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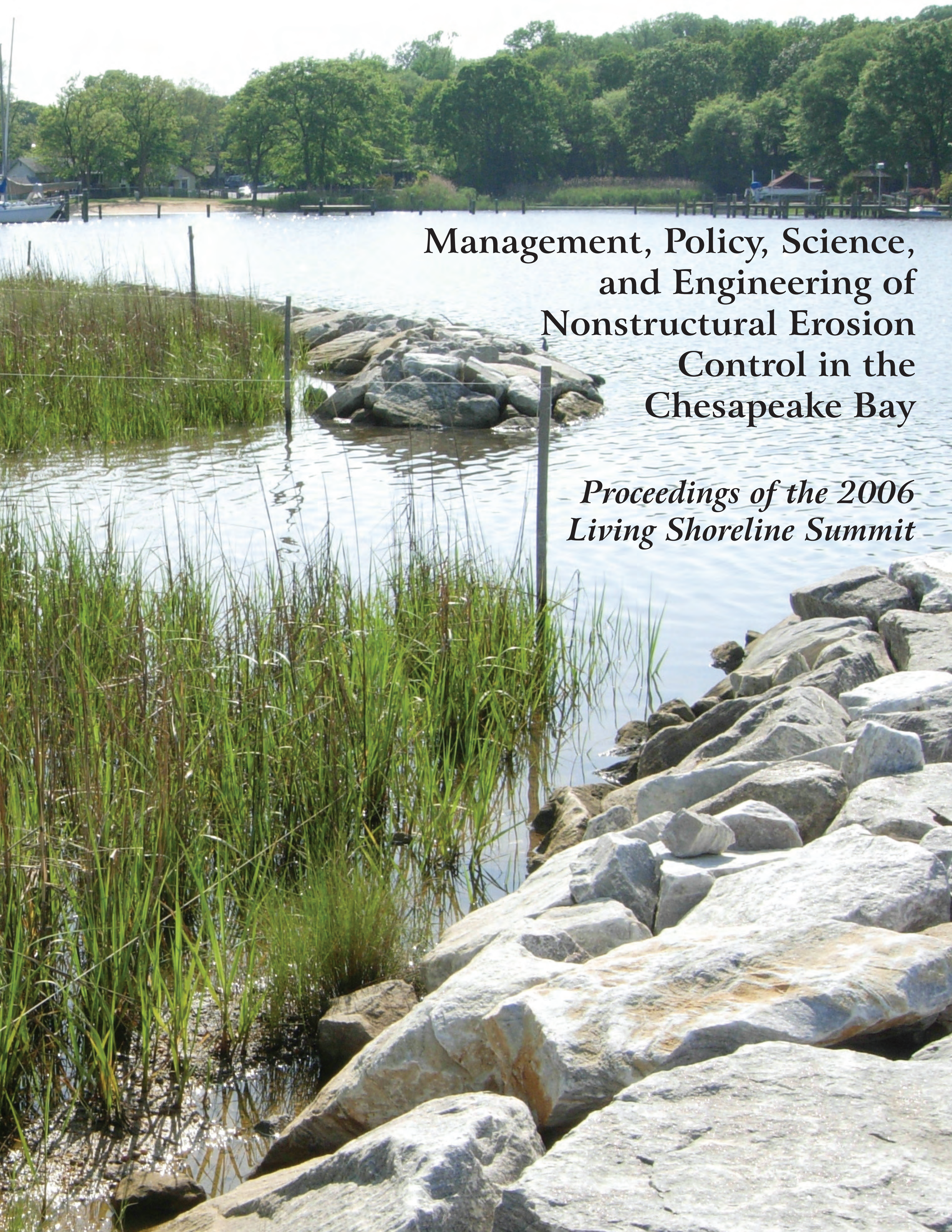

Management, Policy, Science, and Engineering of Nonstructural Erosion Control in the Chesapeake Bay

Proceedings of the 2006 Living Shoreline Summit

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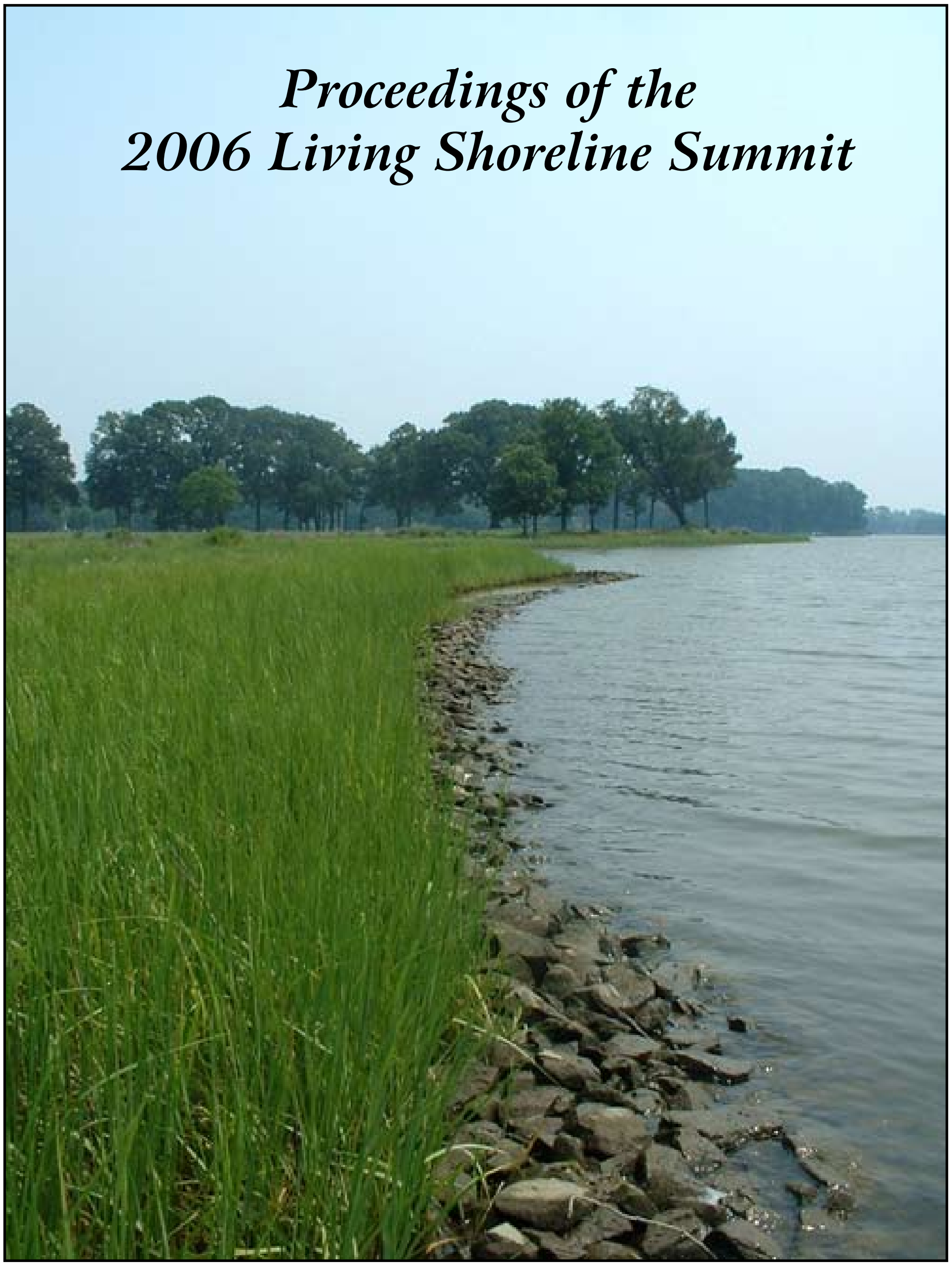

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ABSTRACT

Shoreline stabilization methods that emphasize the use of tidal marshes and riparian vegetation are encouraged as a baseline defense for tidal shoreline erosion in Virginia. The effectiveness of three of these methods in preventing erosion and providing habitat was evaluated, including marsh stabilization structures (marsh toe revetments and sills), planted tidal marshes, and bank grading. This evaluation includes results from a recent field survey of 36 tidal marsh stabilization structures, permitting records, and other monitoring data. Marsh structures effectively reduced erosion of fringing and embayed marshes but were not as effective for gradually disappearing spit marshes. Adverse impacts of restricted tidal exchange were observed where the revetment height was more than one foot above the mean high water elevation. The two nonstructural methods provided both habitat and erosion protection, but were generally not as effective as marsh structures. Planted marshes were most effective where regular high tides do not reach the upland bank. Graded banks that included a flat area for marsh vegetation at the toe were more effective than banks graded steeply landward from the toe. Graded banks maintained as lawns were not as effective for preventing storm erosion as densely vegetated slopes. Additional research is needed to investigate how sand fill and fiber materials can be used beneficially to enhance tidal salt marshes and beaches for erosion protection.

INTRODUCTION

Erosion control structures are widely used on Virginia's tidal shorelines to protect private and public property. Flood reduction, improving riparian access and landscape aesthetics, improving navigation, and creating recreational beaches are other motivating factors for shoreline modifications. Shoreline armoring, or hardening, refers to the cumulative impact of fixed structures, such as vertical bulkheads, stone revetments, offshore breakwaters, groins, and jetties. These structures are effective for protecting the upland from wave attack and erosion, yet it is now apparent that they may not be appropriate for all shoreline types. Multiple structures installed in a piecemeal fashion degrade estuarine ecosystem conditions due to increased wave reflection and water depth, decreased sediment supply, tidal wetland and beach loss, and forest fragmentation (1-3).

Coastal erosion management programs generally discourage shoreline modifications unless they are absolutely necessary to protect property from coastal hazards. Where erosion must be stabilized, the "living shorelines" approach suggests using environmentally sensitive protection. Methods that enhance tidal shoreline habitats are encouraged where such methods offer effective stabilization (4,5).

Nonstructural methods such as planting tidal marshes, bank grading, and beach nourishment are feasible for shorelines experiencing mild erosion. These low energy shorelines tend to occur where the widest fetch is less than 1 mile (5-7). Planted marshes and other nonstructural methods are not as effective if the wave climate is excessive, the intertidal area is narrow, if there is no sand entrapment by the marsh, or there is regular boat wake influence (4,6).

Some techniques include structures but also incorporate wetland and upland vegetation that acts as an erosion buffer and provides other ecological functions (8). These "hybrid" type projects, such as marsh toe revetments and marsh sills, incorporate both nonstructural and structural elements for successful stabilization. The strategically placed structure forces waves to break channelward from the upland bank with only minimal alteration to the wave climate. A dense vegetation cover or wide sand beach provides additional wave dissipation (6,8).

According to a database maintained by the Center for Coastal Resources Management at the Virginia Institute of Marine Science, 8.2 miles of tidal marsh stabilization structures were permitted in Virginia from 2001-2006. It is presumed that marsh structures are beneficial because they preserve eroding tidal marshes and make it possible to create new ones where they do not naturally exist (3). In order for these projects to effectively provide habitat functions, tidal exchange and the movement of aquatic animals into and out of the marsh cannot be severely restricted. Healthy tidal marsh vegetation requires adequate tidal inundation with complete drainage at low tide. Numerous aquatic organisms utilize fringing marshes along the channelward edge where these structures tend to be placed (9). The indirect effects of marsh stabilization structures on sediment transport, temperature regulation, and access to the marsh for habitat use are still not completely understood (8). The purpose of this study was to compare available information about two nonstructural methods (planted tidal marshes, bank grading) with the hybrid method of using marsh toe revetments and marsh sills. The relative need for the structures and the effectiveness of each method for reducing visible erosion scarps and providing habitat were evaluated.

Figure 1. "Marsh toe revetments" are placed next to the edge of an eroding tidal marsh.

MATERIALS AND METHODS

Marsh Revetment Survey

A recent field survey of existing tidal marsh stabilization structures focused on two types of rock structures. "Marsh toe revetments" are used to stabilize the eroding edge of a natural tidal marsh (Fig. 1). "Marsh sills" are freestanding structures used to contain sand fill needed to create a tidal marsh at a non-vegetated site (Fig. 2).

Thirty-six structures were evaluated from June 2004 to August 2005 in six counties on the Middle Peninsula and Northern Neck of Virginia. General dimensions for each marsh structure were recorded and observations made of erosion evidence, the need for the structure, structural integrity, construction access impacts, and adjacent landscape settings. Baseline information about shoreline erosion conditions at each site and design specifications were obtained from permit records. The widest fetch distance was used to categorize wave climate settings from low to high energy.

The marsh structures were considered effective if evidence of marsh or upland bank erosion was reported before construction, but then there was no evidence of erosion observed during the

Figure 2. "Marsh sills" are used to contain sand fill that is planted with tidal marsh vegetation.

field evaluation. Indicators of effective habitat functions included a healthy and diverse stand of tidal marsh vegetation with only minor disruption of tidal exchange. Other positive indicators include a connected cover of vegetation between upland and wetland habitats plus evidence of wildlife utilization.

Planted Tidal Marshes and Bank Grading

Information about planted tidal marshes and bank grading was obtained from permitting records and shoreline evaluations performed as an advisory service to regulatory agencies and the general public. The planted tidal marshes in this study were relatively small, voluntary habitat restoration projects sponsored by grassroots organizations and individuals (Fig. 3). The presence or absence of visible erosion scarps after planting, the local wave climate, water depth at the bank toe, and frequency of boat wakes were considered.

Numerous bank grading projects were tracked between 2000 and 2006 to monitor how effective this nonstructural method is over time (Fig. 4). Graded banks are effective if active erosion does not continue even with periodic wave action and run up. The presence or absence of dense herbaceous or woody vegetation was noted, particularly at the toe of the graded slope where storm waves are likely to strike.

Figure 3. *A planted tidal marsh with* Spartina alterniflora *on the existing grade using natural marsh vegetation as a benchmark (foreground).*

Figure 4. *A previously vertical, eroding bluff was graded and planted with native and ornamental grasses.*

RESULTS

Marsh Revetment Survey

Ten planted tidal marsh projects that did not include stone structures were evaluated. All but 4 were constructed in the past 5 years. They were all constructed with quarry stone on filter cloth, including 2 projects that used gabions to contain the stone. A small stone size was used in most cases, permitting hand placement at marsh sites with limited access for heavy equipment.

The average revetment length was 271 feet and there were 17 structures that exceeded a 200-foot length. Ten of these long, continuous structures had tidal openings. The base width varied from 3-14 feet, with an average of 6.5 feet at low-energy settings. Four projects at high-energy locations had base widths ranging from 6 to 14 feet where the widest fetch was greater than 5 miles. The height of all the structures above the substrate was less than 4 feet and usually less than 3 feet. The top elevation was more than 1 foot above the mean high water elevation in 21 cases.

Planting tidal marsh vegetation on sand fill was included with 8 project designs. The created marsh width varied from a narrow fringe less than 5 feet wide to a 40-foot wide high marsh and low marsh combination at one of the high-energy sites. The plant species used were primarily *Spartina alterniflora* and *S. patens*. Only one of these planted marshes failed to establish.

Where existing natural marshes were present, marsh erosion was almost always present before installation. Three different types of eroding tidal marshes were targeted, including fringing marshes (n=18), spit marshes (n=12), and embayed marshes with tidal ponds (n=4). The natural marsh width was between 20-50 feet in 25 of these cases and greater than 50 feet wide at 3 sites. The upland banks adjacent to these structures were usually less than 5 feet high. Upland bank erosion was not always reported before construction.

Most of these marsh revetments were located in low energy settings where the widest fetch was less than 0.5 mile (n=20), although nonstructural methods should be sufficient if boat wakes are not frequent (6). There were 9 projects located on minor rivers and major tributaries where the widest fetch is between 1-5 miles. Four projects were located on major tributaries with Bay influence in high-energy settings with a fetch greater than 5 miles.

All 36 structures were structurally sound with a few exceptions, even though most of them were subjected to a coastal storm in 2003 just after construction (Tropical Storm Isabel). In a few older cases, the stone had settled into a wider and flatter profile than designed. Small stone was also scattered over the marsh surface in a few cases. Property owners reported only minor work was performed after storm events, such as replacing the scattered stone and removing tidal debris from the marshes.

The marsh toe revetments and marsh sills effectively reduced both upland and marsh erosion, particularly for fringing and embayed marshes. Both upland bank and marsh edge erosion were visibly reduced because of the structures and the wide tidal marshes they support. The pre-existing erosion trend was reversed in 4 cases where there was evidence of channelward marsh expansion. There was no obvious evidence of sediment accretion or sand entrapment because of these structures.

Erosion of spit marsh features continued even though marsh toe revetments were installed, especially for narrow spit features. Isolated areas of continuing marsh erosion were also observed at 8 sites where marsh toe revetments were placed more than 10 feet channelward from the marsh edge. "End-effect" erosion was observed in two cases where erosion of the untreated marsh edge at the end of the revetments appeared to have accelerated. Upland bank erosion was still evident where the revetment height was less than 1 foot above the mean high water elevation at medium and high-energy settings and also where the marsh width was less than 15 feet.

While the marsh vegetation usually appeared healthy, there was evidence that some structures were adversely interfering with other habitat conditions and functions. This was particularly true where the revetment height was more than one foot above the mean high water elevation. One marsh was perched well above the mean high water elevation due to the height of the stone, isolating it from tidal exchange. Macroalgae growth and dieback of planted *S. alterniflora* was observed where tidal exchange was restricted by tightly packed stone inside a long continuous gabion sill. There was no apparent loss of sand fill.

Planted Tidal Marshes

Ten planted tidal marsh projects were evaluated. These particular marshes were planted on the existing substrate in narrow intertidal areas without the addition of sand fill. Existing marsh vegetation was used for biological benchmarks where possible. Pruning or removal of riparian vegetation was required in three cases to provide enough sunlight during the growing season. Slow-release fertilizer was used below ground at the initial planting and a few property owners continued to fertilize their planted marshes annually in early spring.

Some habitat is provided by these planted tidal marshes, but they were usually too narrow for sufficient erosion protection. None of them was greater than 10 feet wide. The marsh plants did not successfully become established where regular high tides reached the upland bank. At least one planted marsh failed where excessive pruning of trees overhanging a mudflat was required. The pruning activity alone apparently did not improve growing conditions well enough, probably due to sediment chemistry and other limiting factors. Another planted marsh became patchy when pruned vegetation was not maintained.

The time of year for planting also affected the success of these planted marshes. Early summer planting was not as successful as spring planting. The new plants were not established before stressful and prolonged heat spells in June and July. There is also an increasing need for grazing exclusion devices in Virginia: resident Canadian geese and an expanding population of mute swans were attracted to the newly planted marsh vegetation.

Bank Grading

The most common bank grading plan extended landward from the bank toe without cut and fill channelward from the bank. Bulkheads and revetments were installed at the toe of some of these graded banks. Boat wake influence and continued erosion at the toe were cited as reasons for adding these structures.

Landscape restoration on graded banks typically does not include the recommended dense cover of deeply rooted vegetation that is not mowed frequently. In one case where a marsh flat was included with a graded bank, substantial erosion occurred above the marsh vegetation during a storm. This particular slope was routinely mowed and maintained as a lawn down to the planted marsh vegetation. The property owner decided to stop mowing so close to the water in order to extend the stabilizing vegetation buffer further up the graded bank instead of installing a rock revetment between the bank toe and the planted marsh. Other graded banks with a wide dense buffer of naturalized riparian vegetation experienced only minor storm damage.

DISCUSSION

Marsh toe revetments placed along the eroding edge of natural marshes were more common than marsh sills with backfill and planted marshes. Most of the marsh structures were located where the widest fetch was less than 0.5 mile. The presence and effect of boat wakes was not included with this study, yet only one of these projects was determined to be excessive and unnecessary for erosion control purposes. Continued erosion and loss of valuable tidal marshes was expected if a structural, "hybrid" approach was not used. Sand fill was also not expected to remain on site without containment structures.

The wave breaking function of the structures depends on the crest height above the mean high water elevation, yet excessive height also restricts tidal exchange. The target height should be the mean high water elevation and up to 1 foot above mean high water where the fetch distance or boat wakes indicate that additional height is necessary. If additional height is needed, then tidal openings or a variable height should be provided without creating erosion hot spots or shoaling problems. Additional research on the effects of restricted tidal exchange should include temperature regulation and sediment transport.

Formerly vegetated marsh spits continued to disappear after marsh revetments were installed. Planted vegetation on marsh spits also failed, consistent with a previous conclusion that points of land reaching into a body of water are not suitable planting sites (10). It is not clear why these structures failed to protect spits from continued erosion. Sand fill may be a necessary component for marsh spit restoration with strategically placed containment structures that enhance rather than restrict sand entrapment.

Marsh revetment projects that were determined to be effective for both reduced erosion and for supporting living resources had several characteristics in common, including:

- The marsh structure was necessary, i.e., a nonstructural approach would likely not be effective.
- A tidal marsh greater than 15 feet wide was the primary erosion buffer.
- No or only minor erosion of the upland bank and marsh edge was evident after the structure was installed.
- The structure was appropriately designed, with a revetment base width generally less than 8 feet at low energy settings, less than 14 feet at medium energy settings.
- Tidal exchange was provided either with a height <1 foot above the mean high water elevation and/or strategically placed tidal connections.
- Tidal wetland and riparian habitats were connected with a vegetation cover in a natural condition.
- There was evidence of habitat use by typical salt marsh species.

The two nonstructural methods included with this evaluation were not as effective overall as the structural "hybrid" approach, but each method has advantages and disadvantages (Table 1). Planted tidal marshes would be more effective for both erosion protection and habitat enhancement if the marsh width can be expanded either landward with bank grading or channelward with sand fill and containment. This study suggests that the target width for the created marsh should be at least 15 feet, with even more effectiveness expected if the planted marsh is 25 feet wide (4,5). Fertilizing newly planted tidal marshes did enhance plant density that is beneficial for erosion protection, but annual fertilizer treatments do not necessarily improve established marshes (10).

Method	Advantages	Disadvantages
Marsh toe revetments and sills	Wave reduction Longevity	Fish / wildlife movement interrupted Wave diffraction
Planted tidal marshes (at grade)	Fish / wildlife habitat Buffers nutrient and sediment inputs	Limited erosion protection Diligent maintenance, storm repairs
Bank grading	Easily combined with other methods Improves access for maintenance	Sediment runoff during land disturbance Toe protection needed in wave strike zone

Table 1. *Advantages and disadvantages of the three erosion control methods surveyed.*

It appears more emphasis should be placed on including sand fill with both sill projects and planted marshes, assuming only suitable material will be used. The target slope for created or enhanced tidal marshes is 10:1 (6). If the existing slope is steeper than this target grade, then backfill or bank grading with cut and fill should be encouraged to create a stable planting area wide enough for both erosion protection and habitat values. The effectiveness of temporary containment methods, such as coir mats and coir logs instead of marsh structures, should be investigated further particularly in fetch-limited settings. Determining if wave climate anomalies occur where boat wakes are frequent would clarify where structural methods may be necessary.

Renewed emphasis should also be placed on the effective use of bank grading and riparian buffer vegetation for stabilization. Sediment grain size analysis of bank material should be encouraged to determine its suitability for sand fill. The current practice of retaining all bank grading material landward from the mean high water elevation could be reconsidered, to identify those circumstances where channelward fill would be appropriate to create or enhance a tidal marsh or beach feature. If professional landscape designs were available that utilize salt-tolerant, native plants arranged for both stabilization and aesthetic appearance, then perhaps more property owners would be willing to restore a functioning riparian habitat on the graded bank.

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