Texas
Shore Protection

United States Army
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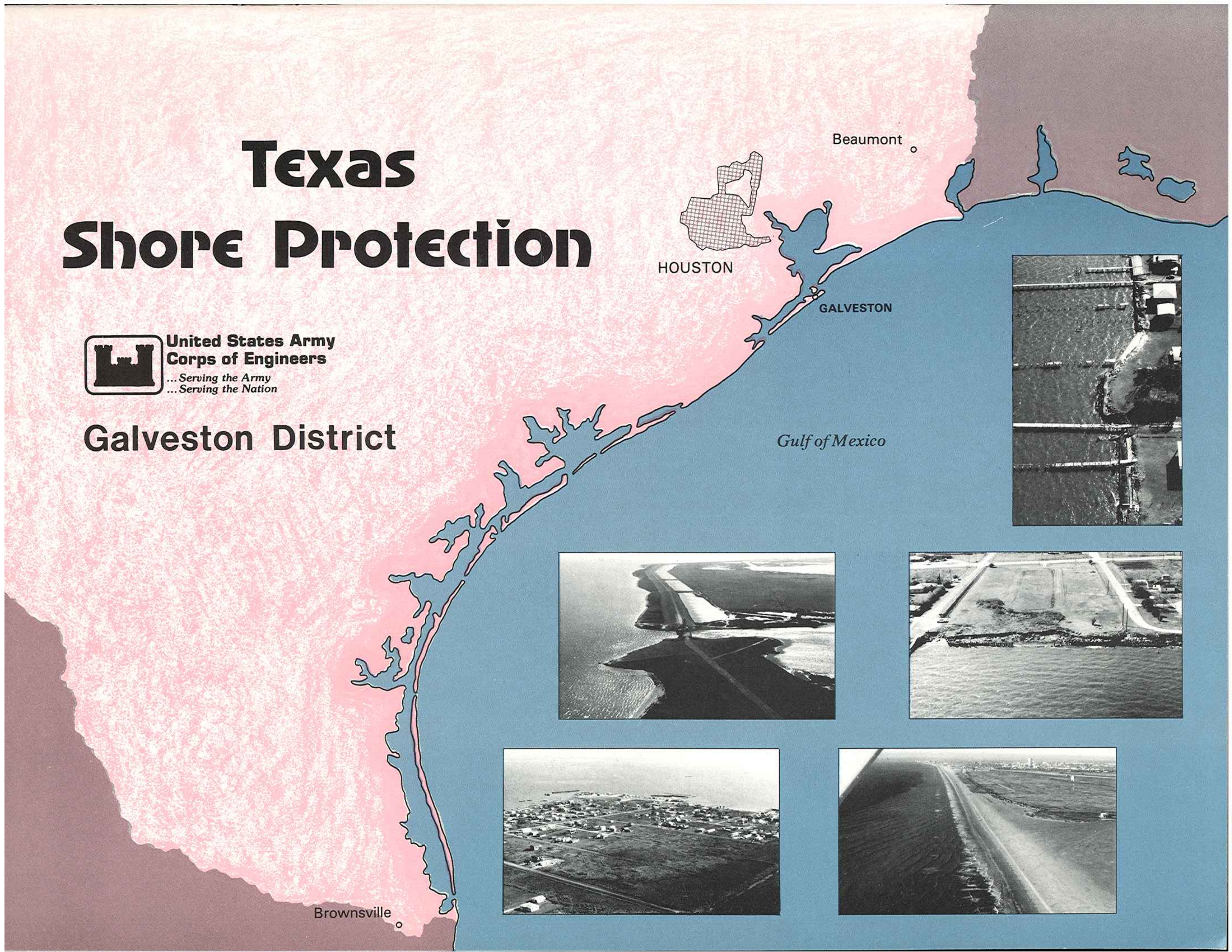
Galveston District



This brochure was prepared by the Galveston District of the U.S. Army Corps of Engineers to provide information on the causes of shore erosion and the possible solutions to shore erosion problems. It is intended for use by owners or potential purchasers of land affected by shore erosion along Texas bay and Gulf shorelines.

This brochure identifies the factors involved in shore erosion; possible solutions to shore erosion; the benefits of group approaches to shore erosion; and the government permits required prior to initiation of shore protection work. For those erosion problems requiring outside engineering advice, this brochure provides appropriate background to enable the owner to select and work with the engineer.

The Corps encourages the interested owner to use this brochure when planning shore protection. However, application of the information presented in this brochure is the responsibility of the owner, who bears the risks and costs inherent in shore protection work.

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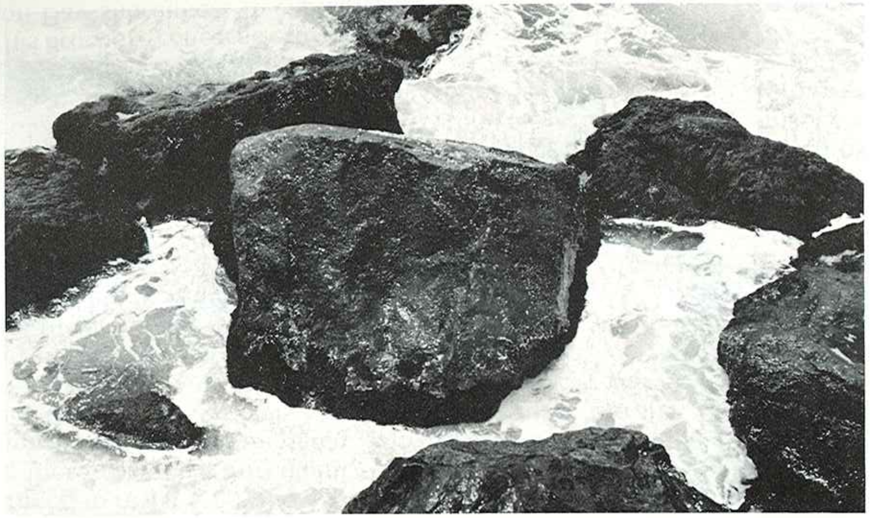


Erosive energy of a wave expended harmlessly on a rock revetment.

CONTENTS

INTRODUCTION

Shoreline. There are about 2,500 miles of tidal shoreline in Texas, and 85% of it is along the bays, estuaries, and other interior waters of the state. The Gulf shoreline accounts for only 15%, or 375 miles, of this total. Of the total shoreline, approximately 82% is privately owned, 16% is Federally owned, and 2% is publicly owned by the state, counties, and cities.

Value to Private Owners. Of the tidal shoreline, a little more than 8% is either privately developed or is privately-owned recreational shoreline. This 8% of the shoreline is concentrated in three areas: Galveston Bay and vicinity, Corpus Christi Bay and vicinity, and the Matagorda Bay area. It amounts to over 200 miles of shoreline, most of which is in need of some shore protection.

The price of protecting this developed shore from erosion is high. After adding the cost of materials, equipment, and labor at 1980 prices, even "low cost" shore protection represents an in-place value to the owner of at least $100 per foot of shorefront. At this rate, the total value to owners of protecting these 200 miles (approximately one million feet) of developed shoreline is about $100,000,000.

These estimates point out the value to the private owner of knowing what causes erosion, and understanding the possible solutions available to control it.

Erosion Processes. Most shore erosion is due to the action of waves removing sediment from the shore. The rate of wave erosion increases markedly during storms when high water levels allow storm waves to attack directly at the upland which is usually out of reach during normal weather conditions. Adequate shore protection must be designed to resist the wave action and water levels that will occur during these relatively infrequent storms.

Wave intensity depends on the **fetch**. The fetch for a coastal site is the distance that the wind travels over the water to reach the site. This means that shorefront on the south shore of a large bay will be subject to severe erosion during "northers" while property on the north shore of the same bay will be unaffected. Wave intensity also depends on the average water depth along the fetch.

Factors other than waves and water levels usually play a lesser role in shore erosion. Among the most important of these other factors is the activity of people using the coastal zone. Such activity may, for example, expose the shore to wave action by deepening the offshore water, or affect drainage from the upland so that rain water is impounded on unstable bluffs, or allowed to erode gullies into the bluffs. This activity is usually more easily remedied than the uncontrolled activity of waves and water level.

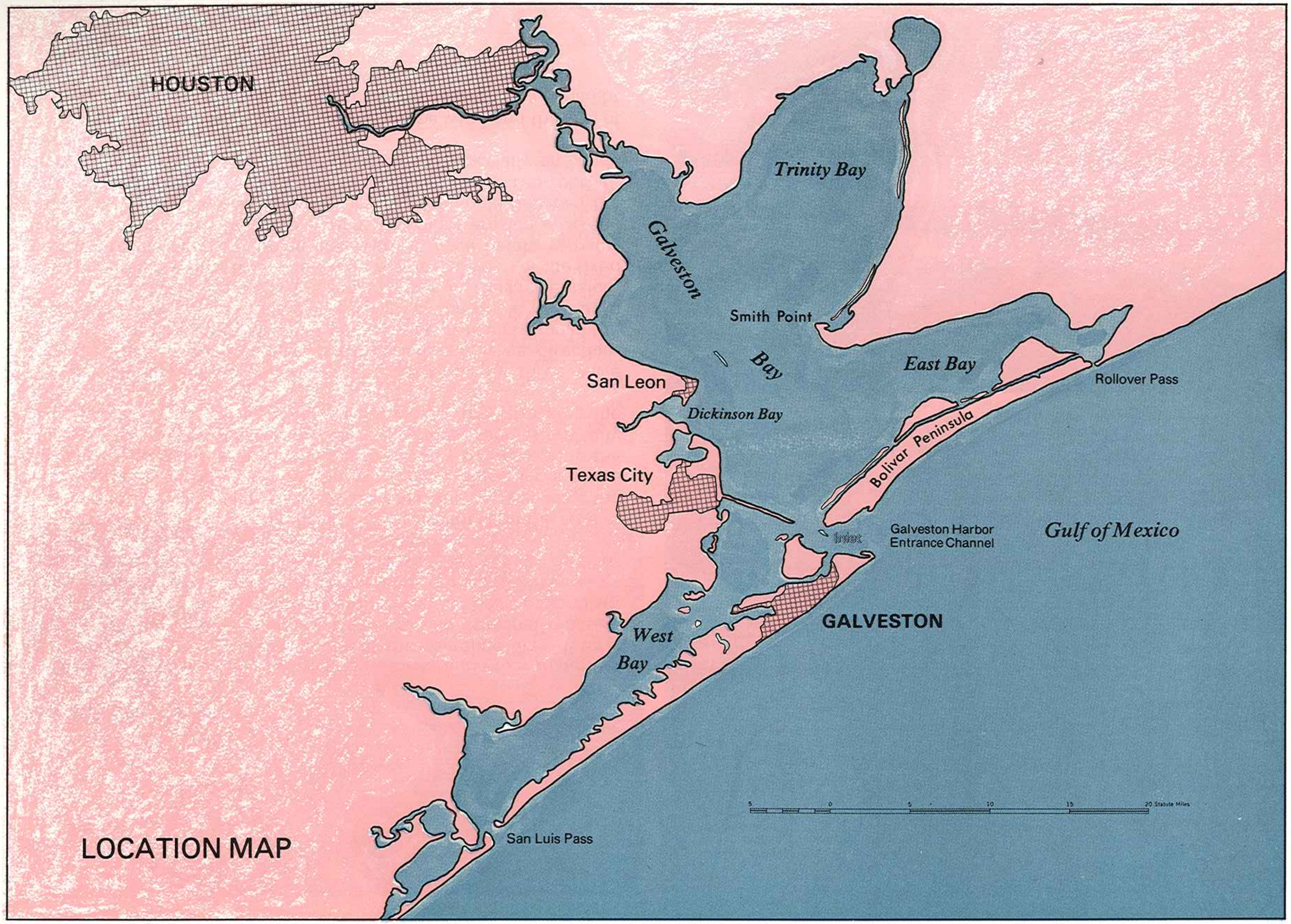
Scope. This brochure concerns erosion of property primarily along the Galveston Bay shorelines. It explains, for private landowners, the causes of this erosion and describes typical solutions available to prevent erosion. Most of the factors affecting erosion in the Galveston area occur on other Texas bays, so this brochure is applicable elsewhere in Texas. Although the brochure does address the erosion problem along the Gulf shoreline, costs involved in providing long-lasting, adequate protection from storm waves and surges developed in the Gulf will generally be too large for individual landowners to incur.

Corps of Engineers Assistance. The conduct of studies and management of construction in beach erosion control projects has been delegated by Congress to the Corps of Engineers. This brochure collects experience gained by the Corps in beach erosion control, presenting it in a form convenient for use by shorefront owners in protecting their own property.

Federal involvement in beach erosion control could consist of a Congressionally authorized study, a small beach erosion project under special continuing authority, or technical assistance. Federal participation in controlling erosion through a Congressionally authorized study requires a detailed evaluation of the erosion problem to determine the most cost-effective, environmentally and socially acceptable solution to the problem. In addition, a local sponsor, such as a state, county, or city must be identified to participate in the project. The degree of local participation is established by Federal statutes and policy and depends on shoreline ownership and use. As a minimum, local interests are required to provide all lands, easements, and rights-of-way; share in the costs of construction; and maintain the project after completion.

Special continuing authority allows small projects to be studied, designed, and constructed without specific Congressional authorization. The study and design criteria and cost sharing requirements are the same as for congressionally authorized studies. The main advantage of this study procedure is that time savings are realized through the preparation of combined feasibility and detailed design studies and the elimination of several authorization and budget steps through the study. The disadvantage of this procedure is that the Federal share of the cost of a project cannot exceed a specified dollar amount which is established by law.

Technical and engineering assistance can also be provided to state, county, or local governments or agencies when implementation of a project is not feasible. However, this assistance is limited to site inspection of problem areas, advice on possible methods of protection, providing copies of available data, review of designs or reports, and inspection and advice on adequacy of construction. Such assistance cannot involve surveys; foundation investigations; preparation of preliminary designs, plans, or specifications; nor supervision of construction.


HOUSTON
Trinity Bay
Galveston
Bay
Smith Point
East Bay
San Leon
Dickinson Bay
Rollover Pass
Bolivar Peninsula
Texas City
Inlet
Galveston Harbor
Entrance Channel
Gulf of Mexico
GALVESTON
West
Bay
5 0 5 10 15 20 Statute Miles
San Luis Pass
LOCATION MAP

SHORE PROCESSES

Littoral Materials. The sediment, soil, rock, and other materials acted upon by waves and currents near the shoreline are "littoral materials." For Texas shorelines, there are two principal types of littoral materials: fine sand, typically found on Gulf beaches; and silt or clay, typically found on shores of bays and connecting waterways. In limited areas, other littoral materials such as oyster shell or gravel may occur.

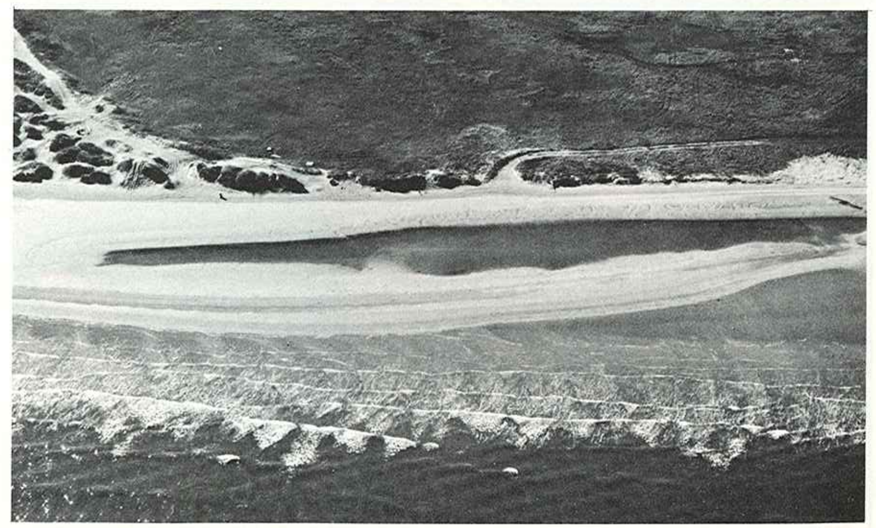
The type of littoral material has a significant effect on the type of shore protection that is feasible in an area and on the way the erosion process works. On Gulf shores, a major objective of shore protection is to retain sand on the beach, usually by preventing the longshore movement of the sand. On bay shores, sand is typically absent, so the objective is to prevent the waves from attacking the bluffs.

Wave Action. Wave conditions are described by three wave climate variables: **wave height, wave period,** and **wave direction**. Wave height is the vertical distance between the peak elevation of the crest and the bottom elevation of the trough as the whole wave goes by one point. Wave height is the major factor in causing erosion. Wave period is the time from one wave crest to the next, at the fixed point where the height is being observed. If wave height remains constant, the shorter the wave period, the more erosion is likely. Finally, wave direction can be measured as the angle between the wave crest and the local shoreline. For a given wave height and period, the higher this angle, the greater the erosion, especially on sandy beaches.

Wave height and wave period depend on the wind and the size of the body of water. If two shoreline sites are compared, wave height and period will be greater at the site where:

a. wind velocity is higher, or
b. fetch is longer, or
c. water is deeper beneath the fetch, or
d. wind has been blowing for a longer time.

Silty sediment along a bay shore.

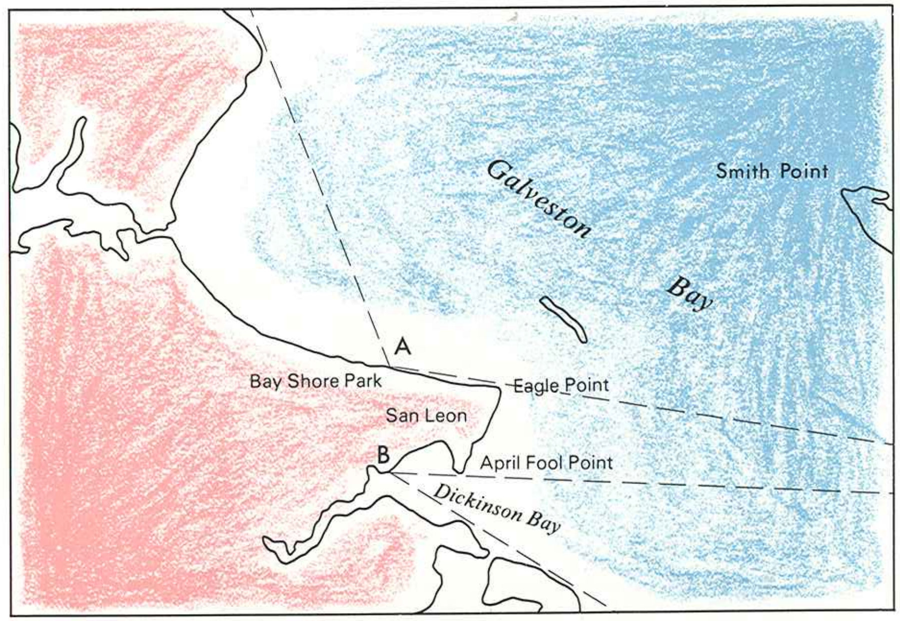


Sandy beaches on a Gulf shore.

Wind. Dominant winds along the Texas coast are of two kinds: persistent southerly or southeasterly winds from March through November, and periods of strong north winds from December through February.

Erosion strongly depends on the exposure of the shore to these dominant winds. If the shore has a long fetch extending to the north or southeast, average wave heights over the year will be larger, and consequently erosion will be greater, compared with other shores having shorter fetches or facing in other directions. In estimating the overwater fetch, the extent and location of mounds of dredged material must be considered. These dredged deposits may act as breakwaters, effectively reducing the fetch, and thus lowering potential erosion.

The angles formed between the dashed lines at sites A and B are measures of the wave exposure at each location. Site A has a wider exposure to waves than site B.



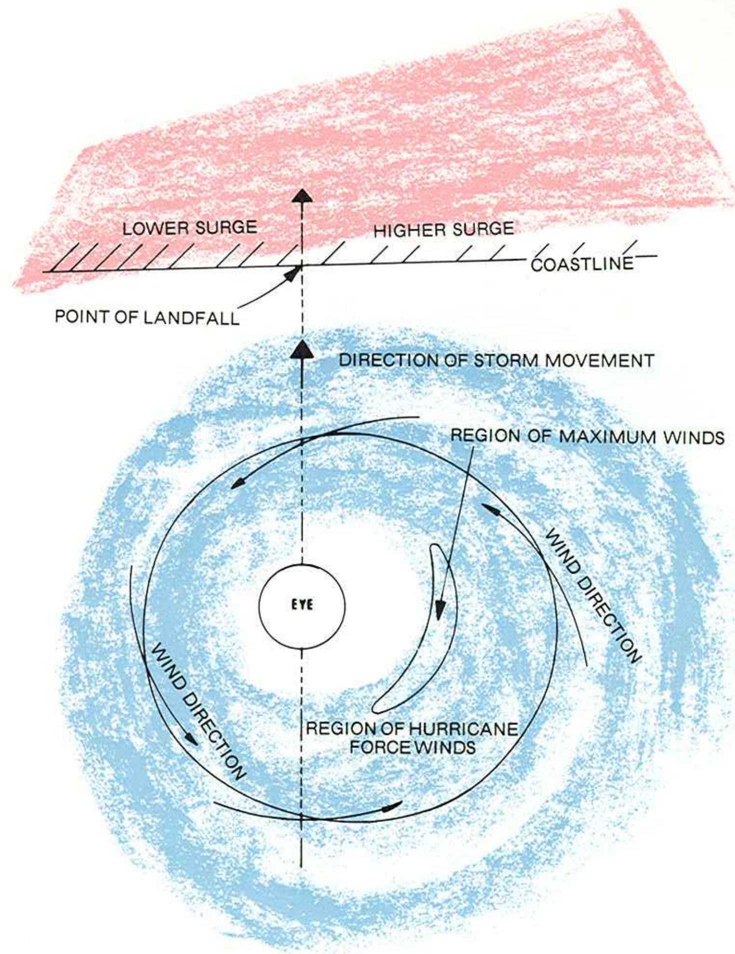
North shore of San Leon, relatively exposed shore of Galveston Bay at site A on map above.

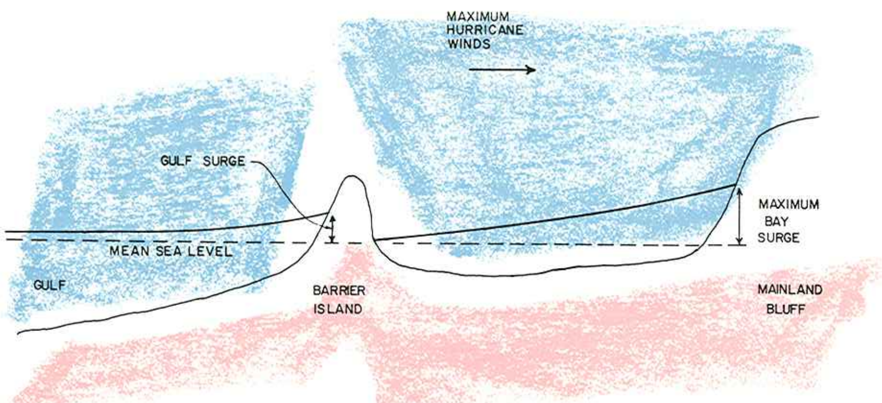
South shore of San Leon, relatively sheltered shore of Dickinson Bay at site B on map above.

STORM PROCESSES

Hurricanes. The most devastating winds to occur along the Texas coast are those that accompany hurricanes. Hurricanes are large circular wind fields, rotating counterclockwise around a low pressure center. Wind velocities within a hurricane usually vary from a minimum at the fringes to a maximum near the eye. The maximum winds of a hurricane usually occur in an area to the right of the hurricane's path.The point of landfall is where the eye of the hurricane crosses the coastline. The figure to the right illustrates the major features of a hurricane.

As the hurricane approaches the coastline, winds act on the water and generate strong currents around the center, and these currents ''pile'' the water up against the coast to cause the high surge as shown below. The highest surges occur to the right of the hurricane's path. Since the winds of a hurricane may generate a high surge and very large waves, shore erosion during a hurricane may be particularly severe.





Carla. Most discussions of erosion damage on Texas shorelines mention the effects of Hurricane Carla which came ashore on 11 September 1961. Of the most severe hurricanes to strike the Texas coast in the 20th Century, Carla was among the worst. Much of the older shore protection now existing was installed in the years immediately after Hurricane Carla; relatively few owner-built structures survive from before Carla.

The shoreline damage during Carla was due to the unusual characteristics of that particular storm. Carla was a very large hurricane covering almost the entire Gulf at times. This large size, combined with the very slow forward movement of the hurricane center, allowed the overwater winds to operate on long fetches in deep water for long durations resulting in very high waves. The slow forward speed also allowed time for the bays to fill up, raising the water levels as high as 20 feet above normal. When the hurricane came ashore, hurricane force winds (at least 75 miles per hour) stretched from near Brownsville eastward to beyond Port Arthur into Louisiana. These high winds, acting on raised water levels in the bays, caused large waves that severely damaged unprotected bay shores and demolished a large part of existing bay shore protection.

While a storm with such a severe state-wide affect as Carla is a rare event, lesser hurricanes and tropical storms are regularly recurring events along the Texas coast. On the average, at least two such severe storms cross the Texas coast every five years. Shore protection design must consider the effects of such storms.

Moderate Storm. A more typical storm causing damage to Texas bay shores is illustrated by the moderately severe tropical storm that affected Galveston Bay in the summer of 1979. The photos show before and after shots of the effect of this storm on an unprotected bluff.

Bank of Bayshore Park in July 1979.

Bank of Bayshore Park in August 1979 following moderate storm. Note erosion of bank relative to fixed rock in both photos.

PLANNING

The fundamental step in shore protection is to realize that an erosion problem exists which, if left unchecked, would result in the permanent loss of valuable shorefront property. In order to solve the problem, an organized sequence of action is needed.

In almost all cases, the important initial step is to establish a community organization of affected shorefront landowners. A well-organized group can obtain better, and certainly more economical, shore protection than individuals acting alone. As a group, first make early contact with the Corps of Engineers and other permit-granting agencies. Then, prepare a comprehensive plan which outlines how the organization will be governed, the key factors in preconstruction planning to be considered, and the actual protection plan.

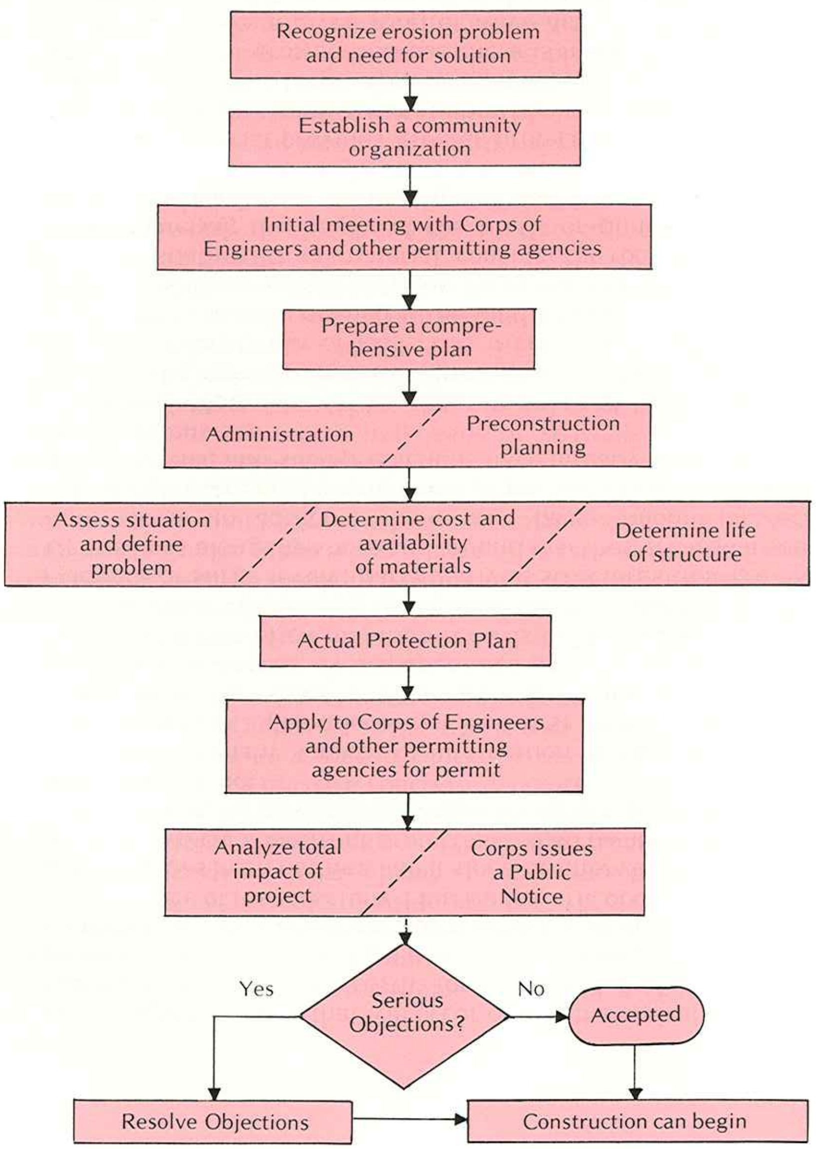
In preconstruction planning, it is first necessary to identify the specific problem or problems. Next, determine what type of shore protection should be used, the cost and availability of materials, and the desired life and function of the structure. These decisions will all be affected by the available budget. No structures work well everywhere. To determine the best solution, all the variables have to be taken into account.

After the actual protection has been developed, it is necessary to apply for a permit at the Permit Branch of the District Office of the Corps of Engineers. Generally, a permit is necessary if the proposed protection plan involves discharge or dredging in navigable waters of the United States, construction of a fill or pile-supported or floating platform, or the construction of boating facilities. In some cases, a Federal permit might be required when a state permit is not. In other cases, there are nationwide permits which allow certain activities without filing individual applications for permits with the Corps.

After submittal, the Corps District Office will analyze the total impact of the proposed project, including environmental and public interest factors. The Corps will then issue a Public Notice describing the proposed work for comment by local, state, and Federal government agencies, adjoining property owners, and interested members of the public. By law, the normal advertisement period is 30 days. If no serious objection is received, the District Office is authorized to issue the permit. The total processing time for applying for a permit is approximately 90 days and allowance for this time should be included in the construction plan. Violation of the permit laws can result in heavy fines and the expense of restoration.

The flow chart on page 9 outlines these steps in graphical form.

PLANNING FLOW CHART



LOCAL SHORE CHARACTERISTICS

Shore erosion is the result of waves and currents acting on the beaches and bluffs of the locality. The intensity of erosion depends on relatively few characteristics of the locality:

1. exposure to waves
2. probable height of the storm surge
3. existing littoral materials
4. structures in the vicinity.

Much of this information is easily available to the individual owner or the shore protection association, and all of it is important in understanding the erosion problem and developing the solution.

Wave Exposure. Wave exposure is a measure of how much wave energy can reach a given locality. It depends mainly on the wind direction, fetch, shoreline curvature, and bottom topography. To evaluate the exposure, determine the following characteristics of the locality:

1. Orientation of the shoreline: relative to the prevailing wind, what is the direction looking seaward from the shore? If the shoreline faces north or southeast, it has a greater exposure to waves than sites with other orientations.

2. Degree of sheltering: how open is the locality to the sea? For example, a locality in Dickinson Bay has only a narrow exposure to open water while a locality only a few miles away on the north shore of San Leon has a wide exposure to winds over Trinity Bay and Galveston Bay (see map on page 5 of this brochure).

3. Fetch: what is the wave generating area that can affect the locality? A measure of the fetch is the maximum distance between the locality and the opposite shore, along the line that the wind blows. If this distance is more than 5 miles on bays, the fetch is long. If less than 1.5 miles, the fetch is short.

4. Bottom topography: how shallow is the sea bottom offshore of the locality, along the line that the wind blows? Shallow water along this line can protect the locality by causing large waves to break early. Deep water may allow the waves direct access to shore.

Height of Storm Surge. Storm surge raises the water level and allows waves that normally would break offshore to break on the shore. Shore protection structures must be built high enough to protect against waves that will occur during the typical storm surges. However, it will be too costly for the shore protection project to protect against the maximum possible storm surge. The owner must gamble that rare maximum storm surges will not occur during the intended life of the structure. Hurricane Carla occurred 19 years ago, and there has been nothing like it since; twenty years is a good life to get from typical shorefront protection, so an owner who rebuilt right after Carla at an elevation less than the Carla surge elevation may have won the bet.

There are many sources of information on the height of typical storm surges in a given locality. Good first sources are local people living along the shore and agencies granting permits for shore protection structures. Newspaper files and businesses operated in coastal localities often maintain records of high surge levels.

Inspection of existing structures in the locality can provide evidence of surge levels, particularly at structures that are too low. Debris lines along the shore and around marshes are also a source of information. In addition, there is a large amount of technical knowledge that enables engineers to predict storm surge levels for given regions, and such predictions have already been published for many regions.

Littoral Materials. If the shore consists of high bluffs of hard rock, it will not erode, and shore protection is not needed. If the shore consists of low banks of loose silt, it can erode rapidly, and shore protection is usually needed if the land has any value. Most littoral material is intermediate between these two extremes.

In evaluating littoral material, consider the rockiness or looseness of the material; the height of the bluffs or dunes that border the shore; the beaches or other material that is at the shore; and any sources of sand that might reach the shore.

Rocky material provides greater protection than loose material. Material that feels gritty when rubbed between your fingers is better than material that feels slippery. High bluffs or dunes reduce the apparent rate of erosion because there is more material to erode in them. Therefore, a given level of wave activity will take longer to erode a high bluff than a low bluff of the same material. Wide sandy beaches indicate protection, especially if the sand is coarse. A shoreline with exposed silt or clay beds almost always indicates a tendency to continued erosion. A natural sand source nearby is a significant factor in reducing erosion. Nearby sandy creeks or eroding sand banks are typical sand sources.

Structures. Existing shore protection structures on a neighbor's property, and structures located offshore, can have a significant effect on shore protection plans. Some structures interrupt the longshore flow of sand. If such structures are updrift of the property to be protected, they usually will increase erosion on the property. If the structures are downdrift of the property, they will lessen erosion.

Structures located offshore may protect the property, or may change the direction of wave attack. Usually, pile-supported structures have a negligible effect on shore erosion, unless the piles are densely spaced. But solid docks, breakwaters, and small islands will have a significant effect, especially if they do not remain in their as-built condition.

Cumulative effect of repeated storms.

INVENTORY OF FEASIBLE SOLUTIONS

Experience has shown that shore erosion can be reduced or stopped by appropriate shore protection structures, particularly when the solution is applied consistently on a regional scale with periodic maintenance. Types of engineered shore protection include shore-parallel protection (revetments, bulkheads, and seawalls), shore-connected or offshore breakwaters, groins, and sand in the form of constructed beaches and dunes. The effectiveness of these structures is enhanced by providing adequate drainage of storm water from the upland to the sea and encouraging growth of vegetation. These solutions are defined below, and their use described in more detail in the following pages.

Revetments. A revetment is a covering of the shore that absorbs the energy of waves to prevent erosion of the underlying soil. A typical revetment is a sloping layer of stones or concrete rubble, underlain by finer stone or filter cloth. A properly designed revetment is an effective protection of bay shorelines and is often used in combination with bulkheads or seawalls to protect those structures from wave erosion.

Bulkheads. A bulkhead is a partition that separates land from water in a way that allows the elevated upland surface to be retained and used right up to the water's edge. The typical partition consists of vertical sheeting embedded firmly in the underlying soil and tied back into the upland. A bulkhead makes efficient use of upland property, but ordinarily, a bulkhead is not adequate, by itself, to withstand direct attack of storm waves.

Seawalls. A seawall is a barrier designed to keep the sea from invading the land, both by serving as a dike against the flooding of storm surge, and as a wall to reflect or dissipate storm waves. A typical seawall is a massive concrete structure, well anchored in the underlying soil, and often having a crest elevation higher than the mainland behind it. Seawalls are appropriate structures along highly developed, lowlying ocean or bay shores where protection of lives and property is the major consideration.

Breakwaters. A breakwater is a barrier, located in the water, designed to reduce wave and current action on the landward side of the barrier. The typical breakwater consists of a rubble mound of rock, covered by a layer of armor stone or cast concrete units. Per foot of shoreline, breakwaters are relatively expensive, and their most common use is to improve navigation rather than to prevent erosion. Most breakwaters are attached to land at one end, but some are isolated offshore, and a few are moored, floating structures.

Groins. A groin is a structure usually placed perpendicular to the shoreline and designed to reduce the loss of sand from a beach. Groins are extended into the water to a depth where they will trap and retain littoral drift. The use of groins should be carefully considered, since trapping littoral drift can initiate erosion on neighboring property. Typically, groins are constructed of rock, timber, or both.

Beach and Dunes. Beaches and dunes occur naturally along the Gulf shores, but are not common on bay shores. Beaches and dunes form a reservoir of sand to be acted upon by waves during storm conditions, and a barrier to prevent overtopping at times of high water level. Depleted beaches and dunes may be built up with sand fill. The size of the sand grains used in the fill has a significant effect on the future erosion of the sand fill. Sand size in the fill should be at least as coarse as the size of the natural beach sand. The volume of sand in the fill depends on the degree of protection required.

Vegetation. Vegetation occurs naturally on dunes and along bay shores. Vegetation by itself does not provide much protection against storm waves, but it acts to retain and collect sand in the dunes and to bind soil along the bay shore, and this sand and soil does act as a buffer in time of wave attack. The growth of vegetation may be stimulated and maintained by proper use of fertilizer and protection of the growing plants.

Drainage. In any shore environment, there is a system of channels that conduct water (usually rainwater) from the upland across the shore to the sea. The natural drainage along Texas bay shores is usually a network of stream channels and gullies which carry water only during and right after storms. The bluff and shore erosion accompanying this natural storm drainage may be reduced by diversion of the flowing water into a channel which is armored with rock where it crosses steep bluffs near the shore.

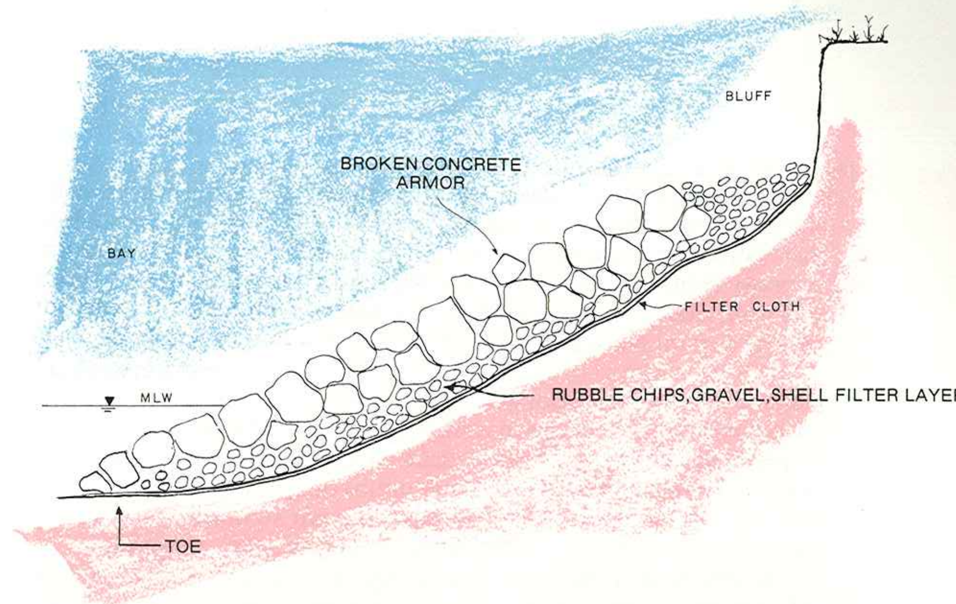
REVETMENTS

A revetment is a facing of resistent material, typically stone or concrete, built along the shore to prevent erosion. This facing consists of two layers: a surface armor and an underlying filter.

Armor. The surface armor may be randomly placed rock, tightly fitted concrete blocks, or any number of specialized revetment armor units. The photo example shows a revetment whose armor layer consists of broken concrete rubble. The function of surface armor is to dissipate the energy of waves and currents without damage to the shore. The proper size of the individual armor units depends mainly on the wave height expected during storms.

Filter. The filter underlying the armor may consist of a layer of gravel, shell, and filter cloth. The filter has two functions. It separates the water currents moving through the armor layer from the fine soil of the shore, thus providing erosion protection on a small scale. It also acts as a strainer allowing water to drain out of the soil while keeping the fine particles in the soil. If water is not able to drain out from under the armor, the resulting buildup of water could weaken the soil along the shore, causing small landslides. The buildup of water also exerts a force on the armor units which could cause the revetment to fail. If the draining water carried soil particles with it, a cavity would form under the revetment, leading to its collapse.

Toe. In revetment construction, it is important to firmly anchor the toe of the revetment. This is difficult to do, because scour has its maximum effect where the toe of the revetment meets the natural bottom. This scour can undermine the toe armor units and result in progressive failure up the revetment slope. Toe placement is done under water, which adds difficulty to the anchoring. Extending the armor layer to the bay bottom provides added protection from scour at the toe of the revetment.



Successful revetment made of concrete rubble. Rubble pieces should be blocky in shape and without exposed steel reinforcing.

Design. Typical requirements of revetment design are illustrated in the sketch of a rubble revetment. The revetment shown has a 1 (vertical) on 2 (horizontal) slope. The slope ordinarily should not be steeper than 1 on 2 for long-term performance, and the revetment will function better if flatter. But a flatter slope requires a greater volume of rock in the revetment. The toe extends seaward of mean low water (MLW), and the armor layer continues seaward of the filter layer. The thickness of the armor layer is about twice the diameter of the average rubble piece in the armor layer.

While such a structure may be readily built by the shorefront home owner, details of filter design, armor unit size, toe and crest elevation, and construction sequence will depend on site-specific information. For exposed sites, the advice of a competent engineer will pay off in long-term performance.

Materials. Angular rock of suitable size is the best material for revetment armor. Concrete rubble is an acceptable substitute for rock if not aesthetically objectionable, and it is the typical revetment material along Texas bay shores. For safety and acceptability, concrete rubble units should not have protruding reinforcing bars. Specifically designed interlocking, concrete armor units may be used in place of rock or concrete rubble. Asphalt pavement should not be used in revetments. Rock or concrete used in revetments must have a dry bulk density of at least 145 lbs per cubic foot, and should be block-shaped rather than slab-shaped. Acceptable filter material includes clean gravel and shell, and filter cloth of suitable mesh and tensile strength. At 1980 prices, suitable filter cloth could be obtained at under $0.25 per square foot from recognized manufacturers.

Construction Requirements. The ground to be covered by the revetment should be cleared of trash and vegetation and scraped to approximate grade. Scraping should be deep enough so that filling of low spots can be avoided, but if fill is necessary, it must be carefully compacted prior to placement of the filter. Filter layer and armor layer may be laid by hand or with available construction equipment, depending on the size of the job. Contruction proceeds from the toe up the slope. The recommended thickness of the armor layer is the thickness of two average armor stone sizes, but if available stone is significantly oversized for the wave requirements, a thickness of one stone may be satisfactory. The top of any given stone should not protrude more than half a stone above the design surface of the revetment armor, and where hand placement is feasible, the largest stones should lie at the surface of this armor.

Successful revetment of inter-locking concrete blocks at toe of Galveston seawall.

Revetment on Trinity Bay constructed of high-density blast furnace slag. High-density materials make good revetments.

Dimensions. The distance along the slope is determined by the design slope and the vertical distance from the toe to the crest. A typical bay shore revetment has a toe elevation of-1 ft mean low water (MLW) and a crest of +5 ft MLW. Individual armor unit sizes for block-shaped units rarely need to be larger than 1.5 feet on a side in a Texas bay environment. Usually, thickness of the filter layer is a minimum of 12 inches if constructed of gravel or shell, but this thickness may be reduced if filter cloth is incorporated in the design.

Maintenance. Periodic inspection, particularly after storms, is required. Repairs should be made immediately to any part where the armor layer has been removed to expose the filter layer. Excessive scour at the toe may require additional stone protection. Drainage must be provided for rain water and water from wave overtopping so that the soil behind the crest of the revetment is not eroded. Sod should be maintained in healthy condition adjacent to the structure.

Rubber tire revetment on intracoastal waterway.

BULKHEADS

Function. A bulkhead is a structure along the waterfront designed primarily to retain usable upland surface by protecting the upland against slumping or gullying. The typical bulkhead is a sheet-pile partition stiffened by horizontal wales, supported by piles on the seaward side of the partition, and, usually, anchored by ties fixed to stable ground landward of the partition. The sketch below shows these basic elements of bulkheads.

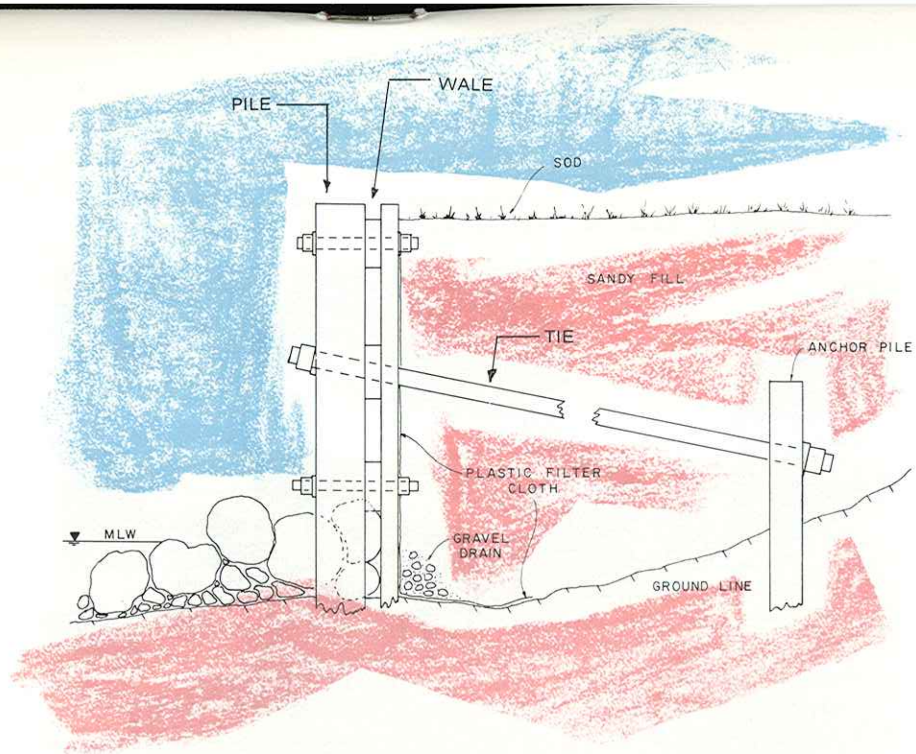
A secondary function of a bulkhead is to protect the upland from limited wave action. However, typical bulkheads along Texas bay shores are unsuitable for protecting the shore from direct wave action where waves of one foot or more in height are common. For effectiveness in such an environment, bulkheads are fronted by a revetment which absorbs most of the wave attack.

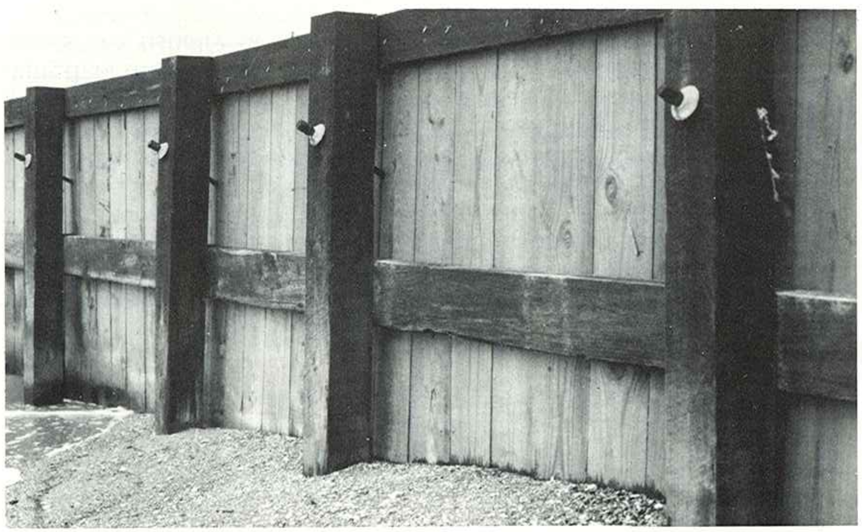
Materials. Bulkheads may be timber, reinforced concrete, aluminum, or steel. The desirable choice for a specific site will be determined by the optimum combination of durability, ease of construction, and looks of the finished structure, within available budget.

Since all materials deteriorate or corrode to some degree in a water environment, durability of the material at the site determines the life of an otherwise well-designed structure. For durability, timber must be treated. Timber may be pressure-treated with CCA (chromated copper arsenate, 2.5 lbs per cubic foot of wood), or for best results, a dual treatment of CCA and creosote.

Reinforced concrete will be more durable in a marine environment with an extra thickness of concrete over the reinforcing bars. Some aluminum and steel companies fabricate bulkhead systems using special alloys. (Alloys designed for hardness or strength are not necessarily the most corrosion resistant.)

Durability of a bulkhead often hinges on the durability of the hardware that fastens it together, or on resistance to corrosion of the ties that anchor it to the upland. Money expended on corrosion-resistant hardware and on coating hardware and ties to protect them from water has long-term benefits in extending the life of the structure.





Typical timber sheet pile bulkhead.

In selecting material for a bulkhead, the owner will benefit by examining successful and unsuccessful bulkheads in the area, paying particular attention to the actual age of successful structures and the causes of failure of unsuccessful structures. The absence of a given style of bulkheads in the area should not be taken as proof that the style is unsuitable for the area. Often, all structures in a given area are built by a particular contractor who selects materials, methods, and design based on past familiarity.

Construction Requirements. To prepare the site, vegetation and trash should be removed and the ground leveled along the bulkhead line. Landward of the bulkhead line, the area to be filled should be cleared of vegetation and other material that may decompose under the fill. Special attention must be given to the natural paths of stormwater drainage from the adjacent upland. Where the bulkhead will intercept this drainage, new drainage paths must be provided around or through the bulkhead.

Sheet pile and support pile may be driven or placed in dug holes, depending on the extent of buried rubble along the bulkhead line and the availability of equipment. Anchor piles or deadmen must be sited in firm ground, usually at a landward distance of at least 1.5 to 2.0 times the length of the sheet pile in the bulkhead.

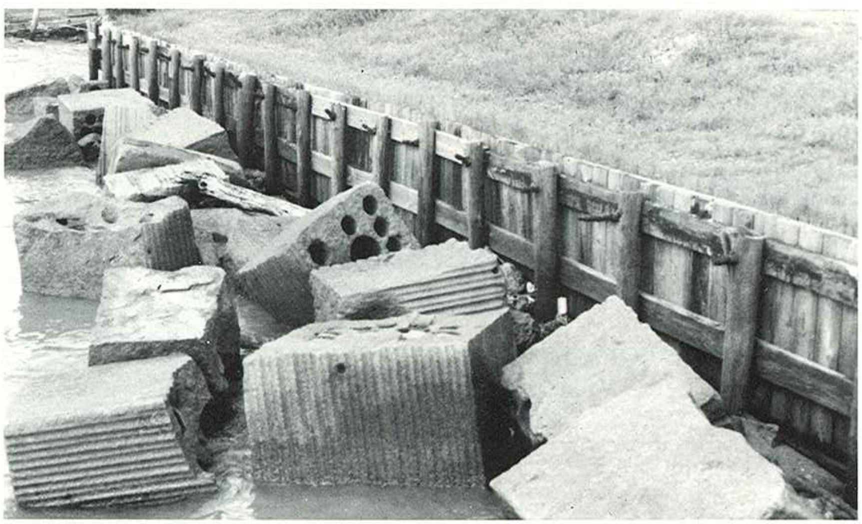
Prior to shipment, materials are prefinished to proper length with holes for hardware. If timber is used, most cuts and holes should be made prior to treatment (plants that do pressure treatment are usually equipped to do this precutting efficiently). Support piles should be bolted rather than nailed to wales. Bolts should fit snugly with minimum exposed length to reduce corrosion from water circulation, and washers must bear flush on the wood surface without crushing the wood fiber. Any surfaces cut into the treated wood must be thoroughly tarred at the site to maintain the integrity of the timber treatment.

Soil must be prevented from washing through the sheet pile. Tongue-and-groove or interlocking sheeting provide the first level of retention. Filter cloth against the land side of the bulkhead will better retain the soil, and a graded drain of sand and gravel will help reduce excess pressures due to trapping of water behind the bulkhead.

Fill must be placed first at the anchor piles or deadmen. Fill should be as granular as possible, well-compacted, and covered with healthy sod. For the benefit of future work on the property, an as-built map showing the anchors or deadmen will be useful.

Dimensions. Sheet pile suitable for shore protection in Texas waters vary so widely in size that there are no typical dimensions. Neighboring bulkheads can vary significantly in the sizes of their components, yet be equally successful since it is the total effect of the structure, with its anchor system, that must be designed.

Bulkheads along open bay shores are typically sited somewhere between the mean low water and the mean high water lines. Sheet piles extend below the ground line at least a distance equal to the length of the sheeting above ground, and the outside support piles or posts are usually deeper. Depth of placement is needed both to protect against wave scour during storms, and to resist the soil pressure landward of the bulkhead. The anchors, or deadmen, are set at a landward distance at least 1.5 to 2.0 times the total sheet pile length. Pile size and the number and location of anchors depend on the amount of load carried by the different elements in the bulkhead.



Timber bulkhead with large granite block revetment. Bulkheads require revetments where exposed to wave action.

The key dimension is how high the top of the bulkhead must be above the water line. This elevation is obtained from knowledge of how high the bay waters rise during common storms in the area, and how much protection the owners can afford.

Maintenance. The best maintenance is the result of periodic inspection and immediate correction of problems. Points to be inspected include: condition of sod and drainage on the upland side of the bulkhead; condition of each end of the bulkhead where it joins the neighboring shore; the alignment of the overall structure; the condition of visible nuts, washers, and bolts; and the toe condition. It is a good idea to keep a written record of the depth to bottom in front of key locations on the bulkhead and the angle of the piles to the vertical at these key locations. Sudden changes in depth or angle indicate a need for corrective action.

SEAWALLS

Design Elevation. Seawalls have a significant, but strictly limited, use as a shore protection. The limitation depends on the elevation of the property to be protected, relative to two water levels: the expected storm surge level and the expected height of the wave runup during that storm surge. Only if the property elevation is between these two water levels should a seawall be considered.

Seawalls are not appropriate if the property to be protected is lower than the expected storm surge because such low-lying property is almost certain to be flooded, either by impounded rain water from the land side, or by flood waters flanking the seawall across adjacent property. Under such flood-prone conditions, other alternatives such as relocation, raising the property level, or diking are usually more effective.

For higher property, above the elevation reached by waves during the design storm surge, a seawall is not needed. Instead of a seawall, the slope below the runup limit can be more efficiently protected by a revetment.

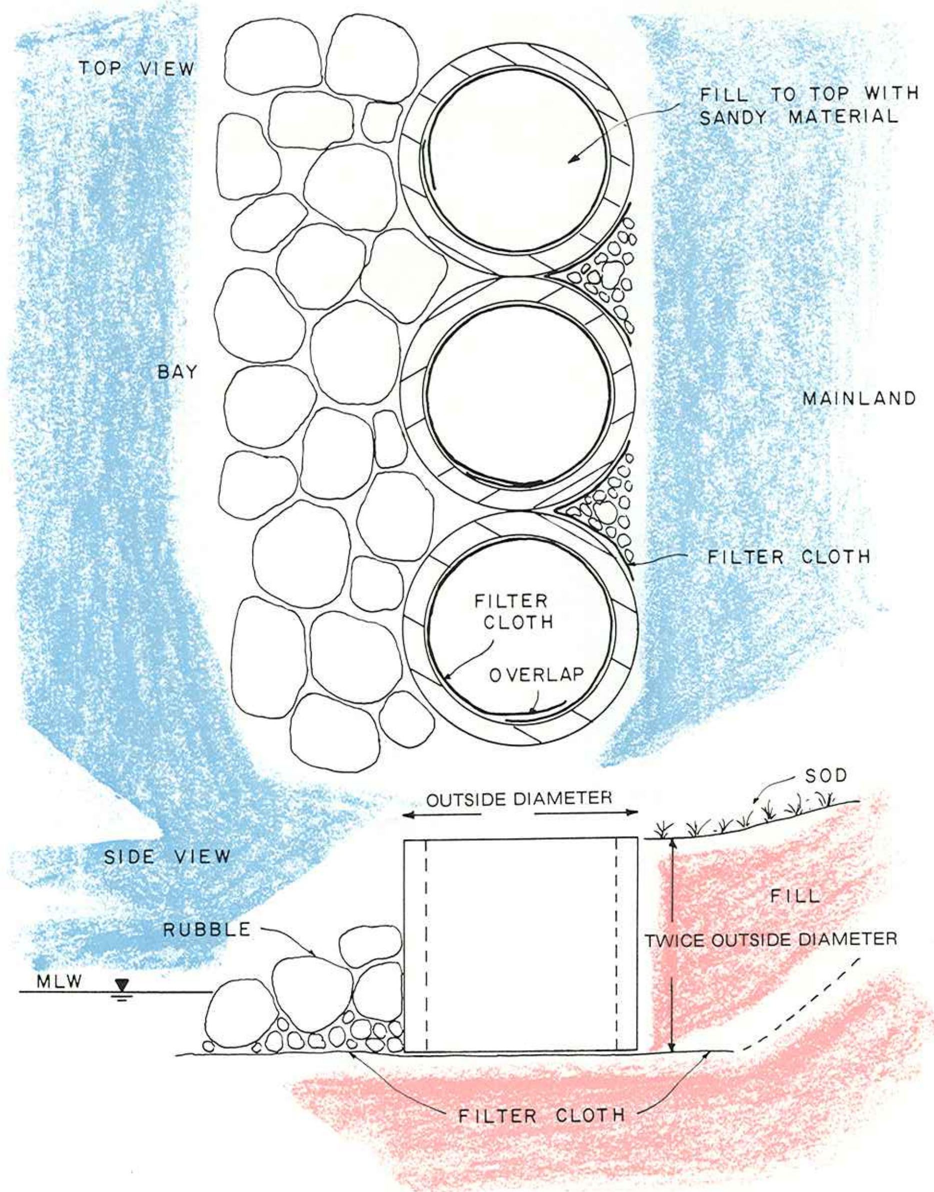
Stability. A seawall is acted on by earth, seepage, and wave forces. The seawall resists these forces by its own weight. The distribution of the seawall weight is determined by the shape of the seawall. This means that the shape of the seawall is a critical design factor.

The weight of the seawall must be spread over a footing which distributes the weight evenly over the underlying soil. If the weight of the seawall is concentrated along one edge of the footing, the strength of the underlying soil could be exceeded, and the seawall might overturn.

The seawall must be designed to allow rain water accumulating on the landward side of the structure to escape, rather than build up pressure. This drainage is ordinarily provided by weepholes and a system of gravel drains.

Galveston seawall.

Grouted rubble seawall reinforced with wire mesh.



Over the lifetime of a seawall, wave forces are probably relatively minor if the seawall has been properly designed to resist the earth and seepage forces. The impact of the wave on the front face of the seawall should be deflected upward and seaward by curving the front face of the seawall to reduce overtopping.

Materials. The typical seawall is constructed from concrete poured at the site. Reinforcing steel is rarely needed for such seawalls on ordinary shorefront property. For long-term performance, the materials in the concrete (coarse and fine aggregate, cement) must be good quality and properly prepared. In addition to the standard concrete seawall, a number of composite seawall designs are in use. A common variation is the grouted riprap seawall constructed by filling the voids in a riprap structure with concrete. This can be an effective shore protection, although it is difficult to achieve a steep reflective seaward face by this technique.

Another variation is a concrete pipe seawall which gets its stability from the mass of material contained within the pipe sections. In the design of a pipe seawall, it is important to have thick, reinforced pipe sections since the fill in the pipes is quickly washed out once the pipe wall is cracked. It is also important to have the upland behind the pipe properly drained in order to lessen the water pressure on the back side of the pipe sections.

Maintenance. The seawall should be inspected periodically and after major storms. The condition of the toe, drainage of the upland, and alignment of the structure must be checked. A well-built seawall will be costly, but it should have a long life.

BREAKWATERS

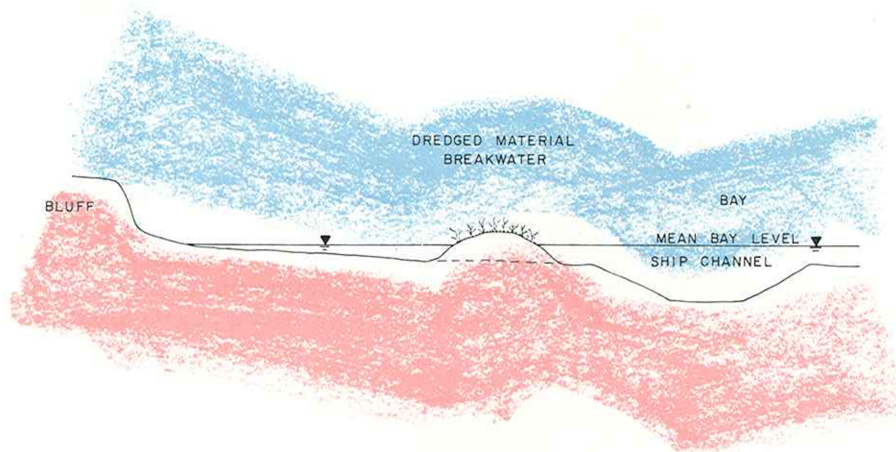
Breakwaters are offshore structures designed to provide shelter from wave action. Primarily, breakwaters are designed to provide quiet water for boats or to protect a navigable channel. In some areas, breakwaters improve or protect recreational beaches.

Breakwaters are typically constructed of rock or concrete armorstone overlying a core made of smaller stone and fill. Such rubble mound breakwaters are designed very much like the revetments discussed previously, except that the underlying soil beneath the revetment is replaced by the breakwater core which must be constructed first.

Besides rubble mound construction, breakwaters have been built of rock-filled cells encircled by sheet pile, moored rafts of floating tires, rows of sheet pile, and numerous other objects. In Texas coastal waters, functional breakwaters have sometimes resulted from the linear islands constructed of dredged material produced during construction and maintenance of the Intracoastal Waterway and major ship channels. These islands may reduce wave energy reaching the shore, as indicated in the accompanying illustration.

Because of their exposed position, breakwaters are prone to damage. Scour at the toe, soil failure beneath the structure, and mooring failure (for floating breakwaters) are common problems. The vertical face on sheet pile or cellular breakwaters causes the wave height to increase right at the breakwater, producing greater forces and toe scour. Small gaps in the breakwater often transmit surprisingly large waves resulting in less protection than anticipated.

Dredged material island providing partial protection to San Leon shores.



GROINS

Groins are structures designed to reduce the loss of sand from a beach. The beach, in turn, protects the shore from erosion.

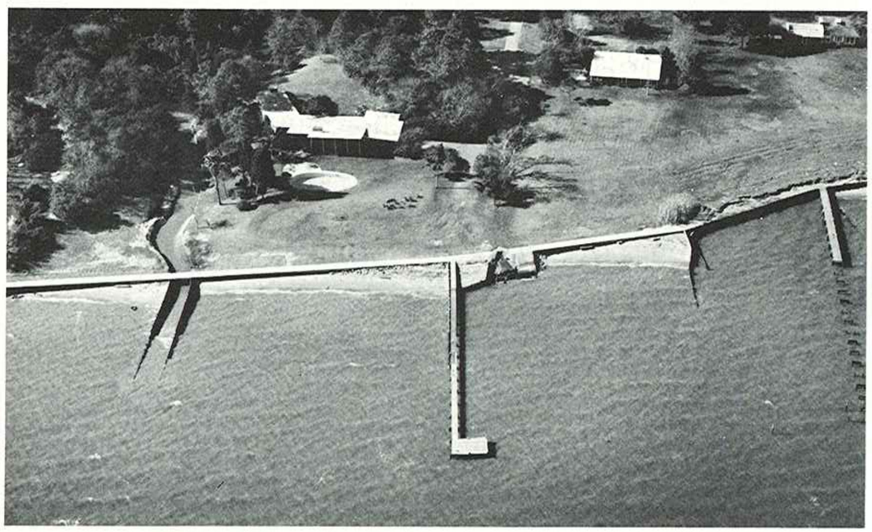
Groins are oriented perpendicular to shore. Since much beach is lost by longshore transport of sand parallel to and near the shoreline, groins act as small dams to reduce this longshore sediment movement. An example of this is shown below in the photo on the right.

A groin is usually built in a groin "field," which is a group of groins at selected spacing, rather than as an isolated structure. The recommended groin spacing is 2 or 3 times the groin length. The length of the groin is measured from the typical high-water mark on the shore to the seaward end. However, the groin must be continued well landward of the high water line in order to prevent isolating the groin by possible future beach erosion.

The top of the groin is usually not higher than the elevation of the berm on the beach. If the groin is higher than this, it will dam up too much sand on beaches where sand is abundant, and it will not serve any purpose on beaches where sand is scarce.

To establish the groin spacing, it is necessary to determine how long the groin will be. The accepted practice is to extend the groin seaward at least to the depth where normal waves are breaking prior to construction. In areas where beach sand is relatively fine, such as along the Gulf shore, the naturally flat slope of the profile requires relatively long groins.

Groins are usually constructed of rock or timber, or a combination of rock and timber. Because the seaward end of the groin is especially exposed to wave action, the groin must be strongly constructed. Other structures, such as storm sewers and docks, may function as groins where they cross the beach, even though they were not built for that purpose.



Successful bay shore groins. Docks and similar structures may function as groins.

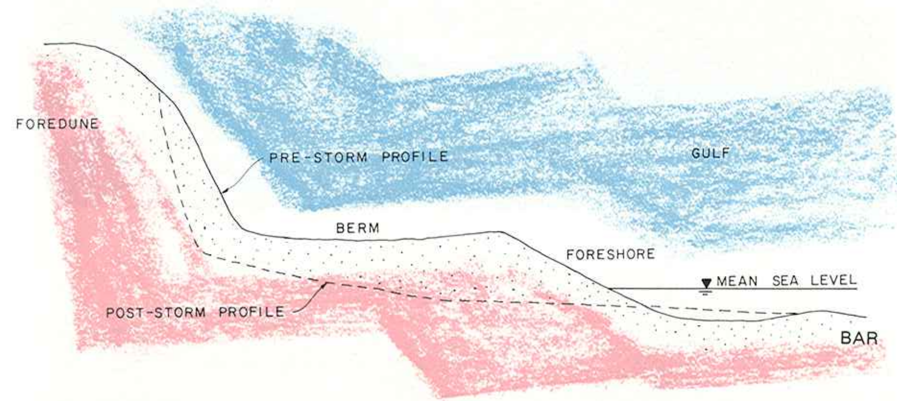
Gulf shore groin.

BEACHES

Sand beaches provide a natural protection for the shorefront property, but significant beaches are found only on the Gulf shorelines in Texas waters. Two factors hinder the development or retention of sand beaches on the bay shores: there is relatively little sand in the eroding bluffs surrounding the bays, and the short steep waves common in the bays tend to remove sand from the shoreline in those places where sand is found. On the Gulf shores, the short steep waves that remove sand from the beaches are often followed by longer, relatively low waves which push the sand back on the beach. In the bays, there is not enough fetch to develop such long low waves.

A cross section of a beach includes an inclined surface called a **foreshore** where the waves run up and down, and a flat backshore **berm** which extends to the dune. Offshore, there may be a longshore bar parallel to the coast. At a minimum, the width of the beach must accommodate the complete foreshore. The flatter the foreshore, the wider the necessary minimum width of the beach. The slope of the foreshore gets flatter as the size of the sand grains in the beach get smaller. Texas Gulf beaches usually have relatively fine sand, making them relatively flat and wide wherever there is enough sand to develop a beach.

Beaches can be developed and maintained by periodically nourishing the beach with new supplies of sand. The sand put on the beach is not a permanent deposit. It will be eroded. However, this erosion can be reduced if the sand used to nourish the beach is noticeably coarser than the sand already on the shore. Even relatively fine sand can be used to construct a useful berm that will last a number of years during the absence of severe storms.



Backshore berm of a typical Gulf beach. As shown by the sand around the log, berms are usually constructed by sand added from the seaward side of the beach.

Foreshore of a typical bay beach.

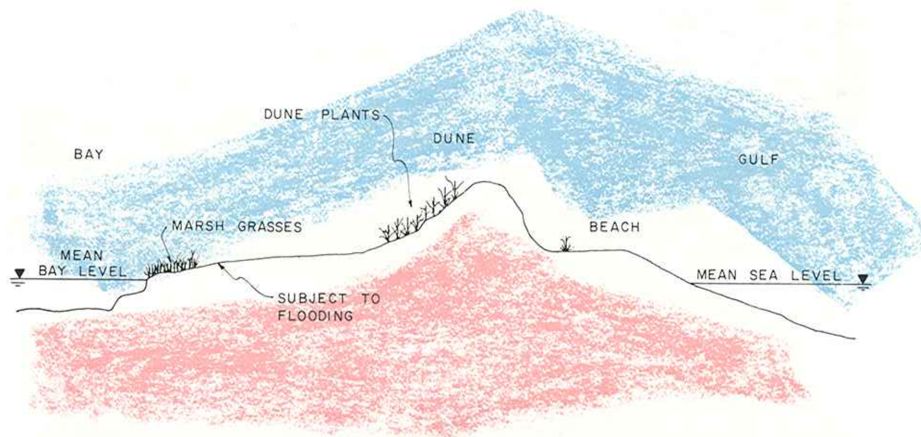
DUNES AND VEGETATION

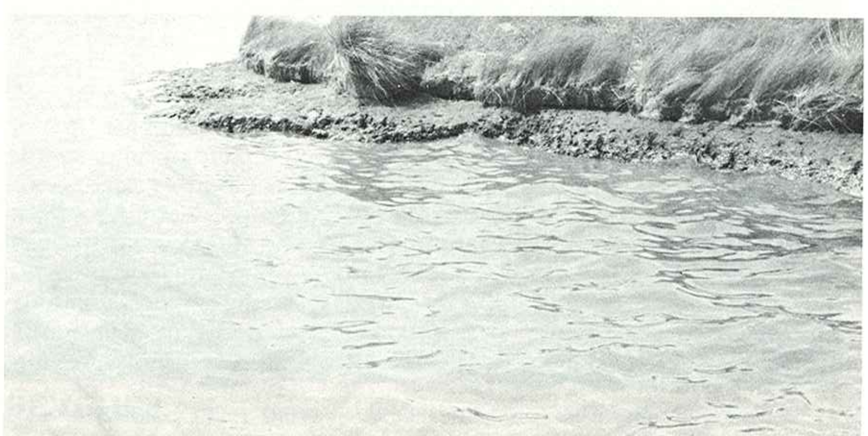
Dunes occur naturally where there is an abundance of sand and strong winds, especially if the amount of naturally occurring vegetation in the source areas is limited, and the dunes themselves are vegetated. Measurements on the Texas Gulf coast have shown that dunes can grow rapidly under proper conditions, accumulating up to 10 cubic yards of sand per foot of shorefront in one year.

Wide unvegetated beaches, and overwash deposits of sand formed during hurricanes, are typical sources of sand for transport by winds on the Texas coast. Sea oats and bitter panicum are common Texas shore grasses that trap the sand in the dunes. When properly fertilized, such plants grow vigorously. The individual blades of grass trap the sand by dissipating the wind energy near the ground and by providing a soft, non-bouncing surface for wind-blown sand grains. As the plants accumulate trapped sand, they grow up through the sand to maintain their position on the sand surface.

During times when severe storms are absent, the dune plants tend to invade the beach. But sooner or later a storm will occur that cuts back the beach, eroding away these invading plants and cutting into the front of the dunes. Plants by themselves do little to retard this erosion, but by stockpiling the sand in dunes, they indirectly serve to slow the rate of shore erosion and to dike off the landside of the dunes from flood waters.

On the bay side of the dunes and in low spots around the bay shores, marsh grasses and other plants are often abundant. In areas where the fetch is limited, these grasses provide moderate protection to the shore, but on the open bay coast, wave conditions are usually too severe to allow such plants to thrive. Appropriate species for protected bay side shores depend on salinity of the bay water and the elevation. Recommended species for moderately saline water include giant reed and Gulf cordgrass for elevations usually above high water, and saltgrass and black mangrove for elevations subject to flooding by high water.





Typical bay shore vegetation.

Vegetated dunes along the Gulf shore.

SOLUTIONS WITHOUT SHORE PROTECTION STRUCTURES

Sometimes it is not feasible to build shore protection to prevent erosion. Often, it is better to try avoiding erosion than fighting it.

Relocation. One possible nonstructural solution is relocation. In many cases, relocating a house 100 - 200 feet landward, although quite expensive initially, may actually be cheaper in the long run. Relocation is sure and can outlast the useful life of the house, unlike structural solutions which may fail in a few years and leave the property owner in the same position as before.

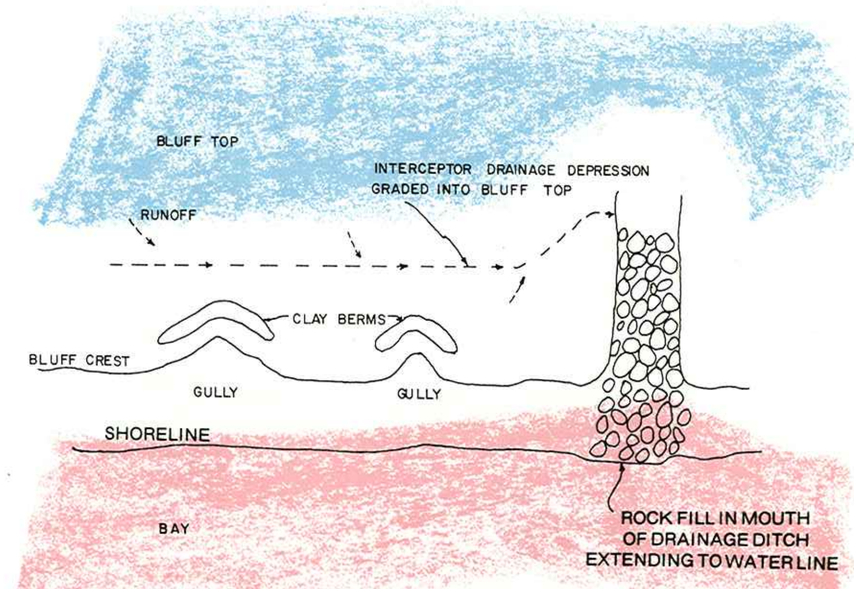
An initial step in relocating is to find historical records which tell the positions of the shoreline and bluffs at previous times. From these records, it is possible to compute the rate of recession of the bluffs and, therefore, to predict the amount of erosion that will occur at a certain location. From this information, the best site to relocate to can be determined.

Relocation can be costly because the most suitable relocation site is often expensive. In addition, the actual moving requires highly specialized, and thus costly, skills and equipment. To be economically feasible, the relocation site must be as close to the original area as possible, and the total cost of the relocation must be less than the replacement value of the relocated structure.

The most obvious drawback of relocation as opposed to shore protection is that it does not stop erosion at all. Erosion continues; it is just farther away for the present.

Drainage. Another example of a nonstructural solution is good drainage. Erosion occurs as a result of surface runoff and groundwater action. Surface runoff can form deep gullies which erode the sides of a bluff. However, diversion berms or small levees can be built in front of the gullies so that water is diverted across the bluff in a controlled manner.

Water movement from seep zones (zones in the bluff where water comes from between differing layers of sediment) causes serious bluff retreat. This groundwater can be intercepted and drained out through a system of horizontal drains. Drainage problems on the whole are very complicated; therefore, a professional should be consulted to help work out the best solutions.



Plan view of drainage diversion.

KEY CONSTRUCTION AND MAINTENANCE CONSIDERATIONS

The shore protection structures recommended in this brochure have an intended design life of about 20 years. Although they are not capable of withstanding a direct hit from a hurricane, with proper care these structures can provide adequate protection against ordinary storms and high water throughout this period of time. Once designed, a shore protection structure must be carefully constructed and maintained for it to properly function throughout its intended design life.

Construction. Proper construction begins with the preparation of the site. Clear away vegetation and debris and grade the soil to the required slope. The soil should have a bearing capacity sufficient to provide a sound base for the structure. In some places where clay is the predominant soil, it may be necessary to replace it with a more stable material.

Surface and ground water must drain safely through the structure to prevent development of gullies or a possible build-up of water pressure behind the structure that could lead to failure. The top of the structure should be high enough to protect against high water as well as overtopping. Water overtopping the structure as wave runup or splash can lead to shoreside erosion that is common cause of failure (see photo). The effects of overtopping and runoff can be reduced by providing sod and porous gravel surfaces behind the structure.

If possible, plan the construction to take place during exceptionally low tides. By doing so, extra measures to prevent scour at the toe can be taken. If left unchecked, scour at the toe can lead to slumping and cracking, and the structure may eventually collapse.

Flanking, another common occurrence, is the erosion of a structure from the side or the rear, rather than from the sea. This usually occurs because the land adjacent to a bulkhead or revetment has been left unprotected. The best remedy is to develop shore protection plans in association with your neighbors, so that your neighbor's structures will prevent flanking of your own.

Choose only quality materials for the construction. For timber

Bulkhead too low to prevent water overtopping. Erosion from overtopping has exposed the rods.

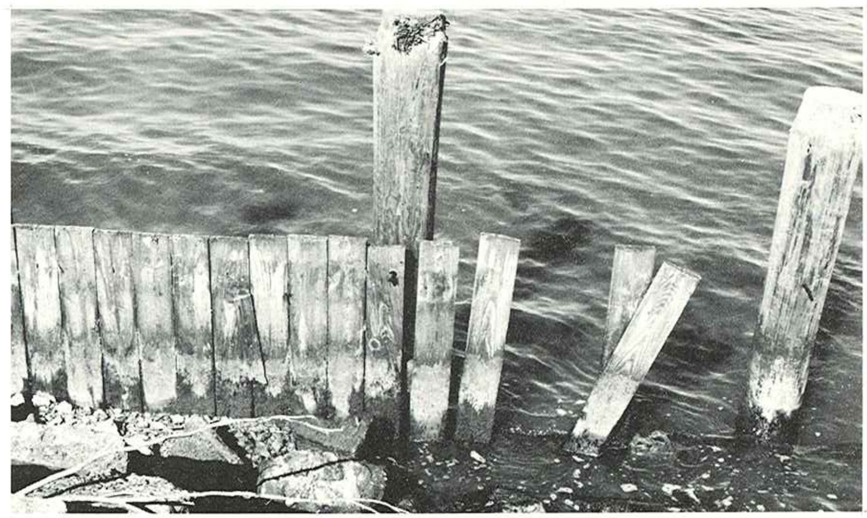
Interlocking concrete block revetment indicating partial failure of toe. Note cracking on the seaward side of blocks.

bulkheads, use only pressure-treated lumber that has received dual treatment with CCA and creosote. Tongue-and-groove sheet pile provides an extra measure of durability and reduces the loss of fine sediment in back of the bulkhead. For hardware, use only heavy-duty double-dipped galvanized coating, and minimize exposed metal.

In the construction of revetments, choose an armor stone with a density of at least 145 pounds per cubic foot. If concrete rubble is used, choose equidimensional pieces without exposed reinforcing bars. Do not use asphalt rubble, as it deteriorates quickly under wave action. It is a good idea to use a filter cloth in contact with the underlying soil since filter cloth is relatively inexpensive, and it reduces the amount of material needed for the base layer. Filter cloth is also useful when nailed across the landward face of sheet piles in a bulkhead.

Maintenance. Periodic maintenance of a shore protection structure is very important. Inspect the structure on a regular basis and particularly after severe storms. Revetments are somewhat self-healing. If minor damage is sustained during a storm or high water, the structure will continue to provide partial protection without repair. Timber bulkheads are not self-healing. Once one structural element has failed, the bulkhead quickly ceases to function usefully. Damage to timber bulkheads should be repaired immediately. Broken tie rods and bolts are a major cause of failure and collapse. Keep a permanent record of repairs as this may be useful in the future.

Flanking of rock revetment by erosion of neighboring unprotected shore.



Failed bulkhead. Failure initiated by corrosion of bolts.

SELECTION FACTORS [PLANNING]

(See pages 8 and 9 for additional information)

Shore Protection to be Considered	Suitability		Land Value		Project Life		Maintenance Frequency	Weak Link	Cost
	Bay	Gulf	High	Low	50 yrs	20 yrs			
Revetments	Yes	Maybe	Yes	Yes	Maybe	Yes	after major storms	toe failure	moderate
Bulkheads	Yes (with revetment)	No	Yes	No	No	Maybe	annual and after major storms	hardware and ties	high
Seawalls	Yes	Yes	Yes	No	Yes	Yes	infrequent	toe failure	high
Beaches	Yes	Yes	Yes	Yes	Yes	Yes	new sand fill periodically	erodes in storms	moderate
Dunes	Not usually	Yes	Yes	Yes	Yes	Yes	fertilize annually: continued isolation	vegetative cover	low
Marsh Vegetation	Yes	No	No	Yes	Maybe	Yes	infrequent	eroded easily by waves	low
Groins	Yes (if beach sand present)	Maybe	Maybe	No	Maybe	Yes	after major storms	need sand beach	high
Relocation	Yes	Yes	Yes	Yes	Maybe	Yes	never	erosion continues	land lost
No Action	Yes	Yes	No	Yes	Maybe	Maybe	never	erosion continues	land lost

SELECTION FACTORS [LOCALITY]

(See page 10 for additional information)

Shore Protection	Wave Exposure		Fetch		Bluff			Shoreline Soil	
to be Considered	Exposed	Sheltered	Long	Short	High	Low	Absent	Silt Clay	Sand
Revetments	Yes	No*	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bulkheads	No	Yes	No	Yes	No	No	Yes	Yes	Yes
Seawalls	Yes	No*	Yes	No*	No	Maybe	Yes	No	Yes
Beaches	Yes	Yes	Yes	Yes	Maybe	Yes	Yes	Yes	Yes
Dunes	Yes	Yes	Yes	Yes	No	No	Yes	Yes	Yes
Marsh Vegetation	No	Yes	No	Yes	No	No	Yes	Yes	Yes
Groins	Yes	No*	Yes	No*	Maybe	Yes	Yes	No	Yes
Relocation	Maybe	Yes	Maybe	Yes	Yes	Yes	Yes	Yes	Yes
No Action	Yes	Yes	No	Yes	Maybe	Yes	Yes	Yes	Yes

*Usually not needed, too costly.

DICTIONARY OF TECHNICAL TERMS

Backshore - that zone of the shore or beach including the berm or berms which lies between the foreshore and the dunes or bluffs. The backshore is acted upon by waves only during severe storms, especially when combined with exceptionally high water.

Beach - a deposit of unconsolidated sand along the edge of a sea that extends landward to the base of the dunes or bluff. A beach includes foreshore and backshore.

Bluff - a high, steep bank or cliff.

Breakwater - a structure protecting a shore area, harbor, anchorage, or basin from waves.

Bulkhead - a partition to retain or prevent sliding of the land. A secondary purpose is to protect the upland against damage from wave action.

Downdrift - the longshore direction of predominant movement of littoral materials.

Dunes - ridges or mounds of loose, wind-blown material, usually sand.

Erosion - on a shore, the carrying away of material by wave action, currents, and wind.

Fetch - The area in which seas are generated by a wind having a rather constant direction and speed.

Filter - a porous material that separates the water currents from the fine soil of the shore and allows the water to pass out of the soil while keeping the soil intact.

Foreshore - the part of the shore lying between the crest of the berm (or upper limit of wave wash at high tide) and the ordinary low-water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

Groin - a shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore.

Life - an estimated time period over which a structure will function if limited only by deterioration of materials.

Littoral - of or pertaining to a shore, especially of the sea.

Littoral Drift - the sedimentary material moved in the littoral zone under the influence of waves and currents.

Littoral Material - see Littoral Drift.

Longshore - parallel to and near the shoreline.

Permit - a document granting permission to do something. A Corps of Engineer's permit is a document issued by the Department of the Army expressing the assent of the Federal Government so far as concerns the public rights of navigation and the general public interest of certain works on or adjacent to navigable waters of the U.S.

Pile - a long, heavy timber or section of concrete or metal to be driven or jetted into the earth or seabed to serve as a support or protection.

Pile, sheet - a pile with a slender flat cross section to be driven into the ground or seabed and meshed or interlocked with similar sheets to form a bulkhead.

Revetment - a facing of stone, concrete, etc., built to protect a bluff, embankment, or shore structure against erosion by wave action or currents.

Riprap - a layer, facing, or protective mound of stones, randomly placed to prevent erosion or scour at a structure or embankment; also the stone so used.

Rubble - rough, irregular fragments of broken rock or concrete.

Sand - soil finer than gravel and coarser than silt. Grain size is considered to be between .0625 mm and 2.0 mm, and is capable of passing through U.S. standard sieve size no. 10 but retained on sieve size no. 200.

Scour - removal of underwater material by waves and currents, especially at the base or toe of a shore protection structure.

Seawall - a structure separating land and water areas, primarily designed to prevent flooding and erosion due to wave action.

Shore - the narrow strip of land in immediate contact with the sea, including the zone between high and low water lines. A shore of unconsolidated material is usually called a beach.

Silt - soil finer than sand but coarser than clay, but not so fine that it can remain suspended in water for long periods. The grain size is considered to be less than .0625 mm.

Specifications - a detailed description of particulars such as size of stone, quality of materials, contractor performance, terms, quality control, etc.

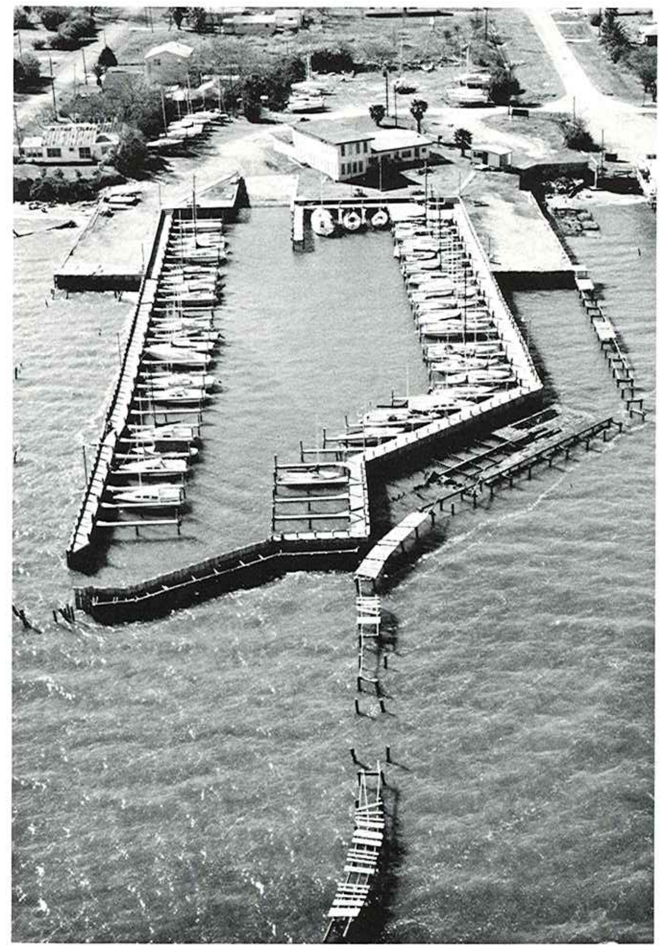
Storm Surge - an increase in water level above the normal water level on the open coast due to the action of wind stress and atmospheric pressure on the sea surface.

Toe - base of a shore protection structure, usually located below low tide level.

Updrift - the longshore direction opposite that of the predominant movement of littoral materials.

Wales - structural element of a bulkhead, fixed horizontally between the vertical piles on the seaward side and the sheet piles on the landward side.

Water Level - the elevation of the free water surface of a body of water above or below any datum. Mean water level is the average water elevation at a particular place and time.



Successful sheet pile breakwater providing quiet water for mooring boats.

U. S. Army Corps of Engineers, Galveston District
Attention: SWGED-PC
P. O. Box 1229
Galveston, Texas 77553

Dear Sirs:

My comments are as follows:

(Additional pages may be attached, if necessary)

DEPARTMENT OF THE ARMY
U. S. ARMY ENGINEER DISTRICT, GALVESTON
CORPS OF ENGINEERS
P. O. BOX 1229
GALVESTON, TEXAS 77553

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POSTAGE PAID MAILER - PUBLIC MEETING - October 28, 1983

For use in submitting comments concerning proposed beach erosion control measures for the Galveston County Shore Erosion Study.

Written statements mailed on or before November 28, 1983 will be included in the meeting record.