DEPARTMENT OF THE ARMY CORPS OF ENGINEERS

BEACH EROSION BOARD
OFFICE OF THE CHIEF OF ENGINEERS

BEHAVIOR OF BEACH FILL AT VIRGINIA BEACH, VIRGINIA

TECHNICAL MEMORANDUM NO. 113

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JUNE 1959

FOREWORD

This report presents the results of a study of movement of beach material made in connection with a beach fill operation at Virginia Beach, Virginia. The beach fill was placed by the City of Virginia Beach generally in accordance with a plan developed by the Corps of Engineers. The study reported herein was made under the Beach Erosion Board's general investigation program which includes observation of the results obtained by work completed under shore protection projects and development of criteria for the design of beach fill projects.

The report was prepared by George M. Watts, Assistant Chief of the Engineering Division of the Beach Erosion Board, under the supervision of Jay V. Hall, Jr., Chief of the Division. The field data utilized in the report were obtained by the Virginia Beach Erosion Commission, U. S. Army Engineer District at Norfolk, and the Beach Erosion Board. Mr. E. H. Church, Chairman and Mr. T. J. McDonald, consulting engineer for the Virginia Beach Erosion Commission, provided many pertinent details of the beach fill project including maintenance features after the initial fill was placed. At the time this report was prepared, the technical staff of the Board was under the supervision of Major General W. K. Wilson, Jr., President of the Board. Colonel Allen A. Futral was Executive Officer and R. O. Eaton was Chief Technical Advisor. The report was edited for publication by A. C. Rayner, Chief, Project Development Division.

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BEHAVIOR OF BEACH FILL AT VIRGINIA BEACH, VIRGINIA

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INTRODUCTION

During the years 1946 to 1951, a study* of beach erosion at Virginia Beach, Virginia was made by the Corps of Engineers in cooperation with the City of Virginia Beach to determine the most suitable method of restoring and preserving an adequate beach for protecting the seawall and upland, and for recreational use. A comprehensive analysis of the problem led to the conclusion that the erosion was the result of a deficiency in material supply, and that the most suitable plan of restoration and protection of the shore of Virginia Beach comprised artificial placement of suitable sand to provide a minimum beach width of 100 feet at elevation 7 feet above mean low water, and maintenance of this beach by periodic replenishment of losses to insure continuous protection. A groin system was included in the plan for deferred construction to be undertaken at such time as the estimated annual charges therewith would be less than the annual cost of beach replenishment alone. The recommended beach fill was placed in 1952 and 1953.

A basic survey of the shore and offshore area was made in 1946 as part of the cooperative study. Surveys of the beach zone were made by the Virginia Beach Erosion Commission immediately before the fill was placed and at frequent intervals thereafter. Additional surveys of the beach and offshore zones between Rudee Inlet and 49th Street were made in September 1955 and July 1958. The field survey data have been studied with a view to evaluating the movement and effectiveness of the 1952-53 beach fill and subsequent beach nourishment program.

SUMMARY OF PHYSICAL DATA

Virginia Beach, as shown on Figure 1, is located on the east coast of Virginia about 19 miles east of Norfolk and 3.5 miles south of Cape Henry, which is the south point of the entrance to Chesapeake Bay. The shore frontage of the City of Virginia Beach is about 3-1/3 miles in length.

The ocean shore of Virginia is characterized by dunes 20 to 30 feet in height, however, within the Virginia Beach city limits all of these dunes have been leveled or removed in developing the area. The beach material prior to placement of beach fill had a median diameter of from 0.3 to 0.4 millimeter. The median size of bottom material decreased with

*Virginia Beach, Va., Beach Erosion Control Study, House Doc. No. 186, 83d Congress.

increasing depth; the median diameter of bottom material at a depth of 20 feet below mean low water was about 0.12 millimeter.

The tides at Virginia Beach have mean and spring ranges of 3.0 and 3.6 feet respectively. The Virginia Beach sector of shore line is exposed to wave action of the Atlantic Ocean from the north-northeast through east to south-southeast. Due to storms from the northeast direction during the winter months, waves approaching the shore from the northerly quadrant transmit more energy shoreward than those approaching from the southerly quadrant.

No conclusive information is available concerning the predominant direction and net rate of littoral transport in the Virginia Beach sector. The greater energy of waves approaching the shore from the northerly quadrant would be expected to produce a predominant southward littoral drift. The configuration of shoals extending into the entrance to Chesapeake Bay on its north side is indicative of such southward drift. As at most large tidal inlets the drift direction at Virginia Beach is influenced by the tidal currents of Chesapeake Bay. The wave action from the south during the summer months combined with the flood tide currents toward the bay entrance could cause a seasonal northward drift, as indicated by the effects of an experimental groin, the short jetties at Rudee Inlet and the influence on the shore of the pile supporting structure of the fishing pier located opposite 15th Street at Virginia Beach. Available evidence indicates that the resultant drift on an annual or longer term basis has a northward predominance, opposite to the direction to be expected because of the dominance of wave energy from northerly directions.

The beach or shore north of the city toward Cape Henry has, in general, been fairly stable over the period of record. Within the city, over the period 1931 to 1946, the shore had experienced recession. The average annual high water line recession rate ranged from zero near the north end to 5 feet near the southerly limit of Virginia Beach.

The most extensively developed portion of the Virginia Beach ocean front extends from 7th Street to 35th Street, a distance of about 1.9 miles. This frontage is protected by a concrete seawall and promenade constructed in 1927 at a cost of about $250,000. Maintenance and repairs to this structure to April 1949 cost about $326,500. During the years 1934 to 1938 the following structures were built: a timber bulkhead between 35th Street (north end of concrete seawall) and 40th Street; a cantilever, concrete-capped steel sheet pile bulkhead from 40th Street to Cavalier Drive; and another timber bulkhead between Cavalier Drive and Avenue B. These three bulkheads have required virtually no maintenance since their construction.

PROJECT CONSTRUCTION AND NOURISHMENT

The Virginia Beach Erosion Commission, acting for the City of Virginia Beach, initiated the beach fill portion of the plan of improvement in June 1952 and completed fill operations in June 1953 generally in accordance with the plan recommended as a result of the cooperative beach erosion study. The material for the fill was dredged from Rudee Inlet, Lake Rudee, and Lake Wesley and placed by pipeline along the shore from Rudee Inlet to 42nd Street, a shore line distance of about 15,000 feet. The general areas are shown on Figure 1 and specific borrow locations are shown on Figure 2. Thirty-one borings were made throughout the borrow area. The location of each boring is indicated also on Figure 2. Table 1 gives the size analysis of composite samples taken from various combinations of borings. A total of about 1,352,000 cubic yards of fill was placed at a total cost of $712,517. Subsequent to the initial placement of beach fill, about 211,000 cubic yards of nourishment fill were placed between 9th and 17th Streets, mostly from sources remote from the beach, through July 1958 at a total cost of about $154,000.

Year	Quantity Cu. Yds.	Source and Method of Placement
1953	60,000	Lake Rudee, hydraulic dredge
1953	17,000	Dunes, truck haul
1954	17,000	" " "
1956	1,000	Owl Creek, hydraulic dredge
1957	89,000	" " " "
1958	27,000	" " " "

Between December 1954 and July 1958 about 232,000 cubic yards of material were also placed on the beach north of Rudee Inlet by a bypassing plant located on the south jetty of that inlet, and by hydraulic dredge or clamshell and truck haul from a shoal zone immediately inside the inlet. These operations were as follows:

Year	Quantity Cu. Yds.	Method of Placement
1954	44,000	Hydraulic dredge
1955	30,000	Clamshell and truck haul
1955	28,000	Bypassing plant
1956	26,000	" "
1956	31,000	Hydraulic dredge
1957	57,000	Bypassing plant
1958	16,000	" "

Figure 3 consists of comparative ground photographs showing the southerly sector of the shore in 1952, 1953, and 1958.

SURVEY DATA

The 1946 survey was made on five range lines spaced along the Virginia Beach frontage, at 49th, 35th, 22nd, 7th Streets, and 450 feet north of Rudee Inlet. Soundings extended seaward to about the 18-foot depth. Figures 4A and B show the profiles of these five ranges. In June 1952 soundings were taken along five range lines, designated G, F, E, D, C, and located at 46th, 34th, 24th and 7th Streets, and at a point 2,200 feet south of Rudee Inlet. These soundings extended from shore to about the 30-foot depth, except that on range lines at 34th and 46th Streets soundings did not extend landward of the 10-foot depth contour. Beach sections taken in May 1952 were utilized to estimate bottom elevations on the inshore portions of these two ranges. Figures 4A and B also show the profiles of these five range lines. Since May 1952 the Virginia Beach Erosion Commission has made periodic beach surveys from Rudee Inlet to 49th Street. In general, these surveys have been made at about 2-month intervals and extended from the concrete seawall to between the 3 and 5-foot depths (MLW). Data from these surveys have been utilized for purposes of studying material movement within the beach zone, however, the basic field data are not presented herein due to the volume of the data and the limitation of offshore coverage. A hydrographic survey was made of the study area in September 1955 by the Virginia Beach Erosion Commission and the Beach Erosion Board. This hydrographic survey provided a more comprehensive coverage than all other surveys and extended from about 5,000 feet south of Rudee Inlet to 68th Street, a shore line distance of about 29,200 feet. The soundings extended seaward to about the 30-foot depth. Figures 5A and B show the baseline stationing and range locations applicable to all other surveys, and the depth contours constructed from this survey; also certain profiles from this survey are plotted on Figures 4A and B. Through cooperative arrangements between the Virginia Beach Erosion Commission, the U. S. Army Engineer District at Norfolk and the Beach Erosion Board, six ranges were sounded out to about the 30-foot depth in July 1958. The range lines were located at 46th, 35th, 24th, 8th, and 4th Streets, and 2,200 feet south of Rudee Inlet. Figures 4A and B also show the profiles of these range lines from the 1958 survey.

Beach and bottom samples were taken, in connection with the hydrographic surveys, in 1951, 1955 and 1958. Sample locations and size analyses are given in Tables 2, 3 and 4 respectively.

ANALYSIS OF DATA

The relatively wide spacing of range lines for the 1946, 1952, 1955 and 1958 surveys precludes a precise computation of material movement throughout the study area, even though the shore line is straight and essentially free of structures in the littoral zone. The 1955 survey covered the shore in more detail than did any of the other surveys;

however, the scope of surveys in 1946, 1952, and 1958 control the use of the 1955 survey data for computing volumes of material movement over the periods between surveys. By noting where the profiles intersect or approximately meet in the offshore zone (usually between the 20 and 25-foot depths), and utilizing the end-area method, net volume changes from the centerline of Rudee Inlet to 46th Street, a shore line distance of 16,645 feet, were computed. The borrow materials taken from Owl Creek and inland dunes and placed on the beach, after placement of the initial fill, are considered supplementary to the normal supply of littoral materials reaching the study area. The littoral materials transferred across and from Rudee Inlet are considered as part of the natural littoral supply reaching the study area and therefore not additional nourishment for the initial beach fill. The volumes of material placed and the computed volume changes are as follows:

Period	Years	Material Placed	Volume Changes
		cu. yds.	cu. yds.
Sept. 1946-June 1952	5.7		-1,313,000
June 1952-June 1953	1.0	1,352,000	+1,405,000
July 1953-Sept 1955	2.2	94,000	
Sept 1955-July 1958	2.8	117,000	+99,000
SUMMARY			
Sept 1946-July 1958	11.7	1,563,000	+191,000

The computations for the period September 1946 - June 1952 (the latter date being immediately prior to placement of fill) indicate a loss of material from the study area of 1,313,000 cubic yards, or 232,000 cubic yards per year. This amounts to about 14 cubic yards per year per lineal foot of shore. From June 1952 to June 1953 the initial beach restoration was accomplished. Nourishment material was placed artificially from July 1953 to July 1958 to maintain the stability of the restored beach. This periodic nourishment amounted to about 94,000 cubic yards from July 1953 to September 1955 and 117,000 cubic yards from September 1955 to July 1958, a total of 211,000 cubic yards over this 5-year period. The survey data show a net increase of 53,000 cubic yards in addition to the 1,352,000 cubic yards initial beach fill between the surveys of June 1952 and September 1955. Presuming that this increase occurred after the initial fill, accretion resulted at the rate of about 24,000 cubic yards per year from nourishment at a rate averaging 43,000 cubic yards per year. From September 1955 to July 1958 about 117,000 cubic yards were placed on the beach for nourishment and the survey data show a net increase of 99,000 cubic yards, therefore over this 2.8 year period the average nourishment rate was 42,000 cubic yards per year and accretion resulted at the rate of about 35,000 cubic yards per year. These data would indicate that over the 5-year period from July 1953 to July 1958 the periodic nourishment has averaged about 42,000 cubic yards per year and accretion has resulted in the amount of about 30,000 cubic yards per year. Therefore beach nourishment has averaged 2.5 cubic yards per year per lineal foot of shore and profile stability out to about the 20-foot depth could presumably have been achieved at an average nourishment rate of a little less than one cubic yard per year per lineal foot. The survey data for the period September 1946 to July 1958 show an increase of sand on the beach and nearshore bottom of 191,000 cubic yards in 1958 over that in the same area in 1946. This indicates that the overall maintenance of the profile during this 11.7-year period, approximately to the 1946 beach dimensions, has averaged 117,000 cubic yards per year (1,352,000 cubic yards initial fill plus 211,000 cubic yards periodic nourishment minus indicated accretion of 191,000 cubic yards divided by 11.7 years). This is an indicated rate of artificial supply of about 7.0 cubic yards per year per lineal foot of shore.

From the beach section data (basic data not presented) the relative width of the beach above mean high water datum may be obtained at various times from September 1946 to July 1958. The following tabulation presents the results of measuring areas landward of the mean high water line on the beach:

Date	Area* (sq. ft.)		Dates	Change in Area* (sq. ft.)
Sept. 1946	997,000			
June 1952	583,300		Sept. 1946 - June 1952	-413,700
June 1953	1,493,000		June 1952 - June 1953	+909,700
Sept. 1953	1,259,000		June 1953 - Sept 1953	-234,000
Sept. 1954	1,094,000		Sept. 1953 - Sept 1954	-165,000
Sept. 1955	577,000		Sept. 1954 - Sept 1955	-517,000
July 1958	918,000		Sept. 1955 - July 1958	+341,000
		and	Sept. 1946 - July 1958	-79,000

*Area between seaward edge of concrete walkway and mean high water line on beach, from 7th Street to 35th Street (a distance of 10,200 feet)

The tabulated data show the rate of recession of the mean high water line from September 1946 to June 1952 to be about 7 feet per year between the defined shore limits. Between June 1952 and July 1958 there was, first, seaward advance of the mean high water line due to the placement of the restoration fill; thence, recession of the mean high water line due to foreshore adjustment of this fill; and thereafter gradual seaward movement of the line due at least in part to periodic placement of nourishment material on the beach. The data show that an average of 98 feet of beach existed between the concrete walkway and the mean high water line on the beach in September 1946 and an average of 90 feet of width existed in July 1958. These data would indicate that the width of beach above mean high water datum in July 1958 is about equal to that of September 1946 and that the nourishment material placed since June 1953 has been sufficient to maintain a beach width above mean high water in the order of 90 feet.

The survey data do not show the predominant direction of alongshore material transport. Over the 11.7-year period there has been general shoaling in the offshore zones, with the greater shoaling indicated at the northern and southern limits of the study area. Data covering shorter increments of time, such as the 1955 to 1958 period, may not necessarily be indicative of the general trend of material movement in the offshore zone as shown by the following bottom depth change tabulation:

DEPTH CHANGES IN FEET
(+ = accretion, - = erosion)

Distance Seaward from Baseline (feet)	Rudee Inlet 1946-1958	Rudee Inlet 1955-1958	7th Street 1946-1958	7th Street 1955-1958	24th Street 1946-1958	24th Street 1955-1958	34th Street 1946-1958	34th Street 1955-1958	46th Street 1946-1958	46th Street 1955-1958
300	+3.5	+1.5	+1.0	-3.0	0	0	0	0	+2.0	+4.0
600	0	0	+3.5	+4.5	-1.5	+1.5	+1.5	+3.5	-0.5	0
1200	+1.5	-7.0	+1.2	0	-1.0	-0.5	+1.0	+2.5	+0.5	0

The offshore zone between depths of 20 and 30 feet has a slope in the order of 1 on 2,000, therefore, movement of a very large volume of material is required to effect measurable depth changes in this zone.

As given in Table 1, each composite borrow material sample represents a combination of samples from borings taken in the borrow area. Each composite sample and its respective grain size analysis is also related to a volume of material in the borrow area. Since the potential volume of beach fill material represented by each composite sample was not equal, in order to obtain the average size distribution of the total fill, the size distribution for each composite sample was weighted by the ratio of the volume indicated for each composite sample and the total volume available (about 1,079,000 cubic yards). A summation of the weighted size distributions for the eighteen composite samples indicated the following size gradation for the total fill.

Size in millimeters	0.210	0.149	0.105	0.074
Percent coarser	52.2	71.4	77.7	80.9

Although the size analyses for the borrow material did not include sizes greater than the 70-mesh sieve (0.21-mm. openings), the above gradation for the fill material would indicate the median size to be about 0.22 millimeter. About 22 percent of the material would be finer than 0.1 millimeter in size.

The median diameters for material at various positions along the profile were averaged for all ranges for the sand samples collected in 1951, 1955, and 1958 and the following is indicated:

Position along profile	1951 (Md_o -mm.)	Sep 1955 (Md_o -mm.)	Jun 1958 (Md_o -mm.)
Midway between dune & MHW			0.33
MHW	0.31 (Mar)		0.32
MTL	0.38 "	0.33	0.25
MLW	0.42 "		0.24
-5 feet	0.18 (Jun)	0.24	0.16
-10 feet	0.19 "	0.19	
-15 feet	0.16 "	0.13	0.13
-20 feet	0.17 "	0.12	
-30 feet			0.11

The 1951 sand sample data indicate the coarse gradation of material in the foreshore zone which is frequently characteristic of a foreshore zone receiving an inadequate supply of littoral materials. The initial beach fill material would correspond to the bottom material found between mean low water datum on the beach and the 5-foot depth. By 1955 there had been substantial adjustment of the beach fill as shown by material at the 5-foot depth being coarser than in 1951 and finer gradation at mean tide level on the beach than in 1951. The 1958 median diameters along the profile indicate the material to be of a finer gradation than in 1955 or 1951 and that the profile is probably approaching final adjustment compatible to the fill that was placed on the beach.

DISCUSSION

From September 1946 to June 1952, the 5.7-year period immediately prior to placement of beach fill, the movement of material out of the study area is indicated to have been about 232,000 cubic yards per year, or about 14 cubic yards per year per lineal foot of shore line. This indicated deficiency of supply, before placement of beach fill in 1952, is probably excessive due principally to the fact that the September 1946 survey was not extended sufficiently seaward to incorporate the offshore shoaling in the computation of net material movement. A comparison of the positions of the mean high water line on the beach for each of these surveys may be more representative of net material movement between these dates. This comparison indicates there was an average recession of the shore of about 7 feet per year. The elevation of the natural berm along the beach is about 7 feet above mean low water datum; therefore, as an approximation each square foot of recession of the mean high water line would represent one cubic yard loss between 7 feet above and 20 feet below mean low water, respectively, along the foreshore profile. This would indicate the deficiency of supply between the study limits (Rudee Inlet to 46th Street) to be in the order of 117,000 cubic yards or 7 cubic yards per lineal foot of shore per year from September 1946 to June 1952. Although a determination of the deficiency of supply of littoral materials within the study limits before the restoration fill was placed is of importance, these data serve only for comparison. A determination of the nourishment rate to maintain the restored beach is the primary objective. The deficiency between 1946 and 1952 could be expected to be higher than from 1953 to 1958, as during the former period the foreshore zone was receiving no artificial nourishment and apparently very little natural supply (particularly during the time when the mean high water line was at or close to the seawall backing the beach); therefore, the offshore zone was receiving virtually no supply to maintain its stability.

The comparative positions of the mean high water line on the beach for the period June 1953 to July 1958 show the progressive adjustment of the initial beach fill throughout the foreshore zone and the influence of the periodic artificial nourishment of the beach over this period of time. These data do not offer a direct means of establishing the required annual rate of artificial nourishment for stabilizing the initial beach fill however the data may supplement the findings indicated by the hydrographic survey data. The hydrographic survey data indicate that over the 5-year period from July 1953 to July 1958 there was an accretion of about 152,000 cubic yards in the foreshore zone (out to about the 20-foot depth) for the shore line limits between Rudee Inlet and 46th Street. During this 5-year period supplementary material was placed on the beach in the amount of 211,000 cubic yards. These data would suggest that the total artificial nourishment over this 5-year period could have been the difference between these figures (59,000 cubic yards) to have achieved comparable foreshore stability. The significant fact is that between June 1952 and July 1958 about 1,563,000 cubic yards of material were placed on the beach and the survey data for this period indicates about 1,504,000 cubic yards are still within the study limits. The difference between these two figures (59,000 cubic yards) is not significant, particularily in view of the spacing of survey ranges and the resulting degree of accuracy that could be expected of volumetric computations. Therefore the general indication of the hydrographic survey data is that the annual replenishment program of about 42,000 cubic yards carried out by the Virginia Beach Erosion Commission has been sufficient to maintain stability of the initial beach fill. Design dimensions for the beach do not exist at all points along the study area, however in general, the dimensions approach those specified in the design. The comparative positions of the mean high water line on the beach and comparative hydrographic survey data show that substantial changes have occurred in the foreshore zone when short intervals of time are considered. Also the 5-year period considered herein may not be of sufficient length to provide a precise measure of the nourishment requirements to maintain stability of the initial fill. However, it is probable that future annual nourishment requirements would not greatly exceed the 42,000-cubic yard figure.

If Rudee Inlet were allowed to close by natural littoral processes, the littoral materials reaching this inlet from the south would continue in the direction of Virginia Beach. The mechanical bypassing plant intercepts some of the northward moving littoral materials and mechanically transports those materials to the beach zones north of Rudee Inlet. This operation in effect immediately places material at points where needed on the beach north of the inlet; however the average annual supply of material from the south to the beaches north of the inlet is not altered to any degree by this operation. Although limited in effectiveness, this operation also aids in keeping Rudee Inlet open to tidal flow between the jetties.

The survey data do not aid in determining the magnitude or dominant alongshore direction of littoral material movement. The survey data would suggest that the quantity of alongshore material movement is substantial, but that the net movement to the north or south is not too great. Extremely detailed field data over a long period of time would be required to establish the predominant direction. This type of alongshore material movement would cause cyclic patterns of accretion and erosion to the beach on the north and south sides of a littoral barrier placed along the study area, the extent of accretion and erosion being dependent on the design of the barrier.

The quantity of beach fill of suitable characteristics required for the recommended beach fill plan was 1,100,000 cubic yards, which would provide a beach width of about 100 feet at elevation 7 feet above mean low water. The actual quantity of material placed on the beach in the initial fill was 1,352,000 cubic yards, of which about 20 percent was of a size characteristic which would be transported very quickly to the offshore zone by wave action and serve to adjust the bottom slope in the offshore zone. This finer fraction of the initial fill is believed to have had a definite role in effecting stability of the bottom slopes in the foreshore zone, and hence a definite influence on maintaining specific beach widths above mean high water datum. The quantity of beach fill of suitable characteristics to remain in the foreshore zone and rapidly stabilize that zone appears to have been about the same (1,100,000 cubic yards) as originally estimated for the recommended plan.

The cost of the initial beach fill was about $712,500. Since the initial fill, the average annual placement of nourishment material and cost thereof have been about 42,000 cubic yards and $31,000 respectively.

On this basis the annual cost of maintaining the design dimensions of the beach over a 50-year period could be estimated as follows:

Interest on initial investment of beach fill $712,500 at 3.5%	$25,000
Amortization	5,400
Nourishment 42,000 cu. yds. at $1.00*	42,000
	$72,400

*Assumed as average unit cost

Considering the 16,700 feet of shore line, shore stability would be obtained at approximately $4.30 per lineal foot per year. The maintenance of the beach at Virginia Beach has a definite influence on the stability of the adjacent shore line. As a conservative estimate, the shore will receive incidental benefits for at least 2 miles north and south of the respective limits of Virginia Beach, therefore, the annual costs should be actually applied to about 40,000 feet of shore line rather than 16,700 feet, making the annual cost about $1.80 per lineal foot of shore. The annual charges may be estimated for maintaining a seawall or revetment along the study area which would provide stability of the shore comparable to that of the beach fill. The existing seawall from 7th Street to 35th Street would need extensive modification, or complete replacement with a modified design to provide the desired shore stability. The seawall should be comparable in stability to the stone seawall or revetment constructed at Fort Story, Virginia, located approximately 3 miles north of Virginia Beach. The Fort Story seawall is estimated to have a present replacement cost of $180 per lineal foot. Therefore, the cost for constructing a properly designed seawall at Virginia Beach, allowing some salvage value for the existing wall, could conservatively be estimated at $150 per lineal foot. Annual maintenance per lineal foot may be estimated at 1 percent of the initial cost. The total annual charges would be as follows:

Interest on initial investment (16,700 ft. at $150) or $2,505,000 at 3.5%	$87,700
Amortization	19,100
Maintenance (16,700 ft. at $1.50 per ft.)	25,000
	$131,800

The annual charge per lineal foot of stabilized shore would be about $8.00. The economic advantage of maintaining the beach in front of the existing seawall and concrete walkway is apparent. Construction of a new seawall would not aid in maintaining the beach. The fact that an adequate beach zone is essential to the Virginia Beach area for recreational purposes further justifies the beach fill form of shore stabilization.

It must be recognized that the present beach fill and nourishment program would not provide complete protection to the backshore from a storm of hurricane intensity. It is apparent that the existing seawall must be maintained to effect a high degree of backshore protection during these conditions. Complete protection to the backshore against storms of hurricane intensity would require substantial modification of the existing seawall or protective beach or both.

The general pattern of littoral material movement within the study limits is not favorable for the installation of a groin system to substantially reduce the net losses of material from the beach zone or stabilize the shore in a more seaward position. The effectiveness of a groin system would be difficult, if not impossible, to realistically evaluate with present data; however, an estimate may be made of the cost of such a system and compared with present annual beach nourishment requirements. The estimated present cost of a groin system similar in design to that proposed as deferred construction in the 1952 report (i.e., consisting of 21 creosoted timber groins, 300 feet in length, between Rudee Inlet and 35th Street) is $1,167,000. The annual charges for a 50-year period could be estimated as follows:

Interest on initial investment at 3.5%	$40,800
Amortization	9,000
Replacement, after 25 years, of outer 200 feet of groins	11,800
Maintenance	9,500
	$71,100

The annual cost for artificial nourishment of the beach is estimated at $42,000, therefore, the groin system would not be justified if it would completely eliminate the artificial nourishment requirements. In view of the type of littoral processes at Virginia Beach it appears that an estimate of 20 percent reduction in nourishment requirements due to the presence of a groin system would be overly liberal for establishing the justification for construction of the system. On this basis of evaluation annual nourishment requirements of the beach without groins would have to be substantially higher before a groin system would approach justification. A groin system that would be effective in reducing nourishment requirements of the problem area would cause some recession of the shores adjacent to the Virginia Beach area and the repair of such damages should be included in determining the justification of a groin system. Therefore, the ultimate annual cost of maintaining the shore with a groin system would be substantially more than the estimated $71,000.

CONCLUSIONS

The study has resulted in the following conclusions:

a. The beach fill and subsequent periodic nourishment have served to virtually stabilize the shore within the study limits and for considerable distance north thereof at reasonably low cost per lineal foot of shore. The required annual artificial replenishment rate to maintain the restoration fill appears to be about 2.5 cubic yards per lineal foot of shore.

b. The data do not indicate the magnitude or dominant direction of alongshore material movement, but do indicate that there is a substantial onshore-offshore type of material movement which is probably related to the seasonal and storm changes in wave characteristics in the area.

c. Maintenance of the present beach dimensions by periodic artificial nourishment is the most economical method of providing stability of the shore and protection to installations located on the backshore.

TABLE 1

MECHANICAL ANALYSIS OF BORING SAMPLES IN BORROW AREAS

(Supplied by Virginia Beach Erosion Commission)

Composite Sample No. and Volume Indicated	Boring Number	Sample Numbers	PERCENT RETAINED 70 Mesh .210 mm.	100 Mesh .149 mm.	140 Mesh .105 mm.	200 Mesh .074 mm.
	3	1,2				
1	5	1	73.53	94.39	96.87	98.31
	6	1,2				
(58,200	8	1,2				
cu.yds.)	9	1				
	20	1,2,3,4				
	3	3,4,5				
	5	2,3				
	6	3				
2	7	1,2	43.21	57.53	62.96	67.45
	8	3				
(67,450 cu.	9	2				
yds.)	20	5				
	5	4,5				
	6	4,5				
	7	3,4,5,6				
3	8	4,5,6	54.88	78.60	86.51	90.93
	9	3,4,5,6				
(95,450 cu.	18	4,5				
yds.)	20	6,7,8,9				
	7	1,2				
	9	2				
4	18	1,2,3	41.56	54.55	59.42	64.61
(52,120 cu.	19	1,2,3				
yds.)	21	1,2,3,4				
	7	3,4,5				
	9	3,4,5,6				
5	18	4,5	56.03	74.14	82.76	86.21
(63,880 cu.	19	4,5				
yds.)	21	5,6				
	8	1				
	9	1				
6	20	1,2,3,4	62.20	93.13	96.22	96.91
(63,800 cu.	22	1				
yds.)	23	1				

Composite Sample No. and Volume Indicated	Boring Number	Sample Numbers	PERCENT RETAINED 70 Mesh .210 mm.	100 Mesh .149 mm.	140 Mesh .105 mm.	200 Mesh .074 mm.
	8	2,3				
	9	2				
7	20	5				
	21	1,2,3,4				
(81,700 cu.	22	2,3				
yds.)	23	2	31.33	43.99	48.93	54.08
	24	1,2,3				
	8	4,5,6				
	9	3,4,5,6				
	20	6,7,8,9				
8	21	5,6	61.57	82.64	87.60	89.88
	22	4,5,6				
(137,000 cu.	23	3,4,5,6,7				
yds.)	24	4,5				
	19	1,2,3				
	21	5,6				
9	23	2	34.47	46.12	51.14	56.62
(111,100 cu.	24	1,2,3				
yds.)	25	1,2,3				
	19	4,5				
	21	5,6				
10	23	3,4,5,6,7	58.86	77.93	82.56	85.29
(109,100 cu.	24	4,5				
yds.)	25	4,5,6				
	1	1,2				
	2	1				
11	3	1,2	69.65	92.26	96.23	97.15
	4	1				
(45,910 cu.	5	1				
yds.)	8	1,2				
	3	1,2				
	26	3,4,5,6				
12	6-N	1	51.47	76.43	87.20	91.53
(39,200 cu.	1-N	1				
yds.)	4-N	1				
	10	1,2,3,4,5				
13	11	1,2,3,4,5	54.38	73.98	85.02	89.96
(44,600 cu.	12	1				
yds.)	1-N	1,2,3,4				

Composite Sample No. and Volume Indicated	Boring Number	Sample Numbers	70 Mesh .210 mm.	100 Mesh .149 mm.	140 Mesh .105 mm.	200 Mesh .074 mm.
	12	1				
14	1-N	1,2,3,4	48.33	69.75	82.25	88.25
(30,500 cu. yds.)	13	1,2,3,4,5,6,7				
	3	3,4,5,6				
15	5	2,3	27.27	47.73	58.33	59.09
(13,668 cu. yds.)	8	3				
	3	7				
16	5	4,5,6	62.06	87.10	92.93	94.93
(15,090 cu. yds.)	8	4,5,6				
	13	1,2,3,4,5,6,7				
17	14	1,2	49.18	73.48	86.37	92.20
(23,200 cu. yds.)						
18 (27,000 cu. yds.)	1-N	1,2,3	53.76	80.92	93.06	96.82

(TOTAL VOLUME = 1,079,000 cu. yds.)

TABLE 2

MECHANICAL ANALYSIS FOR SAMPLES FROM VIRGINIA BEACH, VIRGINIA

Onshore Samples Collected in March 1951 and Offshore Samples in June 1951
by U. S. Army Engineer District, Norfolk

Locations Taken	1.680	1.168	0.840	0.589	0.420	0.297	0.210	0.149	0.105	0.074	0.062	Md.	So.	Sk.
	Screen Openings in Millimeters — Cumulative Per Cent Coarser													
	Range 1800 Feet South of South End of Sea Wall													
Approx. Center of Back-Shore				0.3	8.0	47.6	83.5	98.0				0.29	1.27	0.97
M.H.W.				1.3	27.7	67.4	85.0	98.2				0.35	1.28	0.92
M.T.L.	0.6	1.2	5.2	12.2	33.2	65.1	83.8	96.1	99.5			0.35	1.36	0.95
M.L.W.	2.0	5.4	16.0	29.4	51.4	74.5	96.8	96.4	99.3			0.43	1.48	1.04
-5 feet				0.6	3.6	10.0	24.6	58.5	91.1	99.7		0.16	1.28	1.06
-10 feet		0.6	2.1	4.3	6.0	7.6	14.6	60.9	93.9	99.5		0.16	1.19	0.97
-15 feet	3.6	5.7	9.1	22.8	16.7	18.4	21.7	33.6	64.2	79.5	81.8	0.12	1.42	0.97
-20 feet					2.3	5.4	9.0	16.7	65.8	93.0		0.12	1.18	1.14
	Range at 7th Street													
Approx. Center of Back-Shore				0.9	11.4	61.4	91.8	98.8	99.5			0.32	1.19	0.99
M.H.W.				2.8	8.9	31.9	63.3	92.3	99.0			0.24	1.31	1.04
M.T.L.	4.2	9.9	41.9	73.4	83.7	90.6	94.5	98.6				0.80	1.28	0.80
M.L.W.	9.1	18.0	44.1	56.2	71.1	83.4	90.0	97.2	99.4			0.73	1.63	0.73
-5 feet			1.1	2.6	8.2	18.8	36.0	74.1	96.0	99.8		0.17	1.79	1.18
-10 feet					4.9	8.5	16.5	31.8	89.8	99.5		0.13	1.75	1.15
-15 feet					0.3	0.5	1.1	5.6	59.6	93.5		0.11	1.11	1.03
-20 feet			0.7	1.7	7.1	13.5	18.1	28.4	67.1	93.9		0.12	1.29	1.07
	Range at 22nd Street													
In Front of Sea Wall				0.1	4.1	39.9	81.8	97.5	99.5			0.27	1.23	1.02
M.H.W.				1.8	17.8	55.5	84.5	98.0	99.5			0.31	1.27	0.97
M.T.L.				2.1	12.5	29.7	54.7	84.6	98.6			0.22	1.38	1.37
M.L.W.	6.5	8.8	14.1	20.3	43.0	64.7	75.9	91.1	97.7			0.38	1.57	0.79
-5 feet			0.4	1.0	4.7	16.4	37.5	72.1	96.3	99.8		0.18	1.32	1.08
-10 feet					2.1	3.1	7.1	38.6	92.9	99.4		0.14	1.14	0.99
-15 feet					2.1	6.7	13.7	24.3	51.3	66.8	71.4	0.14	1.16	1.00
-20 feet			1.3	7.7	5.9	9.0	14.5	29.7	77.0	97.0		0.12	1.20	1.17
	Range at 35th Street													
At Base in Front of Sea Wall				4.6	21.8	51.8	77.7	95.9	99.6			0.30	1.35	0.93
M.H.W.			0.2	2.6	28.5	60.1	79.9	95.6	99.1			0.34	1.36	0.86
M.T.L.			0.4	3.7	31.2	59.1	82.1	96.6				0.34	1.38	0.92
M.L.W.			0.6	3.7	32.8	59.1	82.0	97.5				0.34	1.40	0.90
-5 feet			0.9	1.4	6.0	15.9	33.4	67.0	92.9	99.7		0.17	1.31	1.09
-10 feet					4.5	6.1	11.5	30.2	85.1	99.4		0.14	1.20	1.03
-15 feet					0.4	0.7	1.7	12.3	77.2	77.6		0.12	1.13	1.01
-20 feet					3.2	8.8	16.5	31.0	69.9	94.7		0.13	1.29	1.06
	Range at 49th Street													
Approx. Center of Back-Shore				0.2	21.1	72.7	95.3	99.0	99.5			0.35	1.19	0.98
M.H.W.			2.4	12.9	56.6	82.5	93.7	99.0				0.44	1.21	0.88
M.T.L.	6.8	10.6	14.1	27.1	56.3	77.4	90.3	98.5				0.45	1.39	0.93
M.L.W.	3.1	4.3	7.3	14.7	47.5	70.3	85.3	96.9				0.41	1.36	0.80
-5 feet				0.6	4.7	15.1	38.3	77.6	96.9			0.19	1.30	1.14
-10 feet					0.4	0.6	2.7	22.3	90.6	98.5		0.13	1.13	0.99
-15 feet					1.6	2.7	4.8	12.5	68.4	95.2		0.12	1.14	0.96
-20 feet					1.0	6.4	11.8	24.3	67.1	94.1		0.12	1.29	1.02

TABLE 3

MECHANICAL ANALYSIS FOR SAMPLES FROM VIRGINIA BEACH, VIRGINIA

Collected in September 1955 by Beach Erosion Board

Locations Taken	1.680	1.168	0.840	0.589	0.420	0.297	0.210	0.149	0.105	0.074	0.062	Md	So.	Sk.
	Screen Openings in Millimeters — Cumulative Per Cent Coarser													
Range "C" (2200' So. Rudee Inlet)														
M.T.L.					6.8	40.0	84.8	99.3				0.28	1.21	1.00
-5 feet					10.5	27.0	55.5	89.0	99.8			0.22	1.32	1.08
-10 feet				3.1	11.1	27.5	46.5	77.0	97.0			0.20	1.43	1.18
-15 feet							2.1	14.5	70.0	100.0		0.12	1.14	1.02
-20 feet							5.4	17.0	49.0	93.0	99.0	0.10	1.20	1.08
-25 feet					0.8	1.9	6.0	18.0	53.0	95.8		0.11	1.20	1.03
-30 feet						8.7	17.6	27.5	49.0	94.8	99.5	0.10	1.34	1.33
Range "D" (8th Street)														
M.T.L.						15.0	73.0	99.5				0.24	1.14	1.02
-5 feet					4.0	11.5	30.0	72.0	99.7			0.18	1.23	1.07
-10 feet					8.5	14.8	28.0	70.0	99.5			0.17	1.24	1.09
-15 feet						1.4	10.9	26.0	51.0	100.0		0.11	1.28	1.23
-20 feet			0.3	1.2	1.6	2.7	3.3	10.1	62.1	90.1	94.3	0.11	1.19	0.99
-25 feet	0.1	0.1	0.2	0.2	0.5	0.8	1.6	7.4	46.4	75.4	81.1	0.10	1.27	0.85
-30 feet	0.2	0.3	0.5	0.7	1.2	2.2	3.2	5.3	38.2	75.8	83.1	0.10	1.18	0.81
Range "E" (24th Street)														
M.T.L.				4.3	29.9	73.9	95.3	99.1	99.8	99.95	99.99	0.36	1.22	1.00
-5 feet	1.0	1.6	2.5	5.8	18.1	49.4	80.4	97.7	99.9	99.99		0.29	1.30	0.99
-10 feet	2.2	3.7	9.2	25.6	52.3	74.8	89.8	97.8	99.8	99.9	99.99	0.43	1.41	0.94
-15 feet	1.0	1.0	1.1	1.2	1.3	1.5	2.9	40.1	93.6	99.4	99.8	0.14	1.11	0.99
-20 feet	0.1	0.2	0.2	0.3	0.4	0.7	2.4	15.2	81.5	97.6	98.6	0.12	1.12	1.05
-25 feet		0.1	0.2	0.3	0.6	1.6	3.7	11.6	49.8	75.3	81.2	0.105	1.31	0.95
-30 feet	0.1	0.1	0.1	0.1	0.2	0.3	0.5	3.5	39.8	77.7	85.7	0.098	1.21	0.92
Range "F" (34th Street)														
M.T.L.	0.4	0.6	2.9	14.9	57.0	95.3	99.5	99.7	99.8	99.9	99.99	0.44	1.17	1.04
-5 feet	0.1	0.2	0.4	1.5	8.7	31.0	65.0	92.5	98.4	99.8	99.9	0.25	1.30	1.01
-10 feet	0.1	0.3	1.2	3.3	7.2	12.1	29.3	73.1	97.9	99.8	99.9	0.17	1.22	1.10
-15 feet	2.0	2.1	2.1	2.2	2.2	2.6	6.4	44.0	94.9	99.5	99.8	0.15	1.12	1.00
-20 feet	1.3	1.4	1.4	1.5	1.6	2.1	3.9	12.6	77.6	94.3	96.6	0.118	1.11	0.94
-25 feet	0.1	0.2	0.2	0.3	0.7	1.9	4.6	15.7	61.0	88.0	93.2	0.114	1.20	0.92
30 feet	0.02	0.02	0.02	0.1	0.1	0.2	0.6	5.1	51.0	88.5	95.0	0.107	1.17	0.93
Range "G" (46th Street)														
.T.L.				32.0	67.5	90.0	98.6					0.50	1.30	0.97
-5 feet					9.2	30.5	69.0	94.0	99.7			0.25	1.27	1.02
-10 feet					6.2	15.8	40.5	83.0	99.3			0.20	1.25	1.05
-15 feet							6.5	26.0	71.0			0.12	1.21	1.07
-20 feet	0.2	0.2	0.2	0.2	0.3	0.7	2.5	13.2	73.1	94.7	96.9	0.12	1.15	0.95
-25 feet	0.1	0.1	0.2	0.2	0.5	1.8	6.5	20.9	66.2	88.7	93.0	0.12	1.21	0.94
30 feet	0.4	0.5	0.7	0.8	0.9	1.2	2.5	10.5	44.4	79.0	87.4	0.10	1.27	0.98
Range "H" (57th Street)														
M.T.L.				4.0	17.5	50.0	90.4	99.9				0.30	1.22	1.03
-5 feet					8.0	25.0	54.0	87.0	99.8			0.22	1.32	1.05
-10 feet					1.8	5.1	20.2	58.0	99.6			0.16	1.20	1.08
-15 feet						2.9	4.9	27.0	85.0	100.0		0.12	1.17	1.08
-20 feet	0.2	0.3	0.5	0.9	1.9	3.8	9.1	21.0	71.7	94.3	97.1	0.12	1.17	1.02
-25 feet						2.3	6.7	21.5	55.0	99.3		0.11	1.23	1.09
-30 feet							1.6	5.5	88.0	98.0		0.09	1.13	1.00
Range "I" (68th Street)														
M.T.L.				3.9	18.0	50.0	87.0	99.9				0.30	1.26	1.01
-5 feet				6.5	22.0	50.0	83.0	100.0				0.30	1.31	1.04
-10 feet				5.9	9.2	12.7	23.0	51.0	95.0			0.15	1.36	1.12
-15 feet							0.8	10.0	82.0			0.12	1.09	1.01
-20 feet				0.8	1.7	3.1	5.1	13.0	46.0	92.0	99.2	0.10	1.17	1.02
-25 feet						0.8	1.8	5.8	31.0	85.0	98.0	0.09	1.18	1.00
-30 feet							1.6	5.0	25.0	77.0	94.5	0.09	1.18	1.02

TABLE 4

MECHANICAL ANALYSIS FOR SAMPLES FROM VIRGINIA BEACH, VIRGINIA

Collected in July 1958 by Beach Erosion Board

Sample Location	2.380	1.680	1.190	0.840	0.590	0.420	0.297	0.210	0.149	0.105	0.074	Md	So	Sk
	Screen Openings in Millimeters — Cumulative Per Cent Coarser													
(Range "C"-"2200' So. Rudee Inlet)														
½ Bet. Dune & M.H.W.	-	-	-	0.5	5.9	24.3	57.3	81.9	98.2	99.6	99.9	0.320	1.32	0.97
M.H.W.	-	-	0.4	2.8	9.9	24.5	50.0	75.4	98.1	99.9	99.9	0.297	1.49	1.03
M.T.L.	-	-	0.1	0.3	0.8	2.2	7.8	34.6	92.3	99.7	99.9	0.192	1.15	1.03
M.L.W.	4.8	7.4	9.6	10.7	11.5	12.3	14.1	27.6	83.3	99.7	99.9	0.178	1.17	1.06
-5 feet	-	-	0.2	0.9	2.9	8.7	16.5	32.7	73.5	97.6	99.8	0.173	1.27	1.39
-15 feet	0.6	-	0.7	0.8	0.9	1.5	2.6	6.6	28.3	80.7	96.9	0.128	1.28	1.03
-30 feet	0.3	0.5	0.7	0.9	1.0	1.3	1.9	3.3	8.5	49.8	88.0	0.105	1.15	0.95
Range "D" (8th Street)														
½ Bet. Dune & MHW	-	-	-	-	1.0	9.0	47.2	78.1	98.1	99.7	99.9	0.292	1.25	0.91
M.H.W.	-	-	-	0.3	2.3	12.8	42.4	73.9	97.3	99.7	99.9	0.277	1.33	0.93
M.T.L.	0.4	0.5	0.8	4.0	14.2	32.6	61.0	84.1	98.6	99.9	99.9	0.340	1.37	1.01
M.L.W.	0.6	0.9	1.6	3.1	6.6	14.4	33.3	62.8	94.5	99.7	99.9	0.240	1.33	1.08
-5 feet	-	-	0.2	0.7	2.6	7.5	16.2	31.9	72.1	97.2	99.6	0.170	1.27	1.24
-15 feet	-	-	-	0.2	0.5	0.8	1.3	3.0	21.2	80.4	97.5	0.130	1.25	0.97
-30 feet	2.3	4.2	6.2	10.6	16.1	20.6	23.6	27.0	39.0	72.2	94.1	0.139	1.57	1.58
Range "E" (24th Street)														
½ Bet. Dune & M.H.W.	-	-	-	-	1.6	21.6	67.4	89.7	99.5	99.9	99.9	0.339	1.21	0.97
M.H.W.	-	-	0.1	2.3	13.2	35.1	65.9	84.7	98.8	99.8	99.9	0.353	1.35	1.03
M.T.L.	0.1	0.2	1.0	4.8	11.3	18.4	30.9	52.8	91.1	99.8	99.9	0.218	1.43	1.22
M.L.W.	0.1	-	0.3	0.5	0.7	1.5	5.3	23.0	76.0	99.1	99.9	0.170	1.18	1.07
-5 feet	-	-	0.1	0.4	1.0	3.4	9.3	20.5	56.9	92.5	99.2	0.156	1.21	1.08
-15 feet	-	0.3	0.7	1.8	3.2	4.9	7.3	15.6	56.3	92.6	99.3	0.154	1.17	1.04
-30 feet	-	0.1	0.3	0.7	1.1	1.5	1.9	2.5	9.4	56.0	90.3	0.110	1.19	0.97
Range "F" (34th Street)														
½ Bet. Dune & M.H.W.	-	-	-	0.2	2.5	23.6	69.6	91.3	99.6	99.9	99.9	0.348	1.22	0.96
M.H.W.	-	-	-	-	0.2	12.2	57.8	82.8	98.4	99.8	99.9	0.313	1.23	0.93
M.T.L.	-	-	-	0.1	0.4	4.7	27.6	61.5	95.5	99.7	99.9	0.235	1.27	1.01
M.L.W.	-	-	0.4	3.8	11.4	27.0	54.7	82.3	97.4	99.7	99.9	0.310	1.36	1.04
-5 feet	-	-	-	0.2	0.9	3.3	9.5	22.2	56.4	93.9	99.7	0.156	1.23	1.09
-15 feet	0.4	0.5	0.7	1.1	1.6	2.5	4.4	8.2	29.5	81.0	97.3	0.130	1.18	1.00
-30 feet	0.1	0.2	0.3	0.4	0.6	1.1	1.7	2.8	10.2	56.9	90.4	0.108	1.16	1.00
Range "G" (46th Street)														
½ Bet. Dune & M.H.W.	-	-	-	0.1	3.2	26.2	68.4	91.5	99.6	99.9	99.9	0.348	1.23	0.97
M.H.W.	-	-	-	0.1	1.7	25.6	77.0	93.6	99.7	99.9	99.9	0.360	1.18	0.98
M.T.L.	0.1	0.3	0.8	2.1	5.3	18.3	47.3	73.7	97.0	99.8	99.9	0.285	1.36	0.94
M.L.W.	5.9	7.9	10.3	13.9	19.9	34.1	50.8	76.1	96.6	100.0	-	0.327	1.53	1.95
-5 feet	-	-	-	0.1	0.4	2.3	8.4	25.2	70.5	97.2	99.8	0.168	1.20	1.09
-15 feet	-	0.1	0.2	0.3	0.6	1.2	2.4	5.6	23.5	77.4	96.6	0.127	1.17	0.98
-30 feet	-	-	-	0.1	0.2	0.4	0.8	2.4	11.5	54.4	87.4	0.108	1.19	0.96

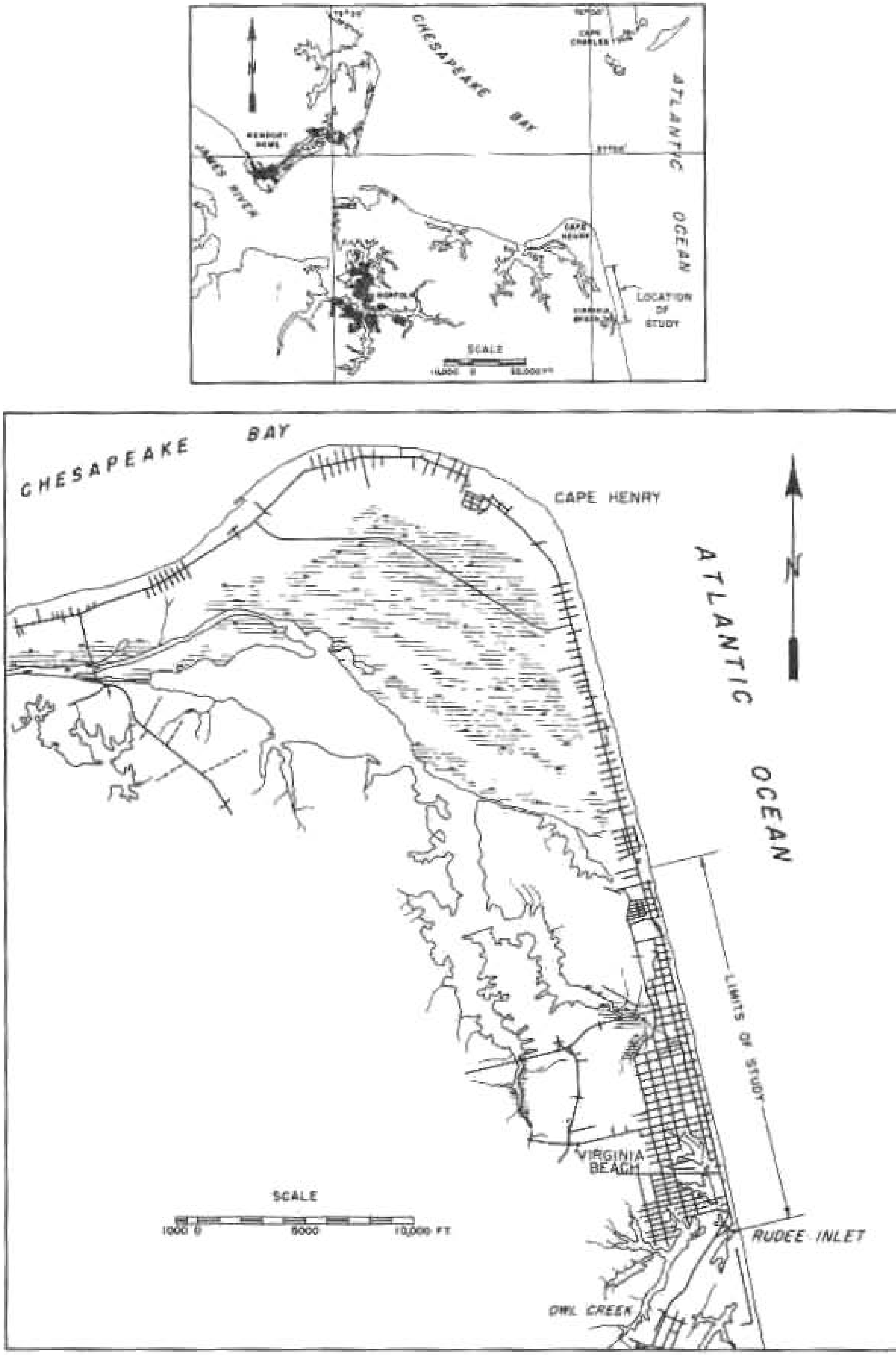

FIGURE 1. LOCALITY MAP, VIRGINIA BEACH, VIRGINIA

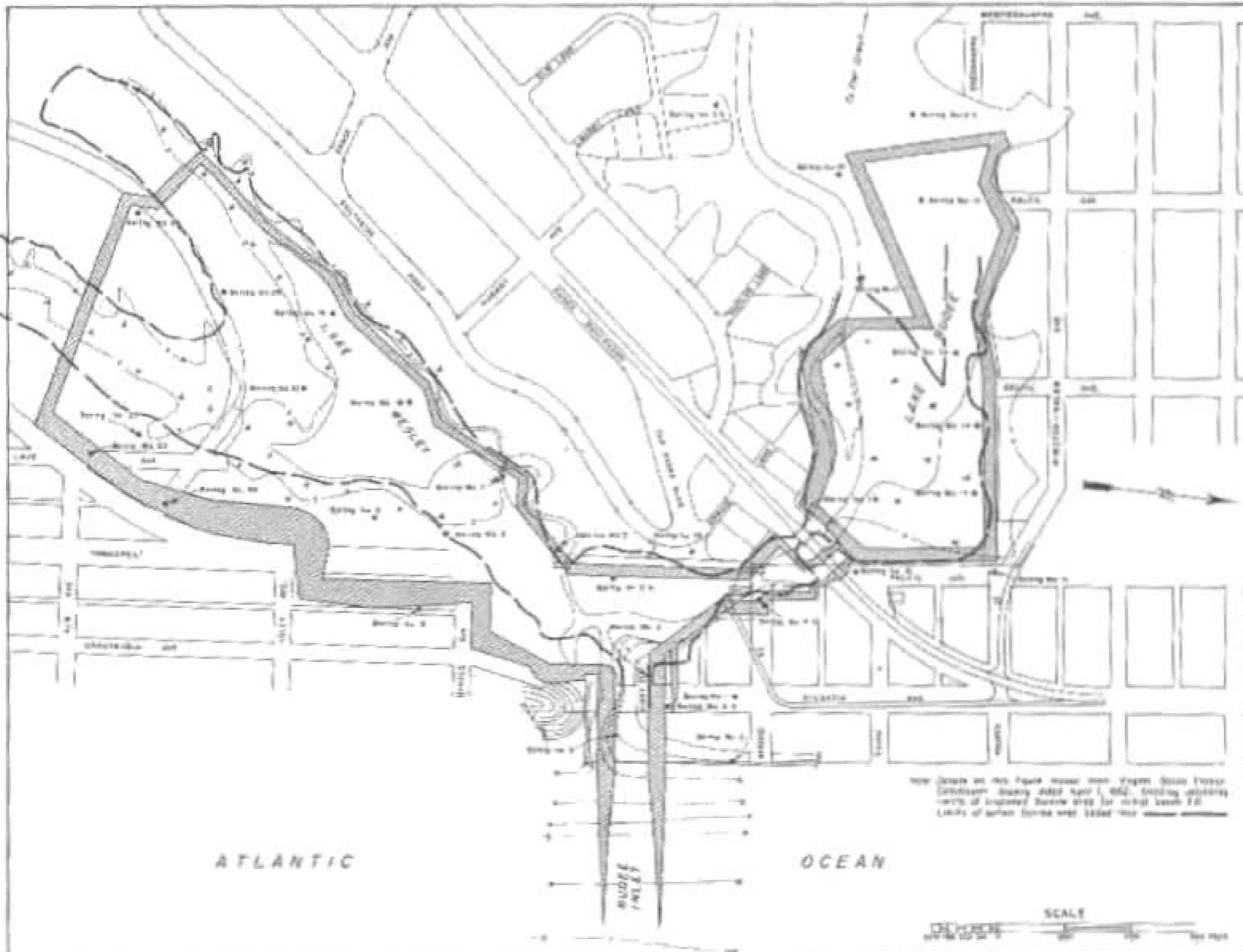

FIGURE 2. BORROW AREAS IN VICINITY OF RUDEE INLET.

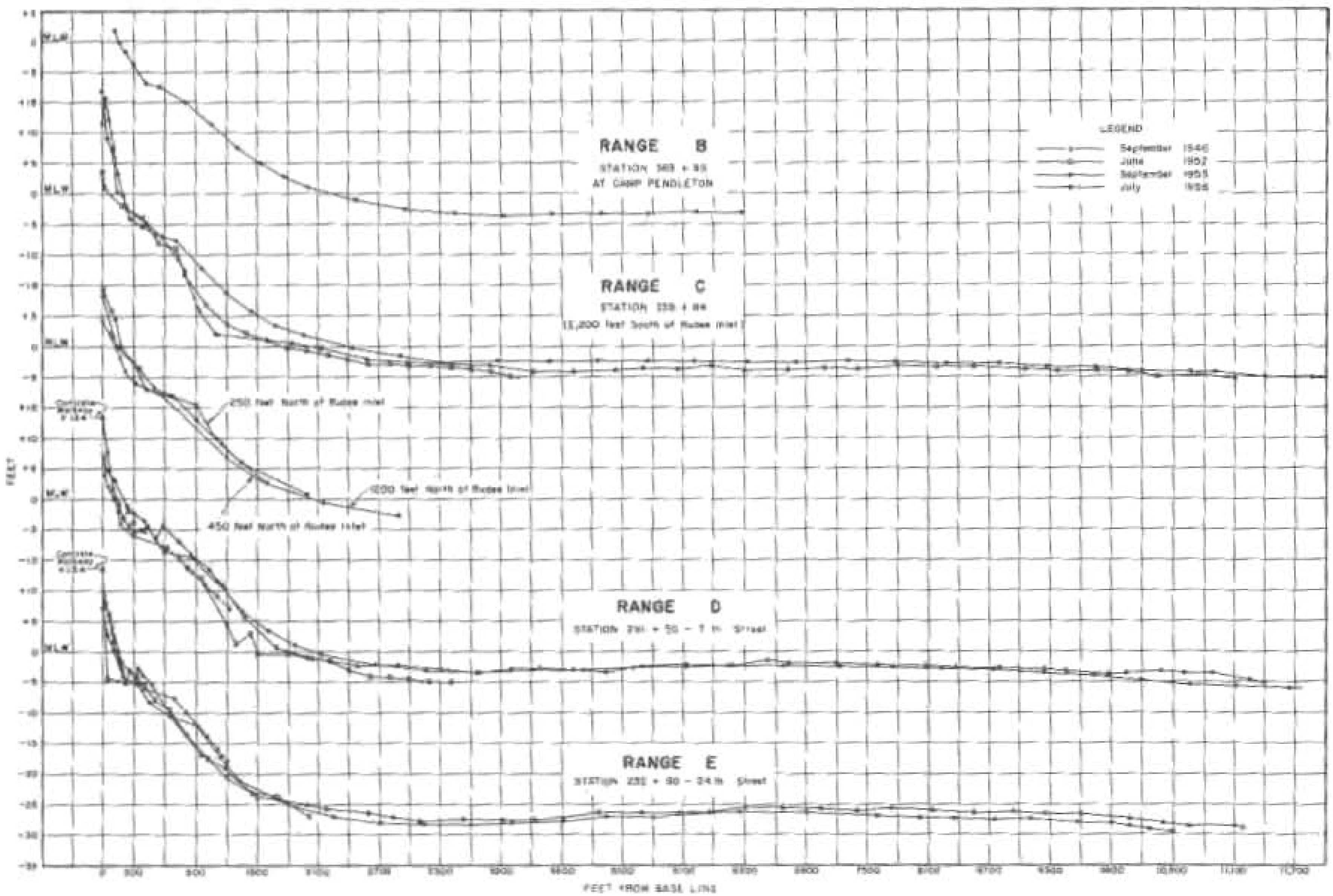

FIGURE 4 A. COMPARATIVE PROFILES (Ranges B through E).

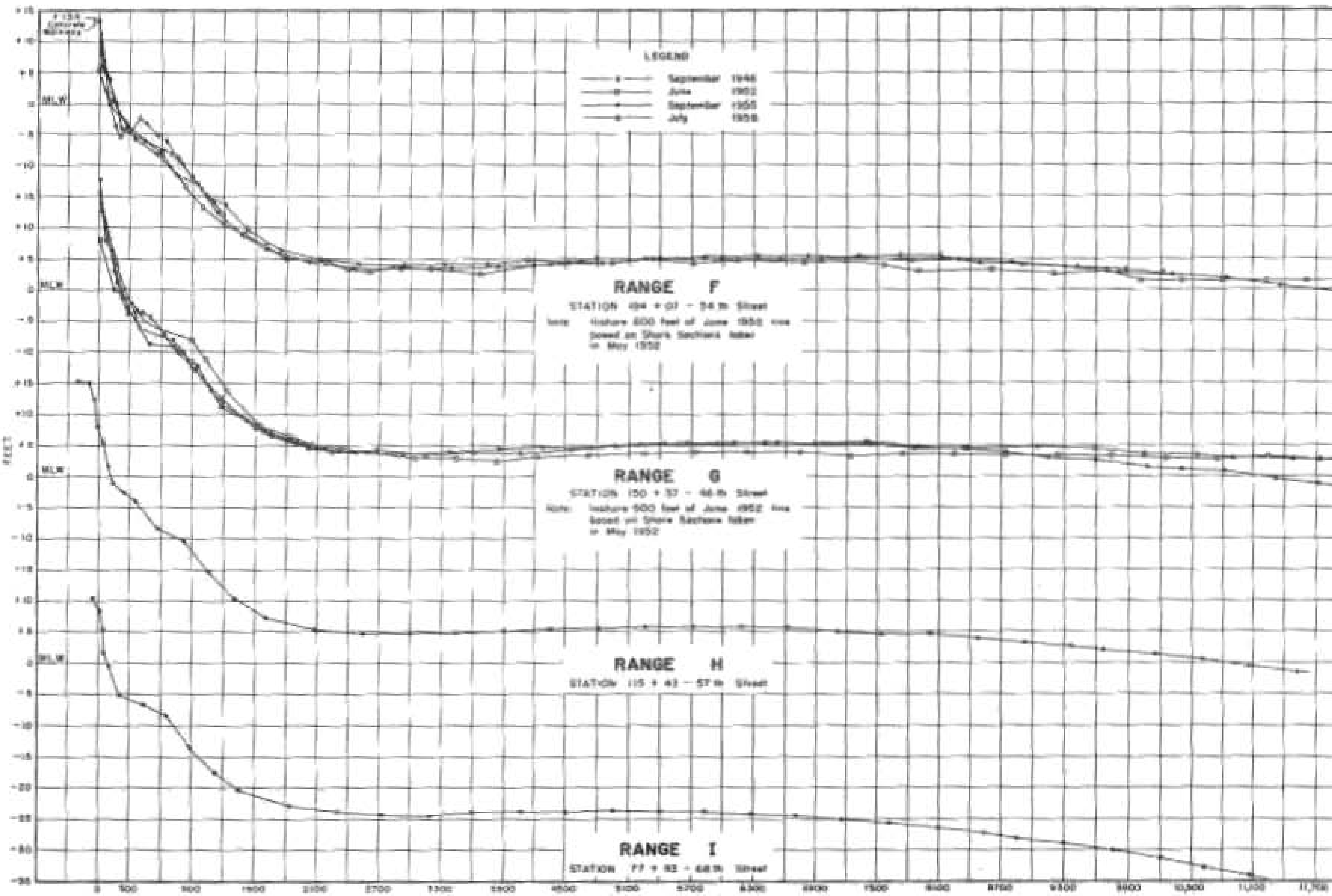

FIGURE 4 B. COMPARATIVE PROFILES (Ranges F through I).

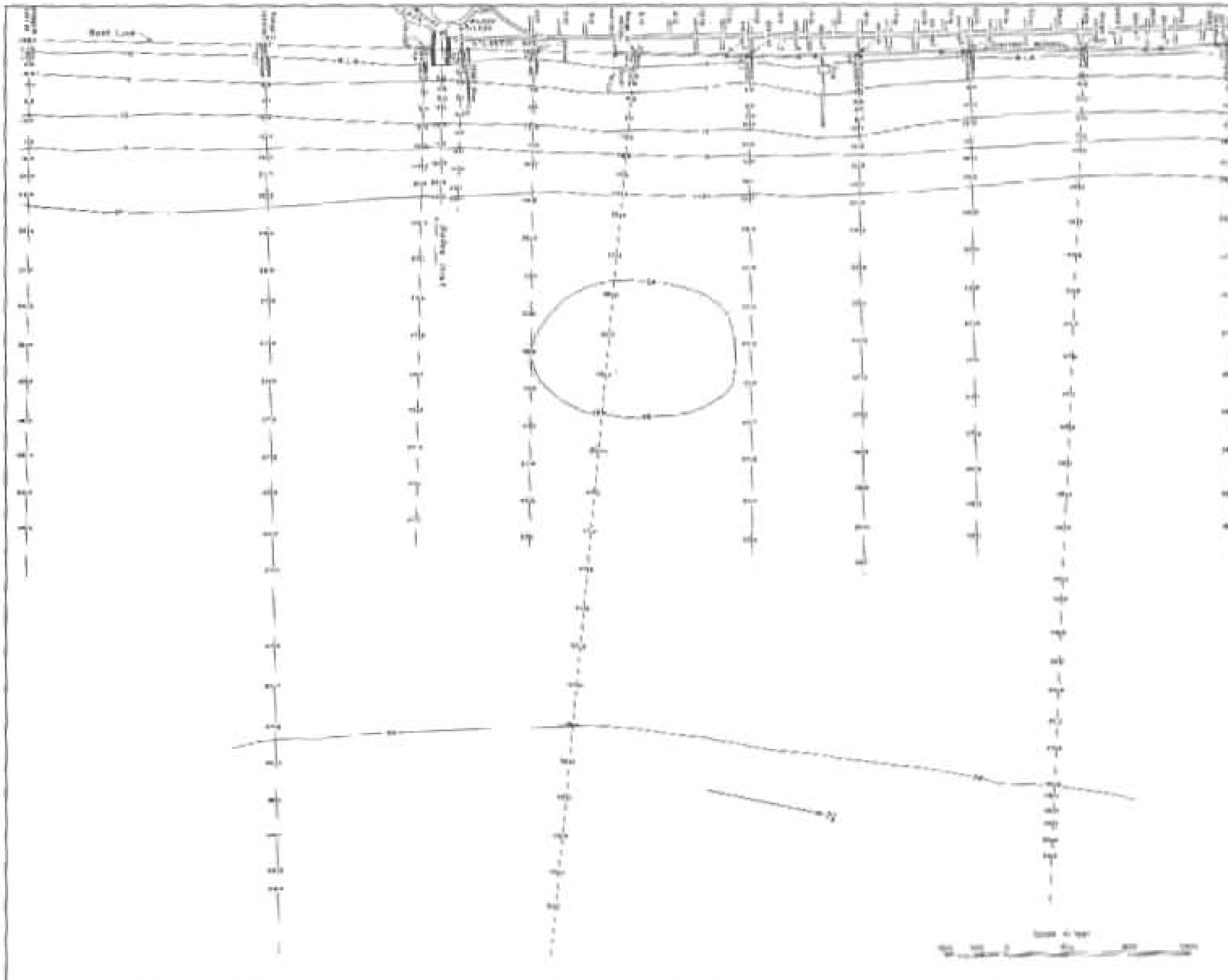

FIGURE 5A HYDROGRAPHIC SURVEY SEPTEMBER 1955
(From 5000 feet south of Rudee inlet to 29th street)

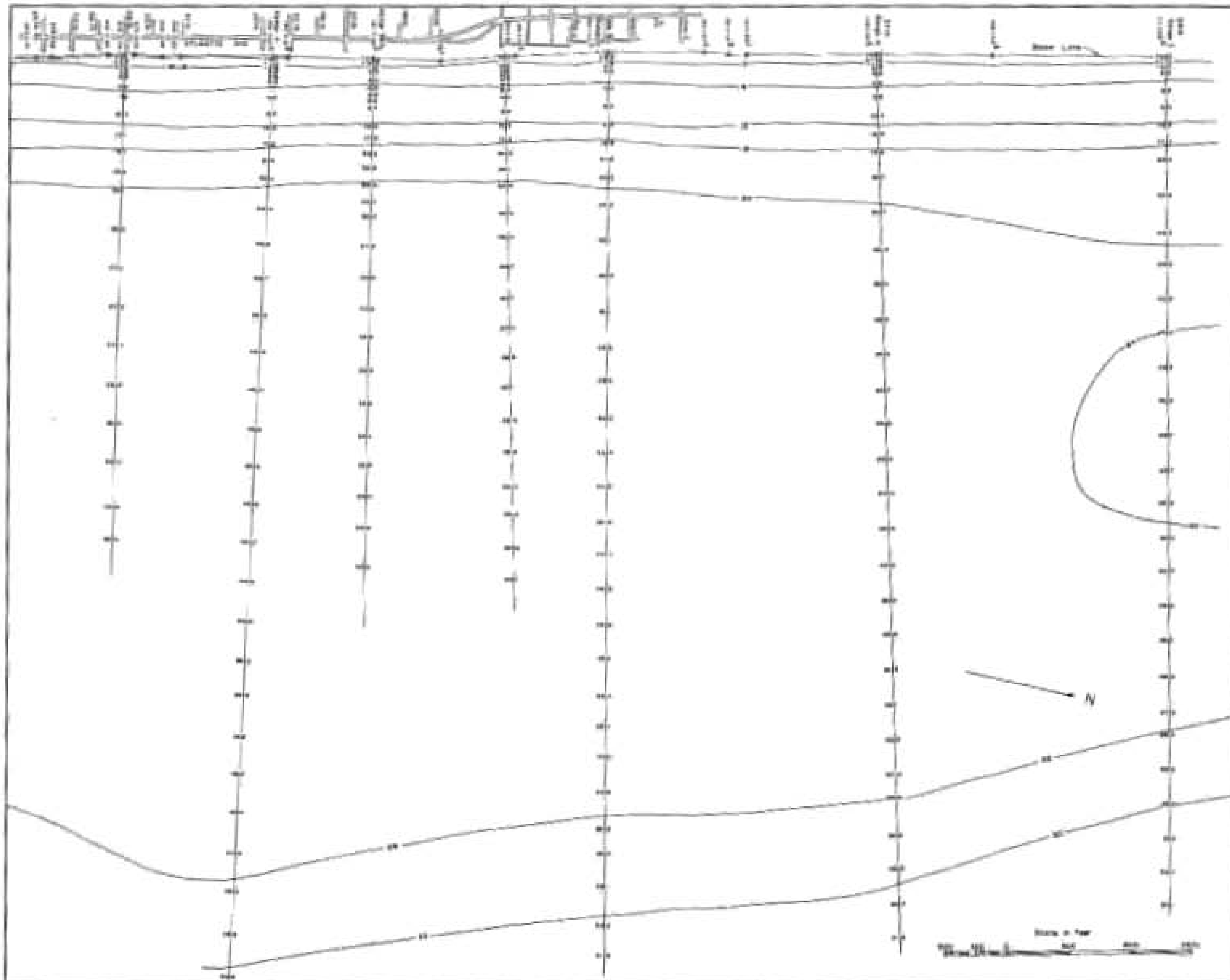

FIGURE 5.8. HYDROGRAPHIC SURVEY SEPTEMBER 1955.
(From 29th street to 68th street.)

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WASHINGTON, D. C.

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1. Artificial Nourishment
2. Beach Fill
3. Virginia - Artificial Nourishment Virginia Beach
4. Virginia Beach, Va.

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UNCLASSIFIED

Comparative survey and sand sample data are analyzed to determine the behavior of beach fill placed to restore and nourish the beach at this resort location. Initial restoration was accomplished in 1952-53 and sand nourishment added periodically thereafter. Conclusions are drawn that the restored beach has been virtually stabilized by annual nourishment at the rate of about 2.5 cubic yards per lineal foot of shore. Periodic nourishment at this rate is concluded to be the most economical method of maintaining required beach dimensions.

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