FINDING AND DEVELOPING COST EFFECTIVE BEACH COMPATIBLE SAND SOURCES IN THE GULF OF MEXICO, LESSONS LEARNED IN FLORIDA, LOUISIANA AND TEXAS

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ABSTRACT

The success of a beach nourishment project is often judged by the quality and price of the sand. Cost effective beach compatible sand is getting harder to find. As quality standards increase, regulatory scrutiny of borrow areas also increases. More effective sand investigation management can locate higher quality sand at lower overall cost to meet these new challenges.

Since the early 1980's Coastal Planning & Engineering, Inc. has utilized geological and geophysical techniques to identify, classify and verify suitable sand for over thirty-five (35) beach restoration and renourishment projects. Based on this experience with beach nourishment in the Gulf of Mexico and the Atlantic shoreline, a number of techniques have been developed to find acceptable sand in challenging areas. These techniques fall into the following categories: sand search methodology, engineering quality criteria, regulatory strategies, and cost reduction strategies. This paper will discuss the first category (sand search methodology) in detail.

Introduction

The traditional sand search has consisted of taking seismic survey and vibracores along a pre-planned grid, often in the form of a checkerboard or zigzag. Typically a pre-planned investigation is often carried out by one group of specialists and analyzed by another group once the information has been collected and reduced. This method often leads to a waste of resources with much of the exploration occurring in areas of minimum potential.

A modern sand search investigation can be completed in five phases. The first phase consists of researching all geotechnical, environmental and physical data within, and adjacent to, the project area. This data is formulated into a database and a regional and local geomorphic analysis is performed. A reconnaissance field survey is conducted in the second phase to test and further evaluate the phase one analysis. In the third phase, a comprehensive geotechnical field survey is planned, executed and analyzed and preliminary maps are developed. A vibracore investigation is undertaken in phase four.

One to two vibracores are obtained in each potential site identified on the preliminary map developed in phase three. These cores are split open, field logged and analyzed on the vessel or at the dock. From the information developed, areas of low potential are rejected and sites with high potential are investigated with additional cores. By splitting all cores lengthwise and field logging them as they are obtained, the limits of a potential borrow area are defined in one field operation and cores are not wasted in outlying low-quality areas. After all cores are laboratory analyzed, logged and photographed, the preliminary seismic isopach is redeveloped and finalized utilizing the new core data. In the final phase, all the geotechnical analysis is re-evaluated, updated and the limits of the borrow areas are defined. Cross-sections are produced showing the clean sand layer and the proposed depths of cut. A final report is written documenting the techniques, methods, analysis and results.

Phase I – Preliminary Investigations of Historic Data:

The first phase is sometimes referred to as a desktop study. In this phase all historical data within the project area and adjacent sites are researched and a regional map and GIS database are developed. The database and map are used to develop a flexible survey plan for Phase II. This plan should identify primary and secondary sites to be investigated. The geotechnical field crew should be directly involved in the plan development so that they can be best equipped to modify and adapt to the conditions they encounter in the Phase II investigation. The overall success of the sand search relies on the geotechnical crew's experience at making decisions in the field and following the unexpected finds as well as focusing on high potential sediment lenses.

The initial task includes analysis of existing offshore geotechnical literature and geotechnical data obtained by previous consultants, universities and governmental bodies including the State Geologic Survey and other state agencies responsible for offshore data, MMS, USACE, NOAA, and the USGS. A key component of this phase is to develop a hydrographic contour map of the region using NOAA bathymetric depth data available on CD. This data should be used with caution in that it is a compilation of different NOAA surveys taken in different years that may be saved in different datum. It is recommended that a certified hydrographer or a professional surveyor familiar with offshore surveying oversee the data conversions.

All of the information gathered during this phase is evaluated and incorporated in a GIS database which, in turn, is used to develop a regional and local geomorphic synopsis of the project area.

This information should also include all relevant environmental and physical features such as pipelines, cables, wrecks, artificial reefs, and any other objects or boundaries that may impact a potential borrow site. The GIS database and geologic analysis are utilized to identify offshore areas that could contain beach quality sand: i.e. areas that would be candidates for further field investigations.

Phase II – Reconnaissance Geotechnical Surveys:

Phase II consists of a reconnaissance field survey. The reconnaissance survey should be considered the most important phase of any sand search.

The method of reconnaissance field survey includes verifying hydrographic features with widely spaced bathymetric surveys, surface sand samples, and jet probes of historical core sites and other potential sand features across the study area. These methods also allow the geologists/diver to see and evaluate the site firsthand. The methods are described in more detail below.

The reconnaissance bathymetric survey ground-truths and verifies features of NOAA hydrographic data in selected areas of potential sand deposits. The reconnaissance bathymetry can also be compared with historical bathymetry to identify locations where sand has accumulated by natural coastal process or offshore dredge disposal. However, one of the most important reasons to conduct the reconnaissance bathymetry is to identify the location, boundaries, and high points of shoal areas.

Jet probes are taken in areas that show promise for sand deposits and to confirm historical vibracores. Geologists who are proficient in SCUBA diving conduct the jet probes by water jetting a twenty (20) foot length of pipe into the seafloor. As the jet probe penetrates the seafloor the geologist notes the resistance and observes sand coming up from the hole. Jet probes and surface sand samples provide an indication of the thickness and characteristics of the unconsolidated sediment layers. With two dive teams, consisting of a geologist and a support diver, generally 15-25 jet probes can be obtained in a day depending on water depths.

The dive team conducts the jet probe by penetrating a graduated 20-foot water pressure probe into the ocean bottom and making observations as it passes through the sediment layers. The geologist is on the bottom and the support diver stays at the upper end of the probe to hold it upright against the current. The support diver also observes the turbidity level changes from above as silt is washed out of the probe hole during penetration of the seafloor.

The geologist on the bottom observes the graduated scale on the probe and by the feel of the objects it encounters makes mental notes of the depths of each change in texture. An experienced diver geologist can distinguish layers such as shell, rubble, sand, peat, clay and rock. The probe is jetted to the total length of 20 feet or until it encounters a layer it is unable to penetrate.

To obtain sediment samples from various depths, wash borings samples are obtained by the following method:

The geologist takes two sample bags labeled "mid-depth" and "surface" sample. The support diver takes one sample bag labeled "bottom of hole." The probe as described above is driven to its total depth of penetration. If that depth is 18 feet the probe is pulled out and a second hole is probed to a depth of 9 feet, five to ten feet away from the first probe hole. The geologist pulls the probe out of the 9-foot hole and the support diver signals the boat to pull it to the surface. The geologist takes a sample of the material that has formed a mound around the probe hole and puts it in the "mid-depth" sample bag. He next swims against the current at least five feet from the probed area and obtains an undisturbed "surface" sample. While the geologist is obtaining his samples the support diver returns to the first probe hole and obtains a sample from the top of the washout mound.

The samples taken from the washout mounds provide a representative composite sample of the material that the probe passed through. The samples by the nature of the method that they were obtained are typically low in percent silt. This is why it is important for the support diver to observe the turbidity level changes during the probing process as discussed above. These samples are useful in screening potential borrow areas, but should not be used to replace vibracores in selecting and defining borrow sites.

Once on the surface, the diver geologist and support diver relay their probe observations and depths of penetration to the second geologist who records them in a logbook. The descriptions relayed should also include surface conditions such as sand ripples, algae, seagrass, surface rubble or other observations. This information can later be used to assist with the interpretation of the side-scan sonar data. The sand samples are cataloged and notes on the textures and color are recorded.

To prepare the jet probe data for inclusion in the appendix of the final report, the data recorded in the logbook is digitally entered into a jet probe log formatted similar to a core log. The sand samples are sieved to compute grain size and analyzed for wet and dry Munsell color. Representative samples are archived in small sample bags for presentation and review by the client.

Following completion of the field investigations the GIS database is updated to include the findings from the reconnaissance level surveys. Specific sand deposits are identified for potential detailed field surveys. A summary report is prepared which details the findings and presents a composite of existing and new information in GIS database format (electronic and hard copy).

Prior to conducting any additional surveys, a meeting is held with the client to review results and recommendations from Phase I and II investigations. Aesthetic and cost considerations are evaluated with engineering and geological data. This information is utilized to select the deposits to be investigated further with comprehensive geotechnical studies, including detailed seismic, side-scan sonar and bathymetry surveys.

Phase III - Detailed Geotechnical Survey of Specific Candidate Borrow Sites:

The third phase of the sand search is a comprehensive geotechnical and hydrographic field survey to identify the limits of potential borrow areas and offshore geologic features including fluvial channels and sand ridges. At a minimum, four major system components are required; a dual frequency side-scan sonar; a chirp sonar seismic system; an accurate and rapid updating DGPS navigation system and a state-of-the-art digital data acquisition and processing system (Roberts et al., 1999; 2000). Mapping of the seafloor and sub-surface with side-scan sonar and high-resolution sub-bottom profilers has been conducted for over 30 years. Recent technological advances in shallow water applications have revolutionized sand search investigations to include true digital seismic and side-scan sonar systems. These systems allow for advance data acquisition and processing. The ability of workstations and more recently PC's to store and manage large volumes of data has also allowed the computation and mapping of geologic features unattainable only five years ago.

A survey grade fathometer is utilized to determine accurate water depths across the investigation area. The fathometer applies a harmonic mean velocity that converts the two-way travel times to depths. The mean velocity is obtained by bar check calibration and by taking a sound velocity cast within the project area. Tide values are recorded by an electronic tide gauge within, or adjacent to, the investigation area. The elevation of the tide gauge sensor should be surveyed and certified to the local datum by a professional surveyor. The bathymetric data is recorded in real time both on analog paper and digitally stored with the positioning data.

A Differential Global Positioning System (DGPS) interfaced to a software package like the Coastal Oceanographic Hydrographic Data Collection and Processing (HYPACK) System (or equivalent) should be used for positioning and navigation during all phases of the project. The U. S. Coast Guard Navigation Beacon is typically utilized as the source for differential correction for Hydrographic and Geotechnical surveys. A typical GPS, with differential correction, provides for a position accuracy of 1 to 3 meters. The U. S. Army Corps of Engineers has conducted tests of the U. S. Coast Guard beacons and found accuracy of less than 1.5 meters, 94% of the time.

The Hydrographic Data Collection and Processing (HYPACK) System interface to the DGPS, fathometer, side scan sonar and the Chirp seismic system and provides real-time navigation fixes and stores depth data during the survey. On-line screen graphic displays include the pre-plotted survey lines, the updated boat track across the survey area, adjustable left/right indicator, as well as other positioning information such as boat speed, quality of fix and line bearing. Post processing of navigation and depth data is also provided by the system.

A side-scan sonar system with a dual frequency (100/500 kHz) towfish is best suited for shallow water mapping of the seafloor since large areas and a high percent of overlap can be mapped simultaneously with the seismic survey. Surface features such as hardbottom (reefs), underwater wrecks, rubble, and other features are easily identified on the records using the surface information obtained during the phase II jet probe investigation to interpret the patterns seen on the side scan record.

The side scan sonar image of reflected acoustic energy is similar to the image produced through radar. Darker returns represent areas where more acoustic energy is reflected back to the sonar, such as hard debris targets, rock ledges, or sand ridges, and light returns are representatives of low reflectivity zones. As the fish follows the tow vessel's track, this beam scans a bottom segment ranging from the point directly beneath the fish outward on each side.

One of the most important technological advances for sand searches investigations has been the introduction of the Chirp seismic sonar system. Coastal Planning and Engineering, Inc. was the first coastal engineering firm (October, 1990) to have a chirp seismic sonar system used to conduct a sub-bottom investigation for a beach renourishment sand search investigation in Captiva Island (CPE, 1991).

Seismic surveys of unconsolidated sediments are accomplished by sending an acoustic signal through the seafloor and receiving reflecting acoustic signals in the form of a recording chart signature. Seismic systems operate on the principal that a transmitted seismic pulse "incident on an acoustic interface is partly reflected from this interface" (Sieck and Self, 1977). An acoustic interface results from a change in the acoustic properties causing an apparent contrast to occur. Typically, the acoustic interfaces are incident with physical changes in sediment properties. Layers in the sediment column are indicated as traces that are recorded on an analog chart and in electronic formats onboard the survey vessel. The seismic record identifies the sediment surface and other layers or features within the sediment column.

The Chirp Sonar is a broad spectrum FM (Frequency Modulated) seismic profiler that produces a very high-resolution record of the shallow sub-bottom. The main advantage of full spectrum technology over a conventional system is increased penetration with high resolution through the use of matched filter correlation and waveform weighting techniques. The images resulting from tapered waveform spectrum have virtually constant resolution with the depth.

It has been our experience that the model SB-512 Tow Vehicle which generates an FM pulse with amplitude and phase weighting in the frequency ranges of 500 Hz to 12 kHz is best suited for sand search applications. This tow vehicle weighs over 300 pounds and to be safely deployed must be operated from a sufficiently large vessel equipped with a davit or crane. The model SB-512 Tow Vehicle contains four transmitters and four receive arrays. The model SB-512 transducers have Uniboom type penetration and are far superior in penetration through sands compared to smaller higher frequency towfish. This frequency range generates a very high-resolution image of the sub-bottom stratigraphy in sand to the depth of 20- 50 feet, which are the typical depths of interest for sand searches.

A data acquisition system like Triton Elics Isis (or equivalent) should be employed to collect and store all the survey data in a digital format. The Isis sonar software is capable of recording the side-scan sonar data as well as the bathymetric data from the fathometer and the seismic data from the chip sonar system. The data acquisition system digitizes, stores and processes side scan sonar signals and combines the sonar imagery with navigational inputs to geo-reference the data in real-time. The data acquisition system also allows for slant-range correction and water column removal of the side-scan sonar data. Data processing is accomplished with software that can produce side-scan sonar mosaic images exportable as georeferenced data for incorporation into a GIS utility.

The data obtained from Phase III will be used to prepare charts and maps for analysis. A bathymetric contour chart is prepared of water depths over specific potential borrow sites. The isopach charts, which document sediment thickness is also prepared. The results of the side scan sonar survey are incorporated into the bathymetric and isopach maps delineating various bottom features. The sub-surface traces on the record are subject to interpretation and require further investigation to ground-truth the actual nature of the layers (i.e. sand, silt mud, etc.). Based on historical vibracores, jet probe and wash borings, a preliminary isopach of sediment types can be prepared prior to Phase IV vibracoring. This isopach will require modification following Phase IV as more information is developed when final vibracores are analyzed.

Phase IV – Vibracoring:

After the phase three comprehensive geotechnical field surveys are completed, isopach and bathymetric preliminary maps are developed and a vibracore investigation is planned. The proposed vibracore sites are plotted on the bathymetric and isopach charts. The areas identified as containing potential sand resources, which are clear of environmental constraints, are developed for the vibracoring investigation. Tracks of the seismic vessel and navigation fixes are also plotted on the above maps. The core sites are refined to fall on a seismic line coordinate. Cores are taken on the seismic lines to assist in the refinement of the final isopach by allowing direct correlation of the sub-bottom records and cores. Cores are typically 20 feet long but depending on the project can vary from 10 to 30 feet in length.

To achieve higher levels of sand search efficiency, a follow-the-vein technique has been developed by CPE during the vibracore operations. This method requires the geologist/marine specialists in the field to have the flexibility, authority and knowledge to direct the vibracore operation by the following technique: One to two vibracores are sited and identified as reconnaissance cores in each potential deposit on the preliminary maps. Additional cores are laid out at 1000 foot on centers in each deposit and will only be drilled if reconnaissance cores indicate beach compatible sediments. As the reconnaissance cores are drilled, they are cut open lengthwise on the vessel or at the dock. From the information developed, areas of low potential are rejected and sites with high potential are investigated with additional cores. By this method the limits of acceptable sand deposits are defined and developed into potential borrow areas prior to demobilizing the coring vessel. The follow-the-vein technique typically identifies the sand within borrow areas with only one vibracore field operation, eliminating the need for multiple mobilizations and return coring cruises which is common practice for many investigations.

Phase V - Analysis and Report:

After all cores are returned from the field they are laboratory analyzed, logged and evaluated based on appearance. A core log is prepared for each core describing the sediments by layer including layer width, sediment color, texture, presence of shell or clay layers and any other identifying features. During the logging procedure, particular attention is paid to lithology, texture, silt, and rock content. Textural classification is according to the *Unified Soils Classification System* described under the American Society for Testing Materials (ASTM) Standard D-2487. As the cores are logged they are also photographed in overlapping segments which are approximately three feet in length. Both halves should be viewed when logging and photographed to ensure all objects are noted. When only one half of the core is observed during the logging process there is a potential for individual shells and small rock fragments to be missed. This can result in a low estimate of rock content for the beach fill material.

Grain size analysis is to be performed on samples obtained from distinct layers in the core, or periodically through the sediment if the material appears uniform. Grain size analysis is conducted in accordance with the American Society for Testing and Materials (ASTM), Standard Material Designation D422-63 for particle size analysis of soils. Mechanical sieving is accomplished using calibrated sieves, with a gradation of half phi intervals, per U.S. Army Corps of Engineers standards. Grain size distribution curves and analysis reports are prepared for each vibracore.

The preliminary seismic isopach is redeveloped and finalized utilizing the new core data. In this final phase, all the geotechnical analysis is re-evaluated, updated and the limits of the borrow areas are defined. Cross-sections and fence diagrams are produced showing the clean sand layer and the proposed depths of cut. Weighted estimates of the mean grain size, sorting, silt content and other parameters are developed for each borrow area. Utilizing the information developed for each sand deposit in the study area an analysis of compatibility with native beach sand at the fill site is conducted. The compatibility analysis focus is on similar sand mean grain size and should meet state and federal rules for offshore borrow site development. Other factors which are considered in selection of potential beach nourishment sand borrow areas include the following:

a. <u>Minimum Available Layer of Sand:</u> Hydraulic dredging becomes difficult to accomplish with the sand layer of less than 4 to 5 feet. If, for example, the existence of rock, or silt and clay, restricts the available sand layer for dredging to less than 5 to 6 feet, these areas may be restricted from using a hydraulic dredge and be considered only if a hopper dredge is used for the beach nourishment. Conversely, dredging economics improve with the available depth of sand. Sand layers approaching 20 feet in thickness provide the most economical sand resources for dredging in a beach nourishment project and warrant greater consideration in the selection of potential dredge borrow areas.

b. Location of Sand Deposit: Sand deposits which are located closer to shore, without creating a deleterious coastal effect such as increased wave impact, are the most economical to use for beach nourishment projects. The production rate of dredging increases as the distance to move the sand decreases; therefore, borrow areas closer to shore would yield lower beach nourishment construction bids because contractors can maintain high production rates. For this reason, sand resources closer to shore warrant greater consideration in the development of beach nourishment borrow areas. Similarly, the alongshore location of the borrow area in relationship to the beach restoration project also affects the project cost. The best economic scenario is for borrow areas to be located directly offshore of the beach nourishment construction site. If suitable sand is not located directly offshore, sand deposits as close to the project site as possible provide the most economic sand sources for beach nourishment.

At the conclusion of all geotechnical surveys and evaluations, a report is prepared identifying the sand sources (borrow areas), indicating the quality of the sand, the volume of the sand, the location of the sand, and any additional information that would be required for the permitting process and/or by the contractor for construction of the beach nourishment project. The report should also include a practical assessment of feasibility to recover the sand for use as beach nourishment and an estimate of the cost.

Based on findings from the data analysis and side scan sonar mapping, sensitive habitats and hardbottoms are identified. The need for an environmental assessment and environmental field investigations are analyzed. The final borrow areas will also require a magnetometer and cultural resource investigation be conducted. This data should be obtained under the direction of a marine archaeologist. The marine archaeologist also provides a Cultural Resources Report for the State Department of Historical Resources approval.

The appendices of the report should provide the grain size analysis of composite and discrete sand samples taken from the vibracores, vibracore logs and jet probe log results. Additionally, the report presents the isopach (sand thickness) and bathymetric charts for the beach nourishment project. The charts include mapping of the hardbottom and other marine habitats and features mapped by the side scan survey.

Conclusion

The results of an offshore sand investigation for beach compatible sand can be improved by including the following elements:

1. Develop a comprehensive historical geotechnical database and feature map to locate all potential sites and to start screening out undesirable areas.

2. Conduct a reconnaissance geotechnical survey that further screens out unsuitable sites.
3. Use state-of-the-art digital seismic and side scan sonar equipment and analysis. Develop preliminary seismic sediment isopach using historical cores and jet probes.

4. Obtain reconnaissance vibracores in each potential borrow site. Split and field log all cores on the survey vessel. Refine and adjust coring sites based on field core analysis.

5. Redevelop seismic isopach utilizing new vibracore data.

The success of a sand search investigation can be measured by the numbers of vibracores that lie within the final limits of the borrow area.

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