unit of shoreline. The diverse conditions dictate a wide variety of protective measures.

It must be recognized that coastal protection is usually an expensive undertaking, as the amounts of energy imparted to the shore by waves are enormous by comparison to the forces which are normally encountered in non-coastal areas.

It is generally recognized that a natural beach is one of the best features for dissipating wave energy. The existence of a protective beach depends upon a number of physical factors; the location of a particular portion of shoreline in relation to the prevailing winds, the expanse of water facing it, the amount of littoral drift or beach sand that moves along the shore front, the configuration and depth of the offshore and the character of the offshore bottom material are contributing factors to the maintenance of a beach. Hurricane winds sometimes churn up and change the physiography and character of the offshore. Such changes eventually affect the shoreline and may also have an adverse effect on established protective devices.

Most of the simple shore erosion problems considered within the scope of these guidelines can be solved with one or some combination of four basic practices. These four practices are: groins, bulkheads, vegetative cover and protective riprap.

GROINS

Groins are installed to retard beach and shoreline erosion by building up and maintaining protective beaches. The use of groins is recommended where they will be successful in collecting littoral drift. The question of when and how long they will be effective is dependent on the same variables which affect the existence of a beach.

In order to avoid situations where one property owner gains at the serious cost of his neighbors on the downdrift side, groins should be low and they should not extend to such depth that they present a definite littoral barrier to normal drift. Where there is no littoral drift available, or where the supply of littoral material is insufficient to prevent the withdrawal from the littoral stream of enough material to fill the groin without damage to downdrift areas, artificial fill may be used to fill the groins. Where this is done, artificial fill may also be needed periodically to nourish the groins.

The length of a groin is determined by the depths of the off-shore area and the planned beach dimensions. The length and spacing must be so correlated that when the groin is filled to capacity, the fillet of material on the up-drift side of each groin will reach to the base of the adjacent up-drift groin with sufficient margin of safety to maintain the minimum beach desired or prevent wave cutting at the shore ends of the groins.

BULKHEADS

When groins alone will not provide the needed protection because of the absence of conditions which will cause them to successfully collect littoral drift, then some form of bulkheading may be necessary. Bulkheads are vertical walls placed parallel, or nearly parallel, to the shoreline. The primary purposes of a bulkhead are to prevent sliding of the land and to protect the shore against damage by wave action.

Bulkheads may also be used where it is desired to maintain a depth of water along the shore such as for a boat dock.

The three most common failures of bulkheads are:

1. The top moves out due to anchorage failure, or
2. The bottom kicks out due to scour at the toe, or
3. Material is piped or leached through cracks in bulkheads or between pilings.

VEGETATIVE PROTECTION

Vegetative cover is established to protect sloped and graded banks and to stabilize beach material collected and held by groins. A protective structure is only part of the solution to adequately protect a shoreline. Of equal importance is the use of vegetative cover properly selected for the site conditions.

RIPRAP PROTECTION

The primary purpose of riprap is to protect the land from damage by wave forces. It is generally used where it is necessary to maintain the shore position and where there is little or no littoral material available to the area. Riprap may also be used to protect the toe of bulkheads from the eroding effects of wave forces. To

be effective, riprap should be placed on stable slopes and be properly graded. A well graded gravel blanket several inches thick should be used as a base to prevent soil piping and displacement. The largest rock riprap (100# size) should be placed on the outside face to deflect the force of the waves without movement.

PROCEDURE

All requests for technical assistance on shore erosion problems should have the approval of the Soil Conservation District Board of Supervisors. The Service will then provide such assistance as is available, subject to the following conditions:

1. The district governing body should determine the priority to be given each job based on the total workload and available personnel.

2. A method of identifying each site will be used along with a system of recording a description of the original conditions on each site and a system of recording evaluations at periodic intervals following treatment.

3. Only situations within the following limits should be approved for assistance:

   a. Shorelines of tidal rivers, bays, sounds and estuaries excluding ocean front sites;

   b. Sites where reaches can be treated as a unit to the extent that adjacent landowners will not be adversely affected;

   c. Failure of the installation will not directly create hazard to life or result in serious property damage.

4. All recommendations for structural and vegetative measures should be based on site investigations and designs made on an individual job basis.

5. Property owners and sponsors should thoroughly understand the level of protection being provided and their responsibilities for maintenance and repair.

6. All landowners should be informed of general permit requirements involving alterations to tidelands, marshlands,

estuarine bottoms and navigable streams. No layout or supervision of construction should be done until landowners have received notice from the appropriate agency that all permit requirements have been met.

AGENCIES REQUIRING PERMITS

Federal: District Engineer
Department of the Army
Wilmington District Corps of Engineers
P. O. Box 1890
Wilmington, N. C. 28401

State: Permit Division
Division of Commercial & Sports Fisheries
Department of Natural and Economic Resources
P. O. Box 27687
Raleigh, N. C. 27611

DESIGN INVESTIGATIONS

Design investigations should take into consideration such factors as history and average rate of shore erosion, direction and characteristics of winds, waves and currents, water levels of normal and storm tides, composition of beach materials, amount, direction and rate of littoral transport, beach slope, seasonal variation of beach profile, offshore beach and upland topography, character of foundation, applied forces on structures, construction and maintenance costs, and the use of the upland area.

DESIGN CRITERIA

Groins:

Groins should be of the fixed, low, impermeable type. Alignment should be straight and approximately perpendicular to the shoreline. The shoreward end of groins should extend to a bulkhead or be keyed into the natural bank for at least three feet. Groin height, measured on the beach at the point of normal high tide elevation should be normal high tide elevation plus two feet minimum for surge height. (Where there is no tidal effect, groin height should be a minimum of two feet above normal water level on the beach at the waterline.) Height of the groin should decrease seaward, at a gradual rate, to normal high tide elevation. (Where there is no

tidal effect, extend groin height to 6" above normal water level). When following the above criteria, generally, groins should not be installed when the distance between the existing ground surface to the top of the groin exceeds four feet for significant distances along the groin.

Experience indicates that a spacing equal to the groin length is desired, and that the length of the groin from the normal high tide elevation at the beach to the offshore end should be from 40 to 80 feet. A 40 foot spacing should be used where small amounts of littoral drift are anticipated. Where larger amounts of littoral drift are anticipated, 60 to 80 foot spacing is suggested.

Groins may be constructed of any impermeable material that is sufficiently durable for the site conditions encountered. The material found most suitable, to date, is treated timber and pole piling.

The groin cross section should be of 2-inch thick tongue and gruve lumber or wakefield sheet piling. Timber should be creosote-treated for marine use. Groin sheet piling should be embedded in the existing beach surface a distance not less than three and one half feet.

Structural supports for groins should be piling of not less than 6-inch butts and stringers of not less than 12 square inch cross section. The pole piling should be spaced on 8-foot centers unless shown otherwise on the plans and should be at least 4 feet deeper than the required depth of groin sheet piling.

Bolts of at least 7/16 inch diameter should be placed at each stringer butt joint and through each pole pile. Bolts should not be placed more than 8 feet apart. Washers should be 1½ inches in diameter. Sheet piling shall be nailed securely to the stringers. All hardware should be galvanized or otherwise resistant to the corrosive action of salt water.

Bulkheads:

Vertical walls located so they frequently are hit by waves or wave uprush will be subject to souring of the beach in front of them unless special designs of protective aprons, such as riprap or short groins in front of the wall are used. This deepening of the water at the toe of the wall will eventually cause failure of the wall if the design is not adequate. Where adequate littoral drift is

available, short groins should be installed in conjunction with bulkheads. Where littoral drift is not available, the toe of bulkheads should be protected with properly sized riprap. When groins are used with bulkheads, they should generally be short in length (20-25 feet) and have a spacing of about two times the length. When riprap is used, the rock should range in size from 30 lbs. to 120 lbs.

Bulkheads should be built to an elevation equal to mean high tide plus a minimum of three feet. Where bulkheads are used in combination with groins, they should be about 6 inches higher than the groin.

Bulkhead sections and materials should be the same as for groins, except that pole piling butt diameter should not be less than 8 inches. The depth of bulkhead sheet piling below the existing beach surface should not be less than five feet. Bulkhead pole piling should be spaced on 8 foot centers and should be embedded at least 7 feet below the existing beach surface. Bulkheads should be braced to withstand a minimum of 1 foot surcharge.

Water Disposal:

Provision should be made for disposal of surface and subsurface drainage at all shore line erosion control sites. Surface drainage should be diverted away from the face of an erosive bank and discharged into a suitable outlet. Subsurface drainage is very important in relation to construction of bulkheads. Where no provision is made for subsurface drainage, hydrostatic pressures against the bulkhead may exceed the design conditions. To accomplish drainage, a permeable gravel backfill may be placed directly behind the bulkhead or adequate sub-surface drains installed.

Construction and Installation:

Jetting with water is normally used to place sheet piling and pole piling. Where stiff clay, hard and/or cemented soils are encountered, trenching or driving can be used for placing sheeting and anchors.

Jetting is normally done with a portable pump using flexible hose and a short piece of pipe for a nozzle.

Care must be taken during jetting of sheet piling to assure that a close fit is obtained. One method of accomplishing this is to cut a taper on the lower end of boards which are to be jetted in,

thus causing each successive board to crowd the previous board as it is placed.

ESTABLISHMENT OF PROTECTIVE VEGETATION 1/

Vegetation to Protect Sand Deposits between Groins - After sand deposits have accumulated along shorelines between groins, they can be protected with vegetation. The most adapted species for this is marshhay cord grass, Spartina Patens - a common perennial grass of the lower coastal plain. At present, it is necessary to dig native plants and use the rhizomes for establishing new plantings. Rhizomes with a few leaves attached are best. Plant any time of the year. Optimum time, however, is February, March and April. Planting depth should be about 3". Lay out rows 2' apart with plants 1' apart. Broadcast 20 lbs. of 8-8-8 fertilizer per 1,000 square feet immediately before or after planting. Do not plant out into standing water or areas subject to daily innundation by the tide.

Management - Fertilize in spring and mid-summer annually until dense growth is secured. American Beach Grass has also proved successful in many locations.

Vegetation for Sloped Banks and Berms Protected by Bulkheads and Groins - Vegetation cover is needed to protect these areas against surface erosion. Soil characteristics, use to be made of the area, location and maintenance should be considered in selection of the vegetative species. Centipedegrass (Eremochloa ophiuroides); Bermudagrass (Cynodon dactylon); and Bahiagrass (Paspalum notatum) are three warm-season perennials for droughty sites. Tall fescue (Festuca Arundinacea) predominates on wet sites. Centipede is best established by planting runners on one or two foot centers. Growth is quite slow. Two to three years are needed to attain full cover. After establishment, it should receive one moderate fertilization high in nitrogen and low in phosphorous. Mow about every three weeks. Tufcote, Coastal and all of the fine bermudas are hybrids and must be sprigged. Common bermuda grass may be sprigged or seeded. Plant spacing is about 2 feet, except for Coastal which can be opened up to 3 feet. Growth is very fast and a full cover may be expected in the first year. Bermudagrass should be fertilized liberally. Bahiagrass will do well on relatively poor sites and is established from seed. This grass is disease free, traffic resistant, and requires little maintenance except for mowing. Tall fescue is a cool-season perennial bunch grass established from seed. A highly vigorous grass resistant to wear, it remains green all