GUIDELINES
FOR PREPARATION OF
COASTAL PROTECTION PROJECTS

CENTRAL WATER COMMISSION
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PREFACE

A substantial portion of the country's coast is affected by sea erosion. It is more extensive and severe in some maritime States/Union Territories, while in others, it is life, property, valuable beaches and adjacent coastal land used for habitation, agriculture, recreation etc. The planning, investigation, design and execution of anti-sea erosion scheme is mainly the responsibility of the maritime State and Union Territory Governments. They have been implementing anti-sea erosion schemes depending on the severity of the problems faced by them.

The Government of India had been providing Central Loan Assistance to State Government/Union Territories for protection of sea coast till 1991-92. As per the decision taken in the 43rd meeting of the National Development Council held in December 1991, the Central Assistance was discontinued as part of the process of decentralization. The fresh construction works for coastal protection suffered due to paucity of funds with the maritime States/UTs. Realizing the setback in the progress of coastal protection works, on the advice of Beach Erosion Board (now Coastal Protection and Development Advisory Committee), CWC is preparing a consolidated draft National Coastal Protection Project (NCPP) for seeking external funding. The maritime States/UTs have been requested to formulate comprehensive proposals for protection coastal reaches from sea erosion and submit to CWC for inclusion in the NCPP.

Coastal protection project planning and design is a slightly different type of work when compared to other water resources development projects. Maritime States/UTs are facing difficulties in formulating comprehensive proposals for coastal protection projects. An attempt has been made to compile and bring out guidelines exclusively for preparation of coastal protection projects through this publication titled "**Guidelines for preparation of coastal protection projects**".

I hope that maritime/UT Government will find the publication useful in the preparation of proper coastal protection projects. I appreciate the efforts put in by Shri J. Chandrasekhar Iyer, Director (Beach Erosion) in bringing out the initial draft of this documents. Besides, I also acknowledge S/Shri T.G.A. Balan, Chief Engineer (C&SR), Shri Devendar Sharma, Director (Coastal Erosion Directorate) and Shri Sengupta, Chief Engineer (P&D), CWC New Delhi for their assistance.

Comments and suggestions for improvement in the contents of the publication welcome.

(M. GOPALAKRISHNAN)
Member (River Management)
Central Water commission

Place: New Delhi
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CONTENTS

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1.0 INTRODUCTION

India has a coastline of 7516.6 km as per National Hydrographic Office, Dehradun. A substantial portion of the country's coast is affected by sea erosion. It is more extensive and severe in some States/Union Territories, while in others, it is observed in varying intensities at isolated stretches. Coastal erosion has resulted in loss of life, property, valuable beaches and adjacent coastal land used for habitation, agriculture and recreation. It has resulted in loss of precious natural coastal ecosystems. Coastal erosion is posing a serious threat to many important buildings, factories, monuments of historical importance, highways, bridges and strategic installations along the country's coast.

Coastal erosion occurs generally due to natural causes. This however, is being aggravated further by human activities which has been on the rise along the coast of the country. The coastal zone in many parts of the country has come under tremendous pressure due to high density of population, indiscriminate urbanization and development of industries related to tourism, fishing, shipping, mining, acqua-culture, petrochemicals etc. The activities of some of these coastal development sectors are affecting the stability of the coastline and sustainability of the coastal environment.

The maritime States and Union Territories have been implementing anti-sea erosion schemes depending on the severity of the problems faced by them. Considerable expenditure has been incurred and is being incurred almost every year in constructing protection measures, largely to handle emergency situations. In most cases, the protection works are planned, designed and executed in isolation with the sole aim of mitigating the erosion at the given site. The localized planning and design process for shore protection has adversely affected the adjacent coasts.

This publication brings out broad guidelines for coastal protection projects. Coastal protection project planning and design being an interdisciplinary task, needs inputs from coastal, geotechnical, hydrology, hydraulics, structural, meteorology, economics, environmental, geology, oceanography and other related disciplines. A systematic and integrated approach for planning and developing optimum solutions to the problems of coastal erosion is necessary. Each segment of the coastline has its own characteristics. Hence it is essential to understand in detail the behavior of the coast in totality and examine various alternatives before arriving at an appropriate solution for the specific site. In sum, one has to think global and act local while addressing coastal erosion problems.

2.0 COASTAL EROSION

A beach is eroded when material being removed by the wave breaking at its shore, for deposition elsewhere, exceeds the rate of supply. The result is that the shoreline shifts landward. Man cannot control nature. Coastal erosion too, cannot be controlled. It can only be mitigated.

Coastal protection measures moderate the long-term average erosion rate of shoreline change from natural or man-made causes. Reduced erosion means a wider buffer zone between the land and the sea. Erosion mitigation also helps in storm damage reduction from flooding and wave attack. The main causes of coastal erosion attributable to nature and man are listed in Table 1.

Table 1 - Causes of erosion attributable to nature and man

Nature	Man
Rise in sea level	Dams, dykes and other coastal structures causing rise and concentration of tides.
Protruding headlands, reefs and rocks causing downdrift erosion.	Groins, breakwaters, jetties etc., causing downdrift erosion.
Tidal entrances and river mouths causing interruption of littoral drift.	Man-made entrances causing interruption of littoral drift. This includes jetties for protection of tidal entrances.
Shoreline geometry causing rapid increase of drift quantity.	Fills protruding in the ocean to an extent that they change local shoreline geometry radically. Such fills are often bulkheaded.
Blocking of river outlets carrying sediments to the shore by flood stage barriers, change of location of outlets due to floods, erosion, tectonic movements etc.	Damming up of rivers without providing material sluices which allow continuation of drift of materials. Irrigation projects decreasing flow of water and sediments to the shore.
Removal of beach material by wind drift.	Removal of materials from beaches for construction and other purposes.
Removal of beach material by sudden outbursts of flood waters	Digging or dredging of new inlets, channels and entrances. Offshore dumping of materials.

The ocean holds many different types of waves with different wave periods. The principle causes of wave generation are wind, earthquake, storms and the attraction of moon, sun and other celestial bodies on the earth. The principle restoring forces are surface tension, gravity and coriolis forces. Wave takes birth in the mid ocean and moves towards the coast. Waves bring an enormous amount of energy to the coast that is dissipated through wave breaking, generation of currents, water level changes, movement of sediment, turbulence and heat. Incident waves vary spatially and temporally, with their properties changing with movement over the bottom. Waves are the major factor in determining the geometry and composition of the beaches and significantly influence the planning and design of coastal protection structures. The wave forces on any structure can be due to non-breaking waves, breaking waves or broken waves.

The beach is composed of sediments of varying types, sizes and shapes which move along and across the shore. The beaches and dunes mainly erode during the periods of storms when the waves are high and steep forming bar or storm profiles. The beaches build up during calm weather periods when the long waves called 'swells' occur forming ridge profiles. The maximum beach fluctuations with special reference to the minimum elevation occurring during the monsoon period should be known for proper planning of coastal protection measure.

The situation regarding the beach material balance or erosion condition has to be properly evaluated to determine which type of beach protection is preferable. This can be done using a simple classification namely '*undernourished*', '*sufficiently-nourished*' and '*overnourished*' profiles and defining '*source*' and '*sink*' of the materials.

The *overnourished* beach profiles are fed by nature with more material than the waves are able to shape them into regular beach profiles. These profiles, therefore, are irregular and may, sometimes, appear as irregular shoals. There are two different types of *sufficiently-nourished* profiles. In one type, the profiles are not fed with more material than what is required by the waves to shape them into profiles having an 'equilibrium form'. In the other, the loss of material equals the supply of material and the profiles are able to maintain an equilibrium form.

The *undernourished beach* profiles erode, that is, the shoreline and the depth contours shift shoreward. The undernourished beach profiles will always maintain an equilibrium form but its form may change from one locality to another, depending upon the local conditions. Therefore, beach and shore accumulation may take place with or without equilibrium profiles while the erosion of a shore takes place only for equilibrium profiles attaining maximum steepness corresponding to the quantity and characteristics of the littoral drift. An equilibrium profile, therefore, can be defined as a stable profile with maximum steepness.

The erosion of the bottom decreases seaward until an 'eroded base' is reached where it becomes zero. This base may be located 4 and 6 m depth for less exposed shores and 15 to 20 m depth on exposed shores. All undernourished and sufficiently-nourished profiles seem to have certain 'standard forms'. Where such 'standard erosion profiles' occur, the erosion is probably not of a temporary nature but old and of a progressive nature. This type of information is very useful. If no erosion takes place, we can expect that only a slight adverse change in the littoral drift balance will start the erosion.

A source of materials is a coastal area from where material is delivered continuously to other beaches. The source might be an area where erosion takes place, a shoal or a bar in the sea, a shallow area in front of an inlet which has been closed, a river which transports sand material to the sea or a sand drift from dunes to the beach. Artificial nourishment of sand to an eroding beach from a borrow pit also functions as a source. A *sink or drain of materials* is a coastal area where materials are deposited. A sink could be any marine foreland such as a spit, a tombolo, a bay, an inlet, shoal etc. Man-made structures such as jetties, groins or dredged sand traps usually act as sinks.

A coastal protection should be built in a such a way that it functions as a sink. It should therefore have a source but not a sink on the updrift side. If there is a sink, the coastal protection will not be very successful unless material is supplied artificially to replace the material eroded.

SITE CHARACTERIZATION

The solution of a coastal erosion problem always should start with a clear definition of the problem, its area and boundary conditions. Site characterization involves identifying, distinguishing qualities and features of a region that have a direct and indirect effect on the planning, design, economics, construction and maintenance of a coastal project.

The total project area encompasses not only the physical limits of the problem area but also the area in which the project has an effect. A project planner and designer should be aware of the effects of the project on the adjoining coasts. The amount of data needed for each project varies with the type and scope of the problem. A comprehensive list of data/information required to be compiled is listed below.

a) Hydrodynamic Processes(Waves, Water levels, Currents)
b) Seasonal variability of waves and currents
c) Storm Characteristics/Meteorology
d) Topography and Bathymetry
e) Geomorphology/Geometry and Sediment Characteristics
f) Littoral Drift and Sediment transport patterns
g) Shoreline change trends
h) Land/Shore Use
i) Geotechnical requirements
j) Availability of construction materials
k) Accessibility
l) Environmental considerations
m) Potential for project impacts
n) Regional considerations

A systematic coastal data collection mechanism should be in place so as to provide reliable current and historical data inputs.

COASTAL PROTECTION

Nature not only erodes but also protects. Protection of coastline from erosion is provided by nature in the form of a stable beach, capable of dissipating incident wave energy. Unfortunately, such beaches are not available at all places along the coast. Nature's coastal protection is also demonstrated at the headlands, reefs, rocky shores, dunes etc.

The country's coast varies from place to place with respect to the coastal characteristics, climate, meteorology, geology etc. The nature of erosion, severity, its extent, damage potential also varies accordingly. The erosion may be wave-induced or current-induced. It may be a cyclic phenomenon along some of the coasts. As a result, the necessity, type and extent of protection required vary.

For any given site, the coastal protection measure planned should be economically viable and has to be designed for its maximum functional, hydraulic and structural performances. For complex erosion problems, physical and mathematical modeling should be made use of for better understanding of the problem and arriving at an appropriate solution.

The six coastal protection alternatives for planning and design can be as follows.

4.1 Coastal Armoring Structures

Seawalls, bulkheads and revetments are the main coastal armoring structures. The cost of armoring is justified when flooding and wave damage in low areas threatens substantial human investment. Seawalls are onshore structures with the principal function of preventing or alleviating overtopping and flooding of the land and the structures behind due to storm surges and waves. Seawalls can be classified into three groups namely *vertical* face structures such as massive gravity concrete walls, *tied* walls using steel or concrete piling, and stone-filled cribwork and *sloping* structures with typical surfaces being reinforced concrete slabs, concrete armor units, or stone rubble. Gravity walls are useful at places where wave action is limited i.e. in estuaries and protected bays. Their main drawback is their high reflection coefficient due to their vertical faces. This stirs up the beach and bottom sediments in front of the structure. A protective apron in front of such walls becomes absolute necessary. In order to avoid erosion of the area just behind the wall, a proper oversplash protection may also be necessary. The details of the performance of seawalls is given in Table 2.

Rubble mound seawall is the most commonly used protection measure. A conventional rubble-mound structure consists of a core of finer material covered by big blocks forming the armor layer. To prevent finer material being washed out through the armor layer, filter layers must be provided. The filter layer just beneath the armor layer is also called the underlayer. The beach and bottom profile survey in relation to the tides and wave action during the storms and soil conditions are important inputs for seawalls. Seawalls are in danger of instability caused by erosion of the seabed at the toe of the structure and by an increase in wave slamming, runup and overtopping for which necessary precautions are to be taken. Any structure resting on an erodible sea bottom should be protected against scour for which appropriate mattresses should be used. Concrete armor units are used as armor blocks in areas where sufficient amount of large quarry stones are not available.

Revetments are onshore structures with the principal function of protecting the shoreline against erosion by currents and light wave action. They typically consist of a cladding of stone, concrete or asphalt to armor sloping natural shoreline profiles. Bulkheads are structures primarily intended to retain or prevent sliding of the land, whereas protecting the hinterland against flooding and wave action is of secondary importance. Bulkheads are built as soil retaining structures, and in most cases as a vertical wall anchored with tie rods. Bulkheads can be of concrete, steel or timber. All these three are built parallel, or nearly parallel to the shoreline. These are usually constructed along that line landward of which further recession of the shoreline must be stopped.

The functional design of coastal armoring structures involves calculations of wave runup, wave overtopping, wave transmission and reflection. These technical factors together with economic, environmental, political (social) and aesthetic constraints all combine to determine the crest elevation of the structure to minimize the overtopping from storm surge and wave runup.

Table 2 - Details of the performance of seawalls

			Comments
	What is wanted	Storm tide and/or extreme protection of shore and beach. Protection of specific valuable areas (industry, buildings highways etc.)	Energy-absorbing wall or revetment on dyke or dune. Any type of substantial wall with as little adverse effects as possible.
2.	Layout and geometry	As streamlined as possible. It is best to leave and maintain a beach in front of the wall.	Erosion may be stopped at the wall but artificial nourishment may be needed to maintain beach in front of the wall.
		Influence on adjoining shores.	Leeside erosion may result if erosion continues leaving wall as protruding headland or if wall is built too far seaward and is not streamlined in horizontal geometry. Transfer of sand or other nourishment of downdrift shore may be needed.
3.	Combination with other coastal protective measures	Groins	To break longshore current and possibly build up beach in front of wall.
		Artificial nourishment	To maintain beach in front of wall and/or to check downdrift erosion.
4.	Design	Energy-absorbing (sloping and/or mound type)	Considerate to beach stability due to friction and low reflection.
		Non-energy-absorbing (vertical sheet pile or slab)	May create local erosion due to less friction against currents and more reflection.

4.2 Beach Stabilization Moderation) structures

Offshore breakwaters, groins, sills and reefs moderate the coastal sediment transport processes to reduce the local erosion rate. These structures should be considered where chronic erosion is a problem due to the diminished sediment supply. They are often combined with beach nourishment to reduce downstream effects. Their purpose is slow the loss of placed sand and not to trap sand from the littoral system and create more problems elsewhere.

4.2.1 Groins

Groins are built to stabilize a stretch of natural or artificially nourished beach against erosion that is due primarily to a net longshore loss of beach material. Groins function only when longshore transport occurs. The details of the performance of the groins is given in Table 3.

Groins are built either perpendicular or inclined to the pre-project shoreline. The effect of a single groin is accretion of beach material on the updrift side and erosion on the downdrift side; both effects extend some distance from the structure. Consequently, a groin system (series of groins) results in a saw-tooth-shaped shoreline within the groin field and a differential in beach level on either side of the groins. Some of the situations where groin field alternative for shore protection and sand management should be considered are as follows.

- At divergent, nodal points for littoral drift
- On the downdrift side of a harbour breakwater or jetty
- At the updrift side of an inlet entrance where intruding sand is to be managed
- To reduce the loss of beach fill, but provide material to downdrift beaches in a controlled manner
- Along the banks at inlets, where tidal currents alongshore are strong

Groins may not function well and should not be considered under the following conditions

- Where a large tidal range permits too much bypassing at low tide and overpassing at high tide
- Where cross-shore sediment transport is dominant
- When constructed too long or impermeable, causing sand to be jetted seaward
- When strong rip current are created to cause potentially dangerous swimming conditions

The orientation, length, height, permeability and spacing of the groins determine, under given natural conditions, the actual change in the shoreline and the beach level. Because of the potential for erosion of the beach downdrift of the last groin in the field, a transition section of progressively shorter groins is provided to allow more bypassing. Even so, it might be necessary to protect some part of the downdrift beach with a seawall or to nourish a portion of the eroded area with beach material from an alternative source.

Table 3 - Details of the performance of groins

			Comments
	Degree of efficiency wanted	Just beach stabilization. Also widening of beach.	Short groins mainly covering the beach. Longer groins, possibly extending beyond bar or breaker zone.
2.	Layout and geometry	Streamlined in horizontal geometry. No sharp turns or corners. Influence on adjoining shores	Reaction of shore protected. Stable or widening and then stable. Usually beneficial or neutral updrift but adverse downdrift.
3.	Combination with other coastal protective measures	Seawalls Artificial nourishment	To cope with extreme conditions including storm surges. To fill groins and widen beach initially and maintain width. To eliminate adverse effects on downdrift beaches.
4.	Design : Length in agreement with point 1. Height to match beach profile wanted to the practical extent possible. Length/spacing ratio from 1:1 to 1:4 depending upon quantity of drift and beach material. Most common ratio is 1:2.	<u>Impermeable :</u> Energy absorbing. Non energy absorbing. Adjustable elevation. Fixed elevation. <u>Permeable :</u> May be adjustable or fixed.	 Less reflection, less loss of sand. More reflection, more loss of sand. May be operated to match fluctuations of beach. Cannot be operated to match fluctuations of beach May provide beneficial results where currents are the main agents in transport of materials, that means in rivers and estuaries.

Groins can be of timber, steel, concrete or rubble mound constructions. The latter is preferably used at exposed sites because of a rubble-mound structure's ability to withstand severe wave loads and to decrease wave reflection. Groins can take various shapes in plan.

The sequence in which a groin field is constructed is a practical design consideration and may not be straight forward. To minimize downdrift effects, beach nourishment and groin construction should be concurrent. Construction of the first groin should be at the downdrift end of the project, preferably the terminal groin adjacent to an inlet. Net drift will combine with the artificial beach nourishment to fill and stabilize the first compartment. The second groin is then constructed and the process repeated.

The landward end of the groins must extend to a point above the high water line in order to stay beyond the normal zone of beach movement and thereby avoid outflanking by back scour. The position of the seaward end is determined such that the groin retains some proportion of the longshore transport during more severe wave conditions. This means that the groin must protrude some distance into the zone of littoral transport, the extent of which is largely determined by the surf zone width.

Groins that transverse the entire surfzone are considered long, whereas those that extend only part way across the surf zone are considered short. Groins may be classified as high or low depending on the possibility of sediment transport across the crest. Permeable groins allow sediment to be transported through the structure while impermeable ones do not. Low and permeable groins have the benefit of reduced wave reflection and less rip current formation compared with high and impermeable groins. Proper maintenance of groins is very important to prolong the life and functional effectiveness.

4.2.2 Offshore Breakwaters

Offshore breakwaters are small, relatively short, nonshore connected nearshore breakwaters with the principal function of reducing beach erosion. They are built parallel to the shore just seaward of the shoreline in shallow water depths. Multiple detached breakwaters spaced along the shoreline can provide protection to substantial shoreline frontages. The gaps between the detached breakwaters are in most cases on the same order of magnitude as the length of one individual structure.

Table 4 - Details of the performance of offshore breakwaters

			Comments
	What is wanted	Protection or protection and beach.	If breakwater is built on littoral drift shore both are usually obtained.
	Layout and geometry	Parallel to shore or largely following depth contours.	Tombolo formation will result on shore to be protected. Severe downdrift erosion may result due to littoral barrier effect.
3	Combination with other coastal protective measures	Groins	This combination is unlikely unless groins are used to check downdrift erosion, thereby transferring problem further downdrift.
		Seawalls	May be built to protect against extreme storms and tides to check downdrift erosion.
		Artificial nourishment	May be used to create beach more rapidly if natural supply of material is limited or to check downdrift erosion.
4.	Design	Energy-absorbing structures preferable. Combination with natural reefs often advantageous.	

Each breakwater reflects and dissipates some of the incoming wave energy, thus reducing wave heights in the lee of the structure and reducing shore erosion. Beach material transported along the beach moves into the sheltered area, behind the breakwater, where it is deposited in the lower wave energy region. The nearshore wave pattern, which is strongly influenced by diffraction at the heads of the structures, will cause *salients* and sometimes *tombolos* to be formed, thus making the coastline similar to a series of pocket beaches. Once formed, the pockets will cause wave refraction, which helps to stabilize the pocket-shaped coastline.

Just downdrift of the last detached breakwater in the series there is an increased risk of shoreline erosion. Consequently, it might be necessary to introduce a transition section where the breakwaters gradually are made smaller and placed closer to the shoreline. In addition, seawall protection of the downdrift stretch of beach might be necessary.

Offshore breakwaters are normally built of rubble mound structures with fairly low crest levels that allow significant overtopping during storms at high water. The low crested structures are less visible and help promote a more even distribution of littoral material along the coastline. Submerged detached breakwaters are used in some cases because they do not spoil the view, but they do represent a serious non-visible hazard to boats and swimmers. The details of the performance of offshore breakwaters is given in Table 4.

Reef breakwaters are coast parallel, long or short submerged structures built with the objective of reducing the wave action on the beach by forcing wave breaking over the reef. These are normally rubble mound structures constructed as a homogenous pile of stone or concrete armor units. The breakwater can be designed to be stable or it may be allowed to reshape under wave action. Reef breakwaters might be narrow crested like detached breakwaters in shallow waters or, in deeper water they might be wide crested with lower crest elevation. They represent a non-visible hazard to swimmers and boats.

A submerged sill is a special version of a reef breakwater built nearshore and used to retard offshore sand movements by introducing a structural barrier at one point on the beach profile. However sill may also interrupt the onshore sand movement. The sill introduces a discontinuity into the beach profile so that the beach behind it becomes a perched beach as it is at higher elevation and thus wider the adjacent beaches. Submerged sills are usually built as rock armored, rubble mound structures or commercially available prefabricated units. They represent a non-visible hazard to swimmers and boats.

4.3 Beach Nourishment

Beach nourishment is a soft structure solution used for prevention of shoreline erosion. Material of preferably the same, or larger, grain size and density as the natural beach material is artificially placed on the eroded part of the beach to compensate for the lack of natural supply of beach material. The beachfill might protect not only the beach where it is placed, but also downdrift stretches by providing an updrift point source of sand. The details of the performance of beach nourishment is given in Table 5.

The main source of sand for nourishment is likely to come from offshore bottom. Hence large and effective pumping equipment, capable of operating in low to moderate sea conditions i.e in wave conditions up to 2 - 3 metres is required.

Table 5 - Details of the performance of beach nourishment.

	What is wanted	Protection and beach.
2.	Layout and geometry	Follow natural shoreline closely on straight or streamlined shores. Fill in pockets on headland shores and artificial pockets.
3.	Combination with other coastal protective measures	Groins : To create or maintain beach and to eliminate leeside erosion. Seawalls. : To protect wall and/or create or maintain beach in front of wall and to eliminate leeside erosion. Offshore Breakwaters : To create and maintain protective beach.
	Design	Nourishment from land or offshore sources. Sand shall be suitable for nourishment. Main requirement is that sand should be as coarse or coarser than the natural beach material and of no less specific gravity. By passing arrangements by fixed or movable plants including weirs and floating plants. Movable arrangements preferable.

The basic requirements for beach nourishment are

a) Grain size of the fill should be sufficiently coarse, or at least coarser than the natural beach sand.
b) Materials should be relatively well sorted with particle size distribution to cover all grain sizes present in the original environment
c) The fill material should be resistant to abrasion against wave attack.
d) It should be clean without much clay, silt and organic matter.
e) It is very important to note that all material required to fill in a beach need not be of a first class grade. All exposed material is considered as suitable. Even the low grade material may prove to be quite suitable to provide volume and support for the upper layer of the actual beach material. However this upper layer must be maintained by replenishment as and when required.

Dune construction is the piling up of beach quality sand to form protective dune fields to replace those washed away during severe storms. An essential component of dune reconstruction is planting of dune vegetation and placement of netting or snow fencing to help retain wind-blown sand normally trapped by mature dune vegetation. Storm overwash fans may be a viable source of material for dune construction.

4.4 Adaptation and Retreat

These are non-structural alternatives for coastal hazard mitigation wherein the society adapts to the erosion situation and as a final option retreats by relocation, abandonment or demolition. Elevating structures, flood proofing, zoning restrictions, storm warning and evacuation planning are some of the types of adaptation methods. Retreat is permanent evacuation or abandonment of coastal infrastructure and for communities subject to high erosion rates and flooding damages, this is always a possible alternative.

4.5 Combinations (and new technologies)

There are many types of coastal erosion and flooding problems. In many cases, combinations of these problems exist, that require a combination of structural measures together with non-structural alternatives to be implemented. These can be beach stabilization structures with beach nourishment, seawalls and revetments with beach nourishment, elevated structures combined with some type of armoring structure together with beach nourishment etc.

Many non-traditional ways to armor, stabilize or restore the beach including the use of patented, precast units, geotextile-filled bags and beach dewatering systems have been tried in the field. Their success depends on their stability during storm events and durability over the economic design life.

To summarize, Table 6 gives some of the main coastal protection measures, their relative ability in providing the necessary protection and their influence on the adjoining shores.

Table 6 – Coastal protective measures their ability to provide protection to large and small shore areas and their influence on the adjoining shores

	Large scale	**Small scale**	**Effect**	**Influence on neighboring shores**
Groins	X	X	May stop or decrease shoreline recession but not if offshore erosion continues	Adverse, often very severe.
Seawalls	X	X	Stop erosion where they are built but do not stop offshore erosion	May to some extent become adverse.
Shore parallel breakwaters	X	X	Will probably stop erosion and build up beach where they are erected	Adverse, often very severe.
Artificial nourishment	X		Widens beaches, provides full protection if well maintained	Beneficial.

4.6 Do-nothing

One final alternative that must always be evaluated is the do-nothing or no-action case. When all structural and non-structural alternatives considered are too costly, then no economically viable solution exists. If the life-cycle costs for protection or relocation exceed the value of investment, then do-nothing is the appropriate response. In cases where social and environmental constraints govern even though benefit-cost ratio exceeds unity, no action may be recommended.

The wave and flood damage potential remains, and the risk increases where erosion exists. The option to allow continued erosion and storm damage with the expected annual costs should be determined. The area affected will decline economically. Social and economic stresses will continue. Provision has to be made for emergency evacuation, compensation etc. The without-project condition provides the basis for measuring the effectiveness to reduce the expected damages of each proposed alternative.

MONITORING AND MAINTENANCE

After implementation of the coastal protection measure, it is very important that the behavior of the structure and the coast is constantly monitored. A 'Monitoring and Maintenance Schedule' should be devised. The observations to be made along with the time schedule should be clearly brought out. The recorded observations should be analysed, interpreted and recorded. The experiences from the project should be beneficially incorporated in the planning and design of subsequent projects. During the fair weather season, regular maintenance of the structures should be taken up.

PROJECT FORMULATION

The project report for coastal protection shall be prepared following the CWC guidelines titled *"Guidelines for preparation, submission, appraisal and clearance of flood management schemes"*.

A coastal protection project report shall consist of the following.

1. Introduction

2. Present status of coastal protection works

Brief details of causes of erosion, vulnerable reaches, works completed so far, performance of these works along with map showing the vulnerable reaches, present status of coastal protection works and proposed coastal protection works, etc. shall be included under this section.

3. Constraints

Brief description of constraints if any, in undertaking /management of coastal protection works shall be given.

4. Need and Objective of the project

5. Participating organizations and their role

Brief description of various agencies involved shall be given.

6. State Integrated Plan for Coastal Protection

Brief description of Master Plan for coastal protection, if any shall be given. The details of site investigations and coastal data collection carried out/propose to carry out for studying the erosion problem and planning remedial measures shall be given. Studies using physical model, mathematical model, remote sensing etc. done shall also be included.

General design principles and typical sections/drawings shall be included here along with the recommendations of the agency approving the design of proposed works like State Design organization/ Research Institution/CWPRS etc.

Details of consultations with Ports and other authorities and neighboring State/UT Government in case of contiguous works shall be given here.

7. Brief description of the States-wise proposals

Brief description of investigations carried out, works proposed to be included, both structural as well as non-structural, along with relevant maps shall be given. Details of the design of the protection works shall be included here. Prioritization of works also needs to be done based on the degree of criticality of the proposed works.

Detailed list of proposed works shall be included as Annexure.

8. Co-ordinated programme for data collection, compilation and creation of Data Bank

Brief description of type of data collected, agencies involved, compilation and use of data, creation of data bank, nodal officer etc. shall be given here.

9. Institutional Strengthening

Details of proposed institutional strengthening for data collection/compilation and creation of data bank, design organization, engineering research station, monitoring of works along with upgradation of infrastructure facilities and cost involved shall be included.

10. Training and Technology Transfer

Details of new technology required for planning, design and execution of coastal protection works, field of training and number of man-months for training of personnel along with cost details, agencies identified for imparting training in India/overseas etc., shall be included here.

11. Environmental Plan) Details of these plans, if any, shall be) included here.

12. R & R Plan)

13. Consultancy Requirement

Requirement of Consultants and their role in planning, designing and execution of works, if any, shall be indicated here.

14. Project Cost

Details of project cost sub-head-wise along with supporting details for sub-heads, like A – Preliminary, B – Land, K – Building, O – Miscellaneous, P – Maintenance, Q – Special T & P, R – Communication etc. shall be given here. Cost estimate for C-Works shall be based on detailed cost estimate per km. length for typical sections of protection works like sea walls etc. Work charged establishment and contingencies at 2% and 3% respectively of the cost of works shall be included.

Estimate should be based on latest schedule of rates and CWC guidelines for preparation of project cost estimates.

15. Phasing of Expenditure

Sub-head-wise phasing of expenditure, including procurement of equipment spread over a period of five years shall be indicated here in the light of prioritization of proposed works.

16. Cost Recovery and Sustainability of the Project

Details of cost recovery, if any, shall be given here.

17. Receipt and Recoveries Plan

Brief description of Receipt and Recoveries by way of sale of Special T & P, temporary building etc. shall be indicated here.

18. Benefit-Cost Ratio Calculations

Benefit-Cost ratio for anti-sea erosion schemes shall be calculated as follows.

a) Annual Benefit

The annual benefit is to be worked out taking into account the average of the damages occurred during the past 10 years (as the damages vary depending on the severity of the storm). The statement showing such damages and their monetary values should invariably be vetted by concerned authorities, i.e. Revenue Department for land loss and Agriculture Department for loss of crops. Benefit should include area and population protected, anticipated revenue, cost per hectare of area protected, betterment levy etc. This vetted monetary value (cost) will be the Annual Benefit.

b) Annual Cost

The annual cost is to be worked out as follows.

i) Interest @ 10% of Capital Cost (Total estimated cost of scheme)
ii) Maintenance @ 5% of Capital Cost
iii) Depreciation @ 2% of Capital Cost

Thus the annual cost will be 17 % of the total estimated cost of the scheme.

$$\text{B.C. Ratio} = \frac{\text{Annual Benefit}}{\text{Annual Cost}}$$

B.C. Ratio should not be less than 1 One) for economic viability of a scheme.

Reformation works

In case of reformation of old sea wall or river bank protection in estuarine range, the cost of original work (i.e the expenditure incurred while these protection works were constructed earlier) should be taken into account to work out annual cost. In such cases the annual cost would be 17 % of the present cost to be incurred for reformation plus the original cost of the damaged works as the area protected is the same.

19. Miscellaneous points

The proposal shall ensure the following.

i) The coastal protection scheme evolved by the State/UT Governments should be based on proper site investigation and collection of coastal data. It is necessary to identify causes of erosion properly and to take remedial measures based on these causes.

ii) The planning and design process should consider the various natural features and man-made structures in the vicinity of the site. It should be ensured that the proposed anti-sea erosion scheme does not transfer erosion problem to other areas.

iii) Both, structural works as well as non-structural works shall be considered to minimize the investment required. The design of protection measures should be vetted by the State Design organization/ Research Institution/CWPRS etc. In complex cases, physical and mathematical modeling should be done to evolve the optimal solution.

iv) The coastal protection scheme should aim at controlling erosion. Reclaiming land should not be the motto.

v) The dynamic coastal processes are constantly changing with time. The changes in coastal phenomenon observed at any site at the time of project implementation than what was at the time of project formulation should be accounted for and suitable modifications should be made.

vi) The Ministry of Environment and Forests (MoEF) notification of February 1991 (and its subsequent amendments) declaring the Coastal Stretches as Coastal Regulation Zone(CRZ) and regulating activities in the CRZ shall be kept in view while framing the schemes.

vii) The scheme needs to be got cleared from the State Technical Advisory Committee / State Flood Control Board.

REFERENCES

1. Coastal Engineering Manual (2002)– Coastal and Hydraulic Laboratory, US Army Corps of Engineers. *Chapters available on their website have been referred*

2. P.Bruun and B.U.Nayak (1980) – "Manual on Protection and Control of Coastal Erosion in India" - National Institute of Oceanography, Goa