E C O L O G I C A L R E V I E W

Terrebonne Bay Shoreline Protection and Oyster Reef (DEMO)
CWPPRA Priority Project List 10
State No. TE-45

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This document reflects the project design as of the 95% Design Review meeting, incorporates all comments and recommendations received following the meeting, and is current as of October 28, 2003.

ECOLOGICAL REVIEW
Terrebonne Bay Shoreline Protection and Oyster Reef (DEMO)

In August 2000, the Louisiana Department of Natural Resources (LDNR) initiated the Ecological Review to improve the likelihood of restoration project success. This is a process whereby each restoration project's biotic benefits, goals, and strategies are evaluated prior to granting construction authorization. This evaluation utilizes monitoring and engineering information, as well as applicable scientific literature, to assess whether or not, and to what degree, the proposed project features will cause the desired ecological response.

I. Introduction

The purpose of the Terrebonne Bay Shoreline Protection and Oyster Reef (DEMO) project is to reduce shoreline erosion and promote oyster reef formation while testing the cost-effectiveness of several experimental techniques designed to protect shoreline in areas where unconsolidated, organic, easily eroded soil types prevent the use of traditional rock dike structures. Because these soil types commonly occur along the Louisiana coast, results from this study will be directly applicable to ongoing statewide efforts to reduce land loss.

This project is located in the north-west portion of Lake Barren, which is open to Terrebonne Bay (Figure 1). This area is ultimately open to the Gulf of Mexico and is, therefore, vulnerable to the damaging effects of high wave energy. Thus, this project will also test these shoreline protection treatments' ability to protect vulnerable shorelines located in high-energy environments.

II. Goal Statement

The goals of this project are to:

- reduce shoreline erosion while minimizing scouring to the bay bottom adjacent to each shoreline protection treatment;
- quantify and compare the ability of each shoreline protection treatment used in this project to reduce shoreline erosion and enhance oyster production and oyster habitat; and,
- quantify and compare the cost-effectiveness of each shoreline protection treatment used in this project in reducing shoreline erosion and enhancing oyster production and oyster habitat.

III. Strategy Statement

The strategies used to achieve these goals are:

- use diverse shoreline protection treatments to reduce erosion within the project boundary;
- select shoreline protection treatments which will provide habitat for oyster spat adhesion and growth; and,
- generate a sound experimental design that will allow for statistical testing of the project goals.

IV. Strategy-Goal Relationship

In this project, diverse non-traditional techniques will be used to reduce shoreline erosion caused by wind- and wake-generated wave energy while also providing suitable habitat for settlement and growth of oyster spat. Replication of treatments and randomized placement of the proposed structures along the site locations will allow for statistical testing of each structure's effectiveness in protecting the shoreline from erosion. The amount of shoreline protected by the structures relative to control sites will be determined. This information will be converted to cost per length of shoreline and acres of marsh protected.

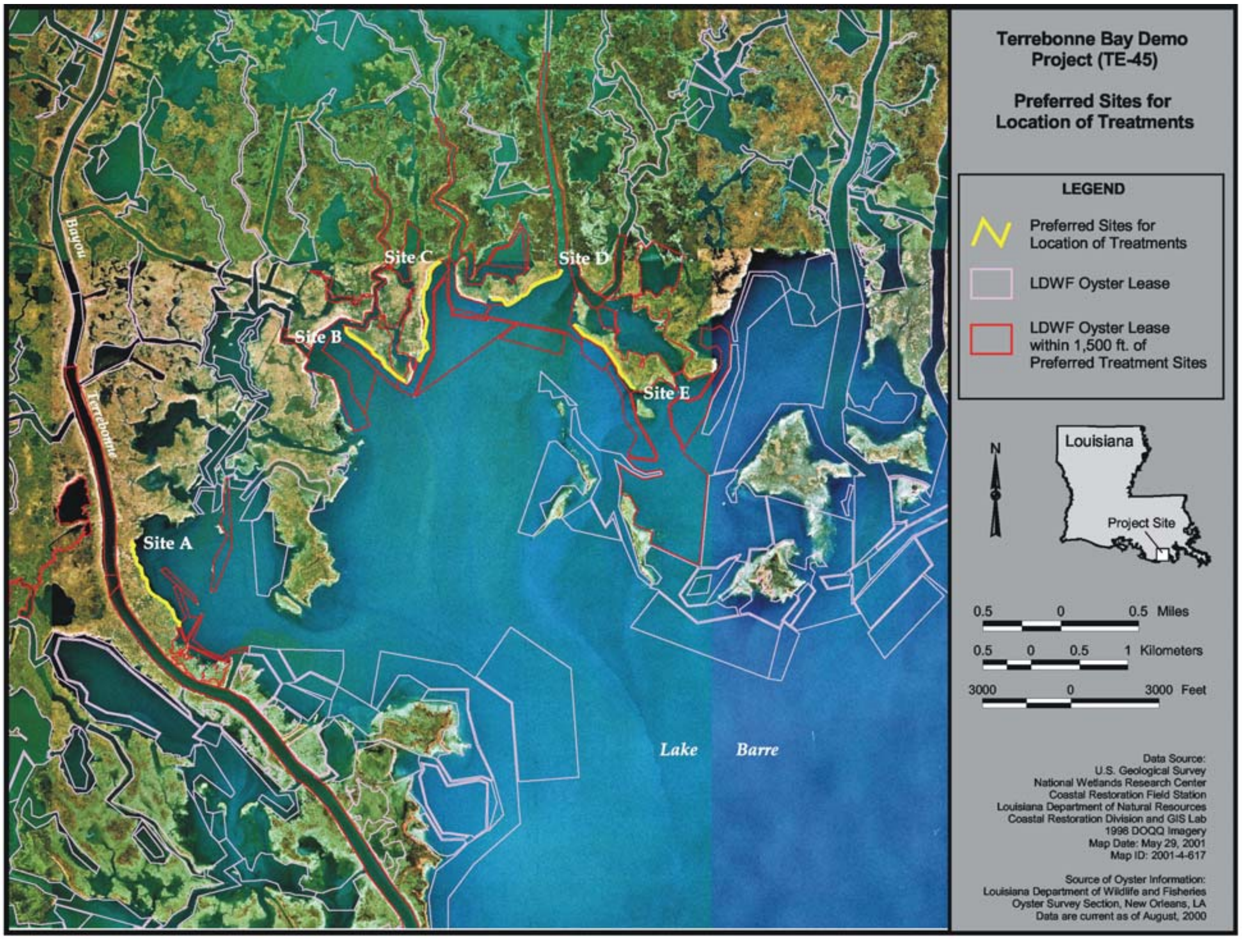

Figure 1. Map of TE-45 project area. Reaches of shoreline considered for use in this project are highlighted in yellow.

V. Project Feature Evaluation

Morris P. Hebert, Incorporated (MPH, Inc. 2003) was contracted by LDNR to produce a preliminary study and design report for this project. They will also provide the full design for this project. Six shoreline protection/artificial oyster reef treatments were recommended for use in this demonstration project based on cost, construction and installation requirements, ease of removal, and impacts on oyster leases (MPH, Inc. 2003). No flotation channels will be allowed, so all structures are capable of being installed using shallow draft equipment. Table 1 provides details regarding estimated costs of the structures recommended for use in this project.

Table 1. Estimated costs of shoreline protection/artificial oyster reef treatments recommended for use (from MPH, Inc. 2003 Tables 1 & 2).

Structure	Unit Dimensions	Cost Each	Cost/ Linear Ft (LF)	Installation Cost/LF	Total Cost/900 ft (3-300ft reaches)
Submar™ Articulating Concrete Mats	8' x 20' x 4.5"	--	$88	$62	
With galvanized steel anchors (225 units)	--	$110	--	--	$159,750
A-Jacks®	2' height	--	$18	$75	
With geotextile & 6" crushed stone base	8' wide	--	$20	--	
With galvanized steel cable (1,800 LF)	3/8" diameter	--	$0.40	--	$102,420
Triton™ gabion mats filled w/ crushed stone	5' x 20' x 1'	--	$68	$75	
With galvanized steel anchors (225 units)	8' wide	$110	--	--	$153,450
Reefballs™	3' base	--	$80	$93	$155,700
Reefblks™	5' base; 2' high	--	$50	$110	$144,000
Prefabricated Concrete Frames	3' x 10' x 2'	--	$87	$75	
With galvanized steel anchors (180 units)	--	$110	--	--	$165,600

Submar™ concrete mats (Figure 2) are patented pre-cast blocks; each individual block is securely adhered to a copolymer fiber reinforcement rope. The mats reportedly have excellent maintenance and removal characteristics because of the cast-on-rope reinforcement. Each mat will also need to be anchored at each corner with a helix- or Manta Ray- type anchor.

A-Jacks® (Figure 3) are individual concrete barrier units that have the shape of children's toy jacks. These structures have been used in various applications from stream bank erosion controls to breakwaters in a marine environment, and they require little maintenance. Individual units will be tied together with galvanized steel cables to reduce the potential for movement. Because the native soils are soft, it is recommended that six-inches of crushed rock overlying a geotextile grid be used as a base for these structures in order to reduce the degree to which the structures sink into the underlying sediment.

Triton™ gabion mats (Figure 4) are geotextile grid material formed into a basket and interconnected to form a mat. The mats are filled with crushed stone. No metal is used in these structures; consequently maintenance should be minimal. However, MPH, Inc. (2003) cautions that removal is expected to be very difficult if failure of the geotextile material occurs.

Reefballs™ (Figure 5) are individual concrete semi-spherical units designed to emulate and create oyster reef. Anchoring is built into each individual unit and consists of fiberglass rods that penetrate into the underlying sediment.

Reefblks™ (Figure 6) are prefabricated double framed steel units which hold mesh bags that are filled with seed oysters. The structures emulate and create new artificial oyster reef. It is also expected that they may provide some immediate shoreline protection.

Prefabricated Concrete Frame structures (Figure 7) are designed to provide a surface for oyster spat settlement and reef development. Their usefulness as a shoreline protection feature is expected to increase over time, as the frame becomes encrusted with oysters. The structure should be anchored with a helix- or Manta Ray- type anchor.

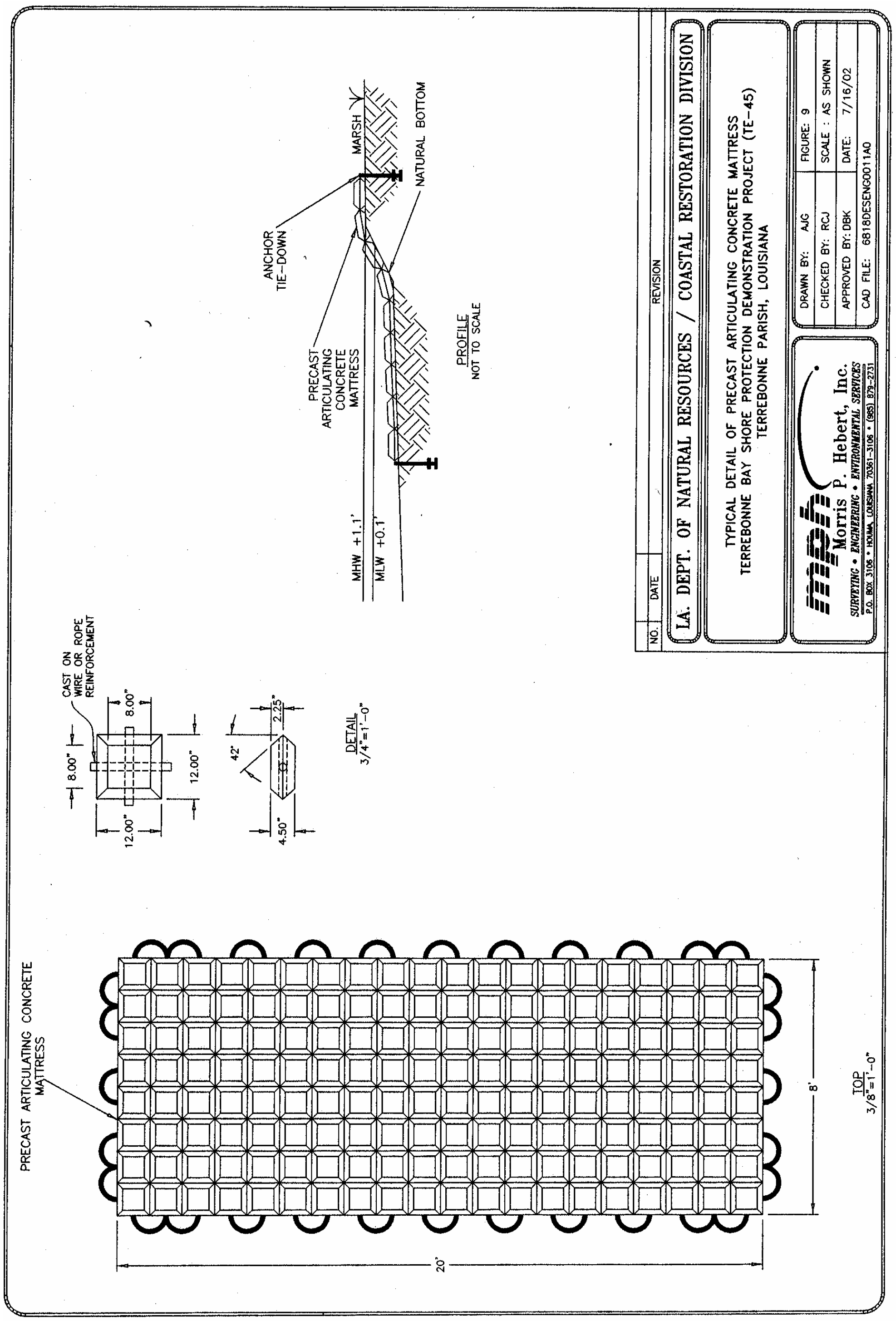

Figure 2. Detail of Submar Articulating Concrete Mat (MPH, Inc. 2003).

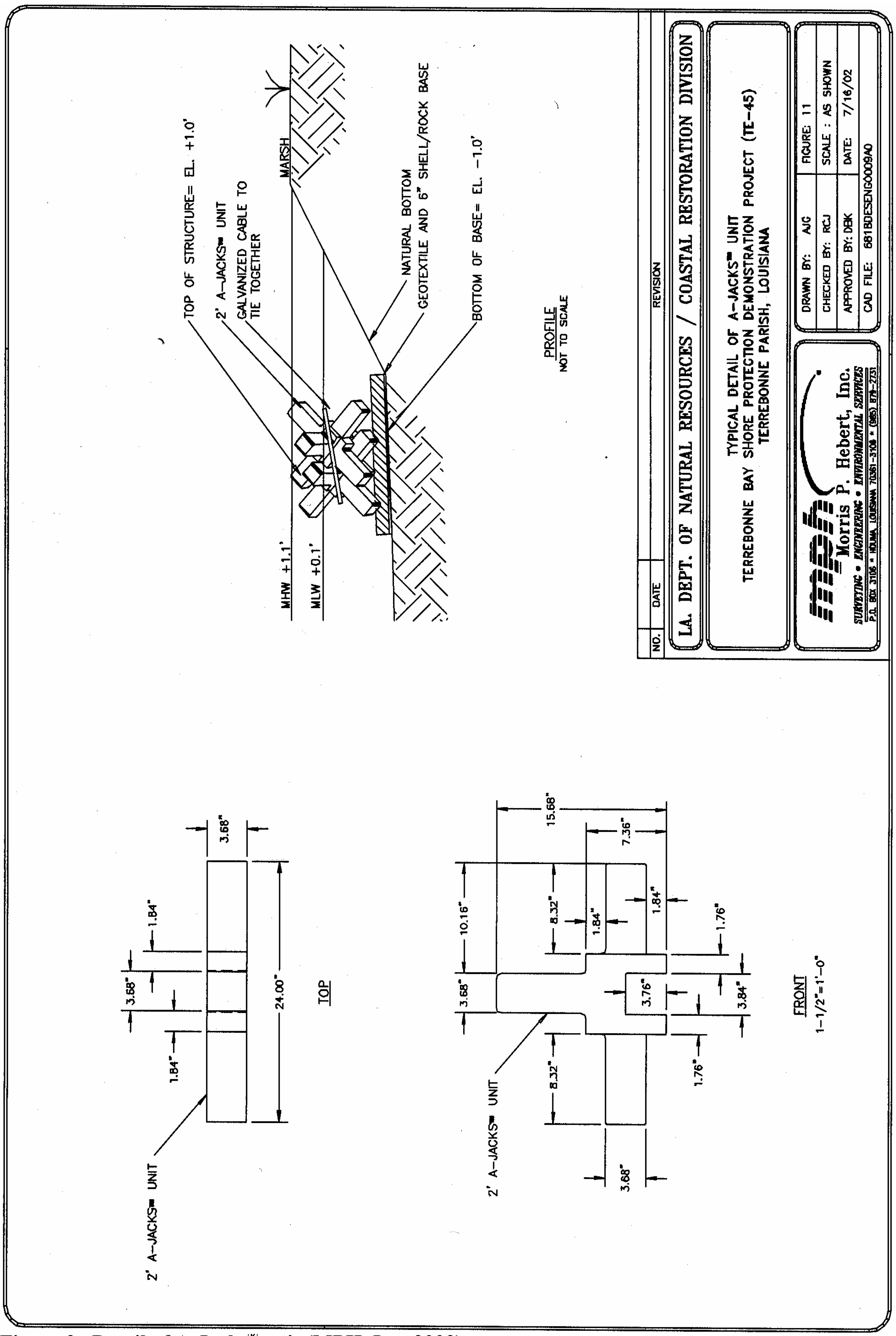

Figure 3. Detail of A-Jacks® unit (MPH, Inc. 2003).

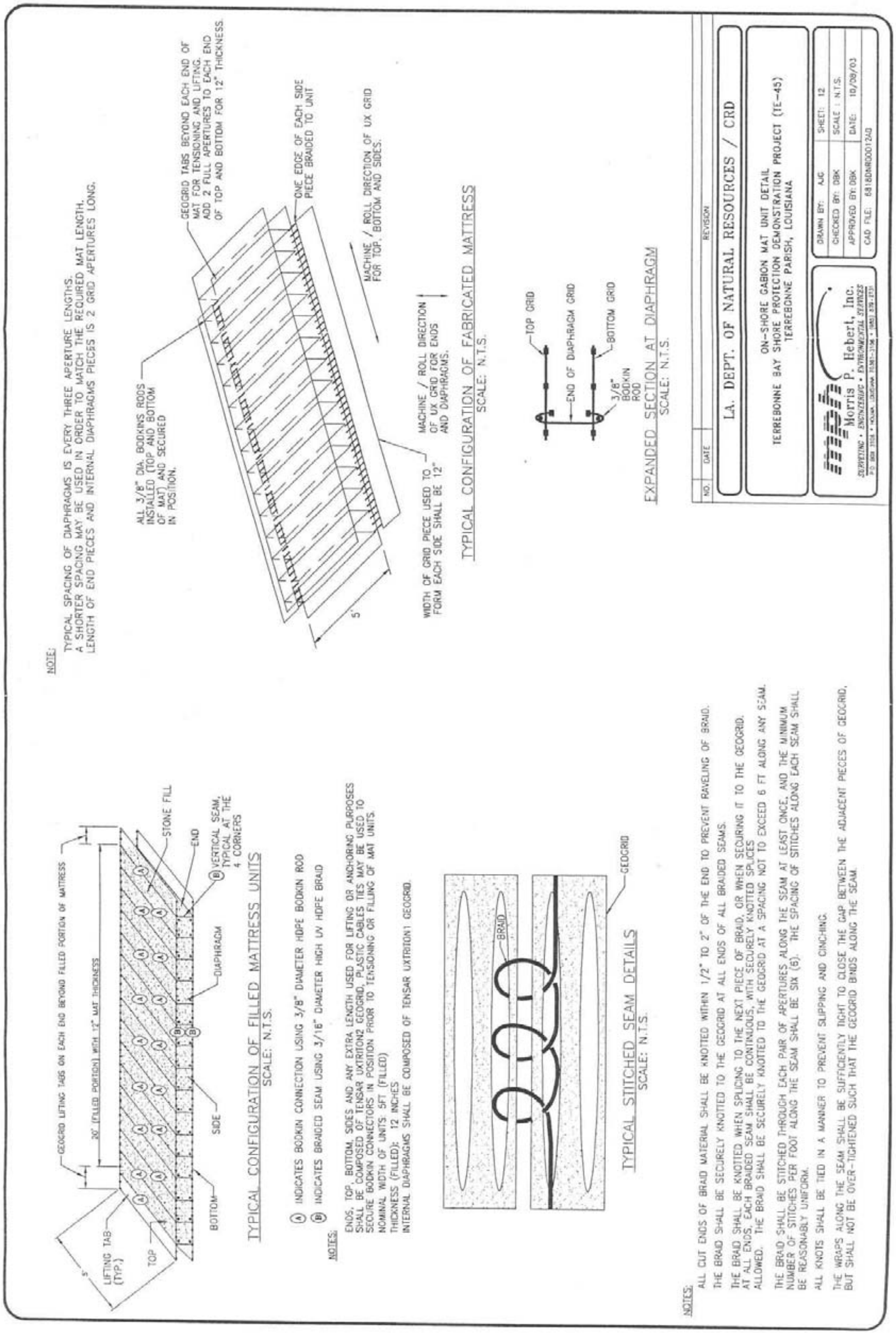

Figure 4. Detail of Gabion mat unit (MPH, Inc. 2003).

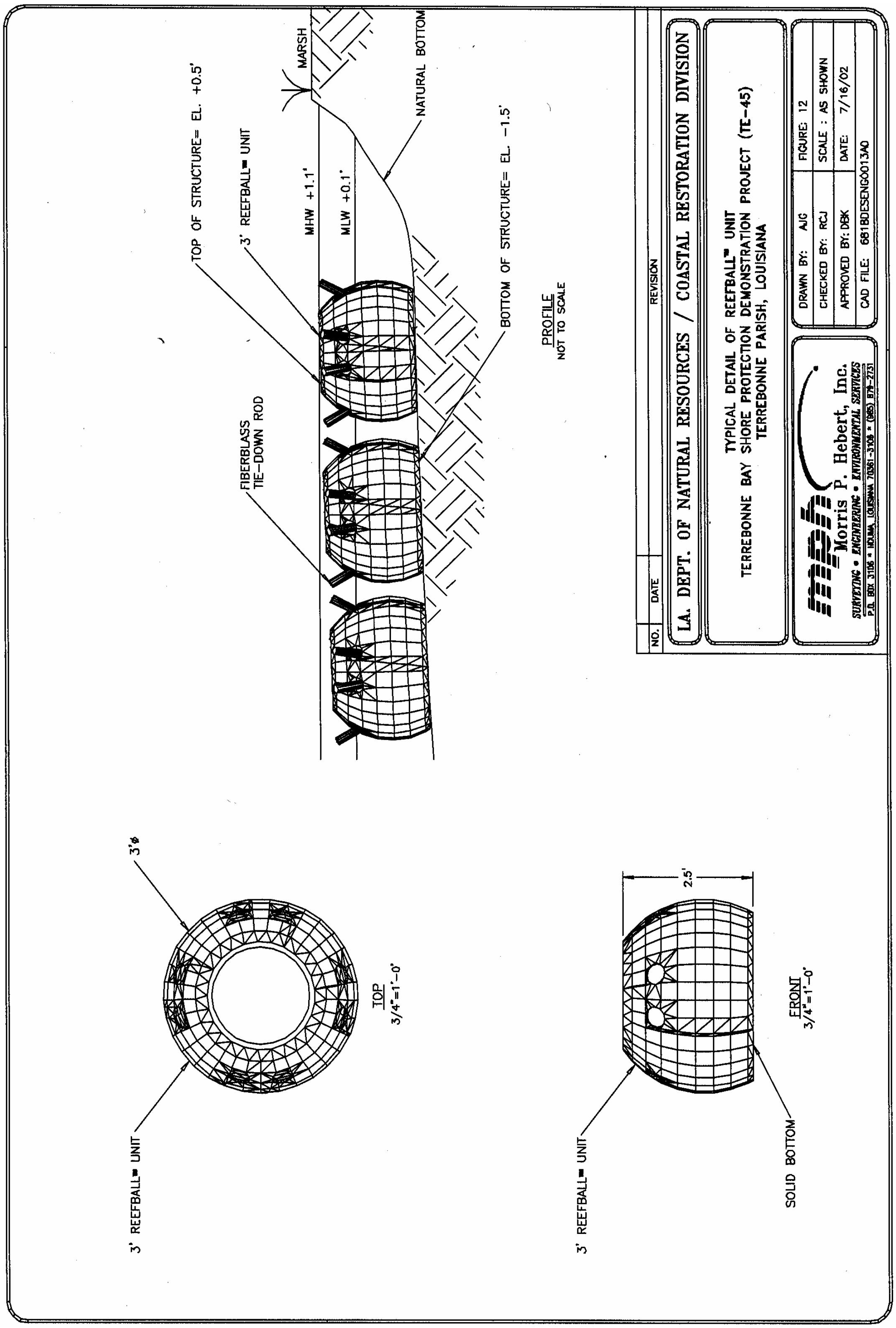

Figure 5. Detail of Reefball™ Unit (MPH, Inc. 2003).

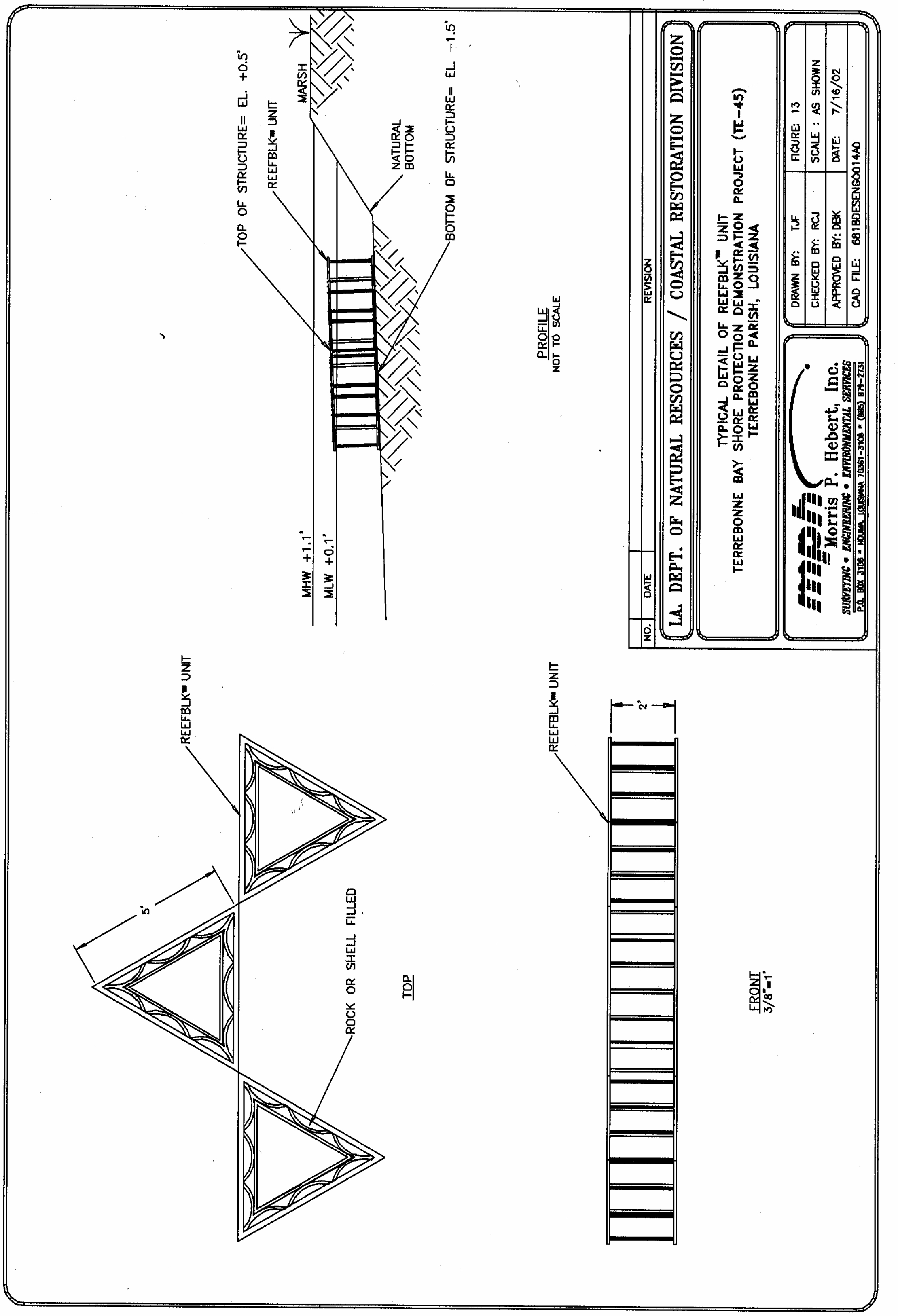

Figure 6. Detail of a Reefblk™ unit (MPH, Inc. 2003).

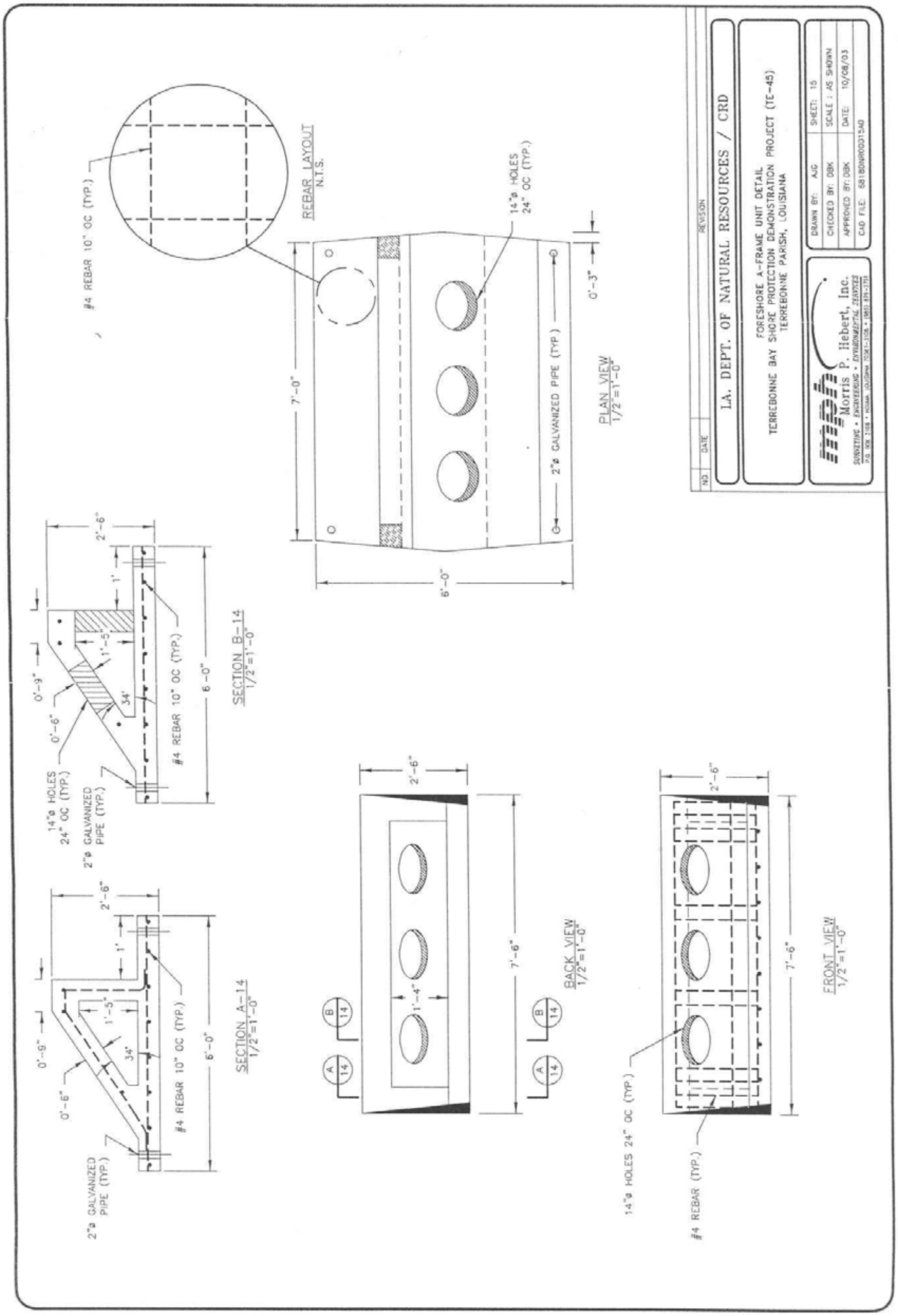

Figure 7. Detail of a Concrete Frame unit (MPH, Inc. 2003).

Additionally, three of five shoreline reaches were recommended based on site parameters such as location; contour and length of shoreline; predominant wave direction; anomalies that could potentially affect the rate of shoreline loss over the project life; and potential for conflict with landowners, oyster leases, or utility structures (MPH, Inc. 2003). Shoreline-reaches A, B, and E were determined to be most suitable for the purposes of this project (Figure 1; MPH, Inc. 2003). Reach A was recommended because it has 3,000 linear feet of straight shoreline which is desired for the statistical design, and because the shoreline protection treatments will benefit a small land mass which currently separates Lake Barre from Bayou Terrebonne. Reach B was recommended to protect a land mass which protects the entrance to a small bayou and because it also has 3,000 linear feet of straight shoreline. Reach E was recommended because the existing landmass protects a large pond that will coalesce with Lake Barre if left unprotected. In addition, this shoreline is nearly perpendicular to the predominant wave direction (MPH, Inc. 2003).

The three reaches chosen contain extremely to very soft humus material overlying soft organic clay and silt (Eustis Engineering Company, Inc. 2002). As a result of the poor weight-bearing capacity of this type of soil, there is potential for the chosen structures to sink when placed into position. The geotechnical investigation has concluded that penetration into the soft sediments of the project area could be problematic for the A-Jacks because of the high contact pressures at the ends of these structures (Eustis Engineering Company, Inc. 2002). It is for this reason that MPH, Inc. (2003) recommends that crushed rock overlying a geotextile grid be used for support of these structures.

Experimental Design (T. Folse, LDNR Monitoring Manager, pers. comm.)

Each of the six chosen shoreline protection/artificial oyster reef treatments and a control treatment will be placed along each of the three chosen shoreline sites and, therefore, will be replicated three times. The sequencing of treatments along each shoreline reach was determined by LDNR Biological Monitoring Section using a random generation method, and results may be found in Table 2. Treatments will be monitored for oyster colonization as well as their ability to reduce rates of shoreline erosion. The 75 feet on the ends of each 300-foot long treatment will not be monitored because of the potential for treatment interactions. Thus, only the center 150 feet of each treatment will be monitored, with a minimum of three transects that will extend from the marsh interior out into the lake.

Table 2. Sequencing of treatments along each shoreline reach.

Reach A	Reach B	Reach E
Reefblks™	Reefballs™	Precast Concrete Frames
A-Jacks™	Reference Area	Reefballs™
Precast Concrete Frames	Submar™ Mats	A-Jacks™
Submar™ Mats	Precast Concrete Frames	Reefblks™
Reefballs™	Reefblks™	Submar™ Mats
Triton™ Gabion Mats	A-Jacks™	Triton™ Gabion Mats
Reference Area	Triton™ Gabion Mats	Reference Area

VI. Assessment of Goal Attainability

Soils found along the Louisiana coast are typically extremely soft, organic, silt-clays which are subject to high rates of erosion. These soils possess very poor load-bearing capacities and are, thus, poor substrate for construction of rock dikes typically used in shoreline protection efforts (Howard et al. 1984; Meyer et al. 1997b). The use of vegetation plantings to stabilize eroding or migrating shorelines has proven useful, but this technique may not be effective in areas of relatively high erosion and high storm energy (Knutson et al. 1981; Meyer et al. 1997b). It is, therefore, important to test the effectiveness of alternative hard-structure techniques in protecting vulnerable shorelines.

Several projects have been undertaken to test the effectiveness of a diverse array of alternative techniques in protecting shorelines from continued erosion. While some options have shown promise under specific environmental conditions, testing of all available alternatives under varying environmental conditions is far from exhausted. It has been suggested that oyster reefs may be effective natural, living erosion control structures for intertidal marsh areas (Meyer et al. 1997b), and a great deal of research has been focused on using artificial substrate to establish oyster reefs (Haywood and Soniat 1992; Wesson 1997; Haywood et al. 1999; Breitburg et al. 2000; O'Beirn et al. 2000). In addition to providing shoreline protection, oyster reefs improve water quality by removing a portion of the phytoplankton standing stock (Dame and Patten 1981; Cloern 1982; Ulanowicz and Tuttle 1992), and provide a structured habitat that may increase secondary production of finfish and decapod crustaceans (e.g. Coen et al. 1999).

<u>Constructed CWPPRA Shoreline Protection Demonstration Projects</u>

Marsh plants have proven to be effective in stabilizing eroding banks in sheltered coastal areas but are not suitable for shoreline protection in areas that experience high wave energy (Knutson 1977). This was verified in the White Lake Protection Demonstration (ME-12) project where attempts to use *Scirpus californicus* (California bulrush) as a wave damping technique were unsuccessful (Courville 1998). Plants were placed in three rows lakeward of the shoreline in water depths of approximately 2 feet. A combination of water depth and high wind-generated wave energy were attributed to the plants failure to establish.

The Lake Salvador Shoreline Protection Demonstration (BA-15) project tested the effectiveness of four types of segmented wave-damping structures in highly organic, unconsolidated sediments with poor load-bearing capacities (Lee et al. 2000). The four treatments (grated apex structures, geotextile tubes, angled timber fences, and vinyl sheet pile bulkheads) were constructed parallel to the shoreline at a distance of 300 feet offshore. Although it was shown that some structures (geotubes and vinyl sheet pile bulkheads) reduced average wave heights when winds were perpendicular to the structures and the shoreline, evidence indicates that the four experimental treatments did not influence shoreline erosion rates. This is most likely because the structures were placed too far offshore, allowing waves to regenerate shoreward of the structures. Thus, the effectiveness of the shoreline protection features in reducing erosion was minimized. Further problems with this project involved the experimental design. The treatments were not randomly placed along the shoreline, and their close proximity to one another resulted in noticeable treatment interactions. As a result, statistical testing of the data was not possible and definitive conclusions regarding the treatments' influence on shoreline erosion rates could not be drawn. Lee et al. (2000) made the following recommendations regarding future shoreline protection projects:

> "First, further investigation of structure placement should be conducted to prevent regeneration of waves between the structures and the shoreline. Next, the effects of bottom scour and bathymetric effects should be identified to estimate benthic sediment movement and its effect on shoreline configuration. Finally, settlement plates need to be installed on all shoreline protection structures and monitored throughout the project life when placed in poor load-bearing environments like Lake Salvador."

Artificial Oyster Reef Construction Considerations

Recent research has emphasized the importance of molluscan-dominated structures as 'essential fish habitat' in that these structures provide habitat not only for the bivalves that comprise the reef but also for other ecologically and commercially important fin-fish species (Coen et al. 1999). However, fishing pressure, disease, and overall habitat degradation have resulted in a marked decline in landings and production of the eastern oyster (*Crassostrea virginica*) throughout the 20th century, particularly in the mid-Atlantic region of the United States (Ulanowicz and Tuttle 1992; Rosthchild et al. 1994; Wesson 1997; O'Beirn et al. 2000). In no small part due to the economic value of the oyster industry (Dugas 1988; Melancon and Condrey 1992; MacKenzie 1996), a great deal of research has been devoted to reestablishing self-sustaining oyster reefs (Rothschild et al. 1994; Meyer et al. 1997a; Haywood et al. 1999; Lenihan 1999; Breitburg et al. 2000; Coen and Luckenbach 2000; O'Beirn et al. 2000). Unlike the mid-Atlantic region of the United States, the oyster industry in Louisiana is quite healthy. Louisiana oyster production often ranks first in the nation, with annual landings as high as 12.5 million pounds of meat (Dugas 1988). In addition to their commercial value, it has also been recognized that oyster reefs have value in their ability to damp wave energy and thereby protect vulnerable marshes from erosion (Meyer et al. 1997b). Oyster reefs influence water flow within an estuary, and consolidate and stabilize intertidal sediment within estuarine environments (Dame and Patten 1981). The physical characteristics of a reef not only affect the hydrology of its surroundings, but also influence its biological function (Lenihan 1999; O'Beirn et al. 2000). Therefore, research which has focused on restoring the oyster industry in other areas of the United States may be applied to efforts to protect fragile marshes in Louisiana. The same design criteria for producing a biologically viable reef (by providing suitable substrate for oyster settlement) may accomplish the dual objective of stabilizing the adjacent shoreline.

In Louisiana, the enhancement of oyster habitat has traditionally involved piling cultch material (usually *Rangia cuneata* shells) in areas with firm, stable bottoms and favorable salinities (Dugas 1988; Haywood et al. 1999). However, environmental concerns regarding shell-dredging activities have caused alternatives to this cultch material to be explored (Haywood et al. 1999 and references within). Additionally, the ideal physical configuration of the created habitat has been studied, as it may influence the successful establishment of a self-sustaining oyster reef (Lenihan 1999; O'Beirn et al. 2000). O'Beirn et al (2000) compared non-traditional substrates (coal ash and surfclam shell) with oyster cultch and found less survivorship on the non-oyster cultch material. This was attributed to diminished spatial refugia (both interstitial and intertidal) from predators. Nonetheless, non-traditional structures may serve as suitable base material for oyster reef formation in areas that experience high recruitment rates if the material provides sufficient vertical relief (O'Beirn et al. 2000) because the height of the reef influences water flow speed, which in turn influences oyster spat recruitment rates and rates of food delivery to the settled oysters (Lenihan 1999). Lenihan (1999) concluded that in order to restore the biological productivity of reefs, the artificial structure should have sufficient height (actual height depends upon water depth and environmental conditions) to enhance flow speed and diminish sedimentation and subsequent burial, which should in turn increase the growth, condition, and survival of oysters. Mean high water elevation in the TE-45 project area is 1.11 feet NAVD-88 (Eustis Engineering Company, Inc. 2002), while the vertical relief of most of the proposed treatments is 2 to 3 feet (MPH, Inc. 2003). Only the Submar concrete mats (4.5 inches in height) potentially have too little vertical relief to be suitable oyster habitat. However, because these structures will extend from above the water line to the bay bottom, vertical relief will be provided by the slopes of the shorelines and should be adequate for successful oyster reef formation.

Area salinities are also a consideration when determining suitable habitat for oyster reef formation. When other environmental conditions are met, including availability of hard substrate for settlement, the prevailing salinity may be the most probable determinant of oyster survival (Melancon et al. 1998), as populations of oysters found beyond the upper or lower limits of the optimal range may exist under marginal conditions. Adults are often decimated by extended flooding conditions in low salinity regions (e.g. Chatry and Millard 1986; May 1972), and by parasitic infection and predation in high salinity regions (Galtsoff 1964; Gauthier et al. 1990). Extreme and sudden changes in salinity during warm weather are also difficult for oysters to withstand (Galtsoff 1964). However, oysters can close their valves in order to isolate themselves from adverse environmental conditions for short periods, and may experience significant mortalities only when salinities are below 2 ppt for several weeks (May 1972; Cake 1983). Additionally, periodic flushing by relatively low salinity water in higher salinity environments is advantageous to oysters because it flushes out predators and parasites that cannot survive in lower salinities (Chatry and Millard 1986; Gauthier et al. 1990). The optimum salinity for the development of oyster larvae appears to be dependent upon the salinity that the parent oysters were exposed to at the time of spawning (Davis 1958). Yet gonad formation, and larval settlement and growth, appear to be inhibited when salinities are below about 6 ppt (Butler 1949; May 1972).

In the Terrebonne-Barataria basins, oysters are consistently found in areas that experience salinities ranging from 3 to 18 ppt (Melancon et al. 1998). Discrete monthly data collected by the Louisiana Department of Health and Hospitals at 5 stations from January 1988 to October 2002, show that monthly mean salinities in Lake Barre range between 10 and 16.5 ppt (Figure 8), although individual values recorded over the 15-year period ranged from 0.3 to 35 ppt. Periodic salinity extremes observed in the project area could prove to be stressful to adult oysters if these conditions persist for many weeks, and may prove to be problematic for larval settlement and growth when salinities suddenly shift towards an extreme. However, the average salinities for the area appear to be ideal for oyster growth and reproduction.

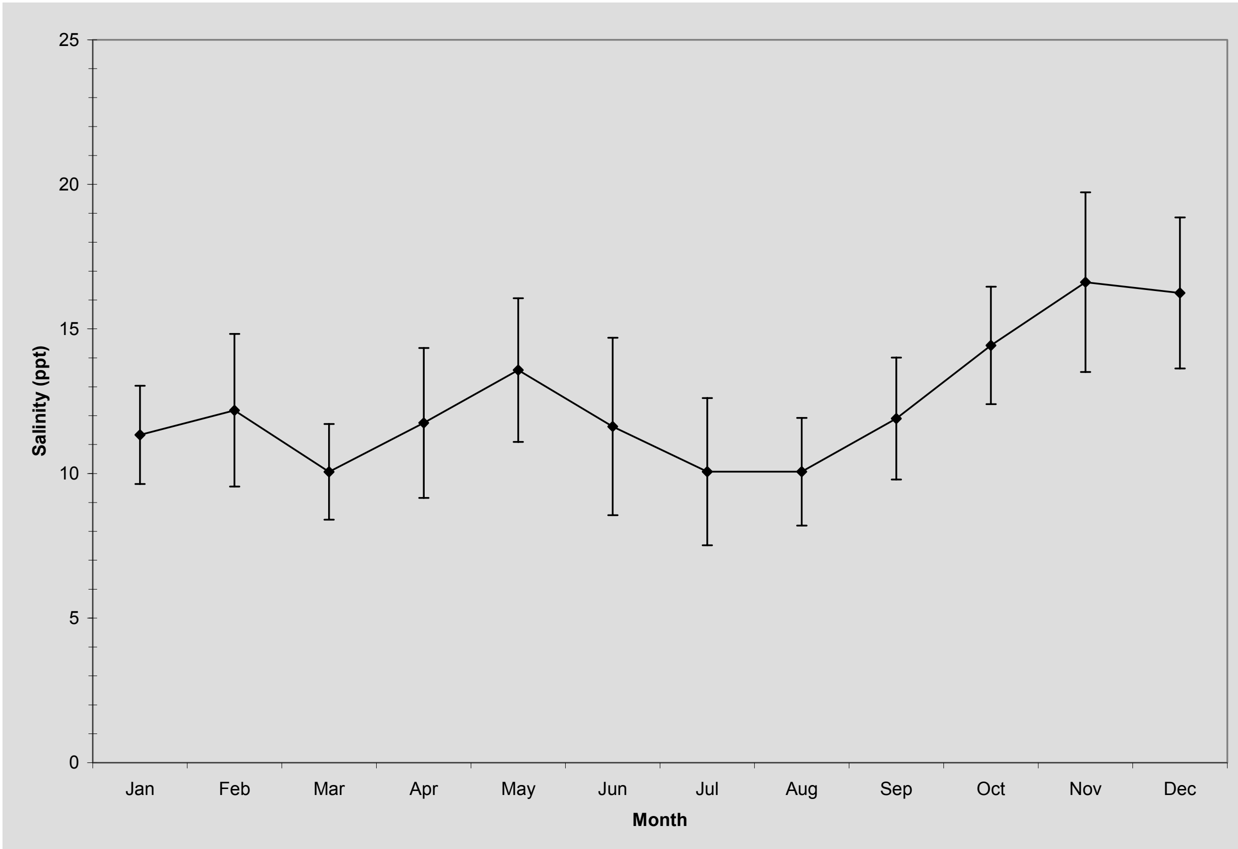

Figure 8. Average monthly salinity in Lake Barre, Louisiana. Individual points represent means of 15 years of discrete monthly data collected at 5 sites; error bars are standard deviations of those data. Data are courtesy of the Louisiana Department of Health and Hospitals.

Summary and Conclusions

Because these techniques are not commonly used shoreline protection measures in Louisiana, it is difficult to determine whether they will accomplish the first goal of reducing shoreline erosion. There is anecdotal evidence that Submar™ concrete matting has been successful in armoring the shoreline along Falgout Canal and Point Chevreuil (company literature found in MPH, Inc. 2003). A-Jacks® have also been used for shoreline stabilization along river banks and coastal areas, and will be used in the Mandalay Bank Protection Demonstration (TE-41) project; however, no data are available regarding their effect on shoreline erosion rates in Louisiana.

The next two goals are readily attainable given a suitable experimental design. The experimental design proposed for this TE-45 project will allow for statistical testing of the project data. Additionally, monitoring will be conducted over an eight-year period, rather than the five years usually approved for demonstration projects, in order to better assess the treatments' success in building living reefs.

VII. Recommendations

As this project was being developed, two major storms (tropical storm Isidore and hurricane Lili) struck the coast of Louisiana, leaving the state of the chosen reaches of shoreline to be used in this project in question. Field investigations made by USFWS and LDNR personnel confirmed that these sights were still intact and viable for use in this project.

During the engineering and design phase of this project, the distance at which the foreshore structures will be placed offshore was discussed and it was agreed that it should be minimized (not more than 100 feet) in order to minimize the potential for wave regeneration behind the structures, as recommended by Raynie & Visser (2002). Additionally, it was agreed that the foreshore structures should tie into the shoreline at the ends so that those reaches would be fully protected from wave energy.

Based on the evaluation of similar projects, the conceptual design for Terrebonne Bay Shoreline Protection and Oyster Reef (DEMO) appears to be acceptable to proceed toward construction.

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