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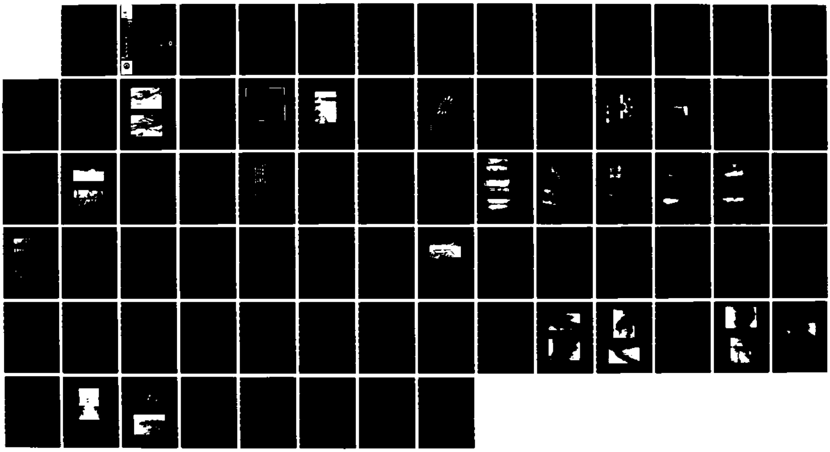

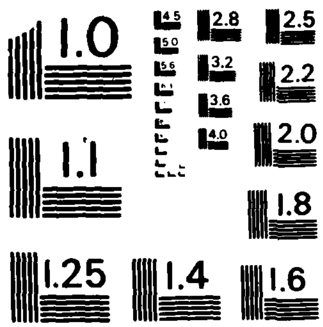
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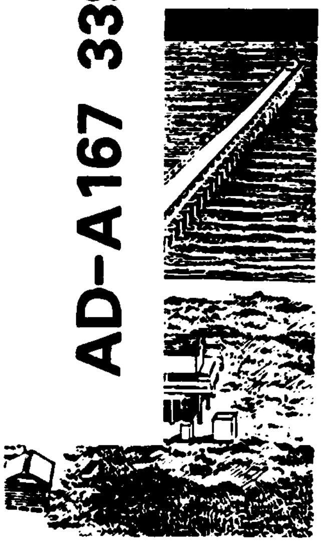

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MISCELLANEOUS PAPER CERC-86-2

GENERALIZED MONITORING OF SEASCAPE® INSTALLATION AT CAPE HATTERAS LIGHTHOUSE, NORTH CAROLINA

by

J. W. Forman

US Army Engineer District, Wilmington
PO Box 1890
Wilmington, North Carolina 28402-1890

Field Data Collected by

Coastal Engineeering Research Center

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

February 1986

Final Report

Approved For Public Release; Distribution Unlimited

Prepared for

The National Park Service
Cape Hatteras Seashore
North Carolina

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Cape Hatteras (N.C.)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This reprint of a report prepared by the US Army Engineer District, Wilmington, documents a monitoring program to assess the effectiveness of SEASCAPE®, an artificial seaweed for temporarily stabilizing the shoreline fronting the lighthouse at Cape Hatteras, North Carolina. This study is part of a larger effort requested by the National Park Service to develop a long-term protection plan for the lighthouse. The monitoring program consisted of aerial photography, beach profile surveys, reconnaissance dives, and ground
(Continued)

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20. ABSTRACT (Continued).

photography. Although considerable accretion occurred during the monitoring period, the accumulation was the result of a general buildup of the beach which averaged 25 ft over the 6.1-mile study area. There was no conclusive evidence to link the buildup to the 5,000 ft of SEASCAPE® which was deployed in October and November 1982. Moreover, it was not possible to attribute burial of the SEASCAPE® to the action of the artificial seaweed versus burial by normal wave-driven migration of sand. The units themselves were found to deteriorate and to fragment with whole units and parts of units washing up on the beach.

PREFACE

This report describes the methods and results of a study undertaken in October 1982 to assess the performance of SEASCAPE®, an artificial seaweed-like erosion control device, at Cape Hatteras, North Carolina. The study was conducted for the Cape Hatteras Seashore National Park Service by the US Army Engineer District, Wilmington (SAW). Field data collection activities were performed by the US Army Engineer Waterways Experiment Station (WES) Coastal Engineering Research Center (CERC) Field Research Facility (FRF) in Duck, North Carolina.

The report was prepared by Mr. J. W. Forman, Project Engineer, SAW Coastal Engineering Branch, under general supervision of Mr. L. Vallianos, Branch Chief. The report was originally published as a Wilmington District report but is being reprinted as a WES Miscellaneous Paper because of its potential interest to a large number of Corps field offices. Funding for publication was provided by SAW and the US Army Corps of Engineers Coastal Flooding and Storm Protection Program.

During the course of the study, COL Wayne A. Hanson was District Engineer, SAW, and Mr. Jaman Vithalani was Chief, Engineering Division. Mr. Michael W. Leffler served as the FRF Project Manager, under direct supervision of Mr. Curtis Mason, Chief, FRF. Dr. James R. Houston, Chief, CERC; Mr. Charles C. Calhoun, Jr., Assistant Chief, CERC; and Mr. Thomas W. Richardson, Chief, Engineering Development Division, provided general guidance.

Director of WES during publication of this report was COL Allen F. Grum, USA; Technical Director was Dr. Robert W. Whalin.

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CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres

Introduction

In 1980, after severe winter storms caused extensive erosion of the shoreline fronting the Cape Hatteras Lighthouse, the National Park Service (NPS) employed the Corps of Engineers, Wilmington District, to provide technical assistance in developing a plan for long-term protection of the historic lighthouse from destruction by the sea. As part of that effort, the Wilmington District also assisted NPS by designing and constructing interim protective measures and conducting a monitoring program to assess the effectiveness of an artificial seaweed product called SEASCAPE® for stabilizing the shoreline fronting the lighthouse.

The purpose of this report is to describe the methods and results of a generalized study undertaken in October 1982 to assess the performance of SEASCAPE® as an erosion control device at Cape Hatteras. The performance of SEASCAPE® is evaluated in terms of the extent of beach and shoreline changes related to the SEASCAPE® installation in the study area, the durability of the material in the nearshore environment, and the adequacy of the anchoring and installation methods used in the installation.

Installation of SEASCAPE® was sponsored and financed by the Committee to Save the Lighthouse, a private organization established to acquire funds through public donations for the purpose of providing protection to the Cape Hatteras Lighthouse. The National Park Service agreed to monitor the installation and, in turn, requested the services of the Corps of Engineers to do so.

During the course of the investigation, Colonel Wayne A. Hanson was District Engineer, Wilmington District, and Mr. Jaman Vithalani was Chief, Engineering Division. The study and report preparation was conducted and managed by the Coastal Engineering Branch under the supervision of Mr. L. Vallianos with Mr. J. W. Forman serving as project engineer. Diving and surveying field activities were performed by personnel from the Waterways Experiment Station, Coastal Engineering Research Center, Field Research Facility (FRF), at Duck, North Carolina, under the direction of Mr. Curt Mason, Chief, FRF, with Mr. Mike Lefler serving as the project manager.

Study Area Location

The Cape Hatteras Lighthouse is located on Hatteras Island in the village of Buxton which is approximately 50 miles* south of Nags Head, North Carolina, along N. C. Highway 12 (see figure 1). Hatteras Island is the most easterly island in a long chain of low narrow barrier islands that separate the Atlantic Ocean from Back Bay and Albemarle and Pamlico Sounds and is part of lands administered by the NPS known as the Cape Hatteras National Seashore Recreation Area. The particular segment of shoreline relevant to the study reported herein extends from Cape Point (Cape Hatteras) northward a distance of 6.1 miles to a point just south of the village of Avon, N. C. The lighthouse is situated in the approximate center of this reach of shoreline.

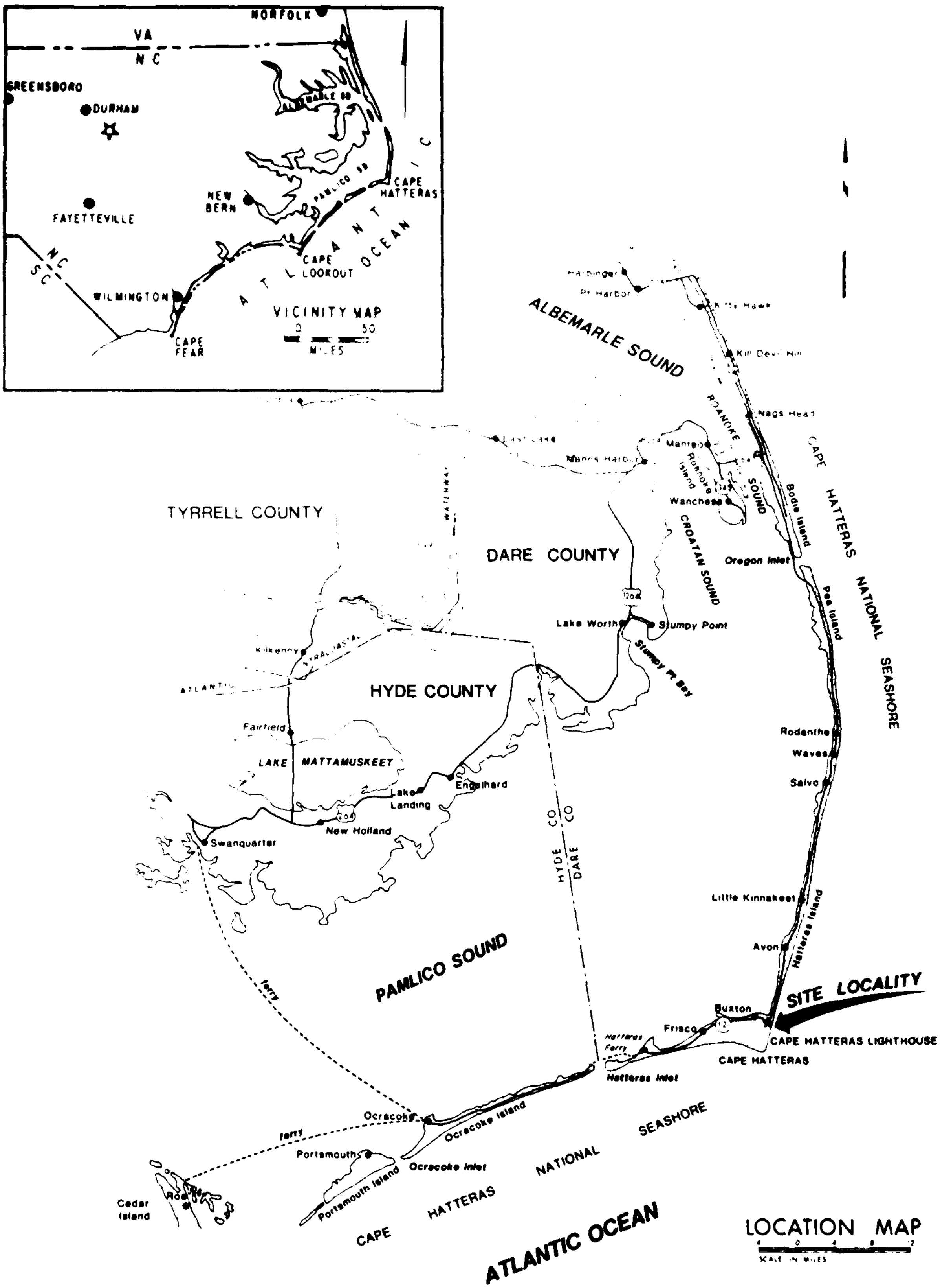
History of Cape Hatteras Lighthouse and Related Shore Protection Measures

The first Cape Hatteras Lighthouse was constructed in 1802. It was a natural sandstone tower, 90 feet tall, supported by a stone foundation.

Construction of the present lighthouse was completed in 1870. The existing striped tower is a masonary structure approximately 208 feet in height. It was built 600 feet north of the original lighthouse at a distance of about 1,500 feet from the shoreline.

By 1919 the ocean shoreline eroded to within 300 feet of the relatively new lighthouse. Groins were installed along the shoreline fronting the lighthouse in 1930, but by 1932 the shoreline eroded to within 100 feet of the present structure. In 1935 a steel skeleton tower 150 feet tall was erected approximately 1 mile inland, and the light was moved from the lighthouse tower. In the decade that followed, the erosion trend reversed, and the light was moved back to its present location in 1950.

* A table of factors for converting non-SI units of measurement to SI (metric) units is presented on page vii.



NORFOLK
VA
N C
GREENSBORO
DURHAM
NEW BERN
FAYETTEVILLE
CAPE HATTERAS
CAPE LOOKOUT
WILMINGTON
CAPE FEAR
ATLANTIC OCEAN
VICINITY MAP
0 50
MILES
ALBEMARLE SOUND
Kitty Hawk
Kill Devil Hill
Nags Head
ROANOKE SOUND
Manteo
Roanoke Island
Wanchese
CROATAN SOUND
TYRRELL COUNTY
DARE COUNTY
Bodie Island
Oregon Inlet
Pea Island
CAPE HATTERAS NATIONAL SEASHORE
Lake Worth
Stumpy Point
Stumpy Pt Bay
HYDE COUNTY
Fairfield
LAKE MATTAMUSKEET
Engelhard
Lake Landing
New Holland
Swanquarter
HYDE CO
DARE CO
Rodanthe
Waves
Salvo
Little Kinnakeet
Avon
Hatteras Island
PAMLICO SOUND
ferry
SITE LOCALITY
Buxton
Frisco
CAPE HATTERAS LIGHTHOUSE
CAPE HATTERAS
Hatteras Ferry
Hatteras Inlet
Ocracoke
Ocracoke Island
Portsmouth
Ocracoke Inlet
Portsmouth Island
Cedar Island
CAPE HATTERAS NATIONAL SEASHORE
ATLANTIC OCEAN
LOCATION MAP
SCALE IN MILES

FIGURE 1

In the mid-1950's, the U. S. Navy constructed a research facility on the oceanfront property just north of the lighthouse. Since 1960, the lighthouse has been the beneficiary of a number of shoreline stabilization measures constructed to protect the naval facility. The initial protection measures consisted of the construction of a nylon bag revetment fronting the naval facility. Constructed in the late 1960's, the bags deteriorated rapidly and were finally displaced during northeasterly storms in the early 1970's. The second attempt to stabilize the shoreline was instituted by the Naval Facilities Engineering Command in 1970. Three concrete and steel sheet pile groins were constructed on the beach fronting the naval facility and lighthouse. As shown in photo 1, the southernmost groin was located on the beach approximately 100 feet south of the lighthouse. Repairs were required immediately following construction to correct failures in the steel sheet pile portions of the groins. Additional repairs have been required since construction. In spite of the maintenance problems, the groins have been successful in stabilizing the shoreline fronting the lighthouse. Without the stabilizing effects of the groins, the shoreline would have continued to recede, allowing the ocean to endanger and, quite possibly, destroy the lighthouse.

Since 1965 the National Park Service has instituted several shore protection measures that indirectly provided some protection for the lighthouse. Specifically, NPS nourished the beach immediately north of the lighthouse in 1966, 1971, and 1972. The largest nourishment effort was in 1972 when 1.3 million cubic yards of sand were pumped from a borrow area at the Cape Hatteras Point to the beach north of the northernmost groin.

In March 1980 during a severe winter storm, the shoreline immediately south of and adjacent to the southernmost groin eroded to within 70 feet of the lighthouse. Taken during 1982, photo 2 shows the eroded condition south of the lighthouse. As a result of this erosion episode, strong public concern was expressed for the future security of the historic lighthouse with a consensus that NPS take action to provide immediate and long-term protection for the structure. Landward extensions of the southernmost groin in 1980 and 1982 provided immediate protection to the southern exposure of the

Photo 1 Groins at Cape Hatteras Lighthouse

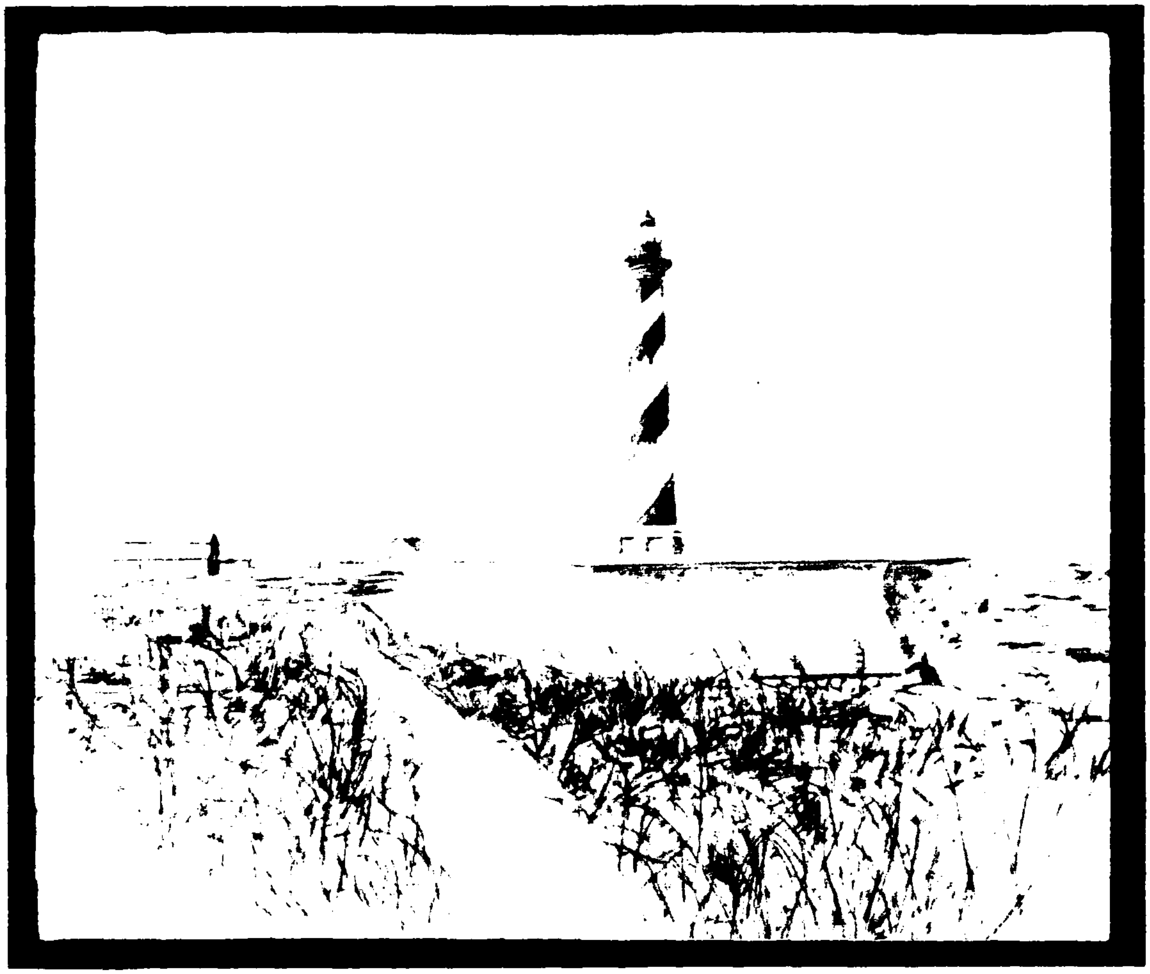
Photo 2 Eroded Condition South of South Groin

lighthouse. Additional protection was provided by NPS with placement of a sand-filled nylon bag revetment along the exposed area in 1982.

In July 1981 NPS requested Corps of Engineers assistance for developing a long-term protection plan for the lighthouse. The protection scheme selected by NPS consists of encircling the lighthouse with a wave reflecting seawall fronted by a rubblestone toe protection apron (see figure 2). The seawall and revetment project design is ongoing with construction scheduled for fiscal year 1986.

In order to ensure the protection of the lighthouse in the interim period prior to construction of the seawall and revetment, two protective measures have been undertaken. A rubblestone scour protection apron was constructed around the toe of the landwardmost 260 feet of the south groin (see photo 3). Constructed by the Corps in March 1983, the scour apron will ensure the continued existence of the functional portion of the groin. The groin's function of stabilizing the beach fronting the lighthouse is critical in the protection of the lighthouse foundation from shoreline erosion along the south flank.

The second interim measure consisted of installation of an artificial seaweed material called SEASCAPE®. The material was installed along lines extending 5,000 feet south from the south groin parallel to shore in 6 to 10 feet of water. This work was done independently of NPS or Corps of Engineers activities; however, because of the untested nature of this particular artificial seaweed product and the novel application of artificial seaweed as a shoreline stabilization measure in a high energy nearshore ocean environment, the Corps was employed by NPS to monitor and report the effectiveness of the SEASCAPE® installation. This report discusses the extent and results of the monitoring effort conducted over the period from October 1982 through February 1984.



PROPOSED SEAWALL FOR LONG TERM PROTECTION
OF CAPE HATTERAS LIGHTHOUSE

FIGURE 2

Photo 3 Construction of Scour Protection Apron Around South Groin

Study Area Environmental Conditions

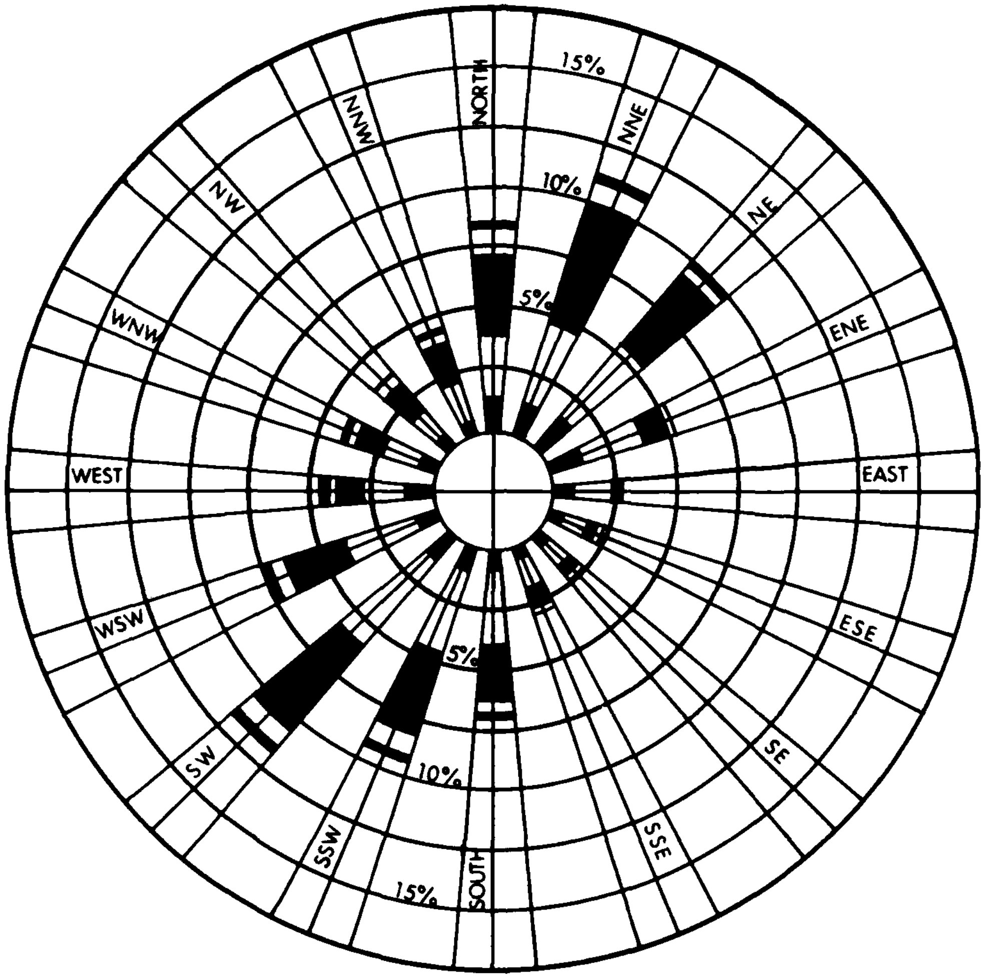
Winds. Surface wind data for Cape Hatteras is summarized in figure 3. As can be seen from this wind rose diagram, the predominant winds occur from the northeastern and southwestern quadrants, which is typical of the entire coastal region of North Carolina.

An indication of the frequency that severe windstorms occur at Cape Hatteras is contained in tables 1 and 2. These tables show the number of windstorms having a maximum wind velocity greater than 45 miles per hour.

According to the data, an average of four storms with wind velocities greater than 45 m.p.h. occur each year.

Waves. The best source of information for describing the wave climate at Cape Hatteras are the data available from the Wave Information Study (WIS) conducted at the Corps of Engineers' Waterways Experiment Station. The WIS Phase III hindcast data provides wave height, period, and direction for 166 U.S. Atlantic coast locations based on 20 years of meteorlogical data. Tables 3 and 4 show monthly mean significant wave heights and maximum significant wave heights for the 20 years of hindcast data. Mean wave height for Cape Hatteras is 2.2 feet (0.68 meter). The maximum wave height from the 20-year record is 16.7 feet (5.1 meters). The wave height and direction rose in figure 4 shows that the largest waves approach the shoreline from the northeast quadrant.

Water Levels. Ocean water level variations at Cape Hatteras are the result of astronomical and wind-driven effects. Astronomical tides are semi-diurnal and have a mean and spring range of 3.4 and 4.1 feet, respectively. Windstorm tides at Cape Hatteras can be significant during winter storms. Wave and water overwash are fairly common during these extratropical storms ("Northeasters").



LEGEND


WIND SPEED VS DIRECTION
FOR CAPE HATTERAS, N. C.

(1955-1964)

FIGURE 3

TABLE 1

DATA ON NUMBER OF WINDSTORMS
ABOVE 45 MILES AN HOUR, BY MONTHS
(1914-1965)

Month	Number of Storms With Winds Over 45 Miles Per Hour: Total	Number of Storms With Winds Over 45 Miles Per Hour: Average Times Per Year	Average Wind Velocity m.p.h.)
January	23	0.44	51
February	25	0.48	53
March	26	0.50	54
April	19	0.37	50
May	9	0.17	49
June	5	0.10	50
July	10	0.19	52
August	19	0.37	55
September	20	0.38	62
October	14	0.27	51
November	22	0.42	53
December	16	0.31	53
Total	208	4.00	

TABLE 2

DATA SHOWING NUMBER AND DIRECTION OF WINDSTORMS
OF OVER 45 MILES AN HOUR (1914-1965)

Item	Direction: N	NE	E	SE	S	SW	W	NW	Total
Number of Storms	45	13	3	16	12	26	25	68	208
Average Per Year	0.86	0.25	0.06	0.31	0.23	0.50	0.48	1.31	4.00
Percent of Total	22	6	1	8	6	12	12	33	100

TABLE 3

LARGEST SIGNIFICANT WAVE HEIGHTS (FEET) BY MONTH
AND YEAR AT CAPE HATTERAS, N.C. (FROM WIS (1))

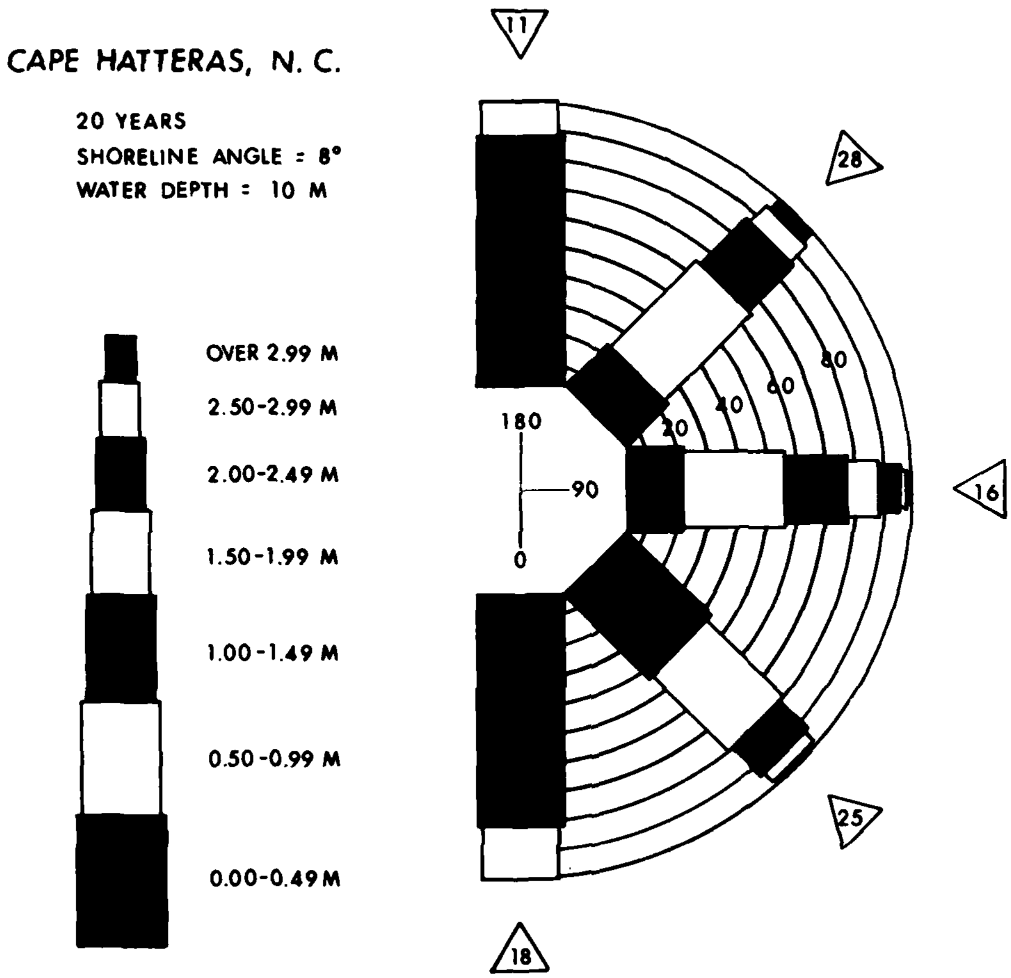
	MONTH											
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1956	9.8	6.9	5.6	7.9	7.5	6.9	3.9	4.9	7.9	14.4	10.2	5.9
1957	7.9	9.2	7.5	7.2	7.2	8.5	4.9	7.9	7.9	10.2	7.2	7.2
1958	7.5	7.2	7.9	9.8	6.9	4.3	3.0	6.6	6.9	12.8	8.2	9.5
1959	5.6	7.5	7.5	7.9	4.3	3.3	6.9	4.6	7.2	8.9	6.6	7.9
1960	10.2	11.8	8.2	6.9	6.9	4.9	6.2	7.2	6.9	7.5	7.5	8.9
1961	6.6	10.5	8.9	7.9	6.9	6.6	4.9	5.9	9.2	9.2	6.9	7.2
1962	8.2	7.9	16.7	6.9	4.3	8.5	7.9	7.2	8.2	9.2	15.1	13.8
1963	6.6	10.2	6.6	7.9	6.2	8.5	3.0	3.3	8.2	11.5	6.9	8.5
1964	9.5	7.2	6.9	7.5	10.2	6.6	4.6	7.2	9.8	9.8	8.5	7.9
1965	5.6	8.2	6.6	5.2	3.3	6.9	7.2	4.3	7.5	9.8	4.9	4.9
1966	10.5	8.2	7.2	4.9	5.6	10.2	4.9	5.6	7.9	8.5	7.2	8.2
1967	7.2	8.2	4.9	6.6	7.9	8.5	4.6	4.9	7.9	5.2	6.2	8.5
1968	10.2	8.5	6.6	4.9	7.2	3.0	2.6	3.9	2.3	5.6	5.2	7.2
1969	8.5	11.2	8.5	4.9	6.9	4.9	4.3	4.6	7.9	8.5	11.8	8.9
1970	8.9	8.2	7.5	6.6	6.6	8.2	4.6	7.2	3.6	10.8	9.2	8.9
1971	7.2	7.2	9.5	8.2	7.2	4.3	7.9	7.5	10.8	10.8	7.5	9.5
1972	7.5	9.2	6.6	5.9	10.8	7.9	6.6	5.2	6.6	8.2	8.5	7.5
1973	8.5	12.8	8.9	6.6	6.6	5.2	2.6	3.3	5.6	6.6	5.9	11.8
1974	7.5	8.2	7.5	5.2	4.6	4.3	2.6	3.3	7.9	7.2	7.5	8.9
1975	7.9	8.5	8.5	6.2	3.0	5.9	10.2	3.0	7.2	6.6	8.2	6.9

LARGEST WAVE HEIGHT FOR CAPE HATTERAS = 16.7 FT.

TABLE 4

MEAN SIGNIFICANT WAVE HEIGHTS (FEET) BY MONTH
AND YEAR FOR CAPE HATTERAS, N.C. (FROM WIS (1))

	MONTH												
YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	MEAN
1956	3.0	2.3	2.0	2.0	2.3	2.6	1.6	1.6	2.6	5.2	5.2	2.6	2.6
1957	2.3	3.0	2.6	1.6	2.3	2.0	1.6	2.0	2.0	3.6	2.3	2.3	2.3
1958	2.0	1.3	2.3	3.0	2.0	1.6	1.3	2.0	2.0	4.6	2.3	3.0	2.3
1959	1.6	2.6	2.3	2.0	1.6	1.0	2.0	1.3	2.6	3.0	3.0	2.3	2.0
1960	2.0	2.6	2.3	2.0	2.3	2.3	2.0	2.0	3.0	2.3	2.3	2.0	2.3
1961	1.6	2.6	3.0	2.0	2.6	2.0	1.0	2.0	2.6	3.3	2.0	1.3	2.3
1962	2.6	3.0	3.6	2.0	2.0	2.3	2.6	2.3	2.3	2.3	3.9	4.9	3.0
1963	2.3	3.6	2.0	1.3	2.3	1.6	1.0	1.3	3.3	3.9	1.6	1.6	2.3
1964	2.3	1.6	2.0	2.3	2.3	1.6	2.0	2.3	4.3	6.6	5.2	4.3	3.0
1965	3.0	2.6	2.3	2.0	1.3	2.0	1.6	1.3	2.6	3.3	2.3	1.3	2.3
1966	2.6	2.6	2.0	1.6	2.3	2.3	1.6	2.0	2.0	3.0	3.6	3.0	2.3
1967	2.0	2.3	2.6	2.0	2.3	3.0	1.6	2.3	3.3	2.3	1.6	2.3	2.3
1968	3.3	2.3	1.3	1.6	1.3	1.0	0.7	0.7	0.7	1.3	1.0	1.3	1.3
1969	2.6	3.3	2.0	2.0	2.3	1.6	1.3	2.3	3.0	3.6	3.0	1.6	2.3
1970	2.0	3.3	2.3	2.3	2.0	2.0	2.0	1.6	1.3	3.9	3.0	2.0	2.3
1971	2.0	2.0	2.0	1.6	1.6	1.0	2.0	2.3	3.0	3.9	2.6	3.9	2.3
1972	2.3	3.0	2.3	2.0	3.3	2.3	1.6	2.0	2.3	3.6	2.6	2.3	2.6
1973	2.3	3.6	3.3	1.6	1.6	1.6	0.7	1.0	1.3	2.6	1.3	3.3	2.0
1974	2.0	2.3	2.0	1.6	1.0	1.0	0.7	1.0	1.6	2.0	1.6	1.6	1.6
1975	2.0	3.0	2.0	1.3	1.0	1.3	2.3	0.7	2.0	2.0	2.0	2.3	2.0
MEAN	2.3	2.6	2.3	2.0	2.0	1.6	1.6	1.6	2.3	3.3	2.6	2.6	



WAVE HEIGHT AND DIRECTION ROSE FOR CAPE HATTERAS, N. C. (From WIS[1])

FIGURE 4

The SEASCAPE® Product

The synthetic seaweed material SEASCAPE® was developed and is marketed by SEASCAPE® Technology, Inc., of Greenville, Delaware. Each unit is constructed of spunbonded polypropylene Typar® fabric and consists of a 5-foot-long anchor tube with 2-inch-wide, 4-foot-long fronds attached. The anchor tube is filled with sand or gravel to provide a gravity anchoring system upon installation. Photo 4 shows a SEASCAPE® unit in an aquarium with positively buoyant foam sewn to the ends of each frond so the fronds will float vertically in the water column.

Photo 4 SEASCAPE® Unit in Aquarium (REF.3)

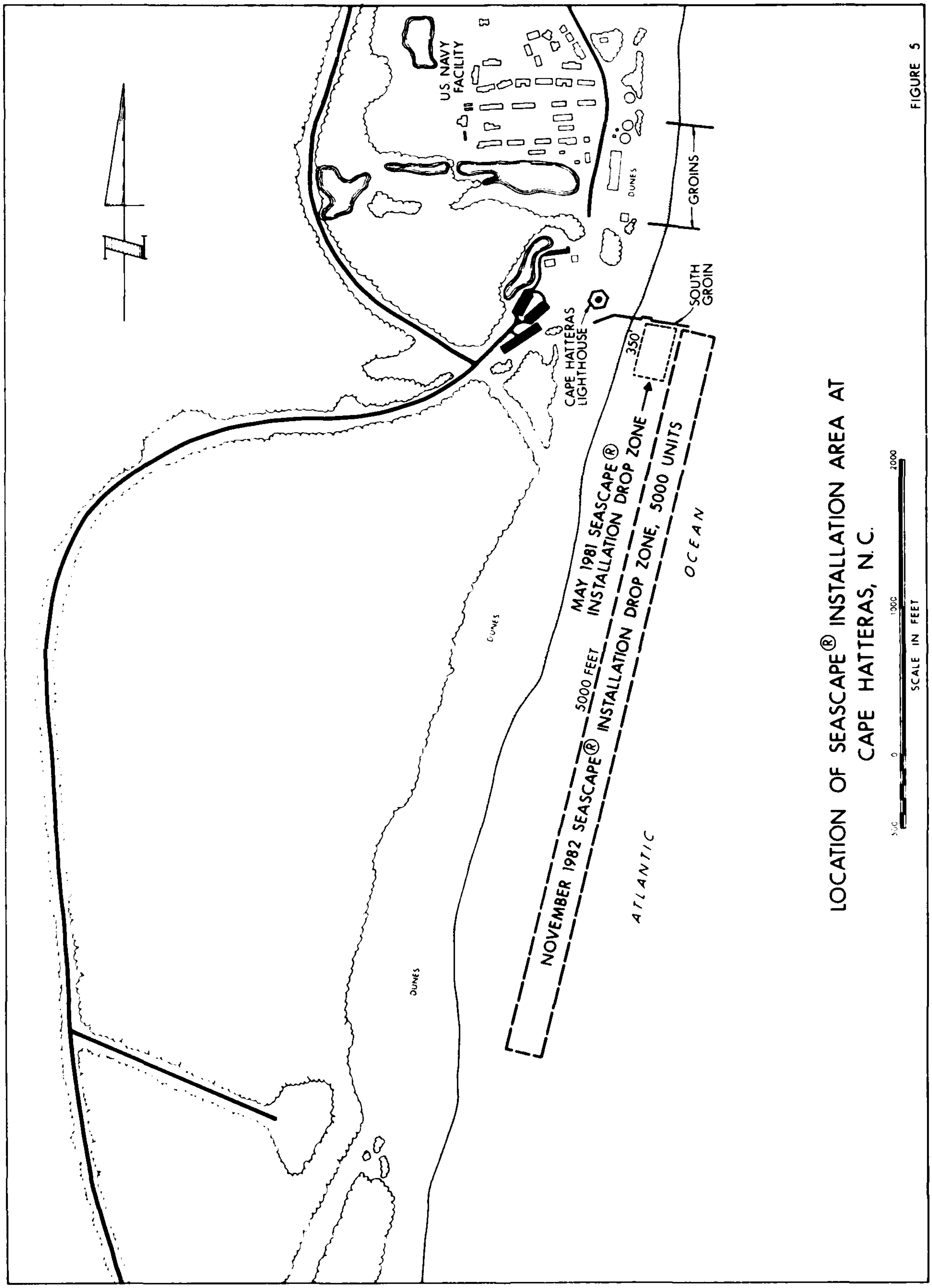
The intended function of the artificial seaweed is to reduce the speed of sand-bearing currents, allowing sand to settle and accumulate in the vicinity of the seaweed material. With this mechanism in mind, SEASCAPE® was placed in the nearshore zone at Cape Hatteras Lighthouse in several shore-parallel rows approximately 1 mile long. The installation was based on the premise that the accumulation of sand around the SEASCAPE® would build an offshore sandbar. Wave energy would be dissipated causing the beach inshore of the SEASCAPE® to accrete or erode at a rate much less than normal.

SEASCAPE® Installation at Cape Hatteras Lighthouse

First Installation. The artificial seaweed material SEASCAPE® was installed in the ocean adjacent to Cape Hatteras Lighthouse on two separate occasions. The first installation was a demonstration project by the product manufacturer, Seascape Technology, Inc., in which the SEASCAPE® material and installation was provided at no cost to the NPS or the Committee to Save the Lighthouse. During May 6, 8, and 9, 1981, five hundred SEASCAPE® units were installed in five shore-parallel rows in approximately 4 to 7 feet of water. As shown in figure 5, the installation zone extended south from the southernmost groin a distance of approximately 350 feet. No survey control information or construction drawings are available for the installation, so the exact location and dimensions of the drop zone are unknown.

The first installation took place during a mild northeaster with 35 m.p.h. winds and 5-foot seas. The anchor tubes were filled with sand on the beach and hauled to the water's edge with a front loader. The units were then strapped to surfboards and hauled to the offshore drop zone marked in the water by buoys.

Second Installation. Following the first installation of SEASCAPE®, there was significant buildup of the beach south of the south groin. This buildup is described in the report prepared for SEASCAPE® Technology, Inc. (2) Because of the apparent success of the first installation of SEASCAPE® and



LOCATION OF SEASCAPE® INSTALLATION AREA AT CAPE HATTERAS, N.C.

FIGURE 5

the attendant media coverage, there was strong desire for a second, much larger installation for protection of the lighthouse.

The second installation took place between October 18 and November 12, 1982, and, as mentioned previously, was sponsored by the Committee to Save the Lighthouse. On a much larger scale than the May 1981 demonstration project, the November 1982 installation involved the placement of 5,000 SEASCAPE® units in 5 shore-parallel rows approximately 10 feet apart. The drop zone was in 6 to 10 feet of water and extended south 5,000 feet from the south groin (see figure 5). No horizontal control information or construction drawings are available for the second installation; accordingly, the exact locations of the various units is not known.

The anchor tubes were filled with sand hauled to the village of Hatteras, N.C. The sand filled SEASCAPE® units were then transported to the drop zone out of Hatteras Inlet aboard the fishing trawler shown in photo 5. Each unit was released into the drop zone marked by buoys by sliding down a chute mounted on the stern of the trawler (see photo 6).

SEASCAPE® Monitoring Methods and Results

Scope

The program for monitoring the performance of SEASCAPE® at Hatteras Lighthouse was developed by the Wilmington District in cooperation with the Coastal Engineering Research Center, Field Research Facility (FRF) at Duck, N.C. The monitoring program was designed and implemented to address the following basic questions:

1. Did the installation of SEASCAPE® artificially stabilize the stretch of shoreline where it was placed? Were changes in the plan form of the beach that occurred during the period following installation of SEASCAPE® directly attributable to SEASCAPE®?

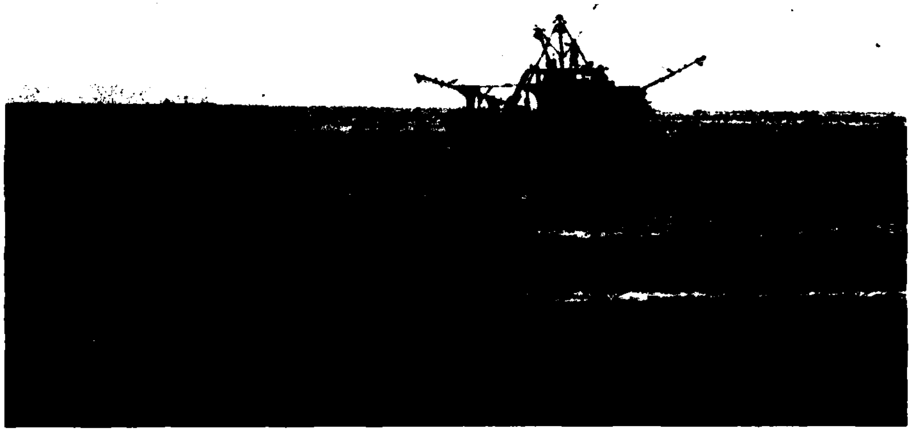


Photo 5 Trawler Used to Place SEASCAPE® at Cape Hatteras

Photo 6 Placement of SEASCAPE® Off Stern of Trawler (REF.3)

2. Did the presence of SEASCAPE® noticeably result in any specific zones of stability in the offshore zone?

3. Did the material remain in place following installation? How did the SEASCAPE® material perform in terms of methods of placement, anchoring method, and material strength and durability?

A program consisting of quarterly aerial photography, low altitude oblique photography, ground photography, reconnaissance dives, and beach profile surveys was combined to provide a generalized evaluation of SEASCAPE® performance.

The initial monitoring plan was implemented in October 1982 during the initial stages of the second and most extensive SEASCAPE® installation at the lighthouse. Dates of the specific monitoring activities are provided in table 5. Figure 6 provides a graphic chronology of the monitoring activities. The initial plan proved to be insufficient in terms of providing information on whether the SEASCAPE® units remained in place and whether the SEASCAPE® affected and stabilized the beach profile by forming and maintaining an offshore sandbar. In January 1983, the monitoring program was revised to include beach profile surveys of the installation zone and a more quantitative diving plan. In all, FRF personnel made seven field visits to the study area. Diving, beach profile survey, and ground photography data were collected during each visit and supplied to the Wilmington District. The monitoring was terminated at the end of calendar year 1983.

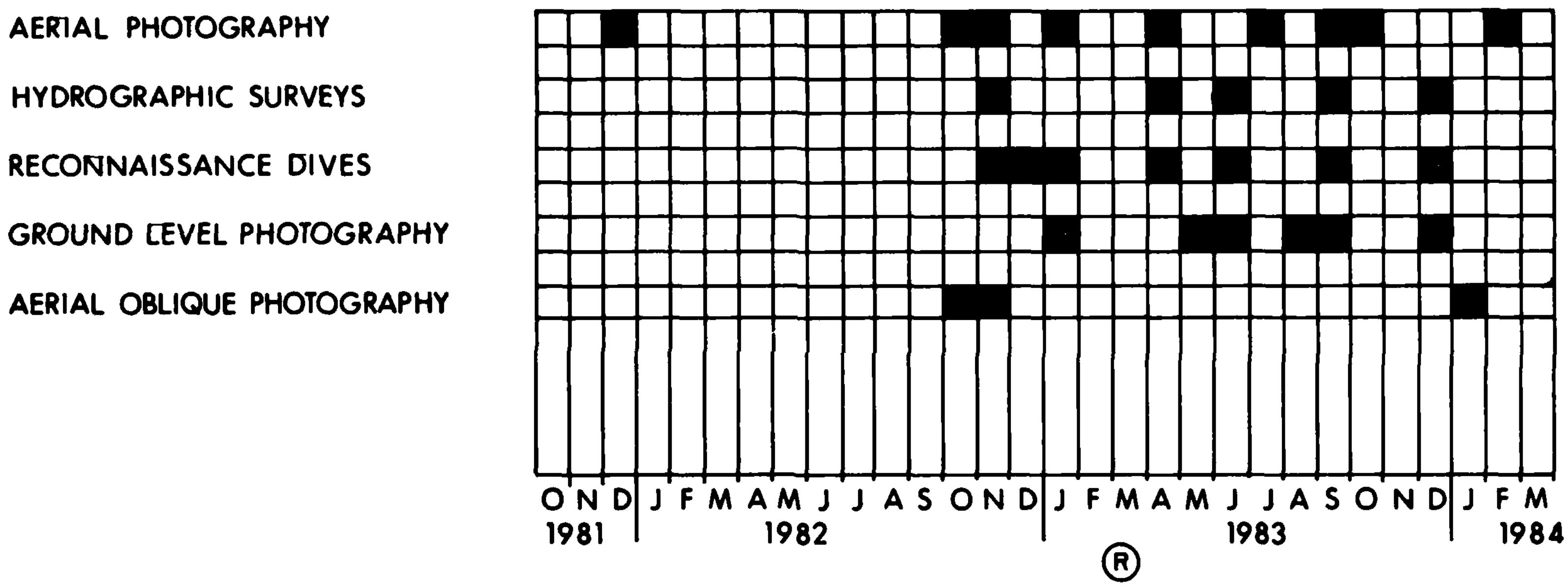
Definitions of the beach features and items used in discussion of the monitoring activities are presented in figure 7.

TABLE 5

DATES OF SEASCAPE® MONITORING
ACTIVITIES AT CAPE HATTERAS LIGHTHOUSE

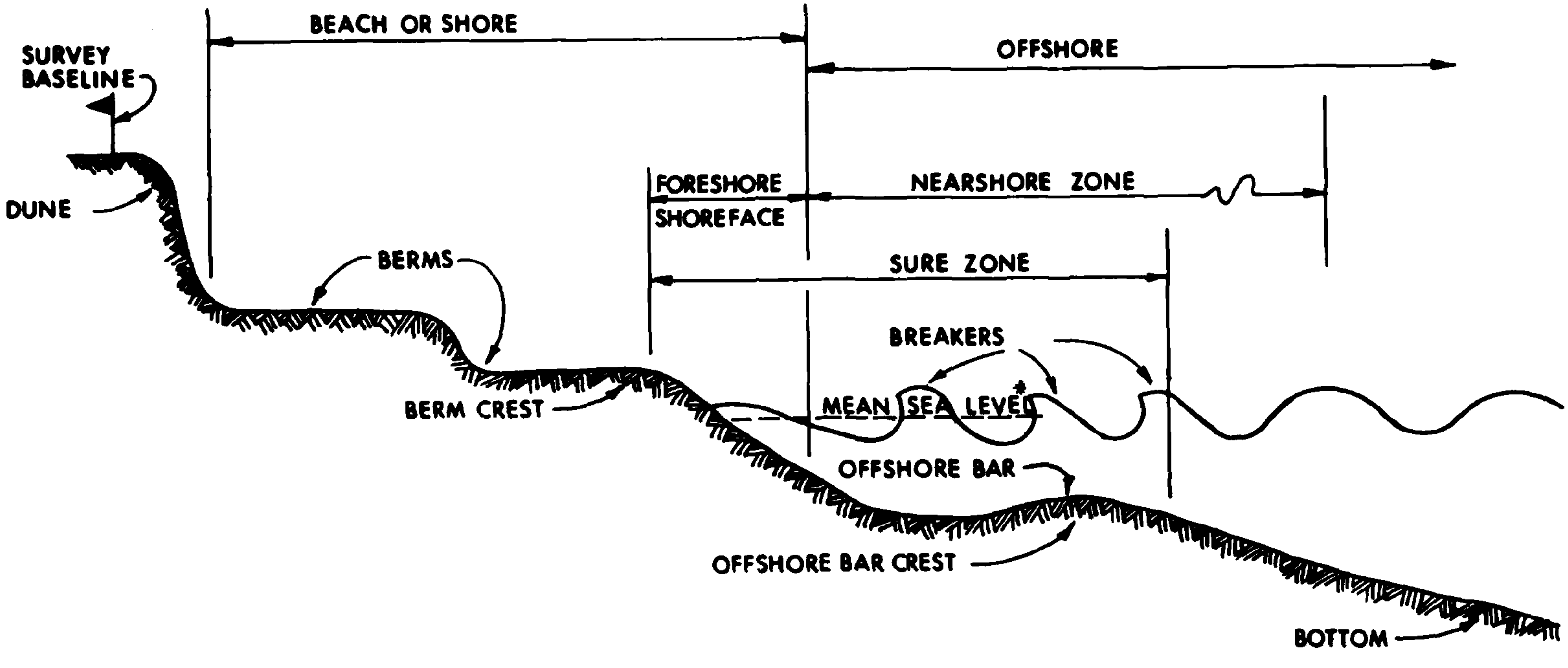
AERIAL PHOTOGRAPHY	BEACH PROFILE SURVEYS	UNDERWATER OBSERVATIONS	GROUND LEVEL PHOTOGRAPHY	AERIAL OBLIQUE PHOTOGRAPHY
DEC 81	NOV 82*	NOV 2, 82	JAN 25, 83	OCT 15, 82
OCT 27, 82	APR 27, 83	NOV 30, 82	JUN 27, 83	NOV 18, 82
NOV 24, 82	JUN 27, 83	JAN 25, 83	SEP 1, 83	JAN 12, 84
JAN 26, 83	SEP 1, 83	APR 27, 83	DEC 4, 83	
APR 27, 83	DEC 8, 83	JUN 27, 83		
JUL 8, 83		SEP 1, 83		
SEP 83		DEC 8, 83		
DEC 3, 83				
FEB 1, 84				

*Initial survey by Wilmington District Survey Vessel; all others by CERC sea sled.



CHRONOLOGY OF SEASCAPE MONITORING ACTIVITIES AT CAPE HATTERAS LIGHTHOUSE

FIGURE 6



* MEAN SEA LEVEL - NATIONAL GEODETIC VERTICAL DATUM OF 1929 (NGVD)

BEACH PROFILE — RELATED TERMS

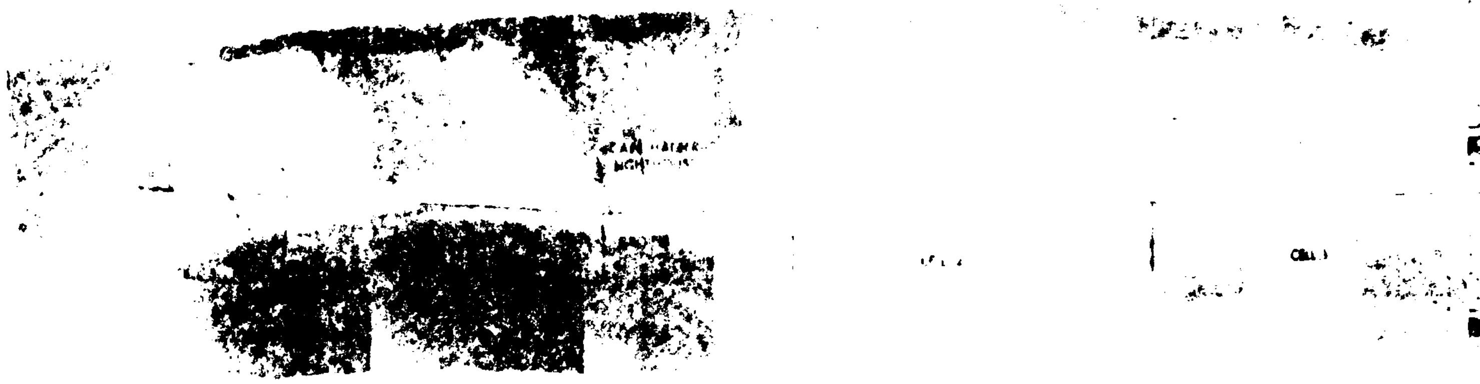
FIGURE 7

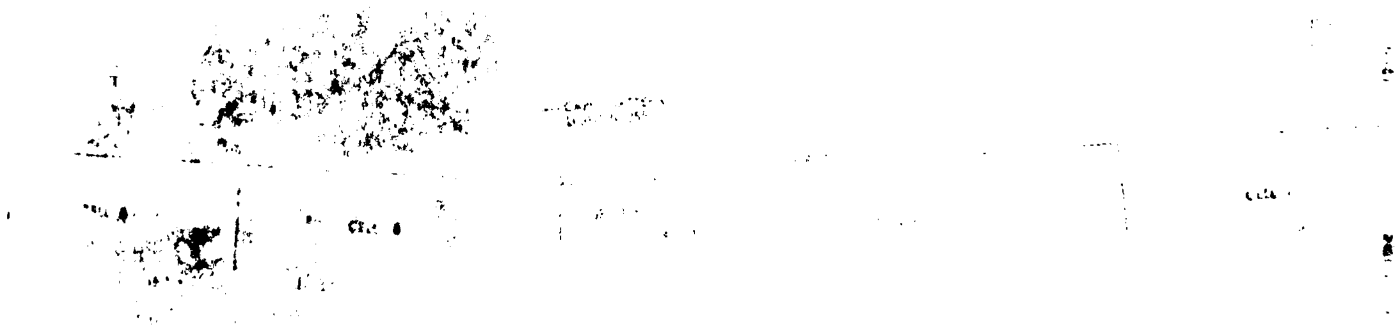
Aerial Photography

General. A time series of aerial photography was assembled for the shoreline south of Avon, N.C., to Cape Hatteras Point. The photography was used to obtain a quantitative evaluation of shoreline movement within the study area. The study area was defined as the reach of shoreline starting at a point four miles north of Cape Hatteras Lighthouse and extending to the Cape Point. The collection of photography consisted of photography on hand in the Wilmington District and photography obtained during and specifically for the monitoring effort.

Method of Analysis. Color and black and white 9x9 inch consecutive vertical aerial photographs with a nominal scale of 1 inch equals 1,000 feet and 60 percent overlap between photographs were collected for nine overflights ranging in time from December 1981 to February 1984 (see table 5). Consecutive photos for each flight were assembled into uncontrolled aerial mosaics by matching image details in adjoining photographs. In order to minimize tilt distortion, only the middle 50 percent of each frame was used to construct the mosaics.

The December 1981 aerial mosaic in figure 8 shows the study area divided into five segments denoted as cells 1 through 5. Each cell is defined by a shore-parallel baseline and perpendicular boundaries at ground points identifiable on each set of mosaics. Cells 1 and 2 are shoreline segments outside the direct influence of the groin field. Cell 3 includes the groin field and the shoreline immediately north of the groins. Cells 3 and 4 are the areas of specific interest in this study. As shown in figure 8, this reach of shoreline is directly affected by the groin field and the SEASCAPE® installation which is located offshore in cell 4. The Cape Hatteras Point area is contained in cell 5 and is the termination of a large-scale littoral cell reaching some 40 miles from Oregon Inlet (see figure 1).





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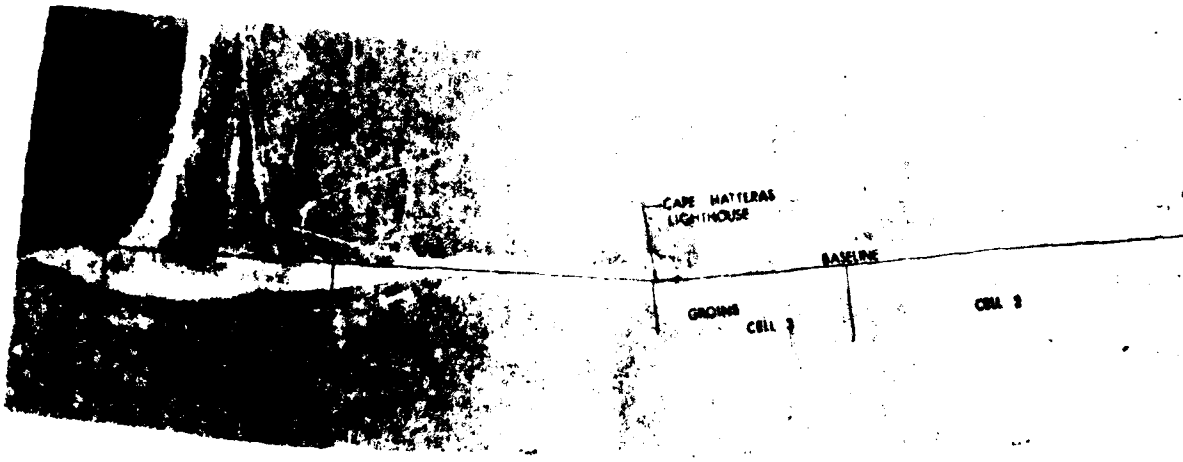


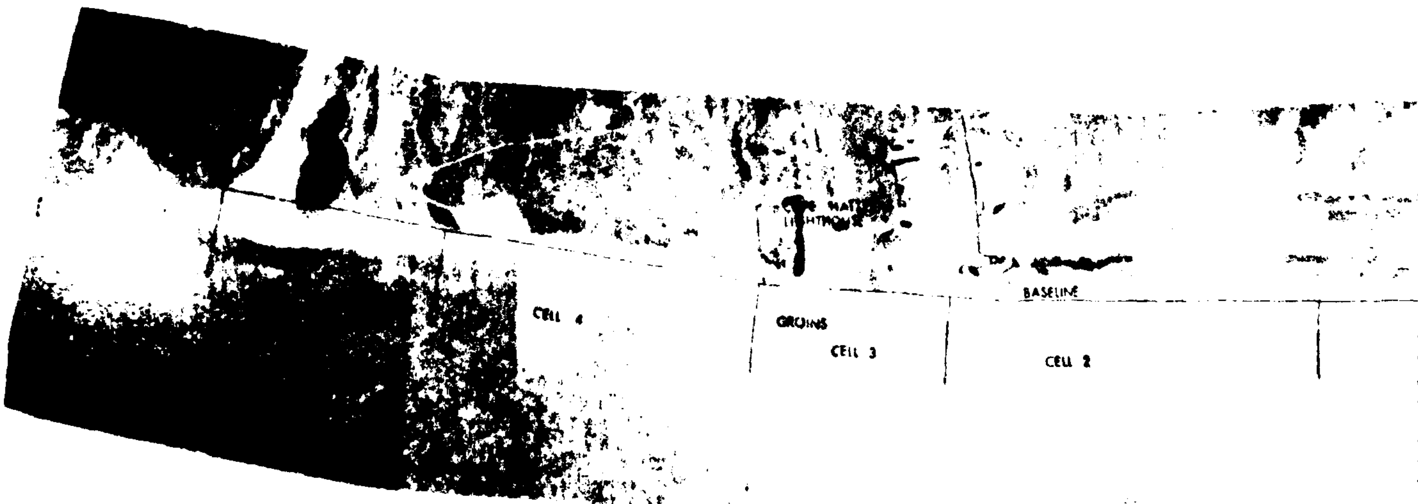
CAPE HATTERAS SHORELINE

PHOTO DATE JANUARY 26 1983

[illegible] 1000 2000 [illegible]

[illegible] IN FEET

FIGURE [illegible]



CAPE HATTERAS SHORELINE

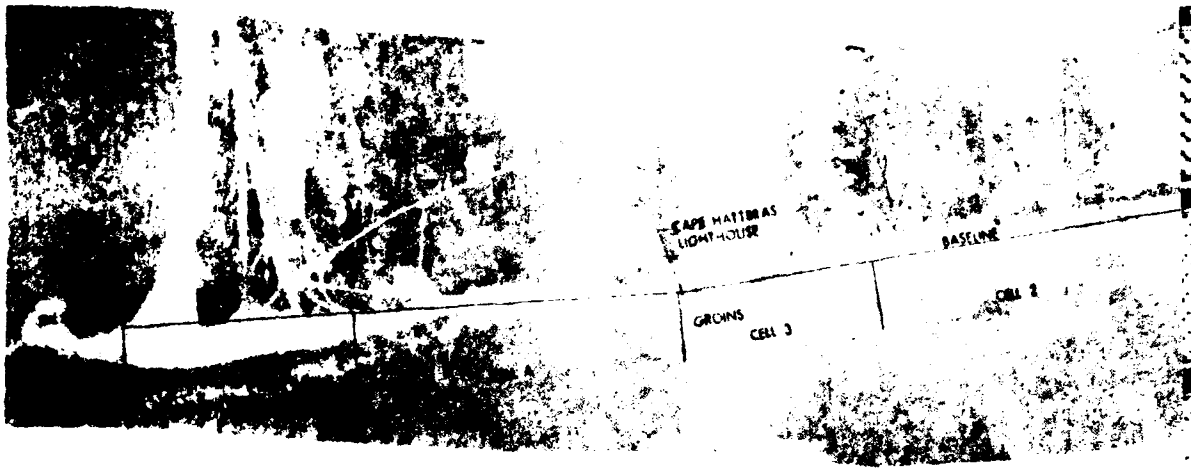
[illegible] APR[illegible] 1983

[illegible]

TERAS SHORELINE

DATE JANUARY 26 1983

TERAS SHORELINE



CAPE HATTERAS SHORELINE

PHOTO DATE JULY 8 1983

FIGURE 13

CAPE HATTERAS SHORELINE

[illegible] DATE SEPTEMBER [illegible]

TTERAS SHORELINE

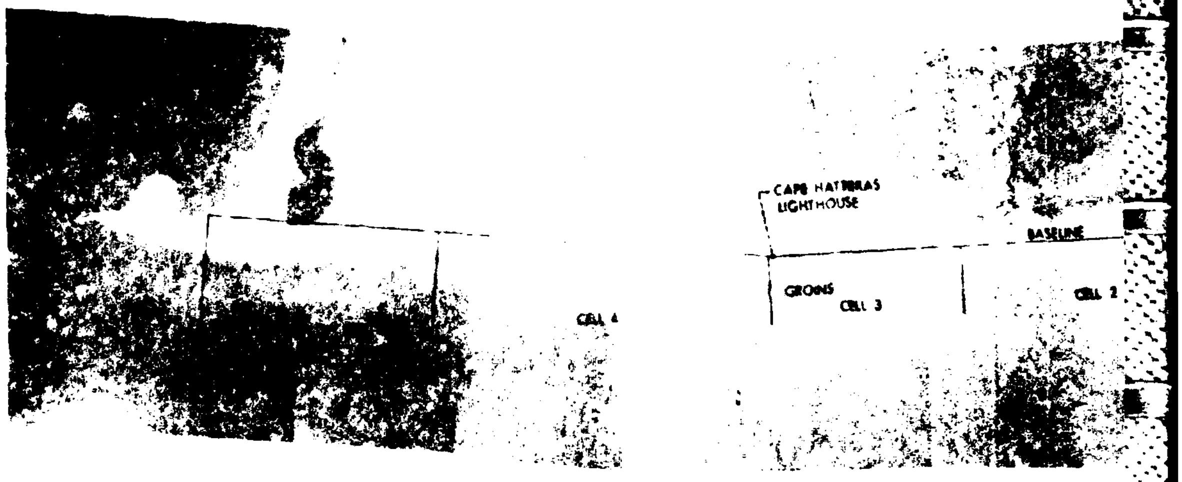
DATE [illegible] 983

[illegible]

ERAS SHORELINE

[illegible] SEPTEMBER [illegible]

[illegible]

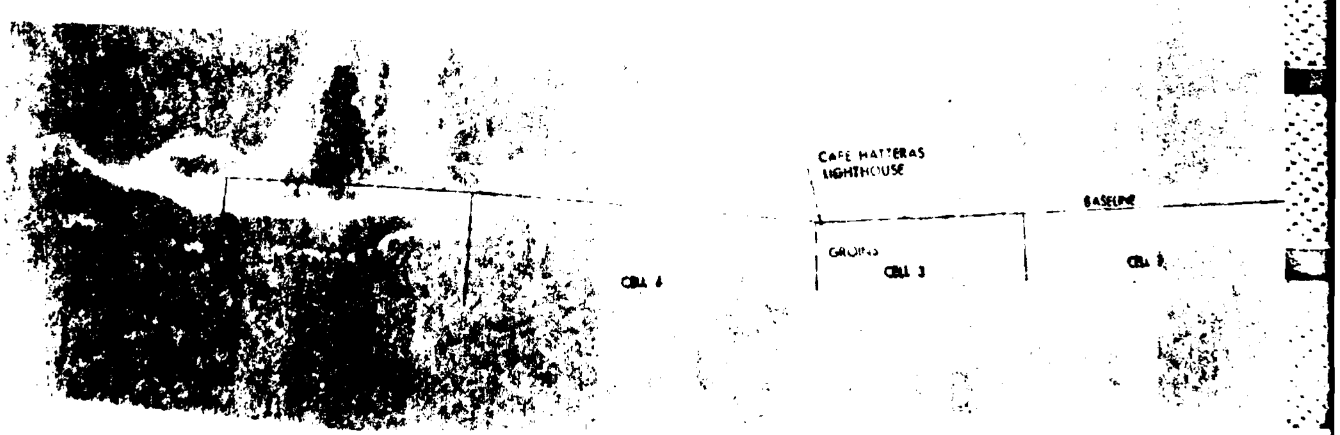


CAPE HATTERAS SHORELINE

PHOTO DATE OCTOBER [illegible]

SCALE IN FEET

FIGURE 15



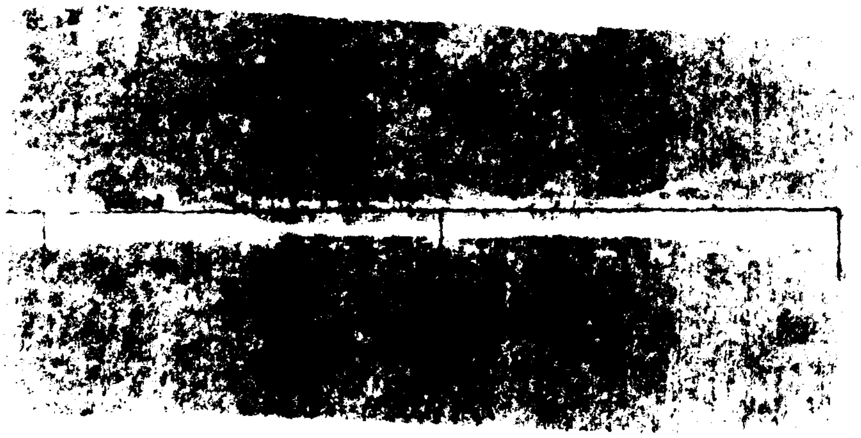
CAPE HATTERAS SHORELINE

PHOTO DATE [illegible]

FIGURE 16

…TERAS SHORELINE

DATE OCTOBER [illegible] 1983



…TERAS SHORELINE

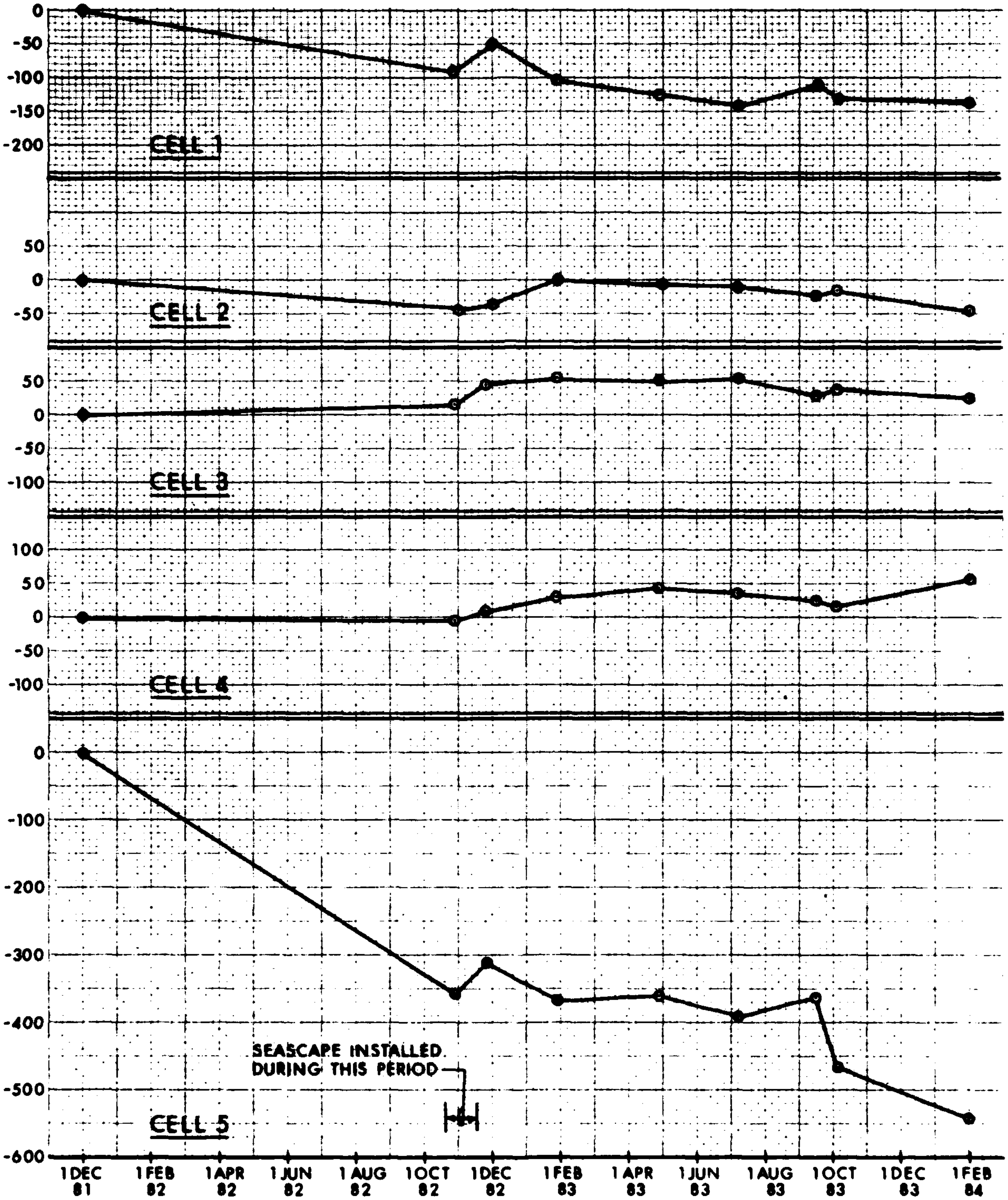
DATE FEBRUARY 1984

Changes in shoreline plan form were analyzed for each of the 5 cells in the study area. Shoreline changes were described in terms of the average shoreline position in each cell determined by dividing the area between the baseline and high water line within the cell boundaries by the length of the cell.

Results. Measurement of shoreline positions on the nine sets of aerial mosaics used in this study results in a series of instantaneous shoreline positions which, when plotted versus time for each shoreline cell in figure 17, provide a picture of the erosion accretion trends for different sections of the study area shoreline. Figures 8 through 16 are the aerial mosaics used in this study. Examination of this sequence of aerial photos shows the small-scale shoreline changes not detectable by the quantitative method used to produce figure 17.

The plotted data in figure 17 reveals that, with the exception of the shoreline segments directly affected by the groin field, there is an overall trend of erosion in the study area over the period December 1981 to February 1984. The shoreline segments affected by the groins, cells 3 and 4, experienced a slight accretionary trend during the study period amounting to an average buildup of the shoreline of 25 to 60 feet, respectively.

During and immediately following the installation of SEASCAPE® in October and November 1982, an accretionary trend is apparent over the entire study area. The result is an average buildup of the beach in the study area of 25 feet. Close examination of figures 8 through 13 (Oct 82 through Jul 83) shows a progressive buildup in the southerly direction of the shoreline immediately south of the south groin. This is accompanied by general filling of the shoreline segment between and immediately north of the groins. However, during the accretionary period in cells 2, 3, and 4, the shoreline not directly affected by the groins, cells 1 and 5, experienced a period of fairly rapid erosion amounting to an average shoreline retreat of 80 feet.



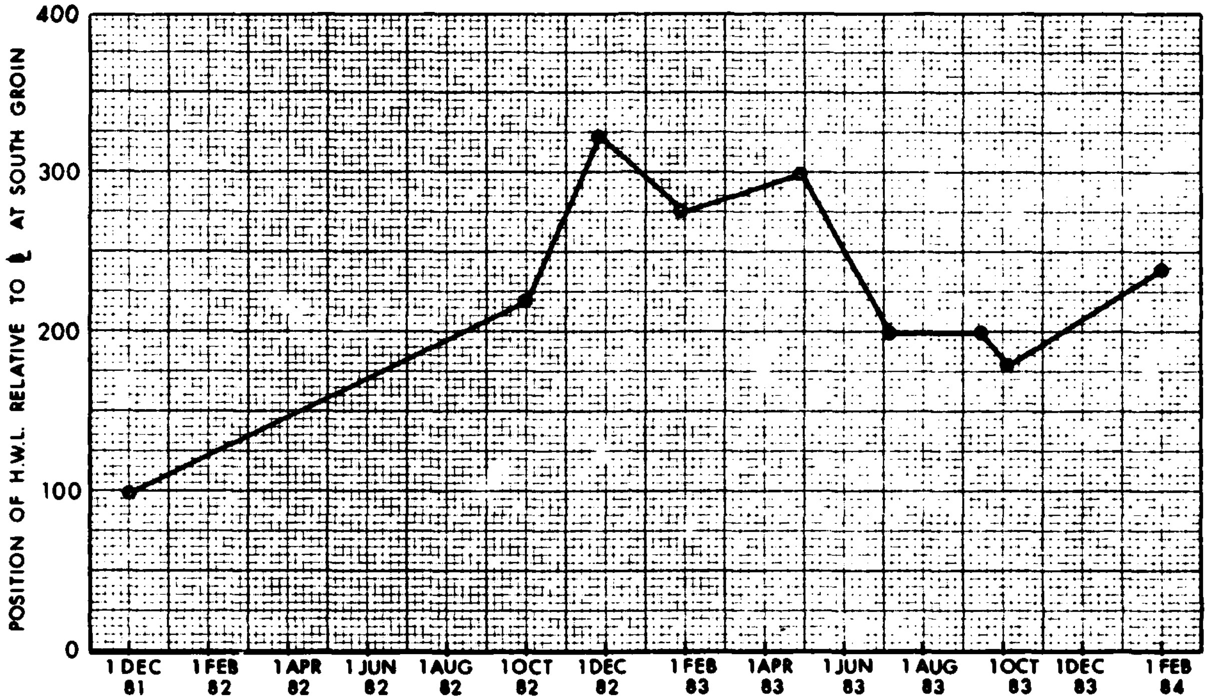
AVERAGE SHORELINE POSITIONS IN EACH
STUDY AREA CELL, DECEMBER 1981 TO FEBRUARY 1984
(FROM AERIAL PHOTOGRAPHS)

FIGURE 17

In the period July 1983 to September 1983 (figures 13 and 14), the shoreline immediately south of the south groin eroded significantly to nearly the October 1982 position (figure 9). Through the end of the study period, the erosion trend reversed and the area accreted to the February 1984 position (see figure 16). From July 1983 through February 1984, the overall trend in cell 4 was accretionary amounting to an average gain of 40 feet. Over the same period, the shoreline position in cells 1, 2, and 3 did not change significantly, but the Cape Point area (cell 5) eroded an average of 150 feet.

The trends made apparent in the analysis of the sequence of aerial photographs indicate that the groin field is the most influential element affecting shoreline stability in the vicinity of the lighthouse. The shoreline directly affected by the function of the groins, cells 3 and 4, acts contrary to trends along the remainder of the study area. Except for the October and November 1982 period when the entire study area shoreline built up simultaneously, the analysis shows that an accretionary trend along the groin-influenced shoreline is accompanied by erosion of adjacent shoreline reaches.

Changes in the shoreline position immediately south of the south groin, the area of specific interest in this study, are plotted in figure 18. The position of the shoreline at the south side of the groin measured from the baseline is plotted for each aerial photo date. Comparison with the plots in figure 17 for cells 3 and 4 shows a direct correlation between buildup in the area south of the groin with accretion of the entire shoreline affected by the groin field. This favorable shoreline condition has generally existed throughout the history of the groin field and its attendant impacts on shoreline configuration, with the singular exception of the condition generated by the March 1980 storm which induced a rapid and major temporary retreat of the beach immediately adjacent to and south of the southernmost groin. The fact that the immediate shoreline reach south of the groin field is favorably affected by the groin structures can be attributed to several factors. First, the groin field site is along a section of shore which



SHORELINE POSITION SOUTH OF SOUTH GROIN
AT CAPE HATTERAS DECEMBER 1981 TO FEBRUARY 1984
(FROM AERIAL PHOTOGRAPHS)

FIGURE 18

experiences a large volume of littoral transport ranging in magnitude to 1.5 million cubic yards per year and moving predominantly from north to south. This high volume of sediment transport is very large by comparison to the entrapment capacity of the 3-groin structures comprising the existing field, particularly on considering that the outer sections of the groin have been significantly damaged over time and that considerable quantities of littoral sediments pass through the groin system in a southerly direction. Additionally, the inner portions of the groins, extending landward from the high water line are low relative to the subaerial beach profile. This has allowed for passage of sediment through the inner portions of the groin field. Transport through the groin field is evidenced by a continuous beach berm and foreshore slope from north to south through the groin field, and the general absence of the saw-tooth pattern of upcoast accretion and downcoast erosion adjacent to groins which characterizes high groin structures. In regard to the effects of the March 1980 storm, causes of the anomalous rapid retreat of the shore immediately south of and adjacent to the southern groin are indeterminant but, in all probability, those causes were associated with the particular wave characteristics and wave direction generated by the storm. In any case, the storm also further damaged the outer portion of the southern groin and left a substantial gap between the inner and outer sections of the south groin structure. This structural gap serves as an excellent passageway for littoral sediments moving southward from the center - south groin compartment to the shore immediately south thereof. In return, the remaining outer section of the southern groin acts to diffract the predominant waves from the north to east ocean sector, resulting in a localized wave pattern which serves to accumulate sediments south of and adjacent to the southern groin.

Beach Profile Surveys

General. Analysis of beach profiles collected in the study area focuses on changes in the offshore zone where the SEASCAPE® material was placed. The exact location of the SEASCAPE® installation is unknown in terms of the distance of the installation zone from any horizontal control which could be related to the baseline control used in the profile surveys in this study. Therefore, it is impossible to determine the exact locations of the installed SEASCAPE® units on the profile surveys and study the dynamics of those specific areas in the offshore zone. Accordingly, this study looks at the behavior of the offshore profiles in an effort to identify features or zones which exhibit any singular behavior which might be attributable to SEASCAPE®.

Profile Surveys and Analysis. The beach profile surveys were a byproduct of the revised diving plan implemented in April 1983. A method was needed to record the location of any SEASCAPE® units discovered by divers as they searched the ocean bottom along preselected profile lines. The small sea sled shown in photo 7 was built by FRF personnel. The sled was towed by an inflatable boat along each profile line while a Zeiss electronic survey system recorded the horizontal location and elevation of a reflecting prism mounted atop a mast rigged to the sled (see photo 7).

The SEASCAPE® units were placed in approximately 6 to 10 feet of water along a reach of shoreline extending 5,000 feet south of the south groin. Five beach profile stations were selected at locations established by a November 1982 Wilmington District survey. Four profile lines, stations 10+00, 20+03, 35+19, and 50+56, were reestablished over the SEASCAPE® placement zone. A fifth profile line, station 60+81, was reestablished south of the installation zone to provide a comparison with the profiles that crossed the installation zone. Profile locations are shown relative to the survey baseline and SEASCAPE® installation on figure 19.

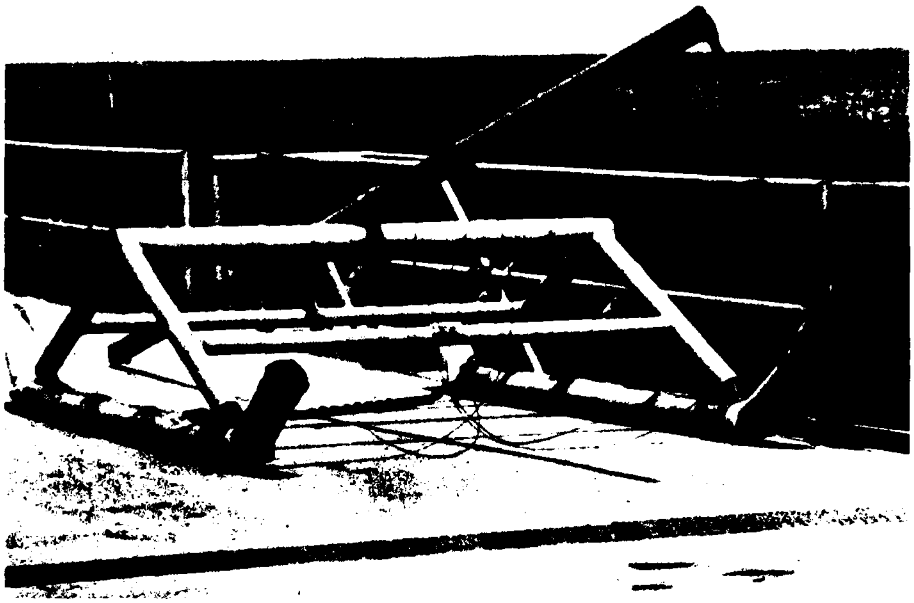
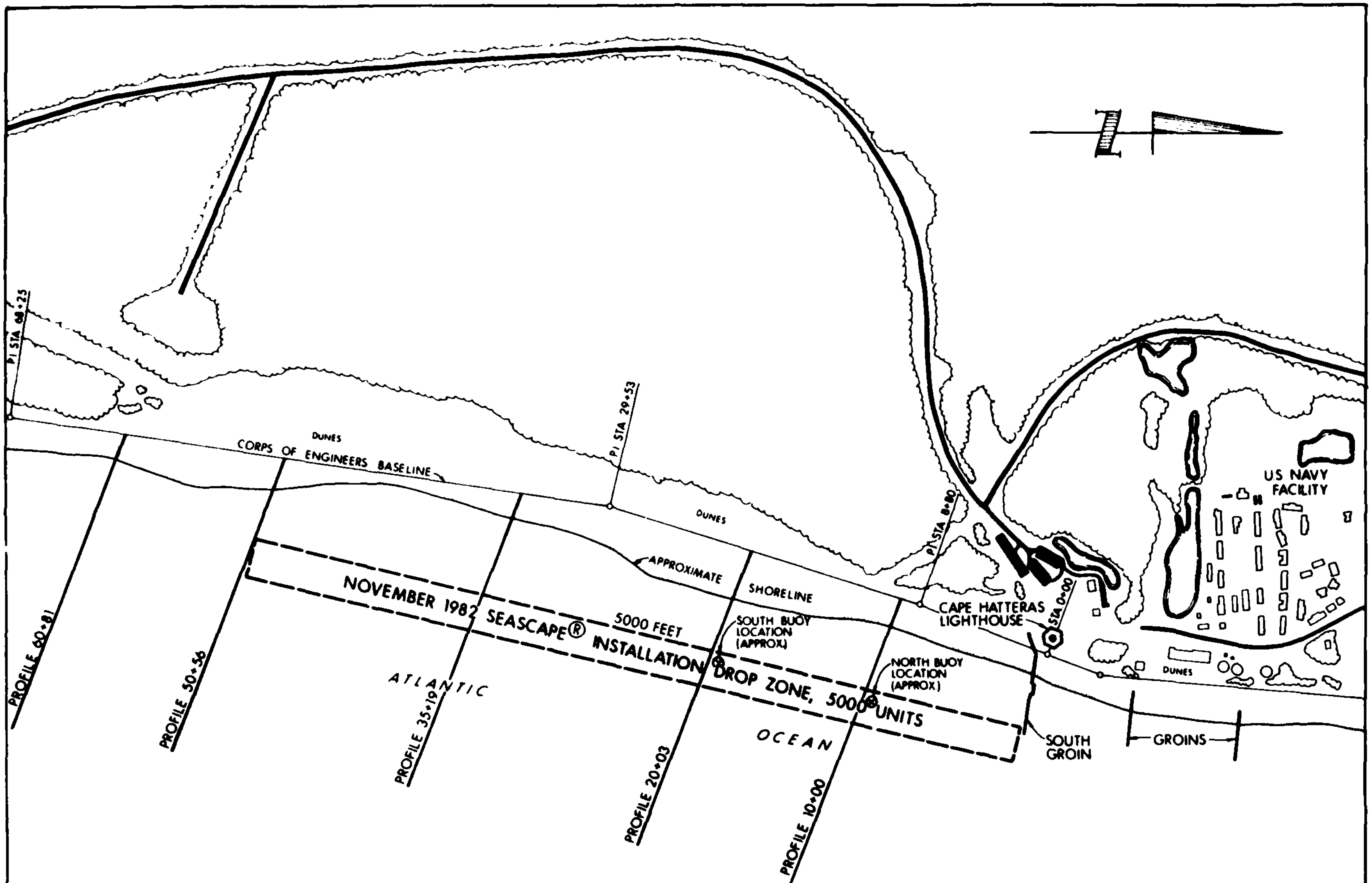


Photo 7 Sea Sled - Disassembled



LOCATION OF SURVEY & RECONNAISSANCE DIVE PROFILES
RELATIVE TO SEASCAPE® INSTALLATION

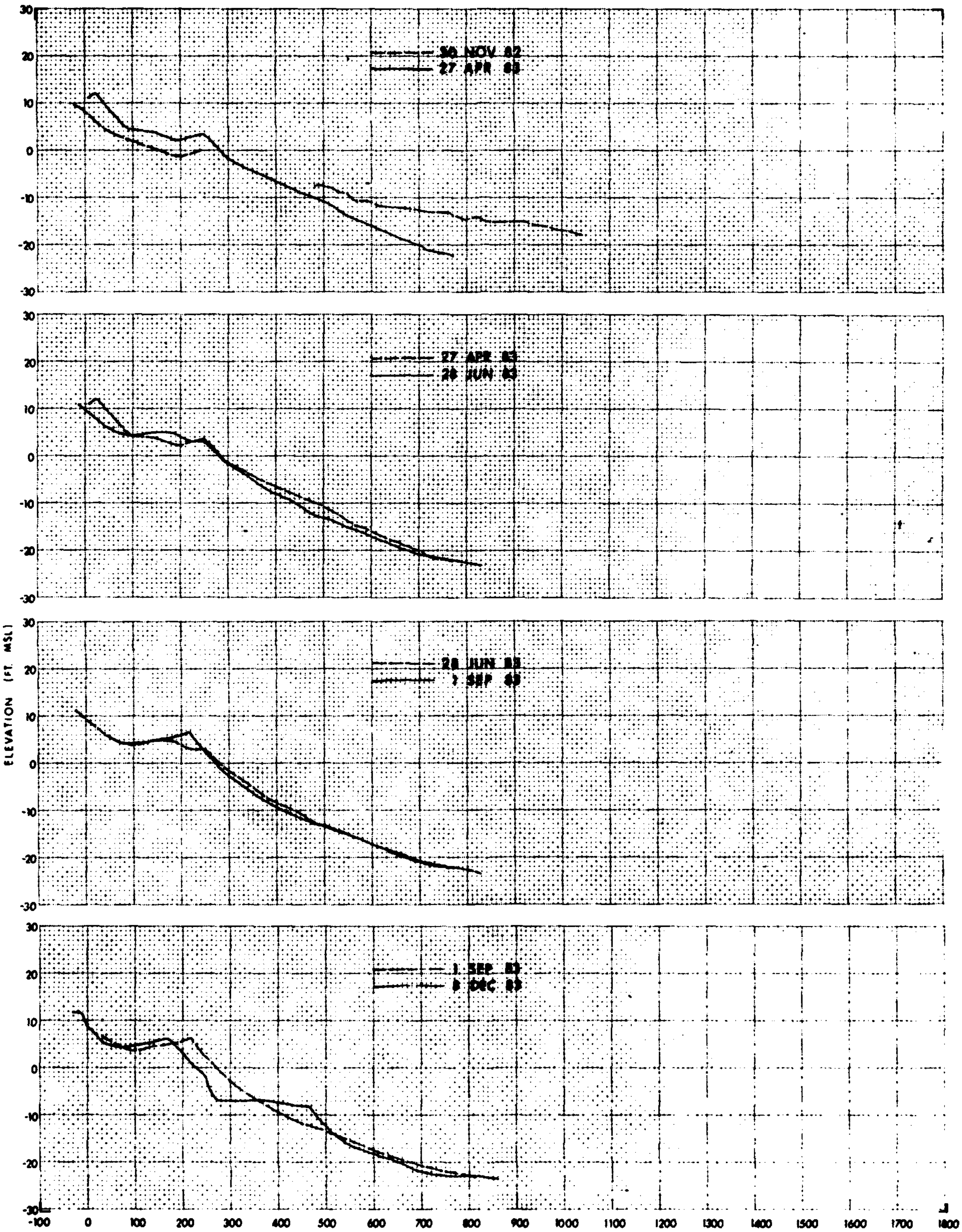
500 0 1000 2000
SCALE IN FEET

FIGURE 19

The profiles were surveyed with the sea sled four times, during April, July, September, and December 1983. As part of initial engineering and design of long term lighthouse protection, an extensive survey of the adjacent beach and offshore zone was performed by the Wilmington District in November 1982. This survey established baseline control and profile locations which were reoccupied for subsequent sea sled surveys. Data gaps in the November 1982 survey are the result of the inability of the hydrographic survey vessel and the onshore survey team to safely survey the surf zone. The profile survey data was digitized and plotted as a time series of beach profiles. The plotted profiles are presented in figures 20 through 24.

The variability of the offshore portions of the profiles was quantified by measuring changes in the position of the offshore bar crest relative to the baseline and plotting the measurements versus time. Examination of the plots of bar position versus time in figure 25 shows that there is no uniform pattern of bar behavior among the profiles south of station 10+00. No bar form is apparent in the profile at station 10+00 until the December 1983 survey. The location of the offshore bar in profile 20+03 changes drastically over the study period, migrating over 500 feet seaward from April to June 1983 and then returning seaward the same distance by the December 1983 survey. The bar in profile 35+19 displays a trend opposite to that in profile 20+03. The bar migrates inshore nearly 300 feet between April and June 1983 then reforms offshore by the December survey. No bar form is apparent in the September 1983 survey at station 35+19. Figure 25 shows the offshore bar locations for profiles 50+56 and 60+81 displaying a similar trend of progressive onshore migration during the study period.

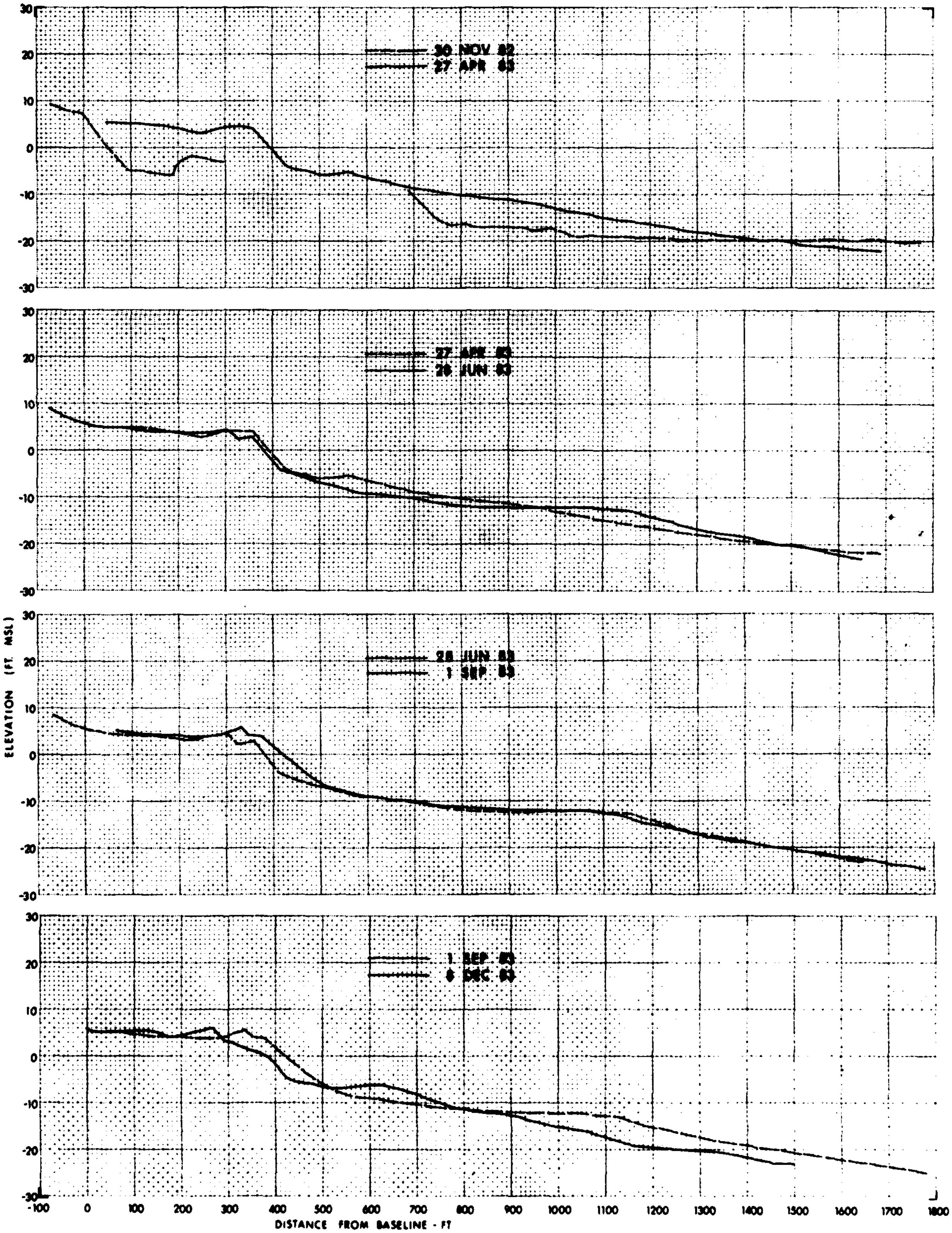
Examination of figures 20 through 24, the time series of plots for each beach profile, shows that the northern profiles, stations 10+00, 20+03, and 35+19, act somewhat opposite to the southerly profiles, stations 50+56 and 60+81. Between November 1982 and April 1983, surveys at stations 10+00, 20+03, and 35+19 showed significant accretion of the foreshore and berm portions of the profiles. During the same period, surveys at stations 50+56



STATION 10+00

COMPARATIVE BEACH PROFILES
CAPE HATTERAS LIGHTHOUSE SEASCAPE® MONITORING
NOVEMBER 1982 TO DECEMBER 1983

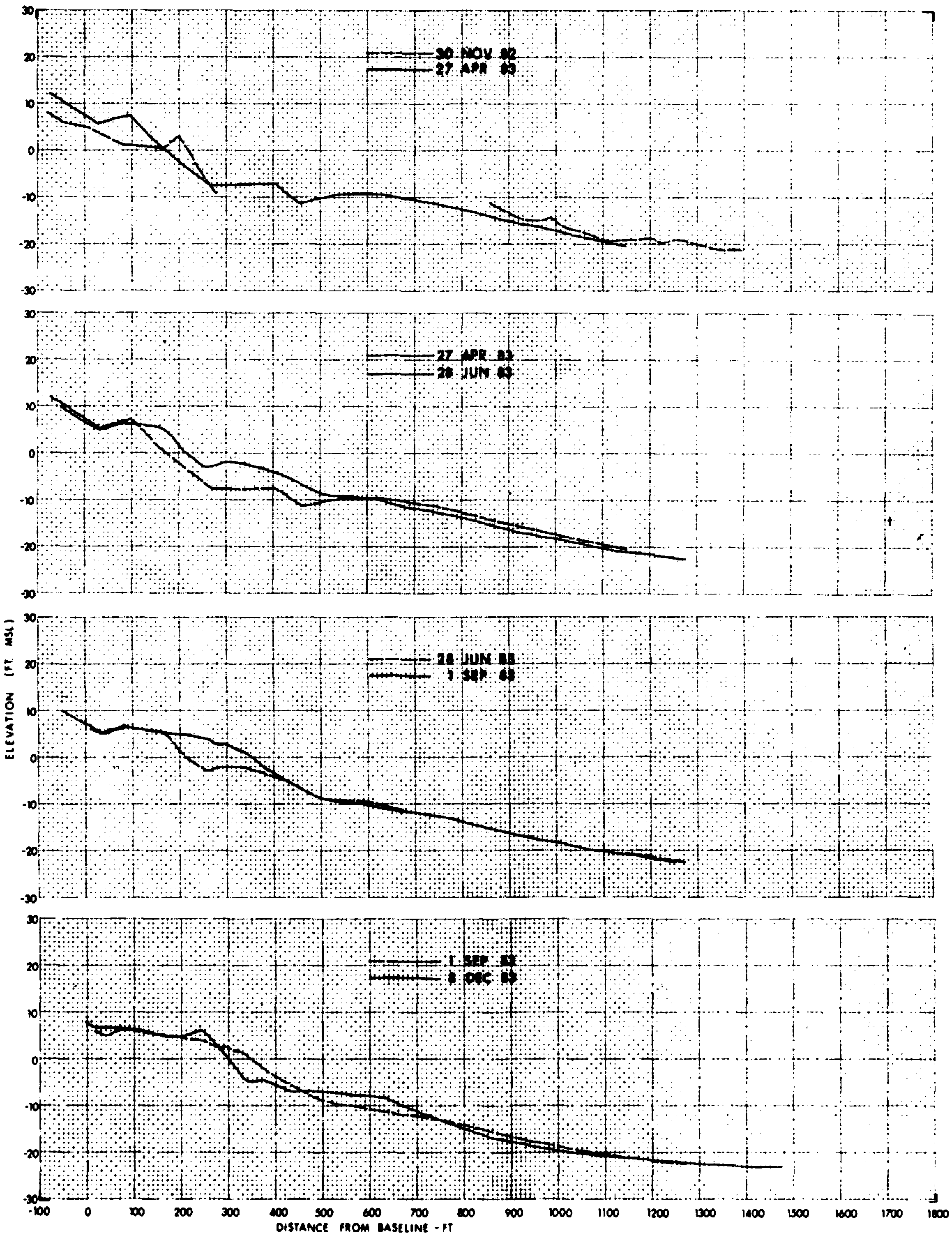
FIGURE 20



STATION 20+03

COMPARATIVE BEACH PROFILES
CAPE HATTERAS LIGHTHOUSE SEASCAPE® MONITORING
NOVEMBER 1982 TO DECEMBER 1983

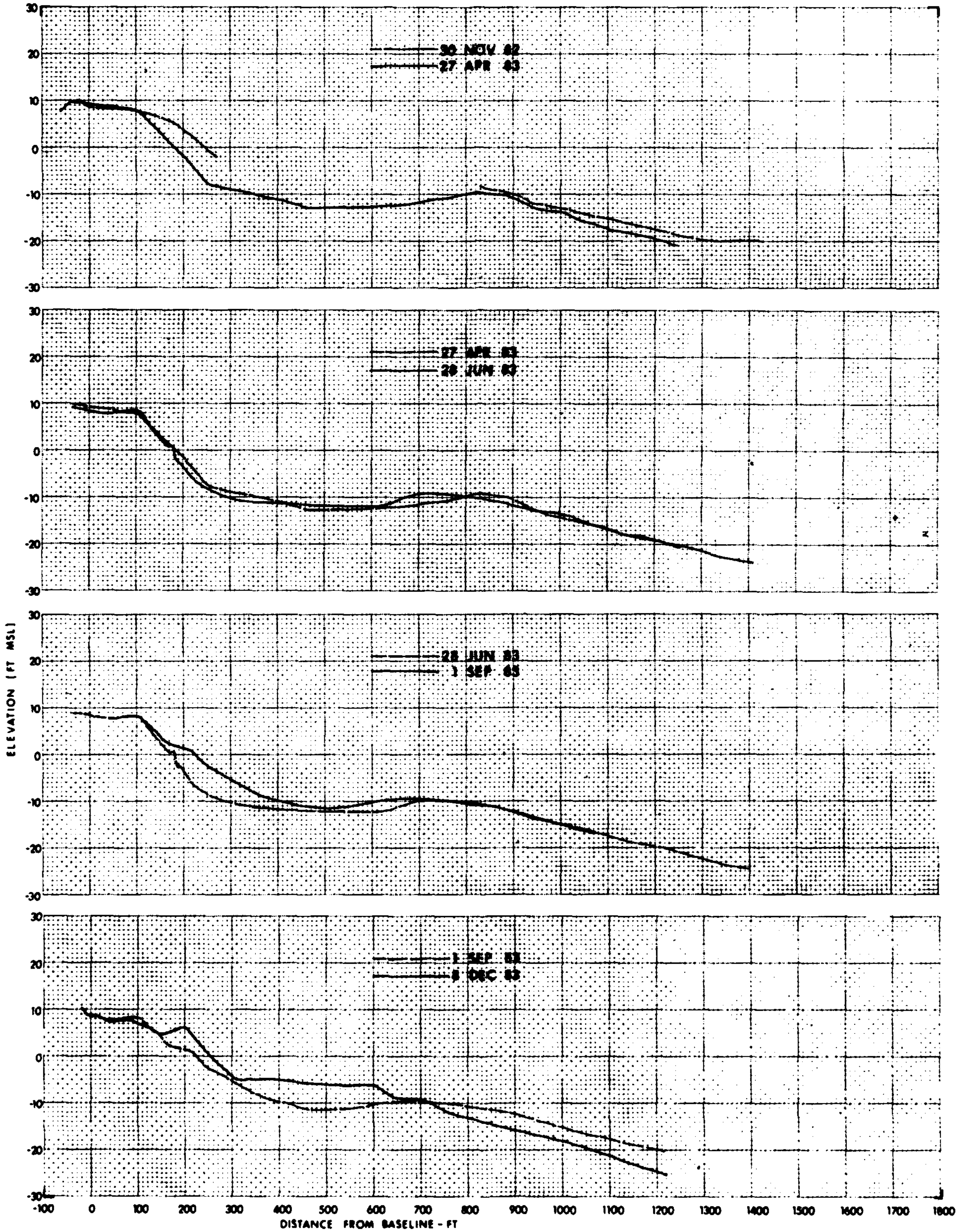
FIGURE 21



STATION 35+19

COMPARATIVE BEACH PROFILES
CAPE HATTERAS LIGHTHOUSE SEASCAPE® MONITORING
NOVEMBER 1982 TO DECEMBER 1983

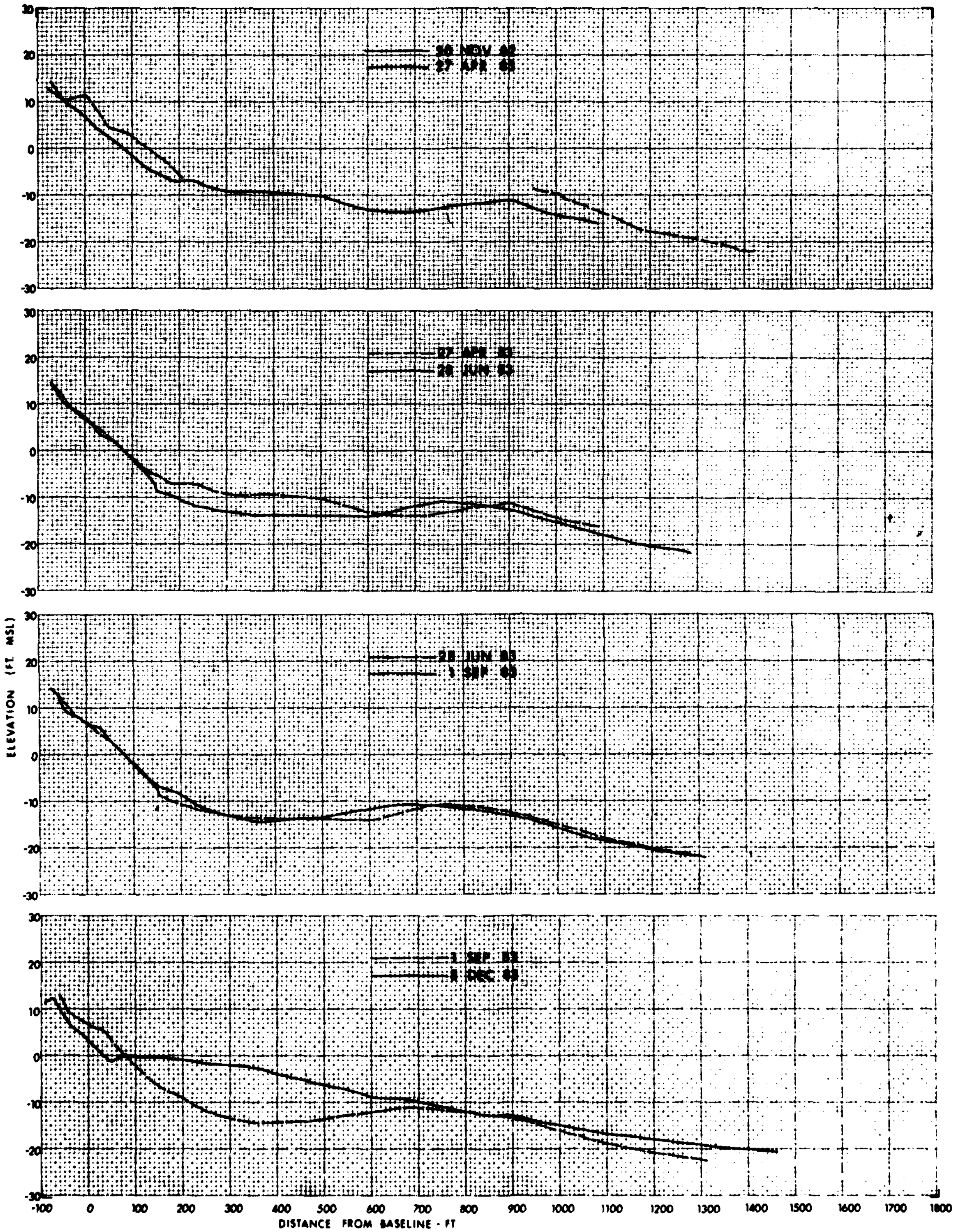
FIGURE 22



STATION 50+56

COMPARATIVE BEACH PROFILES
CAPE HATTERAS LIGHTHOUSE SEASCAPE® MONITORING
NOVEMBER 1982 TO DECEMBER 1983

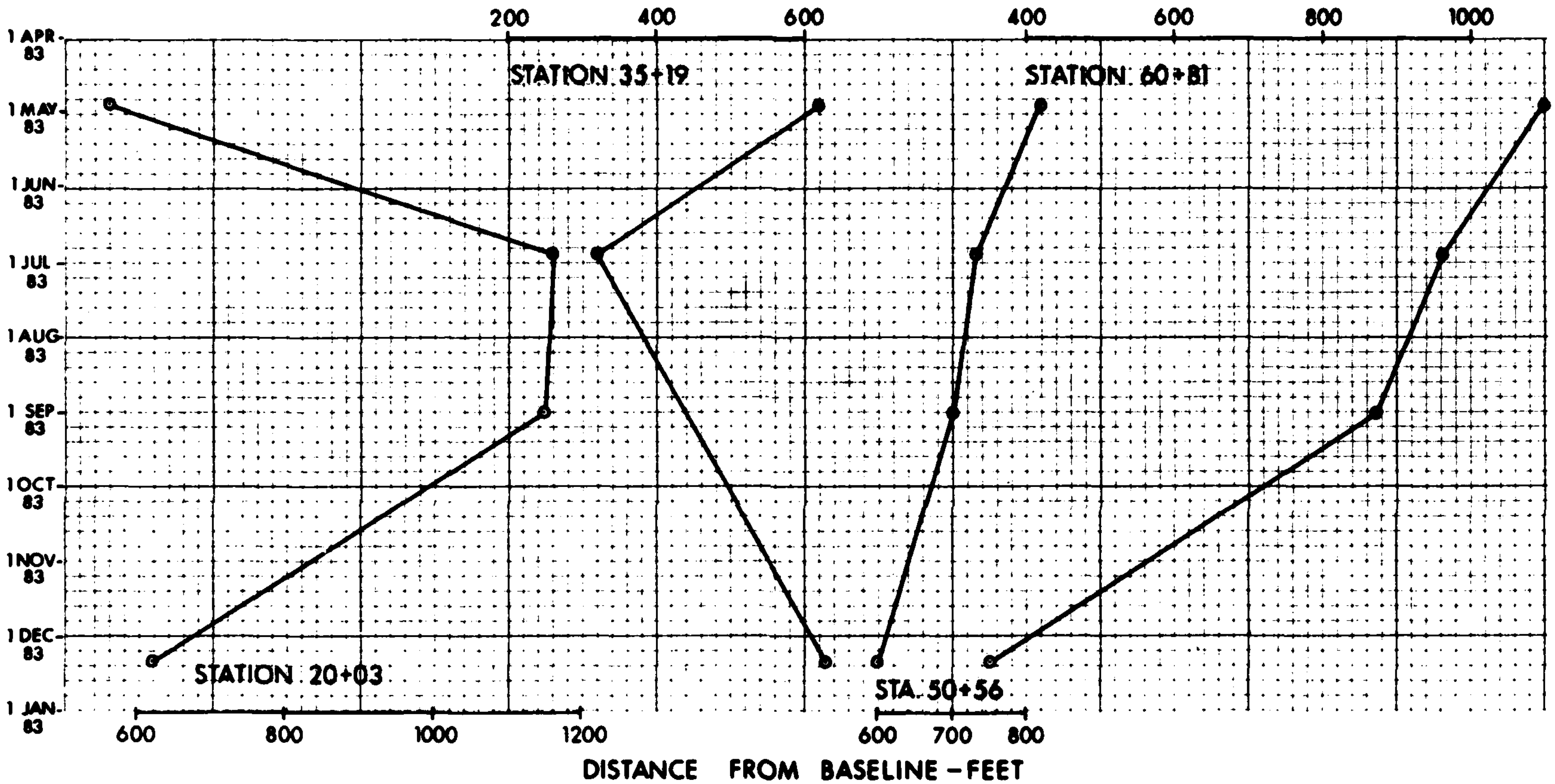
FIGURE 23



STATION 60+81

COMPARATIVE BEACH PROFILES
CAPE HATTERAS LIGHTHOUSE SEASCAPE® MONITORING
NOVEMBER 1982 TO DECEMBER 1983

FIGURE 24



LOCATION OF OFFSHORE BAR CREST RELATIVE TO BASELINE

FIGURE 25

and 60+81 showed erosion of the foreshore and berm. Over the period from April to September 1983, the surveys show no real significant profile changes in the offshore zone in any of the profiles. Stations 20+03, 31+19, and 50+56 did experience some foreshore and berm accretion amounting to seaward movement of the MSL contour of 30 (station 20+03) to 100 feet (stations 35+19 and 50+56).

The period from September to December 1973 was the period of the greatest change in profile form over the study area. Again, the northern half of the study area exhibited behavior opposite to the southern profiles. The surveys for Stations 10+00, 20+03, and 35+19 all show berm and foreshore erosion accompanied by bar formation close to shore and loss of material from the offshore zone during the September through December period. At station 50+56 there is significant buildup of the berm and foreshore portions of the profile accompanied by loss of material from the offshore zone. At station 60+81, significant filling of the foreshore resulting in gains in elevation of over 12 feet at a point 500 feet from the baseline (see figure 24) is accompanied by losses of material from the berm and offshore zones.

The profile at station 60+81 was used in this study as a comparison with the profiles that cross the SEASCAPE® installation zone. However, no features of the profile exhibited any singular behavior which could distinguish it from the other four profiles over the installation zone.

Reconnaissance Dives

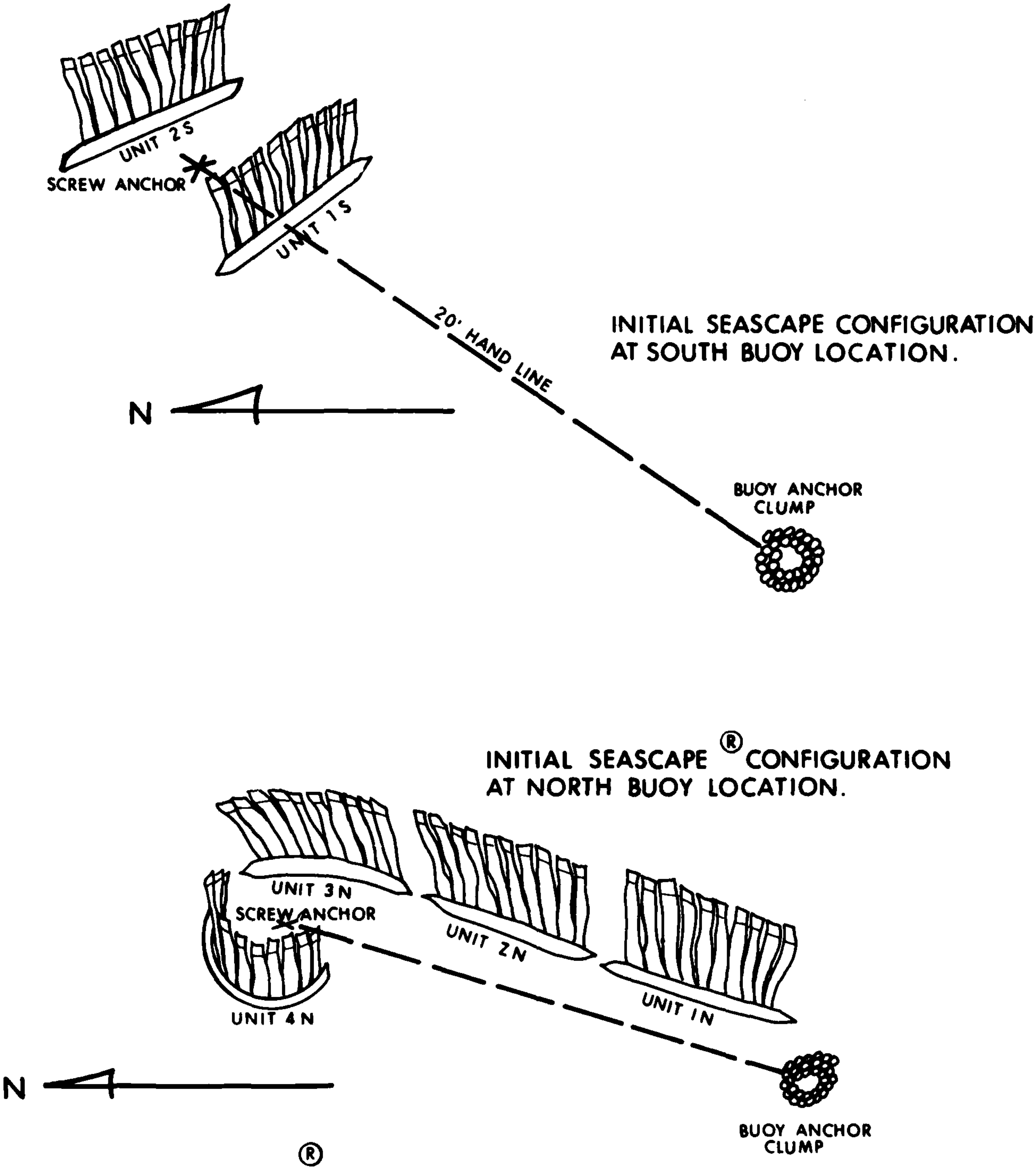
General. Reconnaissance dives on the SEASCAPE® installation zone and adjacent ocean bottom areas provided a means of inspecting the physical condition of the units in place. Diver observations are compiled to provide an assessment of the placement method, method of anchoring, and the durability of the SEASCAPE® material installed at Cape Hatteras.

Diving Plans and Results. The initial monitoring plan, implemented in October 1982, included reconnaissance dives on two sites in the installation zone shown on figure 19 designated as the North Buoy and South Buoy. The sites were marked with buoys to provide reference points for inspection of the nearby samples of SEASCAPE® units during subsequent dives. Inspections were made of the units on the bottom from the buoy anchors along hand lines extending 15 to 20 feet northeast to screw anchors in the approximate configuration shown in figure 26. Reconnaissance dives were attempted on the two buoy locations three times between November 1982 and January 1983 to inspect the physical conditions (orientation, depth of burial, fouling, deterioration, and entangling of fronds) of the SEASCAPE® units in the sample areas. The lengths of the exposed shanks of the screw anchors were recorded as an indication of the degree of sand accumulation in the study areas.

Between the initial dive and the November 30, 1982, dive, the south buoy was lost and the divers were unable to reoccupy the original location.

Following the third dive in January 1983, the monitoring plan was revised to include a more quantitative diving plan. Four shore perpendicular transects across the installation zone and one additional transect south of the installation zone were established at baseline stations identified by the November 1982 survey performed by the Wilmington District. As shown in figure 19, the transects extended from the beach offshore to a depth of 20 feet.

Divers equipped with scuba swam with the sea sled as it was towed along each transect line searching for any SEASCAPE® units that were visible, noting the condition of the units and then surfacing to signal the electronic survey instrument operator that SEASCAPE® had been found. The survey notes were then annotated where seaweed was found on each transect. This allowed the diver bottom search and beach profile survey to be accomplished simultaneously. Inspection dives were performed in November 1982 and January, April, June, September, and December 1983. Two dives were made in November 1982 during the installation, the first to install buoys and mark SEASCAPE® units for future reference and the second to inspect the condition of the sample units.



SEASCAPE® CONFIGURATIONS AT NORTH AND SOUTH BUOY LOCATIONS

FIGURE 26

The following is a summary of diver activities and observations for each of the seven reconnaissance dives made during the study period.

1. Date: November 2, 1982
   Underwater Visibility: 6-7 feet

Diver Activities: During the initial dive, two marker buoys and screw anchors were installed at the approximate locations and depths shown in figure 19. Screw anchors were driven into the bottom approximately 20 feet northeast of the buoy anchor clumps and connected with a hand line. The length of the exposed shank was measured and recorded. Small ping-pong size buoys were tied to fronds (1 per unit) of SEASCAPE® units in the vicinity of the buoy anchors to distinguish the units on subsequent dives.

North Buoy Observations: A group of four SEASCAPE® units was in place along the hand line from the buoy anchor to the screw anchor (see figure 26). Limited visibility prevented divers from observing the anchor tube sections of the units; however, divers did observe that the bags were approximately half exposed and the fronds were free and untangled. A spot dive about 20 feet inshore of the north buoy location revealed SEASCAPE® units with only 6 inches of fronds exposed. No attempt was made to determine if the fronds were buried in a vertical position. Most of the material in the anchor tubes was located at one end, leaving 25% of the tube without material.

South Buoy Observations: A group of 2 SEASCAPE® units were in place at this location. Excellent bottom visibility allowed divers to thoroughly examine the two units. Scour holes ranging from 0.2 to 0.5 feet completely surrounded both units, exposing the entire anchor tubes. Material in the anchor tubes was evenly distributed, and the fronds on both units were floating free and untangled. A bottom search revealed no other existing SEASCAPE® units within a 15-foot radius of the buoy anchor. Divers concluded that units appeared to be located in clusters separated by intermediate gaps rather than in long parallel rows.

2. Date: November 30, 1982
   Underwater Visibility: 2-3 feet

North Buoy Observations: Due to zero visibility on the bottom, a visual inspection of the area was impossible. However, divers did conduct a "hands on the bottom" search and were able to discover evidence of only one SEASCAPE® unit. Four 4-inch sections of fronds were exposed west of the screw anchor which would indicate that they belonged to unit 4N (see figure 26) identified during the first monitoring dive. None of the ping-pong size subsurface buoys identifying individual units or evidence of the other three units were found. The 2.05 feet of the screw anchor was exposed indicating that there had been an accumulation of sand at the anchor of 1.4 feet since the initial dive.

South Buoy Observation: Movement of the marker buoy approximately 100-200 feet shoreward prevented reoccupation of the south site. The divers, in an attempt to locate the screw anchor, dove on all (approximately 15) of the "popcorn" buoys (small white floats attached to fronds to mark rows for the installation contractor) in the general vicinity of the south mark buoy's present and past location, but were unable to locate the screw anchor. Generally, most of the units were completely buried with the only frond exposed being the one with the popcorn buoy attached. Burial of the fronds increased in the offshore direction. Exposed frond lengths ranged from several inches on the offshore units (approximate depth 12 feet) to 18 inches on the inshore units (approximate depth 5 feet). Proximity of several SEASCAPE® units to the marker buoy (well within the surf zone) indicates that at least some of the units had moved inshore.

3. Date: January 25, 1983
   Underwater Visibility: 3-4 feet

North Buoy Observation: The sand level was found to have accreted to within 0.20 foot at the top of the screw anchor shank indicating a 1.5-foot sand level rise since the November 30, 1982, installation. Fair visibility allowed a close inspection of the bottom, but no trace of SEASCAPE® units was found. One unit (marked by some floating line used by the contractor) was found approximately 30 feet east of the screw anchor. The tops of 3 fronds were exposed by digging down approximately 1 foot.

4. Date: April 27, 1983
   Underwater Visibility, 4-5 feet

Diver Observation: This was the first reconnaissance dive under the revised monitoring program. As the sea sled was towed across the bottom, divers hung on inspecting the bottom to determine the presence and condition of any SEASCAPE® units. Several units were found on the subaerial foreshore; only one was found in the water on profile 10+00 in about 14 feet of water approximately 270 feet from shore. No units were found along transects at stations 20+03, 35+19, or 50+56. Zero visibility prevented diver inspection of the bottom for station 60+81.

Storms following the January 25 dive destroyed the buoy marking the north screw anchor location.

5. Date: June 27, 1983
   Underwater Visibility: Less than 1 foot on bottom

Diver Observations: Divers accompanied the sea sled on profile lines 10+00 and 35+19, but were unable to distinguish any exposed SEASCAPE® units. Limited visibility prevented diver inspection of the remaining profile lines.

6. Date: September 1, 1983
   Underwater Visibility: 3 to 8 feet

Diver Observations: Divers were able to accompany the sea sled on all five profile lines. Exposed SEASCAPE® units were visible on two profile lines. Two units were found on line 10+00 located approximately 350 and 600 feet from the baseline. Three units were found on line 35+19 located 880, 1,090, and 1,100 from the baseline. All the units had approximately 1 foot of fronds exposed with fronds laying flat on the bottom (i.e., not floating). Divers were able to easily remove fronds from the units indicating some deterioration of the SEASCAPE® material.

7. Date: December 8, 1983
   Underwater Visibility: 6-8 feet

Diver Observations: Divers were able to accompany the sea sled on all five profile lines. No SEASCAPE® units were located by divers. Approximately 6 units were visible in the foreshore area of the beach in various stages of disintegration.

Oblique Aerial Photography

General. Due to limitations on the availability of appropriate aircraft, oblique aerial photography was attained on only three occasions during the study period. Photos were obtained on October 15 and November 18, 1982, during the installation of SEASCAPE®, and in January at the end of the monitoring period.

Observations. The oblique photographs show the highly irregular and dynamic nature of the shoreline at Cape Hatteras. Photos 8, 9, 10, and 11 show the distinctive bulge in the shore alignment caused by the groin field. An offshore bar emerges from the south side of the south groin (see photos 10

Photo 8 Cape Hatteras Shoreline, Looking Southwest - October 15, 1982

Photo 9 Cape Hatteras Shoreline, Looking South - October 15, 1982

Photo 10 Cape Hatteras Shoreline, Looking North - November 18, 1982

Photo 11 Cape Hatteras Shoreline, Looking Southwest - November 18, 1982

and 11) and extends south parallel to shore. South of the Cape Point the breaking waves show the bar feature extending out into the ocean southeast of the Cape (shown in photos 8 and 9).

Photos 13 and 14 were taken on a day when wave heights along the Outer Banks exceeded 8 feet. These photos show the highly turbulent nature of the Cape Hatteras shoreline during a typical northeaster. Winds at Cape Hatteras on January 12, 1984, were blowing from the northeast (34°) at an average speed of 20 m.p.h. (5)

Comparison of photos 8 and 9 with photos 13 and 14 shows the accretion of the shoreline immediately south of the groins documented in the vertical aerial photography study.

Other Observations and Ground Photography

On several occasions during the study period, Park Rangers at the Cape Hatteras National Seashore and Corps of Engineers personnel visiting the study area documented observations made on the beach south of the lighthouse. A significant number of SEASCAPE® units and fragments of units were found on the beach in various stages of deterioration. Dates and observations by Park Rangers and Corps personnel are listed in table 6. Photo 15 shows a unit found on the beach on April 27, 1983. The unit was discovered with the anchor tube still filled with sand. Note that the pieces of foam at the ends of the fronds were lost and the fronds badly tangled and deteriorated. Photos 16 and 17 show fragments of units found on the beach on the different dates listed in the table. Note the level of deterioration of the SEASCAPE® material, especially of the fragments shown in photo 16. NPS personnel at Cape Hatteras National Seashore have stated that bits of Typar® material are now often found on the beach south of the lighthouse.

Photo 12 Cape Hatteras Shoreline, Looking Northeast - November 18, 1982

Photo 13 Cape Hatteras Shoreline, Looking North - January 12, 1984

Photo 14 Cape Hatteras Shoreline, Looking South - January 12, 1984

TABLE 6

DOCUMENTED SEASCAPE® OBSERVATIONS

Date	Observations
October 23, 1982	Over 100 frond fragments found on beach and removed by beach patrol.
April 4, 1983	Over 2 dozen entire units found during walk over 3,000 feet of beach south of lighthouse. Material frayed and disintegrating (see photo 16).
April 27, 1983	One entire unit still filled with sand found on beach. Unit tangled and added buoyancy foam pieces lost (see photos 15 and 17).
January 10, 1984	One entire unit found approximately 3,000 feet south of lighthouse 200 feet landward from breaker zone. Unit badly deteriorated.
February 2, 1984	Two entire units found on beach 1,500 and 3,000 feet south of lighthouse. Both units badly deteriorated.

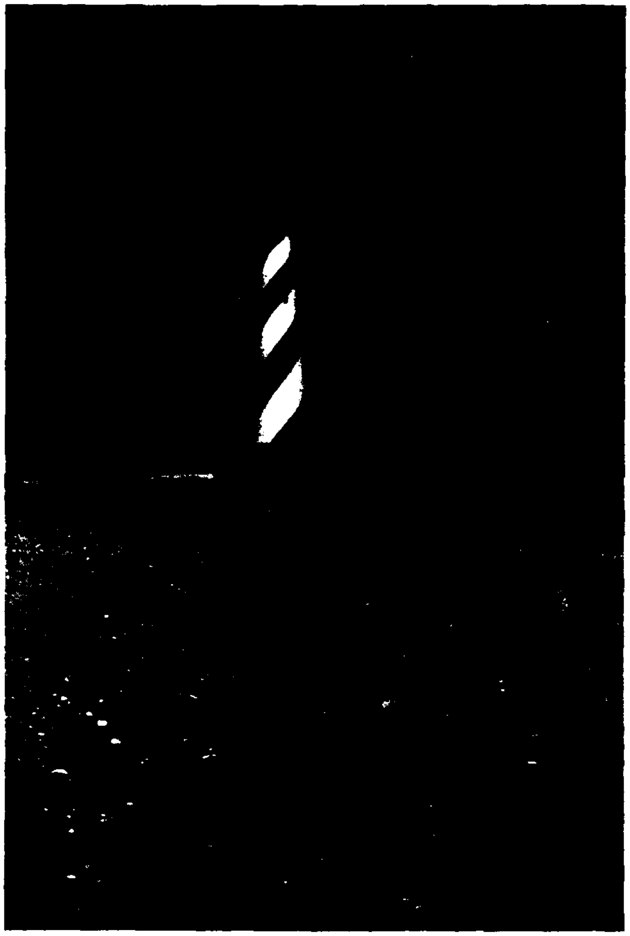


Photo 15 SEASCAPE® Unit Found on Beach - April 27, 1984

Photo 16 SEASCAPE® Fragments on Beach - April 4, 1984

Photo 17 SEASCAPE® Fragments on Beach - April 27, 1984

Summary of Results

Fluctuations in the beach plan and profile form over the study area during the November 1982 to February 1984 period illustrate the variability and highly dynamic nature of the Cape Hatteras coastline. Analysis of aerial photography covering the period from October 1981 to February 1984 showed that, with the exception of the shoreline segments directly affected by the groin field, the study area shoreline showed an overall trend of erosion. Within this period, however, all shoreline segments in the study area experienced reversing trends of accretion and erosion.

During and immediately following the installation of SEASCAPE®, the entire study area shoreline, extending 6.1 miles from just south of Avon, N.C., to Cape Hatteras point, experienced a period of accretion resulting in an average buildup of the beach of 25 feet over the study area. The shoreline segments directly affected by the groins exhibited singular behavior opposite to those areas outside the groins' influence. The groin affected shoreline experienced an overall accretionary trend during the study period. This area of stability on an eroding coastline is best illustrated in aerial photographs by the distinctive seaward bulge in the beach plan form in the area of the groins. Cyclic accretion - erosion related changes in the shoreline immediately south of the south groin were directly related to changes that occurred over the entire groin affected area.

Because the exact locations of SEASCAPE® units on the beach profiles were unknown, evaluation of specific installation zone dynamics was not possible. Analysis of the beach profiles over the installation zone did not show any uniform patterns of behavior of the offshore portions of the beach. However, the general analysis of the beach profiles does show the dynamics of the study area and the absence of any specific areas of stability in the profiles.

Observations by divers provided the best qualitative information on SEASCAPE® performance in terms of durability of the material, the effectiveness of the anchoring system, and method of placement. During initial dives, there was evidence that the SEASCAPE® units located in clusters separated by intermediate gaps rather than in long parallel rows. Some units were observed buried and others found with evidence of scour around the bottom of the anchor tubes. There was evidence of large scale displacement of units from the placement zone. In addition to the units found inshore of the placement zone by divers, a significant number of units and fragments of units were found on the beach by NPS and Corps personnel. The units identified on the beach showed severe fragmentation and deterioration of the Typar® material. Entire units found on the beach were tangled and badly deteriorated.

Conclusions

1. There is no conclusive evidence resulting from this study that the installation of SEASCAPE® at Cape Hatteras was singularly responsible for shoreline changes that occurred during the period October 1982 to February 1984. Accretion that occurred immediately following the installation of SEASCAPE® was part of a general buildup of the beaches over the entire 6.1-mile study area shoreline. During the period October 1982 to June 1983, accretion of the beach immediately south of the south groin and inshore of the north end of the SEASCAPE® installation was related to a general buildup of the entire shoreline area directly affected by the groin field.

2. The three groins adjacent to Cape Hatteras Lighthouse are the most influential elements affecting shoreline stability in the vicinity of the lighthouse. This area acts contrary to adjacent shoreline segments experiencing an overall accretionary trend during a period when the remainder of the study area experienced erosion. This area of stability is best illustrated by the continuing existence of a distinctive bulge in the shoreline plan shape in the area of the groin.

3. There was no evidence from this study that any of the beach profiles monitored over the SEASCAPE® installation zone showed any specific areas of stability in the offshore zone where SEASCAPE® was placed.

4. The system used to anchor the SEASCAPE® units upon placement was inadequate for the nearshore environment at Cape Hatteras. Evidence indicates large scale dislocation of the SEASCAPE® units from the installation zone. Documented observations showed extensive displacement of the units onto the beach inshore of the placement zone.

5. The method of installing SEASCAPE® resulted in the units being placed in groups separated by intermediate gaps instead of the intended long shore-parallel rows.

6. There was evidence of burial of SEASCAPE® units in the offshore zone. However, there was no evidence that burial was caused by the action SEASCAPE® at the bottom versus burial by the normal wave driven migration of sand bodies in the active nearshore zone. Some units were discovered buried while bottom scour was observed around the anchor tubes at another location.

7. There was evidence of significant fragmentation of the SEASCAPE® units following installation. The number of fragments observed on the beach indicates that the units were unable to withstand the abrasion they were subjected to in the turbulent surf zone environment. Additionally, the condition of entire SEASCAPE® units and fragments of units observed in the study area, indicated rapid deterioration of the Typar® material in the nearshore ocean environment.

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