Coastal Protection

A White Paper on Engineering Approaches to Shoreline Management

Prepared by

Janice McDonnell
Dr. Michael Bruno
Dr. Norbert P. Psuty
Thomas Harrington

New Jersey's Shoreline Future Project
Institute of Marine and Coastal Sciences
Rutgers - The State University of New Jersey

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Coastal Hazard Management Plan
Office of Land and Water Planning
New Jersey Department of Environmental Protection

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DEFENDING THE NEW JERSEY SHORELINE

A Review of Shore Protection Approaches and Strategies Utilized in New Jersey

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Introduction

The New Jersey shoreline is an area of continuous and sometimes dramatic change. Atmospheric disturbances generate winds, which in turn cause waves to break on the shoreline resulting in a great release of energy. Shorelines composed of loose sediments are washed in the direction of the waves' advance. If the sediment is replaced with equal quantities of beach sand from other areas, or returns from the same area with no change in sand volume, then the beach is said to be in "dynamic equilibrium." Dynamic equilibrium can be created either as cross-shore input or longshore replacement of the sand that is lost. On the other hand, if less sand replaces that which is lost in natural coastal processes, erosion occurs leading to an overall loss of sand volume. Erosion is a natural process that shoreline communities have attempted to slow or arrest for the last century. As a result of the desire to protect private beachfront homes or businesses, beach communities have responded to erosion with structural engineering approaches to attempt to retain the sand or with non-structural solutions such as beach nourishment or simple replacement of the sand fill. These structural and non-structural protection strategies have been applied independently and in combinations in attempts to counter, or balance, erosional losses.

This report addresses the characteristics of structural and non-structural strategies used to manage shoreline erosion problems in New Jersey. Each strategy is discussed in terms of (1) its location on the shoreline, (2) a physical description (3) short-term positive and negative impacts, (4) long-term positive and negative impacts, (5) associated costs and benefits, and (6) the life expectancy of the method. The cost and the longevity estimates assess the range of costs associated with structural approaches and the average life expectancy of the unit, respectively. A multitude of factors affect the short-term and long-term benefits of any structural approach, including regional weather conditions, storm events, and the maintenance schedule adopted by the community for the up-keep of the unit. Structural approaches are only short-term adjustments to nature's continual erosional loss of sediment. They do not add new sand to the beaches. They either attempt to reduce the rate of loss or to cause sand to concentrate in one location at the expense of another. The changes to the shoreline's sediment budget can create both positive and negative consequences for the host community and its neighboring shoreline communities.

This information is intended as a guide to identify and compare structural and non-structural approaches for shoreline management, and is directed at local and state officials, to assist in the selection of responses under pre- and post-storm conditions. Existing shore protection strategies in New Jersey are used to illustrate the engineered structures and non-structural approaches outlined in the paper.

I. Engineered Approaches

A. Shore Parallel Approaches / Sand Retaining and Stabilizing Approaches

Three approaches are used to armor the coast against wave action. These include revetments, bulkheads and seawalls. In each approach, various construction materials are used to form a hard shoreline structure which is placed parallel to the coast.

1. Revetments

Revetments are the simplest structures of the three. These structures are placed on the seaward face of a slope and are designed to stabilize an eroding shoreline in areas of light wave action. Revetments are made of interlocking concrete blocks or stone interlocking blocks, called rip-rap and are generally built on a slope (Figure 1). The short-term positive impacts of revetments are that they stabilize the slope and they reduce wave run-up, thereby reducing the risk of direct wave attack on the landward infrastructure. However, an increase in wave reflection associated with an increase in local erosion may threaten the long-term survival of the structure. Local beach dynamics and storm events also affect the life expectancy of revetments. With careful thought in the structural design, a revetment may last an average of thirty years or more. The cost of a revetment is approximately $500-1000 per linear foot and varies based on the materials used and the elevation.

2. Bulkheads

Bulkheads are vertical walls constructed of steel or concrete sheet piling, creosote-treated lumber, aluminum, plastic, or timber (Figure 2.) These structures extend from below low water to above high tide and usually do not experience direct wave action except during storms or other high water events. The short-term positive impacts of bulkheads are that they preserve the landward property and generally improve access to the water. However, direct wave action can undercut and undermine the bulkhead and lead to the construction of seawalls in their place. The cost of constructing bulkheads is dependent on the chosen material. Materials such as aluminum and creosote cost approximately $ 600-1000 per linear foot ($50-100 per ton). The life expectancy of the bulkhead is dependent on the material and local conditions. Material such as creosote-treated lumber has been recorded to last approximately 30 years if maintained properly. Aluminum also has been used experimentally in bulkhead construction and is thought to have an extended life expectancy.

Figure 1. Revetment composed of rip-rap stone blocks against headland. Revetments attempt to stabilize the slope. Deal, NJ.

Figure 2. Vertical bulkhead, with rip-rap at toe. Bulkheads defend a line. Strathmere, NJ.

Figure 3. Seawall with waves breaking directly on this wall. Small pocket beach has formed on updrift side of groin in backround. Sea Bright NJ.

3. Seawalls

Seawalls may be constructed of stone or concrete, and are sometimes built with a curved face to dissipate wave energy and prevent undermining (Figure 3). Seawalls are designed to sustain the full force of wave action, and are often used in conjunction with other structures described previously. Bulkheads and seawalls are designed to protect only the land immediately behind them. Beach erosion continues in front of and downdrift of the structure, and may intensify erosion. This can result in scour and eventual collapse of the structure. Costs of constructing seawalls are variable depending on the material but generally range from $ 500-1000 per linear foot ($50-100 per ton). Seawalls may be expected to last depending on the construction, maintenance schedule, and local conditions on the order of 50 -100 years.

B. Shore Perpendicular Approaches / Intercepting Shoreline Transport

1. Groins

A groin extends from the backshore area into the water at right angles to the shoreline (Figure 4). Its function is to slow the rate of littoral drift of sand and to capture sand along the updrift side causing accretion or accumulation of sand. They are constructed of stone, concrete, steel, or timber and are built to varying lengths and with a range of profile shapes (e.g., constant top elevation or sloping top elevation - low profile groin). Groins initially trap sand moving along the shore, creating a pocket of sediment on the updrift side. In the short-term, groins accrete on the updrift side and cause erosion or shoreline displacement on the downdrift side. However, a groin may also accelerate erosion in the downdrift direction to such an extent that it may become necessary to construct a second groin, then a third, and so on. Downdrift erosion may become an urgent problem requiring more elaborate protective measures. Groin installations do not create new sand but are intended to slow the rate of loss created by alongshore transport of sand. Groins function best when there is an adequate supply of sand and are not effective where the littoral or nearshore materials are finer than sand. The problems associated with downdrift erosion may be partially ameliorated by notching the groin, thereby allowing some of the sand to pass across the structure. The top elevation of the groin also may designed so that the seaward end slopes downward or is lower allowing some sand to pass across. When constructed and maintained properly, these structures may last 30 - 40 years at a cost of $1000-2000 per linear foot ($75-100 per ton). Most of the New Jersey shoreline has groins, especially Monmouth County.

2. Inlets and Sand Bypassing

Jetties at inlets are larger structures used primarily to confine tidal flow at an inlet, and to prevent littoral drift from shoaling the channel (Figure 5). Jetties are often constructed in pairs and are designed to help stabilize the depth and location of channels. By their nature and definition, inlets are directly at odds with beach stabilization. A stable, jetty-protected navigational channel prevents or minimizes shoaling of the channel, creating a barrier to littoral transport. This creates accretion on the updrift and erosion on the downdrift sides of the channel. Natural (uncontrolled) inlets will exhibit natural sand exchange across an ebb tide shoal. Most often, controlled inlets (with/jetties) do not exhibit this behavior. This problem can be addressed by transforming the accumulated sediment mechanically, or sand bypassing, via dredge or periodic truck fill, thus minimizing erosion on the downdrift side (Figure 6). Sand bypassing may be conducted at an estimated cost of $2 per cubic yard, excluding capital costs. Sand bypassing is conducted at Indian River Inlet, Delaware, where the capital costs (above annual maintenance costs) of constructing the sand bypassing system were approximately $1.7 million dollars.

3. Breakwaters

Breakwaters are offshore structures constructed of stone and /or concrete armor units (CAU). They are designed to protect shore areas from direct wave action and to create littoral sand traps. In a detached breakwater, or a structure not connected to the mainland, sand accumulates behind the breakwater forming a seaward projection of the shoreline (Figure 7). This structure shields a portion of the beach, but often leads to erosion. These structures are used on the West Coast of the U.S. and more commonly, in the Mediterranean and Australia.

The attached breakwater, which is connected to the mainland, functions slightly differently. Its objective is to shield an area from direct exposure to waves (Figure 8). However, it also intercepts longshore sediment transport, causing accumulation on the updrift side and accelerates loss downdrift.

The long-term positive effects of breakwaters are an increase in beach accretion, and shore protection immediately landward of the structure. However, breakwaters accumulate sand at the expense or sand starvation of the downdrift area. Attached and detached breakwaters can be installed at a cost of approximately $1000 per linear foot and may be expected to last an average of 30 years with proper maintenance.

II. Non-Structural Approaches

A. Beach Augmentation Methods

1. Beach nourishment

Beach nourishment involves bringing quantities of sand from an outside source onto an eroded beach area (Figure 9). This activity can range from periodic replacement of sand lost by erosion to extensive placement of sand for construction of beach areas. Sand may be pumped from an offshore location or may be trucked in and dumped on the beach. Beach scraping, or the mechanical movement of sand from the high water line to dry beach areas, also

Figure 4. Numerous groins projecting seaward from upland. Pockets of sand indicate accumulation associated with northerly drift. Long Branch, NJ.

Figure 5. North Jetty at Barnegat Inlet intercepts southerly sand transport.

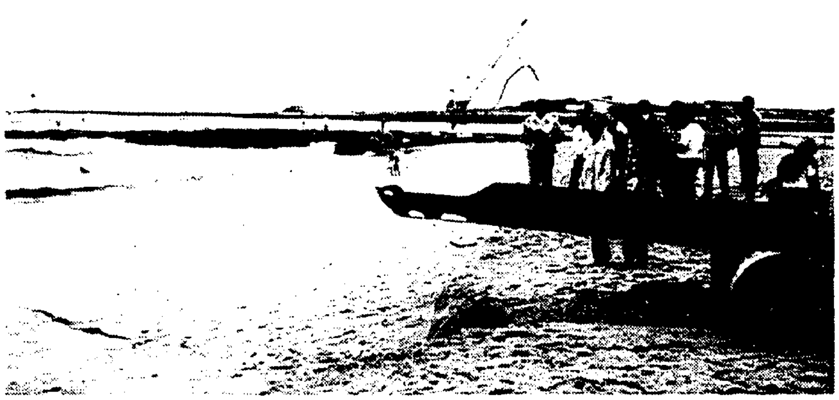

Figure 6. Sand bypass system (attach includes intake hose at crane) updrift of jetty connected to outfall downdrift of jetty. Indian River Inlet. Delaware.

is practiced along the New Jersey shoreline.

In the short-term, beach nourishment creates a large beach berm, and provides for better shore protection and recreational use. However, beach nourishment is a comparatively short-term solution to erosion; sand fill must be replaced periodically to maintain a shoreline position. There are many factors to consider in a nourishment project, including: rate of loss of beach material in the region; predominant direction of littoral drift and its interaction with all existing protective structures; availability and suitability of beach fill material; method of beach fill placement; and effects of removal if from an offshore location. It is important to select fill that closely matches the natural grain size frequency of the beach. Sources of fill which are too fine, as from the back bays, will be rapidly eroded from the beach. Upland sources tend to have a silt component that will wash out quickly and may create a yellowish stain for a short time.

The use of nourishment as an erosion control measure generally requires a continuous commitment to its financial and material maintenance. The costs associated with beach nourishment are generally balanced against the value in protection of infrastructure, property and development. Sand fill may cost $600 per linear foot ($2-8 cubic yard) and usually is replaced on a 2-6 year cycle. The fill cycle is highly dependent on the location and resulting beach dynamics. Ocean City and Avalon, NJ have perhaps the longest running beach nourishment projects in the State. Beach scraping is an alternative beach nourishment practice that moves beach sand one position in the beach profile to another. This process may, however, be detrimental if the beach slope is altered greatly or is scraped too deeply, creating steep slopes or pools in the beach. Seaside Heights and Manasquan both practice beach scraping.

B. Shoreline Stabilization Techniques

1. Dunes

Dunes are a part of the natural shoreline and are the product of many years of interaction between waves, wind, and sand. They create a protective buffer that exchanges sand with the beach to reduce rates of shoreline displacement and may act as a barrier to storm surge, thereby offering protection to properties inland of the dune zone. A common dune-building method consists of erecting wind obstructions, such as picket-style sand/snow fences which break the wind and capture sand particles (Figure 10). Another approach is to create a dune ridge by direct placement of sand on the upper beach, as a short-term stop gap. There are many materials that are used as wind flow barriers along the shore to trap the sand in transport across the beach such as fences of cloth or plastic. Old Christmas trees are often recycled as brush in the dune to help trap sand. The trees can be unsightly and trashy if they are not buried, or if they are uncovered. Sand fencing is inexpensive at $ 1 per linear foot.

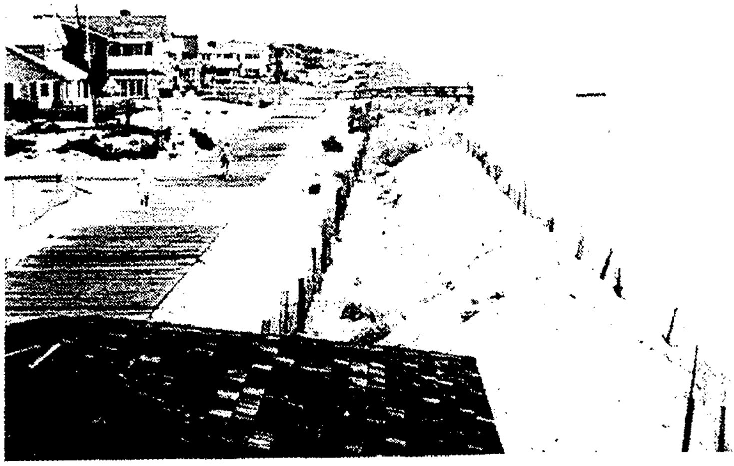

Figure 10. Artificial sand dune, created by bulldozing into ridge form, augmented by sand fences, stabilized by plant vegetation. Lavalette, NJ.

Figure 11. Exposed geotube core of artificial coastal dune. Tude is a type of seawall protecting boardwalk. Atlantic City, NJ.

2. Dune Stabilization

Any artificial or natural dune may be somewhat stabilized with vegetation (Figure 10). Dune vegetation has specific adaptations to the harsh beach environment such as long stems and roots, resistance to salt spray, and tolerance of low nutrient levels. The most common plant used in dune stabilization in New Jersey is American beach grass (*Ammophila breviligulata*). Dune vegetation costs approximately $2 per square yard and can be expected to survive 5-10 years, depending on weather conditions and nutrient supply.

Some dune stabilization projects have included excavation of the area below elevation and the application of a clay fill called I-5. The area is then retopped with sand at a cost of $ 6-120 per linear foot. Some dunes are fortified with a structural core such as a geotube (Figure 11). These geotubes are large filled bags, which are covered with sand to create a dune. Geotubes may be constructed at an average cost of $60-70 per linear foot (9.5 foot diameter, hydrologically-filled with local sediment) and may be expected to survive 5-10 years.

Ideally, dunes must be located above the spring high water line and sufficiently far inland (100-150 feet) of this line to be out of the reach of storm high tides. Many communities enlist the support of their residents for dune grass planting and dune fencing projects. Examples of an on-going artificial dune projects occur throughout the State.

Prognosis

The long-term trend of the shoreline position is an inland displacement accompanied by loss of sediment and drowning of the coastline. The major factors leading to this situation are the general absence of new sediment replacing the material that is being eroded, and the slow drowning of the shore associated with sea-level rise. Several of the engineering approaches discussed in these pages have been applied as an attempt to stabilize portions of the New Jersey shore. The hard structures approach defines a line and holds the ocean back. The soft non-structural approach moves sand to problem areas, and creates a temporary beach with a limited life. All of the approaches outlined in this paper are costly and may not be appropriate in all situations. Choosing an appropriate solution to shoreline problems depends on the location, severity of the erosion problem, availability of materials, associated costs, as well as environmental, esthetic, and social concerns. It is imperative that local resource managers throughout New Jersey have access to accurate, current information on the appropriate strategies to manage the effects of severe storms and erosion on the shoreline.

Summary

All of these methods have been used along the New Jersey shoreline, with varying degrees of success. Table 1 summarizes the physical description of various approaches, the associated costs/benefits, and the life expectancy of the shoreline strategy.

METHOD	PHYSICAL DESCRIPTION	COSTS (linear foot)	LIFE EXPECTANCY (YRS.)
Shore Parallel Approaches			
Revetment	Interlocking concrete blocks or rip- rap built on a slope.	$500-1000	30
Bulkheads	Vertical walls constructed of steel, concrete sheet piling, creosote-treated lumber, aluminum, plastic or timber.	$600-1000	30
Seawalls	Vertical wall constructed (sometimes with a curved face) of stone or concrete.	$500-1000	50-100
Shore Perpendicular Approaches			
Groins	Concrete blocks, steel, or timber built to varying lengths with a range of profile shapes (constant top or sloping top - low profile groin).	$1000-2000	30-40
Sand Bypassing	Mechanically passing sand across an inlet with a dredge or periodic trucked fill.	$2/yd. and cost of pump station	sand is transferred periodically
Detached/ Attached Breakwaters	Offshore structures constructed of stone and/or concrete armor units (CAU).	$1000	30
Beach Nourishment	Process of bringing quantities of sand from an outside source onto an eroding beach area.	$600; $2-8 cu.yd.	2-6
Dune Stabilization	Creation and stabilization of artificial dunes with natural dune vegetation, or I5 fill, or sand fences.	$2 / sq. yd. (vegetation); $6-120 (I5 fill) $1 (sand fencing)	5-10
Geotubes	Large filled bags covered with sand to create a dune/dike ridge.	$60-70	5-10

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Glossary

Adapted from the U.S. Army Corps of Engineers report *Low Cost Shore Protection... A Property Owners Guide*.

Accretion - Accumulation of sand or other beach material due to natural action of waves, currents and wind. A build-up of the beach.

Alongshore - Parallel to and near the shoreline: same as longshore.

Beach fill - Sand or gravel placed on a beach by mechanical methods.

Breakwater - Structure aligned parallel to the shore, sometimes connected to the shore, that provides protection from waves.

Bulkhead - Vertical structure that retains or prevents sliding of land or protects land from wave action.

Current, Longshore - Current shoreward of the breaker zone moving essentially parallel to the shore and usually caused by waves breaking at an angle to the shore. Also called alongshore current.

Downdrift - Direction of alongshore movement of littoral materials.

Dune - Hill, bank, ridge, or mound of loose, wind blown and water deposited material, usually sand.

Dynamic Equilibrium - Cross -shore exchange or longshore replacement of sand.

Ebb tide- Part of the tidal cycle between high water and the next low. The falling tide.

Erosion - Wearing away of land by action of natural forces.

Groin - Shore protection structure built perpendicular to the shore and designed to trap sediment and slow the rate of shore erosion.

Groin field - Series of groins placed along a stretch of beach to trap sediment and slow shore erosion.

Littoral Material - Sediments moved in the LITTORAL ZONE by waves and currents. Also called littoral drift.

Littoral Transport - Movement of LITTORAL MATERIAL by waves and currents.

Littoral Zone - Area extending from the shoreline to just beyond the breaker zone.

Nourishment - Process of replenishing a beach either naturally by longshore transport or artificially by delivery of materials dredged or excavated elsewhere.

Revetment - Facing of stone, concrete, etc. built to protect a embankment, or shore structure against erosion by waves or currents.

Seawall- Parallel structure separating land and water areas primarily to prevent erosion and other damage by wave action.

Updrift - Direction opposite the predominant movement of littoral materials in longshore transport.