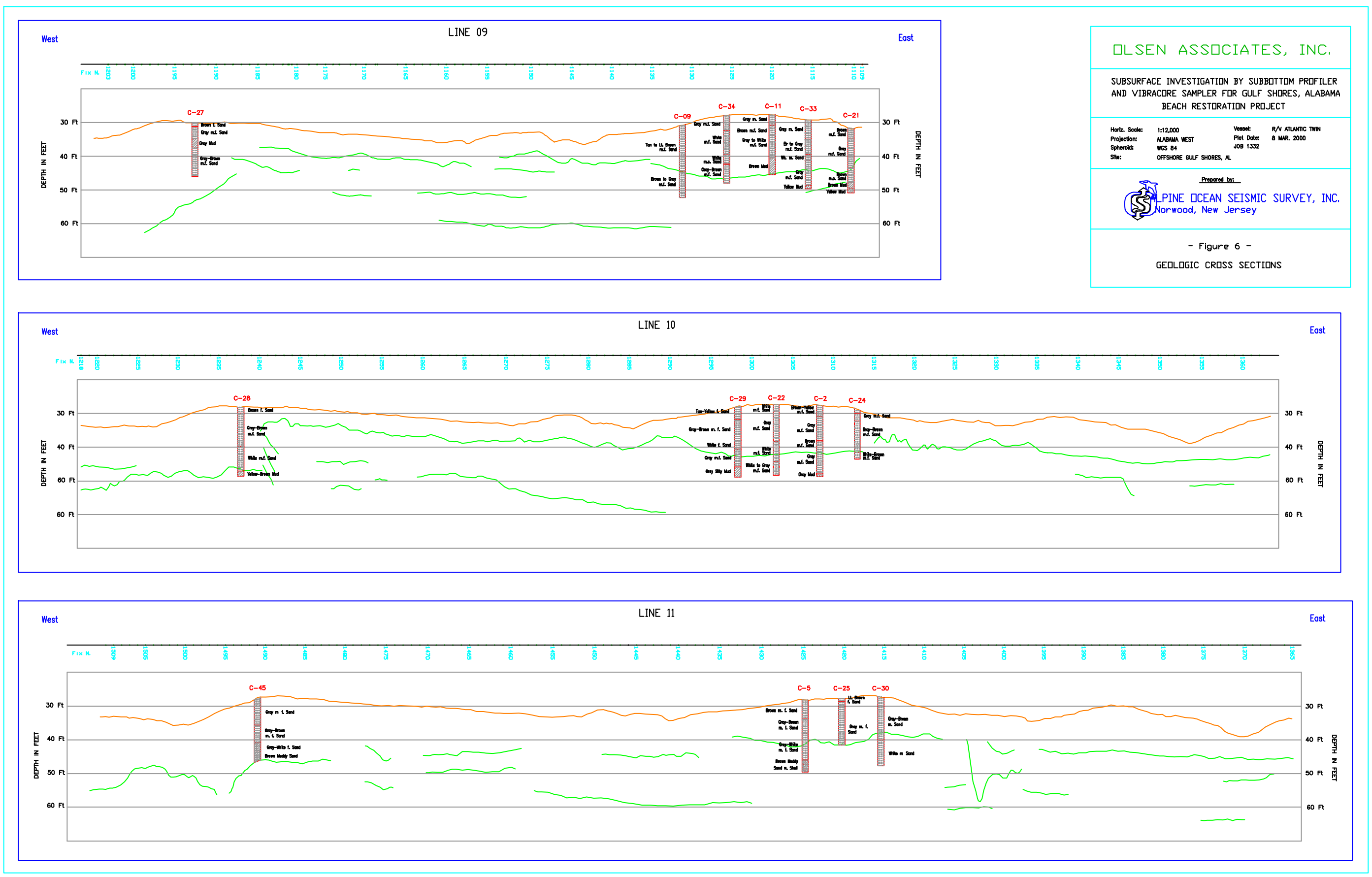
Horiz. Scale:	1:12,000	Vessel:	R/V ATLANTIC TWIN
Projection:	ALABAMA WEST	Plot Date:	8 MAR. 2000
Spheroid:	WGS 84	JOB 1332	
Site:	OFFSHORE GULF SHORES, AL		

Prepared by:

ALPINE OCEAN SEISMIC SURVEY, INC.
Norwood, New Jersey

- Figure 5 -

GEOLOGIC CROSS SECTIONS


LINE 09
West
East
C-27
C-09
C-34
C-11
C-33
C-21
30 Ft
40 Ft
50 Ft
60 Ft
DEPTH IN FEET
LINE 10
West
East
C-28
C-29
C-22
C-2
C-24
LINE 11
West
East
C-45
C-5
C-25
C-30
OLSEN ASSOCIATES, INC.
SUBSURFACE INVESTIGATION BY SUBBOTTOM PROFILER AND VIBRACORE SAMPLER FOR GULF SHORES, ALABAMA BEACH RESTORATION PROJECT
Horiz. Scale: 1:12,000
Projection: ALABAMA WEST
Spheroid: WGS 84
Site: OFFSHORE GULF SHORES, AL
Vessel: R/V ATLANTIC TWIN
Plot Date: 8 MAR. 2000
JOB 1332
Prepared by:
ALPINE OCEAN SEISMIC SURVEY, INC.
Norwood, New Jersey
- Figure 6 -
GEOLOGIC CROSS SECTIONS