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SHORE EROSION AT TANGIER ISLAND

TASK FORCE REPORT

TO

JOSEPH B. WILLSON, JR.
DIRECTOR
VIRGINIA SOIL AND WATER CONSERVATION COMMISSION

FEBRUARY, 1976

I AUTHORIZATION

In May, 1975 the Secretary of Commerce and Resources, the Honorable Earl J. Shiflet requested that the Virginia Soil and Water Conservation Commission convene a meeting to discuss the shore erosion problem on Tangier Island. On 13 May 1975 Commission Director Joseph B. Willson, Jr. held the meeting at the Virginia Institute of Marine Science at Gloucester Point, Virginia with the attendance of federal, state and municipal agency personnel to address the technical aspects of resolving the problem. After discussion of the problem Commission Director Willson appointed a Task Force to further investigate the problem and to make recommendations for their solution.

The Task Force members are:

Robert J. Byrne, Task Leader: (Technical Committee)	Virginia Institute of Marine Science
Donald L. Wells: (Technical Committee)	Virginia Soil & Water Conservation Commission
James R. Melchor: (Technical Committee)	Norfolk District, U.S. Army Corps of Engineers
Fred B. Givens: (Technical Committee)	Soil Conservation Service, U.S. Dept. of Agriculture
James L. Bland: (Technical Committee)	Division of Aeronautics, State Corporation Commission
Tom Barnard: (Technical Committee)	Virginia Institute of Marine Science
S.M. Rogers: (Technical Committee)	Virginia Marine Resources Commission
S.H. Barker:	Virginia Department of Highways

William Bolger:	Virginia Division of State Planning and Community Affairs
Hartford B. Williams:	Mayor, Town of Tangier
Grover Charnock:	Town of Tangier

Full Task Force meetings, or meetings of a Technical Committee were held on 4 June, 10 July and 19 September.

The Task Force viewed their responsibilities as being the following:

a) To conduct a technical assessment of the erosion problem.

b) To evaluate various approaches toward correcting the problem and to identify those which are most likely to be effective.

c) To make first order cost estimates for selected alternatives.

d) To submit the recommendations for erosion control based upon selection from alternatives.

II ENVIRONMENTAL CONDITIONS AND EROSION PROBLEM AT TANGIER ISLAND

Tangier Island, in Accomack County, Virginia, is the southernmost of a series of islands separating Chesapeake Bay from Tangier and Pocomoke Sounds (Figure 1). With the exception of three sand ridges, which are the populated areas, the island is low lying marsh and tidal flat deposits with elevations generally below 6 feet (MLW datum)(Figure 2).

A. Environmental Conditions

Tidal Characteristics. The tides at Tangier are semidiurnal with a mean range of 1.6 feet and a spring range of 1.9 feet.

Winds and storm conditions. Wind data from Salisbury, Maryland and Patuxent, Maryland indicate that 50% of the time (April through August) the wind is from the south to southwest directions with a predominant speed of 10 to 15 miles per hour. However, between September and March the prevalent winds are from the northerly quadrants. Most winds exceeding 25 miles per hour are from the northwesterly to northeasterly directions. The wind regime described above is the same as the regional seasonal wind fields. During the period September through April the passage of low pressure centers generates a sequential wind field changing from the northeasterly flow to northerly and then westerly. These passages characterize the storm known as a "northeaster". Although the northeast winds associated with these storms are not of hurricane strength they may persist for several days. The combined influence of wind and low pressure drives additional water into Chesapeake Bay resulting in an increase in mean water elevations upon which the astronomic tides oscillate. The enhancement of mean water level is called storm surge. The net effect is for the high tides to reach anomolous elevations. The most dramatic surge due to a northeast storm was that of March, 1962 which reached an elevation of about 5.3 feet (MLW) on Tangier Island.

As the wind field shifts to the northerly quadrant the storm surge drops and the "tides" tend to return to normal although the westerly winds within the Bay still push the water against the Eastern Shore. As is the case with the northeasterly winds the intense northwest and west winds may persist for several days.

The other storm type to which Chesapeake Bay is susceptible is the hurricane and tropical storm. These storms are characterized by higher winds of shorter duration than the northeaster; however, the storm intensity can compensate for the shorter duration with resultant high storm surges and wave action. The most severe hurricane to impact Chesapeake Bay occurred in August 1933 with storm surge as high as 7.0 feet in Baltimore (Pore, 1960).

Waves. Once one leaves the vicinity of the mouth of the Bay the waves experienced on the Chesapeake are those generated by local winds. The height of the waves at any given point is controlled by the wind speed and direction, the over the water distance from land (fetch) and the duration of the wind. In addition when waves "feel the bottom" the wave crest tends to bend (refraction), such that ultimately the wave crest would become parallel to the bottom depth contours. In the process of bending the wave energy can become focused or defocused depending upon the bottom contours encountered.

Tangier Island is relatively protected from northeast winds due to extensive shoals in Pocomoke and Tangier Sounds. However, the western shore of Tangier is exposed to waves generated by winds ranging in direction from south to north. Fetch distance is approximately 25 miles from the northwest and southwest and 12 miles from the west. Maximum expected wave heights for the western shore of Tangier Island are shown in Table 1 (U.S. Army Corps of Engineers, Norfolk). The values have been calculated without taking wave refraction into account, which will be discussed in the following section.

Table 1. Calculated Wave Parameters

Fetch (miles)	Wind Speed M.P.H.	Wave Period (seconds)	Wave Height (feet)
25	25	3.1	4.9
	50	4.2	6.5
	75	4.8	6.8
12	25	3.0	4.0
	50	4.1	6.0
	75	4.5	6.4

Waves break when they reach a water depth about equal to the wave height. Under conditions of spring tides and intense winds from the west wave heights of up to three feet can be experienced at the marsh-water interface.

Sediment types and the littoral drift system

The shoreface of Tangier Island is marsh soil composed of cohesive clays and silts and organic matter. There are a few locations with small intertidal beaches but for the most part the intertidal beach is absent. A recent survey of offshore depths and bottom sediments by VIMS for the State Corporation Commission, Division of Aeronautics (Boon, 1975) indicate the immediate nearshore bottom is fine sand (~0.20 mm median size) as shown in Figure 3. However, within two thousand feet of the shore the sands are coarser with a median diameter of about 0.50 mm. The offshore sands are suitable for beach nourishment. The grain size data for the area are summarized in Table 2.

Inspection of the seasonal wind field and examination of the morphology of Tangier indicates that the direction of net littoral sand drift is to the south. There is no quantitative information available on the volume of sand driven by waves and currents along the shoreface. However, since the eroding shoreface is composed of marsh sediment containing very little sand we know that bank retreat itself is not contributing significantly to the sand supply. The inference to be drawn is that whatever sand is moving to the south is derived from transport of sand in the shallow sub-tidal bottom fronting the island. The question of sand supply is important since it is a factor to consider in evaluating alternate approaches to erosion control and impact of control on nonprotected shoreline: in the present case the

TABLE 2. SUMMARY OF SAND SIZE ANALYSES

WEST SIDE OF TANGIER ISLAND

(See location map for sample locations)

BOTTOM GRAB SAMPLES

Sample No.	Median (mm)	Mean (mm)	Sorting Index	Remarks
BG 1	0.47	0.49	0.64	Moderately Sorted
BG 2	0.44	0.47	0.60	" "
BG 3	0.54	0.58	0.68	" "
BG 4	0.59	0.66	0.75	" "
BG 5	0.25	0.29	0.88	" "
BG 6	0.40	0.37	0.77	" "
BG 7	0.22	0.27	0.85	" "
BG 8	0.18	0.19	0.34	Very Well Sorted
BG 9	0.19	0.22	0.50	Moderately Sorted
BG10	0.42	0.37	0.84	" "
BG11	0.53	0.51	0.70	" "
BG12	0.50	0.52	0.64	" "
BG13	0.49	0.50	0.60	" "
BG14	0.56	0.57	0.58	" "
BG15	0.54	0.54	0.52	" "
BG16	0.41	0.40	0.68	" "
BG17	0.50	0.51	0.60	" "
BG18	0.54	0.59	0.62	" "
BG19	0.51	0.52	0.60	" "
BG20	0.49	0.52	0.52	" "
BG21	0.50	0.51	0.62	" "
BG22				
BG23	0.52	0.54	0.60	" "
BG24	0.50	0.52	0.58	" "
BG25	0.50	0.51	0.50	" "
BG26	0.20	0.21	0.56	" " , Trace Organics
BG27	0.16	0.16	0.26	Very Well Sorted, Trace Organics
BG28	0.20	0.20	0.26	Very Well Sorted, Moderately Organic
BG29	0.53	0.64	0.92	Moderately Sorted
BG30	0.43	0.37	1.24	Poorly Sorted

SUMMARY OF SAND SIZE ANALYSES

WEST SIDE OF TANGIER ISLAND

(See location map for sample locations)

SHORT CORES

Sample No.	Median (mm)	Mean (mm)	Sorting Index	Depth (cm)	Remarks
C1	0.20	0.21	0.38	0	Well Sorted
C1	0.20	0.19	0.26	26	Very Well Sorted
C2	0.40	0.38	0.99	0	Moderately Sorted
C2	0.20	0.23	0.55	18	" "
C3	0.38	0.35	0.72	0	Moderately Sorted
C3	0.24	0.20	1.71	11	Poorly Sorted, Moderately organic
C4	0.52	0.52	0.56	0	Moderately Sorted
C4	0.49	0.37	1.43	28	Poorly Sorted, Moderately organic
C5	0.52	0.46	0.94	0	Moderately Sorted
C5	0.48	0.48	1.24	17	Poorly Sorted, Moderately organic
C6	0.54	0.52	0.60	0	Moderately Sorted
C6	0.19	0.22	0.58	17	" "
C7	0.47	0.49	0.70	0	Moderately Sorted
C7	0.43	0.42	0.84	24	" "

large sand spit at the south end of Tangier Island (Fig. 2). Inspection of Figure 4 shows that prior to 1942 the junction between the spit and the marsh portion of the island was such that the shoreline was fairly continuous. Some time between 1942 and 1960 the junction point retreated from the trend of the marsh shoreline and progressed easterly as shown in Figure 2. The retreat of the spit junction is probably a response to decreased sediment supply as well as the tendency for the spit to maintain an equilibrium orientation to wave forces. A wave refraction analysis by VIMS shows that the present spit orientation is in equilibrium with waves from the southwest; that is, the face of the spit is parallel with the refracted wave fronts from the southwest.

The wave refraction analysis indicates that waves from the northwest diverge (spread with height reduction) when approaching Tangier. However, due to the additional fetch within the Potomac River the larger waves to impinge on Tangier are those associated with northwest winds. Moreover, as mentioned previously, most of the winds exceeding 25 mph come from the northerly quadrants. These facts are consistent with the interpretation of the geomorphology which indicate a net sand drift to the south.

B. <u>The Erosion Problem</u>

The magnitude of the erosion rates on the western face of Tangier indicates the problem is severe. Historical shoreline positions are shown in Figure 4. Based upon the years 1850 to 1942 the average retreat rate was about 18 feet per year. Between 1942 and 1967 the average retreat rate was about 20 feet per year and between 1967 to 1975 the rate was about 25 feet per year (Wells, personal communication).

Although the entire western face of the island is experiencing the same severe erosion the area of immediate concern is that half of the island south of Tangier Channel which was dredged for navigation purposes in the early 1960's. The present (1975) condition of the study area is shown in Figure 5. The southern end of Tangier Airport runway is under direct wave attack. In addition, the homes at the southern end of "West Ridge", now about 300 feet from the shoreline, will be in jeopardy within a decade. Thus, in this region the erosion problem is critical.

III EVALUATION OF ALTERNATE APPROACHES TO REMEDY THE EROSION PROBLEM

The shoreline under investigation, approximately 9,000 feet in length, extends from the mouth of Tangier Channel on the north to the beginning of the spit on the south (Figure 6). Approximately 800 feet of the shoreline will be stabilized by a seawall currently (January 1976) under construction by the Virginia Division of Aeronautics (State Corporation Commission); thus 8,200 feet remain for consideration.

The various approaches evaluated included:

a) parallel offshore breakwater

b) revetments of various materials

c) artificial nourishment with offshore sand

d) seawall of various materials

e) groin field with sand fill

f) expended rubber tires to form a shoreface mat

For the purposes of this report the term revetment is defined as a rigid, sloping protective facing applied to a natural or prepared foreshore slope. The term seawall is herein defined as a structure separating the erodable land from the erosion forces of the waves or currents and which possesses its own structural integrity against gravitational forces. A principal difference between the revetment and seawall so defined is that the revetment structure, since it rests on a sloping substrate, does not, itself, possess structural integrity against gravitational forces. Thus, if the underlying material is washed out beneath a revetment the structure itself would collapse.

The evaluation process for the various approaches considered the following factors:

a) the overall applicability of the technique given the physical conditions at the site

b) estimated relative cost of project

c) impact of the application on the adjacent shoreline

d) difficulty in executing the project construction

In addition to the above the known existing material resources which might be applied were evaluated. Specifically, the Task Force considered the utilization of the concrete rubble which will become available with the dismantling of the old James River Bridge. The Highway Department indicates about 19,000 cubic yards of material will be available. When crushed and piled this would occupy about 25,000 cubic yards. The degree to which this material is useful would depend upon costs chargeable to this project. In assessing relative costs it was assumed that the only savings over stone rip-rap were the at-quarry costs and that the rubble would be supplied to the project in a crushed state suitable for rip-rap. Hauling costs were considered to be the same for the quarry stone and the concrete rubble.

a) Parallel Offshore Breakwater

The offshore breakwater considered would be a trapezoidal mound of stone block or concrete rubble running parallel to the shore. The usual choice in design is to have a complete barrier to wave-overtopping or a partial barrier wherein the crown of the breakwater is at the elevation of mean sea-level. Obviously the latter requires much less material in the trapezoidal section. Therefore the mean sea level design elevation was selected for initial consideration. Since some wave energy is transmitted over the crown there is a net transport of water over the structure. In order to avoid the generation of hydraulic currents in the lee of the breakwater a placement of about 1,000 feet seaward of the shoreline was indicated (water depth of 9-10 feet). Material requirements were estimated for a cross-section with 6 ft. crown width and 2 on 1 side slopes: the rubble from the James River Bridge would suffice to cover a linear distance of about 2,800 feet (about 1/3 of the project distance). With the realization that breakwaters require large material volumes per linear yard relative to other approaches further evaluation ended. In addition to the above there is an important environmental consideration against using an offshore breakwater at this site. The shore zone in the lee of the structure would receive little or no wave energy; thus, any sand in the littoral system would tend to be trapped in the shadow of the breakwater. Although this may be locally desirable, sand supply to the downdrift shoreline would be prevented. In the Tangier case this would translate into a reduced supply to the large spit at the south end of the island.

b. Revetments. Although revetments require less construction material than seawalls for protection of a unit distance of shoreline this option was rejected for the Tangier case. The principal reason for rejection was the conviction that scour would occur on the marsh side of the structure due to channelization of the tidal waters with falling tide. Local scour would lead to point collapse which would be followed by flanking of the structure by wave washout.

c. Artificial nourishment with offshore sand. There is ample sand which is suitable for beach nourishment within a few thousand feet of the beach. However simple nourishment without retaining structures would be very costly as the retention time on the beach face would be short. Moreover, waves from the south and southwest would drive the sand into the Tangier Channel with likely severe and rapid shoaling. Given these considerations this option was rejected.

d) Seawalls of various materials.

e) Groin field with sand fill.

f) Expended rubber tires to form a shoreface mat.

These options were selected for detailed evaluation and are discussed in detail in the following section, "Selected Alternatives and Costs".

IV SELECTED ALTERNATIVES AND COSTS

The purpose of this section is to present a detailed evaluation of the three approaches selected as likely to solve the erosion problem on Tangier Island.

These are:

a) Seawall construction along the exposed shoreline.

b) Groin field filled with sand from offshore.

c) An experimental technique wherein an open mesh of expended auto tires are used to form a mat covering the shoreface.

a) Seawall.

The typical seawall cross-section used in calculating material requirements is shown in Figure 7. It is important to note that the shore slope used in the layout of the typical section is thought to be conservative; that is, the volume of materials required are probably overestimated. This is due to the lack of detailed information on the average natural slopes encountered at Tangier. However, some comparisons may be made using the slope information available for the limited airport project. These are shown in Figure 8.

The basic features of the seawall sections are the trapezoidal mound and the seaward apron. The apron is to provide toe protection for the trapezoidal section by transferring the anticipated post-installation slumping and adjustment from wave attack away from the base of the trapezoid. Two options exist for prevention of loss of the sand backfill through the void space of the trapezoidal section. The first of these is to use armor size stone throughout the section and backface the structure with filter stone and filter cloth. The second option is to use a relatively impervious core stone center in the trapezoid section. The principal consideration in this choice would be the timing of the fill behind the structure and cost. The timing element is important since the filter stone/cloth combination would slump over time unless the fill was placed immediately after construction. The Corps of Engineers conducts the maintenance dredging program for Tangier Channel and the backfill space could be used, over time, as a spoil disposal site. For this condition the use of core stone would be preferable.

The plan layout of the seawall installation is shown in Figure 9 as is the current airport project. If this option is adopted the seawall should be continued without break at point A (Fig. 9) where tidal creeks open into Chesapeake Bay. Given this, small circulation channels should be dredged at points B and C to provide tidal circulation to the marsh isolated by the seawall.

The first order cost estimates for the seawall options are shown in Table 3 and the details of material unit cost estimates are given in Appendix A.

The costing procedures used follow those in use by the Corps of Engineers wherein raw construction, total project and annual charges are assessed. Inspection of Table 3 shows the expected Total Project Costs range between 2.1 and 2.8 million dollars. It is of interest to compare these estimates with an

TABLE 3. SEAWALL OPTIONS: COSTS

Structure Element	Unit Cost	Option A Concrete/stone armor w/o core Costs	Option B Stone Armor w/o core Costs	Option C Concrete Rubble Armor w/core Costs	Option D Stone Armor w/ core Costs
Concrete Rubble Armor	$18/ton	756,000		594,000	
Stone Armor	$23/ton	334,857	1,445,757		880,026
Core Stone	$23/ton			722,878	722,878
Filter Stone	$23/ton	239,200	239,200		
Filter Cloth	$3/sq yd	90,189	90,189		
Dredged Fill	$4/cu yd	27,400	27,400		
CONSTRUCTION COST		1,447,646	1,802,546	1,316,878	1,602,904
Mobilization & Demob.	10%	144,765	180,254	131,688	160,290
Sub Total		1,592,411	1,982,800	1,448,566	1,763,194
Contingencies	15%	238,861	297,420	217,285	264,479
Sub Total		1,831,272	2,280,220	1,665,851	2,027,673
Engineering & Design	15%	274,691	342,033	249,878	304,151
Supervision & Adminis.	10%	183,127	228,022	166,585	202,767
TOTAL PROJECT COST		2,289,090	2,850,275	2,082,314	2,534,591
Annual Charges					
Interest @ 6.125%		140,207	174,579	127,542	155,244
Amortization @ 0.3304% (50 yr life)		7,563	9,417	6,880	8,374
Maintenance @ 0.5%		11,445	14,251	10,412	12,673
TOTAL ANNUAL CHARGES		159,215	198,247	144,834	176,291

extrapolation of the cost of the current airport runway protection project. The construction cost plus mobilization for the ongoing project are $356,500 for 1,150 lineal feet or $310 per foot. For similar elements the estimated costs for the 8,200 ft. length, herein reported, ranges from $ 176 to $ 241 per foot. Thus, the experienced costs exceed those projected. However, some difference is to be expected given the difference in the scope of the project, 1100 feet versus 8,200 feet.

The associated benefits and disbenefits of the project are discussed in a later section.

b) Groin field filled with sand from offshore.

The basic function of the groin field in this case is to retain the sand pumped onto the beach from offshore. Neither of the elements, groins or sand fill, alone would present a solution. Given the fact that the eroding material has only a minor amount of sand the groins would not fill under natural conditions and since the erosion is so rapid the groins would be flanked and left isolated very quickly. Similarly, a simple sand nourishment project would likely result in a bare shoreline in a short time. The combination of these two elements, however, offers a feasible solution.

In order to achieve a high sand retention a groin length of 100 feet with 150 foot spacing between groins was chosen. Filled groins would be inappropriate at the entrance to Tangier Channel. Therefore an 800 foot length of seawall is recommended as shown in Figure 10. At a spacing of 150 feet, 51 groins are required to cover the remaining shoreline. Approximately 130,000 cu. yds. of sand would be required to fill the groins. Again the assumed shoreface profile is that shown in Figure 8.

The only variant in design for this approach is the material used in construction of the groins. Four options are presented in Table 4. These are quarry stone, concrete rubble, Longard Tube and timber. In the case of the quarry stone option a core of smaller stone was used in the calculations but the cost per ton is the same as for armor stone. Use of the core stone simply reduces the permeability of the structure to lateral losses of the entrapped sand. Details of quantities required are given in Appendix A. A typical section for the stone/rubble groin is shown in Figure 11.

The Longard Tube is a patented device consisting of a PVC coated nylon fabric tube which, when filled with sand (hydraulically), becomes a rigid structure. The costs used in estimating this item are rough estimates from the Longard suppliers.

The previous comments concerning the drainage channels for the marsh pertain for this approach as well (as shown in Figure 10).

The artificial beach established by this approach would adjust to the incident waves. The expectation is that a high water berm would form which would inhibit tidal flooding of the marsh. However, tidal flushing would continue via the feeder channels off of Tangier Channel. In time, aeolian and washover processes would form a frontal dune behind the beach. The dune growth could then be further encouraged by sand fencing or grass plantings.

TABLE 4. GROIN FIELD OPTIONS: 1. COSTS

Structure Element	Unit Cost	Option A Stone Groins - 150 ft. spacing, 100 ft length	Option B Longard Tube Groins 150 ft spacing, 100 ft length	Option C Rubble Groins no core stone	Option D Timber Groins
<u>Seawall Section</u> (800 ft)					
armor stone	$23/ton	85,867	85,867	85,867	85,867
core stone	$23/ton	70,533	70,533	70,533	70,533
<u>Groin Field & Sand Fill</u>					
concrete rubble				310,284	
armor stone	$23/ton	214,660			
core stone	$23/ton	240,465			
dredged sand	$3/cu yd	390,000	390,000	390,000	390,000
Longard plastic tubing	$58/ft		295,800		
w/filter & anchor tube	$18/ft		91,800		
Timber	$45/ft				229,500
<u>Construction Cost</u>		1,001,525	934,000	856,684	775,900
Mobilization & demobilization					
sand fill	20%	78,000	78,000	78,000	78,000
groin const. & seawall sect.	15%	91,728	81,600	70,003	57,885
Sub Total		1,171,253	1,093,600	1,004,687	911,785
<u>Contingencies</u>	15%	175,688	164,040	150,703	136,768
Sub Total		1,346,941	1,251,640	1,155,390	1,048,55[illegible]
<u>Engineering & Design</u>	15%	202,041	188,646	173,308	157,283
<u>Supervision & Administration</u>	10%	134,694	125,764	115,539	104,855
<1> Replacement costs of groins	*		* ?		* 85,819
<u>TOTAL PROJECT COST</u>		1,683,676	1,572,050	1,444,237	1,396,509
<u>ANNUAL CHARGES</u>					
Interest @ 6.125%		103,125	96,288	88,460	85,536
Amortization @ 0.3304% (50 yr life)		5,563	5,194	4,772	4,614
<2> Maintenance of groins @ 2% for D; 0.5% for A & C, 5% B		3,716	25,630	2,565	7,588
<3> Fill maintenance (5 yr nourishment cycle)		134,550	134,550	134,550	134,550
TOTAL ANNUAL CHARGES		246,999	261,662	230,347	232,288

NOTES: <1> This is the amount which must be obligated at time of construction at 6.125% interest rate to meet cost of groin replacement. This includes total project cost elements; however, location is <u>not</u> considered. Also a 25 year lifetime is optimistic.

<2> These may be conservative throughout. The committee has little information on the long-term survival of the Longard tube.

<3> The nourishment cycle.

The long-term behavior of the Longard Tube is uncertain insofar as prolonged exposure to sunlight and resistance to tearing from beach drifting debris or ice are concerned. Thus, there is a potential, as yet unassessed, for high maintenance costs.

The groin construction cost was based on general costs encountered for conventional light weight groins used in sheltered areas; namely single 2" x 8" tongue and groove sheath piling. A somewhat heavier construction would be required at greater cost.

Ease of construction is also an important factor. In order of increasing difficulty the ranking would be stone/or rubble, Longard Tube and timber. In all cases the groins would be hydraulically filled with sand from 2,000 ft. offshore.

Inspection of Table 4 indicates Total Project Costs vary between 1.4 and 1.7 million dollars with annual charges ranging between \$230,000 to \$261,000. Both the timber groin and Longard Tube construction would require replacement in time.

c) <u>An experimental approach: an expended auto tire mat covering the shoreface</u>

In recent years engineers at the Goodyear Rubber Company have developed <u>conceptual</u> designs on the constructive use of <u>expended</u> auto tires. One of the more exciting concepts is to utilize these materials to form a floating breakwater or an open mesh "mat" covering the shoreface. The floating breakwater application has been successfully executed in Rhode Island in Narragansett Bay (Kowalski, 1975). Moreover, some field tests of the shoreface mat are underway on Lake Michigan by the University of Michigan.

The principal advantage to the approach is lower per foot cost of protection relative to the conventional approaches earlier discussed in a) and b). However, since only a few applications have been made it is difficult to estimate costs. Also, the approach has not been used in Chesapeake Bay so local contractors have had no experience in the method or in offering cost estimates. The principal disadvantage in the method is that there has been so little work in evaluation of the environmental conditions necessary for a successful application. In spite of these factors the relatively low cost and ease of construction suggest it should be tried on an experimental basis and, if successful, considered for application to the entire Tangier project site.

The basic tire lattice work mat is shown in Figure 12. Each module bundle is 7 feet by 6.5 feet in size with 20 tires in the vertical plane. For the Tangier project the following design elements are suggested (as shown in Figure 13):

1) Utilize a mat of 60 ft. width.

2) Anchor 20 ft. of the mat to the marsh surface.

3) Anchor the floating portion of the mat (40 ft.) at the seaward end.

4) Artificially fill the beach face using an hydraulic discharge spray on the surface.

The expectation is that the slurry spray will fill the lower part of tire casings and the structure will sink, become embedded at the surface, and act as a protective mat to keep the artificial beach in place. That portion of the mat on the marsh surface will become partially embedded to form a self-anchor. At the same time the protruding tires will act as a sand trap for overwash sand. It is to be emphasized that the above description is the expected behavior. Initial test applications would be necessary prior to wide-scale application. The element of principal concern is just how effective the mat would be in holding the frontal beach in place. If it were not effective marsh erosion would continue even though the mat would diminish the impinging wave energy.

The cost estimate for this application is shown in Table 5. The quantity details are given in Appendix A. Note should be made of the fact that the cost of placing the mat sections was arbitrarily taken at 30% of construction costs. This figure would include contractor mobilization.

Each tire has a net positive buoyancy of 10 lbs. Discussion with Mr. Richard Candle of Goodyear indicates a small boat can tow a 100-200 ft. raft section with ease. Thus placement of such sections should not constitute a serious engineering problem. It is envisioned that placement would be made at high tide stage when the sections can be winched over the marsh for anchoring. Once in place an anchor placing boat could affix the seaward anchors sequentially. At that point the structure would act like a fixed floating breakwater to suppress waves. During the sand pumping program the lower, submerged, part of the casing would become sand filled providing a net negative buoyancy.

The designs offered above should b viewed with considerable latitude since ongoing research by others may dictate changes in method and details of the approach. For example, considerable attention is being given to the search for the best materials to bind the tires together as well as their wave energy absorption characteristics. Various members of the Task Force will be following these studies so that the most recent information may be applied.

TABLE 5. USED AUTO TIRE SHOREFACE MAT: COSTS

Structure Element	Unit Cost	Costs For 8,200 Ft.
Tire modules		
Tires (196,800 tires)	0.15 ea.	$ 29,520
Wire rope (328,000 ft)	0.40/ft.	131,200
Clips for wire rope	0.70 ea.	60,680
Anchors		
Concrete 250 lb.(586)	15.00 ea.	8,786
Concrete 500 lb.(586)	22.00 ea.	12,892
Dredged Sand (54,670 cu/yds)	3/cu.yd.	164,000
Labor		
Assembly of tires (9371 man/hrs)	6/man hr.	56,228
SUB TOTAL		$ 463,306
Labor - Placement Costs		138,992
Construction Cost		602,298
Mobilization - sand dredging	20%	32,800
SUB TOTAL		$ 635,098
Contingencies	15%	95,265
SUB TOTAL		$ 730,363
Engineering & Design	10%	73,040
Supervision & Administration	10%	73,040
TOTAL PROJECT COST		$ 876,443
Annual Charges		
Interest @ 6.125%		53,682
Ammortization @ 0.3304%		2,896
Maintenance 5%		43,822
		$ 100,400

V COST COMPARISONS OF SELECTED ALTERNATIVES AND ASSOCIATED BENEFITS AND DISBENEFITS

The cost comparisons of the selected alternatives and options within alternatives are shown in Table 6. As previously stated the cost associated with Longard Tube groins and timber groins are somewhat uncertain. In the former there is considerable uncertainty of the lifetime of the installation and in the latter the estimates are based upon a lighter weight structure than that required. In addition there is considerable uncertainty in costing some components of the used tire shoreface mat, particularly the cost of installation on the shoreface.

Before proceeding to the recommendations it is important to address the expected consequences of stabilization of the island. Since stabilization is being considered for only that portion of the shoreline south of Tangier Channel one would anticipate continued retreat of the island north of the channel. This would result in an offset configuration at the entrance of the channel resulting in eventual shoaling and exposure to wave action on the south bank of the Channel. Thus, future corrective action for Tangier Channel, maintained by the Corps of Engineers, is foreseen.

Some minor losses of marsh will occur by the stabilizing action. However, if the shoreline is not stabilized the marsh will be lost rapidly via frontal erosion. Thus, the minor loss of marsh should not be considered an adverse environmental impact.

TABLE 6. COMPARATIVE COSTS

ELEMENT	SEAWALL				GROIN FIELD WITH SAND FILL				USED AUTO TIRE SHOREFACE MAT
	A	B	C	D	A	B	C	D	
	Concrete/ stone w/core	Stone w/o core	Concrete rubble w/core	Stone w/core	Stone Groin w/core	Longard Tube groin	Rubble groin no core	Timber groin	
Construction Cost	$1,447,646	$1,802,546	$1,316,878	$1,602,904	$1,001,525	$ 934,000	$ 856,684	$ 775,900	$ 602,298
Total Project Cost	2,289,090	2,850,275	2,082,314	2,534,591	1,683,676	1,572,050(?)	1,444,237	1,396,509	876,443
Annual Charges	159,215	198,247	144,834	176,291	246,999	261,662(?)	230,347	232,288	100,400
Cost Per Foot = Total Proj. Cost / 8,200 ft.	$ 279	$ 347	$ 253	$ 309	$ 205	$ 191(?)	$ 176	$ 170(?)	$ 106(?)

The alternative actions presented, a seawall, a filled groin field and a used tire shoreface mat, would have different effects on the entrance to Tangier Channel and the curved spit on the southern end of Tangier Island. The principal difference is that with the filled groin field or filled shoreface mat there would be a renewed sand source which would supply sand to the entrance of Tangier Channel and to the spit. The former would be considered a disbenefit since it would contribute to entrance shoaling while the latter might be considered a benefit in that the spit might increase in width thereby reducing the likelihood of breaching in storm high waters. In a comparative sense the shoaling of the channel entrance is a greater disbenefit than the benefit of sand transport to the spit. The seawall installation, on the other hand, would not have the same effect on the adjacent shoreline. However, since it would entirely replace the sandy intertidal zone there would probably be a reduction in the sand transport along the shore.

Another consideration worth mention is the flexibility for alternate use of the shore given the alternatives. The principal point is that application of the filled groins would result in beach area readily accessible to the populace of Tangier and to visitors to the island. The other two alternatives do not present such flexibility.

Finally, it should be noted that filling the beach would involve dredging sand from offshore. There would be a temporary impact at the dredge site on the local benthic populations and burial of the existing intertidal ecotome. However, recolonization would be expected rather rapidly. Surveys of the sand characteristics and the benthic community have already been completed by VIMS for the Virginia Division of Aeronautics. These are included in Appendix C.

VI RECOMMENDATIONS

In view of the foregoing analysis the Technical Committee of the Task Force recommends:

1) That the installation of a continuous seawall be adopted as the preferred solution. In spite of the fact that this would entail greatest cost the seawall offers the most certain protection and least annual cost of the recognized conventional engineering approaches evaluated.

2) That the installation of a filled groin field with a seawall section near Tangier Channel be adopted as the principal alternate solution.

3) That, given the high costs for either 1) or 2) above and likely delay in the appropriation of sufficient funds, immediate steps be taken to test the used tire shoreface mat concept on Tangier Island. Such tests would provide the opportunity to evaluate the effectiveness of the approach, to formulate better cost estimates and most importantly to reduce the erosion at two selected critical erosion areas at the site.

   Specifically it is recommended that funds be appropriated for installation of about 1,000 feet of shoreface mat. This should cost about $100,000. The recommended application areas are shown in Figure 14. It is suggested that at Site A the shoreface mat be used and at Site B the tire assembly be used as fringe attached floating breakwater as this would allow a comparison of the effectiveness. If such action is executed the Virginia Institute of Marine Science would monitor the effectiveness of the program as part of its current program in evaluating erosion control techniques.

4) That the Task Force Technical Committee be maintained as a review body.

VII ADDITIONAL INFORMATION REQUIRED

The following information is needed prior to further action in engineering specification or project action for the full scope of protection:

1) Ownership of the entire shoreline must be specified.

2) A closely-spaced (500 ft.) series of elevation surveys from the marsh surface to a water depth of 5 ft, relative to mean low water. These will be necessary for contractors to bid on the project to protect the entire shoreface.

VIII POSSIBLE AVENUES OF FUNDING

The Task Force did not consider its mission to include the question of project funding. However, it felt that if it had particular knowledge of funding possibilities they should be pointed out.

In 1974 the U.S. Congress passed the "Shoreline Erosion Control Demonstration Act of 1974" which authorized the Corps of Engineers to develop and demonstrate low cost means to combat shoreline erosion in "sheltered" or inland waters. In October, 1975 VIMS submitted the Tangier Island case as a demonstration site (SEAP site) to the Norfolk District Corps of Engineers. Norfolk District, in turn, submitted the site to the Shoreline Erosion Advirory Panel for consideration. If Tangier is selected as a demonstration site it would be possible to secure some of these funds for the project. Since the total funding level of the Act is limited it is doubtful that the entire seawall or filled groin project would be supported; however, one would hope that at least the initial tests with the expended auto tires might be funded. The principal contact in pursuit of this question is:

Colonel James L. Trayers
Executive Secretary
Shoreline Erosion Advisory Panel
Kingman Building
Fort Belvoir, Virginia 22060

REFERENCES

Boon, John D., III, 1975. "The Bathymetry and Nearshore Sand Characteristics off Tangier Island, Virginia." Report to Division of Aeronautics, State Corporation Commission, Commonwealth of Virginia.

Pore, N.A., 1965. "Hurricane Surge in Chesapeake Bay", Chesapeake Science.

U.S. Army Corps of Engineers, Norfolk, "Draft of Detailed Project Report, Shore Protection for Airport at Tangier Island, Virginia."

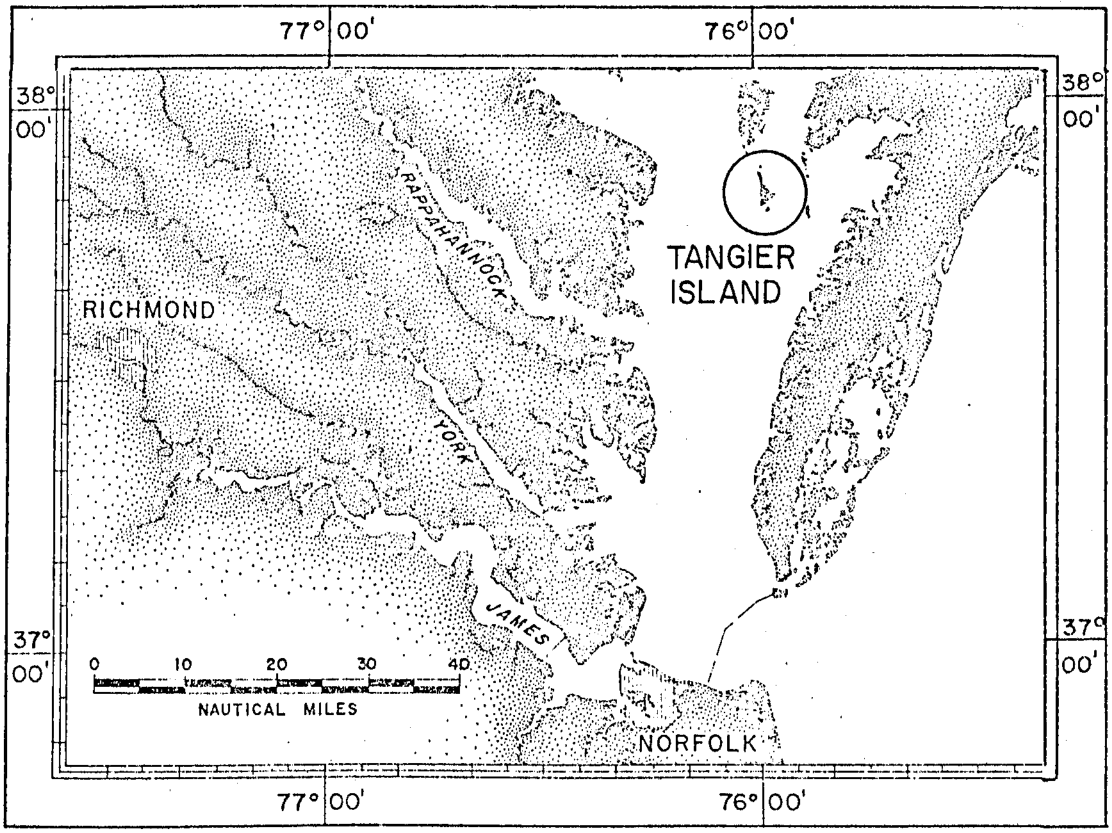


FIGURE I. LOCATION MAP

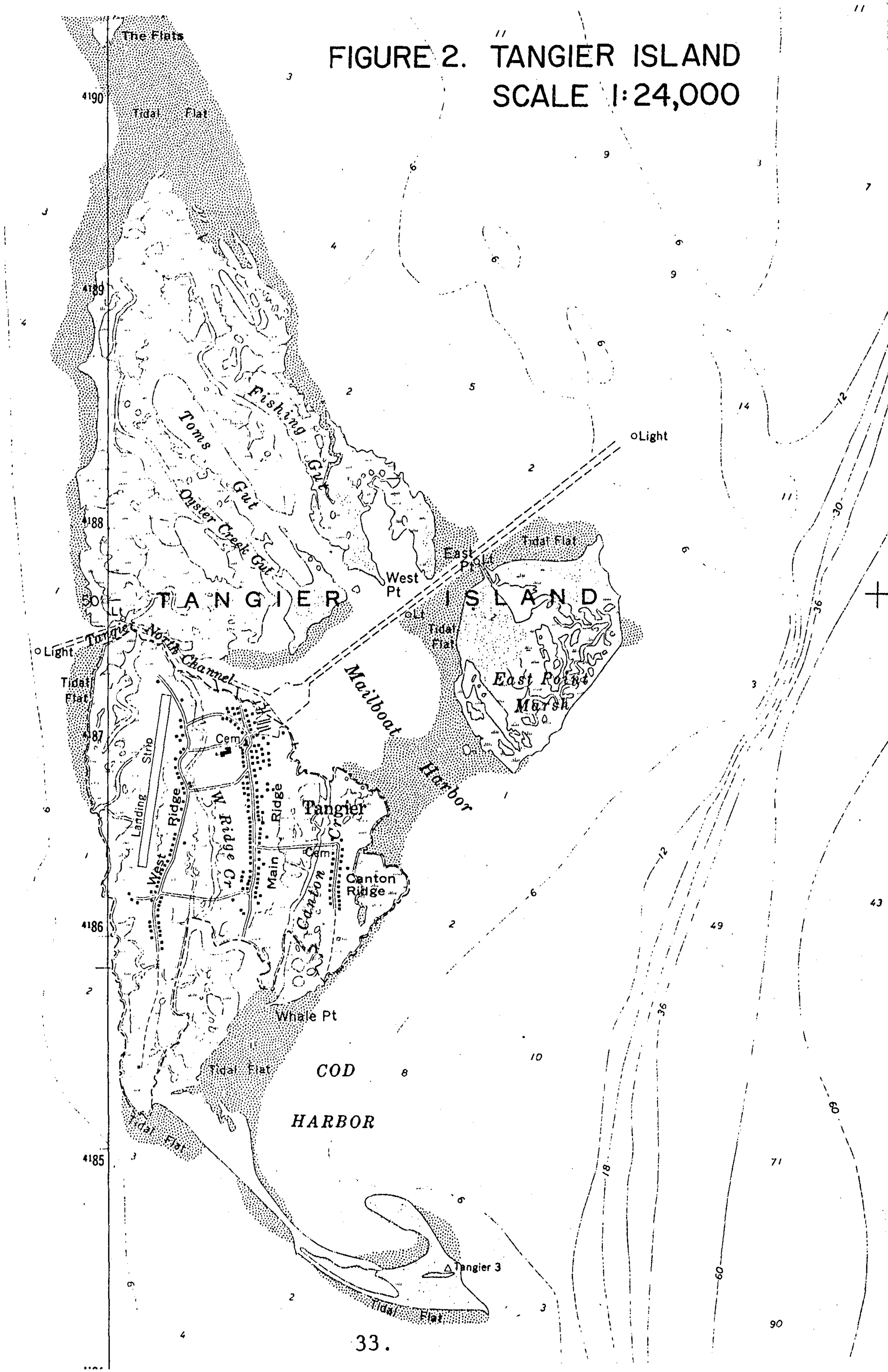
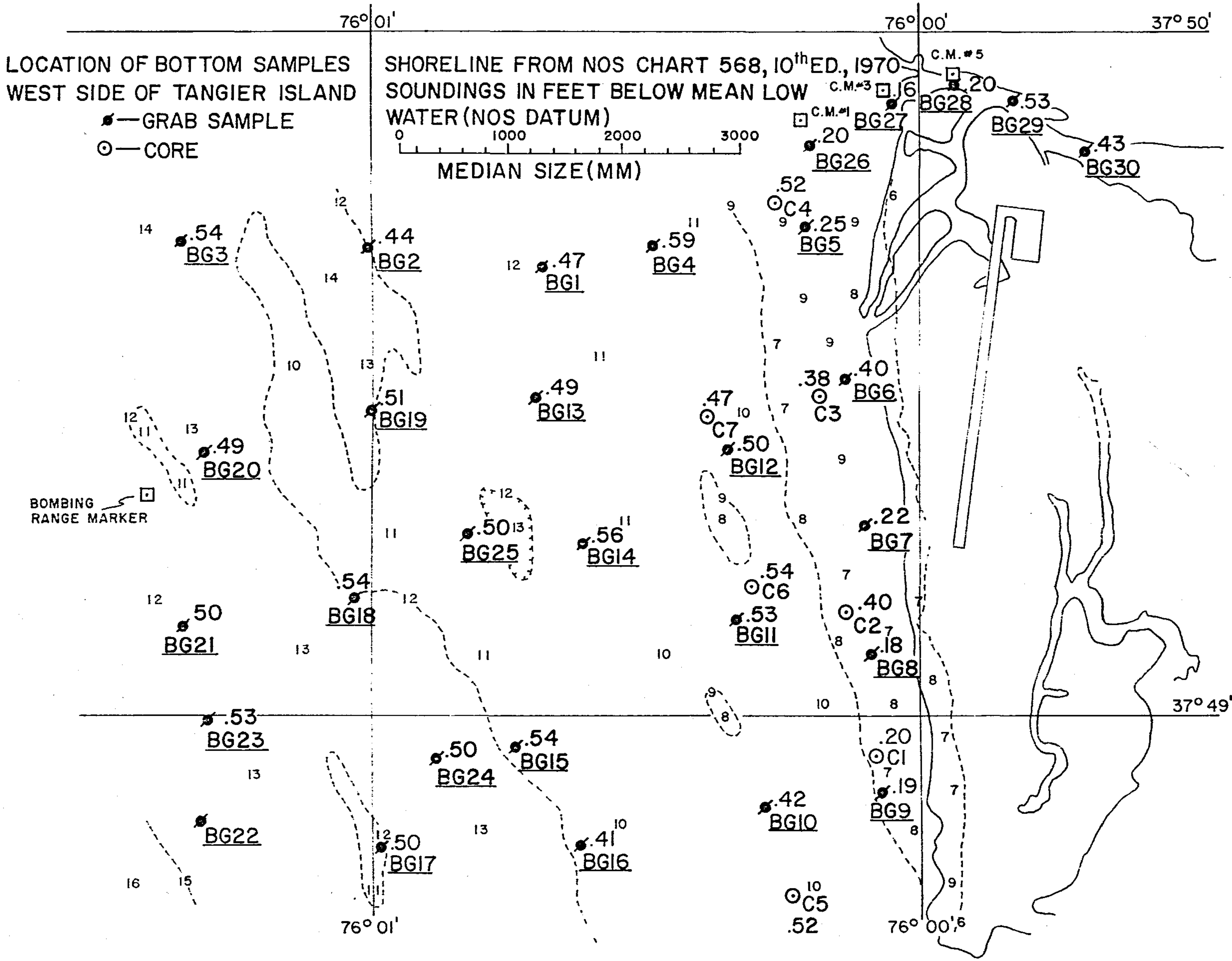


FIGURE 2. TANGIER ISLAND
SCALE 1:24,000

FIGURE 3. DEPTH AND GRAIN SIZE



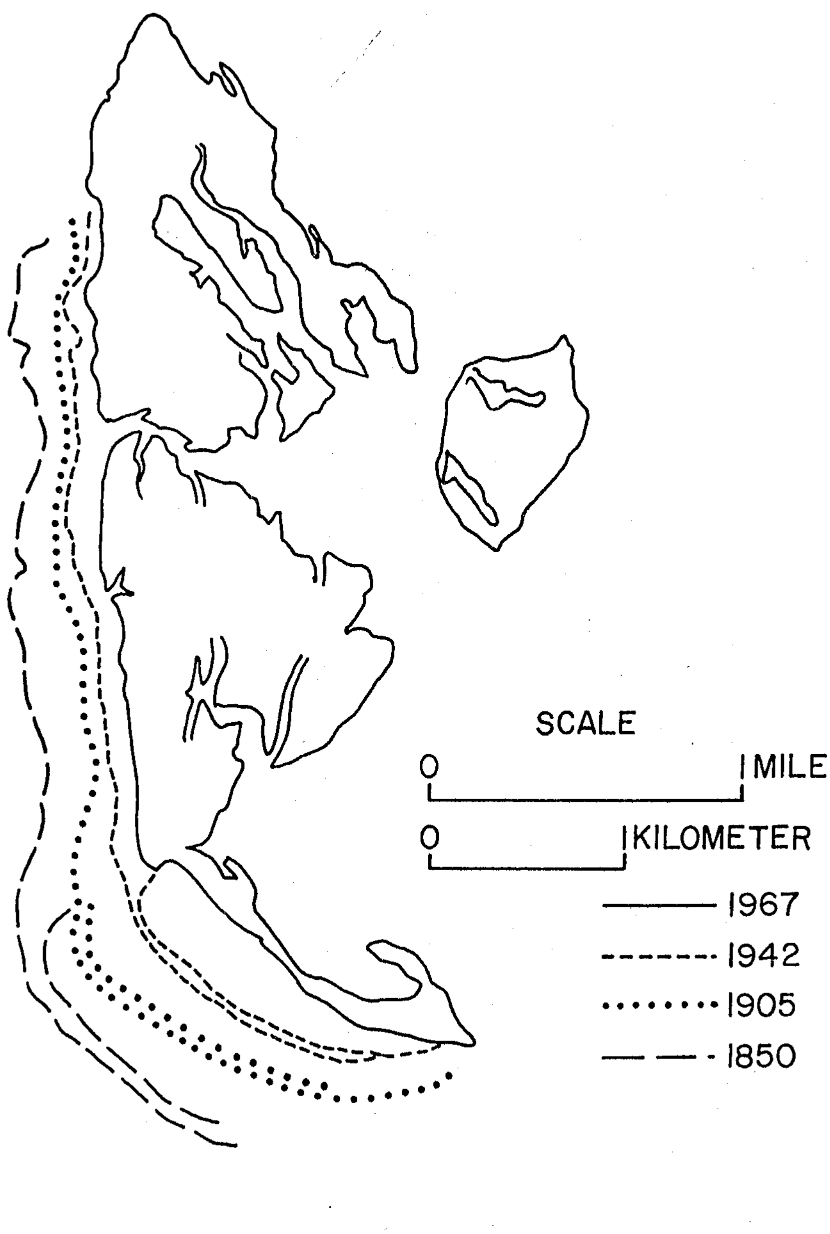


FIGURE 4. HISTORICAL SHORELINE POSITION

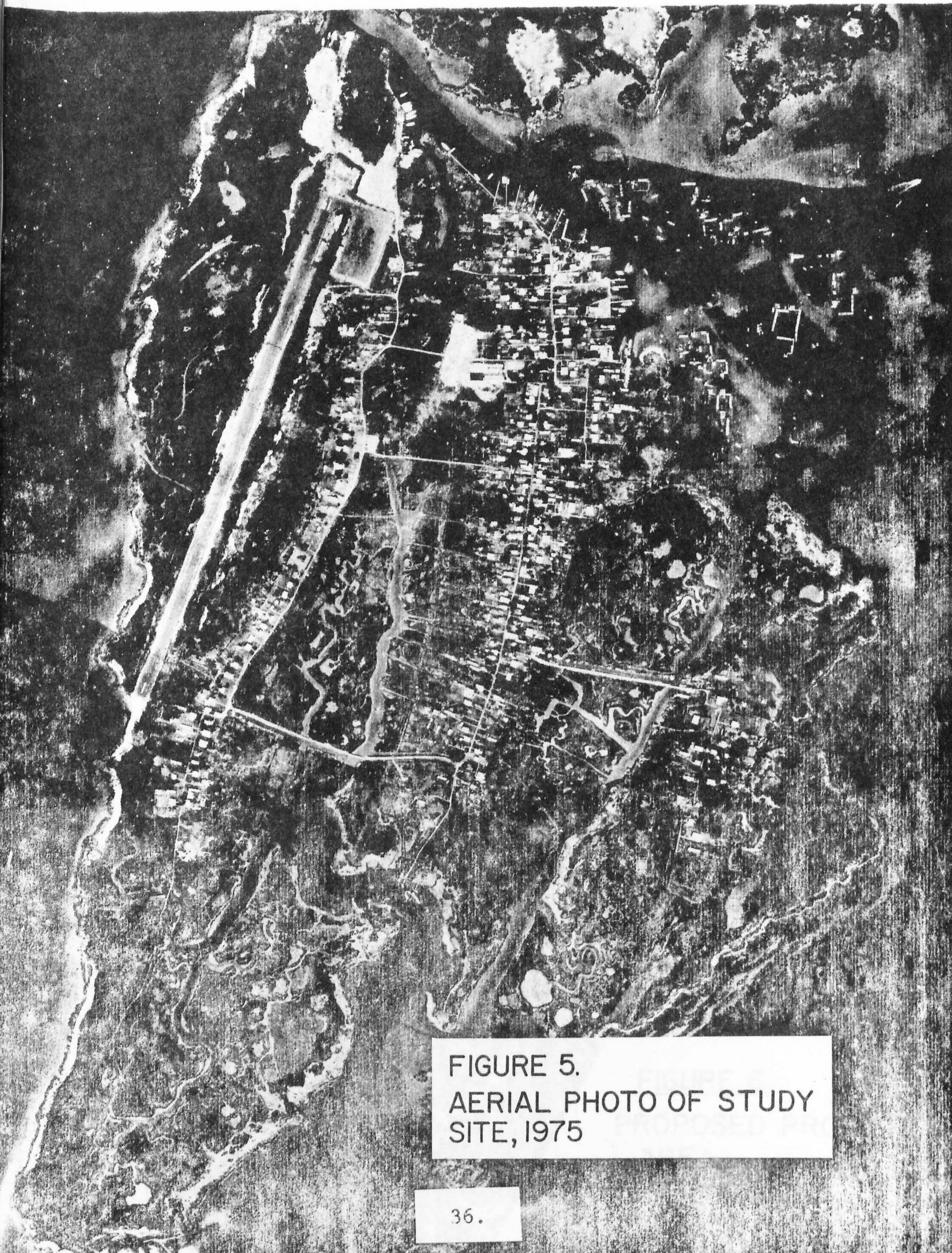


FIGURE 5.
AERIAL PHOTO OF STUDY SITE, 1975

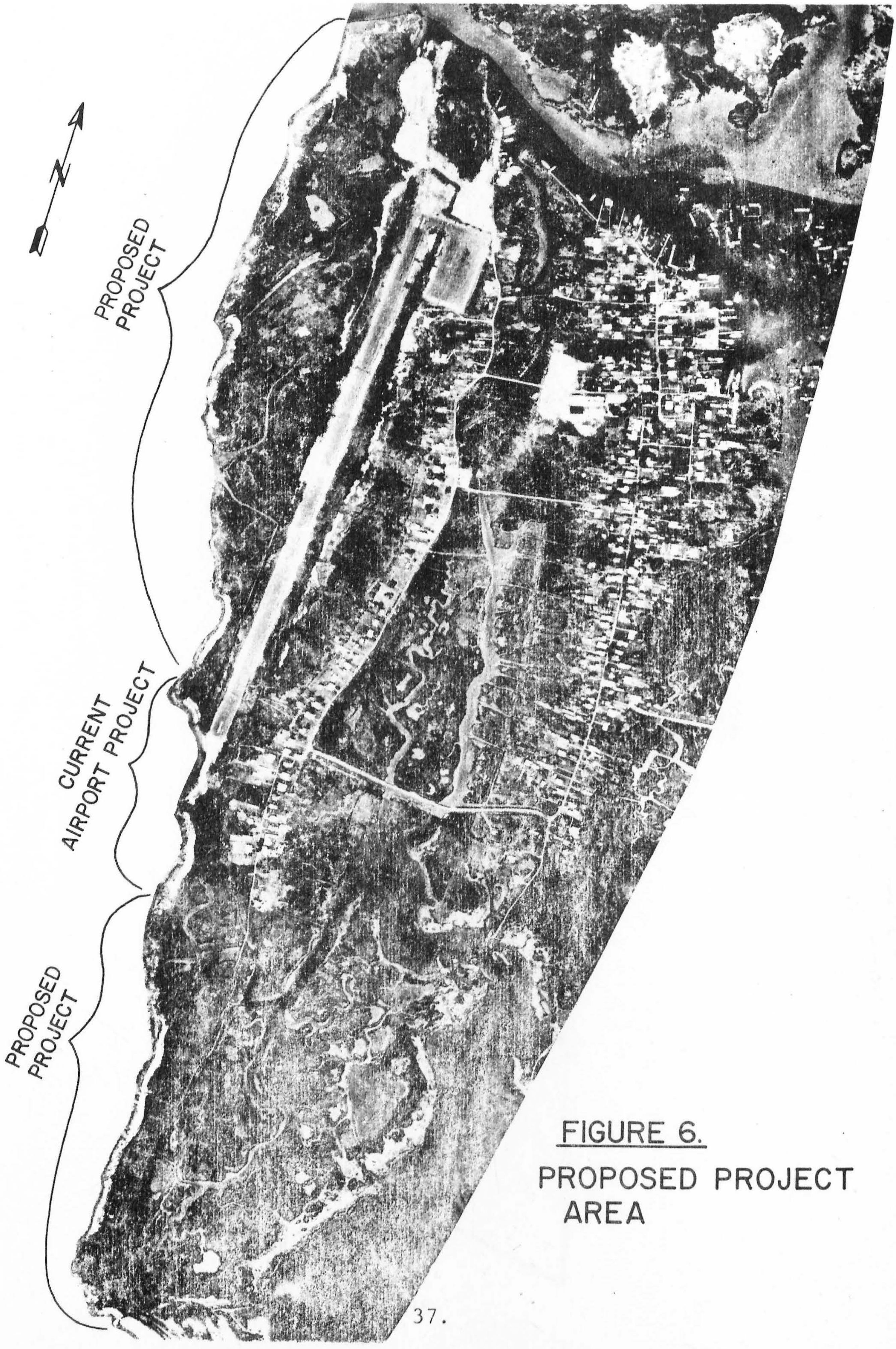


FIGURE 6.

PROPOSED PROJECT AREA

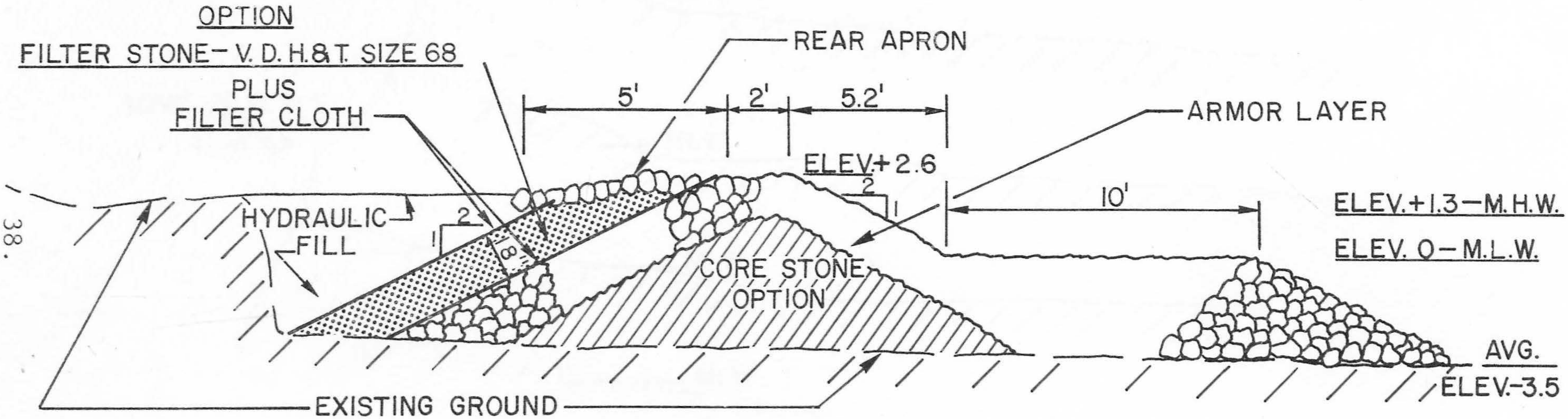


FIGURE 7

TYPICAL SEAWALL SECTION

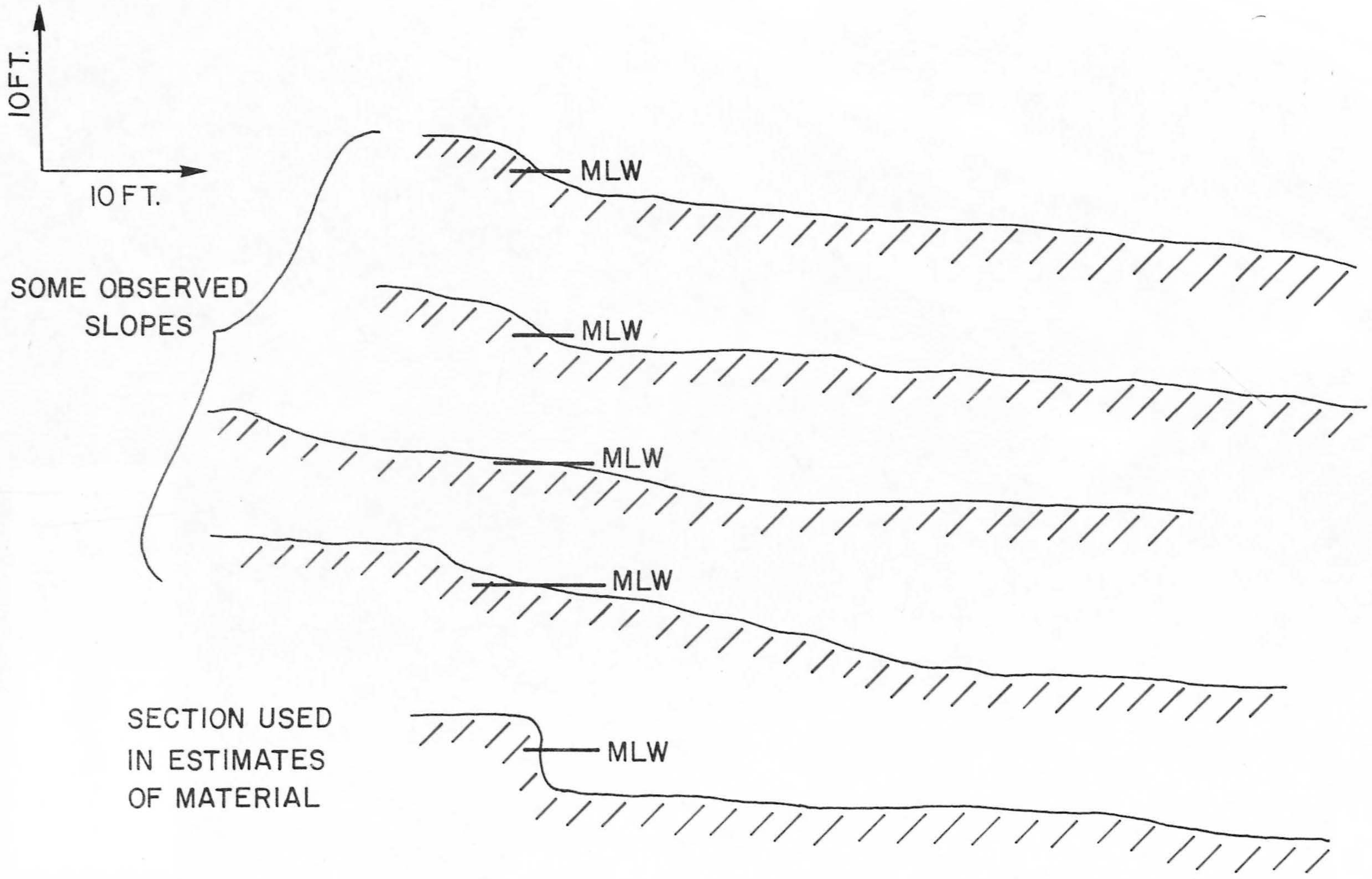


FIGURE 8. ESTIMATED AND OBSERVED SLOPES

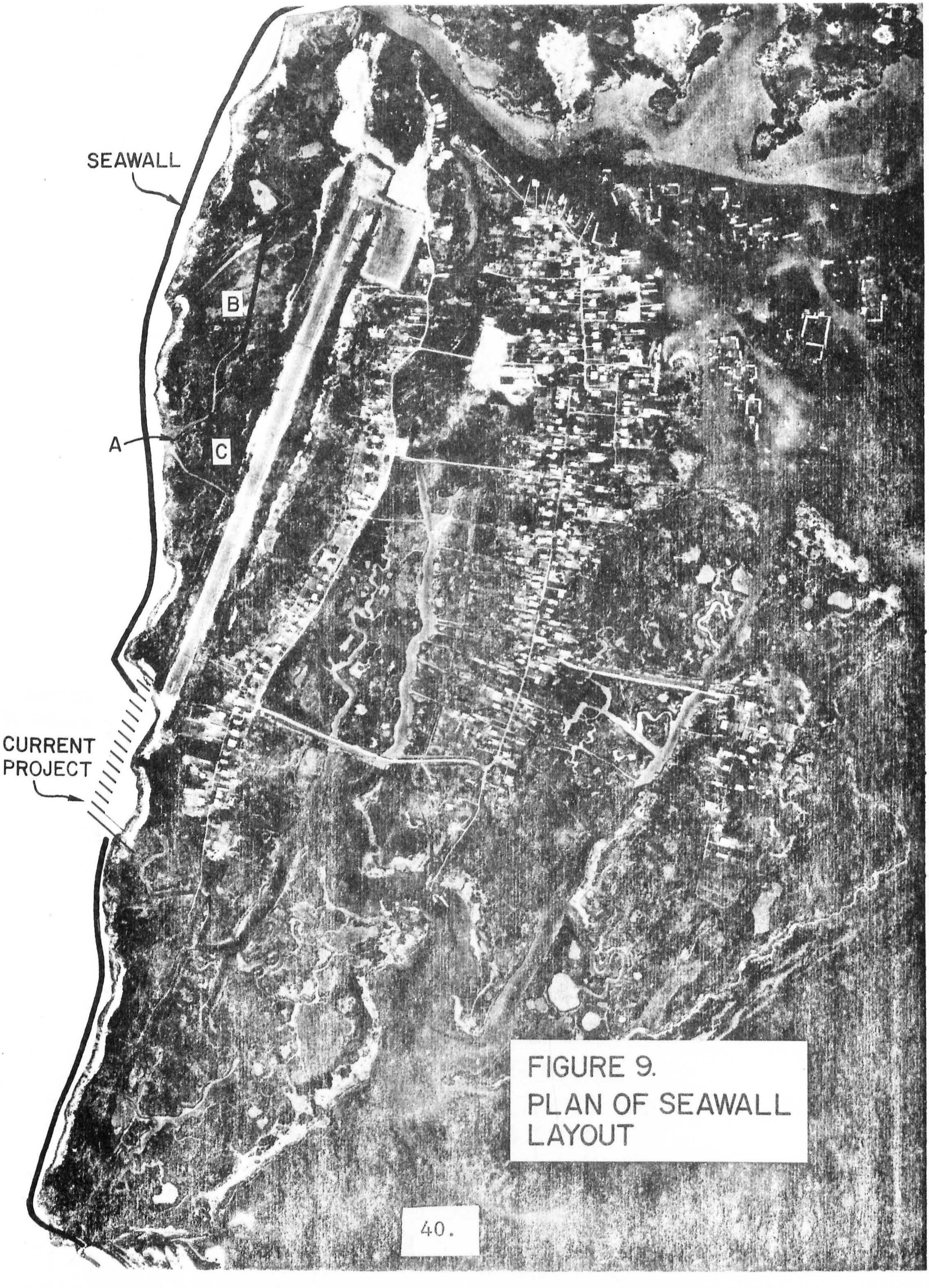


FIGURE 9.
PLAN OF SEAWALL LAYOUT

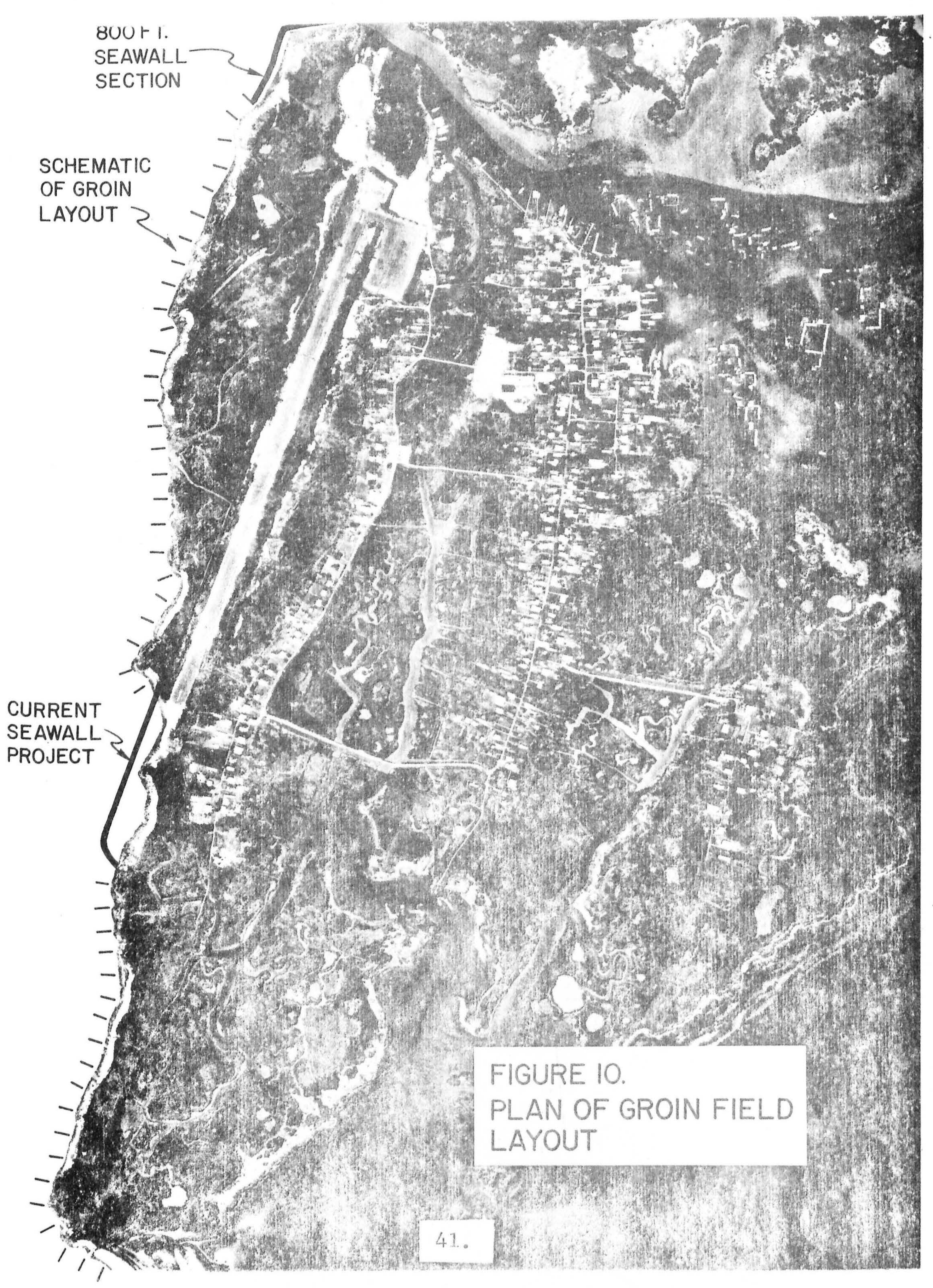


FIGURE 10.
PLAN OF GROIN FIELD
LAYOUT

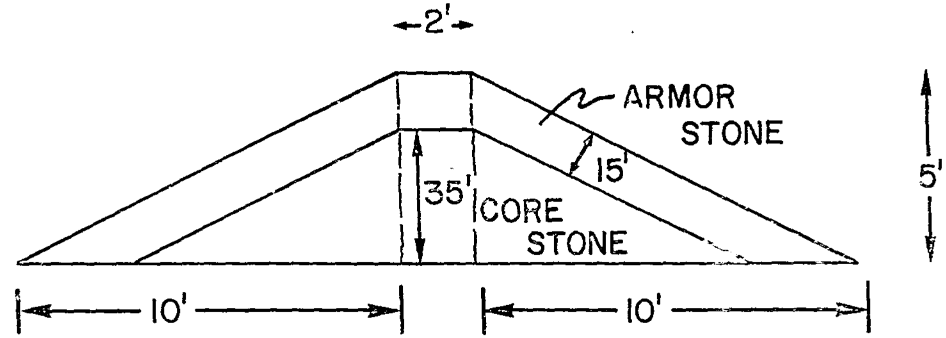


FIGURE II. SECTION OF GROIN

TYPICAL ASSEMBLY DETAILS OF THE GOODYEAR
OPEN GRID EROSION MAT UTILIZING THE BASIC SCRAP TIRE
CONSTRUCTED MODULAR UNIT

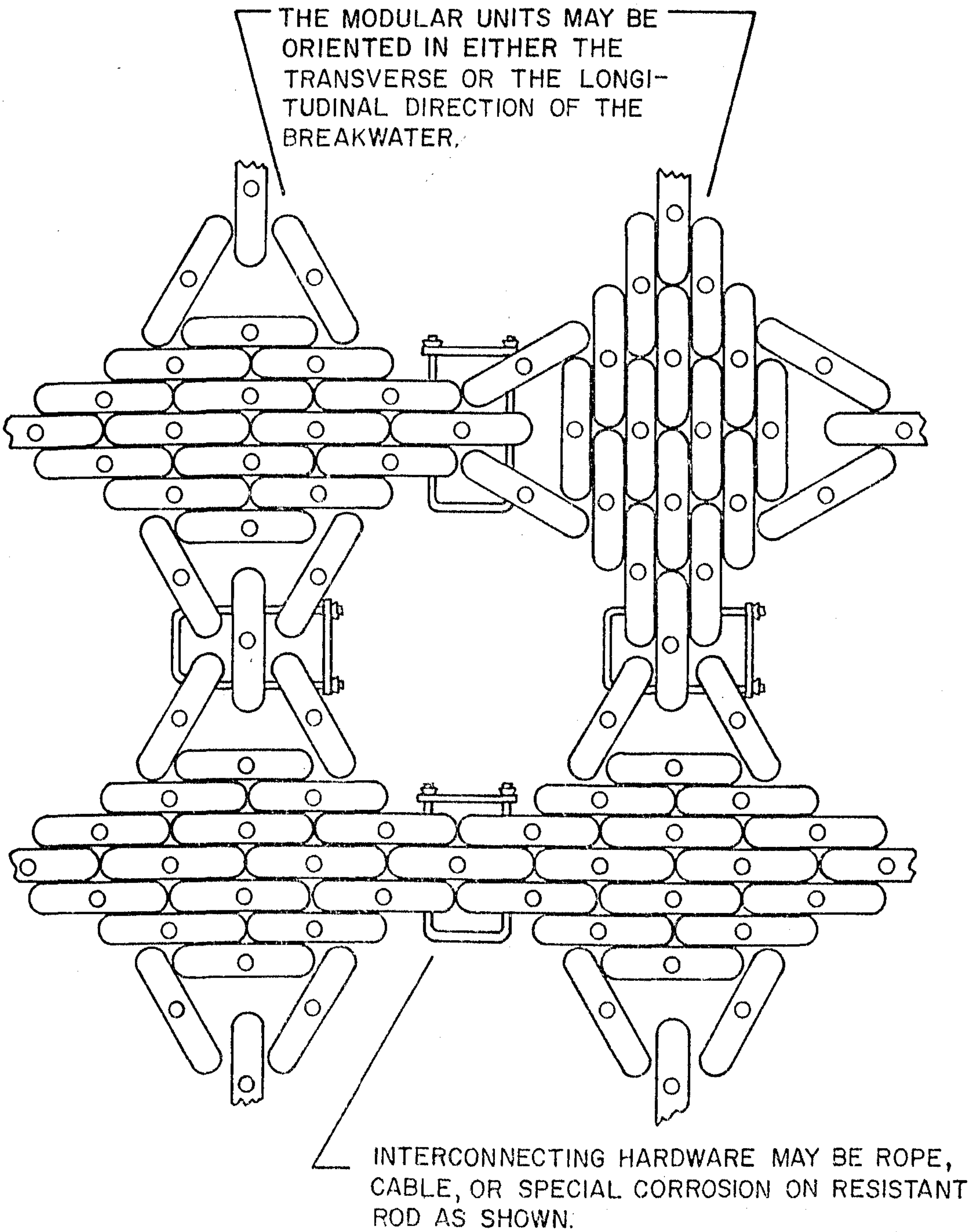


FIGURE 12. BASIC TIRE MAT LAYOUT

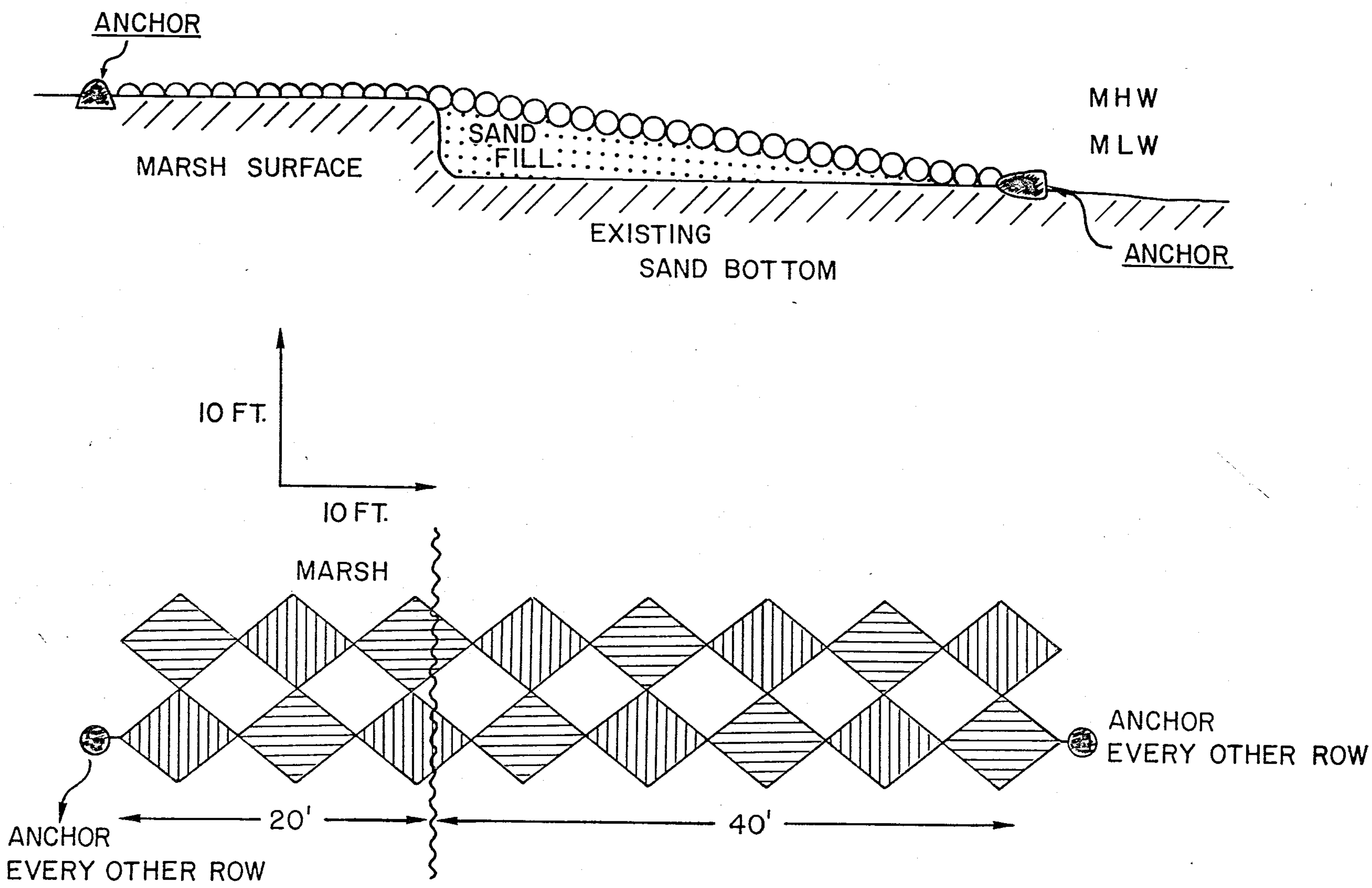


FIGURE 13. SCHEMATIC OF SHOREFACE TIRE MAT LAYOUT

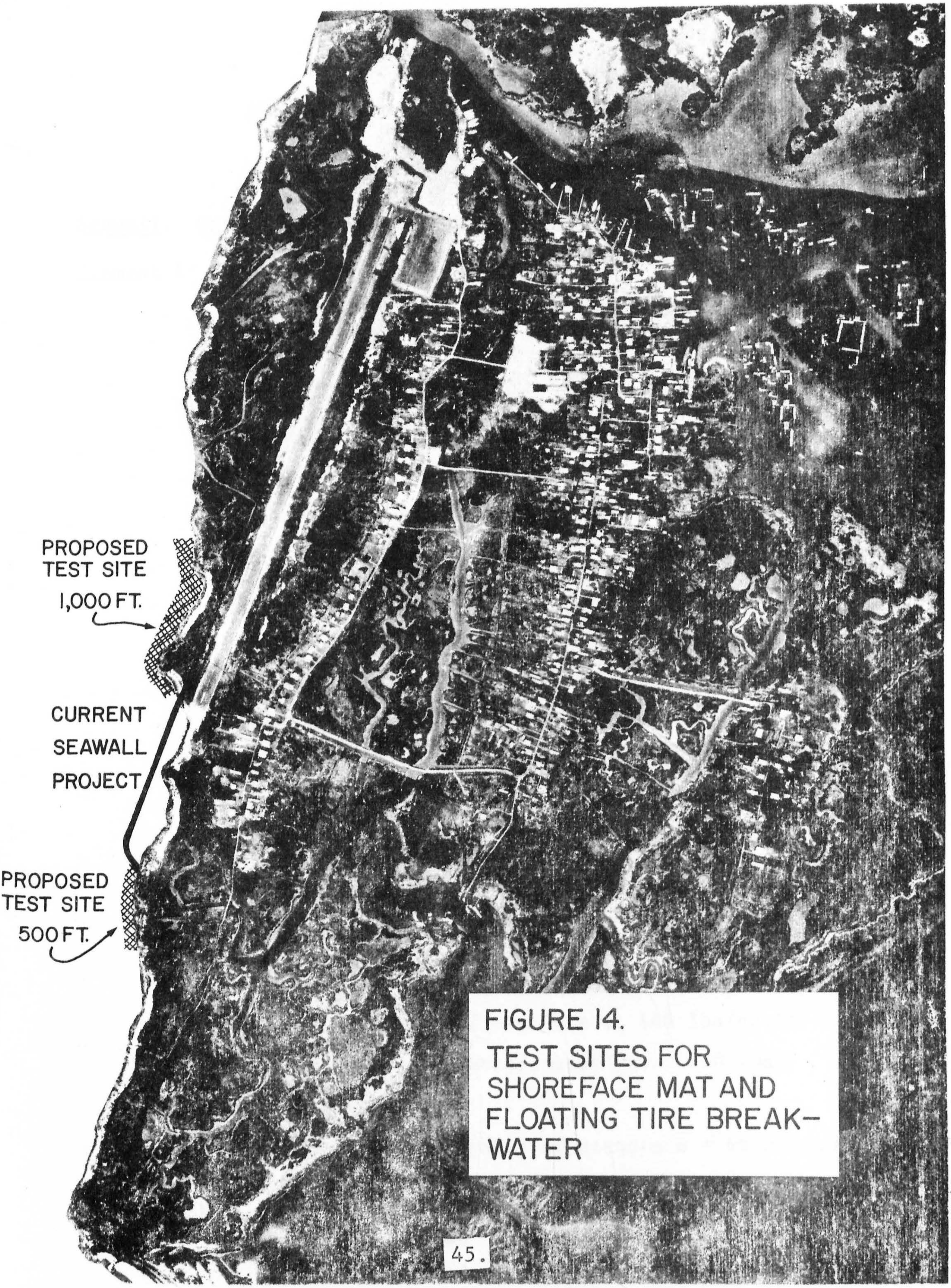


FIGURE 14.
TEST SITES FOR SHOREFACE MAT AND FLOATING TIRE BREAKWATER

APPENDIX A: ESTIMATE OF MATERIALS

SEAWALL

Seawall: Option A,,Concrete/stone armor without core stone

Element 1: Bridge Concrete Rubble Armor

For the typical seawall section shown in Figure 7 the solid volume per linear yard of structure is 13 cu. yd. Assuming an in place porosity of 25% the volume of material required per linear yard is 10 cu. yds.

There will be 19,000 cu. yds. of material (solid volume) which when fragmented (25% porosity) will present 23,750 cu. yds. of in place volume. However, some of this material will be lost in crushing (assume 10%) resulting in a final "swelled" volume of 21,000 cu. yds.

The 21,000 cu. yds. would then be sufficient for 2,100 yds. of structure. This 2,100 yds. (6,300 ft.) is sufficient to cover 76% of the 8,200 ft. of shoreline requiring protection.

In summary:

a) 10 cu. yds. of rubble per linear yard. Using the unit weight of concrete at 145 lbs/cu.ft. 10 cu. yds. of rubble/linear yard $\cong$ 20 tons/ linear yard.

b) 6,300 ft. (2,100 yds.) of structure = 42,000 tons.

Element 2: Stone Armor

a) 10 cu. yds. of stone per linear yard. Using the unit weight of stone at 165 lbs./cu.ft., 10 yds. of stone/linear yard ≅ 23 tons/linear yard.

b) 1,900 ft. (633 yds.) of structure = 14,559 tons.

Element 3: Filter Stone

a) Assuming 25% porosity of the in place stone, 1.7 cu. yds. per linear yard of stone are required. Using 165 lb./cu.ft. unit weight then 3.8 tons of stone per linear yard is required.

b) 8,200 ft. (2,733 yds.) of structure = 10,400 tons.

Element 4: Filter Cloth

a) 11 sq. yds. per linear yard of filter cloth are required.

b) 2,733 yds. of structure = 30,063 sq. yds.

Element 5: Dredged Fill

a) Assumed fill requirement is 2.5 cu. yds. per linear yard of structure.

b) 2,733 yds. of structure = 6,850 cu. yds.

Seawall: Option B, Stone armor without core stone

Element 1: Stone Armor

a) 10 cu. yds. of stone per linear yard of structure = 23 tons of stone per linear yard.

b) 2,733 yds. of structure = 62,859 tons.

Element 2: Filter Stone: as in Option A

Element 3: Filter Cloth: as in Option A

Element 4: Dredged Fill: as in Option A

Seawall: Option C, Concrete rubble armor with core stone

Element 1: Bridge Concrete Rubble Armor

For the typical seawall section with core stone shown in Figure 7, 6 cu. yds. of armor is required per linear yard of structure. The "swelled" volume of rubble available is 21,000 cu. yds. which is sufficient to treat 3,500 yds of structure so no stone armor would be required to supplement as is the case in Option A. In summary:

a) 6 cu. yds. of rubble per linear yard = 12 tons per linear yard.

b) 8,200 ft. (2,733 yds.) of structure ≅ 33,000 tons.

Element 2: Core Stone

a) assuming 25% porosity, 5 cu. yds. per linear yard of core stone are required (= 11.5 ton/linear yard).

b) 8,200 ft. (2,733 yds.) of structure = 31,430 tons.

Seawall: Option D, Stone armor with core stone

Element 1: Stone Armor

a) 6 cu. yds. of stone per linear yard of structure = 14 tons of stone per linear yard.

b) 8,200 ft. (2,733 yds.) of structure = 38,262 tons.

Element 2: Core Stone, as in Option C

FILLED GROIN FIELD

Groin Field; Option A, stone groins, spacing with sand fill 150 feet

Element 1: Core Stone

For the typical groin section shown in Figure 11 the following quantities pertain:

a) 2.7 cu. yds. of stone per linear yd. of structure. Assuming, as before that 1 cu. yd. = 2.3 tons then weight per linear yd. of structure = 6.2 tons per linear yard.

b) For 100 ft. groin length then weight per groin is 205 tons.

c) For a groin spacing of 150 feet 51 groins are required. Therefore, total material required is 51 x 205 tons = 10,455 tons.

Element 2: Armor Stone

a) 2.4 cu. yds. of armor stone per linear yard are required which = 5.53 tons per linear yard.

b) For 100 ft. groin length, 183 tons of armor stone are required.

c) For a groin spacing of 150 feet, 51 groins are required. Total armor stone required is 51 x 183 tons = 9,333 tons.

Element 3: Sand Fill

a) For the typical section shown in Figure the sand fill requirement is 40 cu. yds. per linear yard.

b) For a total length of 2,733 yards the fill required is 107,000 cu. yds.

c) Allowing 20% loss of finer grained material which leaves residence on the filled beach the total fill required is 130,000 cu. yds.

Groin Field: Option B, Longard tube groins.

Element 1: Longard Tube

The Longard Tube is a patented device consisting of a PVC coated nylon fabric tube which when filled with sand becomes a rigid structure. In the present application the recommended design for each groin would be: each groin comprised of three tubes; one 100 ft. long 40 inch diameter tube resting beside the longer tube at the shore end. Finally, a third 28 inch diameter, 50ft. long tube would be placed on top of the double tube section. This would give a staggered elevation groin varying in height from 60 inches at the shore section to 40 inches in the offshore section.

a) Each groin consisting of:
   1-40 inch diameter tube, 100 ft. long
   1-40 inch diameter tube, 50 feet long
   1-28 inch diameter tube, 50 feet long

b) 51 groins required.

Element 2: Sandfill

Same as Option A

Groin Field: Option C, concrete rubble with sand fill without core

Element 1: Concrete rubble

In this option concrete rubble is proposed without the use of core stone.

a) 5.1 cu. yds. of rubble per linear yard of structure are required.

b) Each groin then requires 169 cu. yds. of rubble or (at 145 lgs/ft^3) 338 tons.

c) For 51 groins the total requirement is:

51 x 169 cu. yds = 8,620 cu. yds.

51 x 338 ton = 17,238 tons

d) There is an ample supply of rubble derivable from the James River Bridge (~ 21,000 yds)

Element 2: Sand fill

as in Options A and B

Groin Field: Option D, timber groins

Element 1: Timber pile and sheathing

The estimates following consider groin construction to be of single sheath 2" x 8" T & G piles.

a) Each groin length of 100 feet

b) with groin spacing of 150 ft., 51 groins are required.

c) therefore, 5,100 feet of groin structure are required.

Element 2: Sand fill

same as Options A, B, C

Expended Tire Shoreface Mat

Element 1: Tire modules

The suggested design calls for a structure width of 60 feet (8 bundles x 7ft/bundle). A description of the Goodyear concept is given in Appendix B.

The following components are required for each row:

a) 21 tires per bundle x 8 bundles = 168 tires.

b) Binding with wire rope (3/8 inch)
30 ft. rope per bundle x 8 bundles
times 1.15 factor = 280 ft. wire rope

c) Clips for wire rope connections
8 per bundle x 8 bundles times
1.15 factor = 74 clips

d) Anchors
Onshore anchor - handmade
concrete-250 lb. - estimated cost $15.00 each
Offshore anchor - handmade
concrete-500 lb. - estimated cost $22.00 each
Anchors are suggested at every other row

Element 2: Labor

a) Assembly of bundles and rows
1 man hour per bundle x 8 bundles = 8 man/hr.

b) Placement costs are estimated, arbitrarily, as 30% construction cost.

Element 3: Sand Fill

The sand fill per linear yard is 20 cu. yds.

academic purposes and not recommended or proposed as engineering specifications for practical application.

September 30, 1974

THE PROPOSED GOODYEAR SINKING SCRAP TIRE MARINE MAT

by R D Candle
W J Fischer

The following is a procedure for the fabrication of a general purpose sinking marine scrap tire mat for use as an erosion control device. Scrap tires are the main construction material for building these large marine mat type structures.

Modular Bundle Construction:

The basic designs rely on a modular bundle concept where a relatively few tires are secured together to form a small, easily assembled, portable building unit. The Goodyear Scrap Tire Marine Mats are formed by securing together the modular units as shown in Figures 1 and 2. This construction procedure yields an easily installed, readily adaptable structure which has high energy absorbing capacity for normal loading conditions, but which deforms and yields when subjected to overloads.

Interlocking and Interconnecting Hardware:

a) Galvanized Rod Type:

The scrap tire modules are fabricated by interlocking the worn-out tires to form a compact bundle. "U" bolt type devices as shown in Figure 3 may be used to interlock the tires. A 3/4" diameter steel rod is bent into a 42 1/2" long by 15" wide "U" bolt configuration with 6" long threaded ends to form the interlocking hardware. All steel components are double galvanized to provide maximum corrosion resistance. The interconnecting hardware is identical to the interlocking "U" bolts except that they are only 22 1/2" long. Two interconnecting and two interlocking "U" bolts are required for each bundle assembly.

b) Non-Corroding Wire Rope Type:

The "U" bolt type interlocking devices used in the bundle modules may be replaced with high strength stainless or galvanized wire rope in some applications which do not require the added strength and long life of the 3/4 diameter steel rods. Two nine foot lengths of cable are required to interlock the tires into the modular bundle, and two six foot lengths are required to interconnect the bundles to form the mat assemblies. Each cable requires two cable clips. These scrap tire modules are capable of being constructed with simple hand tools, and require no special handling equipment. Cable sizes up to 3/8" diameter may be used.

c) Synthetic Rope Type:

Synthetic rope may be used for light duty and short life expectancy installations. Many types of synthetic rope such as nylon, Dacron, polypropylene, and polyethylene are suitable for marine applications. But, due to the abrasive nature of the scrap tire mats, the service life of this type of assembly may be short.

d) Plastic Strap Type:

Another possibility is to band the tire bundles with high strength reinforced plastic or metal straps. This method would only be recommended for light duty, or prototype assemblies due to the low strength and the short service life of the bands and the fasteners that hold them.

Selecting the Interlocking Hardware:

The type of interlocking hardware which is used in the construction of the Goodyear Scrap Tire Marine Mat will be dependent upon the desired strength and expected service life of the installation. The estimated breaking strength of each interlocked tire module is about 24,000 pounds in both the longitudinal and transverse directions. This figure is calculated by using the tire bead breaking strength. An equivalent strength in the interlocking hardware would provide an optimum performance, but may not be necessary for all applications.

Factors which should be taken into consideration when selecting hardware are service life, maintenance requirements, installation, location and overall mat size. The design engineer on each project must select the most economical combination of construction components to best suit the particular requirements of the site.

Estimating the Number of Tires Required:

The number of tires required for construction of the Goodyear Scrap Tire Mat may easily be calculated if the final mat size is known. Each of the scrap tire building block modules requires eighteen scrap tires with two connecting tires which gives a total of twenty tires per unit. Each bundle module will measure approximately 6 1/2 feet wide by 7 feet long when standard 14 and 15 inch tires are used. The resulting area coverage for the closed grid mat construction as shown in Figure 5 is about 45 1/2 square feet per bundle. For an open grid mat design such as shown in Figure 6, the number of tires would be reduced by one half or ten tires for every 45 1/2 square feet of coverage.

Venting the Tires for Erosion Mat Applications:

It will be necessary to provide ventilation holes in the tires for applications where the mats are installed on the lake or ocean floor. A single 2" diameter or larger hole in the tread of each tire is recommended to allow trapped air to escape.

The tires must be oriented at assembly such that the vent holes are located at the top of the mats to allow trapped air to escape.

A simple hand punch and mallet may be used to punch the required vent holes. The punch can be mounted on a frame, as is shown in Figure 4, to simplify the operation.

Another simple method of venting the tires is to use an electric drill motor and a circle cutter or hole saw.

For applications which require a large number of vented tires, it may be more economical to use an automatic punching device. An air operated power punch was designed by The Goodyear Tire and Rubber Company for punching vent holes in tires for use in our artificial reef projects. Detailed drawings of the power punch may be obtained by writing to: Community Relations Manager, Department 798, The Goodyear Tire and Rubber Company, Akron, Ohio, 44316. The power punch can be built by most commercial machine shops, or the punch may be ordered from the Reliable Manufacturing Company, 2689 Wingate, Akron, Ohio, which produced the prototypes for Goodyear. The purchase price for the power punch in June 1974 was $2200. The punch requires 100 psi air pressure for operation. If this is not available, a gas driven compressor of sufficient size may be purchased for approximately $800, or an air compressor may be rented.

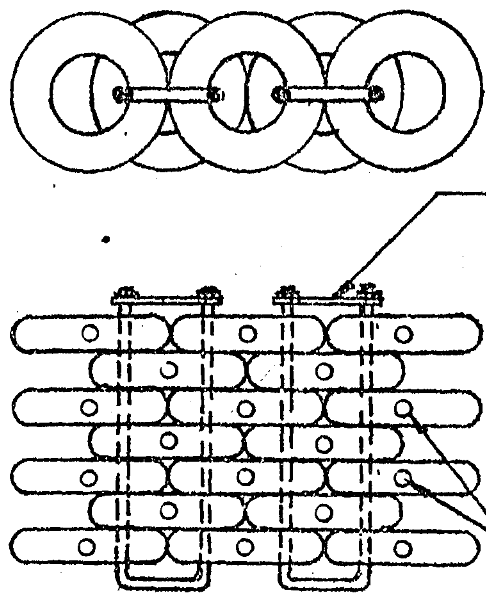
Scrap Tire Sources:

Obtaining the worn-out tires to build a scrap tire marine mat should be no problem in any area of reasonable population density. Recapping shops, service stations, and tire dealers are always looking for ways to dispose of scrap tires. Also, municipal and private waste haulers must find ways to dispose of tires which they collect.

Used tires may also be purchased. Normal charges range from $10 to $20 per ton (approximately 100 tires) delivered to your construction site. Often publicizing your need for scrap tires and providing a convenient drop-off or collecting station will produce an over abundance of tires. Standard 14" and 15" passenger tires work best for marine mat applications.

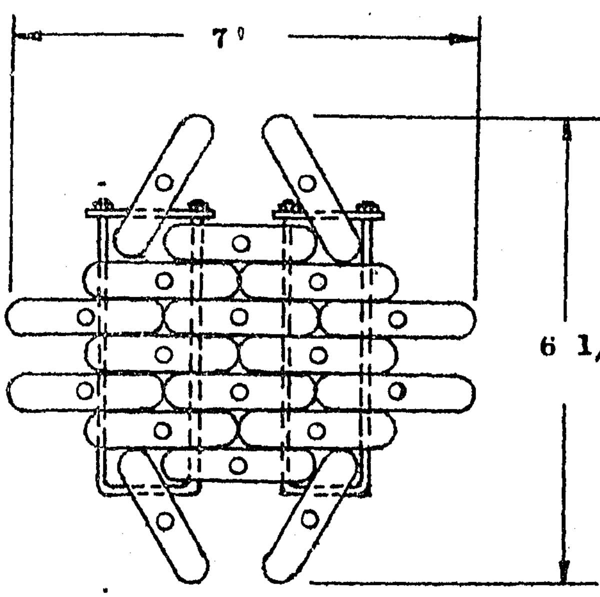
THE PROPOSED GOODYEAR SCRAP TIRE

MODULAR CONSTRUCTION UNIT



Modular Unit Shown as Constructed

Figure 1

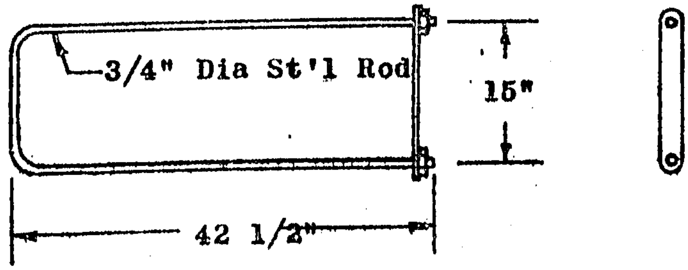


Modular Unit Shown as Installed

Figure 2

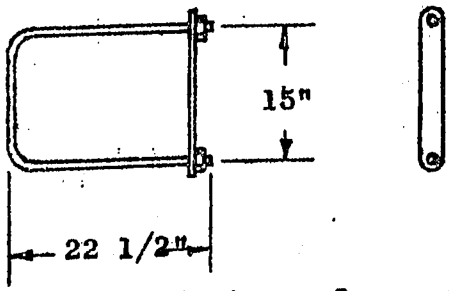
PROPOSED ASSEMBLY HARDWARE

FIGURE 3



Note: All steel surfaces should be double hot dip coated with corrosion resistant zinc.

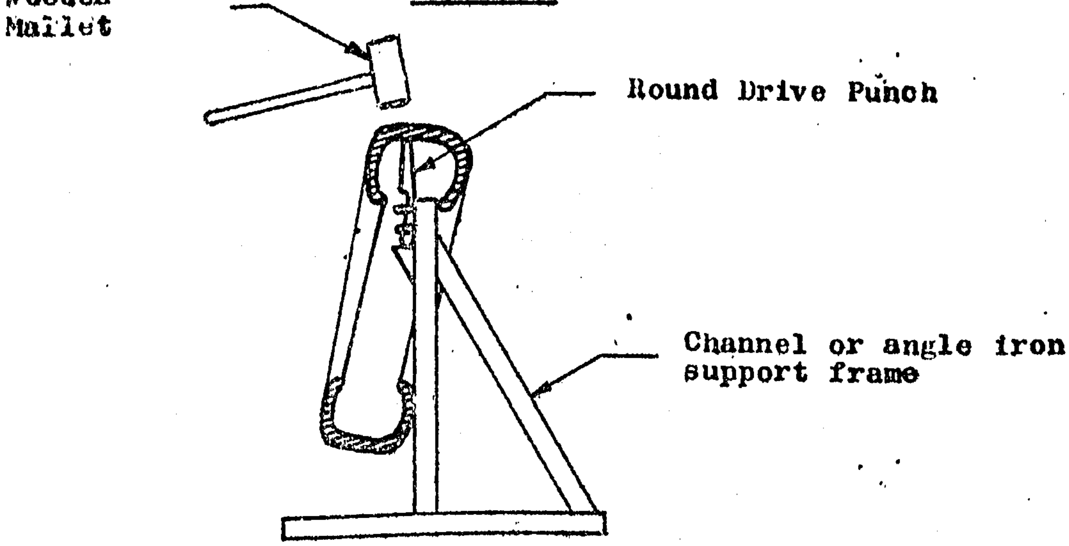
Interlocking Device - 2 required per module



Interconnecting Device - 2 required per module

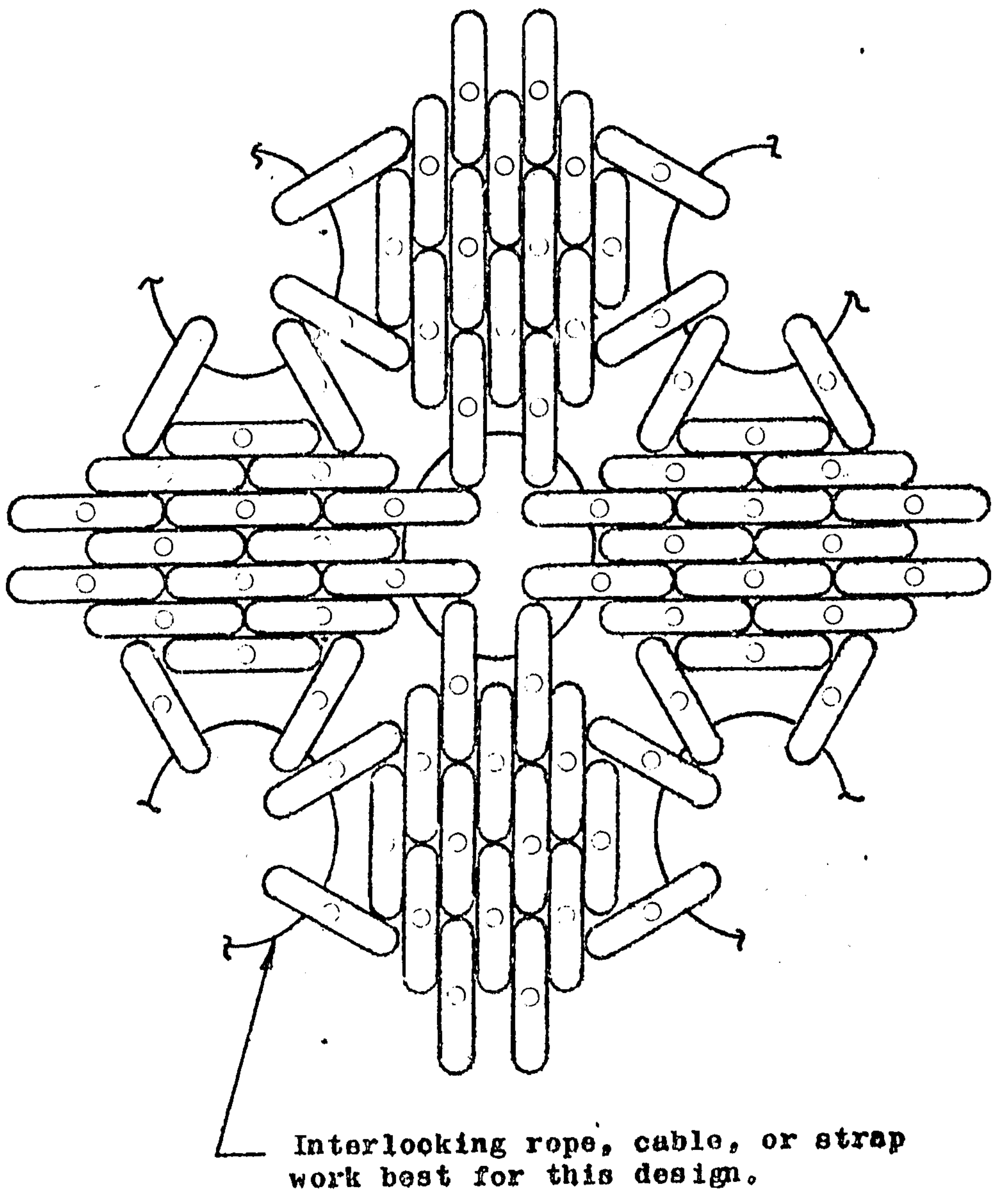
HAND PUNCH AND FRAME

FIGURE 4



TYPICAL ASSEMBLY DETAILS OF THE GOODYEAR CLOSED GRID MAT UTILIZING THE BASIC SCRAP TIRE CONSTRUCTED MODULAR UNITS

FIGURE 5



TYPICAL ASSEMBLY DETAILS OF THE GOODYEAR OPEN GRID EROSION MAT UTILIZING THE BASIC SCRAP TIRE CONSTRUCTED MODULAR UNIT

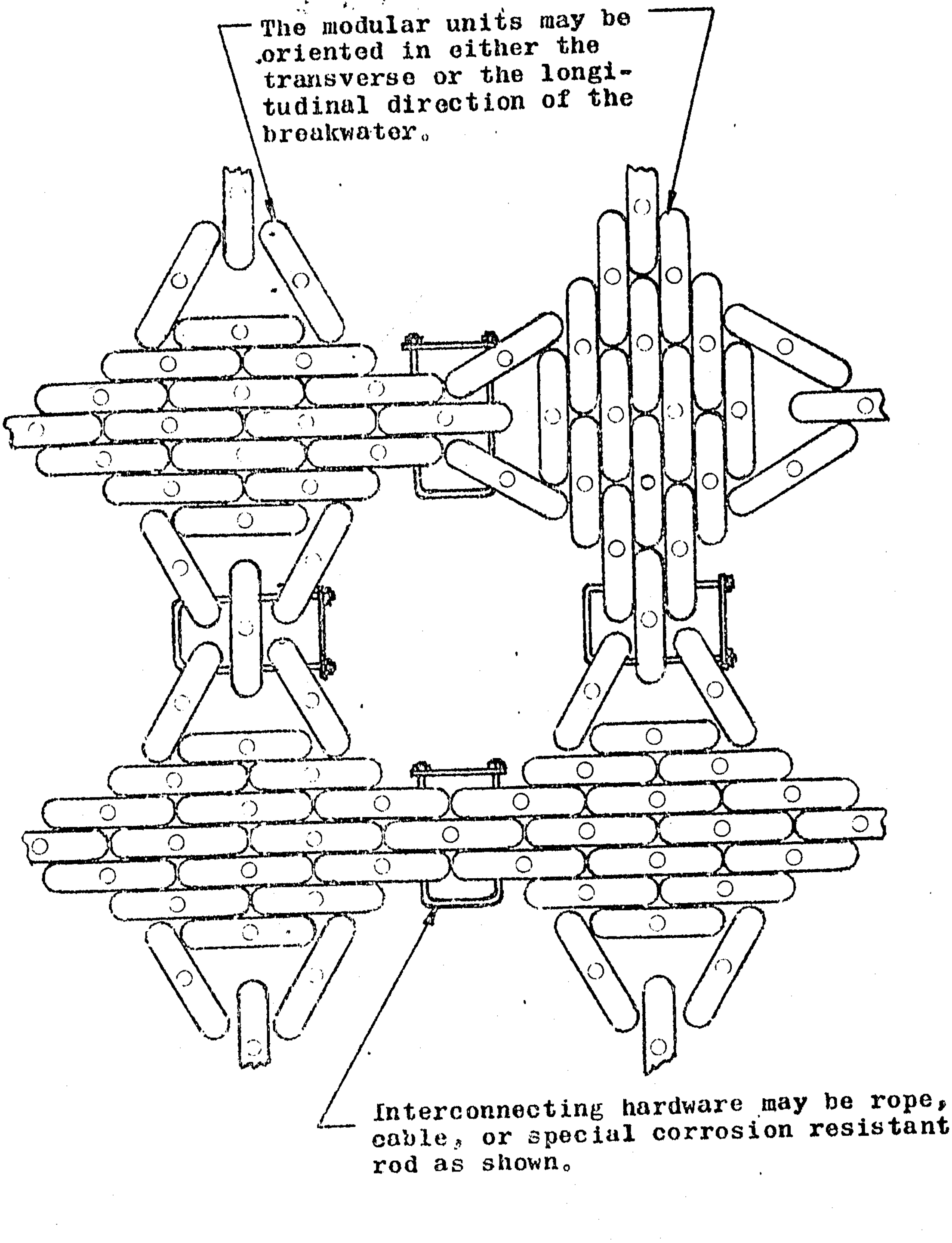


FIGURE 6

Cost Estimate for the Goodyear Scrap Tire Marine Mat:

Bundle Size: 7 ft long x 6 1/2 ft wide x 2 1/2 ft thick.
Bundle Weight: Approximately 400 pounds.

Bill of Materials to Furnish and Install Sub-Assemblies Using Hand Punching Technique and Steel Rod Connectors:

Material Description	Quantity	Cost Each	Cost
Scrap Tires	20	$ .15	$ 3.00
Tire Venting Labor *	1/2 hr	12.00	6.00
3/4" Steel Interlocking Rods **	2	18.50	37.00
Assembly labor	1/2 hr	12.00	6.00

Cost to provide modular bundle sub-assembly - $52.00

3/4" Steel Interconnecting Rods **	2	$14.00	$28.00
Installation Labor	1/2 hr	12.00	6.00

Cost to assemble and install unit - $86.00.

Calculations:

Area Coverage cost = $86.00 ÷ 6.5' x 7' = $1.89 per sq ft.

Bill of Materials to Furnish and Install Sub-Assembly Using Automatic Punch and Steel Cable Connectors:

Material Description	Quantity	Cost Each	Cost
Scrap Tires	20	$ .15	$ 3.00
Tire Venting Labor *	1/4 hr	12.00	3.00
3/8" Galvanized 6 x 19 wire rope	18 ft	.30	5.40
3/8" Crosby-Laughlin Cable Clips	4	.92	3.68
Assembly Labor	1/2 hr	12.00	6.00

Cost to provide modular bundle sub-assembly - $21.08

3/8" Galvanized 6 x 19 wire rope	12 ft	$ .30	$ 3.60
3/8" Crosby-Laughlin cable clips	4	.92	3.68
Installation labor	1/2 hr	12.00	6.00

Cost to assemble and install modular unit - $34.36

Calculations:

Area coverage cost = $34.36 ÷ 7.0 x 6.5 = $ .75 per sq ft.

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* Estimated costs do not include initial cost of mechanical tire punch.
** Estimated costs do not include costly corrosion resistant steel interlocking hardware or mooring lines.

Cost Summary:

a) Estimated cost to install a closed grid modular scrap tire mat which has a 30 feet shore-to-sea dimension is:

For Hand Punching and Galvanized Steel Rod Connectors

30 x \$1.89 = \$56.70 per linear foot.

For Automatic Punching and Galvanized Steel Cable

30 x \$ .75 = \$22.50 per linear foot.

b) Estimated cost to install an open grid modular scrap tire mat which has a 30 feet shore-to-sea dimension and a 7 ft x 6 1/2 ft open grid structure is:

For Hand Punching and Galvanized Steel Rod Connectors

30 x \$1.89 ÷ 2 = \$28.35 per linear foot.

For Automatic Punching and Galvanized Steel Cable Connectors

30 x \$ .75 ÷ 2 = \$11.25 per linear foot.

APPENDIX C

Reconnaissance Survey of Benthic Communities of a Potential Borrow Site off Tangier Island, Virginia

Report to

Virginia Airports Authority

from

Virginia Institute of Marine Science
Gloucester Point, Virginia 23062

by

Robert J. Orth and Donald F. Boesch
Division of Biological Oceanography

July 1975

Introduction

The Virginia Institute of Marine Science was called on to render advice and services to the Virginia Airports Authority concerning the environmental impact and design of an extension of the runway of the airport on Tangier Island, Virginia. The southern end of the present runway is now being threatened by the erosion due to the rapid retreat of the western shore of Tangier Island (Fig. 1). Extending the runway would require the stabilization of the shoreline in the vicinity of the runway and filling a tract of subaqueous bottom.

VIMS geologists have provided information regarding coastal engineering options and fill material acquisition (Boon, 1975). VIMS wetlands scientists were consulted and concluded that the proposed action would not detrimentally impact the intertidal zone and wetlands, which are being lost to erosion at a rapid rate. VIMS advised the Virginia Airports Authority that the only potentially significant impact would be the alteration of the habitat of benthic (bottom-dwelling) organisms in the vicinity of the fill borrow area.

An assessment of the extent of impact must be contingent on knowing (1) the location and dimensions of the borrow area and (2) the nature of the benthic biota in the area. VIMS geologists have located fill material suitable in quantity and quality in the broad shallow area just offshore to the west of the runway and have recommended location, configuration, and dimensions of the borrow site. However, the biology of the area was little known and it was decided that a reconnaissance survey of the benthic macrofauna should be conducted in order to allow a confident assessment of the long term impact of the sand acquisition on the benthos. From this information we could evaluate the recoverability of the system, based on knowledge of life history and reproductive modes of the constituent species and experience elsewhere in the Chesapeake Bay on recolonization of dredged bottoms.

This report presents the results of the reconnaissance survey of benthic macrofauna and an assessment of the long term impact of the fill acquisition on benthic communities. It represents the final report for the contractual agreement for the execution of this work between the Virginia Airports Authority and the Virginia Institute of Marine Science.

Results

Sedimentary Habitats

The nature of bottom sediments have a profound effect on the distribution and abundance of benthic organisms and knowledge of sediment granulometry is essential in interpretation of results of surveys of the benthos. Sediments throughout the area off the western shore of Tangier Island are fine to medium sands and the sorting index (a measure of the standard deviation of particle sizes about the mean) indicates that they are moderately sorted to very well sorted (Table 1). The sediments generally become coarser offshore. The results of our sediment analyses agree very closely with those of Boon (1975). They conclude that the sediments in the area are dynamic and are being actively wave-sorted and transported. Boon and Byrne hypothesize that well sorted coarser sands are being moved toward shore and to the south, and covering nearshore are the finer sands and muds remaining from the eroding island. In some places close to shore, peat, stumps and other relict features are exposed.

Benthic Communities

Table 2 presents the results of the faunal analyses. A total of 15,731 individuals representing 60 species was taken from the 13 sampling sites. Polychaetous annelids were the most numerous and diverse forms, comprising 36.5% of the animals collected and represented by 25 species. Bivalve molluscs comprised about the same proportion (39.2%) of the individuals collected but only 9 species were taken. 16.2% of the animals were amphipod crustaceans which were represented by 6 species and 5.7% were isopod crustaceans

Table 1. Percent weight in grain size classes, median sediment diameter (phi units and mm) and sorting index (S_ϕ) of sediment samples from each station.

Station	Size Fractions (Ø size classes) -1 (>2 mm)	0 (2-1 mm)	1 (1-0.5 mm)	2 (500-250 μ)	3 (250-125 μ)	4 (125-63 μ)	>4 (<63 μ)	Median Particle Diameter Md_ϕ	Md_{mm}	Sorting Index S_ϕ
1	1.1	1.6	9.0	19.8	43.2	16.8	8.3	2.42	0.187	1.03
2	1.3	1.3	10.0	37.3	45.9	3.3	0.8	2.00	0.250	0.72
3	3.1	6.8	27.4	48.6	13.0	0.7	0.2	1.22	0.429	0.83
4	0.2	1.4	18.8	65.0	12.9	1.0	0.7	1.43	0.371	0.55
5	0.0	0.0	17.0	72.4	9.8	0.7	0.1	1.43	0.371	0.45
6	0.4	2.4	15.3	56.7	22.9	2.1	0.2	1.58	0.334	0.66
7	0.0	1.0	3.4	10.8	74.4	9.5	0.8	2.43	0.186	0.44
8	0.0	0.4	11.4	52.0	30.7	4.5	1.0	1.76	0.295	0.69
9	0.0	0.8	6.8	48.3	41.4	2.3	0.3	1.90	0.268	0.60
10	0.8	1.4	10.3	56.4	27.4	3.2	0.5	1.70	0.308	0.63
11	0.0	0.7	18.9	65.7	13.5	1.1	0.2	1.44	0.369	0.53
12	0.6	1.2	15.1	51.5	26.9	4.3	0.4	1.69	0.310	0.72
13	0.0	0.3	6.0	64.1	28.3	1.0	0.2	1.70	0.308	0.49

Table 2. Summary table for all species identified from triplicate grab samples taken at 13 station sites off Tangier Island. For each station the total number of each species for the three 0.1 m^2 grabs, total number of species, total number of individuals, species diversity, evenness and richness are given.

	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
PLATYHELMINTHES														
Stylochus ellipticus											1			1
RHYNCHOCOELA														
Nemertean Unid.	4	8	4	5	5	5	3	7	3	3	6	5	8	66
OLIGOCHAETA														
Peloscolex gabriellae	2	161	2	40	22	45	1	23	12	24	21	18	6	377
POLYCHAETA														
Asabellides oculata		1												1
Drilonereis longa								1						1
Eteone heteropoda	1	6	1	3	1		2	4		1	1			20
Eteone lactea		2			2		2	3	2				3	14
Exogone dispar						1						1		2
Glycera dibranchiata		5	2	1	1	1	1	1	1	2	1	3	2	21
Glycinde solitaria		1		1										2
Gyptis vittata				1	1	2						1		5
Heteromastus filiformis	7	35		4				2						48
Nereis succinea	1	2		2			1	1			1	1		9
Ophelia bicornis	1	5	474	263	280	238	31	268	515	516	257	308	426	3582
Parahesione luteola			1											1
Paraonis fulgens	15	25	21	3	22	5	170	15	41	10	18	6	26	377
Polydora ligni	4	14		5		2				1	2	2		30
Pseudeurythoe paucibranchiata										1		1		2
Sabellaria vulgaris				1										1

Table 2 (Continued)

	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
POLYCHAETA (cont.)														
Scolecolepides viridis	58	53	38	40	42	76	74	31	48	42	49	80	65	696
Scolelepis squamata		6				9						2	1	18
Scoloplos robustus	61	62	30	57	93	39	107	110	60	80	55	31	48	833
Scoloplos rubra		1		2	1	11		1			1	3		20
Spiochaetopterus oculatus											1			1
Spiophanes bombyx		3		1		9						2	5	20
Streblospio benedicti	1	6						1				1		9
Syllidae	2	6				1	1	10	2	4	2	2		30
Tharyx setigera				1										1
GASTROPODA														
Acteocina canaliculata		34	5	11	11	49		8	6	16	28	32	4	204
Doridella obscura										1			1	2
BIVALVIA														
Gemma gemma	81	1352	148	475	308	878	293	303	429	255	479	445	401	5847
Lyonsia hyalina		1	1		4	14			1	3	4	13		41
Macoma balthica	5	3	1	3		4		1		1	2	4		24
Macoma mitchelli							1							1
Mulinia lateralis		4	1	4	6	83		1		8	16	48	2	173
Mya arenaria	5	9	3	10	4	15	1	2	2	1	6	8	3	69
Petricola pholadiformis		9	2	1			1		2	2		1	1	19
Tagelus sp.		1						1						2
Tellina agilis	2	1					1	1		1				6
CIRRIPEDIA														
Balanus improvisus	5			2						1				8
MYSIDACEA														
Neomysis americana		1	2	3	4	6		13	5	4	4			42

Table 2 (Continued)

	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
CUMACEA														
Cyclaspis varians			4	1		2	1	6	5	8	8	1	7	43
Oxyurostylis smithii				2	5							3		10
OSTRACODA														
Cytheridae				1			1							2
ISOPODA														
Chirodotea caeca	1	4	23	2	33	17	26	10	11	15	46	21	40	249
Cyathura burbancki						6					1	7		14
Cyathura polita	1	2												3
Edotea triloba	1	1		5				1						8
Sphaeroma quadridentatum	1		19	2	23	4	3	6	7	2	9	6	3	85
AMPHIPODA														
Acanthohaustorius millsi		5		8	1		247		1	1			6	269
Corophium sp.				1	4				1	2	2			10
Gammarus mucronatus	1				1	3				2	2	15	1	25
Monoculodes edwardsi	81	116	148	164	184	125	200	250	228	239	167	225	112	2233
Paracaprella tenuis				1										1
Stenothoe sp.			1		3					1	1			6
DECAPODA														
Crangon septemspinosa	1	3			2			1		2	1			10
INSECTA														
Clunio sp.												1		1
PHORONIDA														
Phoronis psammophila	1	1		4	11	3		1	2	4	10	50	2	89

Table 2 (Continued)

	1	2	3	4	5	6	7	8	9	10	11	12	13	Total
ECHINODERMATA														
Leptosynapta tenuis		4	1	3	3	13		2	2	3	6	5	4	46
PISCES														
Paralichthys dentatus					1									1
Total Number of Species	25	37	23	37	29	29	22	31	23	33	32	34	24	60
Total Number of Individuals	343	1953	932	1133	1078	1666	1168	1085	1380	1256	1208	1352	1177	15731
Diversity (H')	2.98	1.99	2.34	2.65	2.96	2.61	2.80	2.78	2.37	2.59	2.84	3.01	2.49	2.94
Evenness (J')	0.64	0.38	0.51	0.50	0.60	0.53	0.62	0.56	0.52	0.51	0.56	0.59	0.54	0.49
Species Richness (S-1/lnN)	4.11	4.75	3.22	5.12	4.01	3.77	2.97	4.29	3.04	4.48	4.37	4.58	3.25	6.11

representing 5 species. The remaining 902 individuals were distributed among 15 species in 13 higher taxa.

Three species, the polychaete Ophelia bicornis, the bivalve Gemma gemma and amphipod Monoculodes edwardsi, dominated at all collection sites. These three species comprised 74% of the total individuals with Gemma alone comprising 37.1% of the individuals.

Other species well represented at all stations were the polychaetes Scolecolepides viridis, Scoloplos robustus, Paraonis fulgens, the gastropod Acteocina canaliculata, the bivalve Mulinia lateralis and the isopods Chirodotea caeca and Sphaeroma quadridentatum. The echinoderm Leptosynapta tenuis, a large deposit feeding holothurian, was present at all but the most inshore pair of sites.

Station 2 had the greatest abundance of both species and individuals. This was in part due to the fact that the collections contained the remains of old tree stumps which undoubtedly increased the heterogeneity of the bottom, allowing for more species to coexist.

No obvious trends are apparent in the species diversity measures. Informational diversity (H') was fairly uniform throughout the study area and falls within the range typical for that salinity regime in the Chesapeake Bay (Roberts et al. 1975). The influence of the rather high species richness on H' was moderated by low evenness caused by the dominance of Gemma, Ophelia and Monoculodes.

The density of macrofauna (mean ca. 4,000/m^2) off Tangier Island is relatively high considering the dynamic stress of the shifting sand habitat. Although no directly comparable habitats have been studied in the Bay, Boesch and Rackley (1974) found much lower densities on dynamic sand bars in the lower Bay, although some of the same species were found there (e.g. Gemma gemma). Hamilton and La Plante (1972) found high macrofaunal densities in the nearshore sand habitat off Cove Point, Maryland, attributable to an high abundance of Gemma gemma. Very high densities of the small bivalve Gemma have been reported elsewhere (Sanders et al. 1962). Several species abundant off Tangier were also abundant in the Cove Point sand habitat, e.g. Scoloplos robustus, Chiridotea caeca, Mulinia lateralis and Glycera dibranchiata, but two of the dominant species, Ophelia bicornis and Monoculodes edwardsi are not known to occur in similar abundance elsewhere in the Bay.

Life Histories and Recruitment of Dominant Species

The bivalve Gemma gemma broods its young and releases them as tiny bottom clams, thus there is no wide ranging dispersive life stage as in most bivalves. Gemma is, however, quite capable of small scale dispersion because of its high degree of mobility and its great reproductive potential. Gemma should be able to recover well from local (in the order of hundreds of meters) extinction.

The polychaete _Ophelia bicornis_ is a small, actively burrowing grub-like worm adapted to life in dynamic sediments. It is probably not very mobile in the horizontal direction but its larvae develop in the plankton and can disperse widely. _Ophelia_ larvae are known to be able to "select" a suitable sediment habitat by testing its chemical characteristics before undergoing metamorphosis (Wilson 1952). Recovery from local extinction would depend on successful larval recruitment. Other polychaetes, _Scoloplos robustus_, and _Paraonis fulgens_ are similar to _Ophelia_ in active burrowing habits and life history. They too depends on planktonic larval recruitment. The spionid polychaete _Scolecolepides viridis_ maintains its purchase by building vertical tubes in the sediment and it feeds on surface deposits by means of long palps. _Scolecolepides_ is a commonly abundant form in mesohaline and oligohaline salinities (ca. 0-15‰ salinity) and it is recuited via planktonic larvae. The abundance and fecundity of _Scolecolepides_ suggests recuitment following local extinction should occur within a year of extinction.

The amphipod _Monoculodes edwardsi_ is an actively burrowing animal which lives in mobile surface sediments. It, like all peracarid crustaceans (amphipods, isopods, etc.), broods its young and thus produces relatively few offspring. However, _Monoculodes_ is quite an active swimmer and is frequently found in plankton samples (Feeley and Wass, 1971). Recovery from local extinction, assuming no change in the habitat, should be very rapid. The isopod *Chiridotea caeca* and *Sphaeroma quadridentatum* are also quite active as adults, both crawling and swimming, and should also recover quickly from local extinction.

With the possible exception of the holothurian *Leptosynapta tenuis* and the phoronid *Phoronis psammophila* there seem to be no large, long-lived members of the community. Recovery of the community from local extinction should depend almost totally on recruitment either of adults from surrounding bottom (e.g. *Gemma*, *Monoculodes*, *Chiridotea* and *Sphaeroma*) or of larvae from the plankton (e.g. *Ophelia*, *Paraonis*, *Scoloplos* and *Scolecolepides*) and not on the additional, longer term process of growth and maturation of long-lived inhabitants. Most of the members of the community are probably annuals.

Conclusions

Long-term Impact of Fill Acquisition

The philosophy of the preliminary recommendations of VIMS concerning borrow site location and dimensions was to attempt to assure minimum alteration of bottom topography and rapid physical recovery of the bottom. Thus it was proposed that dredging be limited to 6 feet below the natural bottom. Although it is estimated that it would take many years for the filling in and leveling off of the resulting pit, even in this regime of active sediment transport, the bottom of the depression should be covered with a veneer of surface sediment transported from adjacent bottoms within a short period of time (certainly within a year). We would then expect relatively little qualitative difference in the surface sediments from those now characteristic of the area. The sediments could be slightly finer due to selective transport of fine sands into the area and reduced wave winnowing of silts and clays, but should still consist predominantly of fine to medium sands. This should allow relatively complete recovery of the benthic community within two years, allowing one year for reconstitution of surface sediments and another for recolonization of the biota.

If the design depth of no more than 6 feet is adhered to, we see no chance of stagnation or oxygen depletion in the borrow pit.

Fill acquisition off Tangier Island will cause local extinction of benthic organisms and short term loss in productivity in a limited area. Thus, it still remains desirable to utilize spoil generated from channel maintenance dredging in Tangier Harbor as fill for the runway extension should it prove suitable and available in a timely manner.

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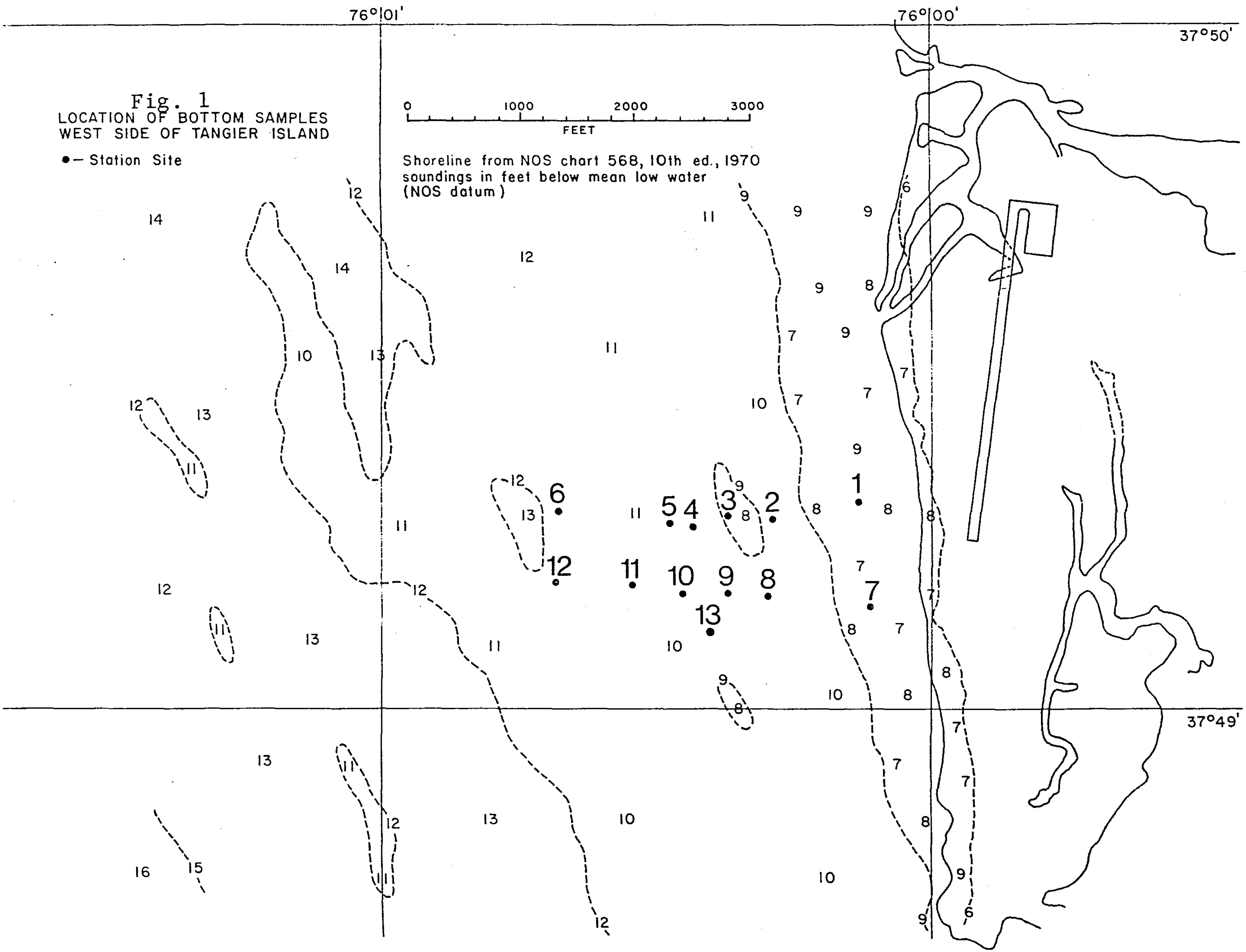

Fig. 1
LOCATION OF BOTTOM SAMPLES
WEST SIDE OF TANGIER ISLAND