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Environmental Effects of Dredging

Section 07 - Beneficial Uses Technical Notes EEDP-07-1 through EEDP-07-5

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Section 07—Beneficial Uses
EEDP-07-1 through EEDP-07-5

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Environmental Effects of Dredging Technical Notes

BUILDING, DEVELOPING, AND MANAGING DREDGED MATERIAL ISLANDS FOR BIRD HABITAT

PURPOSE: This note describes the environmental considerations and techniques that have been developed and tested for building, developing, and managing dredged material islands for use by birds for nesting and other life requirements. The text of this note was taken from lectures presented from 1979 to 1986 at the Dredging Short Courses held each year by the Texas A&M University Center for Dredging Studies and from information compiled for Engineer Manual EM 1110-2-5026 entitled "Beneficial Uses of Dredged Material."

BACKGROUND: One hundred years of dredging and open-water disposal operations by the Corps of Engineers (CE), state agencies, and private enterprise has resulted in the creation of over 2000 man-made islands throughout US coastal waters, riverine waterways, and the Great Lakes. The CE continues to maintain an interest in developing such islands because of its responsibility in using environmentally acceptable disposal methods and sites, the increasing shortage of upland disposal sites, the need for wildlife habitats in waterway areas, and the islands' recreational potential.

As the population in coastal areas has increased, natural areas have been altered and occupied by man. Dredged material islands have provided vital habitat in many areas. The primary wildlife species needing habitat on dredged material islands as part of their life requirements are 37 species of colonial-nesting birds: pelicans, cormorants, anhingas, herons, egrets, ibises, spoonbills, gulls, terns, and skimmers. Several of these species are rare, threatened, or endangered throughout large parts of their ranges, and an estimated 1,000,000 are nesting on dredged material islands each year, especially along the Atlantic and Gulf coasts from Long Island to Mexico.

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Building New Islands

Success stories

Construction of new islands for birds and other forms of wildlife is technically and environmentally feasible. In 1977, the Wilmington District constructed two islands in Core Sound, North Carolina, for habitat development. The two islands are unique in that they were the CE's first to be constructed and placed in a manner to deliberately create habitat for colonial seabirds and aquatic biota and that they were retained by the use of large sand-filled nylon bags (Figure 1).

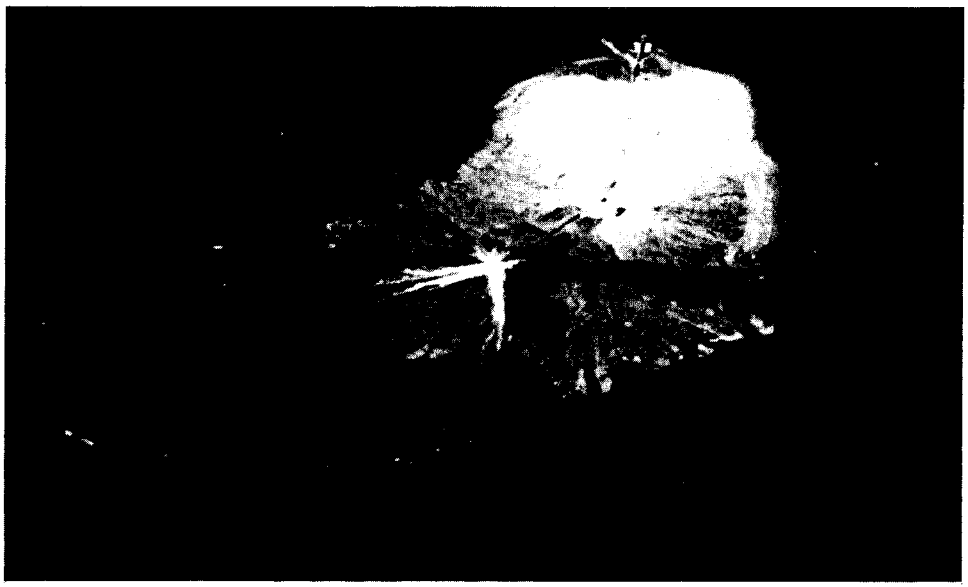

Figure 1. Construction of dredged material islands, Core Sound, N. C. (1977)

The sites were designed so that during future maintenance dredging of the nearby navigation channel, material could be added within the original sandbag retainers and more sandbags could be added to provide higher retention dikes. The islands were placed in an area with adequate shallow water and food resources but with a scarcity of bare-ground nesting habitat.

The kidney shape of the islands formed a small cove where smooth cordgrass and saltmeadow cordgrass were planted around the perimeter of the cove to accelerate marsh development. A marsh developed, and benthic organisms are thriving in the cove. Terns and skimmers nested on the islands during the first breeding season after construction.

Prior to the Core Sound construction, personnel of the Environmental Laboratory had been involved in building or modifying several islands for habitat development for research purposes. A number of dredged material islands have also been built in Florida, Maryland, Alabama, Texas, Louisiana, and the Great Lakes with waterbird habitat development as a secondary project goal.

In the Great Lakes and a number of ports along the Atlantic and Gulf coasts, CE districts have constructed large diked islands for permanent containment areas for maintenance dredged material. These islands are sometimes over 1000 acres in size, often well armored with riprap on both sides of the dikes (Figure 2), and, in most cases, designed for containment of contaminated

Figure 2. Dike building at Pointe Mouillee CDF in western Lake Erie. Habitat for waterbirds, waterfowl, other wildlife and fish was incorporated into the long-range management plan for the 4600-acre site

sediment, especially those islands located along the mid Atlantic to New York coast and in the Great Lakes. They are up to three miles from shore and relatively isolated. From the time of their construction, they have been used more and more by nesting and loafing seabirds. Where seabird use was incorporated into design and management of newer confined disposal facilities (CDFs), seabird colonization has been spectacular, such as at the Gaillard Island CDF in Mobile Bay where over 16,000 seabirds nest each year (Figure 3).

Feasibility of construction

In many areas there may be no need for more islands, and management of

Figure 3. Brown pelicans nesting on Gaillard Island CDF in Mobile Bay, Ala.

existing islands should be given first priority. There are areas, however, where additional nesting habitat would be beneficial; existing dredged material and natural islands are not available; and construction of new islands would be desirable under some conditions.

Generally, construction on new islands for wildlife will not be feasible unless it can be demonstrated that anticipated positive impacts on the target species will outweigh any negative impacts on the environment. If there is a need for nesting habitat in an area lacking suitable islands and if the benefits for the birds will exceed any negative effects of construction of an island to benthic organisms and current flow, then an island could be built. New island construction will be dependent on the concerns of Federal and state agencies and the private sector, and these concerns vary considerably among regions of the country.

Building constraints

Three prime considerations for building dredged material islands for bird habitat are location, timing, and design. Each of these factors is of importance if birds are to be attracted to the islands.

The site selected for an island should be coordinated with knowledgeable wildlife biologists and concerned agencies to establish the best location. Building an island in an area that does not conform to biological and engineering specifications would fail to produce the desired wildlife habitat. Islands must be placed where the birds will be isolated from predators and human disturbances, unless the islands are going to be actively protected.

Timing is important: ideally an island should be built during the fall or winter preceding the initiation of the next breeding season. Birds generally do not use a site until after the initial winnowing of fine material by wind and water. If an island is built in the spring, this sorting may not have had time to take place, and any colony of birds trying to nest there may have their eggs covered by drifting fine material. Also, birds cannot use a site until it has had adequate time to dewater.

The physical design of an island is a major factor in its success as bird habitat. In general, islands must be permanently emergent at high water levels; birds have been found nesting on all sizes and shapes of islands as long as the islands met this crucial breeding requirement. Observations of hundreds of birds colonies on dredged material islands and the kinds of islands they select has led to four categories of recommendations: size, configuration, substrate, and elevation. Whether an island is diked or undiked can also make a significant difference in bird use.

Size. Ideally, new islands should be no smaller than 5 acres and no larger than 50 acres. However, birds have been found nesting on both smaller and larger islands, and this is a highly site- and species-specific feature. Larger islands would generally be more difficult to manage and would also be more likely to support predator populations such as coyotes, snakes, foxes, feral cats and dogs, rats, and raccoons. Islands between the two extremes in size can be managed more easily, and considerable habitat diversity can be achieved. Generally, the greater the amount of habitat diversity to be maintained for wildlife populations, the larger the island should be.

Configuration. The configuration on an island will depend on the target wildlife species. Steep slopes such as those found on some dikes should be avoided for all species. A slope no greater than a 3-ft rise per 100 ft has been recommended. Many bare-ground nesters must have gentle slopes to prevent their eggs from rolling from nest scrapes. There is also evidence that the formation of a bay or pond within an island makes it more attractive to nesting birds.

Substrate. Coarse material such as sand or gravel usually makes better nesting substrates due to its greater stability. Fine material such as silt and clay are subject to wind and rain erosion and usually develop desiccation cracks, settling, and ponding. A mixture of sand and shell material makes good nesting substrate for most of the ground-nesting birds, which prefer sandy beach areas.

Fine-grained unstable dredged material may be improved to form suitable nesting substrate by adding coarse material such as shells over its surface or by planting a ground cover on the material to provide vegetation for those species that prefer that kind of habitat, such as the Forster's tern. Tree-nesting species prefer woody vegetation, which often colonizes best on silty, more fertile substrates, and selected species of shrubs and trees preferred by tree-nesting birds could be planted on such sites.

Elevation. Elevations of constructed islands should be high enough to prevent flooding of nesting areas but not so high that wind erosion will prevent the substrate from becoming stabilized. Generally, the optimum elevation for an island is between 3 to 10 ft above mean high water. The desirable elevation will depend on the texture of the exposed dredged material, wind exposure, and habitat objectives or target species.

Coarser material may stabilize at higher elevations than finer material. If islands are constructed of coarse material, it may be acceptable to exceed the recommended elevation. In general, the higher the elevation of coarse-grained material, the slower the island will be colonized by plants. Therefore, lower elevations to achieve plant cover for some ground-nesting species and all tree-nesting species should be considered where those are the target wildlife species and where substrates are fine-grained material.

It should be remembered that, given the proper substrates and vegetation for nesting, none of the species using dredged material islands for nesting choose one elevation over another so long as they are above the tide or flood lines.

Developing and Managing Islands

Management of existing island habitats has been demonstrated to be an effective disposal technique and wildlife management practice that is desirable because the potential environmental impacts of disposing on an existing site are less than those of building new islands.

Dredging and disposal operations can be acceptably altered to benefit waterbirds and other wildlife on dredged material islands. Developing and managing dredged material islands for birds involves a broad spectrum of techniques: habitat establishment, habitat manipulation, and protection of bird colonies.

Habitat establishment

Habitat establishment may be necessary where nesting habitat is lacking and new islands must be created, often with the resulting need for vegetation establishment; where nesting habitat is expanded by an addition to an existing island; or where undesirable nesting habitats (vegetation) occurring on islands must be cleared out, and desirable habitats established in their place.

A number of suitable plant species could be planted on an island that would increase its attractiveness to avian wildlife. Depending upon the wildlife species specific requirements, plants could be incorporated into an island management plan. No plantings would be necessary for ground-nesting species in most cases, although some of these species use sparse herbs and grasses for nesting. Since tree-nesting species require tree/shrub habitat, planting of this vegetation type would hasten wildlife use by more quickly providing suitable habitat. Woody habitat will require 5 to 30 years to develop, depending upon the region and climatic conditions.

Habitat manipulation

Habitat manipulation, by far the management technique most commonly used by the Corps, includes properly placing the dredged material to maintain or to reestablish habitats; increasing the size of existing islands; and/or changing island configuration, elevation, vegetation, or other features to make more desirable habitats. Manipulation of habitats also included establishing new vegetation and managing existing vegetation on islands through various agronomic and horticultural techniques.

The CE has provided habitat incidental to project purpose since the agency first created dredged material islands. Since that time, islands have been kept in various stages of plant succession through deposition of dredged material from channel maintenance operations. These operations can have a significant positive impact on waterbird breeding populations. Through proper planning, the positive impact of regular deposition could be increased. Since past dredging and disposal operations have been carried out with little or no regard for nesting birds, many areas do not have adequate diversity of nesting habitat. Some areas lack ground-nesting habitats while others lack woody habitats.

Additions to islands may be useful management tools if valuable nesting sites are being altered by erosion and may eventually have to be abandoned. Such additions will prolong island usefulness as nesting habitat. Adding to existing islands that are covered with vegetation will increase habitat diversity by providing some bare-ground habitat, at least temporarily, for those forms of wildlife requiring bare ground. Colonies have responded favorably to island additions, especially bare-ground nesting species.

Once site-specific needs are known, nesting habitat management can easily become a part of the regular maintenance dredging process. To maintain target habitat diversity for certain bird species, islands in any given area could be selected to receive periodic depositions of dredged material on a rotating basis. Restrictions against dredged material deposition on all or parts of some islands may be necessary in order to allow habitats for tree--nesting birds to develop or to preserve existing tree habitats.

Another aspect of habitat manipulation is that sometimes vegetation must be controlled in order to provide the proper or desired habitat for target wildlife species. Vegetation control would be necessary if habitat for ground-nesting species was scarce and there was an abundance of other habitats or if the incorrect species of trees growing on an island precluded its use. Some successful control methods are mechanical removal, hand removal, controlled burning, and applications of herbicides.

Management of CDFs generally consists of continued protective isolation, wildlife monitoring, and posting. Vegetation management has not yet become a problem on any of these relatively new islands.

The feasibility of these management recommendations has been demonstrated by the Wilmington District where local management on an annual basis has been practiced for several years. A long-range CE habitat management plan for colonial sea and wading birds in the lower Cape Fear River estuary includes timing of maintenance dredging and controlled placement of dredged material deposits on existing islands.

Protection of bird colonies

Lack of isolation and protection is one of the primary problems waterbirds face. They are protected under the US Migratory Bird Treaty Act and its amendments, but this law does not protect habitat unless the migratory bird is present. Some of the provisions of the act can be detrimental for long-term protection of the colonies by restricting management activities that are for the long-range benefit of species in existing colonies. Some states have laws and regulations designed to give the necessary protection. It has been shown repeatedly throughout North America that, in general, protected colonies are successful while unprotected colonies are not.

To ensure compliance with law, maintenance operations involving placement of dredged material on existing islands should be conducted in a manner that will not disturb bird colonies. Management should include proper care during placing, surveying, and constructing dikes.

Public education concerning the vulnerability of colonial-nesting birds has the potential of being a valuable management tool. Through various public relations channels, the general public could be made aware of the value of the dredged material islands and at the same time could be told that the continued periodic disposal of dredged material on an island may be a viable management option to improve the bird habitat.

Protective measures for the colonies including posting of the islands with signs such as those used by the Mobile and Portland districts (Figure 4), fencing, designating certain colonies as wildlife sanctuaries such as the Tampa Bay dredged material islands now being managed by the National Audubon Society, limiting scientific study (and thus disturbance of birds by constant observation and measurements), and controlling wildlife predators such as raccoons, foxes, and feral animals.

. . . and a few words of caution

A key to success in the early planning stages of island development is cooperation, communication, and coordination with Federal, state, and local agencies with regulatory authorities. Many obstacles to project success could be prevented or removed by correct planning and public awareness efforts before a project actually begins. Positive public and agency opinion regarding disposal of dredged material may improve acceptance and understanding of the

Figure 4. One of the posted signs erected by the Mobile District to protect sensitive nesting colonies of seabirds on Gaillard Island CDF

operations and allow more of this resource to be beneficially developed for wildlife.

The development of disposal specifications that will create or maintain island habitats and will simultaneously satisfy the need to dispose of a given amount of dredged material requires considerable care. Specifications should include exact locations; time of disposal; final size, elevation, slope, and configuration of deposit; and instructions for movement of discharge pipes to ensure that habitat requirements are met. Onsite monitoring of the disposal operation is highly desirable and is necessary when disposal is on an island with an existing bird colony or population of vulnerable wildlife.

Strategic placement of new sites is a valuable management tool. However, islands should not be placed in areas where they would be used for recreation purposes during the nesting season, thus eliminating or severely reducing their habitat value.

If a steep-sloped dike is built on an existing island and then filled, the dike should usually be at least partially removed or breached to allow ground access to water by young birds. This will require planning for earth-moving equipment to return to the site at appropriate times. Dikes should be erected just prior to disposal for best use of the existing island by wildlife. Temporary dikes may sometimes suffice. Periodic monitoring to determine the after effects of continued disposal will provide useful information for future disposal efforts.

Fishing or boating adjacent to an island during the nesting season can inflict severe damage on a colony through disturbance of young and adults. Dredging and disposal operations, surveying of islands, and constructing dikes could also disrupt nesting birds.

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Environmental Effects of Dredging Technical Notes

WETLANDS CREATED FOR DREDGED MATERIAL STABILIZATION AND WILDLIFE HABITAT IN MODERATE TO HIGH WAVE-ENERGY ENVIRONMENTS

PURPOSE: This note describes successful techniques for developing marsh on dredged material in moderate to high wave-energy environments defined below for habitat creation and substrate stabilization. Marsh creation is often much more economical and practical for dredged material stabilization than the more conventional riprap or revetment methods. Additionally, marsh development on dredged material often offers the advantage of creating wildlife and fisheries habitat, making dredged material disposal more acceptable to environmental regulatory agencies and concerned citizens.

BACKGROUND: Marsh development has been used by Corps of Engineers (CE) districts to stabilize dredged material and establish wetlands in various environments since the early 1970s (Landin 1984). Early marsh development techniques focused on areas with low wave-energy environments and consequently higher probabilities of successful marsh establishment. These areas were usually exposed to average fetches of less than 9.0 km and were in coves (Knutson and Woodhouse 1983) or on shores sheltered or away from prevailing winds (Webb, Allen, and Shirley 1982). In these areas, conventional planting techniques are adequate for creating marsh. These techniques usually consist of transplanting single sprigs (rooted stems) either by using spades or mechanized planters. In conventional planting, no attempt is made to protect the plant from waves or to stabilize the plant stem. Recent efforts have focused on practical techniques for developing marsh on dredged material exposed to moderate to high wave energies previously considered too harsh for marsh planting. Examples of such efforts include using expedient breakwaters and new techniques of stabilizing plant stems. Moderate to high wave-energy environments are defined here to have average fetches over 9.0 km and are areas typified by headlands and straight beaches. This definition is consistent with that of high energy (greater than 8.0 km average fetch) planting sites given by Hardaway, Thomas, and Zacherle (1982) and with that of Knutson and Steele (1987), who examined success rates of 67 dredged material sites in the Chesapeake Bay area. They concluded that average fetch appears to be the most useful indicator of potential planting success on dredged material areas in Chesapeake Bay.

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Breakwaters

One method of establishing marsh in a moderate to high wave-energy environment is to couple breakwaters and transplanted sprigs landward of the breakwater. Experience suggests that a breakwater is only necessary for the first 2-3 years after planting, until the marsh sprigs spread by rhizomes and completely cover the target planting area (Newling and Landin 1985). Therefore, only less expensive and expedient breakwaters, such as sandbag, floating tire, and tire-pole breakwaters, are considered in this note.

Breakwaters should be placed far enough offshore to allow maximum marsh development in breadth (seaward to landward). They should be placed in water depths less than 2.0 m mean low water (mlw), but more than 0.75 m mlw. Marsh planting should begin at a distance equal to or exceeding half an average wavelength landward of the breakwater. This will prevent scouring and erosion of the marsh from turbulence and backwash caused by the breakwater.

Sandbag breakwater. A sandbag breakwater was successfully used in 1975 to protect a developing salt marsh on a dredged material site on Bolivar Peninsula in Galveston Bay, TX (Figure 1) (Allen et al. 1978). There, a breakwater with a 305-m-long and 1.5-m-high front was constructed using 0.5- by 1.4- by 2.9-m nylon-coated bags. Sprigs of smooth cordgrass (*Spartina alterniflora*) and saltmeadow cordgrass (*Spartina patens*) were planted landward of the sandbag breakwater. The developed marsh is the only marsh on the bay side of

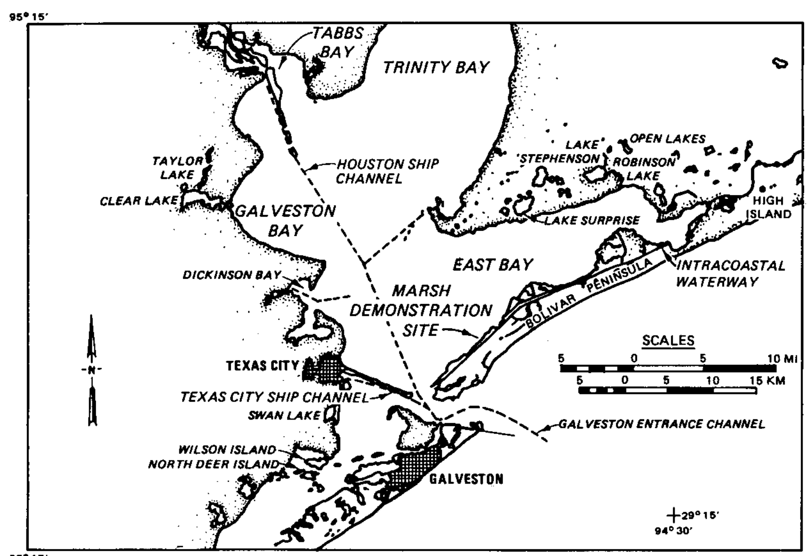


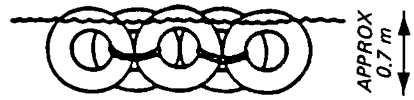
Figure 1. Marsh demonstration site on Bolivar Peninsula, Galveston Bay, TX

Bolivar Peninsula, partly because of a long (32-km) northwest wind fetch that produces large waves in the winter. The sandbag breakwater provided enough initial protection for the transplants to become established, and the marsh is still functioning well (Newling and Landin 1985, and Landin 1986).

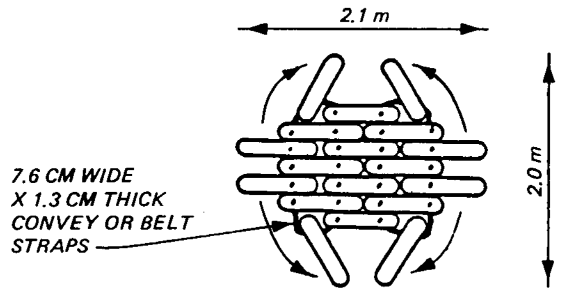
Floating tire breakwaters. Floating tire breakwaters (FTBs) with shoreward salt marsh plantings have been used successfully to stabilize shores of unconfined dredged material deposits at two sites on the Gulf Coast. In 1981, a two-tier FTB (Figure 2) and smooth cordgrass sprigs stabilized part of a dredged material dike in Mobile Bay (Allen and Webb 1983). The dike formed one side of a three-sided, 485-ha confined disposal facility (CDF) called Wilson Gaillard Island (formerly called Theodore Disposal Island), in the middle of Mobile Bay (Figure 3). The stabilized area is subject to an 11.2-km fetch from the north (Figure 3). The FTB was erected after a previous conventional marsh planting had failed.

A three-tiered FTB was tested in 1984 on Bolivar Peninsula, TX, 1 km west of the 1975 site described earlier (Figure 1). The configuration was selected for field testing after wave-tank studies demonstrated that it could reduce wave energies by as much as 80 percent (Markle and Cialone 1987). Smooth cordgrass was planted shoreward of the breakwater using both conventional single-stem and specially stabilized transplants (discussed later). Plantings unprotected by a breakwater were also established nearby as a control. Initial results indicate that the protected areas have an average of 43 percent coverage by smooth cordgrass, while none of the unprotected, single-stem conventional plantings have survived. Forty-three percent coverage after 1-2 years is similar to that seen at the original Bolivar Peninsula (sandbag breakwater) site. Expansion of the marsh and continued success at the newer site is expected and will be monitored for several years.

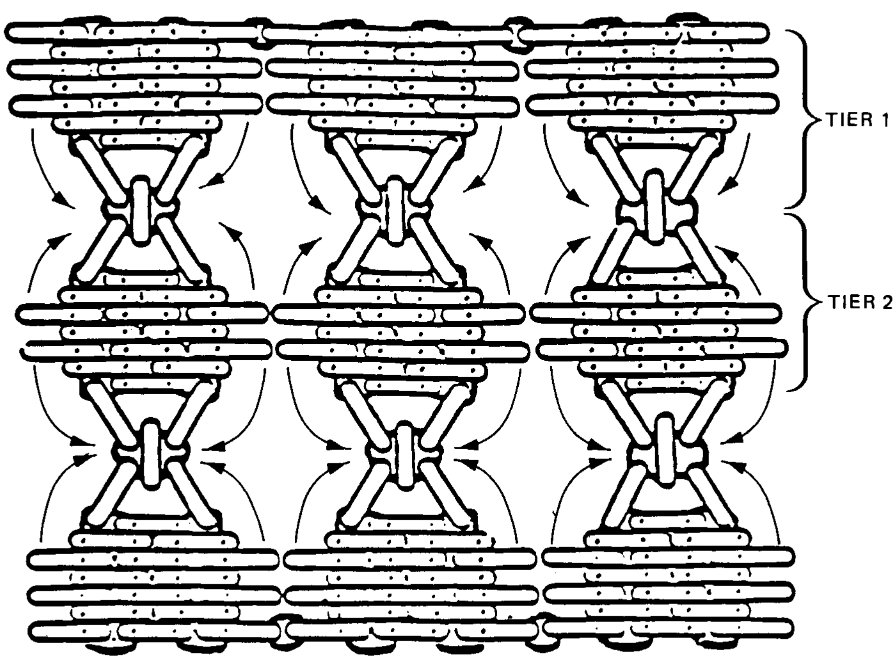
Tire-pole breakwater. A breakwater consisting of tires threaded on 15.2-cm-diam poles (Figure 4) was also tested at the Bolivar Peninsula site in 1984. Shoreward plantings similar to those used behind the three-tiered breakwater were employed. Twenty-seven months later, marsh extended across most of the protected area with an average 47 percent plant cover in the stand. Only a relatively unprotected area at an open end of the breakwater has failed to vegetate. As with the three-tiered FTB area, the area protected by the tire-pole breakwater is also expected to thrive and expand.



PROFILE SCHEMATIC OF ONE FTB MODULE



PLAN SCHEMATIC OF ONE FTB MODULE



PLAN SCHEMATIC OF SEVERAL FTB MODULES

NOTE: ARROWS DENOTE THAT OUTER TIRES OF 18-TIRE MODULE ARE TURNED IN DIRECTION OF ARROW TO SERVE AS CONNECTORS TO OTHER MODULES.

Figure 2. Profile and plan schematics of a two-tier FTB, illustrating its construction by strapping tires and tire modules together

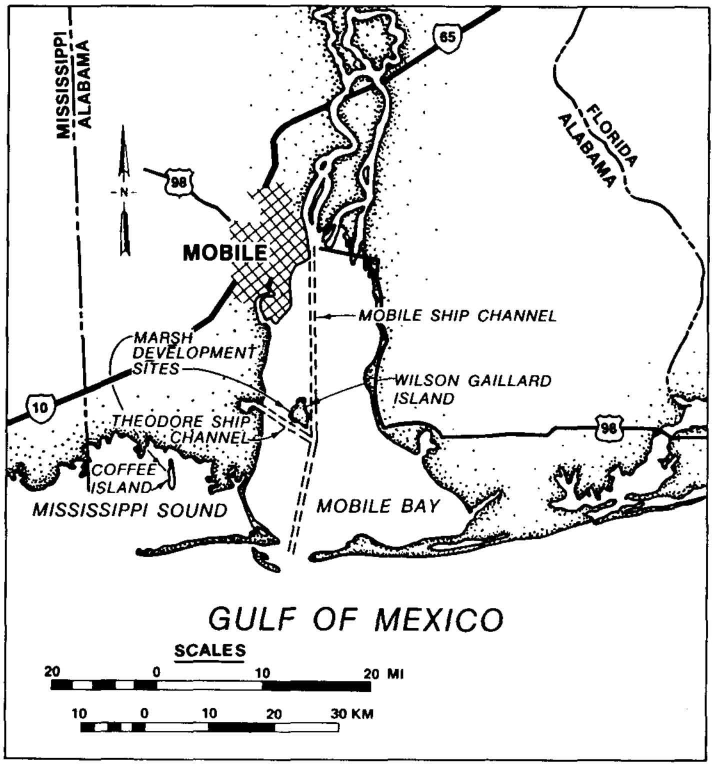


Figure 3. Gaillard Island, Mobile Bay, AL, and Coffee Island, Mississippi Sound, AL, marsh development sites

Planting Techniques for Plant-Stem Stabilization

Breakwaters are a good means of promoting marsh establishment, but other more visually attractive and possibly less expensive techniques exist that may be just as effective. In 1983, the US Army Engineer Waterways Experiment Station (WES) began to work with planting techniques that focus on plant-stem stabilization. The concept is to strengthen the attachment of the plant to the substrate to reduce the likelihood of its being washed out by wave attack and thereby avoid the necessity of a breakwater.

Twelve plant-stem stabilization and conventional planting techniques were tested in Mobile Bay in 1983. The techniques were exposed to about 0.6-m maximum wave heights of various fetches and directions, the maximum being an 11.2-km fetch from the north (Allen, Webb, and Shirley 1984). The conventional single-stem planting techniques proved unsuccessful. Three techniques using erosion-control mats, plant rolls, and burlap bundles demonstrated

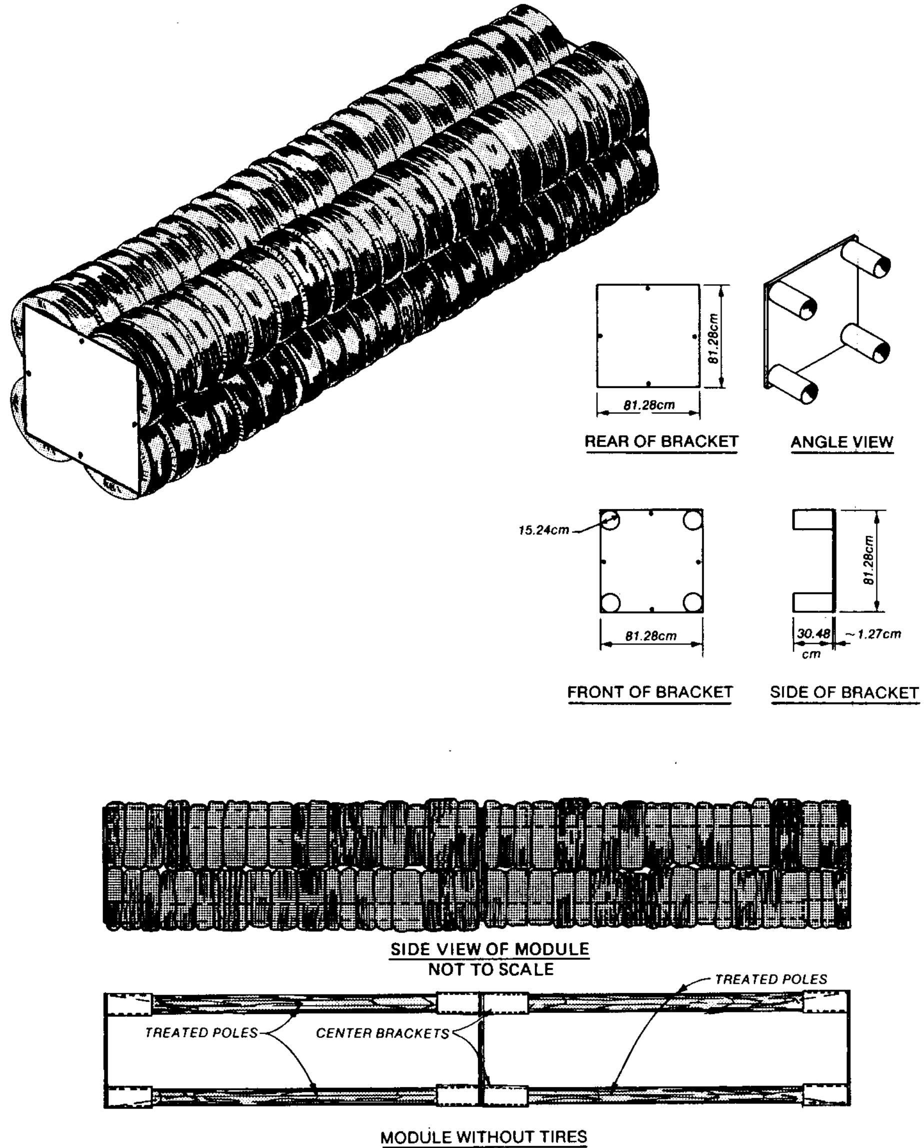


Figure 4. Schematic of fixed tire-pole breakwater

enough potential at Gaillard Island (Allen, Webb, and Shirley 1984) that they were subsequently tested in demonstration plots on Bolivar Peninsula. They were also tested at Southwest Pass on the lower Mississippi River. Potential usefulness of the plant rolls was also demonstrated along a 0.5-km front at Coffee Island in the Mississippi Sound (Figure 3). Results of these demonstrations are described in Allen, Shirley, and Webb (1986), and successful techniques to date are summarized below.

Erosion control mat. A Paratex* biodegradable fabric mat consisting of 0.1 kg/m^2 natural fibers was laid like carpet on the shore at the previously described Bolivar Peninsula site. Then, single stems of smooth cordgrass were planted on 0.5-m centers through slits cut in the material (Figure 5). The edges of the mat were nailed between 5- by 15-cm boards that were then buried in the sediment (Allen, Webb, and Shirley 1984). Four 6- by 9-m plots of the planted mat were placed adjacent to, parallel with, and outside the immediate influence and protection of breakwaters. Twenty-seven months later, three of four original plots remained with an average 41 percent plant cover. Success within the three remaining plots was similar for both those plots protected by breakwaters and those unprotected.

Figure 5. Smooth cordgrass sprigs inserted into fabric mat at Bolivar Peninsula

Plant roll. A plant roll is constructed by placing soil and six transplant clumps (several stems from one intact root mass) at 0.5-m intervals on a strip of 3.7-m-long by 0.9-m-wide burlap. The sides and ends of the burlap are brought together around the plants and fastened with metal rings. This creates a 3-m-long roll of plants and soil (Figure 6). The plant rolls are placed parallel to the shoreline and buried to such a depth that only the plant stems are exposed.

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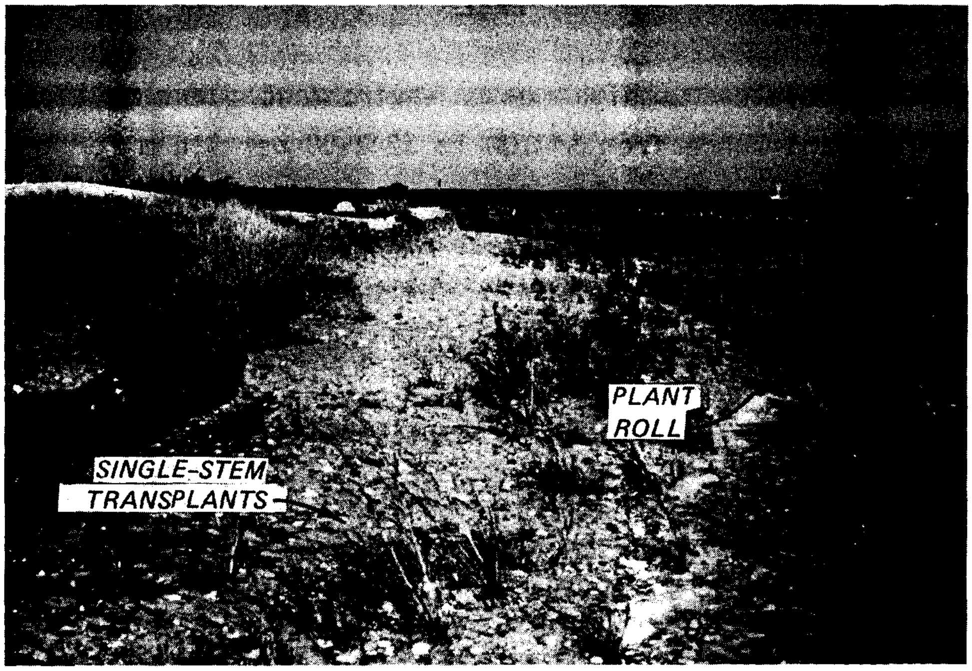
* The contents of this note are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such products.

Figure 6. Plant rolls constructed on site ready for installation

A mixture of single-stem transplants and plant rolls was used successfully at a demonstration site at Coffee Island (Figure 3) in the Mississippi Sound (AL). The site consisted of clayey dredged material and had a maximum fetch of 16 km. Stabilization with smooth cordgrass was undertaken to control erosion. Plant rolls (one row) were placed end to end seaward of single-stem transplants (Figure 7a) over a linear distance of about 0.5 km to cover an area 5 to 10 m wide.

Periodic inspection of this demonstration planting revealed that new stems emerging from the plant rolls satisfactorily colonized and stabilized the eroding dredged material face after 1-1/2 years (Figure 7b). Recent inspection (after 1-1/2 years of growth) of the site demonstrated that the marsh fringe showed signs of accreting sediment, a feature which will further protect the island from erosion.

Plant rolls have not always proved successful; they were washed away at the Bolivar Peninsula site. Two explanations for this are possible. At the Bolivar Peninsula site, the rolls were tested on sandy material with small test plots, and plant rolls appear to be more prone to wash out when they are used on sandy material than on clayey material, because clay is a more stablesubstrate. Also, small plots are more likely to fail than continuous planting because small separated plots encourage gullying between them which eventually erodes the plots.



a. Smooth cordgrass 2-1/2 months after planting using plant rolls seaward with single-stem transplants planted landward

b. Smooth cordgrass 1-1/2 years after planting using plant rolls and single-stem transplants

Figure 7. Coffee Island, Mississippi Sound, AL, marsh demonstration site

Costs

Costs of moderate- to high-energy environment planting techniques are given in Table 1 and range from $48.00 to $242.00 per lin m for a marsh 20 m broad (seaward to landward). Traditional erosion-control construction techniques, such as rock revetments and sheet-pile bulkheads, are much more expensive than these vegetative alternatives, often as much as 5 to 10 times more, depending upon the desired width of protection and logistical factors.

Table 1. Costs of Planting Technique*

Planting Technique	Cost per Plant	Cost/Linear Meter (20 m deep)
Single-stem plants (conventional planting)	$0.15	$ 12.00
Plant roll	0.60	48.00
Paratex mat	1.58	126.00
FTB with planted sprigs	1.58	126.00
Tire/pole breakwater with planted sprigs	1.95	154.00
Sandbag breakwater** with planted sprigs	3.06	242.00

* Costs are based on an hourly labor rate of $6.00 plus 10¢/plant for digging, gathering, and transporting. Costs of materials are included; other direct and indirects costs are not included. Costs per linear meter also assume that plants are placed on 0.5-m centers and are planted in a swath 20 m wide.

** Costs of a 1.5-m-high sandbag breakwater are based on information provided by Mr. James L. Wells, Chief, Dredging Section, US Army Engineer District, Wilmington, 12 April 1988.

Conclusions

The stabilization techniques described here are still experimental and must be used with care. When used properly, they offer considerable promise for cost savings over conventional erosion-control techniques. The habitat developed is an additional benefit that may be applied to the mitigation process or used to improve the attractiveness of a site to local interests.

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EEDP-07-3
February 1988

Environmental Effects of Dredging Technical Notes

CONSTRUCTION OF A SUBMERGED GRAVEL BAR HABITAT USING DREDGED MATERIAL

<u>PURPOSE</u>: This note provides information on techniques, materials, and equipment necessary to construct submerged aquatic habitats in large waterways using coarse-grained sediments.

<u>BACKGROUND</u>: Gravel bars are notable natural features of rivers and streams that have not been altered by water resource development. Gravel and cobble-sized materials provide points of attachment and anchorage for aquatic organisms such as insect larvae, snails, and worms (Hynes 1970). Coarse-grained particulates stabilize fine substrate and allow colonization by long-lived invertebrates such as freshwater mussels. Particle size distribution, degree of embeddedness, and presence of attached organic matter and plants determine the characteristics of invertebrate communities in flowing water systems (Cummins and Lauff 1968, Brusven and Prather 1974, Walton 1978).

Selected reaches of navigable waterways frequently have to be dredged to provide channel depths necessary for navigation. Environmental legislation such as the Rivers and Harbors Act of 1899 and the Endangered Species Act, as amended (1978), has encouraged beneficial uses of dredged silts and sands to create terrestrial or wetland habitat (Harrison and Luik 1980; Perrier, Llopis, and Spaine 1980; Newling and Landin 1985). However, gravel or other large-sized particles from dredging or other sources can be placed in flowing water to create shoals or bars. Gravel has been used to make trout habitat (Stuart 1953), to accelerate biological recovery in streams modified by channel development (Shields 1983), and to increase water velocity and provide substrate for invertebrates (King and Miller 1986). Habitat creation techniques in large waterways are fairly simple, operationally feasible, and should be considered when appropriate material and a suitable site are available. When incorporated into early planning, habitat development provides a mechanism to satisfy environmental concerns and still meet project purposes.

<u>ADDITIONAL INFORMATION</u>: Contact the author, Dr. Andrew C. Miller, (601)634-2141; or the EEDP Program Manager, Dr. Robert M. Engler, (601)634-3624.

Development of the Project

History

In the fall of 1983 a grain company accidentally dredged part of a mussel bed in the Ohio River near Mound City, Ill. The dredging took place during low water and was done to provide access to a loading facility. The mussel bed supports a diverse assemblage of species, including the orange-footed pimpleback, *Plethobasus cooperianus*, listed as endangered by the US Department of the Interior (1986). The grain company agreed to construct a gravel bar to compensate for damage. The bar had to be located outside the navigation channel in an area where physical conditions were suitable and there were no live mussels. Freshwater mussels require flowing water (<0.5 m/sec) and firm, stable substrate that is not susceptible to excessive sedimentation. A design for the habitat was prepared and, in August 1986, construction was initiated in the river.

Site selection

On the Kentucky side of the Ohio River across from Mound City, river miles (RM) 971.3-973.3, is an exposed shoal built with material from maintenance dredging (Figures 1 and 2). A submerged dike at the downstream end of the shoal helps to deflect water into the main channel. At normal pool elevation, water depth on the landward side of the shoal ranges from 3 to 4 m. The main component of the benthic fauna at this site is the Asiatic clam, *Corbicula fluminea* Muller, an introduced species (0-646/sq m, average = 224, standard deviation = 232.6, number = 9). Specimens were medium sized, with total shell length of 2 to 3 cm. Intensive searches in 1984 using a brail (a bar with 200 or more multipronged hooks that is dragged over the river bottom to capture live mussels) and scuba divers yielded only three live mussels. Live specimens in the area included: one ebonyshell (*Fusconaia ebena* Lea) and two pink heelsplitters (*Potamilus alatus* Say). Although substrate that supports mussels usually consists of sand and gravel (Figure 3A), the shoal consisted mainly of coarse sand with less than 10 percent gravel (Figure 3B).

A site with appropriate depth and water velocity was selected at RM 972.0. Water velocity at the bottom ranged from 20 to 33 cm/sec during low water, which is sufficient to remove previously settled silts but not erode larger particles (Vanoni 1975). Presence of Asiatic clams and a few larger

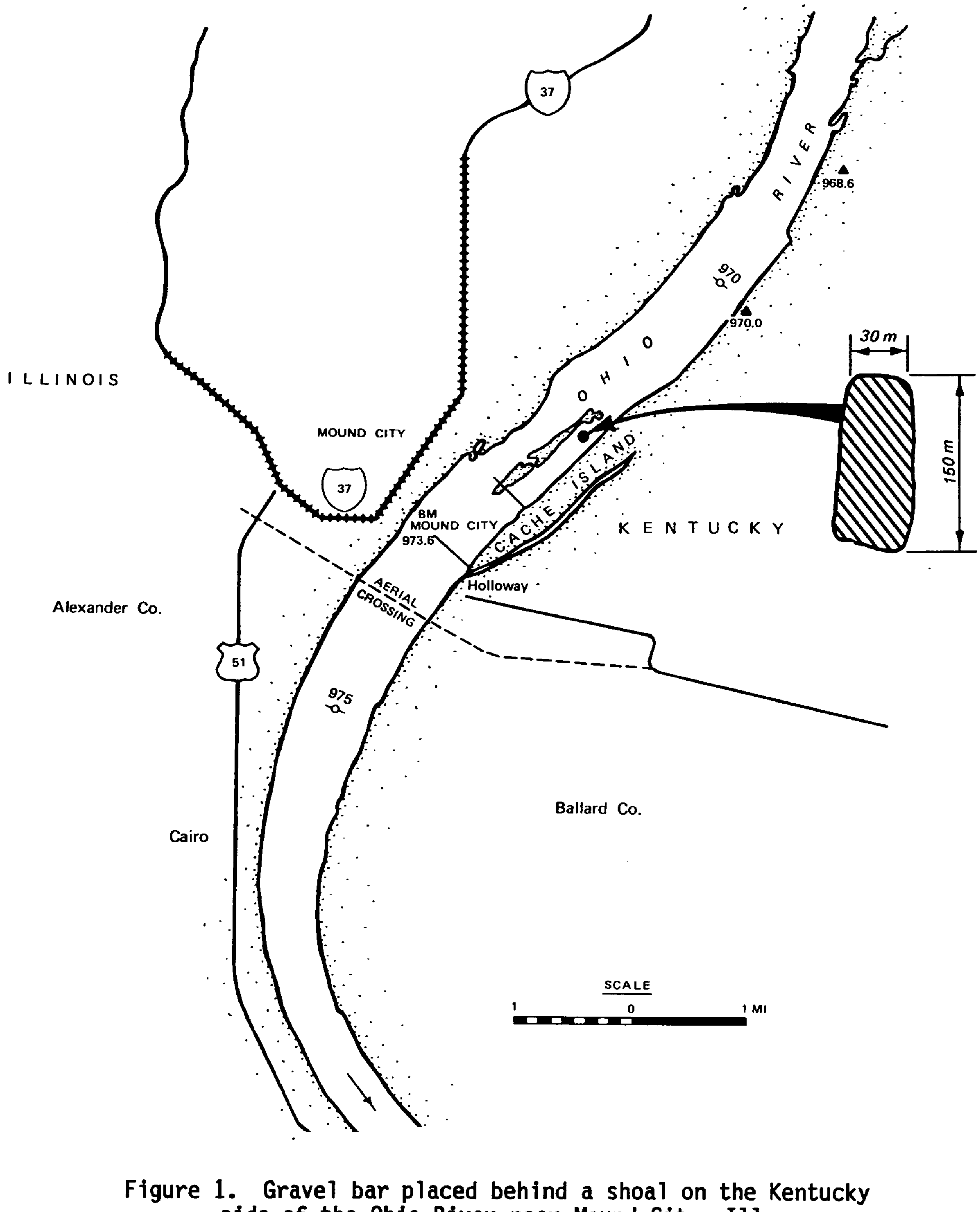

Figure 1. Gravel bar placed behind a shoal on the Kentucky side of the Ohio River near Mound City, Ill.

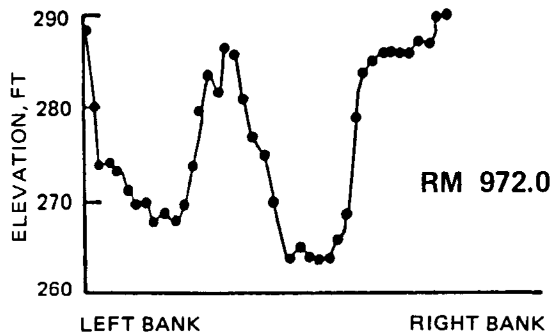

Figure 2. Depth profile at gravel bar construction site

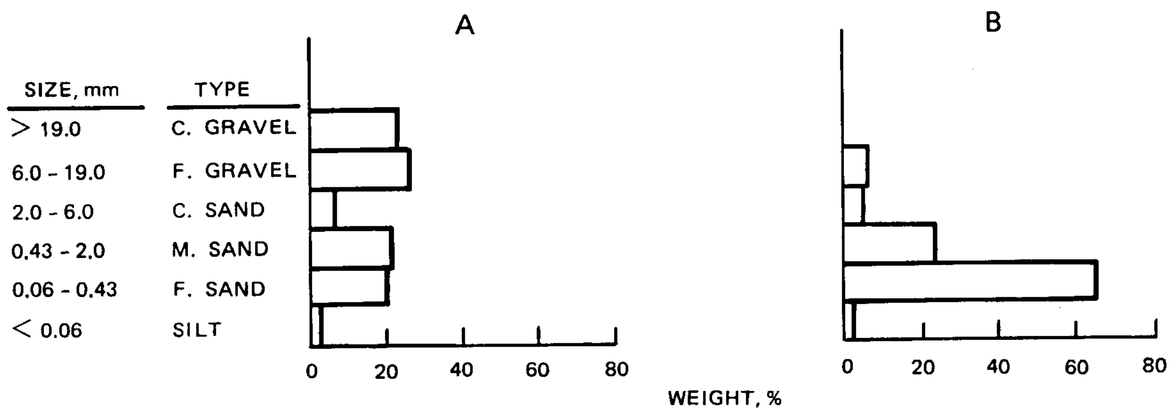

Figure 3. Particle-size distribution of inorganic sediments at at a natural gravel bar (A) that supports freshwater mussels, and from the construction site (B)

mussels indicated that high current velocities do not disrupt the substrate. In addition, this site is outside the navigation channel and is protected from commercial traffic by the shoal and dikes.

Construction Details

Obtaining material

Gravel for the habitat (Figure 4) was pumped from the main channel using a hydraulic dredge with a 27.5-cm-diam intake pipe. Since substrate in the main channel consisted of a mixture of sand and gravel, all material was sieved through a 9.5-mm-diam screen. Only coarse sediments were retained for the habitat. Since sand was the predominant sediment type at the proposed site, only gravel was used to construct the new habitat. It took about 8 hr to pump and load 2,500 tons of material.

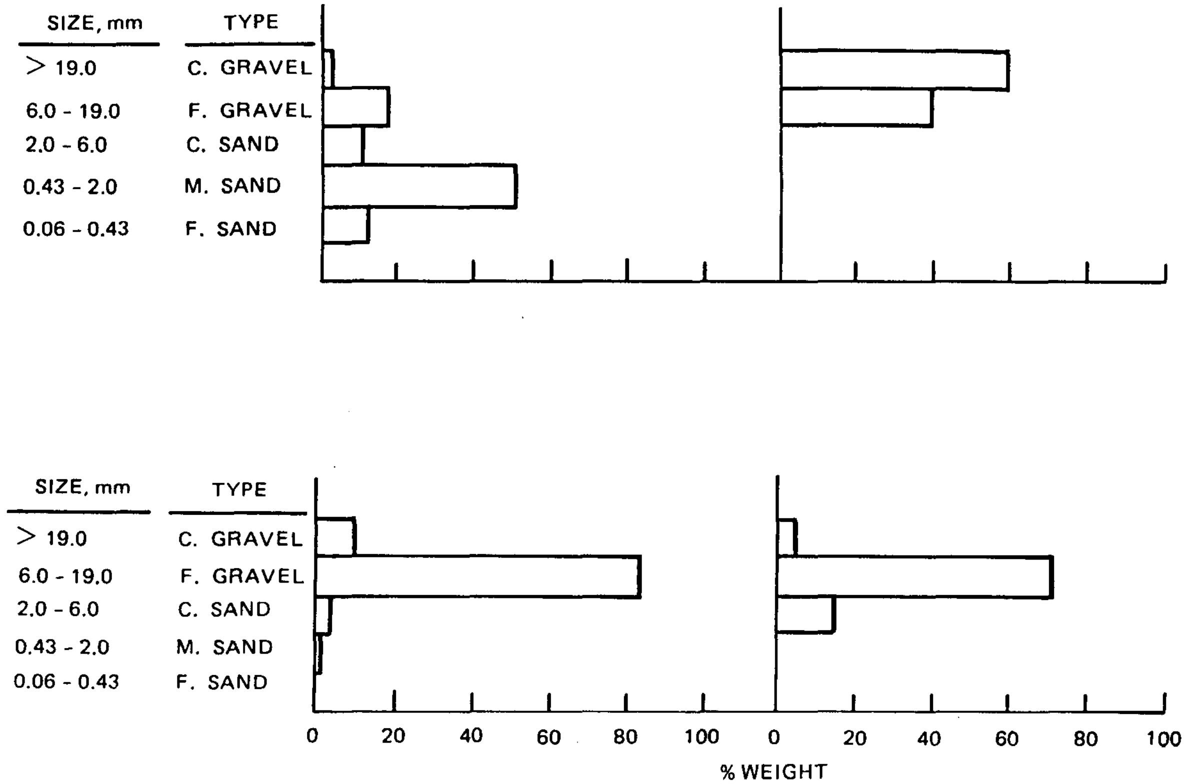

Figure 4. Particle-size distributions of materials used to construct the habitat, illustrating the range of sediment types used

Placing the gravel

The site was delineated by buoys that were set at 46-m intervals along the landward side of the habitat (Figure 5). A tug, crane, and materials (gravel) barge were positioned directly over the outside portion of the habitat. The crane operator used a 24-m boom and a 3.0-cu m clamshell bucket. About two-thirds of a bargeload of gravel was spread along the right side and front of the barge. The tug operator kept the barges in position throughout the operation; no anchors or "spuds" were used. The gravel was placed as evenly as possible by opening the bucket slowly as the boom moved above the water surface. After the majority of the gravel was placed along the front and right side of the barge, the equipment was moved approximately 15 m to the left. The remaining gravel was then placed where the barge was positioned when the first two-thirds of the gravel was spread.

Each 46-m section of the bar required one bargeload of gravel (about 800 cu m). Work proceeded downriver so that propeller wash from the tug would not disturb the newly placed gravel. It took from 4 to 6 hr to position the tug and equipment and unload a single barge. Four bargeloads of gravel, about

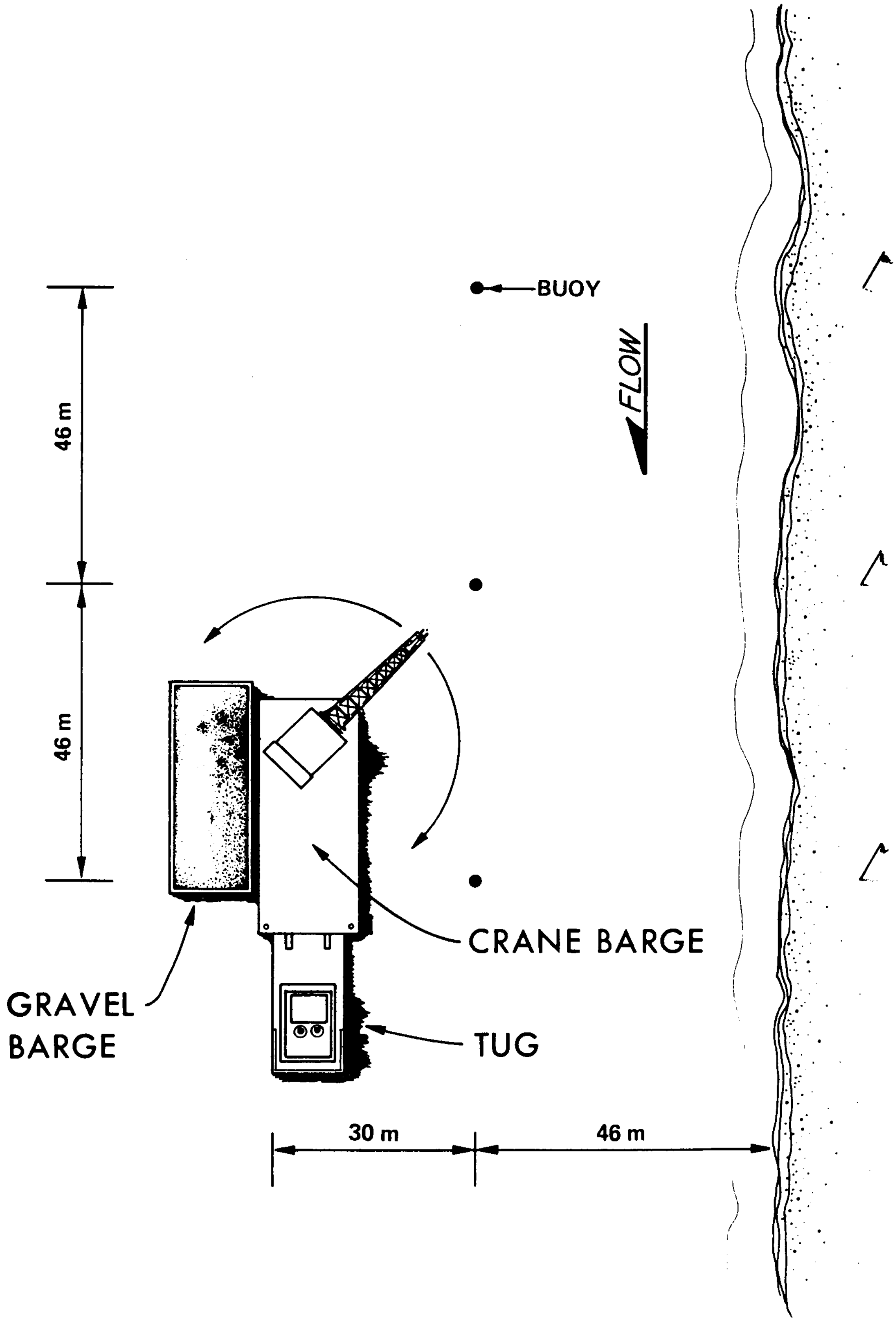

Figure 5. Placement of gravel in the river with a clamshell dredge

3,200 cu m of material, were placed on the river bottom during the 3-day construction period.

Evaluation of the Habitat

Postconstruction conditions

After all gravel had been spread, divers measured the actual dimensions of the bar, secured a reference cable down the center of the habitat (Figure 6), and collected substrate samples with a hand-held corer. The bar was 3 to 75 cm thick and was located within the area marked by the buoys. Each 5-cm increment of substrate contained approximately the same size distribution of particles (Figure 7). An even vertical distribution of dredged material was achieved by having the crane operator open the clamshell bucket slowly and spread the material layers. It was not necessary to smooth the gravel after it had been placed.

Continuing studies

Physical and biological conditions at the habitat have been and will continue to be measured for 4 years after placement (through fiscal year 1990). As part of this work, approximately 100 ebonyshell mussels (*Fusconaia ebena*) were collected from the Illinois side of the river. All specimens were marked and their total length and weight measured and placed either free in the substrate or in wire baskets attached to the cable. The marked mussels will be sampled on an annual basis to determine individual mortality and growth rates. Accumulation of fine inorganic and organic sediments will be measured using sediment traps constructed from 10-cm polyvinyl chloride pipe. The traps were filled with washed gravel (>1.27 cm) and placed just beneath the surface of the bar. The traps will be retrieved after 1 year and the substrate will be analyzed for accumulation of organic and fine inorganic material.

After the habitat has been in place for 1 year, sediment samples will be collected for grain-size analyses and for evaluation of macroinvertebrate density and community composition. Biological and physical characteristics of the new habitat will be compared to conditions at the natural gravel bar on the other side of the river.

Conclusions and Implications

Coarse gravel can be placed on sand substrate at suitable sites in large rivers to provide colonization sites for aquatic organisms. Permanent

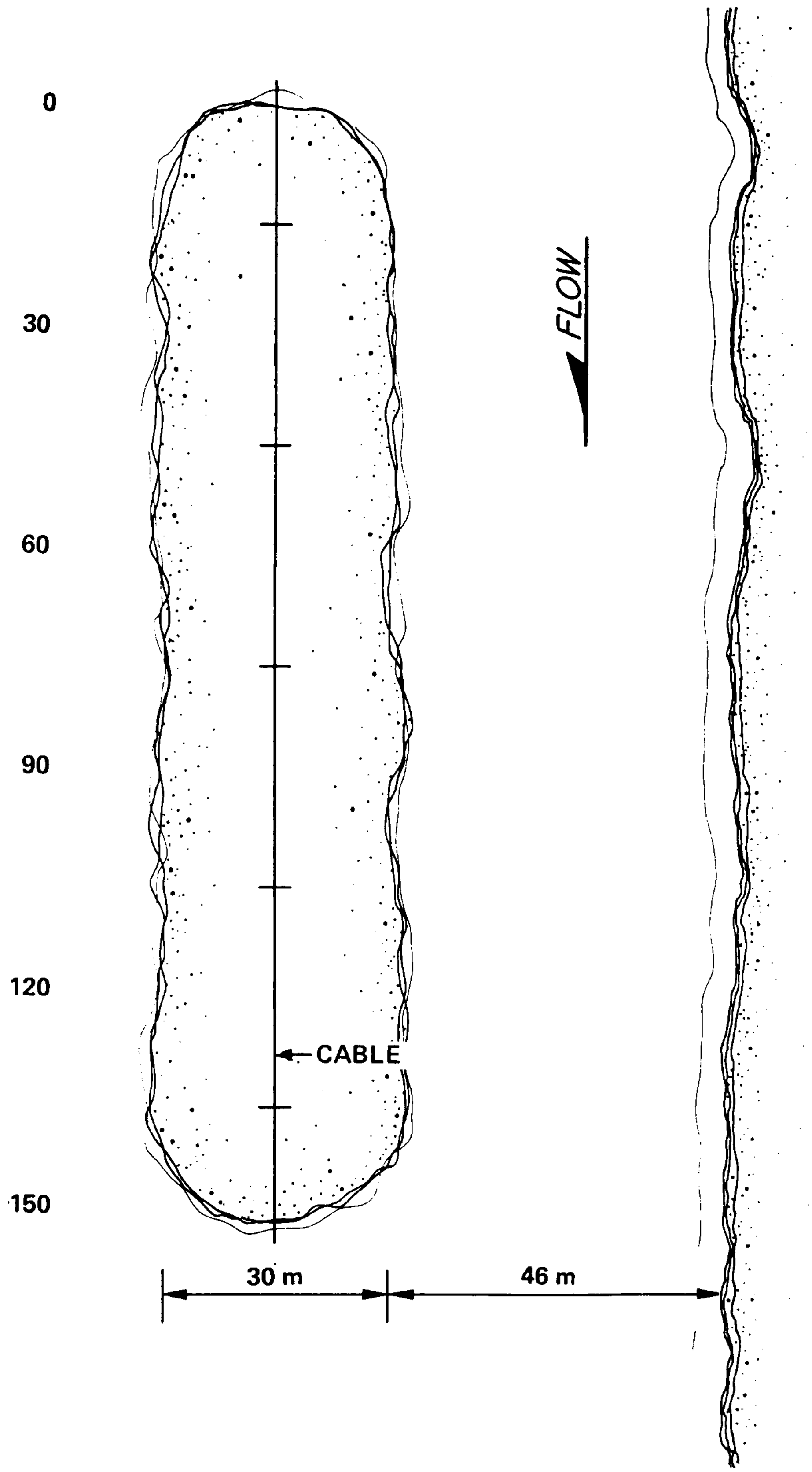

Figure 6. Completed gravel bar with reference cable to mark future study sites

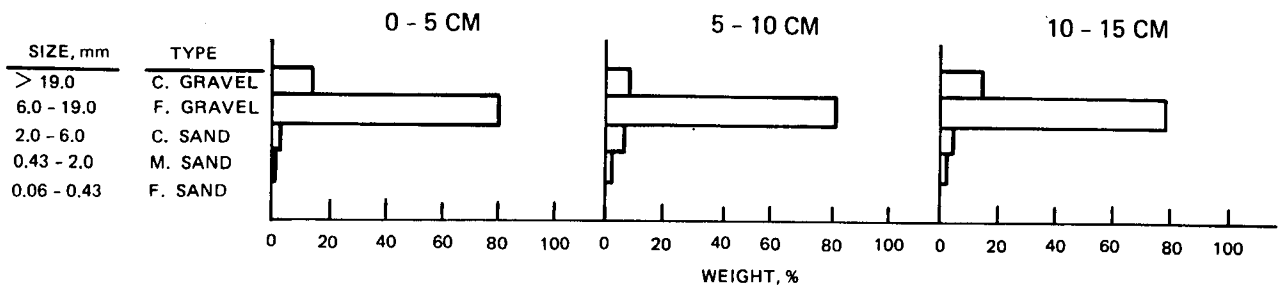

Figure 7. Vertical distribution of inorganic particles at the newly completed gravel bar, September 1986

habitats with a variety of substrate particle sizes, ample food supply, and suitable current velocity are necessary to develop a diverse and dense community of aquatic organisms. Gravel bars placed in carefully selected sites are capable of providing such habitat. They can be constructed in less than a week and, depending upon quantities of material required, for less than $20,000. These habitats can be considered to offset potential adverse effects of maintenance dredging or as water resource development projects. In addition, they provide an opportunity to evaluate short- and long-term effects of habitat construction using coarse-grained sediments.

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Environmental Effects of Dredging Technical Notes

CONSTRUCTION OF A SHALLOW-WATER GRAVEL BAR HABITAT USING DREDGED MATERIAL

PURPOSE: This note provides information on techniques, materials, and equipment necessary to construct a shallow-water aquatic habitat in small to medium-sized rivers using coarse-grained sediments.

BACKGROUND: Two important attributes of flowing water systems (current velocity and substrate type) influence community characteristics, feeding strategies, and density of aquatic organisms (Hynes 1970). Typically, in the upper reaches of streams the substrate consists of cobbles and gravel; in the middle and lower reaches where current velocities are reduced, sands and silts predominate. Darters, many minnows, immature caddisflies, and true flies are fast-water inhabitants, whereas bluegill, other sunfishes, aquatic worms, and mosquito larvae are better adapted for slack-water habitats.

Riffles usually form on a bar where gravel, cobbles, or boulders congregate. Riffle-pool sequences are common features of unaltered gravel-bed alluvial stream channels. Riffles tend to be spaced successively at five to seven stream widths, although they are influenced by bed and bank heterogeneity (Leopold, Waldman, and Miller 1964; Keller 1978; Keller and Melhorn 1978). The greater the variety of particle sizes, the more diverse the invertebrate community. Organisms such as snails and freshwater sponges usually are found on firm substrates such as rocks, logs, or bedrock, whereas immature stoneflies, caddisflies, and mayflies can colonize gravel or cobbles. Thick-shelled freshwater mussels are common inhabitants of gravel bars; their presence usually indicates that substrate is stable, and not subject to erosion or accretion.

Environmental legislation, such as the Rivers and Harbors Act of 1899 and the Endangered Species Act of 1978, have encouraged beneficial uses of dredged silts and sands to create terrestrial or wetland habitat (Harrison and Luik 1980; Perrier, Llopis, and Spaine 1980; Newling and Landin 1985). However, gravel or other large-sized particles from maintenance dredging can be placed in flowing water to create shoals or bars. Habitat creation techniques in large waterways are fairly simple, and when incorporated into early planning, provide a mechanism to satisfy environmental concerns and still meet project purposes.

ADDITIONAL INFORMATION: Contact the author, Dr. Andrew C. Miller, commercial or FTS: (601) 634-2141, or the EEDP Program Manager, Dr. Robert M. Engler, (601) 634-3624.

Development of the Project

History

Construction of the Tennessee-Tombigbee Waterway converted a free-flowing river into a series of run-of-the-river reservoirs with deep, slow-moving water and fine substrate. This provided habitat for slack-water species at the expense of organisms that normally inhabit riffles and gravel substrate (McClure 1985). The Tombigbee River was well known for having a dense and diverse riverine fauna including darters and minnows, as well as invertebrates such as snails, oligochaetes, and insects. The mid-portions of the river provided habitat for freshwater mussels, many of which were collected for commercial purposes. Ecosystems altered by construction of dams and channel diversions are now the most prevalent lotic habitats on earth (Stanford and Ward 1979). Throughout the world, increased demands placed on lotic ecosystems by man have intensified the need for habitat improvement and creation.

Site selection

The Tombigbee River originates in northeastern Mississippi, flows along the eastern section of the state, then enters Alabama south of Columbus, Miss. The Tennessee-Tombigbee Waterway was constructed to provide a more direct shipping route between the eastern Gulf Coast and the mid-continental United States. This was accomplished by connecting the upper portion of the Tombigbee River to the Tennessee River in extreme northeastern Mississippi.

Following completion of the lock and dam at Columbus, a 1-km reach of the Tombigbee River became an abandoned channel (Figure 1). A minimum-flow release structure, designed to pass 5 cu m/sec of surface water, was placed in the dam (Figure 2). However, because the river channel is 60 m wide, water from the release structure produced no measurable current in the channel. Therefore, it was necessary to narrow the channel with gravel to produce a measurable current.

Construction Details

Placing material

The first step in constructing the gravel bar habitat was to transport random fill material, which consisted of sand, silt, or gravel, to the upper end of the channel by barge. A clamshell dredge was used to fill an 80-m

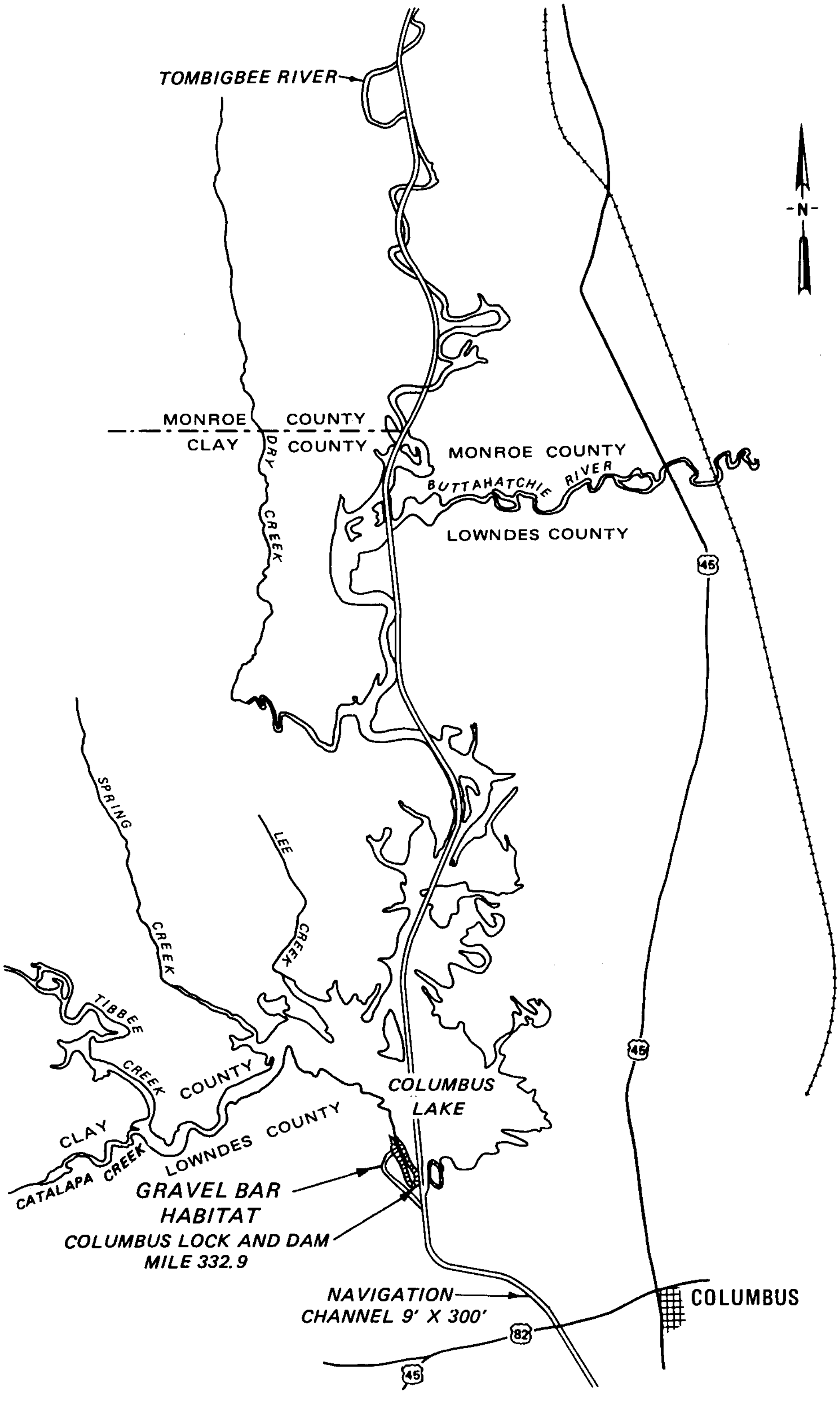
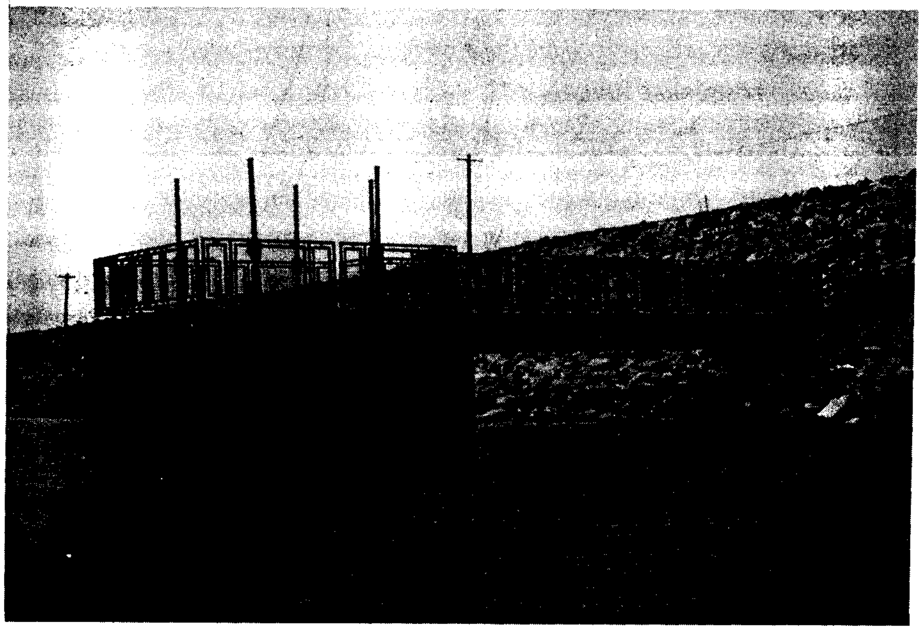
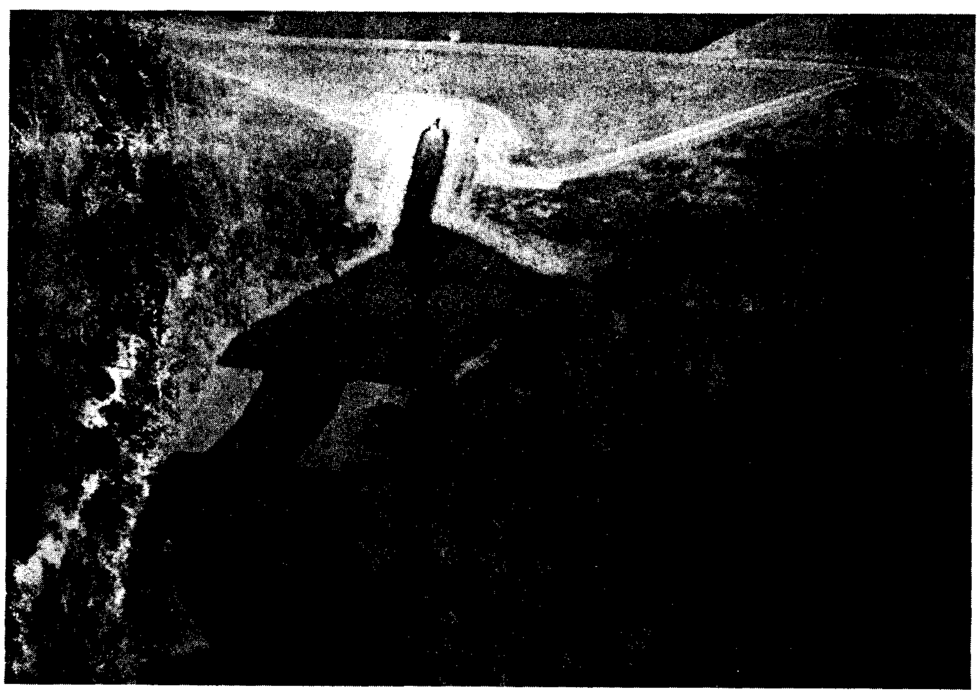


Figure 1. Tombigbee River and location of gravel bar habitat



a. Minimum-flow release structure



b. Aerial view of habitat

Figure 2. Columbus Dam

reach of the channel to an elevation of 39.6 National Geodetic Vertical Datum which was about 2 m below normal water level. The fill was then capped with 24,000 cu m of 2- to 80-mm coarse sand and gravel (Figure 3) obtained from a borrow pit and brought in by barge.

Configuration of the gravel bars

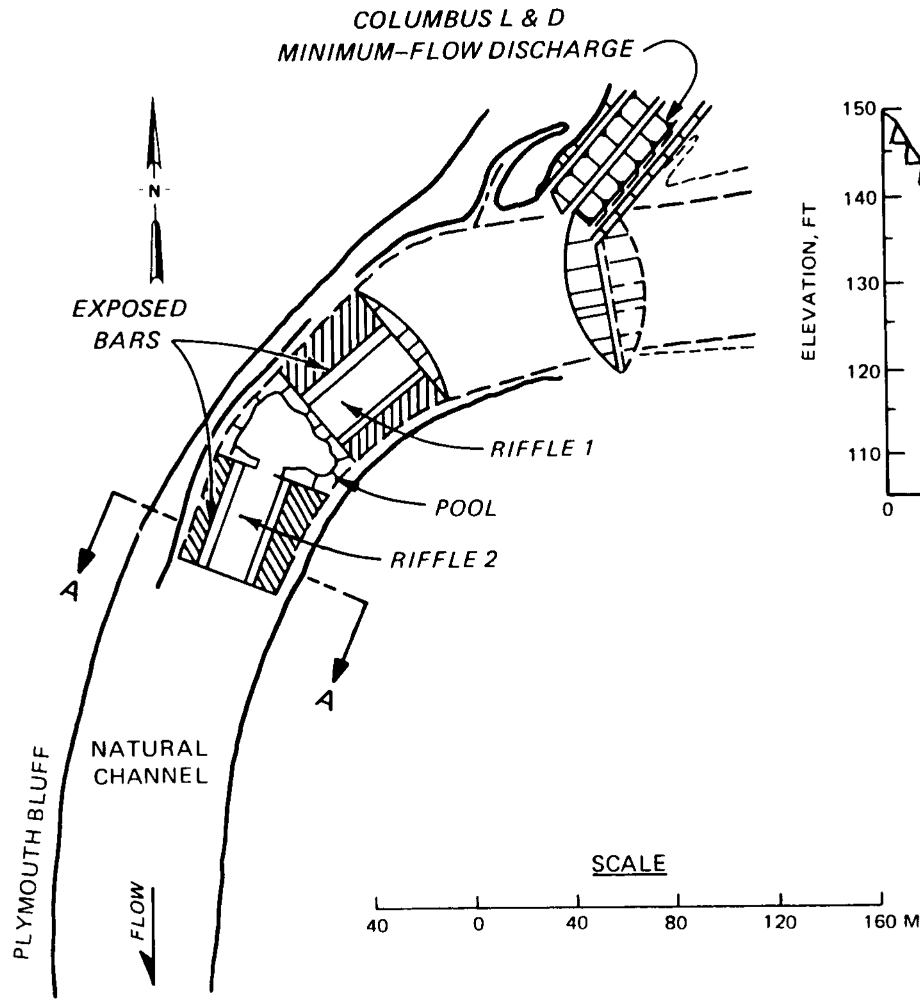
The gravel was placed to create two exposed bars, with a riffle or channel down the center of each. Each riffle is 46 m long, 24 m wide, and has a maximum depth of 1.2 m (Figure 3). The gravel constricts the channel and causes a velocity of approximately 50 cm/sec, which is sufficient to prevent excess sedimentation but not erode the base material (Vanoni 1975). At high discharge the entire habitat, including the normally exposed gravel, is covered with backwater from the Tombigbee River. Water velocity is then essentially zero since the constriction no longer exists. When levels decline, the water is restricted to the channel and the water flows at 50 cm/sec.

Evaluation of the Habitat

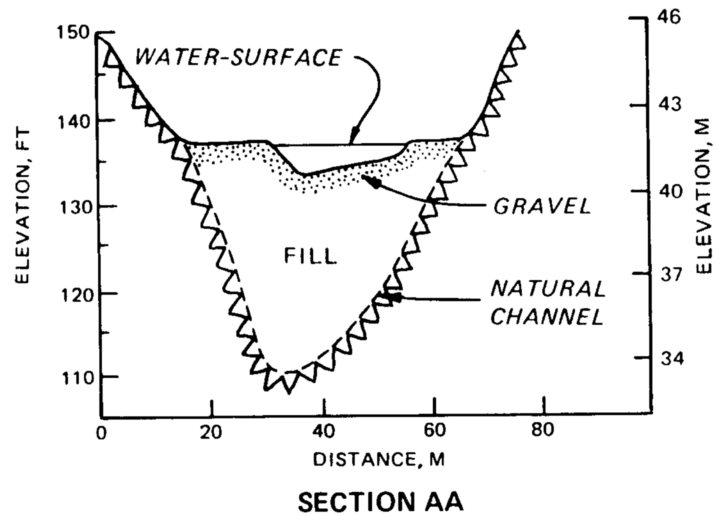
Macroinvertebrates

Colonization by invertebrates was rapid. After 3 months, 19 and 21 taxa were identified at the riffles, with estimated densities of 3,499 individuals/sq m (standard deviation, SD = 1,357; number, N = 15) at Riffle 1 and 2,864 individuals/sq m (SD = 3,072, N = 15) at Riffles 2. By October 1985, approximately 8 months after construction, 34 taxa were found in each riffle. Total density of macroinvertebrates was estimated at 11,450 (SD = 2,270, N = 15) and 10,718 individuals/sq m (SD = 4,081, N = 15) at Riffles 1 and 2, respectively. Total macroinvertebrate biomass was 680.5 and 591.3 mg ash-free dry weight (AFDW)/sq m (N = 15) at both riffles. In October 1986, the last collection date for invertebrates, more than 60 taxa of invertebrates were identified. Density at Riffle 1 and 2 was estimated at 17,949.1 (SD = 77,266, N = 5) and 10,9827 (SD = 4,726.7, N = 5) individuals/sq m, respectively. Total invertebrate biomass was estimated at 15.51 (N = 5) and 4.33 mg (N = 5) AFDW/sq m at the two riffles. The majority of the invertebrate biomass in the latter collections was due to the Asiatic clam, *Corbicula*, an exotic bivalve that lives for several years and can reach a maximum shell length of 3 to 4 cm.

Most aquatic insects colonize new substrate by downstream drift and



a. Aerial view



b. Transverse diagram

Figure 3. Shallow-water gravel bar habitat

dispersal by adults that fly (Fisher 1983, Light and Adler 1983, Minshall and Petersen 1985). At the Columbus site, these two mechanisms probably account for the majority of the aquatic insects in the riffles and pool. However, upstream movement in the water and along the bottom does occur (Bishop and Hynes 1969), and the Asiatic clam, *Corbicula*, can disperse by entering the drift and being carried on currents by a mucus thread (Prezand and Chalermwat 1984).

Fish

Forty-four species of fishes were collected in a four-season investigation; 34 were found at the gravel bar and 24 were found in the river channel immediately below the habitat. The crystal darter, listed as endangered in Mississippi, and the blue sucker, considered to be uncommon in the Tombigbee River, were collected. Shad dominated the catch at the gravel bar (43.2 percent), and minnows and darters were the second most abundant group (23.8 percent), followed by sunfishes (19.8 percent) and crappie (5.5 percent). An abundance of minnows and shiners, indicative of a riverine habitat, was reported by Pennington et al. (1981) in the bendways of the Tombigbee River before construction of the waterway.

Total fish density at the gravel bar (500 to 1,300 fish/ha) was lower than estimates (>2,000 fish/ha) from natural streams with riffles (Kelly, Catchings, and Payne 1981; Schlosser 1985). However, the habitat at Columbus exhibits species composition similar to smaller streams with pool-riffle sequences. The gravel riffles, pool, and outfall from the minimum-flow release structure provide conditions that maintain a unique assemblage of aquatic organisms in a river altered by water resource development.

Conclusions and Implications

The use of artificial gravel bars to provide spawning and rearing habitat for coldwater species, such as trout and salmon, is a successful management technique in the western United States (Bell 1986). Gravel has been used to restore biota in warmwater streams (Edwards et al. 1984) and to facilitate biological recovery in streams modified by channel development (Shields 1983).

Coarse gravel can be placed on sand substrate at suitable sites in rivers to create habitat for aquatic organisms. Gravel can be used not only to provide substrate, but also to constrict the flow, thereby increasing current velocity. Stable substrate with a variety of particle sizes is necessary for development of a diverse community of aquatic organisms. Construction techniques are fairly simple and should be considered when a suitable site and materials are available.

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Environmental Effects of Dredging Technical Notes

THE VALUE OF GRAVEL DISPOSAL MOUNDS IN RIVER SIDE CHANNELS FOR FRESHWATER MUSSELS

PURPOSE: This note provides information on the value of gravel disposal mounds in river side channels for freshwater mussels. Basic guidelines are suggested from this information to guide site selection for beneficial disposal of gravel.

BACKGROUND: Gravel shoals occasionally must be dredged from river navigation channels. Side channels (i.e., the channel around islands that does not include the marked navigation lane) have historically been preferred sites for disposal of such dredged material. Multiple disposal events form closely adjacent disposal mounds during each maintenance dredging operation. These coarse-grained sediment mounds in flowing water are potentially valuable habitat for a number of riverine fishes and invertebrates (Miller et al. 1988) including commercially and ecologically valuable as well as some Federally Endangered species of freshwater mussels (Miller et al. 1987, Payne and Miller, in preparation). Many gravel shoals in large inland rivers were destroyed by major alterations of inland rivers, such as dredging and impoundment, to support navigation and other uses of waterways (e.g., Isom 1969). Strategic placement of dredged material can be used to re-create riverine gravel shoals without interfering with other uses of inland waterways.

This note describes the results of a field study conducted in September 1988 to evaluate the mussel community on disposal mounds of known location and age in a side channel of the Tennessee River. The study was conducted by Dr. Barry S. Payne (Environmental Laboratory, US Army Engineer Waterways Experiment Station) with the assistance of Mr. Richard Tippit (Environmental Resources Branch, US Army Engineer District, Nashville) and divers Larry Neill, William Host Jr., and John Wilson (Tennessee Valley Authority, Muscle Shoals, AL).

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Study Area

Gravel disposal mounds were created adjacent to the right bank of the Tennessee River in a side channel of Wolf Island (River Mile 192-194) as part of dredging operations in 1972, 1981, 1983, and 1988 (Figure 1). In each year, sandy gravel was removed from the navigation channel in the main channel of the Tennessee River using a clam shell dredge. Disposal was accomplished using dump scows. Typically, the dump scow was pushed, at an acute angle into the flow, against the shore at the disposal site, and the dredged material was released from doors in the bottom of the scow as it was slowly backed from the shore. An average dump scow load was 225-250 cu yd. Totals of 29,000, 18,000, 28,000, and 10,000 cu yd of dredged material were disposed in 1972, 1981, 1983, and 1988, respectively. Each successive disposal event in a particular year occurred just upstream of the previous one so that a series of closely adjacent mounds were created. No intentional shaping or contouring of disposal mounds was attempted during disposal. The substrate created by 1983, 1981, and 1972 disposal operations is mostly gravel and cobble. The substrate at the 1988 site, although still gravelly, includes patches of sand among gravel and cobble. The coarse-grained nature of sediments at these sites is maintained by substantial flow (greater than 0.5 ft/sec) that prevent sedimentation of fine-grained particles.

Approach

The assessment of mussel habitat near Wolf Island was performed on 15 and 16 September 1988. Divers sampled sites of 1988, 1981, and 1972 disposal operations as well as an upstream reference area (not disposed on) along the side channel border (open symbols in Figure 1). At each site, a 10-min reconnaissance dive was conducted to preliminarily assess the presence and approximate density of mussels. If mussels were present, subsequent dives were conducted to obtain as many individuals as possible within a total diving time of 50 min along a 100-ft transect. Mussels were collected by touch because visibility in the water was poor. See Miller and Payne (1988) for a discussion of qualitative and quantitative methods of surveying mussel beds.

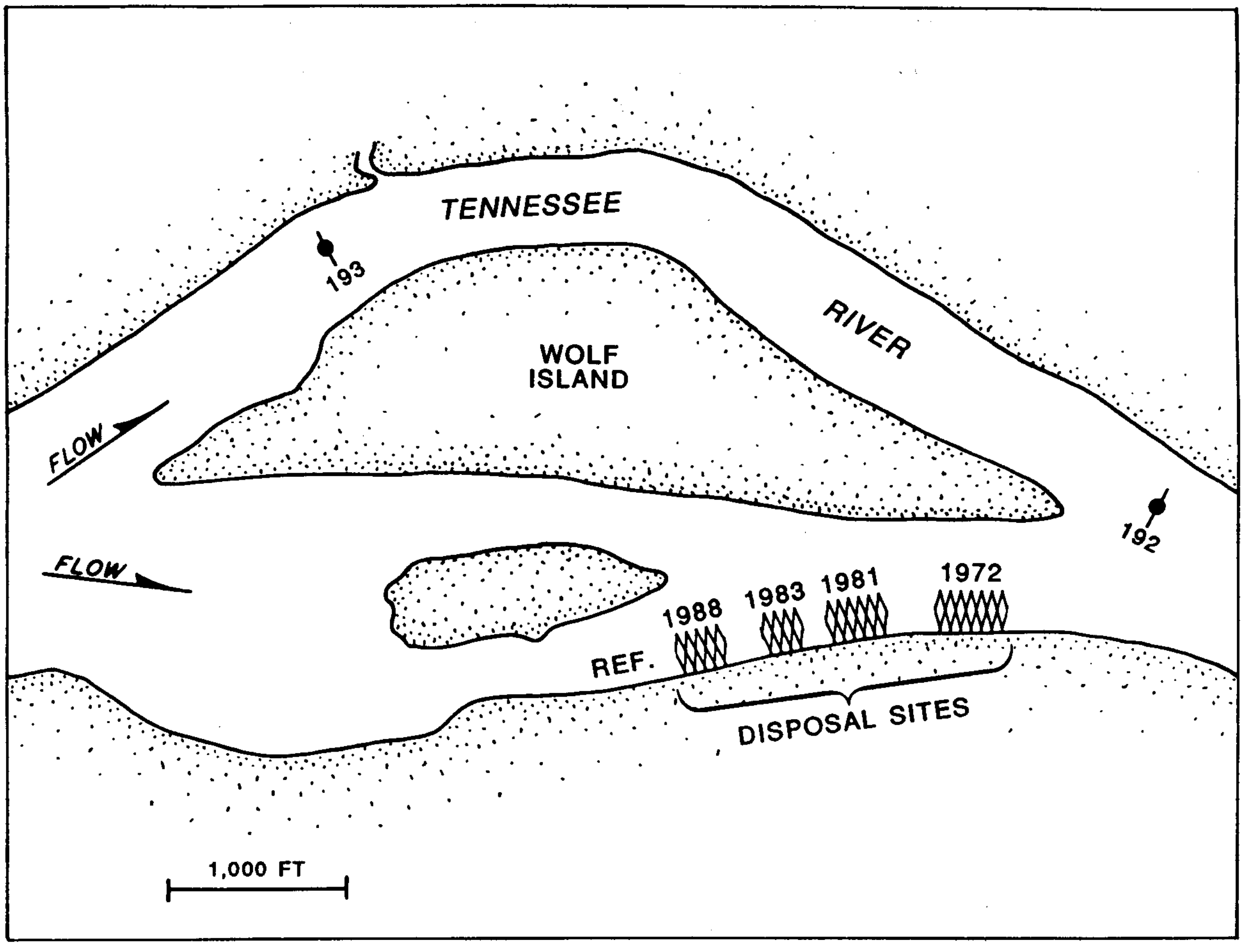

Figure 1. Location of dredged material disposal mounds and sampling sites in the side channel of Wolf Island in the Tennessee River

Results and Discussion

The transect at the reference site showed that the natural side channel border ranged from sand nearest the eroding bank shoreline to relatively fine gravel on the main part of the channel border. The transition from sand to gravel occurred at a depth of approximately 8 ft and a distance approximately 100 ft offshore, then to coarser gravel and cobble on the steepest portion of the slope down into the side channel. Disposal of gravel along the shoreline in 1972, 1981, and 1983 appears to have stabilized an otherwise sandy and eroding bank and created a relatively stable gravel shoal that otherwise would not form at this location. The deep portion of the side channel is characterized by water velocity greater than 1.0 ft/sec and sediments range from scoured clay to gravel and cobble.

The gravel mounds created by 1972 disposal operations (Figure 1) supported the greatest number of mussels observed on the back channel border (Table 1). The 1981 disposal mounds, having had less time for natural colonization by juvenile mussels, showed a lower density of mussels than the 1972 mounds. No mussels were found during the reconnaissance dive at the site of 1988 disposal operations. The reference area did not support as many mussels as the 1972 mounds, indicating that gravel disposal along the shore and shallowest reaches of the channel border has enhanced the value of these areas for mussel. The pink heel-splitter, *Proptera alatus*, dominated samples from the disposal mounds.

The greatest density and diversity of mussels behind Wolf Island occurred in the deep portion of the side channel away from the shallow side channel

Table 1

Mussel Community Samples from Sites behind Wolf Island near Tennessee River Mile 192.5*

	Number of Individuals		
Species	Reference Site	1981 Disposal Site	1972 Disposal Site
Quadrula metanevra	1	1	--
Fusconaia ebena	--	--	4
Quadrula pustulosa	--	--	1
Elliptio crassidens	--	--	3
Cyclonaias tuberculata	1	--	--
Proptera alatus	1	3	18
Megalonaias gigantea	--	--	1
Ligumia recta	--	1	2
Total number of species	3	3	6
Total number of individuals	3	5	29

* Total diving time at all sites was approximately 50 min; thus, comparison of the total individuals collected per site indicates the density of mussels at one site relative to others.

border where disposal occurred.* The main assemblage of mussels in the deeper side channel was dominated by the monkeyface, *Quadrula metanevra*, and the ebony shell, *Fusconaia ebena*. Disposal of dredged material in the shallow portion of the side channel border has not only avoided burial of this important mussel assemblage, but has also provided stable gravel shoal to this otherwise sandy shallow area and created new mussel habitat. Over the past 17 years mussels have naturally colonized the stable gravel disposal mounds, with the density of mussels being proportional to the age of the mounds. Disposal has had the additional benefit of helping stabilize an eroding bank.

Basic guidelines for site selection for beneficial disposal of gravel in a river side channel are suggested by this investigation of conditions behind Wolf Island in the Tennessee River. First, disposal sites should be selected based on knowledge of the distribution of important aquatic resources. Burial of all or a portion of the dense and diverse mussel bed in the deep portion of the side channel was avoided by selection of disposal sites along the shoreline. Disposal along the shoreline had the added benefit of stabilizing eroding banks and creating a stable gravel shoal. The potential for bank and shoreline stabilization should be considered during the selection of aquatic disposal sites. By creating a stable gravel shoal where none otherwise existed, disposal added mussel habitat to the side channel. Site selection should consider bathymetric and hydrologic conditions in an attempt to create gravel disposal mounds that will neither be severely eroded nor covered by silt.

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* From unpublished data, Tennessee Valley Authority, Knoxville, TN; confirmed during the present investigation.