NATIONAL BERM DEMONSTRATION PROJECT: MOBILE ALABAMA

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Abstract

The U.S. Army Corps of Engineers is responsible for dredging and disposal of several million cubic meters of material each year. Alternatives are needed in many cases to conventional open-water disposal for the large volumes of clean material dredged annually. The concept of using suitable dredged material to construct submerged shore parallel features to derive physical and environmental benefits, is gaining acceptance. The Mobile District has constructed two such features in the Gulf of Mexico. In 1987 a feeder berm was constructed with sandy maintenance dredge material. In addition, from 1988 to 1990, 18.7 million cu yd of dredged material derived from the Mobile Channel deepening project was placed in 35 to 50 ft depths reducing bottom elevation to approximately 20 ft in the drop zone. Extensive coordination and communication was conducted to get both projects under way. In addition a physical/biological monitoring program is underway to evaluate the environmental and physical process in and around each berm.

Background

The Corps of Engineers national dredging program involves excavation of a tremendous volume of material each year for channel maintenance and construction. Currently, the annual quantity of maintenance material excavated is about 285 million cu yd at a cost over $ 400 million. The passage of the Water Resources Development Act of 1986 will result in an expenditure of an additional $ 800 million for about 350 million cu yd of channel improvement dredging through FY 1991. The new work dredging cost is expected to increase by about $ 1.5 billion through the 10 year period after passage of the Act, or through FY 1997. Since 90 to 95 percent of the dredged material is non-contaminated, the Corps is constantly seeking more cost effective and environmentally beneficial disposal techniques. One such alternative to traditional offshore placement of dredged material is the berm concept which considers dredged material a resource that should be retained in the nearshore zone for beneficial purposes.

There are two approaches to berm construction: feeder and stable.

A feeder berm is one constructed of beach quality sand placed in relatively shallow water, with the intent that the material will move out of the berm area and become part of the nearshore sand system. A benefit of the feeder berm is that it can become a supplemental sand source for nearby coastlines, thereby contributing to the total volume of material available for natural beach building and recovery processes. A stable berm is generally placed in deeper water; a wider variety of material can be used in constructing it; and the berm itself is intended to be relatively permanent feature. A stable berm can be constructed to shelter adjacent coastlines by partially reducing waves, particularly during large storms. If built from clean sand, it can be used as a stockpile for future beach nourishment. Also, the fact that a stable berm forms an identifiable feature on the bottom means that it has the potential to attract fish. Both approaches have potential for reducing dredging costs if haul distances can be reduced by allowing dredges to place material in a relatively concentrated area close to the navigation channel.

The Corps has a history of involvement in building underwater berms beginning in the mid-1930's with a 200,000 cu yd berm off Santa Barbara, CA, in 20 ft of water continuing with berms built off Atlantic City, NJ, and Long Branch, NJ, in 1948. The Atlantic City berm contained approximately 3.5 million cu yd placed in 38 ft of water. Although these placement operations were originally intended to be feeder berms, subsequent monitoring over a number of years showed that they remained relatively stable (Hall 1950, and Harris 1954). A pilot study initiated by OCE Dredging Division, was conducted in 1982 by the Norfolk District and the Coastal Engineering Research Center (CERC) within the Dam Neck dredged material disposal site in the Atlantic Ocean off Virginia Beach, VA. The purpose was to determine if a designed feature could be created on the ocean bottom with a relatively poor quality construction material with conventional dredging and positioning equipment. The study concluded that the hopper dredges and positioning equipment routinely used by the industry are capable of constructing significant mounds, even when the material is a mixture of fine sands and silts. About 850,000 cy yd of maintenance material was placed in the site in about 40 ft of water. A mound was created which was 11 ft high, 1600 ft wide and 2800 ft long. Routine monitoring has revealed the mound to remain relatively stable, despite three hurricanes and numerous storms which have struck the area since construction in 1982 (Hands and DeLoach 1984).

Zwamborn, Fromme and FitzPatrick (1970) describe a mound constructed of sand in 50 ft of water 4000 ft off the coast of Durban, South Africa. The berm was designed as a wave filter to reduce erosive energy upon Durban's Beaches. The completed berm was to consist of 10 million cu yd of dredged sand, have a crest width of 200 ft and reduce water depths to 24 ft along the crest. Scale and prototype tests indicated mitigation of erosion affects leeward of the berm. During one major storm, protection of the beaches was demonstrated with little loss of elevation to the

berm.

With the advent of shallow draft split-hulled hopper dredges in the mid-1970's, the Corps again attempted, more successfully, littoral zone placement in 1976 (Schwartz and Musialowski 1977). The Wilmington District placed 35,000 cu yd of clean sand between the 6 and 13 ft contours. The placed sediment moved shorewared up to 6 ft /day with a corresponding increase in beach width inshore of the berm. Recently, additional emphasis has been placed on projects demonstrating the berm concept. Both the Corp's New York and Los Angles Districts constructed nearshore feeder berms using dredged material in 1987 and 1988 respectfully. The New York District constructed two similar parallel features off the barrier islands of Long Island. Each was constructed on the 16 ft contour with heights of approximately 6 to 9 ft. The 7500 ft long berms demonstrated the ability to construct berms at or near the loaded draft of the vessel (McLellan, Truitt and Flax, 1988). The Los Angeles District placed 130,000 cu yds of sand in 15 ft of water off Silver Strand State Park, California. Repetitive surveys indicate a shoreward migration of the placed sediment and an increased beach width (Junke, Mitchell and Piszker 1989). No significant problems were reported at any of these construction locations as a result of the placement technique.

National Demonstration Project

Based in part on the positive results of the Norfolk pilot study, the berm concept was endorsed in principle by the Corp's Environmental Advisory Board and the Coastal Engineering Research Board. Also, the headquarters staff of the National Marine Fisheries Service had indicated that a stable configuration had the potential of benefiting fishery resources. These endorsements led to approval by the Director of Civil Works in 1986 of a National Demonstration Project to assess and document potential physical and fishery benefits associated with underwater berms as a beneficial uses application of dredged material. The demonstration would be the first ever extensively documented large-scale implementation of the concept.

Mobile Harbor was chosen as the National Demonstration Site and the Mobile District proposed to demonstrate both berm types. The proposal was to construct the feeder berm as part of a routine hopper dredging contract that was about to be advertised, but place the material in a different location then specified under the existing environmental documentation, and place the material from the Mobile Channel deepening project into a stable berm configuration within the previously designated offshore disposal site (Figure 1). Before starting the demonstration project, coordination with the local Congressional offices, the local sponsor, navigation and environmental interests were conducted in order to gain broad support. There was particular concern in regard to the deepening project, that the demonstration neither

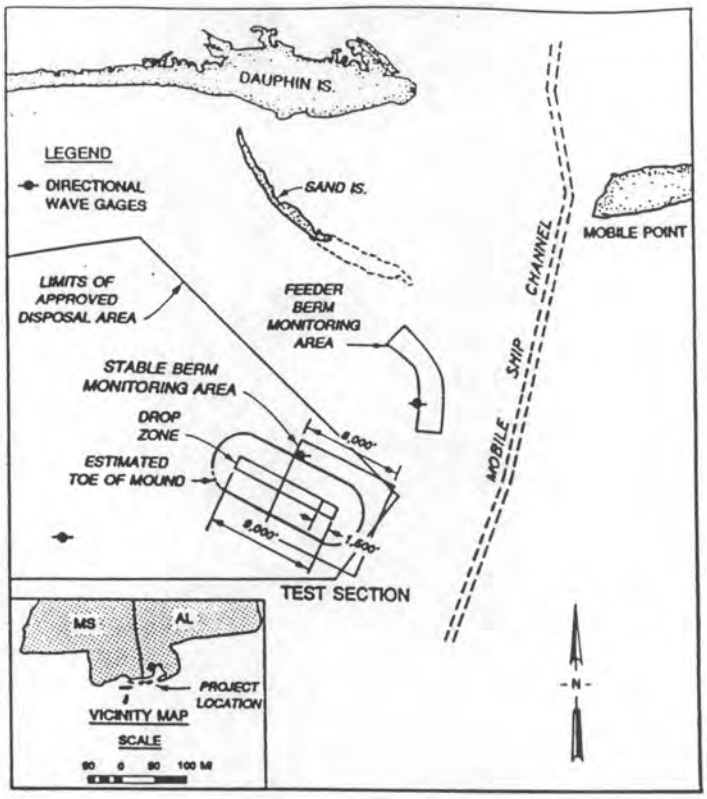

Figure 1. Stable and Feeder Berm Construction Location.

increase project cost nor delayed its start date. The cooperation and support the Mobile District received was exceptional, and as an example, the District was able to perform all of the environmental coordination and documentation including receipt of water quality certification and coastal zone consistency for the feeder berm within a two month period.

In order to maintain proper coordination of the multi-faceted activities and a formal line of communication within all the Corps offices involved in the demonstration, management and technical committees were established. The management committee, represented by the Mobile District, CERC, the Office of Chief of Engineers, and South Atlantic Division, are responsible for the overall direction of the demonstration project. The technical committee consists of the project's principal investigators for each of the feeder and stable berm activities from the Mobile District and CERC. Periodic meetings of both committees have been held and will continue through the project life and subsequent development of report documents.

The National Marine Fisheries is participating in monitoring associated with the stable berm by conducting fisheries assessments to determine any changes in the fisheries potential caused by the stable berm. Trawl samples will be collected in the vicinity of the stable berm and compared to historical fisheries data collected in the area.

Monitoring and Construction

Both berms are located west of the navigation channel within the

Gulf of Mexico, Figure 1. Abston et al. (1987), Otvos (1987), Hoffer (1984) and others have described the Gulf Coast off Alabama as a complex hydrographic area influenced mainly by discharges from Mobile Bay, tides, late fall and early winter storms, and hurricanes. Current velocities in the area range from a low normal of 5 to 15 cm/s to a high normal of 25 to 40 cm/s and can reach up to 140 cm/s as a result of hurricanes in the immediate area. Offshore bottom sediments generally move to the west and range from fine sands to silts in the Mobile North disposal area. Hindcast wave data, McAneny (1986), indicates the average wave height as 1.0 m, with an associated period of 5.1 s. Waves generally approach from the southeast, accounting for the westerly drift direction.

The feeder berm was placed less than 1.5 miles from the channel and the stable berm is about 2.5 miles from the channel and about 3 miles further offshore. The feeder berm was located with the expectation that the sand would gradually move toward the west contributing to the sand system off Dauphin Island. It was built in February 1987 by two shallow draft, split-hull hopper dredges which placed the material in 18 to 19 ft of water. Considerable time was spent by the contractor in following a precise alignment and in an effort to build a maximum height above the bottom, some portions as great as 7 to 8 ft. The contractor performed in an outstanding manner, sometimes grounding his vessel before placement, to achieve the desired feature (Hands and Bradley 1990). A clearly defined feature was necessary to enhance monitoring to determine the extent to which the dredged material moves with littoral processes.

Construction of the stable berm began in February 1988 and involved placement of about 18 million cy yd of widely varying new work material in 40 to 45 ft of water from the Phase I deepening of the bay and bar channels (McLellan and Imsand 1989). The Phase I project consists of deepening the existing channel from 40 ft to 45 ft through the bay and deepening the bar channel from 42 ft to 47 ft, over a total length of about 36 miles. The berm was constructed to 20 ft in height with design crest dimensions of 1000 ft by 9000 ft. The anticipated exterior slopes resulted in a berm about 1 mile by 2.5 miles at its base, making it the largest underwater feature ever constructed. The large placement area resulted in disposal costs savings by concentrating the material in the extreme eastern limits of the designated disposal area, reducing the average haul distances. The deepening contract within Mobile Bay was accomplished by the clamshell Dredge CHICAGO, and 6000 cy yd dump scows which transport the material to the berm construction site in the bay channel. The approach channel was dredged by split hulled hopper dredges. The Phase I deepening effort was completed in May 1990.

The monitoring of both the feeder and stable berm are cooperative efforts between the CERC and Mobile District. Monitoring objects elements are similar for both berms including wave gaging, hydrographic surveys, sediment sampling,and current measurements.

The principal objective of the monitoring is to measure the physical characteristics of both berms and how these characteristics change with time. The program is also designed to measure some of the overall physical forces that cause these changes and any fisheries benefits that may accrue due to the stable berm. The extensive monitoring program was designed in part so that results of the National Demonstration can then be applied to other coastal areas of the United States.

Feeder Berm. Monitoring on the feeder berm was begun in December 1986 with surveys to characterize the pre-berm bathymetry and native bottom sediment characteristics. The first post-construction survey was conducted upon completion of the feeder berm in March of 1987. The berm was constructed between the 18 and 19 ft contours. The completed feature was 6 ft in height, about 1 mile long, and contained about 450,000 cy yd of sand. The depth near the drop zone was reduced to a minimum of 9 ft with an average depth of 13 to 14 ft. By the January 1988 survey, the berm had begun to move west and minimum depths having been increased to approximately 12 ft (Hands and Bradley 1990). Additional survey data continues to be collected and Figure 2 shows a 3-D interpretation of the both berms as of February 1990. Other elements of the feeder berm monitoring task include side-scan sonar surveys, sediment samples, wave gaging, seabed drifter releases and aerial photographs.

Several side-scan-sonar surveys were performed in the early stages of the feeder berm monitoring. Side scan can be very

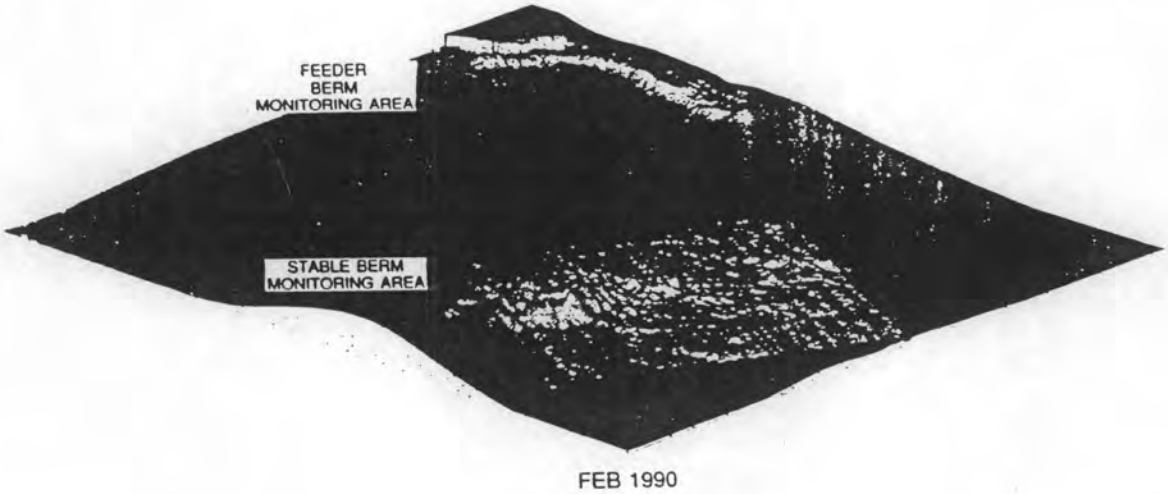

Figure 2. Stable and Feeder Berms February 1990.

effective in helping to delineate the interface between placed material and native bottom material. However, making this delineation depends on physical differences between the native and placed material. In the Mobile feeder berm project, the placement material turned out to be almost identical to the native bottom material and therefore, side scan was not of much use in mapping the exact edges of the feature so the practice was discontinued.

In conjunction with the hydrographic surveys, surface sediment samples were collected at repeated locations. As the feeder berm moves, a sorting of the finer sediment grains, particularly from the crest of the berm and deposition of the finer sediment in the area toward which the berm material is moving, can be observed. This sorting gives an indication of the direction of movement, and can also help supplement the bathymetric data provided by the hydrographic surveys.

One of the potentially most valuable components of the Feeder Berm Monitoring Program for extrapolating the results of this monitoring to other locations is a nearshore directional wave gage. In conjunction with other measurements, directional wave and current measurements can help assess the magnitude of forces required to begin large scale movement of the feeder berm. Accurate wave and current measurement will be of particular benefit when applying the National Berm Results to other localities in the United States.

Current tracking devices called seabed drifters are being used in an attempt to map the direction of net nearbottom transport (Hands 1987). Clusters of these drifters are released in the feeder berm area periodically during the hydrographic surveys and are recovered either by CERC investigators in the field or by local citizens who find them washed up on adjacent beaches. Attached to each seabed drifter is a waterproof, postpaid return card with instructions to the finder to note the time and place of recovery and to mail it back to the Mobile District.

The final component of the feeder berm monitoring consists of aerial photographs and satellite images of the feeder berm area. With sufficient water clarity the aerial photographs can give a good quality picture of the feeder berm and the surrounding area and of large scale changes that might occur in the area during the monitoring period. It is intended to compare results from the aerial photographs with high resolution satellite imagery to assess it usefulness for monitoring nearshore sand placement at other locations.

Stable Berm. For the purposes of the Stable Berm demonstration, the entire berm will not be monitored but only a test section that will be the first part of the berm to be constructed, and that will form one end of the berm feature when it is completed (see Figure 1). After the test section was completed, the dredging contractor was required to place material at the other

end of the berm feature and begin working back towards the test section. The last material moved from the Phase I deepening was used to close the gap between the test section and the remainder of the berm.

Monitoring of the stable berm includes hydrographic and side-scan surveys, and subbottom profiling. Since the Phase I deepening material is considerably different than the native bottom material in the berm placement area, the side-scan surveys have been an effective method in delineating the spread of the placed sediments. Subbottom profiling helps define the interface underneath the berm and the native bottom material and the berm material placed on top (McLellan and Imsand 1989). The hydrographic surveys are used to determine the overall shape of the mound and how it changes with time. After an initial period of adjustment the test area has been relatively stable since January 1989.

As with the feeder berm, surface grab samples are being collected across the test section of the stable berm to characterize the sediment placed there and to measure any armoring of the berm that may take place due to sorting out of the finer material from the berm crest. Grab samples are also used to verify side-scan sonar records for material spread delineation studies. Along the flanks of the berm sediment profiling data will also be collected to measure the thickness of the berm were accuracy hydrographic surveys is reduced (less than 0.5 ft). The sediment profiling data is also excellent tool for evaluating benthic activity (Germano 1983).

Short diver-operated sediment cores are being collected in the test section to measure characteristics such as reworking of the material. At the same time these sediment cores are being taken, the divers are making visual observations of the berm characteristics and noting any changes they see occurring in the stable berm surface.

In October of 1987 a directional wave gage was placed offshore of the stable berm location to begin baseline wave data collection. In April 1988, an additional directional wave gage was placed leeward of the berm. By having the two wave gages in place, not only can the incident wave climate be measured, but the effects that the stable berm has on the incident wave climate, particularly on storm waves can be calculated. The ability of the berm to attenuate wave energy has already been shown to reduce storm wave energy up to 70% (McLellan, Pope and Burke 1990).

Summary and Conclusions

Nearshore berms are being constructed at several locations in the U.S., including the Gulf of Mexico off of the coast of Alabama as part of a National Berm Demonstration Project. The

enormous amount of data is still being processed but some results are already available. The monitoring of each of the berms is scheduled to continue through September 1990. Results from the study will be a valuable source for model calibration, improved methodologies and extending berm technology to other parts of the United States.

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Nearshore Mound Construction Using Dredged Material

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ABSTRACT

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The U.S. Army Corps of Engineers is responsible for dredging and disposal of several million cubic meters of material each year. Alternatives are needed in many cases to conventional open-water disposal for the large volumes of clean material dredged annually. The concept of using suitable dredged material to construct submerged shore parallel features to derive physical and environmental benefits, is gaining acceptance. Field experience with berm construction is limited but ten sites have been identified where the technique has been applied in one form or the other. Site selections and construction for berm projects are similar to other dredging with some additional advanced planning and design. Modeling and evaluation methods are available to aid in design and construction. Additional information on berm design and construction is provided.

ADDITIONAL INDEX WORDS: *Dredged material, dredging, mounds, berms, offshore disposal, wave attenuation.*

INTRODUCTION

The U.S. Army Corps of Engineers is responsible for maintaining the navigability of the waterways of the continental United States. A majority of time and money maintaining the waterways is in the form of new and maintenance dredging. The Corps of Engineers removes 190 to 230 million cubic meters of material annually at an average cost of $400 million per year (MCNAIR, 1989). Recently authorized improvements will increase expenditures by approximately $200 million per year through 1998. The vast majority of this material, over 95%, is clean and available for beneficial uses. The Corps has recognized this potential and used dredged material in the past for creation of wetlands, beach nourishment, habitat development as well as several other uses including offshore berm construction (LANDIN, 1988). While the Corps is committed to utilizing dredged material beneficially, it is equally charged with being concerned about disposal costs.

Approximately 70 to 100 million cu m of dredged material is placed in the 105 designated open water disposal sites annually (MARINE BOARD, 1985). Normally, placement of material in the site is left to the discretion of the dredge contractor. Disposal site coordinates are supplied and the material is placed within the confines of the site, usually closest to channel currently being dredged. The depth of placement can range from 10s to several 100s of meters. The primary concerns of the dredge operators are to maintain safe navigable depth, place the material within the designated coordinates, and perform the operation at the lowest possible cost.

An alternative to the conventional open water placement practices, which can provide beneficial uses of dredged material, is nearshore berm construction. By accurate controlled placement of dredged material, nearshore berms can be constructed to provide physical and/or biological benefits. Potential benefits include attenuation of wave energy, introduction of material into the littoral system, creation of fish habitat and cost reduction. CLARKE *et al.* (1989), MURDEN (1988), and others have documented benefits and potential benefits of dredged material mounds from increased fisheries population and diversity, to creating a substrate for oyster colonization. CLARKE, FREDETTE and IMSAND (1988) describe the

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important design features as orientation of the mound to prevailing currents, height of mound compared to existing bottom, side slope steepness, sediment grain size and mound footprint on the bottom for maximizing fisheries benefits. GUNYAKTI (1987), ZWAMBORN *et al.* (1970), and SCHWARTZ and MUSIALOWSKI (1977) have demonstrated the physical benefits of submerged mounds, which include wave attenuation and beach profile enhancement.

To ensure the proper effectiveness of a nearshore berm the construction cannot be treated as a modification of conventional open water disposal operations. The berm must be considered an engineered structure, requiring a verifiable design, construction methodology, and periodic maintenance throughout the design life of the structure. Traditional equipment and procedures are not precluded from use in nearshore berm construction and in fact have been used successfully in several previous projects (McLELLAN *et al.*, 1988 and McLELLAN and IMSAND, 1989). Previous investigations have focused on specific pilot projects with limited attempts to provide an experience base evaluation for more general applicable design recommendations. The present paper draws on several completed projects and offers comprehensive planning level document for design and construction considerations for nearshore berms.

BERM CONCEPT

Conventional open water placement techniques differ significantly from mound construction operations. In the first case, the dredge contractor is provided with a designated open water area where sediment is to be placed, how the material is spread over that area, however, is left to his discretion within the bounds of local requirements. During the latter case, a specific set of coordinates is defined to receive a specified volume of dredge material with intent to construct a well defined submerged feature above the normal bottom. Construction of submerged mounds in relatively deep water, greater than 20 m, is normally associated with the mitigation of contaminated material. Construction of a well defined mound reduces surface area which allows economic capping with clean material. In relatively shallow water, less than 15 m, the project designer expects strategically placed mounded material to enhance the local area by altering erosive hydrodynamic conditions, thus reducing energy expended upon the coastline, or adding suitable material to the existing profile and allowing natural recovery processes to transport the material to the littoral zone. Additionally, dredged material mounds have been constructed to provide suitable substrate for oil exploration in the Canadian Beaufort Sea.

Capping

TRUITT *et al.* (1989), SHIELDS and MONTGOMERY (1984), MORTON (1987) and others have described several submerged mound construction operations demonstrating the capping concept. In a typical operation contaminated sediment is dredged by a clamshell dredge and transported to the placement site via bottom dump scows. Stringent navigational controls are used during the placement procedure using both electronic systems and taut wire buoys. Mounds several meters in height are constructed, with the central mound having side slopes of 1 on 30 or greater, containing the majority of the material. A sharp break in slope occurs near the bottom and a thin apron of material, representing a small percentage of the entire mound volume, may extend for several hundred meters from the placement location. The contaminated sediment is then isolated by covering with three or more times the volume of clean material to produce a cap 1 to 2 meters thick. The area is always chosen so that the local wave and hydrodynamic climate will have little affect on the mound.

Oil Exploration

Several dredged material mounds have been constructed in the Canadian Beaufort Sea to provide suitable substrate for a variety of exploration platforms. The berms were constructed in 21 to 45 m of water and were often constructed using specialized equipment and/or sandbags to increase side slope steepness and reduce the overall volume required at the site (JANSEN, 1988; DIKKEN and BRAKEL, 1982; and many others). Reduced volumes were necessary due to the short construction season, July to November, in the Beaufort Sea. Construction was normally carried out by trailing

suction hopper dredges assisted by construction barges to place the material accurately, often through a submerged discharge nozzle used to reduce velocity and increase placement accuracy. Side slopes of 1H to 7V were achieved by this construction methodology. Upon construction of the required dimensions, a layer of gravel one meter thick was placed over the berm as protection from erosion and provide a suitable substrate for an exploration platform. SLADEN *et al.* (1985) describe the one Beaufort Sea mound failure that was recorded when the Nerlerk berm experienced five liquefaction slides during construction. The failures were attributed to construction technique and material inconsistencies. Mounds constructed for oil exploration are designed to provide a stable platform and withstand erosion forces from ice, waves and currents.

Nearshore Mounds

Nearshore mound construction can enhance the coastline in two ways: creating a feature that reduces erosive energy on the coastline, or increasing the net volume of material in the sediment transport system. One nearshore placement technique termed thin-layer disposal (NESTER and WARREN, 1987) introduced material in the nearshore zone over a wide area using a splash plate at the end of an oscillating disposal pipeline. A large volume of material may be placed in this method but since the local bathymetry stays relatively unchanged, local hydrodynamic conditions undergo little modification. The other extreme of nearshore placement would be construction of a stable offshore berm with sufficient relief to modify the wave climate without adding significant amounts of sediment into the system. Most nearshore projects will usually produce both effects, but in varying proportion.

If the berm's primary design purpose is energy attenuation, it can be accomplished by placing material with relief high enough and at such a depth to shoal and break waves, dissipating energy through friction or turbulent diffusion losses. Since the material is not intended to nourish the beach, the construction material is open to a wide range of materials. With proper design and construction, the berm will trip high energy storm waves, while allowing lower energy beach building waves to progress onto the beach. The berm's stability will be a function of the sediment grain size, water content, wave climate, structure dimensions and side slope steepness. Potential benefits derived from this type of placement include shoreline protection by wave attenuation, reusable sediment stockpile, reduction of dredging costs, retention structure for fluid muds and fisheries habitat.

Beach quality material placed within the littoral system can benefit the shoreline by providing additional material in the beach profile. The material has the potential for mitigating erosion problems by providing a sacrificial source of sediment, a sill to reduce the movement of material offshore, a source of sand for downdrift areas, and during times of accretion, provide a sand source for the beach profile. The feeder berm erosion rates will depend on wave climate, sediment grain size, depth of placement and dimensions of the mound. By calculating and monitoring the erosion rates (ANDERS and CLAUSNER, 1989), the berm can be nourished at appropriate intervals to provide a continuing source of sand. In the case of artificial beach nourishment, BRUUN (1988a, 1988b), has described the importance of placing material offshore to nourish the beach profile. Since grain size normally decreases moving offshore, placement of suitable grain sized material at the proper depth will increase stability and reduce costs, when compared to similar material placed on the beach. Whatever the desired objectives, the proper equipment, location, and placement techniques must be selected.

NEARSHORE MOUND CONSTRUCTION

HALL (1950), RICHARDSON (1986) and LANGAN (1988), among others have noted that nearshore placement and berm construction are not new to the Corps (Table 1). In 1935, the Corps placed 153,000 cu m of sand in 6.1 m of water at Santa Barbara, Ca. A total of 2.7 million cu m of material were placed in a series of similar projects along Atlantic City, N.J., and in 1948, 460,000 cu m were placed in a mound configuration 2.1 m high in water 11.6 m deep off Long Branch, N.J. These first attempts at beach nourishment through offshore placement were less than successful. Available dredging technology required drafts of over 11 m for safe

Table 1. *Nearshore berms constructed with dredge material.*

Location	Date	Material Quantity (cu m)	Material Type	Water Depth (m)	Mound Height (m)	Reference
Santa Barbara, California	1935	153,000	sand	6.1	NA	Hall (1950)
Atlantic City, New Jersey	1935–1942	2.7 mil	sand	4.6–7.6	NA	Hall (1950)
Long Branch, New Jersey	1948	460,000	sand	11.6	2.1	Hall (1950)
Durban, South Africa	1970	8.0 mil	sand	15.0	7.7	Zwamborn, Fromme & FitzPatrick (1970)
New River Inlet, North Carolina	1976	26,750	sand	1.8–4.0	NA	Schwartz & Musialowski (1977)
Dam Neck, Virginia	1982	650,000	silty sand	11.0	3.3	Hands & Deloach (1984)
Sand Island, Alabama	1987	300,000	sand	5.7	2.1	Bradley & Hands (1989)
Fire Island, New York	1987	320,000	sand	4.9	2.0	McLellan, Truitt & Flax (1988)
Jones Inlet, New York	1987	300,000	sand	4.9	2.0	McLellan, Truitt & Flax (1988)
Mobile North, Alabama	1988–1989	14.3 mil	clay, silt & sand	10.7–13.7	6.6	McLellan & Imsand (1989)

navigation and placement of material was relatively slow. All the mounds remained fairly stable and had little or no measured impact on the beach. A restudy of the Long Branch site by HARRIS (1954) indicated little change to the mound after four years. Even though the berms did not directly enhance the beach, they did demonstrate the relative stability of dredged material mounds.

With the advent of shallow draft split-hulled hopper dredges in the mid to late 1970's, the feasibility of using conventional dredging and placement practices for berm construction began to become a reality. The relatively shallow draft, 6.7 m or less, and rapid placement technique of the split hull, less than five minutes, allows the dredge to place material accurately and safely in the active littoral system. WORLD DREDGING, MINING & CONSTRUCTION (1989) currently lists 13 shallow draft split-hulled hopper dredges, see Table 2, operating in the United States on a routine basis. The dredges are equipped with modern electronic positioning, required for the dredging operation, which can be utilized during the placement procedure to ensure accurate placement for the construction of a well defined submerged feature. There is also a growing number of split-hull hopper barges becoming available for dredging and placement projects.

In 1976 the Corps' Wilmington District placed 26,750 cu m of sand between the 1.8 to 4.0 m contour downdrift of the New River Inlet, North Carolina with shallow draft vessel Currituck. SCHWARTZ and MUSIALOWSKI (1977), reported that during the monitoring period the berm migrated landward up to 1.8 m/day, extended the breaker zone offshore and accreted material on the beach. Within 34 days after disposal 75% of the placed volume had been removed from the construction site. During the early 1980's, the Corps constructed a 3.3 m high stable berm using 650,000 cu m of sand and silt in 11 m of water at the Dam Neck site off the coast of Virginia (HANDS and DELOACH, 1984). The mound demonstrated the ability and stability of constructing a definable offshore mound with relatively fine grained dredged material with split-hulled hopper dredges.

ZWAMBORN *et al.* (1970) describe a mound constructed of sand in 15 m of water 1200 m off the coast of Durban, South Africa. The berm was designed as a wave filter to reduce erosive energy upon Durban's Beaches. The completed berm was to consist of 8 million cu m of dredged sand, have a crest width of 61 m and reduce water depths to 7.3 m along the crest. Scale and prototype tests indicated mitigation of erosion affects leeward of the berm. Both reduction of beach erosion and wave energy were demonstrated by the tests. Physical model test results showed a reduction in non-breaking wave height of 30%, while the amount of reduction increased rapidly with breaking waves. During one major Durban storm, protection of the

Table 2. *United States split-hulled hopper dredges with less than 6.7 m draft.*

Dredge	Owner	Year Built	Loaded Draft (m)	Max Capacity (cu m)	Dredging Depth (m)	Length (m)
Currituck	Corps of Engineers	1973	2.1	239	6.1	43.9
Newport	Manson Const. Co.	1976	5.5	3057	19.8	80.8
Westport	Manson Const. Co.	1976	3.7	1376	19.8	54.9
Manhattan Island	North American Trailing Co. (NATCO)	1977	5.8	2751	21.3	85.6
Sugar Island	NATCO	1979	5.8	2751	21.3	85.6
Atchafalaya	Gulf Coast Trailing Co.	1980	4.6	993	19.8	60.0
Dodge Island	NATCO	1980	5.8	2751	21.3	85.6
Mermentau	Gulf Coast Trailing Co.	1981	4.6	993	19.8	60.0
Padre Island	NATCO	1981	5.8	2828	21.3	85.6
Eagle I	Bean Dredging Co.	1981	6.7	4215	24.4	103.6
Northely Island	NATCO	1983	4.6	1651	13.7	62.5
Ouachita	Gulf Coast Trailing Co.	1985	6.7	2943	19.8	90.5
Atlantic American	American Dredging Co.	1987	5.8	3042	21.3	89.6

beaches was demonstrated with little loss of elevation to the berm. Later surveys indicated accretion of material on the mound to pre-storm elevations above the bottom, indicating no net loss of material to the mound.

Recently, additional emphasis has been placed on the berm concept in the United States. Both the Corps' Mobile and New York Districts constructed nearshore feeder berms using dredged material in 1987. The 150 m wide by 1830 m long feature constructed by the Mobile District was in 5.8 m of water and rose above the bottom approximately 2 m (BRADLEY and HANDS, 1989). The material was placed by split hull hopper dredges with approximately 3.6 m drafts. The New York District constructed two similar parallel features off the barrier islands of Long Island with the shallow draft hopper dredge NORTHERLY ISLAND. Each was constructed on the 4.9 m contour with heights of approximately 2 to 3 m (McLELLAN *et al.*, 1988). No significant problems were reported at any of these construction locations as a result of the placement technique.

At the New York locations near the Fire Island and Jones Inlets, during construction surveys were utilized to identify any gaps occurring in the mound that were returned to and filled during the construction process. Additional construction control was provided by plotting the placement locations on a track plotter. The track plot provided two benefits. It allowed the dredge operator to accurately position the vessel during material placement and to sequence placement events to construct a continuous feature. The second benefit was a margin of safety, enabling the operator to avoid areas that had become too shallow for safe navigation, due to decreased depths from the construction operations.

McLELLAN and IMSAND (1989) describe a project currently being conducted by the Mobile District/Using 14.3 million cu m of dredged material to construct a 6.1 m high berm along a 305 m by 2,743 m drop zone off the coast of Alabama. The clay to sand range material is being placed in depths of 10.6 to 13.7 m at the drop zone. The berm is being constructed from clamshelled and hydraulically dredged material transported and placed by split-hulled barges and by split-hulled hopper dredges. The berm is being constructed to be a relatively stable feature to attenuate wave energy and provide fisheries benefits. Precision bathymetry was collected at the project before, during and currently is being periodically collected following construction. Wave and current data are being measured, along with sediment sampling and analyses. Additional data is being collected at the Mobile stable berm to quantify fisheries benefits (diversification and population) if any. With such large volumes and placement area, navigational accuracy utilized for the berm con-

struction is not as critical as with the feeder berms, however, placement control and construction monitoring are required to ensure that the design of the structure is completed properly.

NEARSHORE MOUND DESIGN

ZWAMBORN *et al.* (1970), FRISCH (1979) and GUNYAKTI (1987) have stressed the importance of design in the berm construction process. Factors such as sediment type, construction methodology, local wave and hydrological climate, depth, berm height and orientation must all be taken into account to ensure the berm performs as the designers intended. Improper planning and design can lead to problems as shown by LUDWICK and SAUMSIEGLE (1976). Numerical model studies of the Dam Neck disposal site showed that improperly mounded dredged material can cause convergence of wave rays, increasing wave height by as much as 20%. In addition ZWAMBORN *et al.* (1970) discussed the erosion caused by the focusing of wave energy by edge effects during Durban Beach stable berm construction. Berm construction is not without its problems but with proper design, stringent placement controls coupled with a well-planned pre-, during, and post-construction monitoring, most of the potential problems can be avoided.

To prevent wave focusing and better produce attenuating effects, FRISCH (1979), GUNYAKTI (1987), and ZWAMBORN *et al.* (1970) suggest the construction of linear feature and avoid singular conical shapes. Orientation of the berm will be determined by desired intent and local restrictions, but in most cases will be shore-parallel to take advantage of energy reduction benefits. In deeper berms designed to be stable, wave focusing edge effects can be reduced by placing material along the entire length of the structure to incrementally raise the bottom elevation to the desired depth. McLELLAN *et al.* (1988) described how periodic bathymetric surveys can be used during construction to identify gaps in the structure that can later be filled to ensure the feature is linear.

Material must be placed within the active littoral zone if it is to provide beach enhancement. HALLERMEIER (1981), BIRKEMEIER (1985) and others have discussed methods for calculating the seaward limit of sediment transport. Even within the active limit, GUNYAKTI (1982), ROELUINK (1989), and VEMULAKONDA *et al.* (1985) have shown that with increasing depth, there is a diminishing percentage of placed sediment moving in to enhance the beach profile, and an increase in the amount of time for the material to move. The optimum depth varies with sediment type, and wave period, height and steepness. For the Dutch coastline, ROELUINK (1989) used a two-dimensional model to indicate little beach enhancement benefits derived by placing material greater than the 8 m contour. Along the North Carolina coast, VEMULAKONDA *et al.* (1985) used a two-dimensional numerical model to show that approximately 98.3% of material placed along the 5.2 m contour would return to the surf zone within 4 years. Material placed at 3.3 m returned to the surf zone faster and in slightly larger percentages for the same hydrodynamic conditions. Local studies can also be conducted to determine the most advantageous location for the berms. McLELLAN and BURKE (1988) used seabed drifters (a bottom trailing drogue), current measurements, wave hindcast data and sand samples to delineate the best construction site downdrift of the Brazos-Santiago Pass Jetties offshore of South Padre Island, Texas. Additionally, the location must be selected to minimize any adverse environmental or physical impacts. Guidelines (U.S. ARMY CORPS OF ENGINEERS, 1984) have been developed to isolate dredged material placement sites from causing adverse effects.

Local hydrodynamic conditions play a major role in the rate, amount and direction of movement of material from a nearshore berm. Although it is difficult to accurately predict storm and/or wave climate, wave hindcast data or models are usually available to determine seasonal trends in wave energy and littoral drift direction, as well as conditions for specific storm events. Utilizing hindcast data will not only aid in selection of proper location but also the appropriate time for placement. Wave Information Studies data (McANENY, 1986), a 20 yr compilation of wave hindcast data, was used to help determine the most advantageous time and location to construct a berm in South Padre Island, Texas (McLELLAN and BURKE, 1988). The hindcast data indicated a southern littoral drift in the fall and early winter months

and a northerly drift the remaining months of the year. Since the berm was constructed north of the channel, the best time for construction was during the late winter and early spring to ensure material moved north and not back into the channel.

Design and construction of nearshore stable features with dredged material have been described by HALL (1950), ZWAMBORN *et al.* (1970), and McLELLAN and IMSAND (1989). To serve as protection for beaches, the mounded material must have above bottom elevation great enough to selectively filter the waves as they approach. By allowing low energy waves to pass unhindered, and breaking the large erosive waves, the feature can provide beach protection. The berm must also be sufficiently stable if it is to perform its function for a significant period of time. ZWAMBORN *et al.* (1970) used nearshore bar technology developed by KEULEGAN (1945) to determine that the depth of the mound crest should be about half the water depth to remain stable. Increasing crest widths were also shown to improve wave breaking ability and reduce wave heights in the lee of the berm. Stability and wave-filtering capability will ultimately be a function of depth of placement, crest elevation, grain size, placement method, and deep water wave height, period and steepness.

SUMMARY AND CONCLUSIONS

The U.S. Army Corps of Engineers is responsible for dredging and disposal of several million cubic meters of sediment each year. Alternatives are needed in many cases to conventional open-water disposal for the large volumes of clean material dredged annually. The concept of using suitable dredged material to construct submerged shore parallel features to derive physical and environmental benefits, is gaining acceptance. Field experience with berm construction is limited, but ten sites have been identified where the technique has been applied in one form or the other. Site selections and construction for berm projects are similar to other dredging projects with some additional advanced planning and design. Modeling and evaluation methods are available to aid in design and construction.

A properly designed berm can provide benefits by reducing erosive wave energy on the shoreline and/or introducing beach quality material into the profile. Modeling and analyses techniques are available to aid in selecting the best location and orientation for mound construction. Material placed to enhance the beach should be limited to beach quality sands, while stable, wave filtering berms can be open to a wide range of sediments.

With the advent of well equipped, shallow draft, split-hulled hopper dredges and barges, the capability to construct a well defined submerged feature using dredged material greatly increases. By utilizing a track plotter better safety and placement accuracy can be achieved. During construction, monitoring should still be conducted to ensure that a well defined linear feature is developed. High relief conical features have the potential of focusing, rather than attenuating wave energy, and should be avoided in the nearshore zone.

The construction of a nearshore berm has been shown to be an economical form of beneficially utilizing dredged material. Although there are some limitations, the berm concept should be one alternative evaluated when dredged material is designated to be placed along the open coasts. In addition, nearshore placement has the potential of augmenting artificial beach nourishment projects through greater fill stability and reduced costs.

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BERM CONSTRUCTION UTILIZING DREDGED MATERIAL

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ABSTRACT

The U.S. Army Corps of Engineers is responsible for dredging and disposal of several million cubic meters of material each year. Alternatives are needed in many cases to conventional open-water disposal for the large volumes of clean material dredged annually. The concept of using suitable dredged material to construct submerged shore parallel features to derive physical and environmental benefits, is gaining acceptance. Berm construction has been demonstrated in a number of projects, but experience with design, construction and quantification of benefits is still limited. The Mobile District, however, has recently begun construction of a submerged stable berm approximately 8 km south west of Dauphin Island in the Gulf of Mexico. Roughly 13.7 million cubic meters of material from the Mobile Channel deepening project will be placed in a 305 m by 2743 m drop zone to construct a 6.1 m high berm in 10.7 m to 13.7 m of water. A physical/biological monitoring program is underway to evaluate the environmental and physical process in and around the berm. The monitoring program includes; hydrographic surveys, directional wave measurements, sediment samples, sediment profiling camera surveys and fisheries studies.

INTRODUCTION

The U.S. Army Corps of Engineers (CE) is responsible for dredging several million cubic meters of maintenance and construction material each year from the nation's waterways. Over $500 million dollars is spent annually accomplishing the task of removal and placement of dredged material in an environmentally and economically sound manner to keep waterways passable. While present and past attentions have focused on the removal and management of contaminated marine sediments, the fact remains that over 90% of dredged material is not contaminated and available for productive uses. One beneficial use for dredged material is the construction of offshore mounds to derive physical and biological benefits.

The CE has recognized and used dredged material as a resource in the establishment of wetlands, land reclamation, beach nourishment and island construction. However, such construction techniques are usually

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more expensive than transporting and placing dredged material in a designated offshore site. Since the Corps is required to select the least-cost placement alternative for navigation projects, the solution most often used is to have local cost-sharing partners pay any increased cost associated with placement alternatives to provide beneficial use. Deliberately constructing relatively high relief mounds by placing dredged material offshore for possible fisheries enhancement and attenuation of storm wave energy is one method for placing dredged material beneficially yet economically.

OVERVIEW OF MOUND CONSTRUCTION

Conventional open water placement techniques differ significantly from mound construction operations. In the first case, the dredge contractor is provided with an designated open water area were material is to be placed, how the material is spread over that area is left to his discretion within the bounds of any local requirements. During the latter case, a specific set of coordinates or area is defined to receive the volume of dredge material with intent to construct a well defined submerged feature above the normal bottom. Construction of submerged mounds in relatively deep water, greater than 20 m, is normally associated with the mitigation of contaminated material. Construction of a well defined mound reduces surface area which allows economic capping with clean material. In relatively shallow water, less than 15 m, the project designer expects strategically placed mounded material to enhance the local area by altering erosive hydrodynamic conditions, thus reducing energy expended upon the coastline, or adding suitable material to the existing profile and allowing natural recovery processes to transport the material in the littoral zone.

Nearshore mound construction can enhance the coastline in two ways: creating a feature that reduces erosive energy on the coastline, or increasing the net volume of material in the sediment transport system. One nearshore placement technique termed 'thin-layer' disposal (Nester and Warren, 1987) introduced material in the nearshore zone over a wide area using a splash plate at the end of an oscillating disposal pipeline. A large volume of material may be placed in this method but since the local bathymetry stays relatively unchanged, local hydrodynamic conditions undergo little modification. The other extreme of nearshore placement would be construction of a stable offshore berm with sufficient relief to modify the wave climate without adding significant amounts of sediment into the system. Most nearshore projects will usually produce both effects, but in varying proportion. Whatever the desired objectives, the proper equipment, location, and placement techniques must be selected.

Truitt (1987), Shields and Montgomery (1984), Morton (1987) and others have described several submerged mound construction operations demonstrating the capping concept. In a typical operation contaminated material is dredged by a clamshell dredge and transported to the placement site via bottom dump scows. Stringent navigational controls are used during the placement procedure using both electronic systems and taught wire buoys. Mounds several meters in height are constructed, with the central mound having side slopes of 1 on 30 or greater, containing the majority of the material. A sharp break in slope occurs

near the bottom and a thin apron of material, representing a small percentage of the entire mound volume, may extend for several hundred meters from the placement location. The contaminated sediment is then covered by three or more times the volume of clean material to produce a cap 1 to 2 meters thick. The local wave and hydrodynamic climate of the area is always chosen so that little effect on the mound will occur.

NEARSHORE MOUND CONSTRUCTION

Hall (1950), Richardson (1986) and Langan (1987), among others have noted that nearshore placement and berm construction are not new to the CE. In 1935, the Corps placed 153,000 cu m of sand in 6.1 m of water at Santa Barbara, Ca. A total of 2.7 million cu m of material were placed in a series of similar projects along Atlantic City, N.J., and in 1948, 460,000 cu m were placed in a mound configuration 2.1 m high in water 11.6 m deep off Long Branch, N.J. During the early 1980's, the CE constructed a 3.3 m high stable berm using 650,000 cu m of sand and silt in 11 m of water at the Dam Neck site off the coast of Virginia (Hands and DeLoach, 1984).

Zwamborn, Fromme and FitzPatrick (1970) describe a mound constructed of sand in 15 m of water 1200 m off the coast of Durban, South Africa. The berm was designed as a wave 'filter' to reduce erosive energy upon Durban's Beaches. The completed berm was to consist of 8 million cu m of dredged sand, have a crest width of 61 m and reduce water depths to 7.3 m along the crest. Scale and prototype tests indicated mitigation of erosion affects leeward of the berm. During one major storm, protection of the beaches was demonstrated with little loss of elevation to the berm.

Recently, additional emphasis has been placed on the berm concept. Both the Corp's Mobile and New York Districts constructed nearshore feeder berms using dredged material in 1987. The 150 m wide by 1830 m long feature constructed by the Mobile District was in 5.8 m of water and rose above the bottom approximately 2 m. The material was placed by split hull hopper dredges with approximately 3.6 m drafts. The New York District constructed two similar parallel features off the barrier islands of Long Island. Each was constructed on the 4.9 m contour with heights of approximately 2 to 3 m (McLellan, Truitt and Flax, 1988). No significant problems were reported at any of these construction locations as a result of the placement technique. Precision bathymetry was collected at each of these projects before, during and periodically following construction. Wave and current data are being measured, along with sediment sampling and analyses.

McLellan, Truitt and Flax (1988), Gunyakti (1987), and Zwamborn, Fromme and FitzPatrick (1970), have raised several questions about berm construction that are still to be fully addressed. If a berm has a high enough relief to mitigate wave energy, what are the effects of the waves on the berm, what is the affect of the altered wave field on downdrift areas, and navigational impacts. Also, the most desirable or attainable side slopes, elevation and placement location vs. economical considerations are still largely open questions in the design. In addition, more economical techniques/ technologies need to be developed to differentiate/ predict consolidation vs. erosional elevation changes

in subaqueously placed material.

MOBILE STABLE BERM

The authorization for deepening the Mobile Ship Channel from the previously maintained 13.4 m below mean lower low water to 15 m, provides for the dredging and placement of approximately 14.3 million cu m of virgin material. The material is being transported to a location approximately 8 km offshore of Dauphin Island, Alabama and placed in the designated Mobile North disposal site (Figure 1). Normal procedures would have left the exact placement location within the disposal area to the discretion of the dredge contractor. However, erosion of the Alabama barrier islands prompted the U.S. Army Corps of Engineers, Mobile District to investigate the construction of a stable berm. Potential benefits derived from creation of the mound on an otherwise featureless bottom, include; reduction of wave energy, and creation of a fish habitat.

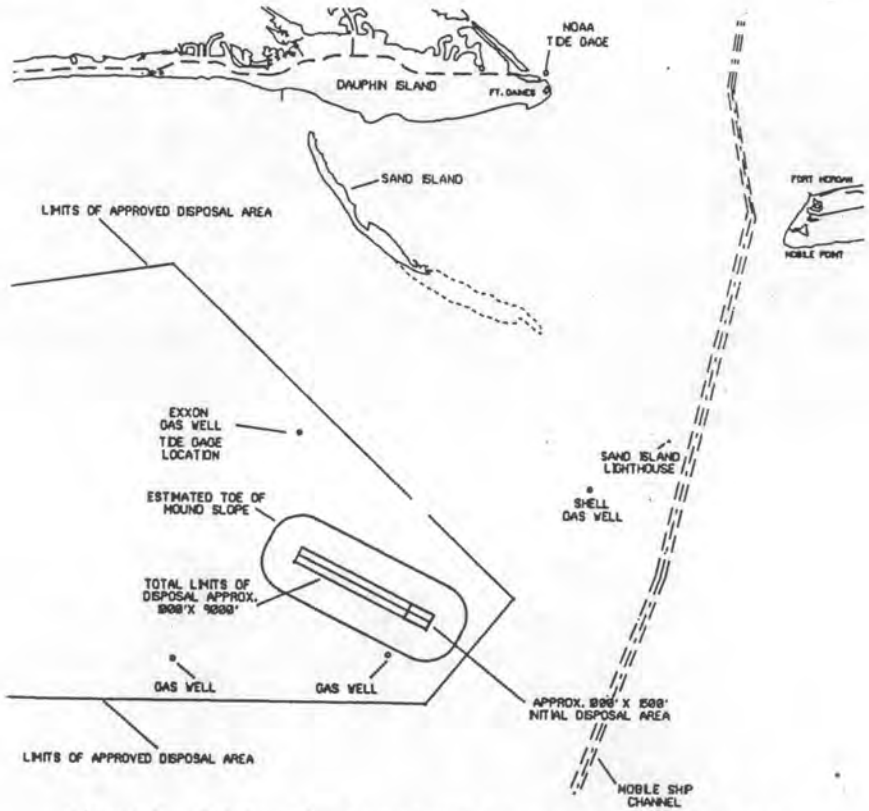

Figure 1. Construction location for the Mobile Stable Berm.

Disposal Site Description

Abston et al. (1987), Otvoss (1987), Hoffer (1984) and others have described the Gulf Coast off Alabama as a complex hydrographic area influenced mainly by discharges from Mobile Bay, tides, late fall and early winter storms, and hurricanes. Current velocities in the area range from a low normal of 5 to 15 cm/s to a high normal of 25 to 40 cm/s and can reach up to 140 cm/s as a result of hurricanes in the immediate area. Offshore bottom sediments generally move to the west and range from fine sands to silts in the Mobile North disposal area. Wind generated wave data, McAneny (1986), indicates the average wave height as 1.0 m, with an associated period of 5.1 s. Waves generally approach from the southeast, accounting for the westerly drift direction.

Within the Mobile North disposal site, a drop zone of 305 m (1000 ft) by 2,743 m (9000 ft) was defined to receive the 14.3 million cu m of dredged material. The intent of the disposal plan was to raise the elevation of the seafloor to an average depth of 6.1 m. Depths within the drop zone range from 10.6 to 13.7 m. In an effort to limit the monitoring to an economically sized area, a test area of 305 m (1000 ft) by 457 m (1500 ft) was designated in the southeast section of the drop zone, see Figure 1. The test area received approximately 3.8 million cu m to raise the seafloor to the desired elevation.

An extensive monitoring plan was designed for the test area which includes; bathymetry, side scan sonar, subbottom profiling, sediment profiling camera surveys, sediment sampling, diver collected cores, directional wave studies and fisheries studies. Baseline investigations were conducted prior to construction, monitoring began immediately after construction, and will continue quarterly for approximately two years, to evaluate changes within the test area and adjacent region. Directional wave data is being collected both in the lee and offshore of the berm to determine the effectiveness of the berm as a wave filter. Fisheries studies will document changes/additions of marine life in the area of the berm.

Dredging Equipment and Placement Techniques

Material destined for the Mobile Stable Berm consists of two general types; those within the bay, and those comprising the bar channel at the entrance to Mobile Bay. A majority of the bay sediments are a clay-rich sediment of high plasticity (CH material based on the Unified Soil Classification System). Minor amounts of silt-rich sediments (MH and ML) are also reported in this area (Hoffer, 1984). Bar channels sediments have wider range of variability with higher percentages of silty sands (SP-SM) and clayey sands (SC) than the bay channel. Approximately 10 million cu m of material from the bay and 4.3 million cu m of material from the bar channel have been targeted for placement in the stable berm.

Before the deepening in the bay could begin, removal of maintenance material or overburden, had to be accomplished. This material was removed by hydraulic pipeline dredge and placed within Mobile Bay. The virgin material is being removed by Great Lakes International's 38.2 cu

m clamshell dredge CHICAGO. The CHICAGO is supported by two 4,590 cu m split hull hopper scows. Ocean going tugs tow the scows to the placement area, once on location, the hopper doors are opened and the entire load is placed within a couple of minutes. Navigation is provided by electronic positioning aboard the tugs. All the material placed in the test section of the stable berm came from bay channel sediments. Bar channel sediments are scheduled to be placed in the area by a hopper dredge at a later date.

Test Area Monitoring and Results

To monitor the test area a 2,440 m by 2,440 m area was established around the test area. Within this monitoring area concentrated sediment, hydrographic and sediment camera profiling surveys were conducted prior to construction and, as of November 1988, one monitoring survey. Additional surveys are planned every three months thereafter for approximately two more years. The pre-construction bathymetric survey identified several small disposal mounds within or near the drop zone and one relatively large mound located approximately 720 m north east of the drop zone from previous past usage. Sediments in the area generally range from fine sands to silts. Natural depths at the test location range from 11 m to 12.5 m.

The dredge contractor began work in February 1988, and reported placing 3.8 million cu m into the test area in July 1988, raising the crest section elevation to a depth of 9.1 m to 5.1 m. After approximately 2.3 million cu m of material had been placed in the test area the disposal scows began to periodically run aground at the site. To expedite the disposal process, the contractor was instructed to place material on the northern boundary of the site. A difference plot between pre- and post-construction bathymetry surveys, Figure 2, shows the berm centerline to be shifted to the north of the test area. The berm reached a height of 6.1 m (20 ft) above pre-construction depths and, as expected, encompasses an area much larger than test area, but within the estimated toe of the berm. Analyses of the side scan sonar data, Figure 2, shows the placed material has gone beyond the estimated toe of the berm in only a couple of locations to the north, and one to the south. The southern location may be a result of an existing gas well in that location. The overall spread of the berm, however, is well within the designated boundaries of the Mobile North disposal site.

Cross-sections of the berm, Figures 3 and 4, indicate some of the variability in the side slopes, crest width, height and thickness of the feature. Figure 3 and 4 represent a cross section on the northern boundary of the test area and a cross section running north to south 76 m west of the test area centerline respectively. Side slopes from the two profiles vary from 1 on 180 to 1 on 24 with the steeper slopes occurring in the northern side of the berm. Base and crest widths vary from 1.4 km (4500 ft) to 1.6 km (5250 ft) and 152 m (500 ft) to 305 m (1000 ft) respectively, with depths at the crest varying form 6.1 m (20 ft) to 7.6 m (25 ft). Both pre-construction profile lines indicate mounds from previous disposal operations. Figures 2 through 4 show that the berm is relatively steep sided to the northwest, with gentler slopes to the south and east. The north section represents the most recently deposited material and is the lee side of the berm. Whether the mound

Figure 2. Difference Plot between Pre- and Post-Construction Bathymetry Surveys

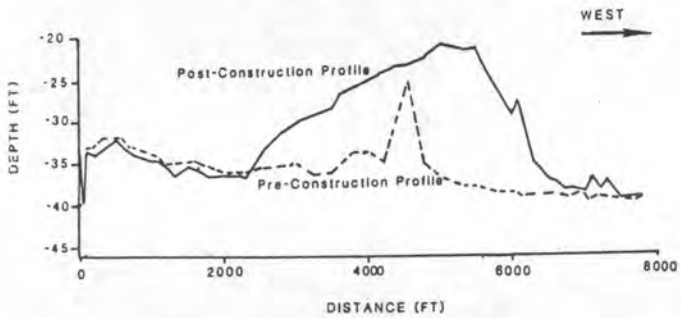

Figure 3. Pre- and Post-Construction Profiles along the Northern Boundary of the Test Area

retains this configuration, or loses elevation or steepness over time, will be investigated by the ongoing monitoring effort.

SUMMARY AND CONCLUSIONS

Nearshore berms are being constructed at several locations in the

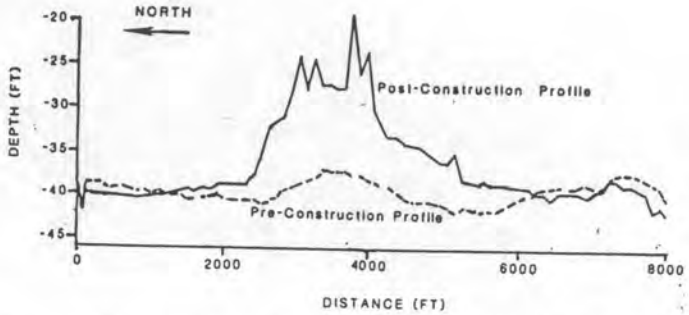

Figure 4. Pre- and Post-Construction Profiles 76 m West of the Test Area Center

U.S., including the Gulf of Mexico off of the coast of Alabama. The construction technique for a stable berm has been shown feasible using conventional dredging and placement methods while restricting the placement location. Research is underway to better quantify the response of the berm to waves, currents and other environmental forces, so that project benefits may be better defined, and provide future planners better design guidance for maximum benefit from berms.

ACKNOWLEDGMENTS

The contributions and cooperation of Browning and Assoc. who collected the baseline surveys and John Chance and Assoc. who collected the first post-construction hydrographic surveys and performed preliminary analyses is gratefully acknowledged. Permission was granted by the Chief of Engineers to publish this information.

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CATCH THE MAGIC!! DREDGED MATERIAL BENEFICIAL USES IN NORTH AMERICA

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U.S. Army Engineer Waterways, Experiment Station, Vicksburg, Mississippi

BEACHES: LESSONS OF HURRICANE HUGO

Proceedings of the 1990 National Conference on Beach Preservation Technology

BENEFITS OF NEARSHORE PLACEMENT

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ABSTRACT

The high costs associated with transporting and placing suitable sediment on the beach is a major concern of many coastal planners. A lower cost alternative, which can derive physical and environmental benefits, is the placement of suitable dredged material nearshore. The U.S. Army Corps of Engineers is responsible for dredging and placement of several hundred million cubic meters of material each year, much of which is placed in coastal waters of the United States. Recently, the Corps has been investigating nearshore placement as one open water placement alternative. Field experience with berm construction is limited, but several sites have been identified where the technique has been applied. Proper siting, construction and evaluation of the nearshore berm must be done to insure the success of the project. Modeling and evaluation methods are available to aid in design and construction. Preliminary results of the Mobile Stable Berm Project are presented. Included is wave data collected offshore and in the lee of the berm to measure wave attenuation across the berm.

INTRODUCTION

Beach nourishment can be an effective method for augmenting, protecting and repairing a beach. The placed material also provides storm and flood protection to the back beach area. To date most beach nourishment projects involve placing suitable material from the dune area to the swash zone. The expense of this type of beach nourishment often limits the quantity of material which can be placed on the beach. In addition, as wave action redistributes the material throughout the active beach profile, severe local erosion can occur. Since the mid-1970s the construction of several shallow-draft split-hull hopper dredges has created the potential for economical and effective placement of sediment in the nearshore. Placement in the nearshore can be as little as half the cost of onshore placement, and can provide several of the same benefits. Two types of berms can be constructed in the nearshore: a stable berm designed to attenuate wave energy or a feeder berm placed to

augment the beach profile. Which type of berm to construct can vary on several different factors, including wave characteristics, type of material, equipment availability, and overall berm intent.

Beach quality material placed within the littoral system can benefit the shoreline by providing additional material in the beach profile. The material has the potential for mitigating erosion problems by providing a sacrificial source of sediment, a sill to reduce the movement of material offshore, a source of sand for downdrift areas, and during times of accretion, provide a sand source for the beach profile. The feeder berm erosion rates will depend on wave climate, sediment grain size, depth of placement and mound dimensions. By calculating and monitoring the erosion rates (Anders and Clausner, 1989), the berm can be nourished at appropriate intervals to provide a continuing source of sand. In the case of artificial beach nourishment, Bruun (1988) has described the importance of placing material offshore to nourish the beach profile. Since grain size normally decreases moving offshore, placement of suitable grain-sized material at the proper depth will increase stability and reduce costs, when compared to similar material placed on the beach. Whatever the desired objectives, the proper equipment, location, and placement techniques must be selected.

If the berm's primary design purpose is energy attenuation, it can be accomplished by placing material with relief high enough and at such a depth to shoal and break waves, dissipating energy through friction or turbulent diffusion losses. Since the material is not intended to nourish the beach, the construction material is open to a wide range of materials. With proper design and construction, the berm will trip high energy storm waves, while allowing lower energy beach building waves to progress onto the beach. The berm's stability will be a function of the sediment grain size, water content, wave climate, structure dimensions and side slope steepness. Potential benefits derived from this type of placement include shoreline protection by wave attenuation, reusable sediment stockpile, reduction of dredging costs, retention structure for fluid muds and fisheries habitat.

NEARSHORE MOUND CONSTRUCTION

Early attempts at beach nourishment through offshore placement were less than successful (McLellan 1990). However, with the advent of shallow-draft split-hulled hopper dredges in the mid to late 1970's, the

feasibility of using conventional dredging and placement practices for berm construction became a reality. Several projects have recently been completed demonstrating berm construction projects with conventional equipment (McLellan, Truitt and Flax 1988 and McLellan and Imsand 1989).

The Corps of Engineers Wilmington, Mobile, Los Angles and New York Districts have recently constructed nearshore feeder berms. In 1976 the Wilmington District placed 26,750 cu m of sand between the 1.8 to 4.0 m contour downdrift of the New River Inlet, N.C. (Schwartz and Musialowski 1977). During the 13 week monitoring period the berm migrated landward up to 1.8 m/day, extended the breaker zone offshore and accreted material on the beach. Within 34 days after disposal 75% of the placed volume had been removed from the construction site. A 150 m wide by 1830 m long feature constructed by the Mobile District was in 5.8 m of water and rose above the bottom approximately 2 m (Bradley and Hands 1989). The New York District constructed two similar parallel features off the barrier islands of Long Island. Each was constructed on the 4.9 m contour with heights of approximately 2 to 3 m (McLellan, Truitt and Flax 1988). In 1988 the Los Angeles District placed 99,000 cu m of sand in 4.6 m of water off Silver Strand State Park California. Repetitive surveys indicated a shoreward migration of the placed sediment and an increase in beach width (Junke, Mitchell and Pisker 1988). No significant problems were reported at any of these construction locations as a result of the placement technique.

A beach restoration project was recently completed in Australia with nearshore placement of offshore borrow material. Approximately 1.5 million cu m of borrow material was placed between the 5.5 to 10 m contour offshore of Australia's Gold Coast, reducing existing depths by approximately 2 m at 1/2 the cost of material placed onshore. Immediately after construction was completed, a long fetch 30 knot wind field sent 4.0 m high 8 s waves against the offshore mound for a fortnight. The waves broke as they progressed over the berm reducing their heights by half. In addition, overtopping of a boulder seawall was also greatly reduced. Repetitive post-storm surveys indicated a shoreward migration of the bar, filling in the beach profile and creation of a sand beach where only a boulder seawall had previously existed. The Gold Coast project demonstrates not only beach restoration and augmentation, but also that some flood protection can be attributed to the creation of nearshore mounds.

Zwamborn, Fromme and Fitzpatrick (1970) describe a

mound constructed of sand in 15 m of water 1200 m off the coast of Durban, South Africa. The berm was designed as a wave filter to reduce erosive energy upon Durban's beaches. The completed berm was to consist of 8 million cu m of dredged sand, have a crest width of 61 m and reduce water depths to 7.3 m along the crest. Scale and prototype tests indicated mitigation of erosional effects leeward of the berm. Both reduction of beach erosion and wave energy were demonstrated by the tests. Physical model test results showed a reduction in non-breaking wave heights of 30%, while the amount of reduction increased rapidly with breaking waves. During one major Durban storm, protection of the beaches was demonstrated with little loss of elevation to the berm. Later surveys indicated accretion of material on the mound to pre-storm elevations above the bottom, indicating no net loss of material to the mound.

During the early 1980's, the Norfolk District constructed a 3.3 m high stable berm with 1 V on 30 H side slopes, using 650,000 cu m of sand and silt in 11 m of water at the Dam Neck site off the coast of Virginia (Hands and DeLoach, 1984). The mound demonstrated the ability and stability of constructing a definable offshore mound with relatively fine-grained dredged material with split-hulled hopper dredges.

NEARSHORE MOUND DESIGN

Zwamborn, Fromme and Fitzpatrick (1970), Frisch (1979) and Gunyakti (1987) have stressed the importance of design in the berm construction process. Factors such as sediment type, construction methodology, local wave and hydrological climate, depth, berm height and orientation must all be taken into account to ensure the berm performs as the designers intended. Improper planning and design can lead to problems as shown by Ludwick and Saumsiegle (1976) and Zwamborn, Fromme and Fitzpatrick (1970). Model tests indicated that improperly mounded sites with single conical shapes, have the potential to focus wave energy and increase wave height. The construction of a linear feature is suggested to prevent wave focusing and produce attenuable effects. In addition, McLellan, Truitt and Flax (1988) described how periodic bathymetric surveys can be used during construction to identify gaps in the structure that can later be filled to ensure a linear feature.

Site selection can be aided by examining long term sediment transport trends, collecting site specific data, bathymetry, structures, and anomalies that may effect sediment transport. Care must be taken to insure that the placement site is far enough downdrift from an inlet or jetty to minimize the sediment's potential to return to the channel or be trapped by existing jetties. However, a minimal travel distance should be maintained to minimize operating dredge costs. Local studies (McLellan and Burke 1988) can be conducted to determine the most advantageous location for the berms.

To serve as protection for beaches, the berm elevation above bottom and site depth must be carefully considered. The mounded material must have an above bottom elevation great enough to selectively filter the waves as they approach. By allowing low energy waves to pass unhindered, and breaking the large erosive waves, the feature can provide beach protection. The berm must also be sufficiently stable if it is to perform its function for a significant period of time. Zwamborn, Fromme and Fitzpatrick (1970) used nearshore bar technology developed by Keulegan (1945) to determine that the depth of the mound crest should be about half the water depth to remain stable. Increasing crest widths were also shown to improve wave breaking ability and reduce wave heights in the lee of the berm. Four different berm crest widths, 0, 30, 61, and 92 meters were tested in a scale model against the no mound condition to determine the reduction of erosive waves. For the no mound condition of 30% erosive waves, the increasing crest widths reduced the percentage of erosive waves to 10, 5.5, 3 and 2.5% respectfully. Stability and wave-filtering capability will ultimately be a function of depth of placement, crest elevation, grain size, placement method, and deepwater wave height, period and steepness.

The complex littoral system extends from the back beach and dune to some distance offshore. Material must be placed within the active littoral zone if it is to provide beach enhancement. The water depth at which sediment is an active part of the littoral system is dependent on wave height and period, and sediment composition. Hallermeier (1981), Birkemeier (1985) and others have discussed methods for calculating the seaward limit of sediment transport. Even within the active limit, Gunyakti(1982), Roeluink (1989), and Vemulakonda et al. (1985) have shown that with increasing depth, there is a diminishing percentage of placed sediment moving in to enhance the beach profile, and an increase in the amount of time for the material to move.

MOBILE STABLE BERM

The authorization for deepening the Mobile Ship Channel

from the previously maintained 13.4 m below mean lower low water to 15 m, provides for the dredging and placement of approximately 14.3 million cu m of virgin material. The material is being transported to a location approximately 8 km offshore of Dauphin Island, Alabama and placed in the designated Mobile North disposal site (Figure 1). Erosion of the Alabama barrier islands prompted the U.S. Army Corps of Engineers, Mobile District to investigate the construction of a stable berm with the dredged material. Potential benefits derived from creation of the mound on an otherwise featureless bottom include: reduction of wave energy and creation of a fish habitat. To measure the amount of wave energy reduction across the berm, directional wave buoys were placed offshore and in the lee of the berm.

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To monitor the test area a 2,440 m by 2,440 m area was

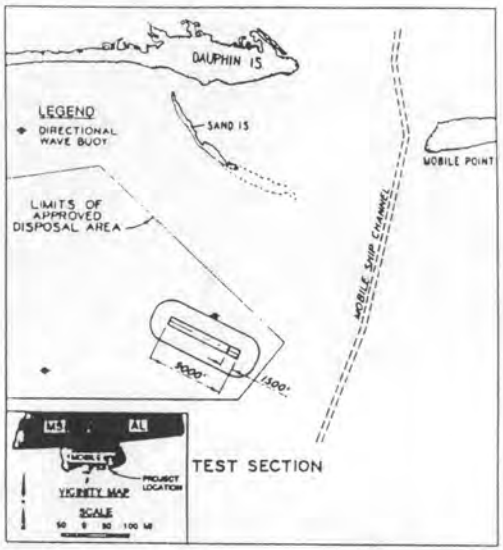

Figure 1. Construction site for the Mobile Stable Berm.

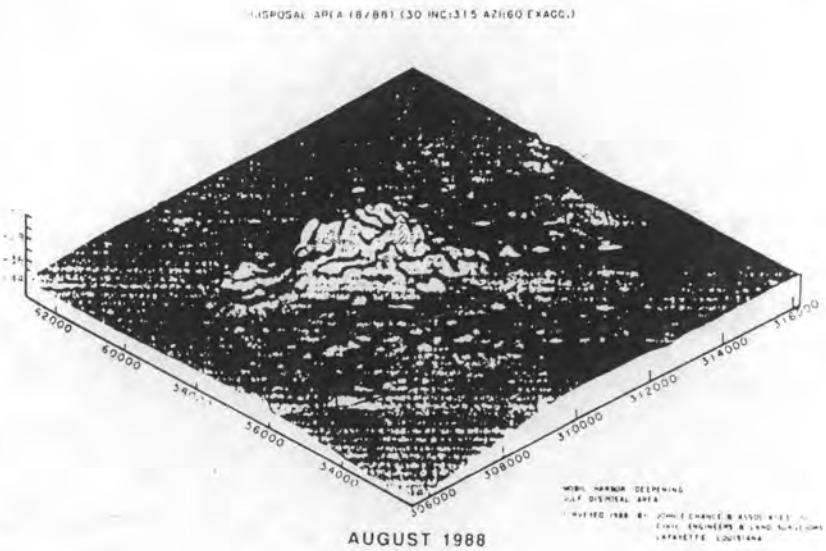

Figure 2. Perspective plot of Test Section, August 1988.

established around the test area. An extensive monitoring plan was designed for the test area which includes: bathymetry, side scan sonar, sub-bottom profiling, sediment profiling camera surveys, sediment sampling, diver-collected cores, directional wave studies and fisheries studies. A complete description of the construction and monitoring plan is presented in McLellan and Imsand (1989).

Wave Analyses

One of the benefits derived from the submerged berm is shoreline protection in the form of decreased wave energy. Even though the total energy of a wave is both kinetic due to the moving water particles and potential due to the wave elevation above sea level, it is simply proportional to the square of the wave height and independent of the water depth and wave length (Dean and Dalrymple, 1984; Earle and Bishop, 1984). Thus, in order to reduce the energy of a wave, it is necessary to reduce its height.

Erosive waves typically occur during storms, and are associated with offshore sediment transport and beach erosion. As storm waves travel over the berm, the elevation of the berm above the surrounding bottom will cause the waves to shoal, steepen and sometimes break. The steeper the berm face and the higher the berm crest the greater the reduction in wave energy. Summer (swell) waves usually do not become steep enough to initiate breaking on most nearshore berms. Thus the berm can act as a selective wave filter causing large steep waves to break, expending energy through turbulent diffusion, and allowing low waves to pass unhindered. As a result, favorable beach-building conditions develop in the lee of the mound.

As indicated earlier, see Figure 1, wave data are being acquired via two 3-meter discus-hulled, directional wave buoys, operated and maintained by the National Data Buoy Center, Stennis Space Center, Mississippi. The 3 m diameter buoy displaces about 3000 lbs and is equipped with a data acquisition, control, and telemetry payload to collect, process, and transmit data and a directional wave analyzer to reduce the directional wave component. The buoy is moored with an all-chain mooring and powered by a battery with a one- to two-year life. Instrument components include: wind anemometers, wave measuring accelerometers and pitch and roll sensors to determine wave direction. The data are collected every 5 minutes and transmitted 3 times per hour by the way of satellite to mainland terminals, were the data is recorded for further analyses. See U.S. Department of Commerce, (1988) for complete description of data collection and instrumentation.

Because sea waves are not monochromatic (i.e., of the same period and wave length), but instead random, their total energy is best represented by a spectral density function, or wave spectrum (Goda, 1985). A wave spectrum shows the amount of energy of various component waves corresponding to a particular frequency or period. It also represents the distribution of wave variance, defined as one-eighth of the wave height squared, over a range of frequencies or periods. Since the wave variance (energy density) is proportional to wave height squared, it is also proportional to the wave energy (Earle and Bishop, 1984). The total variance is obtained by integrating the wave spectrum over all frequencies and must be multiplied by the specific weight of sea water to obtain the total wave energy per wave length per unit crest width.

The reduction of wave energy due to the presence of the submerged berm was determined by comparing the energy spectra of the waves of the offshore and inshore gages. Figures 3 through 5 show energy spectra, indicating the wave energy distribution over the range of frequencies from 0.03 to 0.40 Hertz (wave periods of 33.3 to 2.5 s), plotted for three different days. The three days were selected to present a range of conditions existing at the site. For a choppy day (8/17/88) average significant wave heights at the offshore gage range from 0.5 m to 0.6 m; for a storm day (8/7/88) average significant wave heights are between 1.0 m and 1.5 m; and for a tropical storm day (Tropical Storm Beryl, 8/9/88) average wave significant heights range between 2.0 m and 3.0 m. The time interval for each case is one day (24 hrs). Note that it was necessary to plot each curve on a different scale; otherwise, changes for the choppy and storm days would have been undetectable relevant to the tropical storm day scale.

Figures 3 through 5 indicate that the wave energy is concentrated around a central, or peak, frequency, f_p. The peak frequency is where the majority of the energy reduction occurs. As the frequency past the peak increases, the amount of energy reduction decreases, lending credibility to the mound as a wave filter, allowing lower energy waves to pass and breaking the higher energy waves. The peak frequency for each day is listed in Table 1 with other wave properties and the energy reduction computations. The parameter T_p is the peak period, whereas, T is the average period of the waves. The peak frequency essentially remained constant for each day.

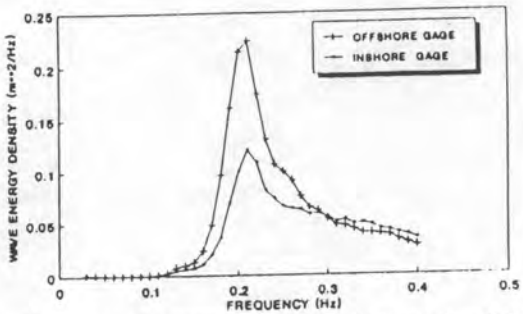

Figure 3. Wave spectrum for inshore and offshore buoys 17 August 1988 (Choppy Day).

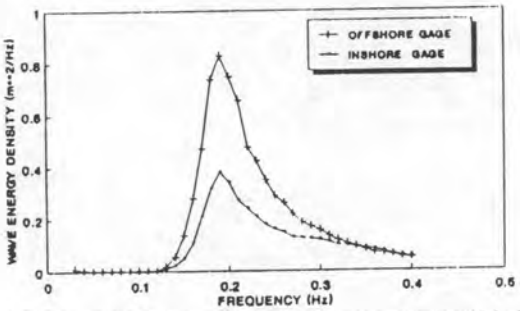

Figure 4. Wave spectrum for inshore and offshore buoys 7 August 1988 (Storm Day).

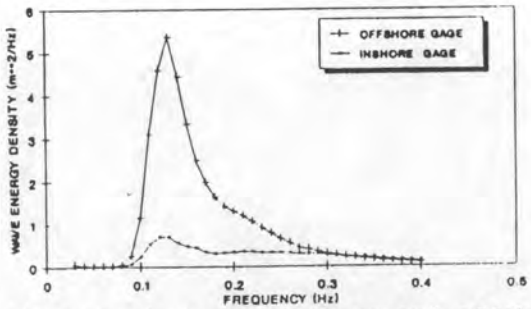

Figure 5. Wave spectrum for inshore and offshore buoys 9 August 1988 (Tropical Storm Beryl).

The total energy for each spectrum was computed by summing the products of the energy density and frequency band (0.01 Hz) over the entire frequency range. The energy reduction is represented as a ratio of the total inshore wave energy to the total offshore wave energy. For the choppy day an average significant wave height of 0.57 m at the offshore gage was reduced to 0.47 m at the inshore gage for a 29 % reduction of wave energy. For Tropical Storm Beryl the average significant wave height of 2.47 m was reduced by approximately one half to 1.23 m, for a 75% total energy reduction for the 24 hr period. Evidently, as the wave height increased, the energy reduction due to the presence of the berm also increased. These observations agree with those made by Zwamborn, Fromme, and Fitzpartick (1970) and Smith, and Jackson (1990).

Table 1. Wave properties and wave energy reduction.

Date	Gage*	H_s (m)	H_{max} (m)	T (s)	f_p (Hz)	T_p (s)	Energy ($x10^{-2}m^2$)	Energy Reduction %
8-17-88	O	0.57	0.9	3.95	0.21	4.76	2.05	
Choppy	I	0.47	0.7	3.62	0.21	4.76	1.46	29
8-07-88	O	1.08	1.5	4.25	0.19	5.26	7.33	
Storm	I	0.79	1.2	3.76	0.19	5.26	3.98	46
8-09-88	O	2.47	3.3	5.57	0.13	7.69	39.73	
Trop. Storm	I	1.23	1.7	4.26	0.12	8.33	10.07	75

* O denotes Offshore Gage
I denotes Inshore Gage

Natural wave energy dissipation without the presence of the berm was calculated using the linear wave transformation program developed by Leenknecht and Szuwalski (1989). Given the known wave properties of height and period, water depth, crest angle, and nearshore slope, the program computes the refracted and shoaled wave height at a different location specified as a water depth. To determine the amount of dissipation due to natural bathymetry, the monthly average wave properties obtained from the offshore buoy, located at a depth of 16 m, were entered into the program to obtain the transformed wave height at the inshore buoy, located at a depth of 13 m. The 24 monthly wave averages ranged from 0.3 m to 0.8 m in height and 3.4 s to 4.6 s in period. The results suggested that without the presence of the berm, an average significant wave height reduction of one and a half percent, approximately 1 cm, can be expected to

occur between the locations of the two buoys. In addition the significant wave height and period for the storm day and Tropical Storm Beryl were also transformed using measured height and period from the offshore site. Calculated wave heights for the two days were reduced to 1.07 m and 2.32 m, respectively, at the inshore site. The measured reduction in significant wave height with the mound in place is far greater than the calculated reduction without the mound.

SUMMARY AND CONCLUSIONS

A properly designed berm can provide benefits by reducing erosive wave energy on the shoreline and/or introducing beach quality material into the profile. Shallow-draft split-hull hopper dredges allow for accurate and economic placement of the material. Modeling and analyses techniques are available to aid in selecting the best location and orientation for mound construction. Material placed to enhance the beach should be limited to beach quality sands, while stable, wave filtering berms are open to a wider range of sediments. Several projects have been discussed that demonstrate benefits occurring from nearshore placement. In addition wave data from the Mobile Stable Berm Project is presented to demonstrate that up to 75% of wave energy has been dissipated from a buoy located offshore of an offshore mound to a buoy located in the lee of the mound.

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UNDERWATER BERMS

S-1 USING DREDGED MATERIAL TO BUILD UNDERWATER BERMS HAS A NUMBER OF POTENTIAL BENEFITS TO THE CORPS DREDGING PROGRAM, OUR COST SHARING PARTNERS, AND THE ENVIRONMENTAL RESOURCE AGENCIES. OUR PROGRESS IN THIS AREA IS DUE TO THE JOINT EFFORTS OF THE ORGANIZATIONS SHOWN ON THIS SLIDE.

S-2 FOR THE MOST PART, MAINTENANCE AND NEW WORK DREDGED MATERIAL IS UNCONTAMINATED AND SUITABLE FOR A WIDE RANGE OF PRODUCTIVE USES, INCLUDING THE CONSTRUCTION OF BERMS.

S-3 A BERM IS AN UNDERWATER MOUND CONSTRUCTED FROM DREDGED MATERIAL TO A SPECIFIED DESIGN.

S-4 AT MANY NAVIGATION PROJECTS, LARGE QUANTITIES OF DREDGED MATERIAL ARE BEING TRANSPORTED MANY MILES TO OFFSHORE SITES. THIS RESULTS IN A SIGNIFICANT COST FACTOR. PLANS FOR MANY OF THE DEEPENING PROJECTS WOULD CONTINUE THIS TRADITIONAL PRACTICE. IN CONTRAST, UNDER THE BERM CONCEPT WE WILL PLACE MATERIAL CLOSER TO THE NAVIGATION PROJECT.

S-5 FOR EXAMPLE, AT ONE MAJOR DEEPENING PROJECT WITH A TOTAL ESTIMATED COST OF $550 MILLION, THE LONG-TERM DISPOSAL AREA SHOWN AS A BLUE CIRCLE, IS ALMOST 30 MILES FROM THE DREDGING PROJECT. BY INCREASING THE CAPACITY OF AN EXISTING SMALLER DISPOSAL SITE, SHOWN IN GREEN, THROUGH AN EXTENSION

TO THE AREA SHOWN IN RED, HAUL DISTANCE COSTS CAN BE REDUCED WITH A RESULTING TOTAL PROJECT COST REDUCTION OF 50 MILLION OR MORE. FURTHERMORE, A VALUABLE SAND RESOURCE CAN BE RETAINED IN THE COSTAL REGIME.

S-6 WHY ARE WE INTERESTED IN UNDERWATER BERMS? BECAUSE WE WANT TO BE PROACTIVE AND LOOK FOR OPPORTUNITIES TO ACCOMPLISH OUR MISSION MORE COST EFFECTIVELY AND IN AN ENVIRONMENTALLY RESPONSIBLE MANNER.

S-7 WE HAVE A UNIQUE OPPORTUNITY TO CONSTRUCT UNDERWATER BERMS, BECAUSE WE EXCAVATE A LARGE VOLUME OF MATERIAL EACH YEAR AS SHOWN ON THIS SLIDE.

S-8 THERE ARE TWO APPROACHES TO THE CONSTRUCTION OF UNDERWATER BERMS. WE REFER TO THEM AS FEEDER AND STABLE.

S-9 THE FEEDER APPROACH INVOLVES THE PLACEMENT OF BEACH QUALITY SAND IN RELATIVELY SHALLOW WATER WHERE THE MATERIAL CAN MOVE TOWARD SHORE.

S-10 THE STABLE BERM INVOLVES PLACEMENT IN DEEPER WATER AREAS WHICH ARE LESS SUBJECT TO WAVES AND CURRENTS. THEREFORE, THE MATERIAL STAYS IN PLACE. A WIDE VARIETY OF DREDGED MATERIAL CAN BE USED IN THE CONSTRUCTION OF STABLE BERMS.

S-11 THE PRIMARY BENEFIT OF FEEDER PLACEMENT IS TO ADD SAND WHICH WILL RESULT IN A MORE GENTLE UNDERWATER SLOPE AND CONTRIBUTE TO A REDUCTION IN THE EROSION EFFECTS ON THE SHORELINE. IN MANY CASES DREDGING COSTS CAN BE REDUCED BECAUSE NEARSHORE SITES ARE GENERALLY CLOSER TO THE NAVIGATION CHANNELS.

S-12 A STABLE BERM WILL BE A SIGNIFICANT, RELATIVELY PERMANENT BOTTOM FEATURE, THAT CAN DISSIPATE THE ENERGY OF STORM WAVES AND THUS CONTRIBUTE TO A REDUCTION IN SHORELINE EROSION RATES. ALSO, THERE WILL BE A ZONE OF REDUCED WAVE ENERGY BETWEEN THE COMPLETED BERM AND THE SHORELINE IN WHICH ADDITIONAL MATERIALS CAN BE STOCKPILED. CONVENTIONAL CUTTERHEAD DREDGES, WHICH ARE VERY EFFICIENT, CAN THEN RECOVER THIS MATERIAL FOR DIRECT PLACEMENT ON THE BEACHES.

S-13 DURING YOUR RECENT VISIT TO THE WATERWAYS EXPERIMENT STATION, HYDRAULIC MODEL TESTS WERE BEING CONDUCTED THROUGH THE CORPS R&D PROGRAM TO MEASURE WAVE DISSIPATION OVER A STABLE BERM.

S-14 FISHERY BENEFITS ARE ALSO EXPECTED AS TOPOGRAPHIC IRREGULARITIES ARE CREATED ON THE OCEAN FLOOR WHICH ARE SIMILAR TO NATURAL MOUNDS.

S-15 IN 1982, THE NORFOLK DISTRICT CONDUCTED A PILOT STUDY IN AN EXISTING OCEAN DISPOSAL SITE. THE PURPOSE OF THE

STUDY WAS TO DETERMINE WHETHER MOUNDING COULD BE ACHIEVED WITH MAINTENANCE MATERIAL USING CONVENTIONAL EQUIPMENT.

S-16 THE NORFOLK STUDY CLEARLY INDICATES THAT THE HOPPER DREDGES AND POSITIONING EQUIPMENT, ROUTINELY USED BY THE INDUSTRY, ARE CAPABLE OF CONSTRUCTING A MOUND. ANOTHER IMPORTANT FINDING WAS THAT SIGNIFICANT MOUNDS CAN BE CREATED EVEN WHEN THE MATERIAL IS A MIXTURE OF FINE SAND AND SILT PARTICLES. EQUALLY IMPORTANT, IS THE FACT THAT THESE MOUNDS ARE STABLE UNDERWATER FEATURES BECAUSE THREE HURRICANES HAVE OCCURRED SINCE THE MOUNDS WERE CREATED IN 1982.

S-17 THE OCE ENVIRONMENTAL ADVISORY BOARD AND THE COASTAL ENGINEERING RESEARCH BOARD HAVE ENDORSED THE FEEDER AND STABLE BERM CONCEPTS. IN ADDITION THE NATIONAL MARINE FISHERIES SERVICE HAS INDICATED THAT THE STABLE BERM MAY CONTRIBUTE TO AN IMPROVED MARINE HABITAT.

S-18 BASED ON THE POSITIVE RESULTS OF THE NORFOLK EFFORT, WE DECIDED TO APPROVE A NATIONAL DEMONSTRATION PROJECT.

S-19 THE NATIONAL DEMONSTRATION WILL BE CONDUCTED IN CONNECTION WITH THE DREDGING OF MOBILE HARBOR. WHY MOBILE? BECAUSE THE MOBILE DISTRICT HAS RESPONDED INNOVATIVELY TO THE ENVIRONMENTAL CHALLENGES BROUGHT ABOUT BY NEPA, INCLUDING THE DEVELOPMENT OF IMPROVED DREDGING AND DISPOSAL EQUIPMENT AND PROCEDURES. THE MOBILE HARBOR DEEPENING

PROJECT DOES NOT OFFER THE LARGE SCALE COST SAVINGS THAT ARE POSSIBLE AT OTHER LOCATIONS. HOWEVER, THE EXPERIENCE, COMPETENCE AND ENTHUSIASM OF THE MOBILE DISTRICT STAFF WERE COMPELLING REASONS TO CONDUCT THE TEST AT MOBILE.

S-20 THE MOBILE DISTRICT HAS COORDINATED EXTENSIVELY WITH THE LOCAL CONGRESSIONAL OFFICES, THE LOCAL SPONSOR, AND THE NAVIGATION AND ENVIRONMENTAL INTERESTS. THE MOBILE DISTRICT BRIEFINGS INDICATE THAT THE NATIONAL DEMONSTRATION WILL NEITHER DELAY THE MOBILE DEEPENING PROJECT, NOR RESULT IN AN INCREASE IN THE CONSTRUCTION COST.

S-21 THE RED SHADED AREA SHOWS THE GENERAL LOCATION OF THE DEMONSTRATION PROJECT.

S-22 THIS SHOWS THE LOCATION OF THE FEEDER AND STABLE BERMS. THE FEEDER BERM IS ABOUT ONE-HALF MILE FROM SAND ISLAND.

S-23 WE EXPECT THE FEEDER BERM MATERIAL TO MOVE ALONG THE PATH SHOWN.

S-24 ABOUT 450,000 CY OF MAINTENANCE MATERIAL WAS PLACED IN 18 - 19 FEET OF WATER TO FORM A FEEDER BERM ABOUT 6 FEET IN HEIGHT AND ONE MILE IN LENGTH. THE PLACEMENT OF THE MATERIAL WAS COMPLETED IN FEBRUARY 1987.

S-25 TWO SHALLOW DRAFT INDUSTRY HOPPER DREDGES PERFORMED THE FEEDER BERM WORK.

S-26 THE STABLE BERM WILL BE CONSTRUCTED ABOUT 3 MILES FROM SAND ISLAND DURING PHASE I OF THE DEEPENING PROJECT. WORK IS SCHEDULED TO BEGIN IN JULY 1987. THE QUANTITY OF NEW WORK MATERIAL IS ESTIMATED AT 23.6 MCY. SOME OF THE MAINTENANCE MATERIAL IN THE LOWER SECTION OF THE BAY WILL ALSO BE PLACED IN THE BERM.

S-27 PHASE I OF THE DEEPENING PROJECT CONSISTS OF DEEPENING THE EXISTING CHANNEL FROM 40 TO 45 FT THROUGH THE BAY AND DEEPENING THE BAR CHANNEL FROM 42 TO 47 FT, OVER A TOTAL DISTANCE OF 36 MILES.

S-28 THE STABLE BERM WILL BE LOCATED IN 40 FT OF WATER NEAR THE EASTERN LIMIT OF THE EPA DESIGNATED DISPOSAL AREA. THE COMPLETED BERM WILL BE ABOUT 1 MILE WIDE AND 2-1/2 MILES LONG.

S-29 MONITORING IS NECESSARY TO VERIFY THE BERM CONCEPT.

S-30 MONITORING WILL INDICATE WHAT HAPPENS TO THE BERM, WHY IT HAPPENS, AND THE TYPES OF BENEFITS WHICH OCCUR.

S-31 MONITORING OF BASE LINE CONDITIONS FOR THE FEEDER BERM WAS INITIATED IN DEC 86 AND WILL CONTINUE THROUGH DEC 87,

BASE LINE DATA COLLECTION FOR THE STABLE BERM WILL BE INITIATED IN MAY 87 AND WILL CONTINUE THROUGH FY 90.

S-32 THE MONITORING TECHNIQUES WILL APPLY, IN GENERAL, TO BOTH THE FEEDER AND STABLE BERMS. IN THE CASE OF THE FEEDER BERM, WE EXPECT THE MATERIAL TO MOVE DOWNDRIFT BUT REMAIN IN THE NEARSHORE ZONE. IN THE CASE OF THE STABLE BERM, THE MONITORING PROGRAM WILL INDICATE WHETHER IT REMAINS IN PLACE, CONTRIBUTES TO WAVE ENERGY DISSIPATION, AND PROVIDES AN IMPROVED MARINE HABITAT.

S-33 FATHOMETER SURVEYS ARE BEING USED TO MEASURE BERM ELEVATIONS AND SIDE SCAN SONAR WILL BE USED TO HELP DEFINE THE BOUNDARIES OF THE BERMS.

S-34 WE WILL BE TAKING GRAB SAMPLES OF THE BOTTOM SEDIMENTS. IN ADDITION, DIVERS WILL BE TAKING CORE SAMPLES TO ASSESS THE CONSOLIDATION OF THE STABLE BERM MATERIAL.

S-35 BOTTOM CURRENTS WILL BE TRACKED USING SEA BED DRIFTERS. WE WILL ALSO MEASURE THE WAVE CLIMATE IN THE VICINITY OF THE BERMS, SINCE WAVES ARE THE PRINCIPAL DRIVING FORCE BEHIND SEDIMENT MOVEMENT IN THE COASTAL ZONE.

S-36 WE WILL BE USING BOTH AERIAL PHOTOGRAPHY AND SATELLITE IMAGERY TO EVALUATE THE STABILITY AND EFFECTIVENESS OF THE BERMS.

S-37 FINALLY, WE WILL BE EVALUATING THE EFFECTS OF THE STABLE BERM ON FISHERIES BY CONDUCTING DIVER INVENTORIES OF KEY FISH SPECIES. TRAWLING WILL BE CONDUCTED TO INVENTORY THE JUVENILES OF THESE SPECIES.

S-38 KNOWLEDGE GAINED THROUGH THE NATIONAL DEMONSTRATION PROJECT WILL BE TRANSFERRED TO OTHER DREDGING PROJECTS THROUGH THE NEW DREDGING RESEARCH PROGRAM TO BE INITIATED IN FY 88.

S-39 THE DREDGED MATERIAL FOR BERM CONSTRUCTION WILL BE USED AS A RESOURCE RATHER THAN A WASTE PRODUCT. THE PROJECT HAS BEEN FULLY COORDINATED WITH ALL INTERESTED PARTIES. THE POTENTIAL BENEFITS INCLUDE DECREASED DREDGING COSTS, DECREASED SHORELINE EROSION, AND AN ENHANCED FISHERY HABITAT. IN ADDITION, THE RESULTS FROM THE NATIONAL DEMONSTRATION PROJECT CAN BE APPLIED TO OTHER NAVIGATION PROJECTS IN THE COASTAL ZONE.

NATIONAL BERM DEMONSTRATION PROGRAM

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The subject of berm construction and the National Berm Demonstration project at Mobile has been reported to the Coastal Engineering Research Board on a number of occasions beginning in 1985 when Mr. Bill Murden, former Chief, Dredging Division, Water Resources Support Center discussed options for dredged material placement and the positive results from an earlier pilot study off Virginia Beach by the Norfolk District.

General Hatch, then Civil Works Director, approved a national demonstration project to assess and document potential physical and fishery benefits associated with underwater berms as a beneficial use application of dredged material. While a number of locations throughout the country were considered for the demonstration project, Mobile District proposed incorporation of the concept of berm construction into the maintenance and deepening of Mobile Harbor and was able to quickly gain support of the sponsor and environmental community for the project.

A steering committee was formed representing Mobile District, WES (CERC and the Environmental Lab), South Atlantic Division, and the Headquarters offices of Operations, Construction and Readiness Division (formerly Dredging Division, Water Resources Support Center), Planning and Policy Division, and the Directorate of Research and Development. The committee met regularly during the course of the demonstration project to oversee the progress of the program by evaluating the ongoing results with the principal investigators and determining program modifications as appropriate, as well as to determine the means for disseminating the information.

In early 1987, Mobile District constructed a 'feeder' berm in relatively shallow water and in February 1988 began construction of a 'stable' berm in deeper water in the Gulf of Mexico south of Dauphin Island (Figure 1).

The feeder berm was constructed with maintenance material from routine hopper dredging of the entrance channel from the gulf into Mobile Bay. Historically material from this area was transported to the gulf site, approximately 5 miles offshore for disposal. The objective of the feeder berm was to place sandy dredged material into the active littoral zone and thereby supplement the sand budget of Sand and Dauphin Islands. The placement site is on the west of the Ship Channel about 1 mile southeast of Sand Island, and about 4 miles from Dauphin Island. Approximately 460,000 cubic yards of material was placed in 18 - 19 feet of water by shallow-draft split hull hopper dredges during construction of the one-mile long, six-foot high structure. A cooperative monitoring program was

developed by the Mobile District and the Coastal Engineering Research Center to investigate the movement of material from the berm. This program included bathymetric surveys, collection of wave information, and deployment of seabed drifters to track bottom currents. Since the haul distance to the 'feeder' location was about the same as to the historical disposal site, construction of the berm was at no extra cost. Extensive monitoring has been conducted over a four year period including wave gauge equipment and instrumentation provided under the Dredging Research Program (DRP).

The objective of the feeder berm monitoring was to determine whether the placed material became incorporated into the active transport system. Results of four years of monitoring indicate a gradual movement of sand westward and toward shore. Highest percentage of seabed drifters have been retrieved on Dauphin Island indicating favorable conditions for movement of sand toward the barrier island.

The stable berm was constructed during the Mobile Harbor, Phase I Deepening and is composed of a variety of dredged materials. The bay channel contained primarily soft plastic clays and silts, whereas the bar channel was a mixture of sands and marine clays. The berm, which is the largest underwater feature ever constructed, is located in 40 to 45 feet of water approximately 3.5 and 5 miles south of Sand and Dauphin Islands, respectively. The 20-foot high structure was constructed by specifying a 1,000-foot by 9,000-foot placement zone. Approximately 17 million cubic yards were placed in this area creating a feature 1 mile wide at the base and approximately 2.5 miles long. Construction took approximately 2 years and 3 months, and was performed by mechanical dredging equipment in the bay and by hopper dredging in the entrance channel. The deepening and associated construction of the stable berm was funded through the Construction General program at a cost of $36.3 million. Some savings in construction cost were realized since the dredged material was all placed in an elevated configuration within the designated placement area closest to the channel. The alternative would have been to place the material in thinner lifts, i.e. 5 feet thick, over a much larger area which would have resulted in increased transportation costs. The Alabama State Docks, local sponsor, shared in all construction and monitoring costs under the Construction General program.

Monitoring purposes of the stable berm were three fold: (1) determine whether the feature remains stable; (2) assess how much the berm contributes to wave energy dissipation; and (3) determine whether the berm provides an improved fisheries habitat. The Environmental Protection Agency, Region IV, the Mobile District, and the Waterways Experiment Station Coastal Engineering Research Center and Environmental Lab participated in the initial design of the program. As the monitoring program developed, additional participants included NOAA National Marine Fisheries Service - Mississippi Labs and Mississippi - Alabama Sea Grant.

Because of the length of time to construct the entire stable berm, the monitoring was conducted on a test section. This section, which represented the eastern most one-mile of the structure, was completed in August 1988, 6 months after initiation of construction, and contained approximately 4 million cubic yards. After completion of this segment construction activities were shifted to the western most end of the structure and placement proceeded in an easterly direction until the two segments of the berm were joined. The stable berm construction was completed in May 1990.

Monitoring of the stable berm included: bathymetric, subbottom profile and side scan surveys, sediment analyses, wave, wind, and barometric pressure data collection, benthic macrofauna and vertical sediment profiling surveys, and fisheries investigations. The fishery investigations included both traditional trawling surveys, feeding analyses and hydroacoustic surveys.

Baseline surveys were conducted prior to construction in October 1987. The first monitoring survey was conducted in August 1988. Various aspects of the monitoring program have occurred either quarterly or semiannually between August 1988 and March 1991. Results of these studies indicate that:

(1) The berm was constructed to the specifications defined in the Plans and Specifications.

(2) The berm, although constructed with varying quality of material, has remained stable since initial consolidation.

(3) The berm is serving to reduce long period wave (i.e., storm waves) energy. Preliminary data analyses show a reduction of as much as 70% of the wave energy from the Gulf to the landward side of the berm.

(4) The construction and presence of the berm has had no adverse impact to the biological resources of the area. Macroinfaunal communities are similar to those in existence prior to the construction of the berm and fishery resources are similar to those defined by historic surveys.

(5) The berm appears to be serving as a fish attractant; however it is too early to draw definite conclusions. Recent analyses indicate that the berm is serving as refuge and feeding location for very young juvenile Red Snapper. Additional surveys will be required to substantiate these benefits.

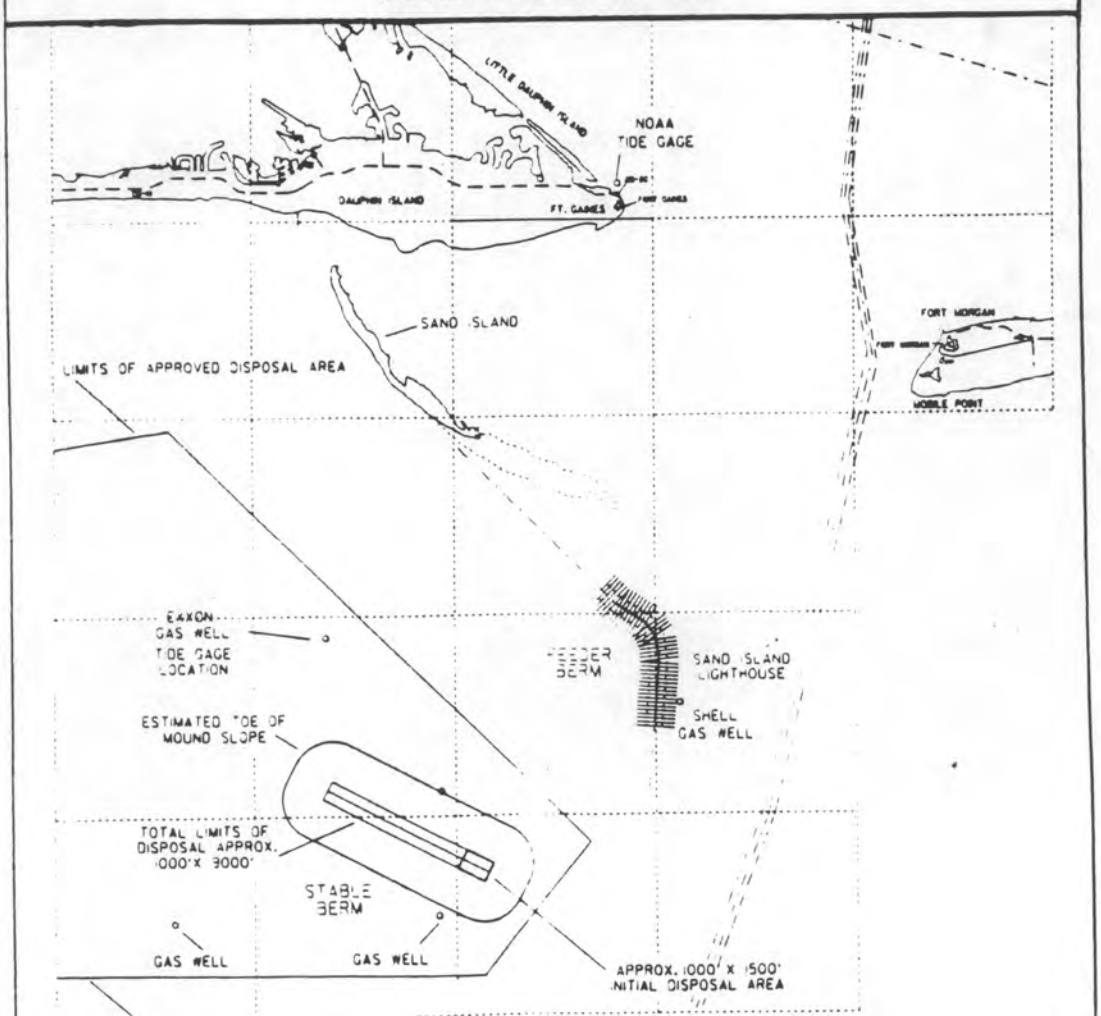
Although the main monitoring program is complete, we intend to continue monitoring of certain aspects of the berm in the future. We will continue the fishery monitoring program for an indefinite period depending upon the results attained in later years. We will also perform annual bathymetric surveys of both berm structures. We believe that this additional information will prove valuable in the design and environmental coordination of other

berms. Results of these programs should have nationwide application. In addition to the potential physical and fishery benefits that might accrue, application of the concept could result in significant cost savings by reducing haul distances for future new work and maintenance projects.

Other Corps programs have taken advantage of the construction of the stable berm including the DRP. DRP Task Area One utilized Mobile Berm placement operations during plume tracking activities in late CY 89, and information from the National Demonstration monitoring has served as a basis for DRP ocean disposal predictive methods.

Since the National Demonstration began, the Corps has constructed successful berms in a number of other locations, including Texas, New York, and California. In all cases, information and experience derived from the National Demonstration was an integral part of the planning and implementation of these features.

In summary, we believe the National Demonstration has achieved its objectives and has served as an excellent foundation for the Corps continued efforts to develop beneficial uses of dredged material.

FIGURE 1

LOCATION OF FEEDER AND STABLE BERMS
MOBILE HARBOR, ALABAMA