EVALUATION OF SMALL FILLS

Staff Report

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
Shoreline Erosion	1
Natural Defenses	3
Report Organization	4
CHAPTER I. SHORELINE PROTECTION	5
General Problems	5
A. NON-STRUCTURAL METHODS OF EROSION CONTROL	8
Land Use Controls	8
Vegetation	8
Beach Nourishment	10
B. STRUCTURAL METHODS OF EROSION CONTROL	12
Revetments	12
Bulkheads and Seawalls	17
Breakwaters and Sills	18
CHAPTER II. SHORELINE PROTECTION IN SAN FRANCISCO BAY	19
Methods	19
Assumptions and Limitations	20
Results of Permit Review	21
Field Observations	23
REFERENCES	25

FIGURES

Figure 1 - Littoral Drift	3
Figure 2 - Perched Beaches	11
Figure 3 - Quarrystone Revetment	13
Figure 4 - Gabions	14
Figure 5 - Revetment Blocks	16
Figure 6 - Small Fills Data	22

APPENDIX

Appendix A - Small Fills Study - Characteristics of Shore Protection Devices

INTRODUCTION

Storms, wind, waves, rain, runoff, vertical and hortizontal land movement, and changes in sea level are continually reshaping California's shoreline. For 86 percent of the California coastline, this dynamic interplay of land and water has resulted in the shoreline retreating inland. In increasingly urbanized San Francisco Bay, such retreat will inevitably threaten buildings, roads, recreation facilities, and farmlands. As a result, owners of bayfront property eventually face the decision of whether to: (1) let erosion proceed unchecked, and lose property and buildings (2) move structures away from eroding shoreline areas, or (3) protect and stablize the shoreline.

Shoreline Erosion*

Rates of shoreline erosion vary widely, affected by the shoreform, prevailing winds, storm severity, fetch (the unobstructed distance over water in which waves are generated by wind of relatively constant direction and speed), and wave energy. There are four basic shoreforms: **Cliffs** are steep rock formations which erode extremely slowly. Cliffs rarely need shoreline protection because the material of the cliff is more durable than most shoreline protection measures. **Bluffs** are also steep rock formations, but

*This discussion is largely adapted from the U. S. Army Corps of Engineers publication entitled "Low-Cost Shore Protection."

consist of much softer, more erodible material, such as sandstone, sedimentary rock or clay. Bluffs suffer erosion both from wave action at their base and from seepage of groundwater that weaken the rock formation. **Marshes** are vegetated, low erodible plains frequently inundated by tidal action. Marshes provide some measure of shore protection because the roots and rhizomes of marsh plants anchor the soil while the aerial portion of marsh plants both dampen waves and trap sediment. As sediments are deposited, the resulting shallow foreshore cause waves to break farther offshore. Prior to 1850, marshes were the most prevalent shoreform in San Francisco Bay. In the United States as a whole, however, **beaches** are the most common shoreform. Typically, beaches are gentle slopes covered with loose material ranging in size from fine silts to cobbles. The long, flat slope of the foreshore, and the buildup of material normally deposited on beaches in summer also provide a natural defense to shoreline erosion.

The shape of the shoreline, offshore islands and rocks, and submerged topographic highs and lows also play an important role in the erosion process because such features alter the distribution of wave energy. For example, headlands receive more concentrated wave energy then bays and inlets. As a result, structures projecting out from the shoreline usually require extra protection.

Wave motion, particularly that of breaking waves, is the major force in both the erosion and the building of shorelines. The characteristics of waves are determined by the speed of the wind, its duration, the water depth, and the fetch. As waves break, runup the shore, and return, material is carried onshore and offshore. Water's ability to move material is determined by its speed. Thus, large waves or strong currents can carry larger quantities and heavier material. Because waves generally arrive at an angle to the

shoreline, material is transported along the shoreline in a series of ligzags. This process of moving material is called littoral drift (see Figure 1). The result of littoral drift is that material eroded from one location is carried and deposited at another.

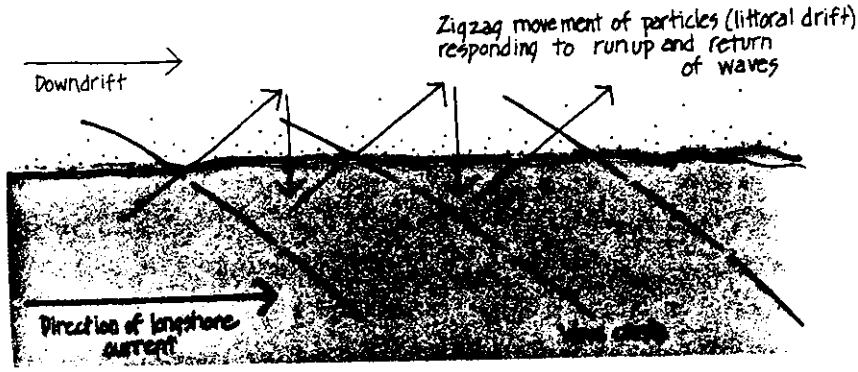

Figure 1.
LITTORAL DRIFT

Source: Army Corps of Engineers

These erosional processes are influenced by changes in water level and land subsidence, which expose new surfaces to erosion, as well as seasonal changes which are generally accompanied by shifts in the severity and direction of both wind, currents, sea level and waves.

Natural Defenses

The gently sloping shores of beaches, marshes and mudflats cause waves to break offshore and lose a significant part of their energy, a natural defense to the erosive force of waves. The next line of defense for upland areas fronted by beaches and marshes is the material that has been deposited above the normal high tide line, an area known as the berm. The berm prevents normal high water from moving further inland. In beach settings, dunes offer

the last line of defense against storm-driven high water, as well as providing material for rebuilding the beach. The Army Corps of Engineers recommends that "erosion control should begin with protection of the natural shoreline defenses wherever possible."

Report Organization

This report investigates how measures to halt shoreline erosion have changed San Francisco Bay. The first chapter describes measures that have been employed to halt or slow shoreline erosion in the United States, their relative costs and effectiveness, and their environmental impact. This chapter highlights structures and measures that have been used, or have the potential for use, in San Francisco Bay.

Chapter II evaluates the impact of shoreline protection measures administratively approved by the Commission between 1978-1987. This chapter summarizes both field observations of approved shoreline protection measures, as well as calculations of the amount of Bay shoreline, surface area, and volume that has been affected by efforts to halt shoreline erosion.

Chapter III presents the report's conclusions and recommendations for minimizing the impacts of shoreline protection measures and for improving the Commission's processing of small fills for shoreline protection.

CHAPTER I
SHORELINE PROTECTION

There are three basic approaches to combating the problems caused by shoreline erosion: (1) lessen the impact of erosion by locating structures away from erosion-prone areas; (2) prevent or lessen wave attack on the shoreline by altering the prevailing coastal process, usually with offshore measures; and (3) harden the shoreline to make it more resistant to erosion. This chapter discusses various approaches for halting shoreline erosion that have been tried in the United States, their relative costs and effectiveness, and their environmental impact. As literally hundreds of different structures and techniques have been used in the United States to protect the shoreline, this is not an exhaustive list. Instead, this chapter highlights structures and measures that have been used, or have potential for use, in San Francisco Bay. A more comprehensive, but by no means complete, listing of shoreline protection measures, their relative costs, and an evaluation of their effectiveness is presented in Appendix A.

General Problems*

The first step in designing and implementing any shoreline protection measure is to ascertain the prevailing coastal processes at work at the site. Each particular coastal situation is different and no particular protective measure can be applied successfully in all situations.

*This discussion is largely adapted from "Coastal Protection Structures and Their Effectiveness", a joint publication of the State of California's Department of Boating and Waterways and the Marine Sciences Institute of the University of California at Santa Cruz.

Second, it is important to recognize that protecting a shoreline in one area may accelerate erosion in an adjoining area by redirecting erosive forces and by interrupting or altering the natural flow of water and sediments. For this reason, it is almost always more effective and economical to coordinate shoreline protection under a comprehensive plan that considers the erosional processes for a discrete section of shoreline.

It is also important to recognize that virtually all measures to protect the shoreline will fail in time. Although it may be theoretically possible to construct a long-lasting protective structure in an area subject to intense wave energy, such a structure would be prohibitively expensive. As a result, engineers design shoreline protection for a specified design life, typically a storm that, on average, will occur once every 15 or 25 years. But such a storm could occur the day the project is completed, causing extensive damage or complete failure of the protective structure. This design limitation led the authors of one study of coastal protection measures along the central California coast to conclude that:

> On the whole, few protective structures in the study area have stood the long-term tests of time, surviving unassisted and preventing damage and erosion, for more than twenty years or longer than their design life. Many structures have become structurally unsound, required considerable maintenance or repair, and/or failed to adequately reduce property damage for more than one severe storm period. Thus, the effective lifetime of a structure often depends on how many mild winters pass before the next severe storm. However, most of the structures have reduced erosion rates, at least over the short term (Fulton-Bennett and Griggs).

The factors that typically lead to the failure of shoreline protection measures are:

1. Overtopping. Overtopping is when significant amounts of water move over the top of a protective structure. Overtopping damages the structure by eroding the support material behind the protective structure, and by exerting direct force on the protective structure itself as the water returns to the Bay.

2. Outflanking. Outflanking occurs when erosion exposes the ends of a protective structure and threatens both the structure and the material behind it. In a eroding shoreline, outflanking will eventually occur at all isolated, successful protective structures as material from neighboring, unprotected areas is washed away.

3. Scouring. Scouring is when underwater material is removed by waves and currents, particularly at the base or toe of a protective structure. Scouring undermines the foundation of the structure and can lead to rapid loss of fill behind a wall or structure.

4. Piping. Piping is when the material behind the protective structure is sufficiently saturated with water that it becomes fluid and is pumped by wave action through holes under or through the protective structure.

5. Vertical Forces. The energy of waves and wave splash can exert powerful, vertical forces on a protective structure, particularly when the protective structure has a vertical face or adjoins moderately deep water. These vertical forces have lifted riprap and other rocks up to two feet across from the base of vertical walls and thrown them inland.

6. Floating Debris and Suspended Material. Floating debris, when hurled against a protective structure by waves, can significantly damage a protective structure. Similarly, suspended material such as sand and gravel, can abrade protective structures.

NON-STRUCTURAL METHODS OF EROSION CONTROL

1. Land Use Controls. Coastal erosion problems can be combated simply by lessening the problems caused by erosion, rather than attempting to prevent, halt, or retard erosion. In San Francisco Bay, such land-use controls could be implemented by requiring shoreline set-back lines of all new or reconstructed facilities. Such a set-back requirement could simply exclude development in erosion-prone areas, or set aside sufficient upland area to allow construction of shoreline protection facilities when needed without significant Bay fill. Because so much of the shoreline of San Francisco Bay has been developed, set-back lines may be difficult to implement here. However, such set-back lines may be appropriate for new shoreside developments proposed for large undeveloped tracts or in areas where massive protective structures may be needed to prevent flooding from a rise in sea level.

2. Vegetation

a. Background. Vegetation has been used mostly on an experimental basis for controlling shoreline erosion in San Francisco Bay (Newcombe et al, 1979). Marsh plants slow shoreline erosion in three ways: (1) the aerial part of marsh plants form a flexible mass which dampen wave energy; (2) as wave energy is reduced, sedimentation is increased. Dense stands of vegetation can create a depositional environment that can lead to a building of the foreshore, which in turn cause waves to break farther offshore; and (3) the roots and rhizomes of the marsh plants add stability to the shore sediment. This mass of roots is of particular importance in the winter when much of the aerial portion of the plants has been lost (Knutson and Woodhouse, 1983).

Dune and upland plants also retard shoreline erosion by anchoring shoreside sediments from the erosive effects of wind and storm-driven waves.

b. Effectiveness. In undisturbed environments, marshes are one of the most important elements in the natural defense of the land. Unfortunately, marshes usually only slow the rate of erosion, rather than stop it and are relatively ineffective in protecting against major winter storms. In addition, marshes can only be established at sites where the elevation, tidal regime, exposure to wave action, and soil type are conducive to the growth of the desired vegetation. Even at suitable sites, it usually takes at least one to three years before a dense stand of plants will become established on the site, longer if severe storms occur during establishment. In addition, there has been little success in establishing marsh vegetation in areas experiencing even moderate wave activity without temporary wave-stilling structures, such as breakwaters. These limitations led the authors of the most extensive study of using vegetation to control bank erosion in San Francisco Bay to conclude that "California cordgrass is suitable for stabilizing relatively sheltered areas....[but is not likely to be effective in stabilizing] ...eroding banks in San Francisco Bay unless the plants are protected from waves." (Newcombe et al., 1979) As a result, planting may be most effective in erosion control when used in conjunction with other measures of shoreline protection.

c. Environmental Impacts. The establishment of a marsh has several beneficial environmental impacts. Marshes serve as valuable sources of primary production (energy), as nursery grounds for sport and commercial fish, and as a natural system for storing and recycling nutrients and pollutants. Once established, erosion control plantings function as natural

marshes and eventually attract comparable animal communities (Knutson and Woodhouse, 1983). Marshes are also one of the few shoreline protection measures that are natural in appearance, and as a result, are perhaps the most aesthetically pleasing of all erosion control measures.

d. Cost. Erosion control plantings are among the least expensive of all shoreline protection measures, costing between $8 and $17 per linear foot.

3. Beach Nourishment

a. Background. Beach nourishment projects involve placing quantities of sand on the shoreline to function as an eroding or sacrificial buffer zone. There has been at least one successful application of beach nourishment for shoreline protection in San Francisco Bay - the restoration of Alameda Beach and the protection of Shoreline Drive in Alameda (Permit No. 9-81).

b. Effectiveness. The useful life of a beach nourishment project depends on how quickly it erodes; thus, a rapid succession of severe storms can completely eliminate the sand placed to nourish the beach. The rate of erosion is also dependent on the size of the sand grains - larger (and therefore, heavier) grained sands erode more slowly than finer grained sand. In most cases, a single nourishment will not provide a permanent solution to the erosion problem and the beach must be periodically renourished to replenish sand washed away. In the case of the Alameda Beach project, both groins and sand traps (holes excavated in the beach) were authorized to capture the sand that was expected to wash away.

c. Variations. A variation of the beach fill is the perched beach. Perched beaches combine a low breakwater or sill with sand fill so

that the beach is elevated above the surrounding area. The perched beach provides a broad buffer zone against wave action while offering a potentially valuable recreation site. A filter cloth is typically used behind the breakwater and under the fill to prevent sand from escaping through voids in the sill. Perched beaches are suitable where offshore slopes are gradual enough so that the sill can be constructed offshore in shallow water and are appropriate where sand loss is too rapid for economical and convenient replenishment (see Figure 2).

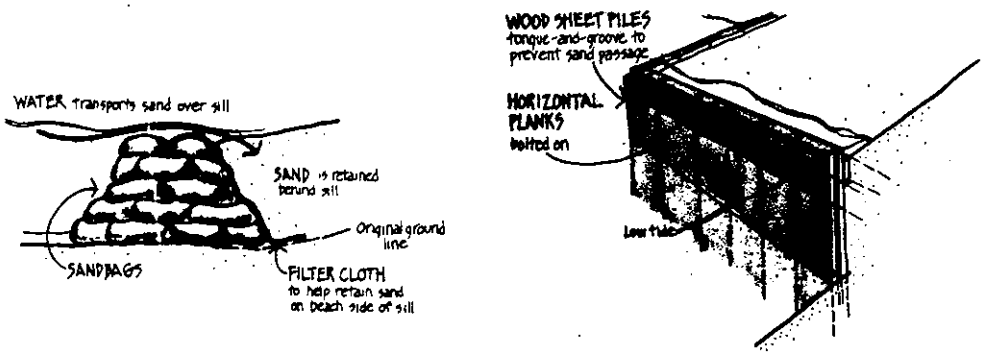

Figure 2.
PERCHED BEACHES

Source: Army Corps Of Engineers

d. Environmental Impacts. Beach nourishment projects can serve as valuable recreation areas. Such projects can also benefit downdrift shore areas as littoral drift transports sand to them. But, as in the case of the Alameda project where the downdrift area was a tidal marsh, littoral transport of sand can lead to increased sedimentation in adjoining areas and a rapid change in their resource value. In addition, the sand placed to nourish the beach reduces the Bay's surface area and volume, and may cover intertidal

mudflats which typically have greater species diversity and productivity than sandy beaches.

e. Cost. Beach fills generally have low initial costs (approximately $50 per linear foot) but periodic maintenance costs (for adding new fill).

STRUCTURAL METHODS OF EROSION CONTROL

1. Revetments

a. Background. Revetments are protective, blanket type structures built at the toe of a bluff and extending below low water. Revetments are by far the most common type of shoreline protection both in the United States and in San Francisco Bay. They work by hardening the shoreline or by separating the land from the erosive effect of waves. Revetments rest upon, and are supported by the land behind it, which is usually at or near its natural angle of repose. Slopes steeper than 1-1/2 horizontal to 1 vertical are unsuitable for revetments unless flattened. The revetment must be built high enough so that it will not be overtopped, the sides must be protected from outflanking, and the toe must be protected from scour. There are many different kinds of revetments, the most common being: concrete rubble, quarrystone riprap, gabions, stacked bags, and interlocking blocks and mats.

b. Variations and Their Effectiveness

(1) Concrete Rubble revetments consist of loose dirt, flat concrete and asphalt slabs of varying sizes, bricks, and other construction debris dumped along the water's edge for shoreline protection. These revetments are often used in emergency situations and are generally very ineffective largely because their haphazard placement and sizing fails to

protect the bank material underneath (Fulton-Bennett and Griggs). Although the initial cost of such revetments is usually low, the use of concrete rubble may lead to unexpected future costs because it may have to be removed before constructing any engineered protective structure at the site.

(2) Engineered Quarrystone Riprap consists of carefully placed layers of different sized rock, excavated foundations, and filter cloth and can be adapted to a variety of different conditions (see Figure 3). Quarrystone riprap offers several advantages over other protective structures: (a) the rough surfaces of the rock and the spaces between the rocks help dissipate wave energy and reduce the extent of wave runup and overtopping; (b) their flexibility allows them to settle without massive or rapid structural failure; (c) they are easily maintained and modified; (d) they are resistant to damage by debris; and (e) they are relatively inexpensive to construct (Fulton-Bennett and Griggs). However, quarrystone riprap is prone to settlement problems that can be caused by scour at the toe of the riprap, fluidization of the foundation material, or "plucking" by waves which mobilize one or more of the armor stones. Quarrystone riprap is also subject to vandalism.

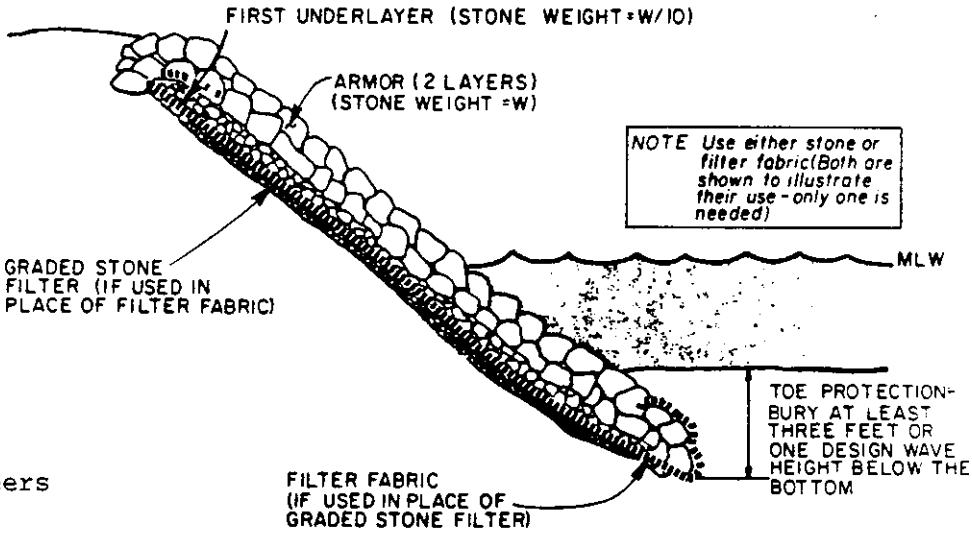

Figure 3.
Quarrystone Revetment

Source: Army Corps of Engineers

(3) Gabions are rectangular mattresses of stones enclosed in a wire mesh. Gabions are flexible, retain some of their effectiveness even if the foundation settles, are easily repaired, and can be built without heavy equipment. However, the wire mesh of the gabion is susceptible to damage by water-borne debris and abrasion by suspended sands, gravel, and the enclosed stones if they are not tightly packed. Rusted and broken wire baskets also pose a safety hazard (U. S. Army Corps of Engineers).

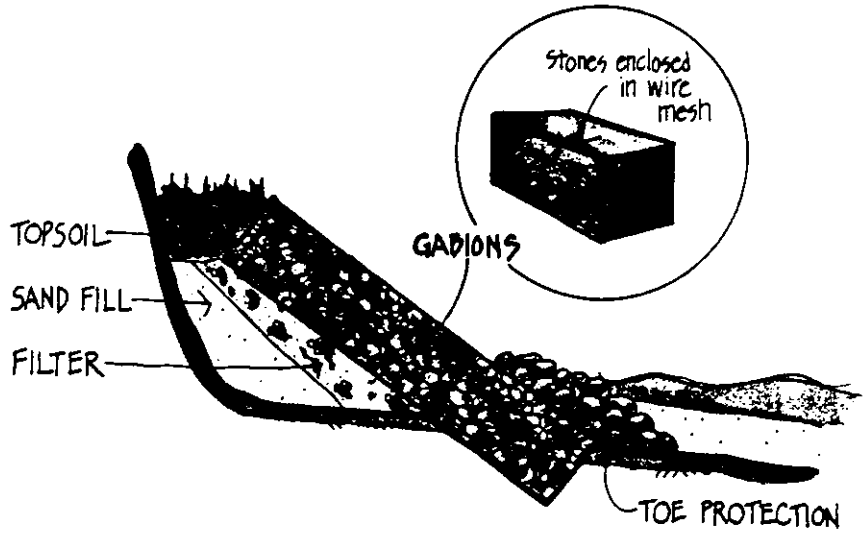

Figure 4.
Gabions

Source: Army Corps of Engineers

(4) Stacked bags are usually filled with either sand or concrete and stacked against the eroding shoreline. Although suited for emergency protection, stacked bag revetments are generally limited to low energy areas, have a relatively short life, and are unattractive. In addition, since concrete-filled bags are rigid, any failure of one bag can lead to catastrophic failure of the entire structure through erosion of the foundation material (U. S. Army Corps of Engineers).

(5) A variety of interlocking blocks and mats have been developed for shoreline protection and many have proved relatively effective. They all require a good, stable foundation and present a neat and clean appearance. Some have been designed to accomodate vegetation which may increase their stability. Such revetments have two major disadvantages. The first is that the interlocking between units must be maintained. Once one block is lost, other units can quickly become dislodged leading to possible catastrophic failure. The second disadvantage is that the smooth face of such revetments allow greater wave runup which increases the possibility of overtopping. Figure 5 shows various types of revetment blocks.

c. Environmental Impacts. In most situations, a revetment is a dramatic alteration in the shoreline which can be expected to bring about many changes in the biota. The structure itself covers established flora and fauna and usually represents a major change in substrate. Thus the plants and animals that live among a revetment are typically quite different from the plants and animals that lived on the site previously. Revetments constructed in wetland areas can destroy narrow fringe marshes leading some observers to describe wetland destruction as the "most significant ecological impact of riprap construction" (Carstea et al. 1975). However, revetments are not devoid of life and in some instances have increased species diversity (U. S. Fish and Wildlife Service, 1980). In general, rough-faced and shallow-sloped revetments provide better habitats than smooth-faced, steep-sided structures because they tend to dissipate wave energy better and have greater ability to support various organisms (Gantt 1975)

d. Cost. Concrete rubble is generally free; the costs tends to depend on transportation costs. The cost of quarrystone revetment depends on

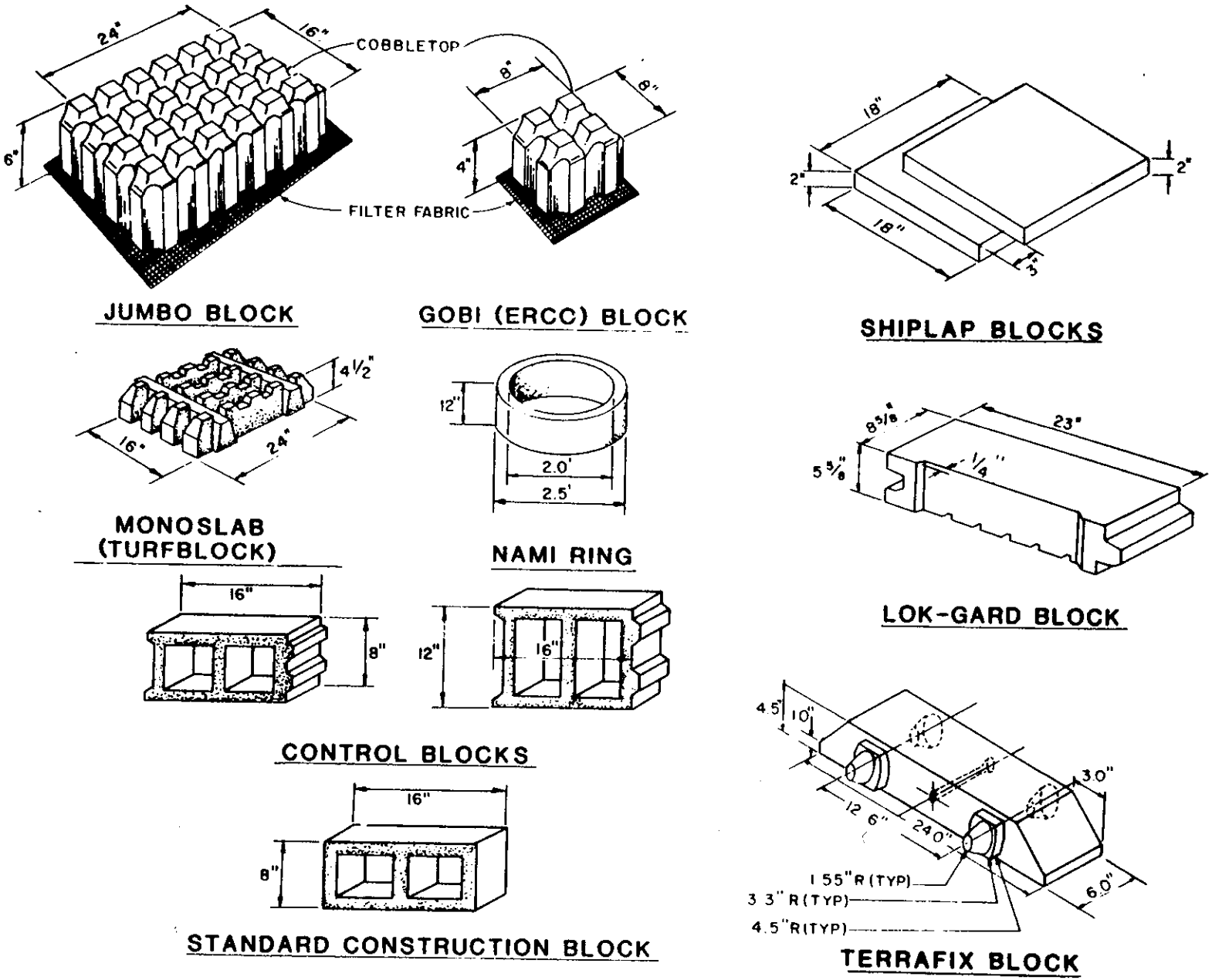

Figure 5.
Revetment Blocks

Source: Army Corps of Engineers

the size of the rock used and the equipment needed to place it; it typically costs from $60 to $145 a linear foot. Gabions, stacked bags and interlocking blocks and mats range in cost from $50 to $245 per linear foot (see Appendix A).

2. Bulkheads and Seawalls

a. Background. Bulkheads and seawalls protect banks by completely separating land from water. Bulkheads act as retaining walls and are designed to keep the land behind them from crumbling into the water as well as protect against shoreline erosion. Seawalls are primarily designed to resist wave action and are usually massive, free-standing structures (U. S. Army Corps of Engineers). The great disadvantage of vertical-faced bulkheads and seawalls is that the hard, smooth surface of the structure reflects wave energy leading to accelerated erosion in front of the wall (scour). Because scour can erode both the foundation of the wall and the foreshore, an apron of heavy stones is generally placed at the base of the wall to absorb the reflected wave energy. In addition, water overtopping such structures tends to flow laterally behind the wall washing away the fill behind the wall. Outflanking is another common cause of failure of such structures.

There are three basic designs of bulkheads and seawalls: (1) Sheet pile walls consist of interconnecting or tightly spaced sheets of concrete, steel or wood driven vertically into the ground. Additional support for these walls is sometimes provided by tying such structures to embedded anchors or by installing bracing on the seaward side. (2) Post supported walls consist of regularly spaced posts with attached facing. As with sheet pile walls, such structures are sometimes provided additional support through anchors and bracing. (3) Gravity or free-standing walls rest on the ground and

are supported by their own weight. Many different materials have been used to construct these walls, including concrete, gabions, longard tubes (large fabric tube filled with sand), and rock and concrete rubble.

b. Environmental Impacts. The major impacts of bulkheads and seawalls stem from the fact that such walls promote erosion of the foreshore by reflecting wave energy. The increased turbulence in front of these walls often prohibits vegetation from reestablishing and has been suspected of producing less favorable conditions for the settling, growth, and survival of various benthic organisms such as clams, oysters, and shrimp (U. S. Fish and Wildlife Service, 1980). In addition, construction of bulkheads, like revetments, usually eliminates much of the intertidal zone, which is one of the most productive zones of estuaries (Odum, 1970).

c. Cost. Because of the tremendous variation in the design of these protective walls, cost per linear foot ranges from $60 for a rubble mound wall to $4000 for the O'Shaughnessy Seawall along Ocean Beach in San Francisco, one of the most successful protective structures on record (Fulton-Bennett and Griggs).

3. Breakwaters and Sills

a. Background. In contrast to bulkheads and revetments, breakwaters and sills are placed offshore to intercept energy of approaching waves and form a low-energy shadow zone on their landward side. Breakwaters have been constructed in San Francisco Bay primarily to protect harbor areas, rather than for shoreline protection, although at one time a breakwater was being considered to protect the shoreline from the waves generated by the Larkspur Ferry.

CHAPTER II
SHORELINE PROTECTION IN SAN FRANCISCO BAY

Typically, small fills authorized by the Commission, such as those placed for shoreline protection, boat docks, utility cables, outfall pipes, etc. ahve been thought to have little impact on Bay resources. As a result, they have been approved routinely. However, no comprehensive evluation has ever been done of the individual or cumulative impacts that such small fills may have on Bay resources.

This chapter evaluates the individual and cumulative impacts of the most common kind of small fill the Commission authorizes - the installation of shoreline protection structures.

Methods

All administrative permits from 1978 through 1987 were reviewed to determine: (1) how many shoreline protection projects have been approved; (2) what types and numbers of structures have been used to provide protection; (3) how many linear feet of shoreline have been affected by such projects; (4) how much of the Bay's surface areas and volume have been lost as a result of such activity; and (5) what information is contained in the permit file regarding the Bay resources impacted by the shoreline protection.

After completing the review of administrative permits, on-site field evaluations were made of approximately half the sites in an attempt to determine what Bay resources were lost as a result of installing the shoreline protection. An attempt was also made to determine if the completed structure was still intact and whether it was impacting adjoining areas.

Assumptions and Limitations

Due to incomplete records, many of the values for length of shoreline and the area and volume of fill had to be estimated. In most instances, enough information was available to make reasonably accurate estimates of these values, that is, within 25 percent of the true value.

Also, in most cases, the quantities used in this report include some material in the shoreline band. Typically, to protect against wave runup and overtopping, one-fourth of the riprap slope is above and landward of the Bay shoreline. Thus the quantities reported here exceed the actual amount of Bay fill, but should be within 25 percent of the true value.

In addition, this study only evaluated administrative permits involving shoreline protection; it did not evaluate the amount of shoreline protection authorized in permits where a public hearing was held, nor did it evaluate shoreline protection projects authorized as amendments to existing permits. The study also did not review permits issued prior to 1978. For these reasons, this study is not a comprehensive review of the amount of fill authorized for shoreline protection in San Francisco Bay, although it does give some indication of the magnitude of fill approved for such uses.

Finally, none of the permits contained specific information regarding the Bay resources impacted by the fill. Because construction of the protective structure typically covered the preexisting habitat, field investigations of the sites conducted in 1988 could not determine with certainty what habitat preexisted the fill. However, present day observations of the site and the adjoining areas does give some indication of whether the fill affected a subtidal or intertidal area, whether tidal marsh was likely to have been affected by the project, and whether the shoreline continues to experience erosion.

Results of the Permit Review

Projects were grouped according to size and shoreline protection type. Totals for these various categories are listed in Figure 6. The first category includes administrative permits with Bay coverage of 10,000 square feet or more. There are 43 projects in this group affecting 147,170 linear feet (27.9 miles) of shoreline, covering 2,181,032 square feet (50.1 acres) of Bay surface area, with a loss of 270,978 cubic yards of Bay volume. The second category is administrative permits with Bay coverage of less than 10,000 square feet. There are 141 projects in this group affecting 28,693 linear feet (5.4 miles) of shoreline, covering 282,768 square feet (6.5 acres) of Bay surface area with a loss of 37,868 cubic yards of Bay volume. Totalling all administrative permits, there are 184 projects affecting 175,863 linear feet (33.3 miles) of shoreline, covering 2,463,800 square feet (56.6 acres) of Bay surface area, with a loss of 308,846 cubic yards of Bay volume.

The table also groups projects employing similar shoreline protection measures. For administrative permits with Bay coverage of less than 10,000 square feet, 84 of the 141 projects (60 percent) involved riprapped slope protection, 20 (14 percent) were aprons placed at the base of outfalls, eight (six percent) involved placing riprap in front and at the base of walls and bulkheads, five were projects where rock was placed over pipelines to anchor and protect the pipeline and 24 (17 percent) were bulkheads. Thirty-nine of the 43 permits (91 percent) with Bay coverage of 10,000 square feet or more involved riprap.

The results of reviewing simply the information contained in the permits indicate that over the last 10 years, the Commission on average administratively approves 18 projects each year, affecting 3 1/3 miles of shoreline, covering 5.7 acres of Bay surface area, and displacing 30,880 cubic yards of Bay volume.

Figure 6.

Totals
Small Fills Data

PROJECT		TYPE OF STRUCTURE	DIMENSION			ENVIR. SETTING			
Type	No.		Length (ft.)	Area (s.f.)	Volume (c.y.)	Sub. Tidal	Mud Flat	Marsh	Prev. Prot
Admin. Permit with Areas of 10,000 s.f. or more	39	Shoreline Prot.	144,126	2,042,530	249,063	1	0	2	24
" "	1	Base of Wall	N/A	59,602	4,415	0	0	0	1
" "	3	Pipeline Cover	3,044	78,900	17,500	2	0	1	0
Subtotal	43		147,170	2,181,032	270,978	3	0	3	25
Admin. Permit with Areas under 10,000 s.f.	84	Shoreline Prot.	21,836	239,480	30,512	0	2	5	35
" "	20	Apron	676	19,488	1,403	0	0	0	2
" "	8	Base of Wall	1,387	13,634	1,477	6	0	0	0
" "	5	Pipeline Cover	159	2,071	926	2	0	0	0
" "	24	Bulkheads	4,635	8,095	3,550	3	1	2	3
Subtotal	141		28,693	282,768	37,868	11	3	7	40
Total of all Admin. Permits	184		175,863	2,463,800	308,846	14	3	10	65
Major Permits with Areas of 5,000 s.f. or more	1	Bulkhead	,250	500	150	0	0	0	0
" "	1	Base of Wall	500	12,000	3,600	0	0	0	0
" "	24	Shoreline Prot.	56,351	1,198,219	145,290	0	0	1	5
Subtotal (Major Permits)	26		57,101	1,210,719	149,040	0	0	1	5
Grandtotal (All Permits)	210		232,964	3,674,519	457,886	14	3	11	70
		PERCENTAGE OF SHORELINE PROTECTION PROJECTS							
Over 10,000	91		98	94	92				
Under 10,000	60		76	85	80				
All Admins.	67		94	93	90				
Majors	92		99	99	97				
All Permits	70		95	95	93				

Field Observations

Field investigations were conducted of slightly more than half of the 181 administrative permits identified as having involved shoreline protection, including 20 of the 43 projects where more than 10,000 square feet of fill was authorized. The results of the field investigations are summarized as follows:

1. Less fill has actually been placed in the Bay than is indicated by the permit files. Some of the projects included in the permit review involved temporary installations that have since been removed (Permit M83-13, Cote d'Azur Apartments in Sausalito), protective installations that were never constructed (Permit No.M 82-80, Bayfront Park in Mill Valley), or involved protective structures that were removed by a subsequent protective structure at the site

2. The habitat most affected by authorized shoreline protection facilities appeared to be intertidal mudflats. Relatively few shoreline protection projects were proposed in subtidal areas or in marshes.

3. Some shoreline protection projects were of questionable value. The two projects involving concrete rubble revetment appeared to be providing only marginal shoreline protection, as both the rubble and the earth behind it were continuing to erode. A few projects simply involved dumping a few rocks on banks at the upper end of a salt marsh.

4. Maintenance of shoreline protection facilities is critical. Rocks from many of the riprapped slopes had tumbled onto the mudflats below. Others were clearly settling and appeared susceptible to overtopping. Many of the wooden bulkheads had totally failed.

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