
SHIP SHOAL/ISLES DERNIERES

CHARACTERIZATION OF THE
DEVELOPMENT POTENTIAL OF SHIP SHOAL SAND
FOR BEACH REPLENISHMENT OF
ISLES DERNIERES
EXECUTIVE SUMMARY

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LOUISIANA BEACH REPLENISHMENT

INTRODUCTION

As part of ongoing investigations related to non-fuel mineral resource targets in the Exclusive Economic Zone (EEZ) of the northern Gulf of Mexico, the EEZ Gulf of Mexico Task Force has assembled and analyzed existing data bases for identifying potential hard mineral resources in the northern Gulf (Gulf Task Force 1989). The task force consists of representatives from the Minerals Management Service as well as members from state agencies in Texas, Louisiana, Mississippi, and Alabama. The most prominent offshore hard mineral resources identified in phase I of the study were sand and shell. As a result of these investigations, several target areas for sand resources were identified, and further studies on selected resource areas were proposed. After reviewing preliminary information from proposed study sites, the task force recommended a concentrated effort on one site with the greatest potential for near-term leasing. This report presents the results of that study in terms of detailed resource identification, physical environmental impacts of dredging, and economic feasibility.

The primary objective of the phase I Gulf Task Force study was to prepare a preliminary assessment of the occurrence and economic potential of non-fuel mineral resources in the EEZ offshore Texas, Louisiana, Mississippi, and Alabama. The primary goal for phase II, however, was to provide an analysis of the geologic, engineering, environmental, and economic considerations associated with sand dredging and placement in the Ship Shoal and Isles Dernieres area, where the near-term use of sand is likely for barrier island restoration and beach replenishment. This area was chosen based on results from a preliminary evaluation of resource abundance and quality, data availability and the necessity for further data collection, proximity to areas for resource utilization, and likelihood of resource utilization. Ship Shoal, a large sand shoal approximately 15 km seaward of the Isles Dernieres barrier island system in Louisiana (figure E-1), was an ideal site for this study because initial results indicated a very high-quality sand deposit that contained about 1.2 billion m³ of material seaward of one of the most rapidly migrating barrier shorelines in Louisiana (long-term rates of change ranging from -10 to -15 m/yr [McBride et al. 1991]). Significant quantities of data existed for characterizing the geologic framework of the shoal (only a limited field effort was needed to provide necessary detail about

the geologic history of the shoal), and nearshore wave climatology was available for analysis of physical environmental impacts of dredging. In addition, sand resource compatibility with deteriorating sand beaches landward of the shoal make it a likely source of material for coastal restoration and protection against accelerating rates of wetland loss.

Five specific tasks were designed to evaluate Ship Shoal as a potential near-term leasable sand deposit for coastal erosion control in Louisiana. High-resolution seismic profiles and vibracore data provided the primary information for identifying the sedimentologic characteristics and geometry of the shoal. A preliminary analysis of existing dredging technology for application at Ship Shoal was assembled for domestic operations. The physical environmental impacts of dredging on the shoal were estimated using a wave refraction model to test resultant effects on the shoreline landward of the borrow area. An evaluation of available upland sand resource targets for quantity of material and cost was accomplished in task 4, and task 5 provides an economic analysis for two potential project conditions consistent with past sand replenishment operations.

The final project report represents a cooperative effort between the Louisiana Geological Survey (tasks 1, 3, and 4), the U.S. Army Engineer Waterways Experiment Station's Coastal Engineering Research Center (task 2), and the Office of Resource Evaluation for the Gulf of Mexico OCS Region, Minerals Management Service (task 5). It provides a prototype methodology for evaluating near-term leasable sand resources for coastal erosion control or construction aggregate. The following discussion presents a synopsis of the report findings with recommendations for further study.

PROJECT OVERVIEW

During the initial stages of the study, significant effort was spent coordinating activities of the five different tasks to ensure a coherent final product that would meet project objectives. Although Ship Shoal was the area under consideration, certain aspects of the analyses required more limited spatial constraints to provide specific recommendations regarding dredging sites as related to physical environmental impacts and projected cost estimates. The geologic framework study provided background information on the regional history of

The shoal ranges from 5 to 6 km wide in its central area and 8 to 12 km wide at the eastern and western ends, with a relief of from 3 to 7 m east to west along its crest axis. Penland et al. (1986, 1988) have documented that Ship Shoal is a marine sand deposit formed by the erosion of a submerged barrier shoreline that has migrated 1.5 km landward since 1853. Over 2,000 line-km of high-resolution seismic reflection data and 50 offshore vibracores have been collected by the Louisiana Geological Survey, U.S. Geological Survey, and Minerals Management Service in support of this study. In addition, borings from other state and federal agencies, as well as private industry, were collected, analyzed, and cataloged into a single data base to assess Ship Shoal sand resources.

Regional Setting

The morphology of the Louisiana delta plain and inner-continental shelf reflects the combined effects of sea level rise, with transgressive and regressive sequences formed from delta building and subsequent abandonment processes of the Mississippi River. Apart from the Modern delta lobe located in deep water near the shelf edge, Holocene Mississippi River sediment has accumulated in shallow water. The delta-building process consists of a prodelta platform, followed by distributary progradation and bifurcation, which results in delta plain establishment. This process continues until the distributary course is no longer hydraulically efficient. Abandonment occurs in favor of a more efficient course, initiating the transgressive phase of the delta cycle. The abandoned delta complex subsides, and coastal processes rework the seaward margin to generate a sandy barrier shoreline backed by bays and lagoons (Kwon 1969; Penland et al. 1981, 1988). Today, the delta plain can be divided into two distinct geomorphic regions: active and abandoned deltas. Delta building is restricted to the Modern delta and Atchafalaya delta complexes. The four remaining, Maringouin, Teche, St. Bernard, and Lafourche, are abandoned. In addition, the Plaquemines delta of the Modern complex is abandoned.

Ship Shoal is one of the largest and most prominent inner-shelf shoals offshore Louisiana. The shoal has a landward-oriented asymmetry and slopes westward. The change in shoal-crest asymmetry and orientation

2 the central body or shoal front, and facies 3 the shoal base. The shoal contains approximately 1.2 billion m^3 of sand. Shoal-crest deposits contain 112 million m^3 of sand and represent a unit within the zone of active normal and storm wave processes. Evidence for this is the presence of symmetrical ripple laminations that reflect the influence of oscillatory wave motion on surface deposits. The shoal crest is subjected to the highest relative energy levels because of its relief above the surrounding shelf. In addition, well-rounded sand particles are indicative of extensive sediment reworking. Water depths range from 2.7 m in the west to 7.0 m in the east.

The shoal-front environment contains an estimated 430 million m^3 of sand. It reflects deposition on the upper depositional slope between the 4- and 6-m isobaths at the western end of the shoal and the 8- and 10-m isobaths in the east. Because of this increase in depth, it is a lower energy environment than the shoal crest. Consequently, more burrowing activity is present in this very fine sand facies relative to shallower shoal-crest deposits. The lower sand facies or shoal-base environment represents the area landward of the shoal front where advancing sand is deposited during migration of Ship Shoal. This region lies between the 8- and 9-m isobaths at the western end of the shoal and the 11- and 12-m isobaths at the east. Because the shoal base is below the fair-weather wave base for this region, more burrowing is observed. This deposit is estimated to contain 640 million m^3 of material.

A discontinuous sand sheet extends seaward from the shoal marking its retreat path. Landward migration of Ship Shoal allows sediment transported from the leeward slope to be retained within the Ship Shoal sand body. This sediment is exhumed and reworked when Ship Shoal has migrated a distance equivalent to its width. At its present rate of migration (10-15 m/yr), the sand body is reworked completely every 500 to 1,000 years. This pattern of shoal retreat and storm-dominated transport generates a remnant sand sheet on the continental shelf. Sand eroded from the seaward slope of Ship Shoal during a storm may be redeposited offshore to blanket the retreat path. This fine sand layer ranges between 0.09 and 0.13 mm and contains occasional graded and flaser bedding.

The facies under the shoal represent relatively fine-grained environments that have limited practical

indicate an overfill factor of 1.03 for replenishment of the Isles Dernieres system (McBride et al. 1989). This infers that for every cubic meter of beach replenished on Isles Dernieres, 1.03 m³ of sand would be required from the Ship Shoal sand body, making it an ideal sand source.

Summary

Ship Shoal is a shore-parallel sand body 15 km offshore, with an estimated 1.2 billion m³ of minable material. The quantity of sand, along with the compatibility of sand characteristics from Isles Dernieres, indicate Ship Shoal is an excellent source for beach replenishment. Should it prove economically and environmentally feasible to utilize this resource, the amount of sand present in Ship Shoal alone could satisfy requirements for beach replenishment and maintenance of Isles Dernieres for the foreseeable future.

DREDGING OPERATIONS

As part of the comprehensive evaluation for near-term leasing of sand from Ship Shoal, the Coastal Engineering Research Center provided a summary of dredging technology that could be used for mining in this area. Through a literature review of pertinent dredging technology, discussions were separated into four categories: general dredging, aggregate mining, beach replenishment, and dredging equipment. Three primary references provide an overview of dredging technology: Hydraulic Dredging (Huston 1970) covers most aspects of dredging contracts associated with hydraulic cutterhead pipeline dredges; Coastal and Deep Ocean Dredging (Herbich 1975) discusses most aspects of dredging with substantial theoretical treatments; and Fundamentals of Hydraulic Dredging (Turner 1984) stresses applying hydraulic principals so as to predict and maximize dredge performance.

Offshore aggregate mining is uncommon in the United States. McCormack Aggregates in Amboy, New Jersey, and Tidewater Sand and Gravel of Oakland, California, are the principal operators in this industry and the main product is concrete (medium) sand. Both operators use hopper barges propelled by integrated tugs, and they pay royalties to the states. Europe, particularly the United Kingdom, has a well-developed aggregate mining industry. This industry has recently been upgrading its fleet of hopper dredges. Wheeler

m, a condition that occurs only 4% of the time in the Ship Shoal area. Of the 20 hopper dredges in the United States, about 12 potentially would be available for a Ship Shoal operation. However, drafts of the hopper dredge may limit their applicability in the project area. Of the 12 available hopper dredges, three draw about 4.7 m loaded. These dredges are split hull and have direct pump-out capability. Another seven draw about 6.1 m loaded. Five of these are split hull, and two can pump out. The remaining two draw about 9.1 m; neither is split hull but one is particularly suited to pump out long distances.

Regardless of the equipment used, haul distance is a primary consideration for economic purposes. Hopper dredges technically have the potential for unlimited haul distances. However, because they must carry the crew and equipment required for dredging all the time, it is economically advantageous to maximize the time spent dredging and minimize the time spent transporting material to the placement area.

Large (27 in. [69 cm] or greater) pipeline dredges are strongly constructed cutter suction pipeline dredges operating on anchor or cable positioning systems that can operate in up to 1.5-m seas. They are the most common dredge type. However, downtime for repairs usually increases significantly in greater sea conditions. Generally, the pipeline is more susceptible to damage than the dredge. Conventional floating pipeline cannot withstand over 1-m seas and would probably not be used at Ship Shoal. Submerged lines that rest on the bottom can withstand virtually any sea condition. Problems occur where the submerged line joins the dredge. Most submerged lines used with pipeline dredges connect to floating line near the dredge to allow the dredge to move around. Although flexible floating hose, which is much more resistant to sea conditions than floating pipeline, may be used, it is much more expensive.

A few European pipeline dredges are self-propelled and have the lines of ocean going ships. These can safely ride out severe weather. There are no dredges of this type in the United States; however, a few of the larger U.S. dredges were designed for offshore operation in not too severe conditions. There are about two dozen large pipeline dredges in this country. It is uncertain if any U.S. contractor would be willing to take his dredge over 20 miles from protected waters. A much less ambitious project in 1984 for placing maintenance material from Cat Island Pass on Isles Dernieres received no bids until it was substantially

get inside Wine Island Pass if the entrance channel were deepened and pump material all along Isles Dernieres. On the other hand, the hopper dredge could dump its load about 1 mi (1.6 km) offshore of the beach, and a pipeline dredge could pump material ashore. The dredge and pipeline would be moved as work progressed along the beach.

The single dredge most successful at procuring large beach replenishment jobs on the east coast is a 16,000-yd³ (12,234 m³) hopper barge designed for long pump-out distances. Being a barge, it is propelled by an integrated tug. It is rarely used for channel dredging, presumably because of maneuverability limitations. It has a maximum loaded draft of 28 ft (8.5 m) and a light draft of 8.5 ft (2.6 m). A 20-ft (6.1 m) draft restriction would allow it to carry 60% of its full load and come within 3.7 km of shore at Isles Dernieres. It usually pumps out via a single-point mooring buoy and submerged line, so it is well equipped for exposed waters. It has two, approximately 6,000-Hp pumps that may be connected in a series. It has pumped sediment distances of up to 45,000 ft (13,716 m), which is more than enough to carry the material to shore.

As an alternative, a pipeline dredge using a spider barge or a mechanical dredge could fill scows. The scows would be towed by a tug to the backside of Isles Dernieres then unloaded by a barge unloader. A barge unloader is basically a suction pipeline dredge modified so it dredges sand out of a barge. To carry sand to the beach, pipeline would be laid across Isles Dernieres. This method may be environmentally restrictive depending on the location for unloading. The scows must have shallow drafts to avoid grounding in shoal waters behind the Isles Dernieres.

Cost Estimates

The uniqueness of this project makes it difficult to provide accurate cost estimates using standard methods. They use many standard assumptions that may be invalid in a unique project, such as Ship Shoal mining. USACE bases its estimates upon the fair and reasonable cost for a prudent well-equipped contractor to perform the work. They do not consider bidding climate. If there is more work than available dredges, bids will rise; if the industry has excess capacity, bids will fall. Considering that the work at Ship Shoal is

Summary

Mining Ship Shoal as a sand resource is technically challenging but appears to be feasible. It seems that the most suitable existing piece of equipment to place sand from Ship Shoal onto Isles Dernieres is a large hopper barge; although, small hopper dredges and a pipeline dredge would also provide a viable alternative. The cost is estimated to be between \$5 and \$12/yd³ for sand placed on Isles Dernieres. Initial projects will most likely cost closer to the high end of the range but may decrease as contractors become familiar with the area and project.

PHYSICAL ENVIRONMENTAL EFFECTS

Now that it has been determined that geological characteristics of the resource target are acceptable and that technology is available for mining the deposit, analysis of physical environmental impacts is the next step taken to determine the likelihood of resource use for coastal erosion control. This includes identifying incident wave characteristics, their impact on shoal morphodynamics, the patterns of wave movement associated with ambient conditions, and resultant change in wave transformation due to potential dredging activities. A common means of evaluating changes in wave propagation patterns for actual and hypothetical situations in response to changes in bathymetry is to perform wave refraction analysis. The two primary data sets needed to perform this type of analysis include a time history of incident wave processes for characterizing the local wave climate and bathymetry. Quantitative understanding of wave transformation is essential for discerning future patterns of coastal erosion in response to changing nearshore bathymetry, such as those associated with removal of material for beach replenishment. If changes in the area used as a borrow source cause adverse effects on the area being replenished (e.g., increased erosion due to wave focusing), alternative sources need to be considered.

Site Selection

Several criteria were used in choosing a potential borrow site. First, it was decided to avoid existing

average out of the south-southwest. Thirty-six model runs for ambient conditions and both dredging scenarios were made using average monthly wave conditions.

Wave rays for pre-dredging bathymetry associated with average wave conditions for all months showed the same general trend; the shallowest portion of Ship Shoal causes convergence of wave rays in the western portion of the study area. This condition is accentuated during winter and spring, when average wave heights are greater and angles are steeper, and reduced between June and August, when waves mainly are approaching from the south. In no cases do waves break over the shoal crest; however, extreme storm conditions were not evaluated, and it is likely that under these conditions, waves would collapse.

For both dredging alternatives, sand was removed from the grid numerically by increasing water depths over a selected portion of the lease block. For the first dredging scenario, extraction of one million cubic yards of sand from the leading edge of the shoal in Block 88 caused insignificant changes in wave refraction patterns. Removal of this quantity of material affected about 3.9% of the lease block area. The most noticeable change relative to ambient conditions was a slight divergence of wave rays (a decrease in wave energy focusing) just shoreward and to the west of the excavation site. Changes in wave refraction patterns associated with extraction of ten million cubic yards of sand was slightly more noticeable but still showed relatively little influence. Although this is a significant amount of sand, only 17.9% of the lease block area was affected. Again, a greater degree of divergence was associated with imposed bathymetric changes (a positive result) although slightly greater convergence was indicated just east of the dredged area.

Summary

Comparisons of pre- and post-excavation scenarios indicate very little change in wave approach patterns relative to pre-dredging conditions. Divergence of wave rays was the most prominent impact, although small areas of convergence were illustrated on a few of the wave ray diagrams. This suggests that the conditions tested pose little to no effect on the physical environment present at the site prior to extraction. It is expected that changes in wave approach related to major storm events may have a greater influence on the imposed extraction scenarios.

transportation down the river to the replenishment site. In addition, sand companies in this area have quoted a maximum of one million cubic yards of sand at the borrow pit. However, several operators indicated they could obtain sand from other sources (river sands from dredging companies along the Mississippi and Pearl Rivers) to increase the volume to 4 to 5 million yd³.

There are a few dredging companies that operate along the Mississippi River. The Yard, a company located in Port Allen between mile 240 and 220, is capable of dredging and barging bottom sediments from the Mississippi through the Intracoastal waterway (approximately five miles from dredge site) to the barrier islands. Another source of sand along the Mississippi River occurs in point-bar deposits at sixty-mile point near the town of Nairn. Brown and Root (1988) studied the sixty-mile point sand source for beach replenishment of Shell Island. The sand resource was estimated at 7.8 million yd³, provided a maximum depth of excavation could be obtained. However, these point-bar sand deposits contain 1.4 million yd³ of mud overburden (Brown and Root 1988). Nairn Enterprises quoted a price of \$0.94/yd³ (not including delivery) in the same area from their dredge site with no overburden. T. L. James is another company with dredging interests in the Mississippi and Pearl rivers. Dredging costs are estimated at \$2.00/yd³ near Nairn, but barging costs skyrocket to \$20.00 to 25.00/yd³ because of down time of the dredges between runs to the island and back.

The closest source of sand near Isles Dernieres occurs along the Caminada-Moreau Headland in Lafourche Parish. Gerdes (1982) obtained vibracores and borings from the Caminada-Moreau beach ridge plain, which indicated that the sand unit of the ridges range from 0.5 to 1.0 m on Plaissance Ridge with additional 3.5 m of sand described as the upper to lower shoreface. The mean grain size for sand on the Plaissance Ridge is 0.125 mm. Borrow pits in this area have reserves of at least 2 million yd³ of fine to very fine sand. Even if all this sand could be mined from the ridge, it represents a minor contribution necessary for coastal restoration. Cost estimates from existing borrow pits are quoted at \$3.50/yd³ for sand at the pit and \$6.00 to \$7.00/yd³ delivered to Isles Dernieres.

beach ridge plain are \$3.50 to 4.00/yd³ at the pit, with an estimated cost of \$6.00 to 7.00/yd³ delivered to the replenishment site. However, the estimated maximum sand volume in this area is roughly 2 million yd³ of material.

ECONOMIC ANALYSIS

Although the cursory examination of costs associated with dredging alternatives provided a mechanism for gauging project feasibility, a more rigorous economic analysis was performed using geologic and engineering parameters with a statistically based mining economics model called QUIKSAND. The model uses a Monte Carlo simulation technique whereby the pertinent variables are sampled from cumulative probability distributions over many trials yielding results derived from an averaging process taken over the number of trials. It provides a means of handling a series of subjective judgments about individual variables. This method explicitly recognizes the probabilistic nature of all variables affecting the evaluation and calculates a large number of possible outcomes based on random samples from input probability distributions. Because much of the geologic and engineering data (e.g., areal extent and thickness of the resource, recovery factors, production rates, product prices, costs) used to evaluate a resources economic potential is known with varying degrees of uncertainty, the Monte Carlo technique provides a range of resource economic values (Net Present Worth [NPW]) with the probability of each occurrence being a direct consequence of data uncertainty.

Economics of Dredging Alternatives

An earlier evaluation of dredging alternatives identified two potential methods of mining approximately one million cubic yards of sand from Ship Shoal and placing it along the eastern half of the Isles Dernieres barrier island arc. The first utilizes a 16,000-yd³ hopper barge dredge using a direct pump-out discharge through a single point mooring buoy and a submerged pipeline to transport the sand to shore and the second uses two, 1,300-yd³ hopper dredges to mine the sand and dump it at some point close to shore where a pipeline dredge would rehandle the sand and transport it onshore through a pipeline.

Costs associated with these methods were redistributed within the framework of the cost parameter

represents a present worth value either above or below the economic break even point of zero MROV. In this way, the model is not used to establish a present worth for a certain commodity price but is used to establish the minimum commodity price at which the dredging project is economically feasible. The economic analysis for each proposed dredging method was performed for the two volume considerations discussed earlier: one million and ten million cubic yards from Block 88 on the northeast half of Ship Shoal. Method 1 generated a commodity price of \$5.19/yd³ for dredging one million cubic yards of sand and \$3.10/yd³ for dredging ten million cubic yards of sand, utilizing one 16,000-yd³ hopper barge dredge with a direct pump-out discharge. Method 2 generated a commodity price of \$8.45/yd³ for dredging one million cubic yards of sand and \$6.36/yd³ for dredging ten million cubic yards of sand, utilizing two, 1,300-yd³ hopper dredges and a pipeline dredge.

An alternative scenario is proposed that depends on technology suited for open water projects. Because this equipment does not exist in the United States, capital outlay associated with design and construction would be large; however, if a long-term dredging operation could be sustained, cost analyses suggest that the project could be economically viable (\$8.35/yd³ for a 14-yr period for one hundred million cubic yards of sand).

Summary

A statistically-based mathematical model was employed to evaluate the economic feasibility of sand mining on Ship Shoal for coastal erosion control. Using results from geological and engineering studies, the model was run using the two most likely dredging scenarios for two different volume requirements. The economic analysis performed with the QUIKSAND model indicates that a commodity price of \$5.19/yd³ is associated with using a 16,000-yd³ hopper barge with direct pump-out discharge through a single-point mooring for the production of one million cubic yards of sand; for ten million cubic yards, the price decreased to \$3.10/yd³. Using two, 1,300-yd³ hopper dredges to mine the sand and a pipeline dredge for rehandling the sand at a point close to shore, a commodity price of \$8.45/yd³ is estimated for the one million cubic yards

Several recommendations have been formulated relative to the results of this study:

1. The information generated from this study should be presented in a workshop to assess interest and/or concern from local, state, and federal agencies, industrial representatives, and private groups in using this sand resource as proposed.
2. If there is sufficient interest in using sand from Ship Shoal, selection of specific potential leasing sites should proceed with consideration for resolving conflict with oil and gas operations.
3. A detailed geological and physical environmental analysis should be performed at selected sites to better define resource and environmental parameters on shoal morphology and shoreline processes.
4. Site-specific analysis of the potential impacts of nearshore dredging activities on the ecosystem of the area should be performed.
5. The methodology developed in this study should be applied to other sites and potential projects along the Gulf Coast.

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