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Gaillard Island Bio-degradable Geotube Test Project, Mobile Bay, Alabama

by Nathan D. Lovelace

PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) describes the use of a natural bio-degradable fabric for dredged material containment in a shallow water test at a demonstration project at the Gaillard Island dredged material placement area in Mobile Bay, AL. The primary purpose of the project was to test the physical limits and constructability of natural bio-degradable materials in the form of geotextile tubes (geotubes), turbidity curtains, and cross dikes. Bio-degradable materials were selected for the project to avoid the use of petroleum-based synthetics and issues associated with the long-term degradation of synthetics in the environment. Bio-degradable structures have been shown to be more hospitable to re-vegetation by deep-rooted plants and may provide a feasible construction alternative in regions that do not allow either synthetic or hard structures on dunes and coastal shorelines. Geotubes, anti-scour aprons, spur dikes, and turbidity curtains incorporated into the project were constructed with bio-degradable products. The performance of these materials was evaluated as part of the overall project. Information and data contained in project reports, including material selection, construction, and monitoring, are summarized herein.

BACKGROUND: The U.S. Army Corp of Engineers (USACE), Mobile District, has the responsibility for maintaining federally authorized navigation projects throughout its jurisdictional area. Approximately 6 million cubic yards of material is removed annually from the Mobile Harbor navigation project alone, at an annual cost of approximately 25 million dollars. Disposal of this material has become increasingly expensive and problematic due to disposal area restrictions and disposal area capacity limitations. Over the years, through the USACE Regional Sediment Management (RSM) Program efforts, an Inter-Agency Working Group (IWG) has been formed and has developed a mission statement that includes finding beneficial uses for local Mobile Bay dredged material. The IWG agreed that it was more desirable to keep Mobile Bay sediment within the natural system than to remove it and dispose of it in the currently approved ocean disposal sites. The IWG chose to explore beneficial placement technologies in support of a conceptual 1,000-acre salt water tidal marsh project in the Mobile Upper Bay with the possibilities of some portions constructed with soft containment.

Beneficial use of dredged material has become a popular and accepted alternative throughout the USACE navigation program. The use of dredged material for creating and restoring environmental resources is one area of emphasis under RSM as well as the Engineering With Nature initiative and aligns with a USACE culture of sustainability and resilience. Typically, some type of containment is required to retain dredged material placed at a beneficial use site, particularly in nearshore or open water areas. Berms and/or permanent structures alter the hydrodynamics of a site, require maintenance, are often aesthetically unappealing, and are prohibited in some areas. The use of a short-term bio-degradable structure offers a potentially more desirable alternative, providing temporary containment for dredged material placed as fill, allowing sufficient time for the material to consolidate, and for stabilizing vegetation to become established.

PROJECT DESCRIPTION: The test project encompassed approximately 4 acres along the northwestern leg of the Gaillard Island disposal site, located in the central western portion of Mobile Bay, AL. Island coordinates are approximately Latitude 30° 30' 31" N, and Longitude 88° 03' 04" W, 3 miles off the western shore of Mobile Bay (Figure 1). The site is accessible to the Mobile Bay channel reach of the Theodore Ship Channel. The depth of water in the project area ranges from 0 to 5 feet (ft) Mean Lower Low Water (MLLW). The existing shoreline is 100% rip-rap with the exception of a sand landing on the west end of the project area. The location is sheltered from the east by Gaillard Island, but exposed to 2 to 4 ft high waves from the open Mobile Bay to the north and ship wakes from the southwest and north. The average daily tide is 0.7 ft but can vary greatly in storm events.

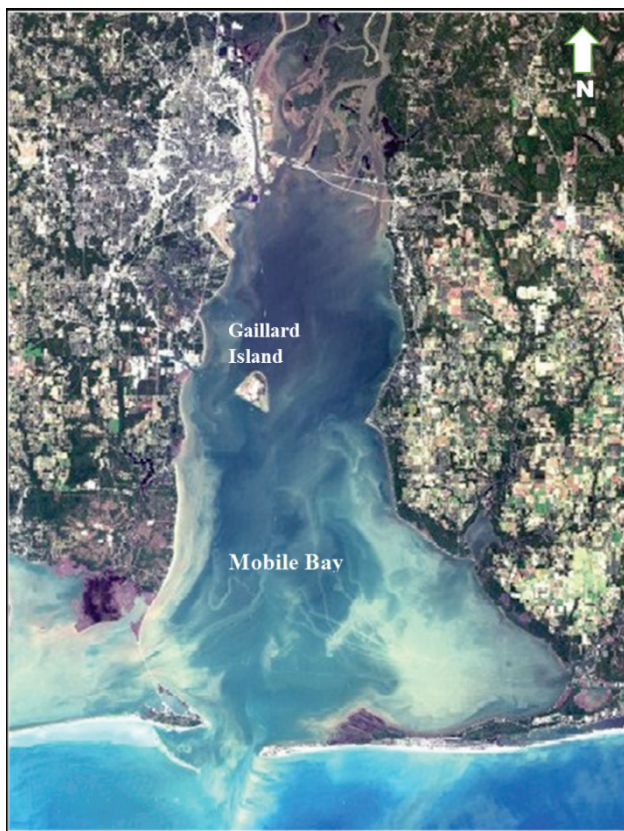


Figure 1. Geographic map depicting Gaillard Island, Mobile Bay, AL.

The scope of the project (Project Locus) called for a 1,500 ft long dike to create a small 4-acre lagoon off the southwest edge of Gaillard Island (Figures 2 and 3). The lagoon perimeter dike was constructed of sand from adjacent borrow excavated with an amphibious marsh buggy. Approximately 750 ft of the dike were covered by using bio-degradable geotubes, and the remaining 750 ft were covered with only the anti-scour aprons. An underwater weir at the outlet end of the site was constructed using a bio-degradable jute geotube. The top crest elevation of the geotube was set at a -1 ft MLLW to allow for tidal influences throughout the life of the site. Internal and external turbidity curtains were constructed from burlap fabric, and one cross-dike was constructed using round hay bales. Immediately following construction of the test site, navigation channel dredge material was pumped into the site to test the turbidity curtains, hay bales, and the underwater weir. Figure 4 shows the completed project with the bio-degradable turbidity curtain, hay bale weir, underwater geotube weir, and composite turbidity curtain.

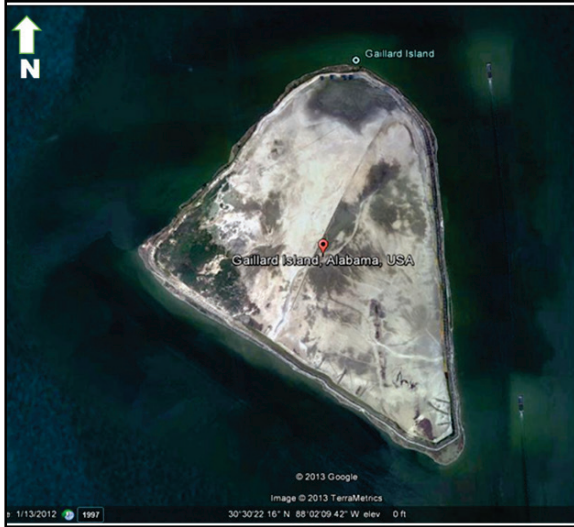


Figure 2. Gaillard Island, Mobile Bay, AL.

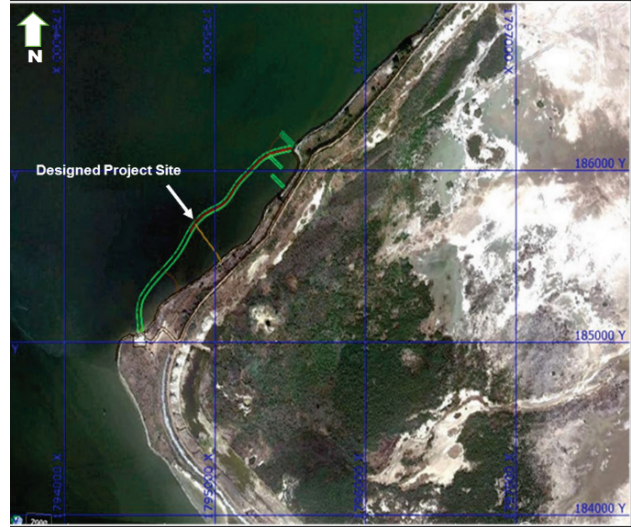


Figure 3. Project Locus, Gaillard Island.

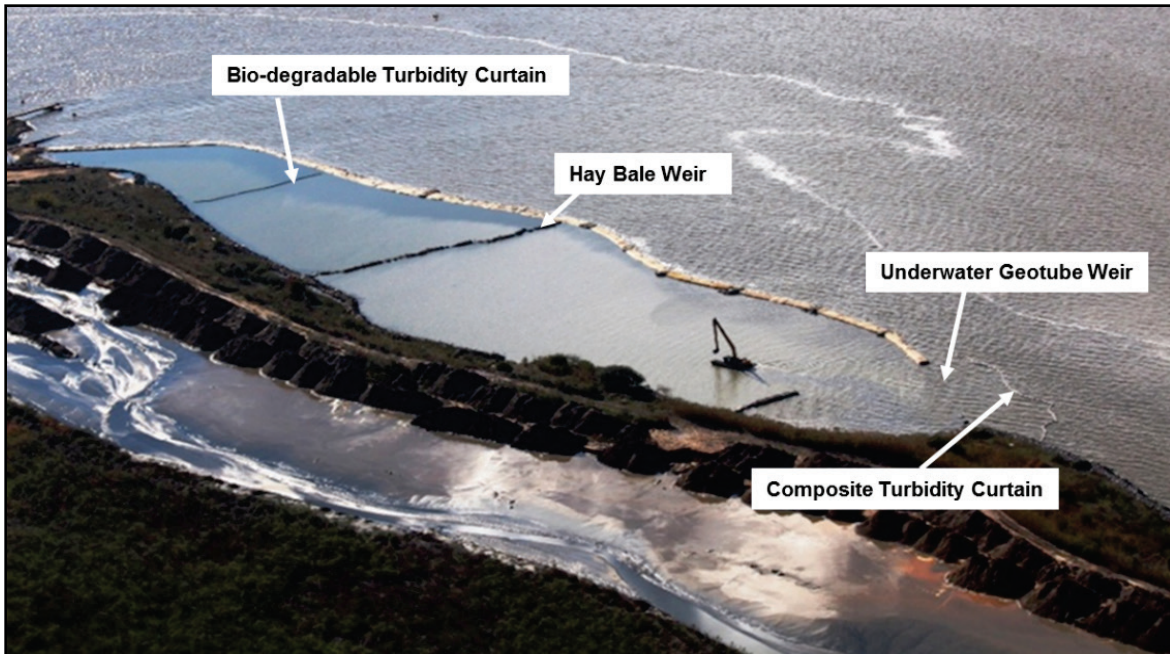


Figure 4. Project Locus completed dredged material containment area.

MATERIAL SELECTION AND EVALUATION: Jute burlap and coir mat have been used in the United States for many years where synthetic or hard structures are prohibited. Coir mat was determined to not be cost effective for hydraulically filled geotubes; therefore, jute burlap material was selected for the project. Jute is a vegetable fiber that can be spun into coarse and strong threads and is second to cotton as one of the most affordable natural fibers produced. Jute is woven into mats and used for many different construction applications, particularly erosion control. Jute burlap fibers have a high strength-to-weight ratio and can be easily manufactured into large products by utilizing machinery common to the synthetic geotextile industry (Figure 5). There are a number of other materials of which burlap is made including cotton, hemp, bamboo, and other fibrous plants; however, all these materials lack the strength of jute and are not available in the necessary quantities or are too costly.



Figure 5. Jute burlap.

Since jute is not grown in North America, it must be imported from geographic areas such as India and Bangladesh. The cost of importing burlap is not prohibitively expensive if marine shipping is used and bulk quantities are ordered. There is an almost unlimited supply of these materials, and the importing network is well established. The standard order-to-delivery time for materials is 8 weeks from the source to a U.S. manufacturing plant. A minimum order is one shipping container with 38,000 linear yards of material shipped in bales. Once in the U.S. plant, with 4- to 6-week lead time, modern textile machines can construct anti-scour aprons, geotubes, and turbidity booms for large projects. This makes the total time needed to deliver products to the construction site after ordering to be 14 to 20 weeks, including allowing for payments and contracts.

The burlap product was tested utilizing standard American Society of Testing Materials test methods for material and seam strength. Four layers of 10-ounce (oz) burlap were necessary to withstand the pressures required to fill the geotubes to a height of 4 ft in the dry. As a result of this test project, new extra-heavy-duty 20 oz jute burlap has been tested in the laboratory but has yet to be constructed in the field. The 20 oz burlap has very small pore openings, which is expected to increase retention of fine materials, thus resulting in a faster filling rate and requiring fewer cloth layers. Minimizing layers also decreases manufacturing labor and the overall cost of the product.

Fishtec Inc. of Daytona Beach, FL, conducted flow testing on the burlap bags to determine whether the materials could pass water at a rate that would permit hydraulic filling. The test showed that hydraulic filling would be feasible provided the fill contained less than 10% fines (operationally defined as particle sizes between 0.0039 and 0.0625 millimeters [mm]). A geotube 50 ft long by 3 ft circumference was constructed of two layers of 10 oz burlap and field tested by filling with a 6-inch (in.)-diameter (diam) line and a flow rate of 1,500 gallons per minute at 20 to 40 pounds per square inch pressure. The geotube was filled within 15 minutes (min) with very little sand loss and no seam failures. Scaling up to larger circumference geotubes (e.g., 45 ft) was considered feasible with additional layer requirements based on material stress-testing results.

Burlap used in salt water environments is typically treated at the factory in India with two chemicals that are used to rot-proof and water-repellant coat the fabric (Benzalkonium Chloride, and NUVA-1541 of Clariant Products [Switzerland] Ltd). One of the seven 100 ft long geotubes used in the project was factory waterproofed and field tested. Readily available off-the-shelf waterproofing and sealer products advertised as “environmentally inert” (Olympic Waterproofing

and Sealant, and Thompson's WaterSeal) were also tested on untreated fabric as a possible alternative to special-order factory-waterproofed fabric. Both sealants were applied with a hand sprayer at 0.2 gallons per square foot. The Thompson's WaterSeal required large amounts to saturate the burlap and took days to dry. There was no apparent advantage associated with either water sealant; however, it appeared to slow the flow rates through the weave openings. Two other coatings that were field tested included sand shoveled over the filled bags and brushed in with a broom and clay plastered over the top of the geotube as a paste to slow the effects of sun degradation. Due to wave overtopping from several winter storms, neither could be properly analyzed.

PROJECT DESIGN: The project layout was designed to take advantage of an area of shoreline on the southeast corner of Gaillard Island between two points of land. The final configuration was designed to make the shoreline parallel to the rest of that part of the island, allowing waves from all directions to roll along the shore and minimize erosion of the dike. A typical cross section of the planned sand and geotube dikes is shown in Figure 6.

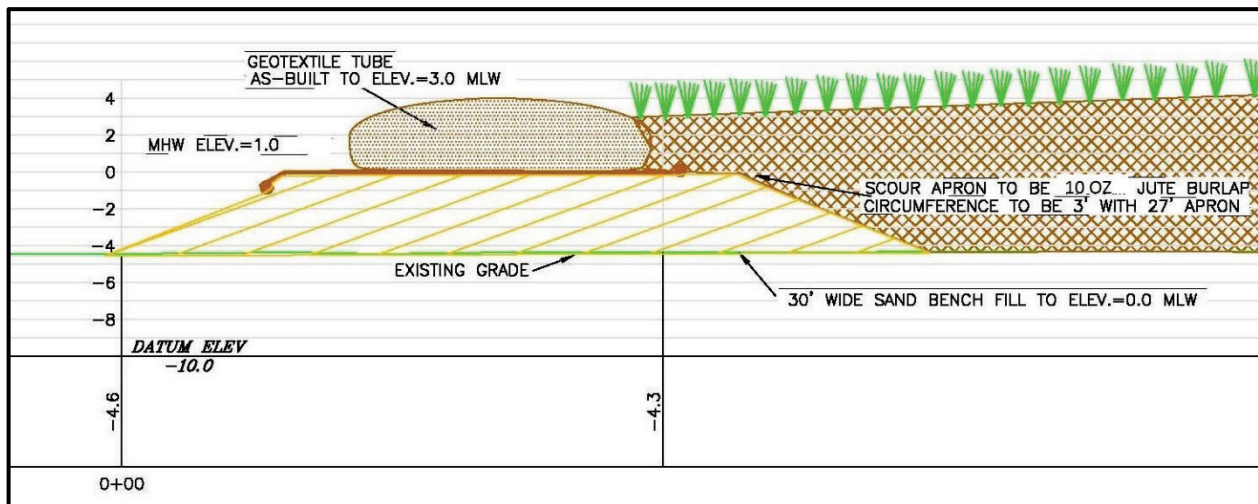


Figure 6. Original typical dike cross section.

A hydrographic and topographic survey was conducted for section and profile design purposes. The median perimeter depth of the project was found to be -4.5 ft MLLW. The dikes and top of the geotubes were designed to match the grade of the top of the existing rip-rap armoring Gaillard Island, which is at +3 ft MLLW.

Once the project profiles and sections were created, the number of layers of material needed to withstand the pressures produced by the geotube filling process was calculated based on the manufacturer's quality certifications. The materials list was then transmitted to an importer to get a schedule of material cost and delivery. To meet project timelines, materials currently in stock in the United States had to be utilized. The time from the approval of the contract to material delivery at the project site was fewer than 3 weeks.

Turbidity curtains were also designed for the project. Buoyancy calculations were done for different types of flotation and for different sizes of anchoring geotubes. (Additional design information for the turbidity curtains is discussed later in this document.) Two internal sand spur

dikes were designed to contain dredge effluent and allow for sediment settling. A hay bale weir was designed to determine if round hay bales could be used as an effective weir/filter system. Buoyancy calculations were performed on the hay bales. A test bale was put into water to determine saturation time, which was found to be at least 48 to 76 hours (hr) to achieve 90% submergence below the water surface. Prior to saturation, the bales proved difficult to secure in place during tidal and wave fluctuations in the open bay.

CONSTRUCTION: The burlap products were transported overland by tractor trailer. Maximum length of the rolls was 100 ft (geotube length) to facilitate handling. A 12 ft × 30 ft work barge was used to deliver materials to the site (Figure 7). Two trips were required due to weight limitations. A hydraulic crane and excavator were used for unloading.

All geotubes were filled using the same equipment, shown in Figure 8. A submerged, hydraulic-powered 8 in. diam pump with a variable speed power pack was used. Intake and outlet lines were sized to keep the pressure of the water at a level that could overcome the dynamic head of the geotube. Higher flow was required to compensate for the greater pore size of the burlap, as compared to standard geo-synthetics. Constant adjustment of the flow rate was required when filling the anchor geotubes to prevent blocking of the geotubes with sand.



Figure 7. Transporting burlap rolls on work barge.



Figure 8. Barge-mounted geotube filling equipment.

The sand berm was constructed using an amphibious excavator (Figure 9). The berm was constructed primarily of sand on top of silty sand containing some clay. Under favorable conditions, up to 130 ft of dike length could be constructed per day. To minimize loss of material during construction, the material was stockpiled in the center of the alignment, and the slopes were subsequently dressed prior to the installation of the anti-scour aprons and geotubes. Up to 30% of the dike material would be lost if the anti-scour aprons were not installed the same day.

The anti-scour aprons were deployed by rolling the 110 ft long by 27 ft wide burlap rolls by hand or with the assistance of the excavator (Figure 10). The material could be easily positioned for placement by two people. The aprons were inspected for holes and/or bad stitching prior to filling the anchor geotubes. The angles in the dike were potentially problematic due to the additional overlap required to accommodate the angles. This created the potential for binding of the inner and outer anchor geotubes. Holding geotubes covered the overlap of the anti-scour aprons. These had to be filled quickly to prevent erosion of the berm at the junctions.



Figure 9. Dike construction with amphibious excavator.



Figure 10. Anti-scour apron placement.

The 100 ft long anti-scour anchor geotubes were constructed with two layers of 10 oz jute burlap with a 1 to 2 mm pore size. The material allowed a large amount of water and fines to pass through the burlap (Figure 11). The anchor geotubes were initially filled from only one end, using a very diluted sand slurry. The sand content and filling pressure were ultimately increased to reduce the filling time to approximately 30 min. Care had to be taken not to push too much sand through the geotubes to prevent blocking of the geotube. A crew of at least four qualified persons was required to perform the filling of the geotubes, including a superintendent familiar with the process. The geotubes were filled to a nominal height of 1.2 to 1.5 ft. Due to limitations in the bearing capacity of the supporting sand, the anchor geotubes were constructed at an elevation of -1 ft MLLW on the outside of the dike and +1 ft MLLW on the inside. The outside geotubes settled to -2 ft MLLW within 1 to 2 days under normal wave conditions.

The specified nominal 30 ft circumference geotubes had an actual circumference of 26 ft due to stitching loss. Geotube failure occurred when filled to a height of 4 ft. This led the installer to believe that filling the geotubes to a design height of only 3.0 ft would prevent failure. The elevation of the sand bench supporting the geotubes was therefore adjusted in the field from the -2 ft MLLW originally specified to 0.0 ft MLLW to ensure a minimum dike crest of +3.0 ft MLLW. The higher bench height proved to be advantageous for constructing the anti-scour geotubes and for placing the geotubes. Geotube filling operations are shown in Figure 12. There was substantial loss of fine material through the fabric during filling. Additional fill had to be excavated to compensate for this volume loss, resulting in extended fill times. The factory-waterproofed geotube was installed in the same manner as the remainder of the geotubes. The differences noted at the time of installation was that the surface of the treated geotubes dried more quickly than the untreated geotubes, and it appeared the apparent opening size had been reduced, which resulted in higher fine content in the geotube. Neither the sand cover nor the clay cover was successful; both washed away during overtopping of the geotubes.



Figure 11. Release of water and fines from anchor geotubes during filling.



Figure 12. Filling operations for the 26 ft circumference burlap geotubes.

Turbidity curtains. Two types of turbidity curtains were installed on the site. Both were 100% bottom sealing, requiring no cables or anchors, and were easily and quickly installed (Figure 13). The purpose of the interior curtain was to observe its performance as an interior barrier, similar to a training levee. The intent was to pump material against it until failure and assess its potential effectiveness in open-water pumping situations. The anchor geotube was filled easily under 4 to 5 ft of water. A 1 in. diam hemp rope was incorporated into the top of the curtain to add shear strength and proved to be a component critical to the integrity of the curtain. The interior curtain performed well and held back up to 4 ft of material before it was pushed under and buried (Figure 14).

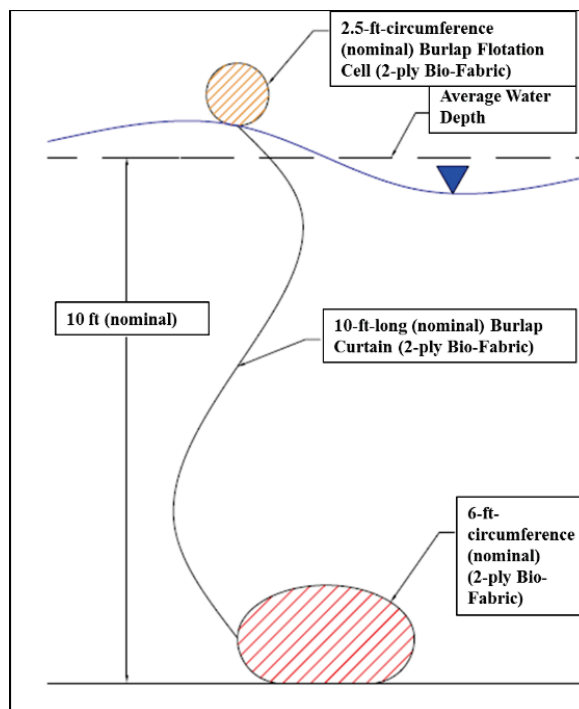


Figure 13. Turbidity curtain design.

The exterior curtain was a hybrid bio-degradable/synthetic turbidity barrier surrounding the underwater weir at the discharge end of the site (Figure 15). The curtain was constructed of

traditional synthetics with a bio-degradable ballast. In shallow coastal environments, it may be desirable to use this type of product to control turbidity during pumping operations and later remove the curtain but leave the ballast in place to support the toe of the material that the boom contained. Wave action caused minor tearing away of the synthetic curtain from the burlap anchor geotube. Redesign will be necessary for use in high-energy environments such as this. This design would most likely be adequate in semi-protected areas. The exterior curtain otherwise performed well by controlling turbidity at the weir, and the curtain was easily detached from the ballast geotube when removed from service.



Figure 14. Burlap silt interior curtain following dredge disposal operations.



Figure 15. Hybrid synthetic/burlap exterior curtain turbidity barrier.

Hay bale weir. The hay bale weir was constructed by utilizing 50 1,000 pound (lb) hay bales (Figure 16). The bales were strung through the middle with a 1 in. diam hemp line, creating a chain of bales. The chain of bales was held in place by 6 in. × 6 in. × 20 ft posts that were spaced 25 ft apart and driven into the bottom. Once saturated, the hay bale weir performed well but separated and dispersed during winter storm events. Labor and transport cost for these materials was considerable, but there appears to be potential for their use in a low-energy environment.



Figure 16. Hay bale weir.

CONCLUSIONS: The test project resulted in successfully testing several bio-degradable containment options for managing sandy and fine-grain dredge material for beneficial use projects. The 3-week-long Gaillard Island test project was one of the first in the United States to be constructed out of 100% natural bio-degradable products except for the exterior turbidity barrier curtain, which was a hybrid bio-degradable/synthetic material. The project tested and

documented the performance of jute burlap silt curtains, anti-scour aprons, geotubes, and a hay bale weir.

Generally, the double-stitched jute burlap structures performed well. One large geotube failure occurred due to a smaller-than-designed geotube circumference being used at one location. Failure occurred when the crew attempted to fill the geotube to the design height. The sand bench height was therefore adjusted to accommodate the smaller fill height of the geotubes, which ultimately facilitated the installation of the anti-scour curtains and the geotubes. The anchor geotubes on the anti-scour curtains performed well with no failures occurring, but a larger circumference and heavier fabric would provide a geotube that is easier to fill and function as a more substantial anchor. The anchor geotubes settled through the sand and created voids under the burlap anti-scour curtains. Anchor geotubes with 4 ft circumference, and with 4-ply burlap or with a tighter weave, are recommended. An excessive amount of sediment was lost through the 1 to 2 mm openings in the anchor geotubes.

A general elevation loss of 0.1 to 0.2 ft was observed in the dikes over a period of 2 weeks. The uncompacted material in the sand bench with anti-scour curtains only slumped to its natural angle of repose of 20:1, resulting in a lower-than-intended crest elevation. Anti-scour aprons also needed to be installed quickly to minimize material losses from the bench. Up to 30% of the dike material was lost when the anti-scour curtains were not installed on the same day as the dike was constructed.

The jute geotubes performed very similarly to a synthetic geotube that was also utilized on site. The finished product was a geotube with 100% compacted sand. Pumping time was observed to be a function of the percentage of fines in the sand, with filling times estimated to increase by 25% to 40% with higher fines contents.

The underwater jute geotube weir stayed in place and worked without an anti-scour apron to stabilize it. However, anti-scour aprons are likely necessary where velocities and wave currents exceed 1 to 2 miles per hour. The bio-degradable and hybrid turbidity curtains, and hay bale weir, also performed as designed. The silt curtains are most suitable for inshore or protected areas; however, they could be suitable for higher energy environments with a heavier (e.g., 20 oz) fabric. Testing on a small scale before any large-scale production is recommended.

The demonstration project generated information sufficient to facilitate design of burlap geotubes for varied sediment types, design heights, and wave heights. Design decisions for other projects may be made based on assessments of the field performance at this demonstration project. Based on the success of the demonstration project, the materials used and the construction methods were sound although some modifications are recommended for future projects. The fabric weight and pore size selected must take into account the characteristics of the fill material to minimize material loss while also preventing binding or blocking of the geotubes. For future projects, 20 oz burlap is recommended. Factory waterproofing must yield a strong and long-lasting product, specifically designed for the desired application. Further testing is needed to evaluate the life expectancy of treated vs. untreated materials, however, and the ecological impacts of the chemicals used in treating the materials should be evaluated.

While the double-stitched jute burlap structures generally performed well, unexpected ship wakes compromised a few spots. These ship wakes and waves produced by several severe winter storms

threatened the stability of the structures and were more damaging than the anticipated wind-driven waves. Following one of the major storm fronts, the dike was eroded, and some areas had no bench remaining on top. However, the anchor geotubes and fabric remained in place. Rapid erosion of the anti-scour curtains required construction of a dune and beach on the north side of the project area to preserve the dike crest width. Wave action also tore the external turbidity curtain from the burlap anchor geotube in some places. Greater longevity would be expected in low-energy environments, such as marshes.

Immediately after the site was constructed, dredge material from the Theodore Ship Channel was pumped into both Gaillard Island and the test site using a “Y” valve in the pipeline to maintain control of the 30 in. diam pipe flow rates. The dredge of choice for the 4-acre site would have been an 8 to 10 in. dredge; however, the timing and equipment availability were non-negotiable at that time. Surprisingly, the interior components (turbidity curtains and hay bales) handled the entire flow from the 30 in. dredge almost without compromise. It was assumed that pumping times would be short; however, for several days the site handled 10 hr of uninterrupted pumping. As expected, the site filled much better at the material placement end and progressively achieved lower elevations following each test barrier. Unfortunately, extremely rough winter Mobile Bay conditions undermined the dike foundation material, lowering the jute geotubes below the surface of the water and making it difficult to monitor their longevity. It was confirmed that the jute geotubes had maintained their integrity at least 9 to 12 months post-placement, of which half of that time was in a submerged state.

ADDITIONAL INFORMATION: This effort was conducted as part of the U.S. Army Corps of Engineers (USACE) Regional Sediment Management (RSM) Program. This Coastal and Hydraulics Engineering Technical Note (CHETN) was prepared by Nathan D. Lovelace, U.S. Army Engineer District, Mobile (SAM) and was extracted from the Project Report prepared for SAM (Okurowski, n.d.). Additional information regarding the RSM Program can be found at the RSM website <http://rsm.usace.army.mil> or by contacting the USACE RSM Program Manager, Linda Lillycrop, USACE Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL) at Linda.S.Lillycrop@usace.army.mil. Information pertaining to this CHETN may be obtained from the Mobile District Point of Contact, Nathan D. Lovelace at Nathan.D.Lovelace@usace.army.mil.

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REFERENCE

Okurowski, R. n.d. *Bio-degradable containment structure demonstration/Gaillard Island disposal area W91278-11-D-0001*. Project report to U.S. Army Engineer District, Mobile. Hyannis, MA: Land and Sea Engineering, LLC.

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