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Coast 2050 Region 2

# LAKE SALVADOR SHORELINE PROTECTION DEMONSTRATION
# BA-15

**First Priority List Shoreline Protection Project of the Coastal Wetlands Planning, Protection, and Restoration Act**
**(Public Law 101-646)**


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## INTRODUCTION

The Lake Salvador Shoreline Protection (BA-15) Demonstration project is a 5-year demonstration of a series of shoreline protection measures at Lake Salvador, St. Charles Parish, Louisiana (figure 1). The project was sponsored by National Marine Fisheries Service (NMFS) under the Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA, Public Law 101-646, Title III). The project area consists of 153 ac (61 ha) in phase 1 and 4,070 ac (1,647 ha) in phase 2 (figure 1). Both phases consist of fresh marsh and shallow, open-water habitat. Phase 1 is a series of wave dampening structures located along the shoreline within the Louisiana Department of Wildlife and Fisheries (LDWF) Lake Salvador Wildlife Management Area (WMA). These structures are located along 5,900 ft (1.8 km) of the northern Lake Salvador shoreline and are bounded to the west by Baie du Cabanage and to the east by Couba Island (figure 2). Phase 1 tests the effectiveness of four types of segmented wave dampening structures in highly organic, unconsolidated sediments with poor load-bearing capacities. Unconsolidated sediments, such as those found in the Lake Salvador Shoreline Protection Demonstration (BA-15) project area, reportedly make traditional shoreline stabilization techniques ineffective (Howard et al. 1984). Phase 2 is a rock rip rap structure located along 8,000 ft (2,438 m) of the western Lake Salvador shoreline bounded to the south by Bayou des Allemands and to the north by Baie du Chactas (figure 3).

The Lake Salvador shoreline in Phase 1 is susceptible to erosion because of the long fetch across Lake Salvador (figure 1) with respect to the predominant southerly wind direction, the shoreline configuration, and a sediment base of highly unconsolidated sediments (HNTB 1992). The shoreline erosion rate within the Phase 1 project area averages approximately 7.74 ft $yr^{-1}$ (2.36 m $yr^{-1}$) and approximately 17.84 ft $yr^{-1}$ (5.44 m $yr^{-1}$) in the Phase 2 project area (figure 4) (May and Britsch 1987). HNTB (1992) reported the average erosion rate along Lake Salvador was approximately 13 ft $yr^{-1}$ (4 m $yr^{-1}$) and has resulted in breaching of the shoreline at several locations. These breaches have been reported to allow wave energy to erode marsh surfaces, resulting in large shallow ponds in the interior marsh (Gagliano and Wicker 1989).

Marsh vegetation in the project area is dominated by *Polygonum* spp. (smartweed) and *Sagittaria lancifolia* (bulltongue). Other common species include *Typha* spp. (cattail), *Colocasia esculenta* (elephant's ear), *Echinochloa walteri* (water millet), *Scirpus californicus* (bullwhip), *Salvinia minima* (floating fern), *Eichhornia crassipes* (water hyacinth), *Spirodela polyrhiza* (large duckweed), and *Lemna minor* (common duckweed). Woody species include *Iva frutescens* (marsh elder), *Myrica cerifera* (wax myrtle), *Quercus* spp. (oaks), and *Salix* spp. (willow). Submerged aquatic vegetation in the project area is dominated by *Myriophyllum spicatum* (eurasian watermilfoil) (Gammill 1993). Evers et al. (1996) classifies both project areas as thick mat, herbaceous floating marsh.

Soil in the project area is composed mainly of Kenner muck with some areas of Allemands, Barbary, and Larose soils. In freshwater marshes, all of these soils are characterized by level, poorly drained, organic soils that are ponded and flooded the majority of the time. Typically, the surface layer is a dark gray, slightly acidic, fluid muck, approximately 21 in (0.53 m) thick. Normally, the next layer

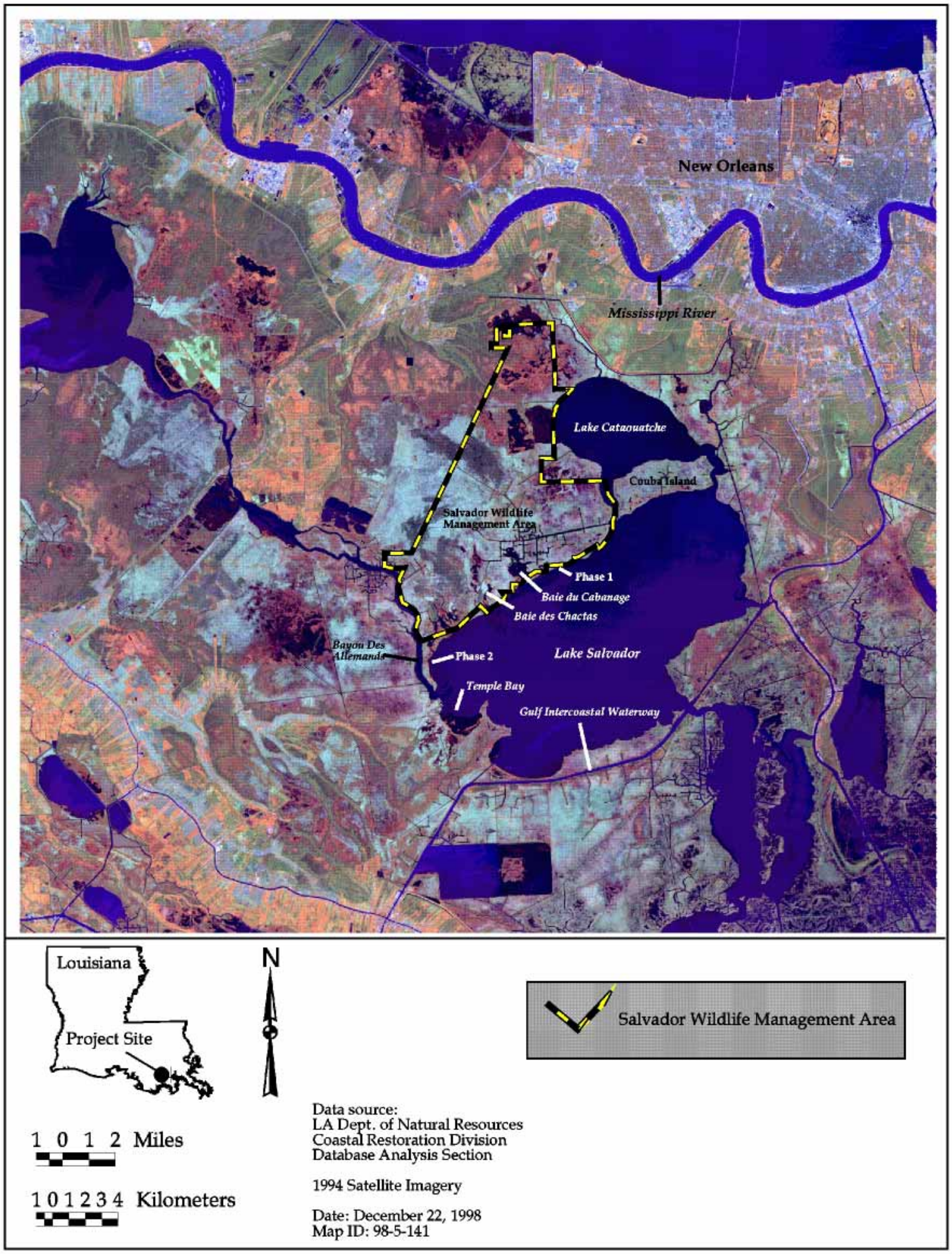


**Figure 1. Location and vicinity of the Lake Salvador Shoreline Protection (BA-15) Demonstration project.**


**Figure 2. Phase 1 project boundary for lake Salvador Shoreline Protection (BA-15) Demonstration project.**


**Figure 3. Phase 2 project boundary for Lake Salvador Shoreline Protection (BA-15) Demonstration project.**

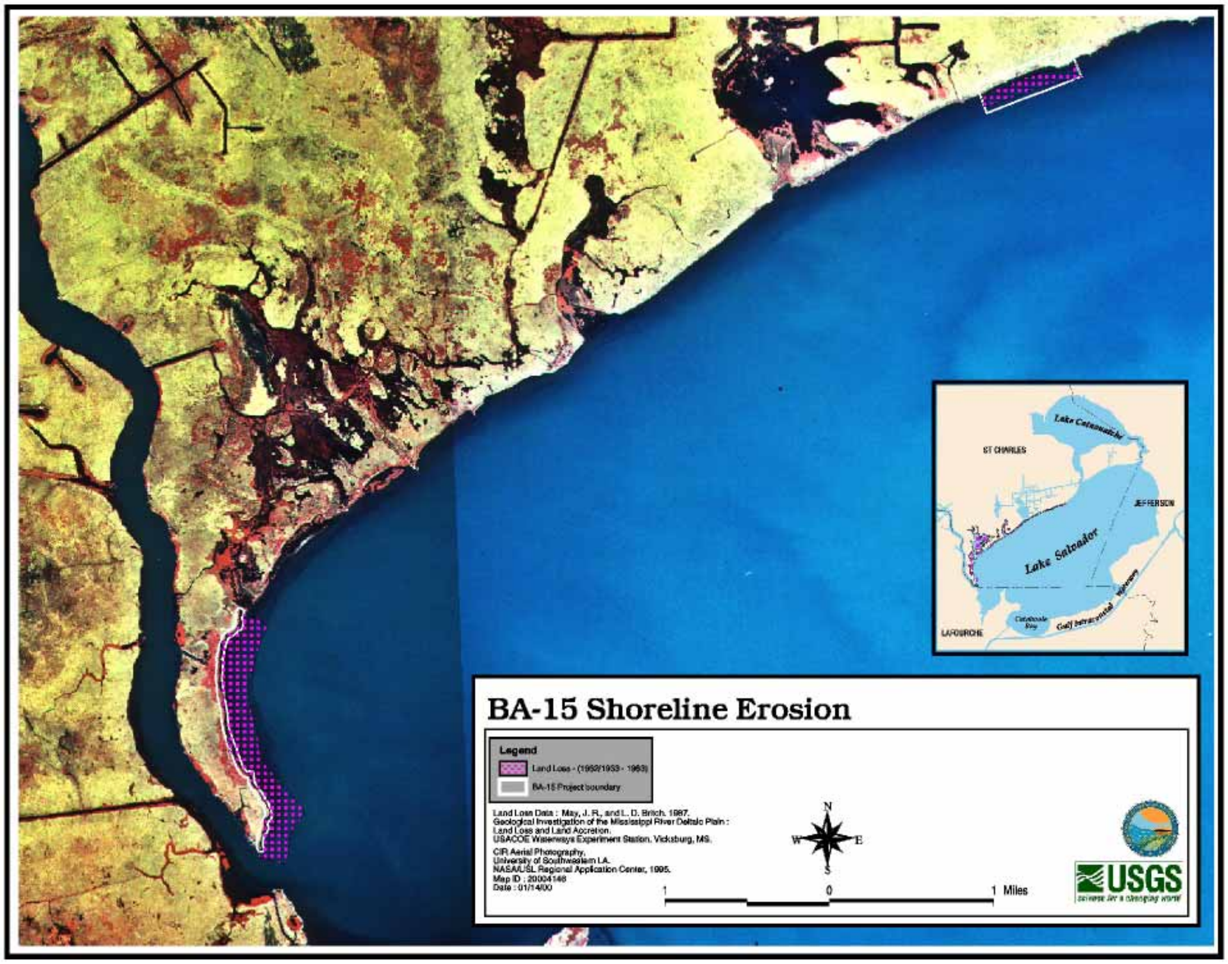


**Figure 4. Historic shoreline erosion data from the USACOE at the Lake Salvador Shoreline Protection (BA-15) Demonstration project.**

is a gray fluid about 2 in (5.0 cm) thick. The underlying material [approximately 78 in (198 cm)] is a black, mildly alkaline, fluid clay. Due to the hydric nature of these marshes, they mainly serve as habitat for wildlife and support recreational fishing and hunting (USDA 1983).

Phase 1 of the Lake Salvador Shoreline Protection (BA-15 ) Demonstration project consists of four treatments, each consisting of a different structure design. The distance between each treatment was100 ft (30.48 m), and all treatments were constructed parallel to the existing shoreline at a distance of approximately 300 ft (91.44 m) offshore. Proceeding from west to east, treatments were Grated Apex structures, Geotextile Tubes, Angled Timber Fences, and Vinyl Sheet Pile Bulkheads (figure 5).

The Grated Apex treatment consists of five, 100 ft (30.48 m) long structures, separated by 30 ft (9.14 m) gaps. The structures were made of 20 ft (6.10 m) long 2 x 12 in (5.1 x 30.5 cm)

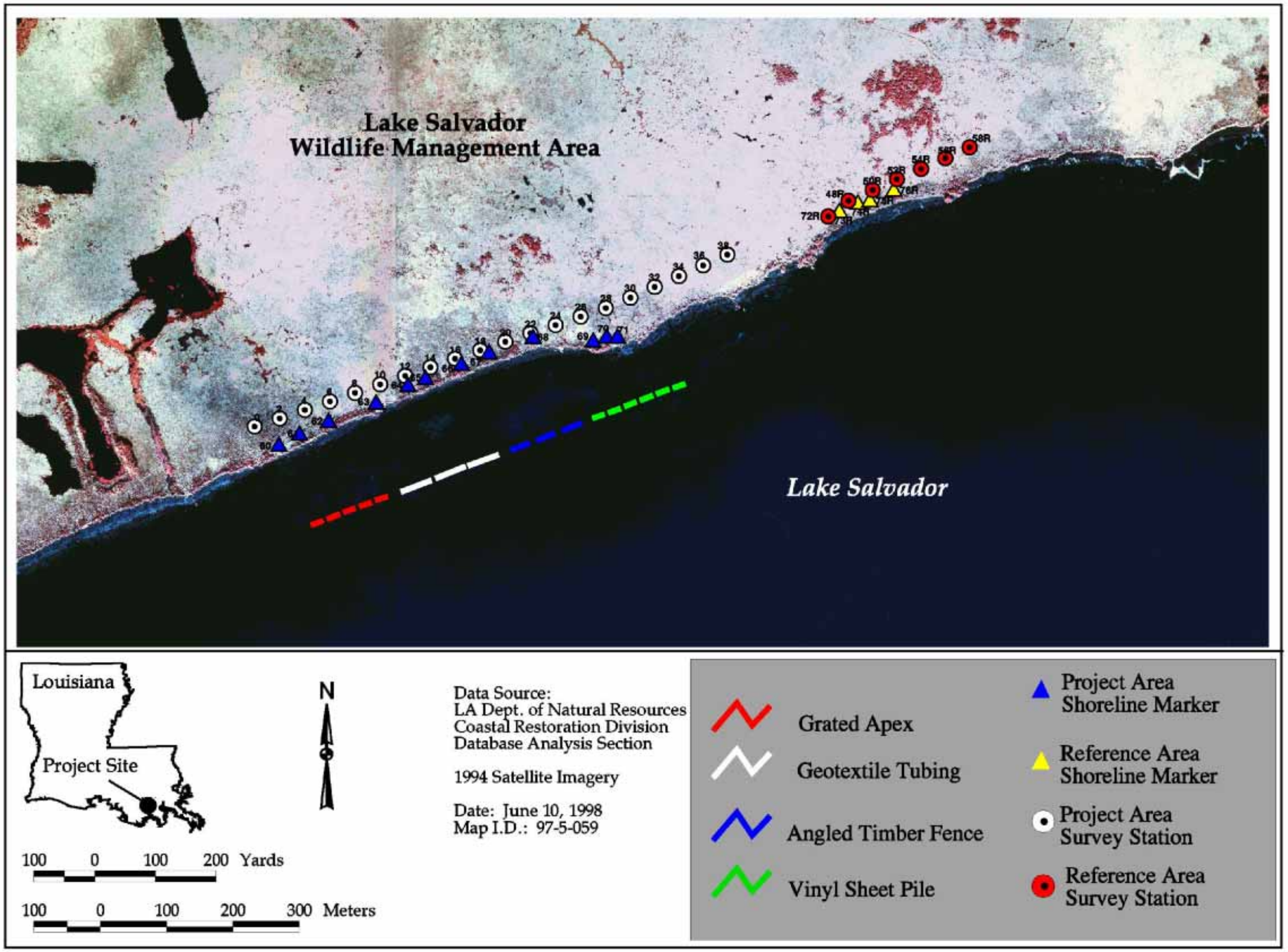


**Figure 5.** **Wave dampening structure treatment positions at the Lake Salvador Shoreline Protection (BA-15) Demonstration project.**

treated lumber horizontally bolted to 40 ft (12.19 m) timber pilings driven into the soil. Lumber was placed in an A-frame design with a 10 ft (3.05 m) base and 5 ft (1.52 m) height, with 6 in (15.2 cm) gaps between the horizontal lumber. The bottom of the A-frame was placed approximately 6 in (15.24 cm) above the bottom. The structures cost $390.00/ft or a total cost of $195,000.00 and are designed to dissipate wave energy and pattern while allowing water to pass through the grated design, therefore preventing bottom scour (figure 6, appendix A-1).

The Geotextile Tube treatment consists of three, 250 ft (76.20 m) long structures, separated by 30 ft (9.14 m) gaps. The three 250 ft (76.2 m) structure was composed of two 125 ft (31.8 m) tubes, separated by approximately 5 ft (1.52 m). The tubes were 32 ft (9.75 m) in circumference and 3.30 ft (1.01 m) high. Each tube was filled with a mixture of imported sand and concrete. The structures had a cost of $340.00/ft or a total of $255,000.00 and are designed to act as an earthen dike by dissipating wave energy (figure 7, appendix A-2).

The Angled Timber Fence treatment consists of three, 167 ft (50.90 m) long structures, separated by 30 ft (9.14 m) gaps. The structures were made of 10 ft (3.05 m) long 2 x 12 in (5.1 x 30.5 cm) treated lumber horizontally bolted to 40 ft (12.19 m) timber pilings driven into the soil. Lumber was placed at a 30° angle to the 40 ft (12.19 m) timber pilings resulting in a V-shape design, with a 17.5 ft (5.49 m) base and 5.5 ft (1.68 m) height, and 6 in (15.2 cm ) gaps between the horizontal

**Figure 6. Typical grated apex structure at the Lake Salvador Shoreline Protection (BA-15) Demonstration project (photo taken December 1998).**

**Figure 7. Typical geotextile tube structure at the Lake Salvador Shoreline Protection (BA-15) Demonstration project (photo taken December 1998).**

lumber. The bottom of the V-frame was placed approximately 6 in (15.24 cm) above the bottom. The structures had a cost of $252.00/ft or a total cost of $126,252.00 and are designed to dissipate wave energy and pattern while allowing water to pass through the grated design, therefore preventing bottom scour (figure 8, appendix A-3).

The Vinyl Sheet Pile bulkhead treatment consists of six, 100 ft (30.5 m) long structures, separated by 30 ft (9.1 m) gaps. The three easternmost sections are composed of 10 ft (3.1 m) long sheet piles and are reinforced every 10 ft (3.1 m) with 40 ft (12.2 m) long treated timber piles, while the three westernmost sections are composed of non-reinforced 22 ft (6.7 m) long sheet piles. The reinforced treatment was constructed at 6 ft (1.8 m) below the mud line, and 4 ft (1.2 m) above the mud line. The non-reinforced treatment was constructed 18 ft (5.5 m) below the mud line and 4 ft (1.2 m) above the mud line. The vinyl sheets are 10 - 22 ft (3.1 - 6.7 m) long Poly Vinyl Chloride (PVC) with a 0.25 in (0.64 cm) thickness. Sheets were attached to 4 x 6 in (10.16 x 15.24 cm) walers. The reinforced vinyl sheets were bolted to 40 ft (12.19 m) timber pilings driven 36 ft (11.28 m) into the soil. The height of the structure was 4 ft (0.91 m) from the bottom. Both the reinforced and the unreinforced structures had a cost of $200.00/ft or a total cost of $120,000.00 and are intended to dissipate wave energy (figure 9, appendix A-4).

**Figure 8. Typical Angled Timber Fence structure at the Lake Salvador Shoreline Protection (BA-15) Demonstration Project (photo taken December 1998).**

**Figure 9. Typical Vinyl Sheet Pile structures at the Lake Salvador Shoreline Protection (BA-15) Demonstration project (photo taken in December 1998).**

Phase 2 of the Lake Salvador Shoreline Protection (BA-15) Demonstration project tests the effectiveness of a rock berm in highly organic, unconsolidated sediments with poor load-bearing capacities. Unconsolidated sediments, such as those found in the Lake Salvador Shoreline Protection (BA-15) Demonstration project area, prevent standard shoreline stabilization techniques (Howard et al. 1984). The rock berm was a total of 8,000 ft (2,438 m) long constructed parallel to the existing shoreline, approximately 75 ft (22.86 m) offshore (figure 10). The rip rap is composed of armor stone ballast placed on a 27 ft (8.23 m) wide woven geotextile fabric bottom. The rip rap structure had an approximate height of 3 ft (0.91 m) and a crest width of 4 ft (1.22 m) (appendix A-5). Installation of the rock berm required dredging a flotation canal 6 ft (1.83 m) deep and 80 ft (24.38) wide 25 ft (7.62 m) offshore from the rip rap structure. A total of 191,000 cubic yards (149,174 $m^3$) was dredged. Approximately one-half of this material was placed in front of the structure and the other half was placed behind the structure. The dredged material placed in front of the structure was used to fill the flotation canal after construction. The material placed behind the structure was placed up to 3 ft NGVD (0.14 m) (appendix A-6). The rip rap structure is a typical rock berm used as a wave break to dissipate wave energy and pattern. The cost of the structure was $150.00/ft or a total cost of $1,200,000.

Phase 1 of the Lake Salvador Shoreline Protection (BA-15) Demonstration project was completed on October 1, 1997 and Phase 2 was completed on June 16, 1998. The objective of the project is to compare the effectiveness and ability of the four structures to reduce wave induced shoreline erosion in areas with unconsolidated organic soils that have poor load bearing capabilities. The specific measurable goals established to evaluate the effectiveness of Phase 1 are:

1) To reduce wave height and energy landward of individual wave dampening devices.

**Figure 10. Typical rock berm structure at Lake Salvador Shoreline Protection (BA-15) Demonstration project (photo taken August 1998).**

2) To reduce the rate of marsh edge erosion along the project shoreline.

The specific measurable goal established to evaluate the effectiveness of Phase 2 is:

1) To reduce the rate of marsh edge erosion along the project shoreline.

A portion of the Lake Salvador shoreline near each phase of the project was chosen as a reference area to provide statistically valid comparisons as a means of assessing project effectiveness. The evaluation of sites was based on the criteria that both project and reference shorelines have similar vegetative, soils, hydrology, shoreline configuration, and salinity characteristics. The Phase 1 reference area is a 1,000 ft (304.80 m) section of the Lake Salvador shoreline located 819 ft (250 m) east of the Vinyl Sheet Pile treatment (figure 5). The Phase 2 reference is a 3,000 ft (914.40 m) section of the Lake Salvador shoreline located 2,000 ft (610 m) north of the rock rip rap structure. The project shorelines and the reference shorelines share similar hydrologic aspects, have similar vegetation, and are located along Lake Salvador where shoreline erosion is occurring (HNTB 1992).

## METHODS

A detailed description of the monitoring design over the entire project life can be found in Alonzo (1996, revised 1998). Measurable variables chosen to evaluate project effectiveness are wave height and shoreline position change. Aerial photos were dropped from the monitoring plan in 1998 due to budget constraints and duplication with other more accurate variables for measurement of shoreline position. Observations of structure conditions were made to evaluate longevity and durability of the different structures that could influence their effectiveness and application.

*Aerial Photography*: The United States Geological Survey/National Wetlands Research Center (USGS/NWRC ) obtained 1:12,000 scale near vertical color-infrared aerial photography of Phase 1 on December 18, 1997 (immediate post-construction) and of the Phase 2 project area on December 19, 1994 (pre-construction) and December 19, 1997 (pre-construction). The Phase 2 site was originally selected as the site for both project phases and a pre-construction photo was taken in 1994. Due to project location changes and time delays, Phase 1 photography was only obtained in 1997 and Phase 2 was flown in 1994 and 1997, both of which were pre-construction. These changes are the reason for duplicate pre-construction phase 2 photos over a 3-year period and a lack of pre-construction photography for phase 1. Due to budget constraints and questions about the accuracy of aerial photos to access project shoreline erosion rates at the required scale, the monitoring plan was revised to eliminate all future aerial photography and photo interpretation of the existing photography.

The December 1997 photography was checked for flight accuracy, color correctness, and clarity. The original film was archived, and duplicate photography was indexed and scanned at 300 dots per inch. Using ERDAS Imagine®, an image processing and geographic information systems (GIS) software package, individual frames of photography were georectified using a real-time differentially corrected global positioning system (DGPS) data with submeter accuracy. These rectified frames were then assembled to produce a mosaic for each phase of the project (figures 2 and 3).

*Analysis of Winds*: The wind speed and direction from January 1996 thru August 1998 was obtained from the Louisiana Department of Climatology at the Moisant Field, New Orleans, Louisiana, located approximately 10 miles north of Lake Salvador project area. A wind summary was developed from the hourly wind speed and direction data to evaluate how the wave property readings and treatments were influenced by local wind conditions.

### Phase 1

*Shoreline Position*: Shoreline position was defined as the edge of the live emergent vegetation (Steyer et al. 1995). All surveys and DGPS shoreline position measurements were conducted in the Louisiana State Plane, South Zone Coordinate System, in the North American Datum of 1983 (NAD 83) and the North American Vertical Datum of 1988 (NAVD 88).

The pre-construction shoreline position for the Phase 1 project and reference areas were established January 4, 1996 by Pyburn and Odum Inc. using conventional survey methods (Pyburn and Odum, Inc. 1996). Measurements were established 200 ft (61 m) apart, perpendicular to a baseline onshore, and three temporary benchmarks were installed along the baseline for future surveys (appendix B - 1). Twenty transects were established in the project area and six transects in the reference area, with position of the shoreline determined at each of the twenty-six transects.

Phase 1 post-construction shoreline positions were determined November 1997 (immediate post-construction), May 1998 (6 months post-construction), August 1998 (1 year post-construction), May 1999 (1.5 years post-construction), and August 1999 (2 years post-construction) by Louisiana Department of Natural Resources/Coastal Restoration Division (LDNR/CRD) and USGS/ NWRC personnel using a DGPS set to achieve sub-meter horizontal accuracy for each reading (Trimble Navigation Ltd. 1996). The November 1997, August 1998, May 1999, and August 1999 shoreline position measurements were conducted by stopping at approximately 5 ft (1.5 m) intervals along the shoreline, and averaging 10 to 20 DGPS readings. A best fit line was drawn to connect the points, thereby establishing the shoreline position for the total area. LDNR/CRD and USGS/NWRC personnel also recorded a point, using the same methodology, for at least two of the temporary benchmarks, to insure the DGPS accuracy at the time of data collection. The May 1998 shoreline was measured with another sub-meter DGPS set to collect a reading every second. A best fit line was generated for those points (appendix B-1 and B-2).

The pre-construction shoreline change rate was determined by overlaying the November 1997 DGPS data on the January 1996 survey using AutoCAD® software. The difference between the January 1996 and November 1997 shoreline was taken along each of the twenty-six transects to get a shoreline position change rate (appendix B-1). The total distance between shorelines was divided by the number of days between the surveys (N = 685) and multiplied by 365 days to get a shoreline change rate per year. The yearly change rate for transects was averaged to provide an average shoreline change per year for each treatment and the project and reference areas.

The post-construction shoreline change rate was determined by overlaying the November 1997, May 1998, August 1998, May 1999, and August 1999 DGPS data using ERDAS ARC/Info® and ERDAS ArcView® GIS Software. A polygon was established for each treatment, from the edges of the structure onshore to the baseline, with sides perpendicular to the structures. Polygons were also established in the gaps between treatments. Within each polygon, the area ($m^2$) was determined and compared to the polygon formed by the shoreline position data for each sampling time period (figure 11). The difference between one time period's area and the next time period's area determined the total area change over the sampling period. This area was divided by the total length of the polygon to calculate average shoreline change within the polygon. The total shoreline change was divided by the number of days between the samples and multiplied by 365 days to get an annual shoreline change rate. A shoreline change rate was also calculated for the entire project area and the gaps between treatments for each time period. However, since this method assumes that there are no treatment interactions, the physical proximity of the treatments, the spacial and temporal variability in the project area due to variable wind and wave orientations, the differential cardinal orientation of the shoreline within and among treatments (figure 5), the potentially different soil erosion properties along the shoreline, and lack of treatment replication, will make it difficult to differentiate

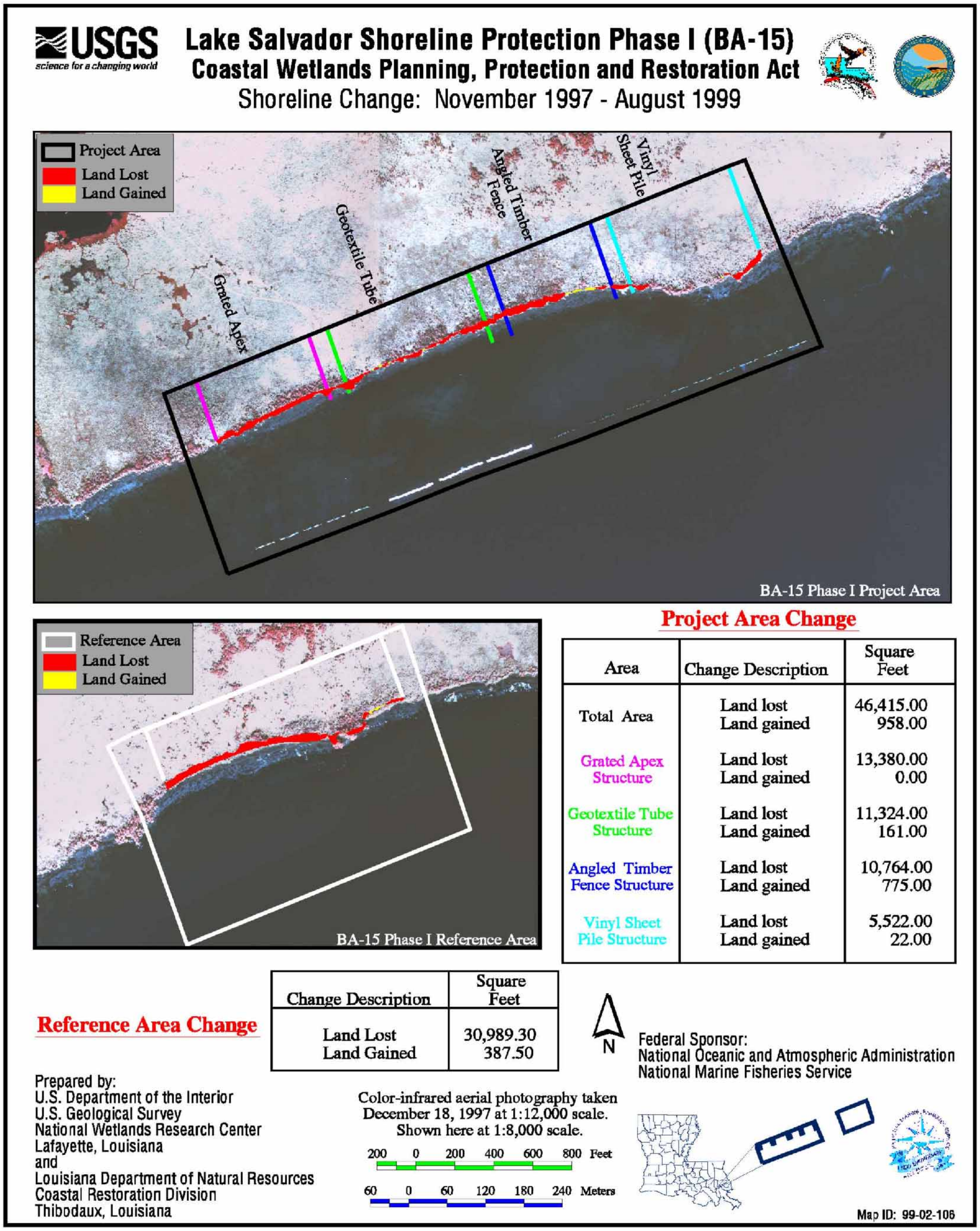


**Figure 11.** **Post-construction shoreline change from DGPS data taken November 1997 and August 1999 at Phase 1 of the Lake Salvador Shoreline Protection (BA-15) Demonstration project.**

treatment effects on shoreline position.

Shoreline markers were established January 1998 in the Phase 1 project and reference areas to provide a quality check on the DGPS data. Seventeen shoreline marker stations were established January 1998, following Steyer et al. (1995) (figure 5). Measurements were taken in May 1998 and the difference between distances along each of the three lines, after correction for measurement angles, were averaged to obtain an average shoreline position change for each station. The average shoreline position change was divided by the number of days between measurements and multiplied by 365 days to get a shoreline change rate per year. The annual change rate for stations was averaged to provide an average shoreline change per year for each treatment, the project, and reference areas. Similar circumstances exist in the interpretation of this data set that exist in the DGPS data, in addition to the short duration, and single sampling period for the stations. The shoreline marker measurements were strictly for a quality check on the DGPS data set and are presented as such.

*Wave Height*: To evaluate the ability of the different structures in reducing wave energy, and responses of the incident wave field to the treatments, wave properties were measured January 1998, May 1998, September 1998, October 1998, February 1999, July 1999, August 1999, and September 1999 by Louisiana State University/Coastal Studies Institute (LSU/CSI) using 4 precise Paroscientific digital quartz pressure transducers. Wave height data was measured at a 4 Hz sampling interval for approximately eight minutes every 10 minutes (Stone et al. 1998a, 1998b, 1998c, 1998d, 1999a, 1999b, 1999c, 1999d, 1999e). Stations were established directly behind each structure type (inside) and in the gap between the structures (gap) approximately 15 ft (5 m) landward of the treatment. Wave properties were simultaneously measured offshore of each different structure type and along the shoreline at approximately the same depth as the stations behind the structures (control) (figure 12). Comparisons of wave properties among the offshore, control, gap, and inside sites allows a quantitative comparison of the structures influence on the nearshore wave field. For a more detailed description of the wave property data analysis procedures, refer to Stone et al. (1998a, 1998b, 1998c, 1998d, 1999a,1999b, 1999c, 1999d, 1999e).

Phase 2

*Shoreline Position*: All pre-construction and post-construction shoreline position surveys established for Phase 2 utilized identical survey methodologies and datums as for Phase 1. The pre-construction shoreline position for the Phase 2 project and reference areas were established February 14, 1997 by Picciola and Associates, Inc. (Picciola 1997). Thirty-two transects were established in the project area, and nine transects in the reference area. The position of the shoreline was determined at each of the 41 transects (appendix B-3).

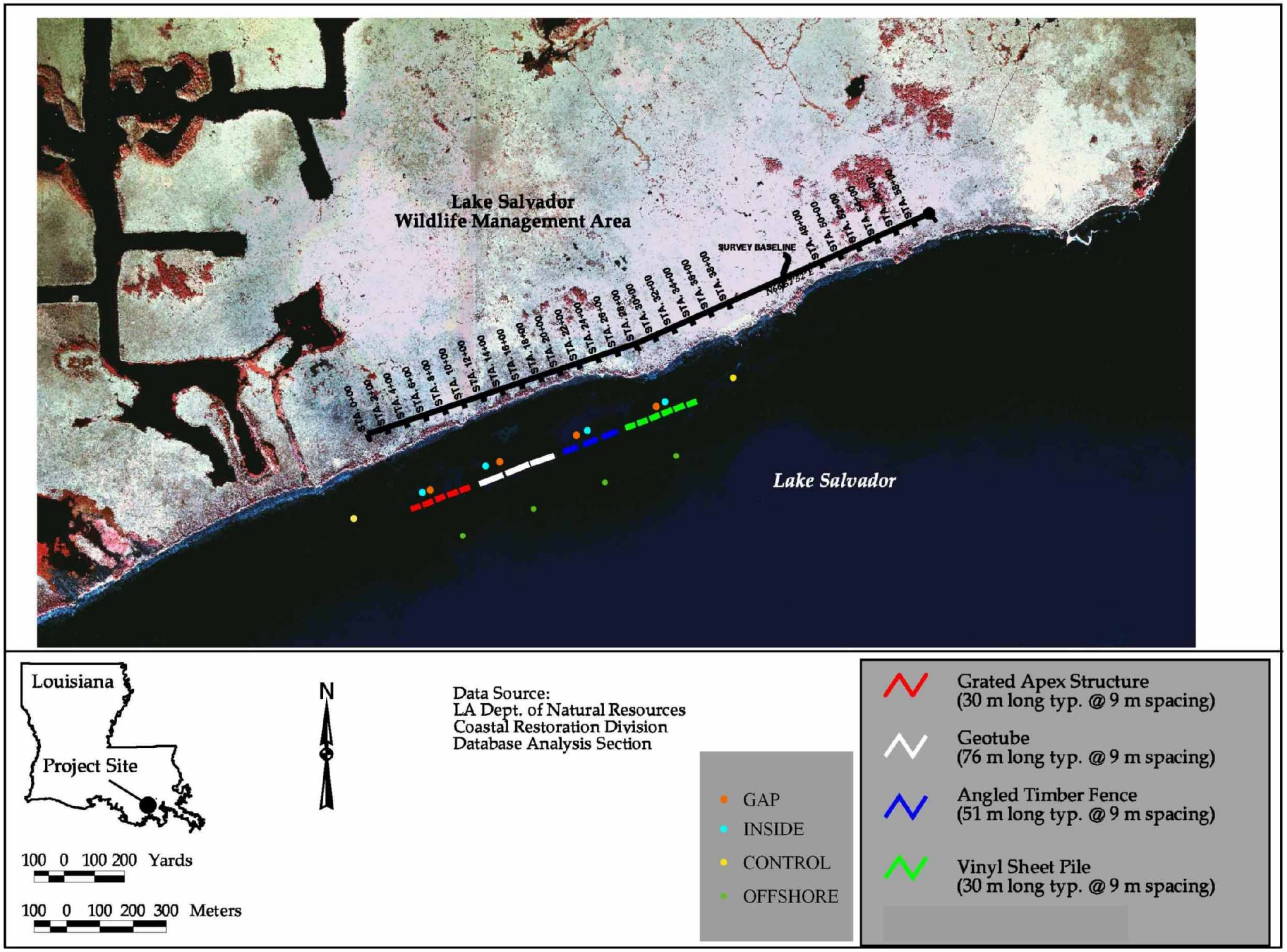


**Figure 12. Location of LSU/CSI wave measurement gauges at Phase 1 of the Lake Salvador Shoreline Protection (BA-15) Demonstration project (modified from Stone et al. 1999d).**

The phase 2 post-construction shoreline position was established October 1998 (immediate post-construction), March 1999 (6 months post-construction), and August 1999 (1 year post-construction) by LDNR/CRD personnel (appendix B-3).

The October 1998 DGPS data was overlaid on the February 1997 survey using AutoCAD® software, and the distance between shoreline position in February 1997 and October 1998 was measured on each of the 41 transects to determine the pre-construction shoreline change rate (appendix B-3). The total distance between shorelines were divided by the number of days between the surveys (N= 617) and multiplied by 365 days to get a shoreline change rate per year. The yearly change rate for transects were averaged to provide an average shoreline change per year for the project and reference areas.

The post-construction shoreline change rate was determined by overlaying the October 1998, May 1999, and August 1999 DGPS data using ERDAS ARC/Info® and ERDAS ArcView® GIS Software. A polygon was established for the project and reference areas, from the edges of the structure onshore to the baseline, with sides perpendicular to the structures. Within each polygon, the area ($m^2$) was determined and compared to the polygon formed by the shoreline position data for each sampling time period. The difference between one time period's area and the next time period's area determined the total area change over the sampling period. This area was divided by the total length of the polygon to calculate average shoreline change within the polygon. The total shoreline change was divided by the number of days between the samples and multiplied by 365 days to get an annual shoreline change rate. A shoreline change rate for the project area was not available due to difficulty establishing the shoreline on the soft dredge material.

## RESULTS

Phase 1

*Shoreline Change*: Comparison of pre and post-construction shoreline position data for Phase 1 indicate that pre-construction shoreline erosion averaged 4.40 ft $yr^{-1}$ (1.34 m $yr^{-1}$) in the project area and 6.82 ft $yr^{-1}$ (2.08 m $yr^{-1}$) in the reference area from January 1996 to November 1997. Post-construction results for the time period of November 1997 to August 1999 (2 years post-construction) indicated an average shoreline erosion rate of 8.14 ft $yr^{-1}$ (2.48 m $yr^{-1}$) in the project area and 13.19 ft $yr^{-1}$ (4.02 m $yr^{-1}$) in the reference area. Only the Geotextile Tubes showed shoreline progradation [1.61 ft $yr^{-1}$ (0.49 m $yr^{1}$)], and this was only during the 1 year post-construction time period. After 2 years post-construction, the Geotextile Tubes showed shoreline erosion rates of 8.01 ft $yr^{-1}$(2.44 m $yr^{-1}$). The Vinyl Sheet Piles had the lowest erosion rate at 4.56 ft $yr^{-1}$ (1.39 m $yr^{-1}$), followed by the Geotextile Tubes structures. The Grated Apex structures had the highest erosion rate [11.94 ft $yr^{-1}$ (3.64 m $yr^{-1}$)] (figure 13). Shoreline change data was incomplete for the Grated Apex structure during the one year post-construction sampling period due to DGPS technical problems.

Shoreline markers were not measured in August 1998 as planned due to the fact that the rapid shoreline erosion had caused the majority of them to wash away, so only the January 1998 to May

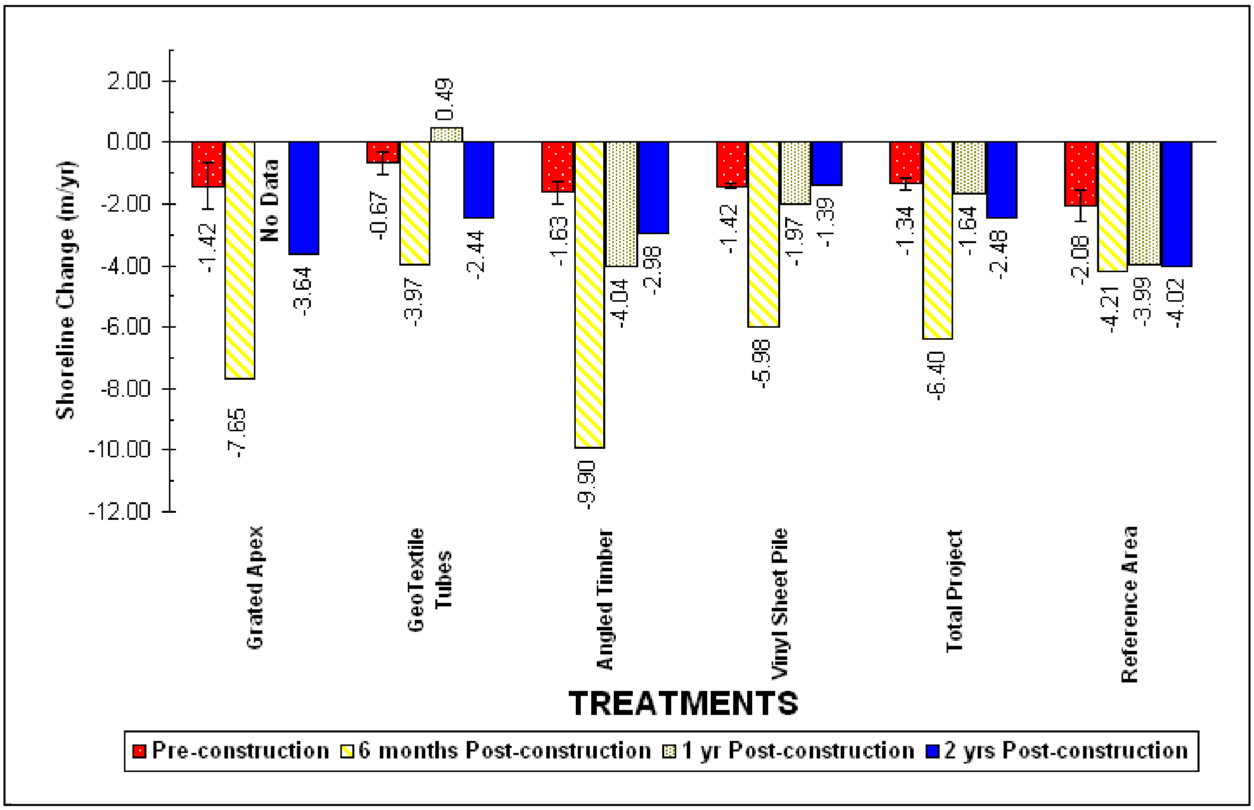


**Figure 13. Shoreline change rates from DGPS data for all treatments at Phase 1 of the Lake Salvador Shoreline Protection (BA-15) Demonstration project from January 1998 to May 1999**.

1998 measurements were available. However, these measurements supported the DGPS data, indicating the shoreline behind all structures and the reference areas continued to erode post-construction during the first 6 months (figure 14).

*Wave Height*: The following data were taken from the LSU/CSI wave height measurement studies from January 1998 thru February 1999 (Stone et al. 1998a, 1998b, 1998c, 1998d, 1999a, 1999b, 1999c, 1999d, 1999e). Percent difference calculations were used to compare the control and inside average significant wave height measurements. The differences between the control and inside average significant wave heights for each treatment are depicted graphically by sampling period in figure 15. Results from the wave height measurements indicated that the Geotextile Tubes and the Vinyl Sheet Pile treatments are consistently effective in reducing wave heights landward of the structures when the prevailing winds hail from the southern direction. The Vinyl Sheet Pile structures reduced average significant wave heights from 89 to 80% and the Geotextile Tubes reduced average significant wave heights from 91 to 60% during the January 1998, May 1998, and September 1998 sampling periods (figure 15). During these sampling periods, the winds were generated predominantly from the southern quadrant. Figure 16 delineates wind speed and direction measurements taken during the January 1998 sampling period. These wind measurements are also relevant for the May and September 1998 sampling periods since wind speed and direction were fairly

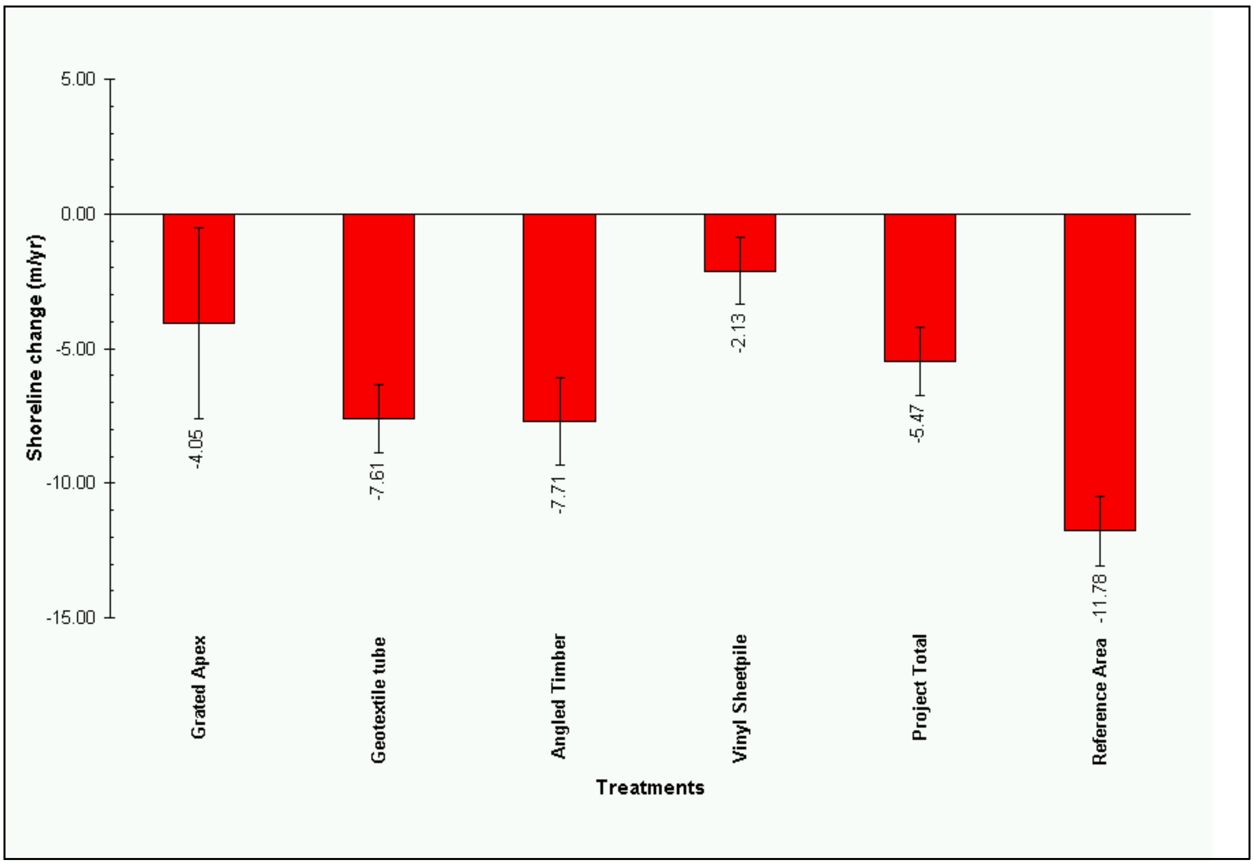


**Figure 14. Shoreline change from shoreline markers data for all treatments at Phase 1 of the Lake Salvador Shoreline Protection (BA-15) Demonstration project from January 1998 to May 1998.**

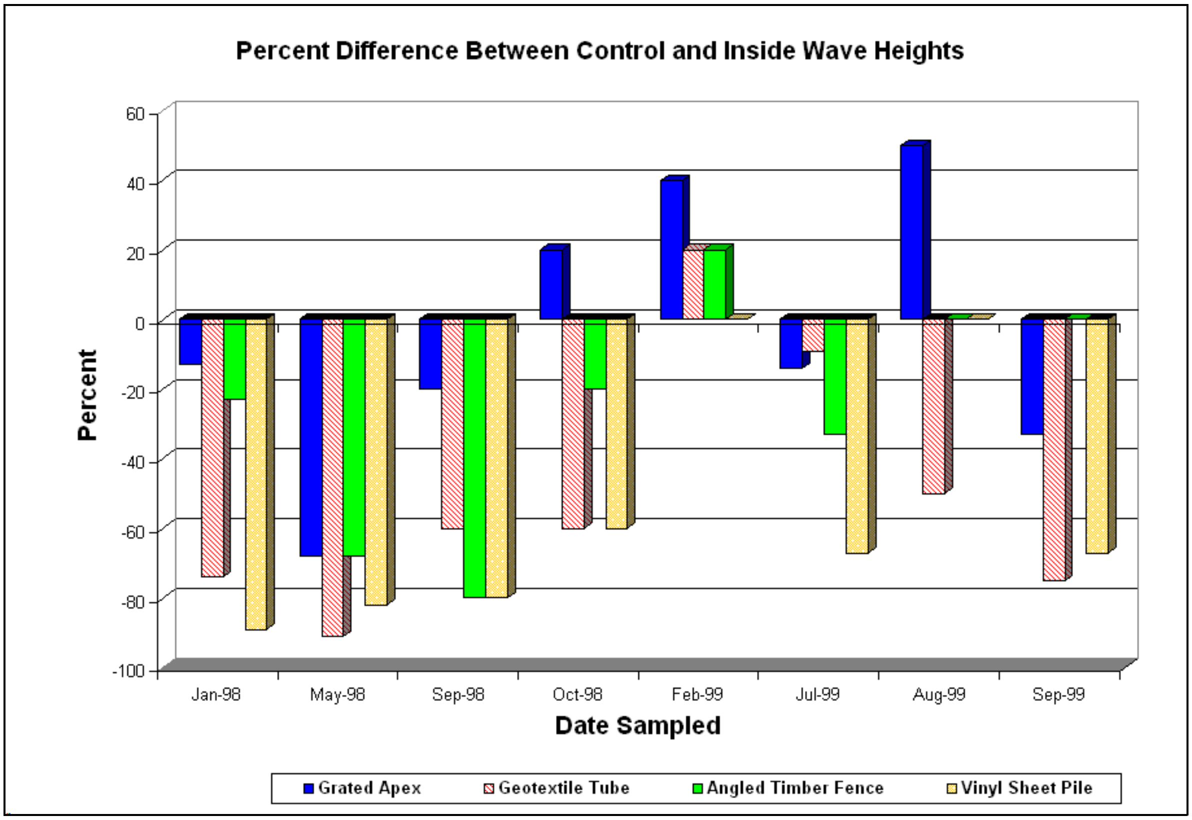


**Figure 15. Average significant wave height reductions for all treatments during all sampling periods at Phase 1 of the Lake Salvador Shoreline Protection (BA-15) Demonstration project (from Stone et al. 1998a, 1998b, 1998c, 1998d, 1999a, 1999b,1999c, 1999d, 1999e).**

consistent throughout the first three sampling periods. While these impermeable structures were fairly consistent in damping wave energy during the first three sampling periods, the performance of the Grated Apex structure (approximately 20% porosity) and Angled Timber Fence structures (approximately 30% porosity) were variable although the prevailing winds hailed from the south in January 1998, May 1998, and September 1998. The Grated Apex treatment reduced average significant wave heights from 68 to 13% and the Angled Timber Fence treatment reduced average significant wave heights from 80 to 23% during the first three sampling periods (figure15).

The impermeable structures (Geotextile Tubes and Vinyl Sheet Pile) were equally successful in lowering average significant wave heights (60% reduction) when prevailing winds were reported out of the northeast in October 1998. Conversely, the permeable treatments were not effective in lowering average significant wave heights during the October 1998 sampling period (figure 15). The Angled Timber Fence structures lowered average significant wave heights by 20% while the Grated Apex structures showed a 20% increase in wave heights when comparing the inside measurements with the control (figure 15).

Although the prevailing winds were reportedly out of the southwest for the July 1999 sampling period, reductions in wave heights were erratic during this sampling period because a thunderstorm

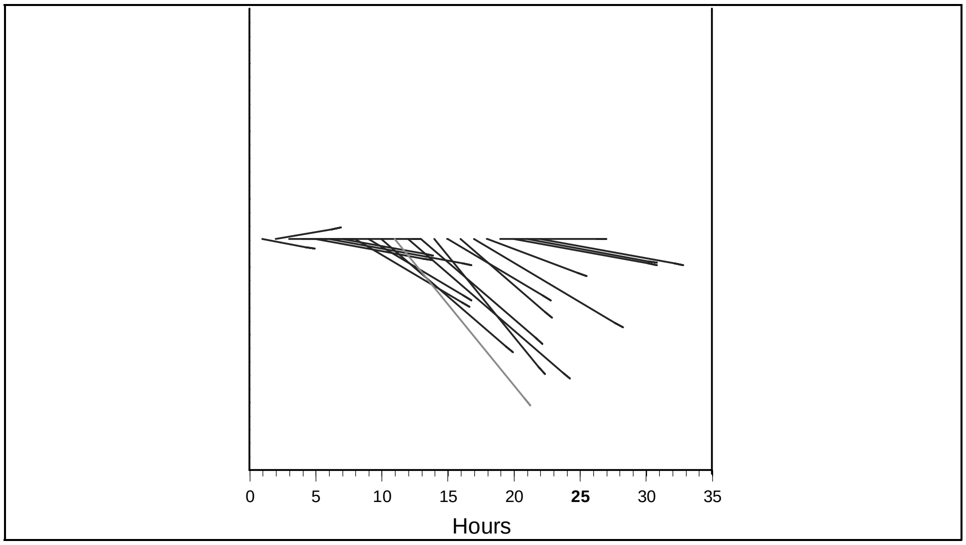


**Figure 16. Hourly wind speed and direction measurements at Moisant Field, New Orleans, LA during January 21, 1998 wave sampling time period.**

occurred, which induced considerable increases in average significant wave heights while sampling activities were taking place. The Vinyl Sheet Pile structures reduced wave heights by 67% while the Geotextile Tubes, Angled Timber Fence, and the Grated Apex structures only lowered average significant wave heights by 9%, 33%, and 14%, respectively (figure 15).

None of the structures lowered average significant wave heights during the February 1999 sampling period when the prevailing winds were out of the west. In fact, a 40% increase in average significant wave heights were measured for the Grated Apex structures, and 20% increases in average significant wave heights were recorded for the both the Angled Timber Fence and the Geotextile Tube treatments (figure 15).

Only the Geotextile Tubes reduced average significant wave heights (50%) during the August 1999 sampling period when the prevailing winds were out of the north while the Grated Apex structures showed a 50% increase in average significant wave heights (figure 15).

The September 1999 wave height sampling period resulted in 75% and 67% reductions in average significant wave heights for the impermeable structures (figure 15). In contrast, the Grated Apex treatment reduced average significant wave height by only 33% while the Angled Timber Fence structures did not reduce average significant wave heights (figure 15). The prevailing wind was reportedly out of the east for this sampling period.

Also, a substantial amount of wave energy maintained itself through the gaps between the structure segments. During January 1998 and May 1998, the wave height reduction landward of the gaps between the structure segments was generally less than 30% (figure 17). Moreover, average significant wave height reduction through the gaps between the structures seems to be independent of structures design since all four types of structures generated similar average significant wave height reductions in the gaps.

*Analysis of Winds*: An analysis of wind direction at Moisant Field north of Lake Salvador indicated that for a 2.5 year time period, winds were out of a southerly direction approximately 20% of the time, whereas the northerly component comprised 13% of the time (figure 18). Wind speed ranged from 0 to 20 knots but averaged 10 knots.

Phase 2

*Shoreline Change*: Comparison of pre and post-construction shoreline position data for Phase 2 indicate that pre-construction shoreline erosion rates from February 1997 to October 1998 averaged 3.71 ft $yr^{-1}$ (1.13 m $yr^{-1}$) in the reference area while the project area prograded at a rate of 1.90 ft $yr^{-1}$ (0.58 m $yr^{-1}$) (figure 19). Post-construction analysis from the period of October 19, 1998 to March 11, 1999 indicated the project area transgressed at a rate of -14.41 ft $yr^{-1}$ (4.40 m $yr^{-1}$) while the reference area prograded 1.80 ft $yr^{-1}$ (0.55 m $yr^{-1}$) (figure 19). No DGPS data was collected in the project area for the August 17, 1999 sampling period because of soft soil conditions encountered along the vegetation line (Hubbell and Rapp 2000) while the reference area prograded at a rate of 1.35 ft $yr^{-1}$ (0.41 m $yr^{-1}$).

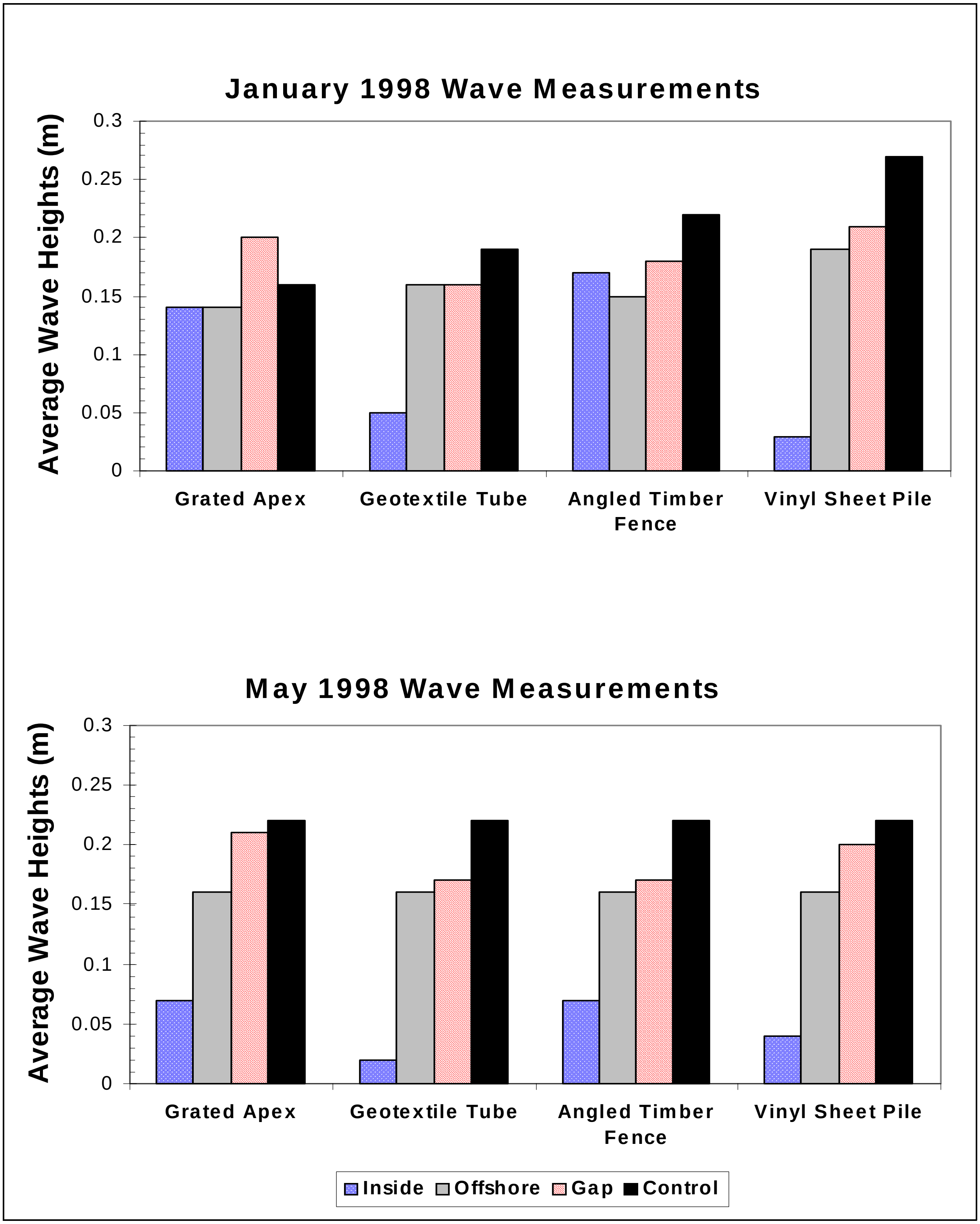


**Figure 17.** **Significant average significant wave heights at each treatment on January 21,1998 and May 6, 1998 at Phase 1 of the Lake Salvador Shoreline Protection (BA-15) Demonstration project (from Stone et al. 1998a, 1998b).**

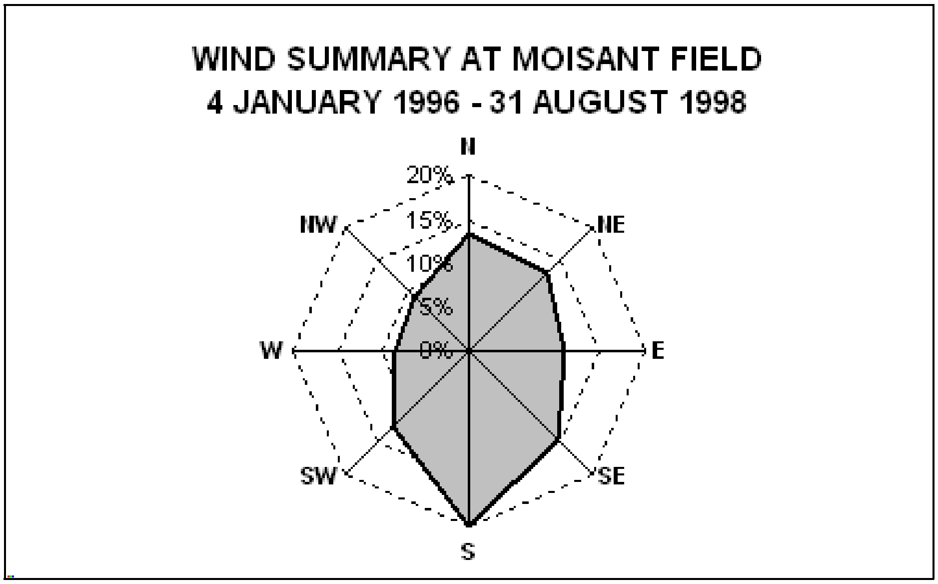


**Figure 18. Hourly wind data summary from January 4, 1996 through August 31, 1998 at Moisant Field, New Orleans, LA.**

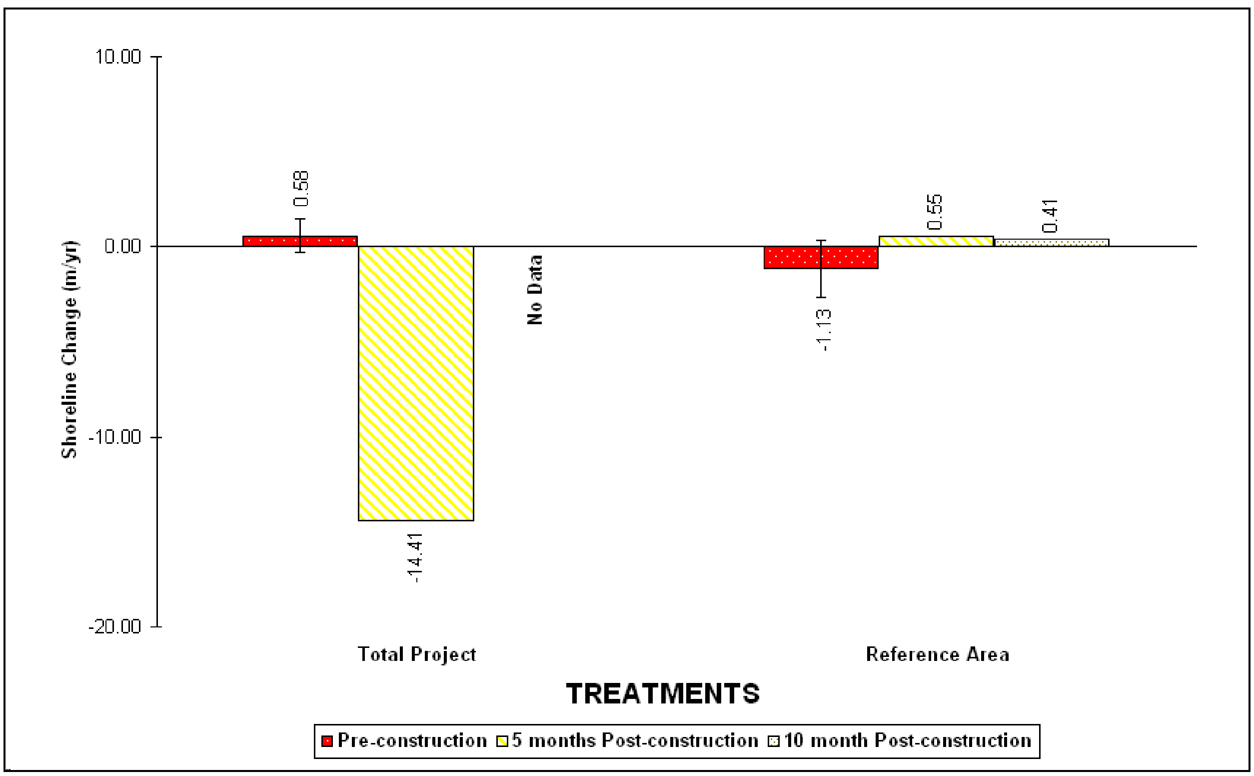


**Figure 19. Shoreline change rates from DGPS data for Phase 2 of the Lake Salvador Shoreline Protection (BA-15) Demonstration project.**

# DISCUSSION

## *Phase 1*

The initial goal of reducing marsh edge erosion was not indicated by the DGPS shoreline position data (figure 13). The shoreline markers as well as the DGPS data indicated that none of the structures appeared to affect shoreline erosion rates over the 2 year post-construction period when compared to the reference area. It should be noted that the reference area exhibited a higher erosion rate than the treatments pre-construction, as well as 2 years after construction, and direct comparisons are difficult due to the confounding factors mentioned earlier such as spacial and temporal variability, lack of treatment replication, and treatment interactions. The Geotextile Tubes and the Vinyl Sheet Pile treatments showed the lowest erosion rates during the 2 year post-construction time period, at 8.01 and 4.56 ft $yr^{-1}$ (2.44 and 1.39 m $yr^{-1}$), respectively. However, it should be noted that these 2 treatments had the lowest shoreline erosion rates pre-construction.

During the first year after construction, the Geotextile Tube treatment did show a shoreline progradation rate of 1.61 ft $yr^{-1}$ (0.49 m $yr^{-1}$), which could have been due to the structures (figure 13). Also, the wave energy reductions effected by the Geotextile Tubes was high (approximately 90%) during the first year post-construction (Stone et al. 1999e). While considerable wave energy was dissipated during the first three sampling periods, it must be noted that the prevailing winds were out of the south during these sampling periods (figure 15). When the wind direction shifted, the amount of wave energy dissipated by these structures declined. To illustrate further, westerly wind conditions that occurred during the February 1999 sampling period actually increased average significant wave height by 20% since westerly winds generate waves that travel almost parallel to the structures (Stone et al. 1999a) (figure 15). Interestingly, when the prevailing winds shifted to the eastern direction (waves almost parallel to the structures) during the October 1999 sampling period, the Geotextile Tubes reduced the average significant wave heights by 75% (Stone et al. 1999d). However, the wind velocity was quite low during the September 1999 sampling period, which might artificially inflate the influence of the structures on average significant wave heights, and winds out of the westerly quadrant during the February 1999 sampling could cause waves to be generated behind the structures since they were so far offshore (figure 5).

The Geotextile Tubes began to show signs of structural failure after the September 1998 sampling period (Stone et al. 1998c) (figure 20), and this may indicate that there was some impact to the shoreline change rate due to this treatment. However, since the longevity of the structures and potential maintenance must be considered in the evaluation of these treatments, the long-term implication of the Geotextile Tubes to reducing shoreline erosion looks poor, unless better designs or different deployment conditions can be formulated.

The structural failure of the tubes appears to be due to: 1) differential settlement rates within each tube causing the internal concrete and sand to fracture and then wear the fabric during motion caused by wave energy (Stone et al. 1999e) and 2) problems with these Geotextile Tubes design and

**Figure 20. Typical damage exhibited by the Geotextile tube structures at the Lake Salvador Shoreline Protection (BA-15) Demonstration project (photo January 2000).**

installation (Kendrick 2000). Once the tube failed, the wave energy removed fill material, depositing some of it landward of the structure. Geotextile Tubes have been used in other areas to successfully reduce shoreline erosion (Gill et al. 1995), and may still have potential in Louisiana. Gill et al. (1995) reported on Geotextile Tubes in Chesapeake Bay and noted during the winter of 1994 ice in the area up to 12 ft (3.6 m) thick, and no movement or apparent damage to the Geotextile Tube structures the following spring. Possible changes in fill material, installation methods, placement of the tubes in relation to the shoreline, and restrictions of the Geotextile Tube treatment to firmer soil locations could maximize the durability and performance of this treatment. However, it should be noted that this was the second most expensive treatment and over twice as expensive as the rock structure placed at Phase 2 (table 1).

The Vinyl Sheet Pile treatment also showed significant reductions in wave energy (approximately 90%) during all wind conditions except westerly winds (Stone et al. 1999a, 1999e) (figure 16). Despite this, the Vinyl Sheet Pile treatment had structural problems as well. The unreinforced Vinyl Sheet Pile structure showed failure, due to wave energy warping the structure and loosening the sheeting from the waler attachments and removing it (Stone et al. 1999d; Kendrick 2000) (figure 21). However, the reinforced Vinyl Sheet Pile exhibited better structural integrity over the 2 years of monitoring, and the Vinyl Sheet Pile was the least expensive of the treatments tried at Phase 1 (table 1) (figure 22). The Vinyl Sheet Pile structures were still more expensive than the rock structure placed at Phase 2. Due to the reinforced Vinyl Sheet Piles ability to reduce wave energies (Stone et al. 1999e) and better maintain structural integrity 2 yrs post-construction, they appear at this point

**Table 1. Structure cost versus effects on wave heights and shoreline erosion rates at the Lake Salvador Shoreline Protection (BA-15) Demonstration project.**

| TREATMENT | Approximate Structure Cost ($/ft) | Approximate Wave Height Reduction[a] (%) | Post-Construction Shoreline Change Rate ($m/yr^{-1}$) |
|---|---|---|---|
| Grated Apex | 390 | 30 - 80 | -3.64 |
| Geotextile Tube | 340 | >90 | -2.44 |
| Angled Timber Fence | 252 | 20 - 80 | -2.98 |
| Vinyl Sheet Pile | 200 | >90 | -1.39 |
| Phase 1 - Reference Area | 0 | 0 | -4.02 |
| Rock rip-rap | 150 | No Data | 13.68 |
| Phase 2 - Reference Area | 0 | 0 | 0.41 |

[a] approximate wave height reductions from Stone et al. (1999e).

**Figure 21. Typical structural damage to the unreinforced Vinyl Sheet Pile structures at the Lake Salvador Shoreline Protection (BA-15) Demonstration project (photo January 2000).**

**Figure 22. Typical structural stability of the reinforced Vinyl Sheet Pile structure the Lake Salvador Shoreline Protection (BA-15) Demonstration project (photo January 2000).**

to perform the best of all the treatments applied at Phase 1. It should be noted however, that it has only been 2 years since they were built, and no definitive reductions in shoreline erosion rates can be detected due to current project design with a lack of replication, treatment interactions, and other confounding factors.

Both the Grated Apex and Angled Timber designs showed little affect on the shoreline erosion rate and exhibited variable affects on wave energy. The Grated Apex structures reduced average significant wave heights from 23 to 80% while the Angled Timber structures reductions ranged from 13 to 68% (figure 16) (Stone et al. 1999e). However, these permeable structures demonstrated increases in average significant wave heights on several occasions. Wind direction, velocity, and mean water level contributed to the performance of these structures. The western wind conditions encountered during the February 1999 sampling period (Stone et al. 1999a) produced 20 and 40% increases in average significant wave heights (figure 16). Both treatments effect on wave energies appeared dependant upon the average water level and wave height. When water levels were such that the mean water level was mid way between the horizontal slats, and the waves were low, a significant amount of the wave energy propagated through the structures. This was reduced as wave heights increased or mean water levels were at the same height as one of the horizontal slats (Stone et al. 1999e). Stone et al. (1999e) suggest that the direction from which the waves were propagating was another factor in these treatments ability to reduce wave energies. This phenomenon accounted for the variable wave energy reductions of both treatments and their affect on shoreline erosion rates.

The Angled Timber and Grated Apex both exhibited better structural performance than the Geotextile Tubes and unreinforced Vinyl Sheet Pile treatments. However, the Grated Apex structure is showing damage at piling attachments near the bottom, and loosening of bolts though out the structure (Kendrick 2000). The Angled Timber Fence treatment seems to be holding up the best of all the treatments, and shows only some minor wear, as boards and bolt attachments begin to wear and loosen (figure 23). The Grated Apex structure was the most expensive treatment applied at Phase 1, while the Angled Timber fences had the second lowest cost (table 1). Both were more expensive than the rock structure installed for Phase 2.

Since both the Grated Apex and Angled Timber treatments seemed to have some of the best structural integrity at this time, but the worst wave energy reductions, it has been suggested that a change in the design to eliminate all the horizontal slats from being aligned (appendix A-1 and A-3) and or modifying the slats themselves, may help improve efficiency of the treatments in reducing wave energies. This would insure that some portion of the structure will be at the elevation required to impact a portion of the wave regardless of average water level and average significant wave heights. However, it should be noted that an increase in efficiency of wave energy reductions could influence structural integrity, due to greater stresses on the structures as they absorb more wave energy. Also, the distance of all treatments offshore and orientation to the shoreline, has been noted as potential factors contributing to a lack of better results in reductions of shoreline erosion rates.


**Figure 23. Typical structural damage exhibited by the Grated Apex and Angled Timber Fence structures at the Lake Salvador Shoreline Protection (BA-15) Demonstration project (photo January 2000).**

Phase 2

The project area behind the Rip Rap Shoreline Protection structure at Phase 2 has shown a fairly high shoreline erosion rate 5 months after construction of the rock berm while the reference area prograded at a rate of half a meter per year six months after construction (figure 20). No plausible explanation for the high erosion rate in the project area has been extracted from the data set to date and no additional factors can be attributed to the erosion such as tropical storms or floods. Since the 10 month post-construction data could not be collected in the project area due to poor environmental conditions, it is not known whether the shoreline erosion rate has reduced. However, Hubbell and Rapp (2000) reported irregular colonization of the dredge spoil material by vegetation. If this vegetative colonization trend continues, the shoreline behind the rock structure may prograde substantially. While the shoreline change rate for the project area is not known one year after construction of the rock berm, the reference area continues to prograde although at a slightly reduced rate one year after the Phase 2 shoreline protection structure was installed (figure 20). Also, the rock structure itself appears to be holding up well, showing little signs of deterioration and subsidence (Kendrick 2000).

## CONCLUSIONS

Due to the treatment interactions, lack of replication and other confounding effects mentioned previously, definitive conclusions concerning different treatment effects on shoreline erosion rates are not possible. Our results indicate that the four experimental structures (Phase 1) have not influenced shoreline erosion rates to date. In fact, the rate of shoreline erosion has remained near the long-term average of 7.74 ft $yr^{-1}$ (2.36 m $yr^{-1}$) (May and Britch 1987). One important factor affecting shoreline erosion rates is the long fetch [500 ft (150 m)] of Lake Salvador between the structures and the shoreline. This distance allows waves to regenerate since the low amplitude, high frequency waves of Lake Salvador are locally generated by the prevailing winds (Stone et al. 1999e). Therefore, the placement of the experimental structures seems to have induced little change in the shoreline erosion rates.

However, the four experimental structures demonstrated varying effectiveness in dampening average significant wave heights depending upon wind direction, mean water level, and structure porosity. Generally, reduced average significant wave heights occurred most under southern wind conditions when winds were perpendicular to the structures and the shoreline, and least during westerly wind conditions when winds were almost parallel to the structures and the shoreline. Mean water level also influenced average significant wave height reduction, but only for the permeable structures. The porosity of the Grated Apex and Angled Timber Fence structures allowed wave energy to propagate through the horizontal slats when mean water level fell between the slats. As a result, the permeable structures impact on wave energy seems to be dependent on mean water level.

The structural durability of the treatments affected average significant wave height reduction. While the Grated Apex and Angled Timber Fence structures were durable, the Geotextile Tube and Vinyl Sheet Pile structures displayed signs of deterioration, which impacted their ability to reduce wave energy over time. The Geotextile Tube structures showed signs of structural failure within a year after installation. Moreover, these structures have continued to degrade and will not hold up over time. Although the unreinforced Vinyl Sheet Pile structures have been degraded by constant wave energy, the Vinyl Sheet Pile structures that are reinforced with pilings have held up better 2 years after installation. To this point, Vinyl Sheet Pile structures have been the most successful of the experimental structures at reducing wave energy while maintaining structural stability.

While the experimental structures (Phase1) have had little effect on Lake Salvador's rapidly eroding shoreline, the Rip Rap structure's (Phase 2) effect on the shoreline change rate is unclear one year after installation. Incomplete sampling in the project area, placement of dredge material behind the Rip Rap structure, and shoreline progradation in the reference area confounded results. Additional sampling is necessary to determine the effectiveness of the Rip Rap structure.

In conclusion, the results of this study suggest that the Rip Rap structure and reinforced versions of the Vinyl Sheet Pile structures have the most potential to stabilize wetland shorelines with poor load-bearing capacities from high frequency, low amplitude wave generating water bodies. However, several parameters should be addressed before these treatments are installed in 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 it's 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.

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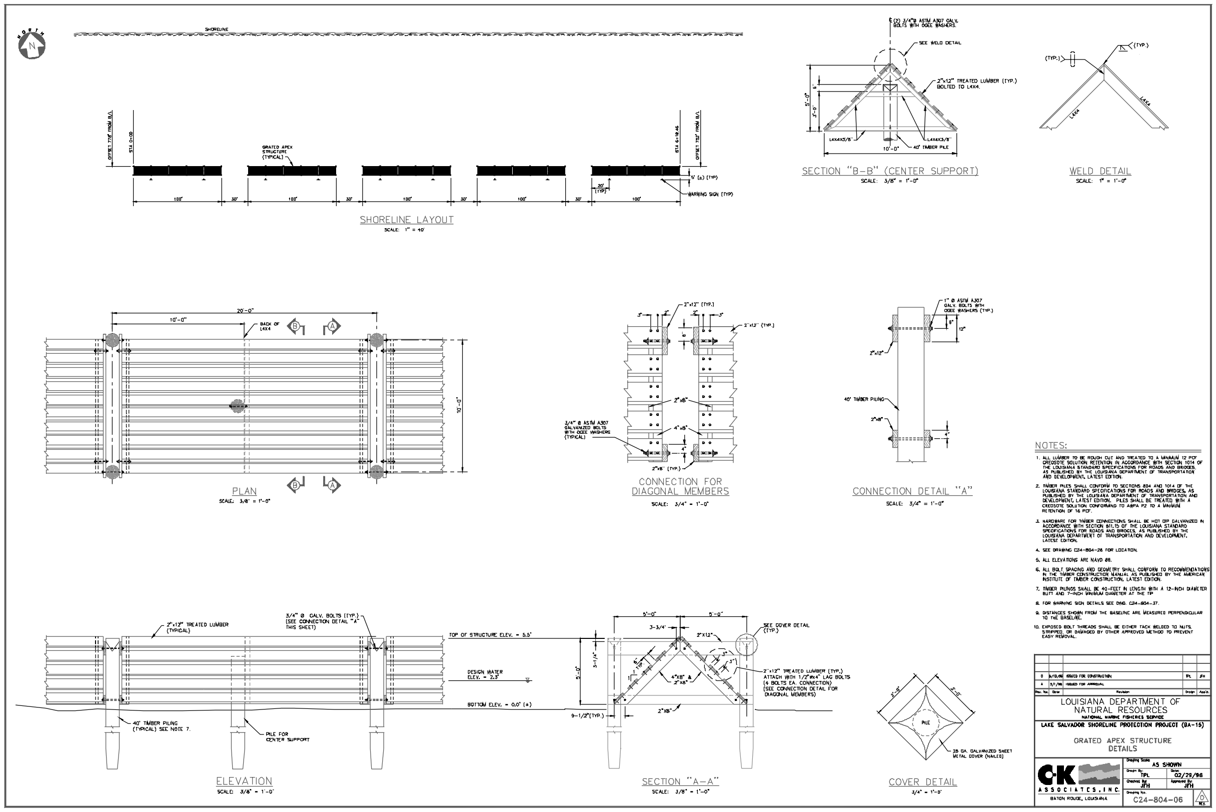
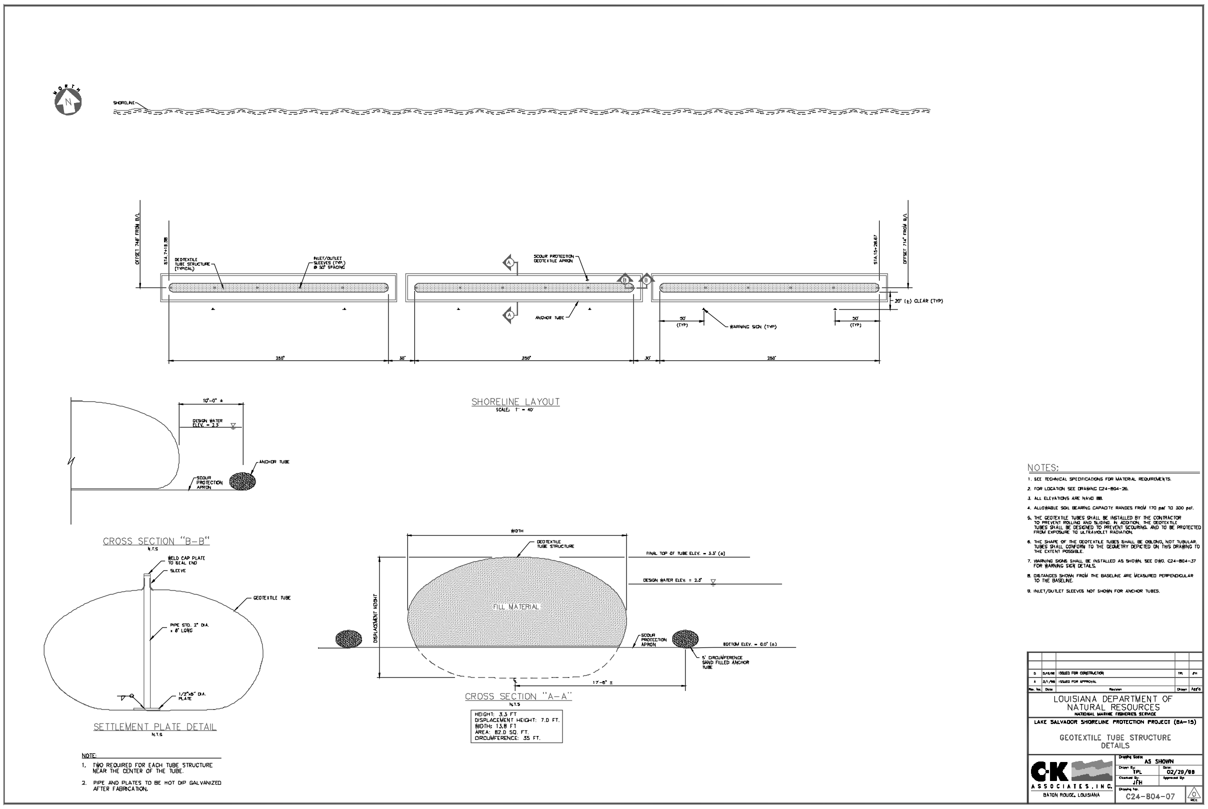
For further information on this report, please contact Glen Curole at (504) 447-0991 or the LDNR and CWPPRA homepages at http://www.savelawetlands.org and http://www.lacoast.gov, respectively.

# APPENDIX A

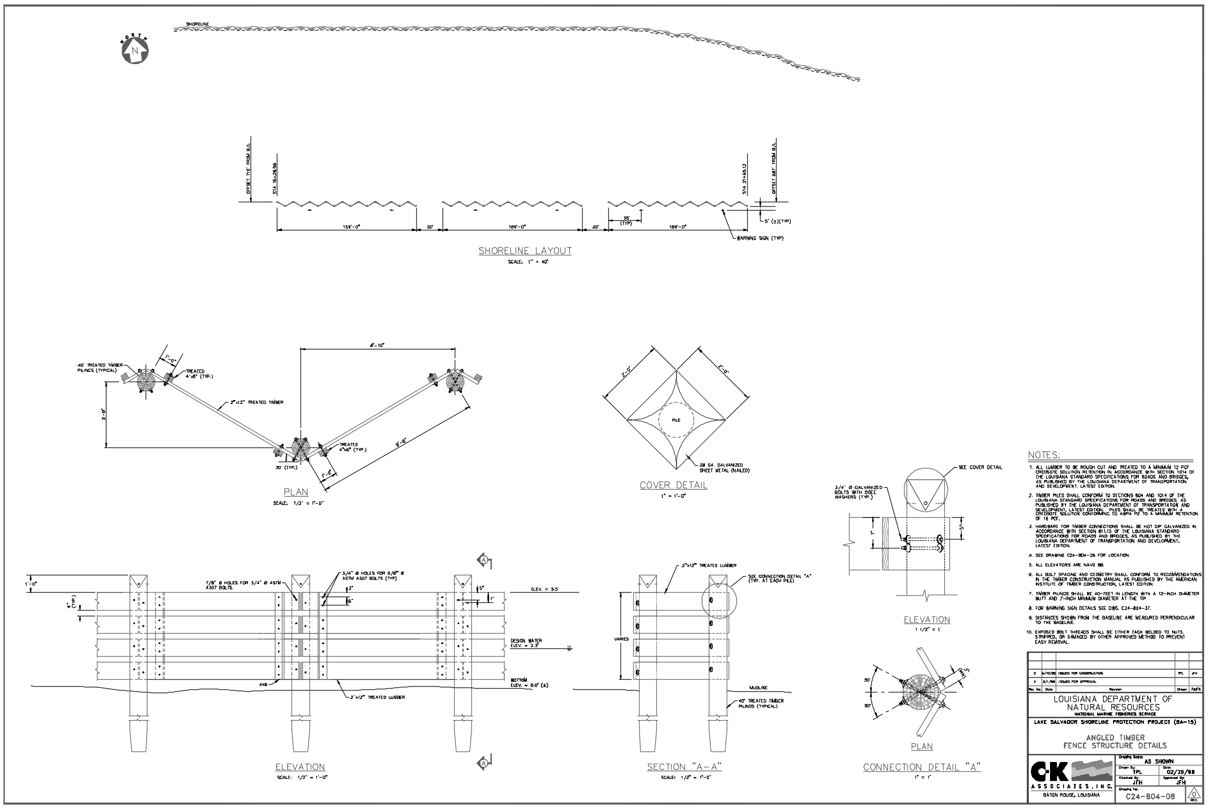
## Structure Designs



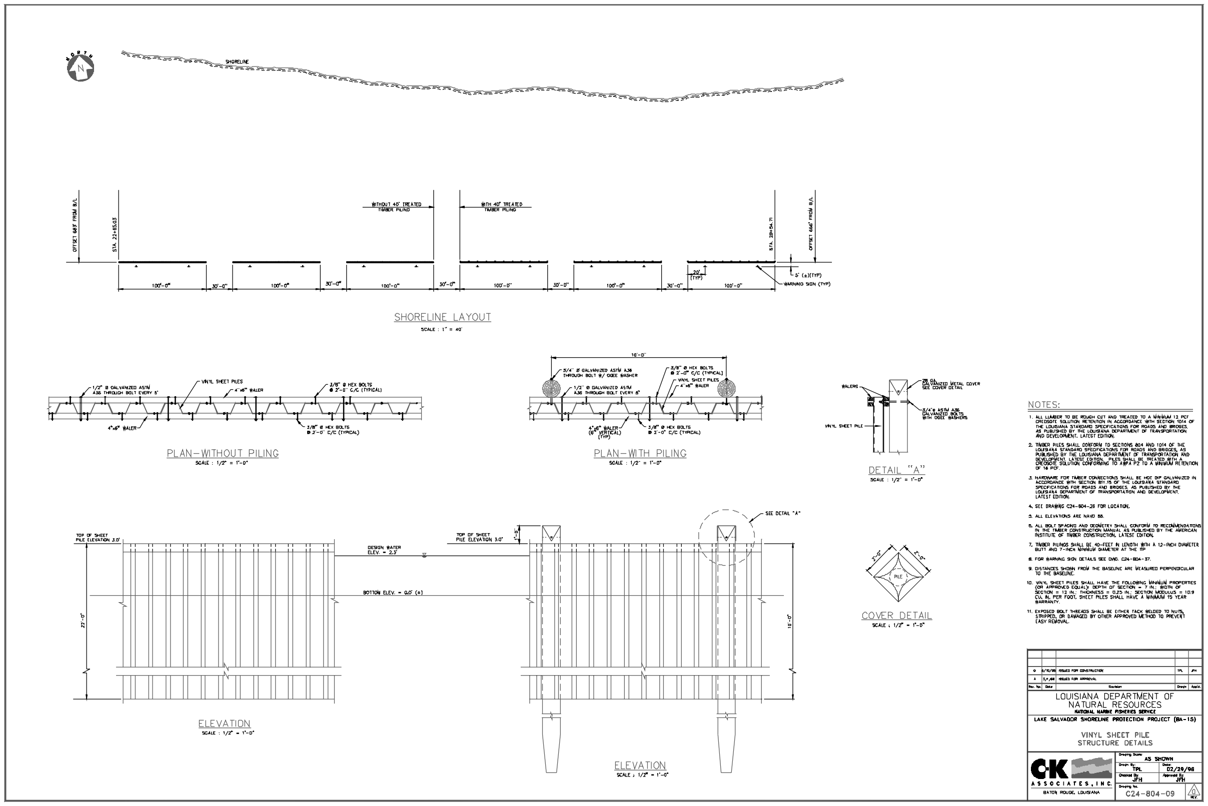

AutoCAD design drawing of typical Grated Apex structure construction and layout by C-K Associates, Inc. (not to scale).



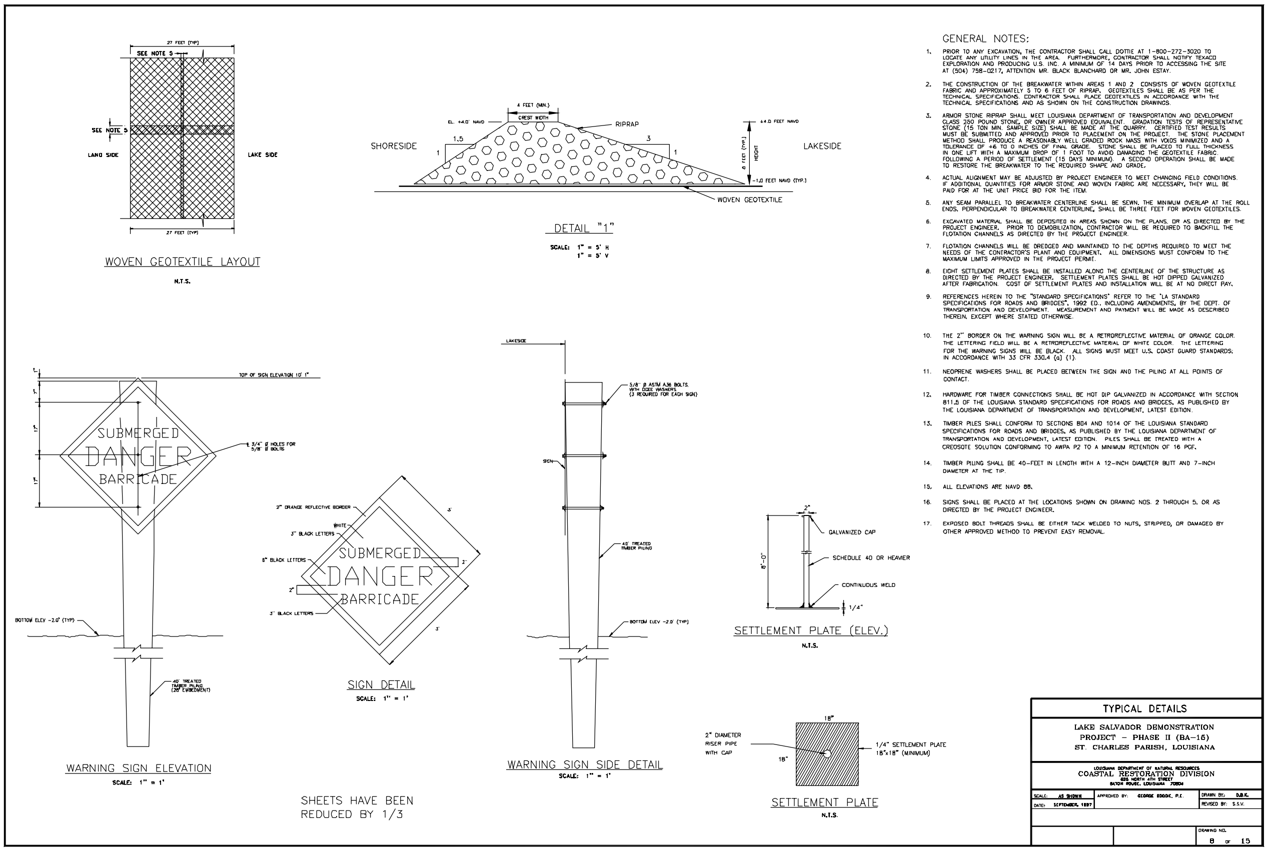

AutoCAD design drawing of typical Geotextile Tube structure construction and layout by C-K Associates, Inc. (not to scale).



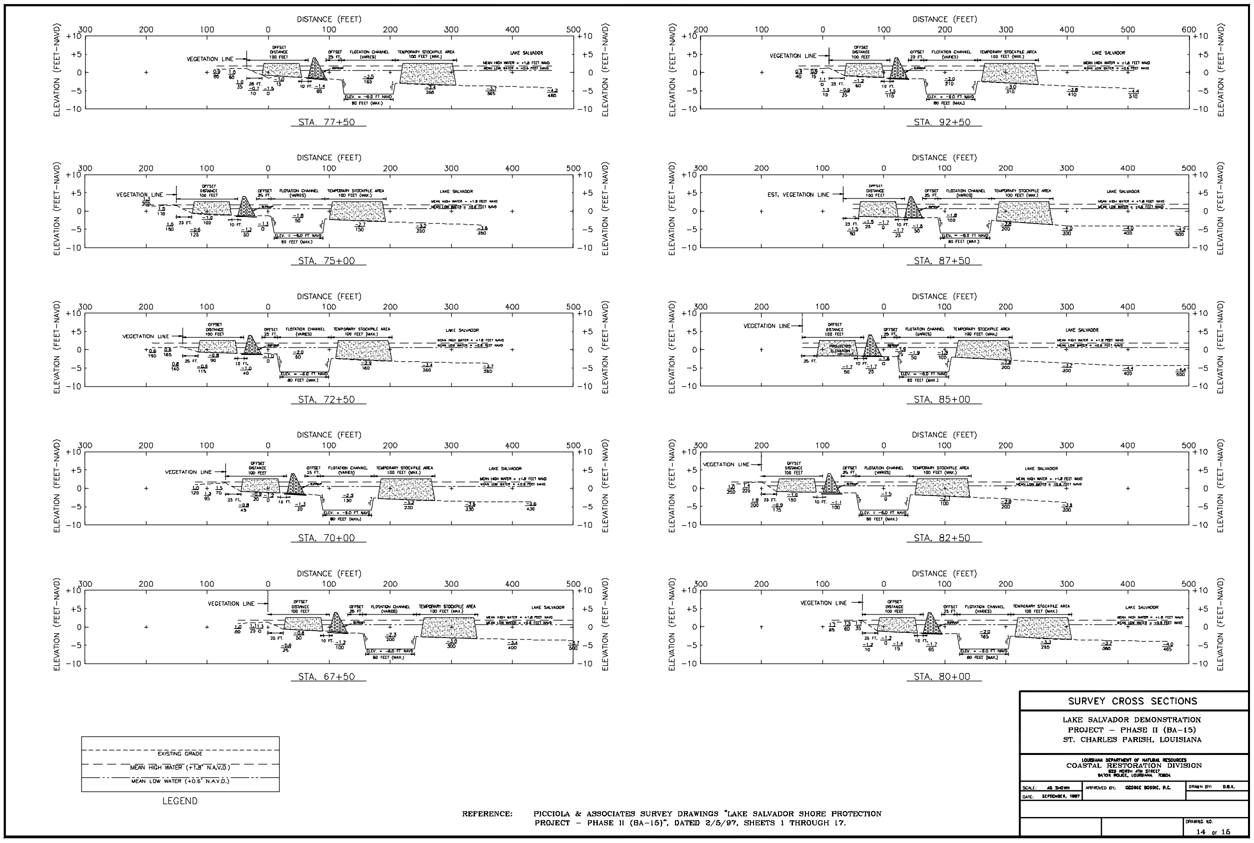

AutoCAD design drawing of typical Angled Timber Fence structure construction and layout by C-K Associates, Inc. (not to scale).




AutoCAD design drawing of typical Vinyl Sheet Pile structures construction and layout by C-K Associates, Inc. (not to scale).



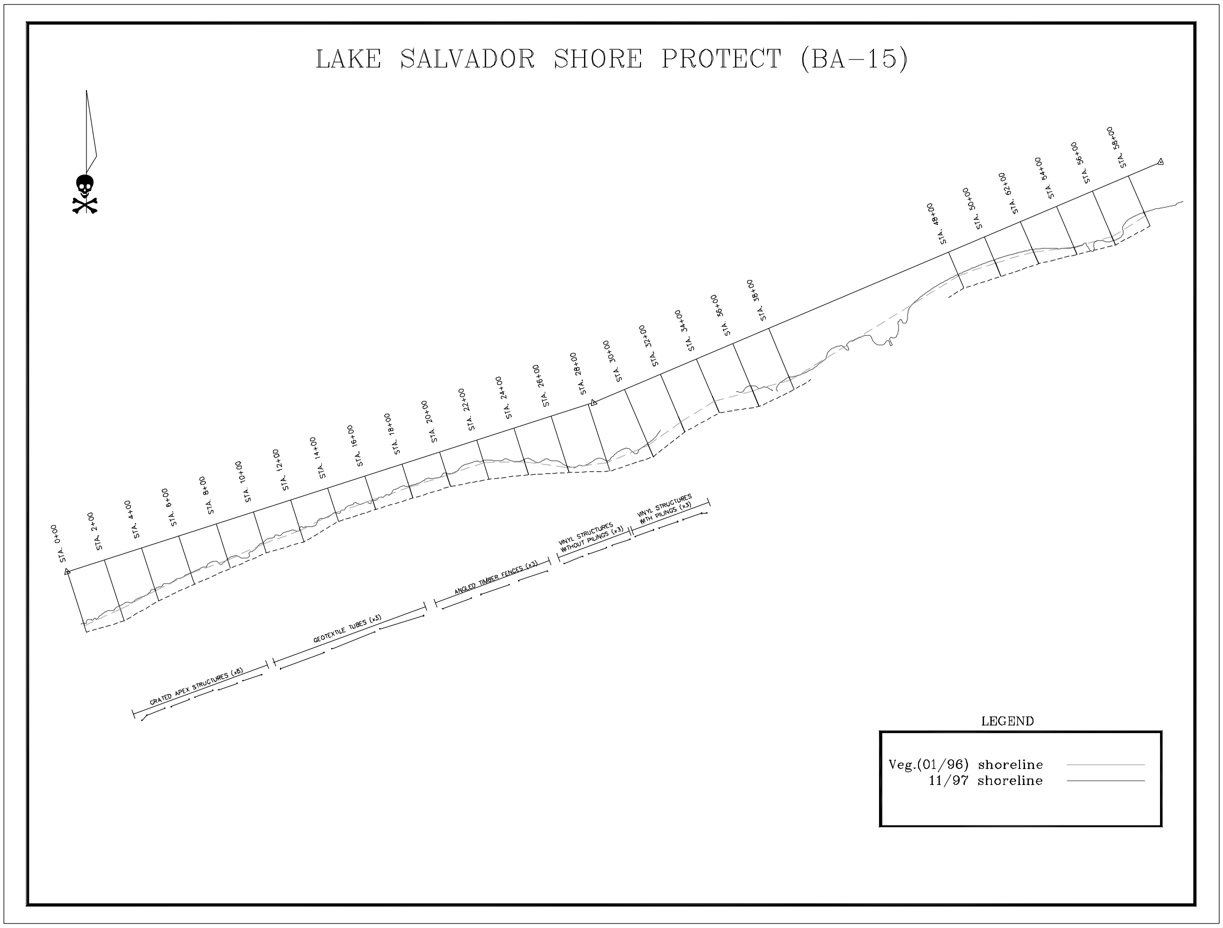

AutoCAD design drawing of typical rock structure construction and layout by LDNR/CRD (not to scale).



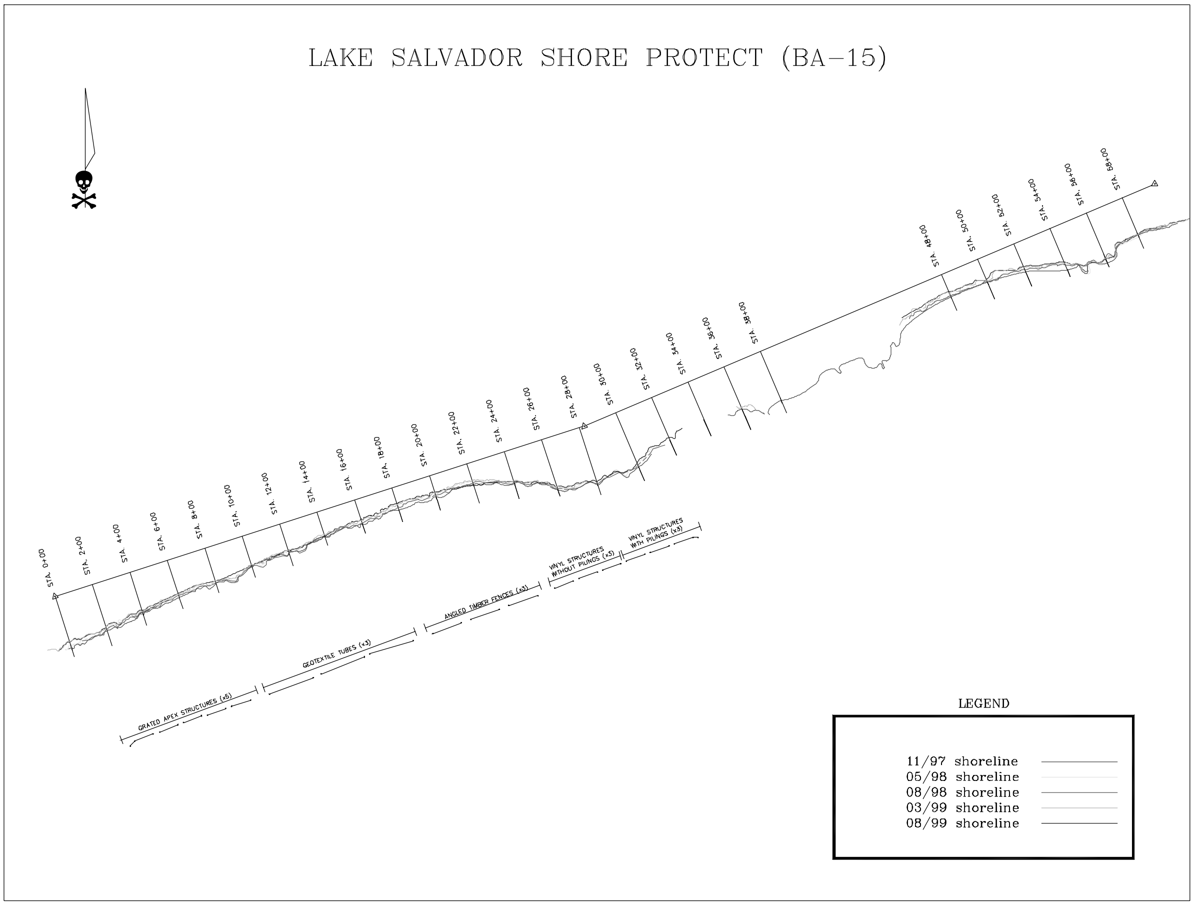

AutoCAD design drawing of typical Flotation Canal and dredge material placement by LDNR/CRD (not to scale).

# APPENDIX B

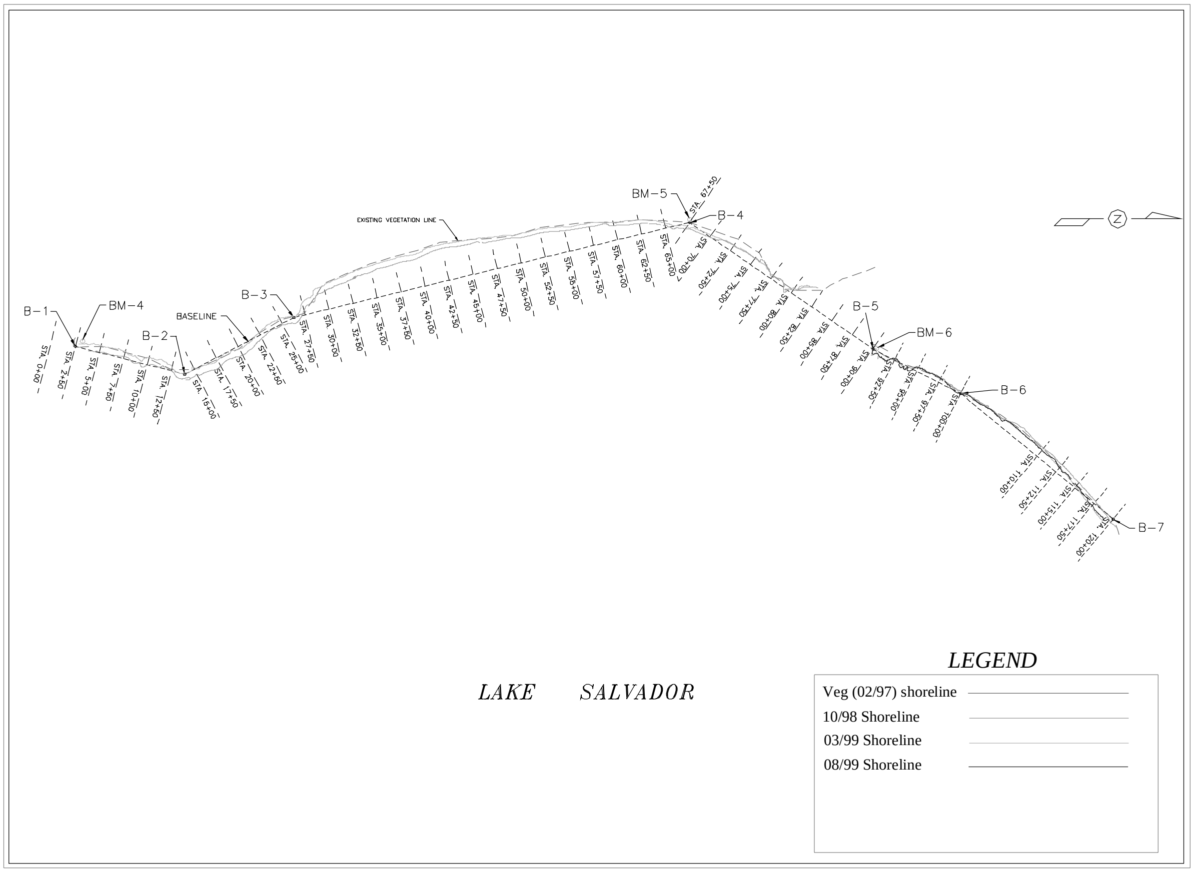
## Shoreline Positions




Pre-construction shoreline positions from Pyburn and Odum 1996 survey and LNDR/CRD DGPS data in November 1997 at Phase 1 of the Lake Salvador Shoreline Protection (BA-15) Demonstration project (not to scale).




Post-construction shoreline positions from DGPS data collected by LDNR/CRD and USGS/NWRC in November 1997, May 1998, August 1998, March 1999, and August 1999 at Phase 1 of the Lake Salvador Shoreline Protection (BA-15) Demonstration project (not to scale).




Pre- and Post-construction shoreline positions from Picciola and Assoc. 1997 survey and LNDR/CRD DGPS data in October 1998, March 1999, and August 1999 at Phase 2 of the Lake Salvador Shoreline Protection (BA-15) Demonstration project (not to scale).