

## CHAPTER 22

# EXPERIMENTAL STUDY OF DUNE BUILDING WITH SAND FENCES

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### ABSTRACT

In 1957 the State of North Carolina, in cooperation with the Beach Erosion Board and the Wilmington District of the Corps of Engineers undertook an experimental dune building study on the Outer Banks of North Carolina. The experimental study consists of the construction of various types and arrangements of sand fences to determine the fence type and arrangement most effective in building a dune by trapping wind-blown sand. Four miles of experimental fencing were constructed in 1960. During the following year, four sets of profiles were made to determine the sand accumulation of the fences and a rather intermittent wind record was made in the area. The performance of the various fence types and arrangements has been compared and some conclusions have been reached concerning the best fence type and arrangement.

### INTRODUCTION

The Outer Banks of North Carolina is a series of sand barrier islands which lie between the Atlantic Ocean and the mainland. The islands are separated from the mainland by a series of shallow sounds varying in width from 1 to 20 miles and are broken by several inlets, some as much as 1 mile wide. The Outer Banks form a protective barrier between the Atlantic Ocean and the mainland and serve as the basis for some recreational and commercial activities based on the hunting and fishing potentialities of the area.

Core Banks is that part of the Outer Banks that lies between Portsmouth Island and Cape Lookout (Figure 1). The islands composing Core Banks presently range from 1/4 to 1/2 mile in width. While in historic times they may have been high and covered with lush vegetation, the disappearance of the dune formations now allows waves to wash completely across the barrier during storms. This frequently results in the opening of temporary inlets that serve to increase the rate of erosion of the islands.

In 1957, after the rash of hurricanes which swept the North Carolina coast in the early and mid 1950's, officials of the State became quite concerned about the condition of North Carolina's barrier islands, especially those in the Core Banks area. It was felt that if the islands were permitted to deteriorate any further, they might no longer provide protection for the mainland from the waves and surges of hurricanes and other storms.

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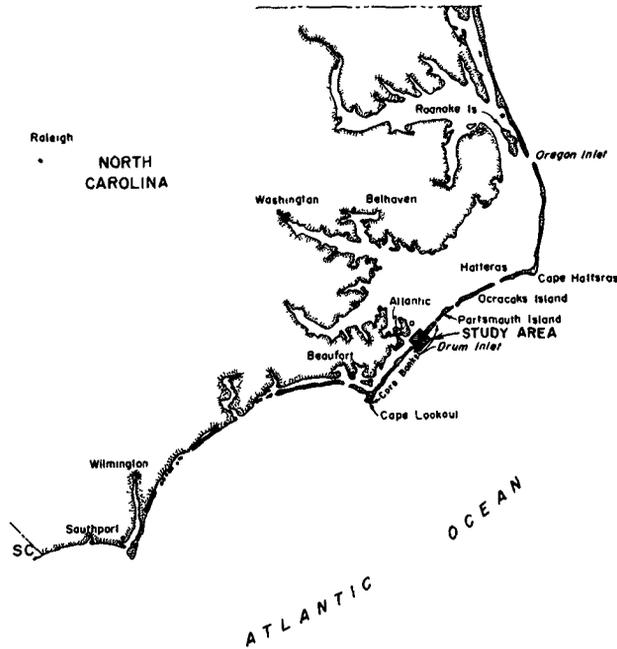


Fig. 1. Location Map.

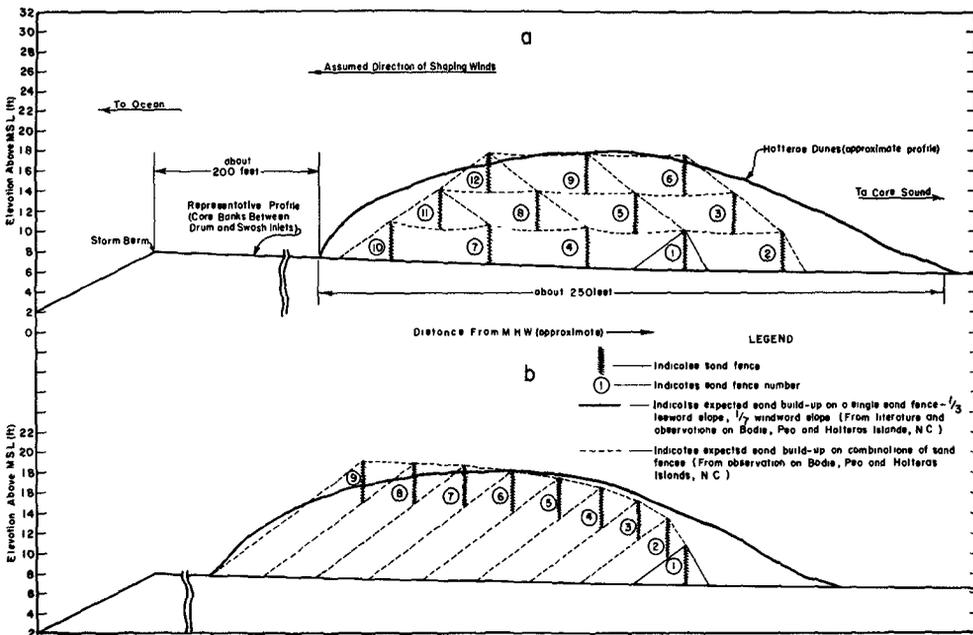


Fig. 2. Proposed Programs for Building a Barrier Dune on Core Banks.

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As a result, the State in 1957 asked the Beach Erosion Board staff to enter into a cooperative research study aimed at developing a method for restoring the dunes along Core Banks. The Beach Erosion Board staff indicated that sand fencing might be used to restore the dunes and agreed to enter into a cooperative research study to determine by experimental field installations the comparable effectiveness of various types of sand fences and sand fence arrangements in restoring the dunes. The final cooperative arrangement provided that the State would provide fencing and install it in the study area. The Beach Erosion Board staff would provide consultative advice in setting up and conducting the program of study and furnish the instrumentation required for the study. Since the study area was a part of an area which was to be the subject of a cooperative beach erosion control study by the Corps of Engineers, the District Engineer in Wilmington was interested in the study and came into the cooperative arrangement to provide personnel for making field measurements.

### PROPOSED STUDY PROGRAM

In October, 1957, the Beach Erosion Board submitted a proposed study program to the State which covered the setting up of the study and the measurements to be taken during the first year. The study program visualized as its objective the construction of a barrier dune about 500 feet from the sea to a height of +20 feet MSL with a base width of about 300 feet. Two possible methods of constructing the dune with sand fencing were presented (see Figure 2). Using method (a) of this Figure, fences 1 and 2 would be installed and allowed to fill by installing either fence first and installing the other after the first had filled, or by installing them both at the same time and allowing them to fill together. Fence 3 would then be installed atop the accumulation of fences 1 and 2. Fence 4 would be installed concurrently with fence 3 or after fence 3 had filled. Fence 5 would be installed after fence 4 had filled and then fences 6 and 7 would be added. This process would be followed, using the fences in numerical order, to achieve the desired dune profile. Using method (b), fence 1 would be installed and allowed to fill. Fence 2 would be constructed 2/3 of the distance up the front slope of the accumulation of fence 1 and allowed to fill. Fence 3 would then be constructed 2/3 of the distance up the front of the accumulation of fences 1 and 2 and allowed to fill. This process would be continued until the desired dune profile had been created.

In order to obtain the information needed to use the sand fences efficiently and economically, the study program proposed initial experimentation with 21 sections of fencing, each about 1,000 feet in length, along Core Banks just north of Drum Inlet. It was proposed that two types of fencing be used - brush fencing and snow fencing. Each of these fence types would be constructed in three arrangements (see Figure 3). Each fence type and arrangement would be tested as a single fence and as a double fence (two fences side-by-side) to establish their relative

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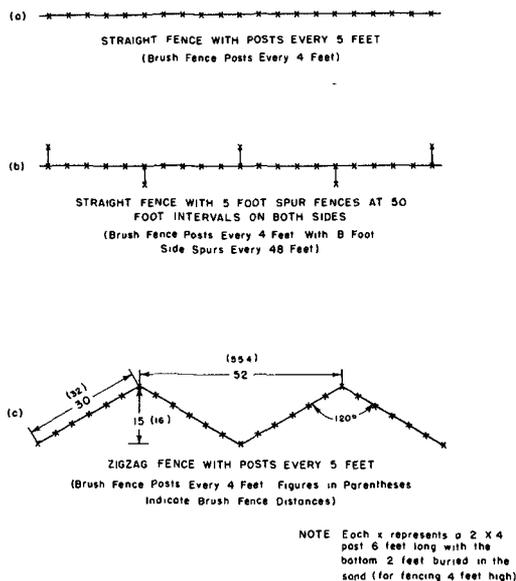


Fig. 3. Proposed Sand Fence Arrangements.

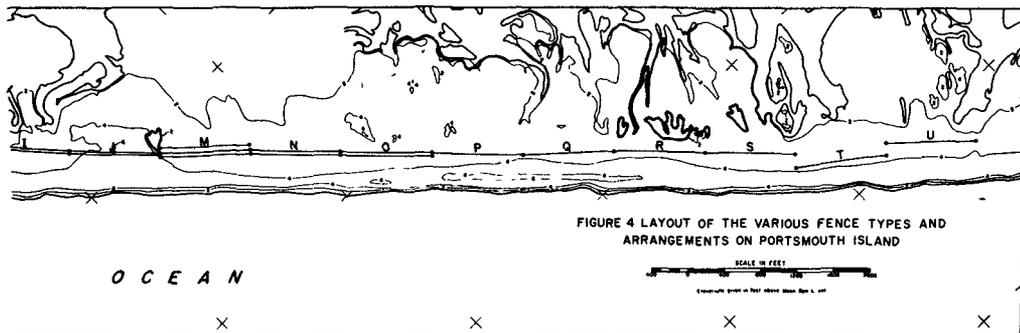
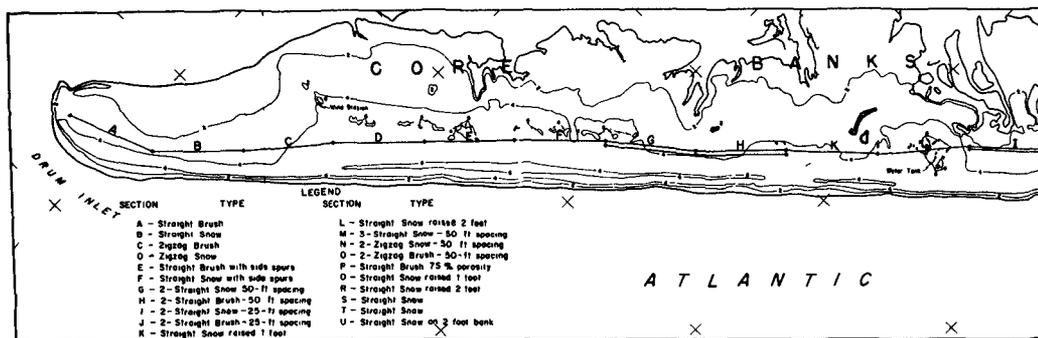


Fig. 4. Layout of the Various Fence Types and Arrangements on Core Banks.

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sand trapping efficiencies and to determine the best spacing between multiple fences. To determine the best spacing between multiple fence sections, fence spacings of 25 and 50 feet were recommended for initial testing. In addition, it was proposed that two sections of the straight snow fencing be constructed with the bottom of the fencing one foot off the ground and that two sections be constructed with the bottom of the fencing two feet off the ground. This arrangement was proposed to determine whether or not the effective height of the fencing could be increased by constructing it initially in this higher position. The construction of one section of brush fencing atop a 2-foot bulldozed dune was also proposed to evaluate starting the fencing on an artificial dune.

It was proposed that the sand accumulation of the fences be measured by periodic surveys across three ranges for each fence section - one in the middle of the fence section and one 250 feet on either side of the middle range. The proposed surveys covered enough distance landward and seaward of the fences to include all of the area in which there would be any sand accumulation.

Measurements of the winds, existing sand characteristics, and other natural conditions in the study area were considered desirable in the hope that some data might be obtained on the relationship between the winds and the rate of sand movement.

### CONDUCT OF THE STUDY

The Beach Erosion Board's recommendations were accepted by the State of North Carolina and the fences were installed on Core Banks in late 1960 and early 1961. The layout of the various fence types and arrangements is shown on Figure 4. The contours show the island condition before the fences were installed.

Cross-section surveys of the sand accumulations during the year were made by the Wilmington District personnel in December 1960, April 1961, and July 1961, and October 1961.

A wind station was installed in the study area (see Figure 4) in April 1961. The station was installed in a steel tower with the anemometer and wind direction indicator devices approximately 30 feet above ground level. Since no electrical power was available locally, the recording mechanism was spring wound.

### RESULTS OF THE FIRST YEAR OF THE STUDY

Considerable difficulty developed with the recording mechanism of the wind station and the records from it were somewhat intermittent,

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however, records were obtained during most of the period from April to December 1961. This data is shown on Figure 5. Wind data available from the U. S. Weather Bureau station at Hatteras, North Carolina, about 45 miles northwest of the temporary station on Core Banks, are shown in Figure 6. In the Figures, it has been assumed that the sand transporting capacity of the winds is proportional to the third power of the wind velocity and the relative transporting capacities of the sand-moving winds from various directions are shown. The Figures show that the onshore transporting capacity is relatively small, especially the eastern and southeastern components. Also, the transporting capacity of the winds parallel to the fences is relatively large. Since most of the sand available for movement is on the seaward side of the fences, the fences in the study area operated at a considerable disadvantage. However, the sand fences were effective in trapping wind-blown sand. Even fences which were installed in or near areas of ponded water on the island completely filled in the first year after their installation.

Some of the fencing was destroyed by waves which overtopped the front of the island, and since the island then slopes gently toward the sound, washed across the island and into the sound. Too, the fences were subjected to some flooding by high tides from the sound, but this is thought to have been much less likely to have caused damage than the waves overtopping the ocean side of the island. It is estimated that approximately 50 percent of the fencing had been damaged by October 1961. The area was affected by Hurricane Esther in September 1961, which may have caused a considerable portion of the damage.

Volumes of sand collected by the fences are given in Table 1. Table 2 contains summaries of data for all single-fence sections, all double-fence sections, and the one triple-fence section. The values given in these tables are the volume of sand collected by each test fence section in cubic yards per foot of beach. These figures show that, on the average, the fence sections caught about 2.5 cubic yards of sand per foot of beach during the first 8 or 9 months after installation.

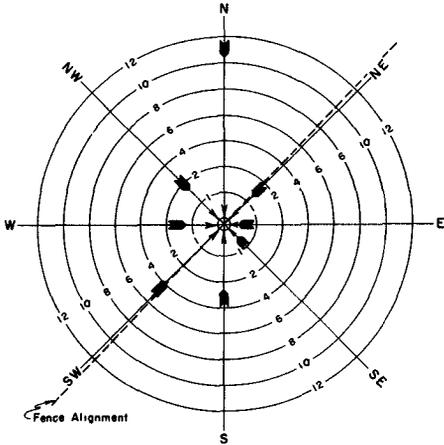
It should be noted that these values are given in volume per foot of beach and not per foot of fence. However, volume per foot of beach becomes volume per foot of fence where single-fence sections were used. Too, in arriving at these values, fence sections which were damaged or lost were not considered. This was done by ignoring the cross-sections at points where the fence was lost and averaging the remaining cross-sections available for the experimental section under consideration.

Tables 3 and 4 have been prepared from the data given in Table 1. Table 3 is a comparison of the volume of sand trapped by various brush

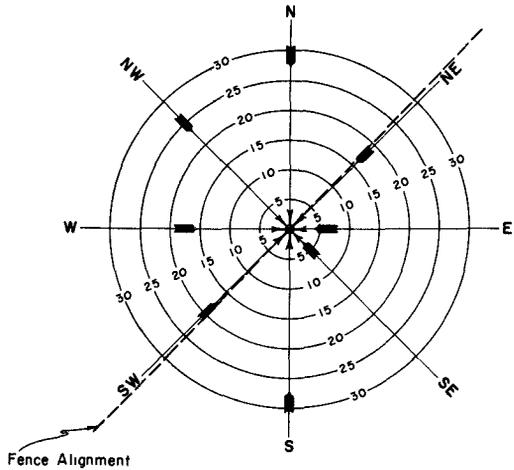
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Compiled from data from B E B Wind Station on Core Banks for period April 1961 to December 1961

Compiled from data furnished by the U.S. Weather Bureau of Hatteras, N.C. for the period from Jan, 1953 to Dec, 1957



Capacity of the wind to transport sand assumed to be proportional to the wind velocity cubed



Capacity of the wind to transport sand assumed to be proportional to the wind velocity cubed

Fig. 5. Relative Transporting Capacity of the Sand-Moving Winds in the Study Area (3.E.B. Data).

Fig. 6. Relative Transporting Capacity of the Sand-Moving Winds in the Study Area (U. S. Weather Bureau Data).

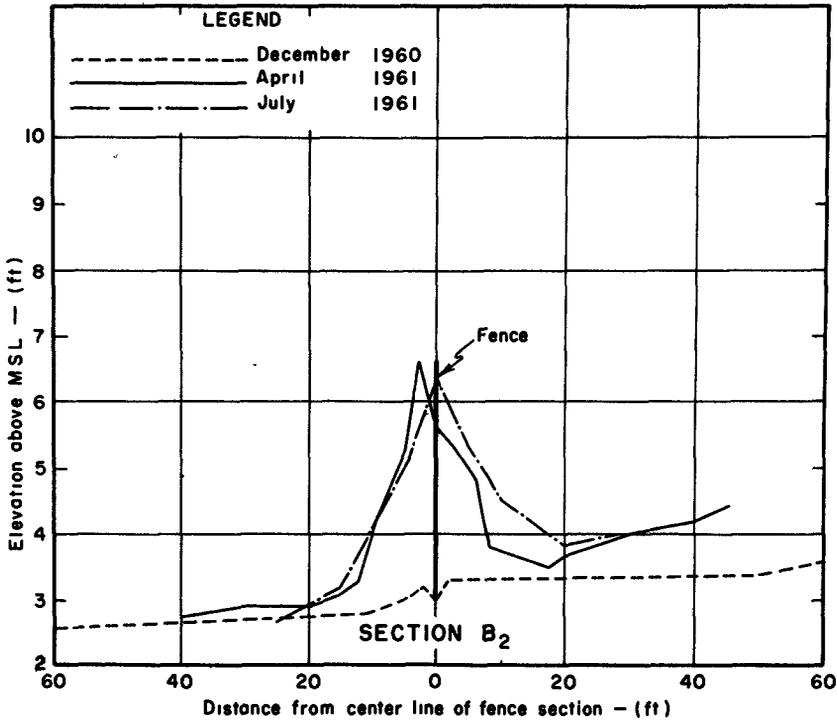


Fig. 7. Typical Sand Accumulation Profiles - Single Fence Section.

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TABLE 1

VOLUME OF SAND COLLECTED BY SAND FENCES ON CORE BANKS  
Cubic Yards Per Foot of Beach

<u>Section</u>	<u>Type</u>	<u>Installation* to December 1960</u>	<u>December 1960 to April 1961</u>	<u>April 1961 to July 1961</u>	<u>Installa- tion to July 1961</u>
A.	St. Brush	0	0.96	1.04	2.00
B.	St. Snow	0	2.27	0.35	2.62
C.	Zigzag Brush	0.89	1.39	0.24	2.52
D.	Zigzag Snow	0.59	1.20	0.59	2.38
E.	St. Brush with side spurs	0.51	0.87	0.51	1.89
F.	St. Snow with side spurs	0.44	0.96	0.37	1.77
G.	2-St. Snow 50-ft. spacing	0.37	1.98	0.51	2.86
H.	2-St. Brush 50-ft. spacing	0.51	1.58	0.87	2.96
I.	2-St. Snow 25-ft. spacing	0.56	1.64	0.23	2.43
J.	2-St. Brush 25-ft. spacing	0.15	1.17	0.91	2.23
K.	St. Snow raised 1 ft.	0.37	0.77	1.14	2.28
L.	St. Snow raised 2 ft.	0	0	0	0
M.	3-St. Snow 50-ft. spacing	0.56	1.82	0.42	2.80
N.	2-Zigzag snow 50-ft. spacing	0.33	2.31	0.48	3.12
O.	2-Zigzag Brush 50-ft. spacing	1.09	1.36	0.80	3.25
P.	St. Brush 25% Porosity	1.17	1.06	0.74	2.97
Q.	St. Snow raised 1 ft.	0	1.82	0.84	2.66
R.	St. Snow raised 2 ft.	0	0	0	0
S.	St. Snow	0.60	1.75	0.18	2.53
T.	St. Snow	0.80	1.57	0.17	2.54
U.	St. Snow on 2-ft. bank	0	0.86	0.34	1.20
Average all fences**		0.47	1.44	0.57	2.47

\*Installation of Sections A-T made in October-November 1960

\*Installation of Section U made in January 1961

\*\* Does not include Sections L&R

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TABLE 2

VOLUMES OF SAND COLLECTED BY SAND FENCES ON CORE BANKS FROM INSTALLATION TO JULY 1961

<u>Section</u>	<u>Type</u>	<u>Cubic Yards per foot of beach</u>
<u>Single-Fence Sections</u>		
A.	Straight Brush	2.00
B.	Straight Snow	2.62
C.	Zigzag Brush	2.52
D.	Zigzag Snow	2.38
E.	Straight Brush with Spurs	1.89
F.	Straight Snow with Spurs	1.77
K.	Straight Snow raised 1 ft.	2.28
L.	Straight Snow raised 2 ft.	2.22
P.	Brush fence 75% Porosity	2.97
Q.	Straight Snow raised 1 ft.	2.66
R.	Straight Snow raised 2 ft.	--
S.	Straight Snow	2.53
T.	Straight Snow	2.54
U.	Straight Brush on 2 ft. Bank	1.20
Average of all single fence sections		2.28
<u>Double-Fence Sections</u>		
H.	Straight Brush 50-ft. spacing	2.96
I.	Straight Snow 25-ft. spacing	2.43
G.	Straight Snow 50-ft. spacing	2.86
J.	Straight Brush 25-ft. spacing	2.23
O.	Zigzag Brush 50-ft. spacing	3.25
N.	Zigzag Snow 50-ft. spacing	3.12
Average of all double fence sections		2.81
<u>Triple-Fence Sections</u>		
M.	Straight Snow 50-ft. spacing	2.80

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TABLE 3

COMPARISON OF THE VOLUME\* OF SAND TRAPPED BY VARIOUS BRUSH  
FENCE SECTIONS WITH THE VOLUME TRAPPED BY COMPARABLE SNOW  
FENCE SECTIONS

<u>Section</u>	<u>Type</u>	<u>Volume-Installation To July 1961</u>	<u>Ratio Brush/Snow</u>
C.	Brush	2.52	1.06
D.	Snow	2.38	
E.	Brush	1.89	1.07
F.	Snow	1.77	
H.	Brush	2.96	1.04
G.	Snow	2.86	
J.	Brush	2.23	0.92
I.	Snow	2.43	
O.	Brush	3.25	1.04
N.	Snow	3.12	

\*Volume given in cubic yards trapped per foot of beach.

TABLE 4

COMPARISON OF THE VOLUME\* OF SAND TRAPPED BY STRAIGHT FENCING  
WITH THE VOLUME TRAPPED BY ZIGZAG AND SIDE SPUR FENCING

<u>Section</u>	<u>Type</u>	<u>Volume-Installation to July 1961</u>
B.	Straight	2.62
S.	Straight	2.53
T.	Straight	2.54
	Average	2.56
C.	Zigzag Brush	2.52
D.	Zigzag Snow	2.38
E.	St. Brush with Side Spurs	1.89
F.	St. Snow with Side Spurs	1.77

\*Volume given in cubic yards of sand trapped per foot of beach.

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Fig. 8. Filled Single Fence Section.

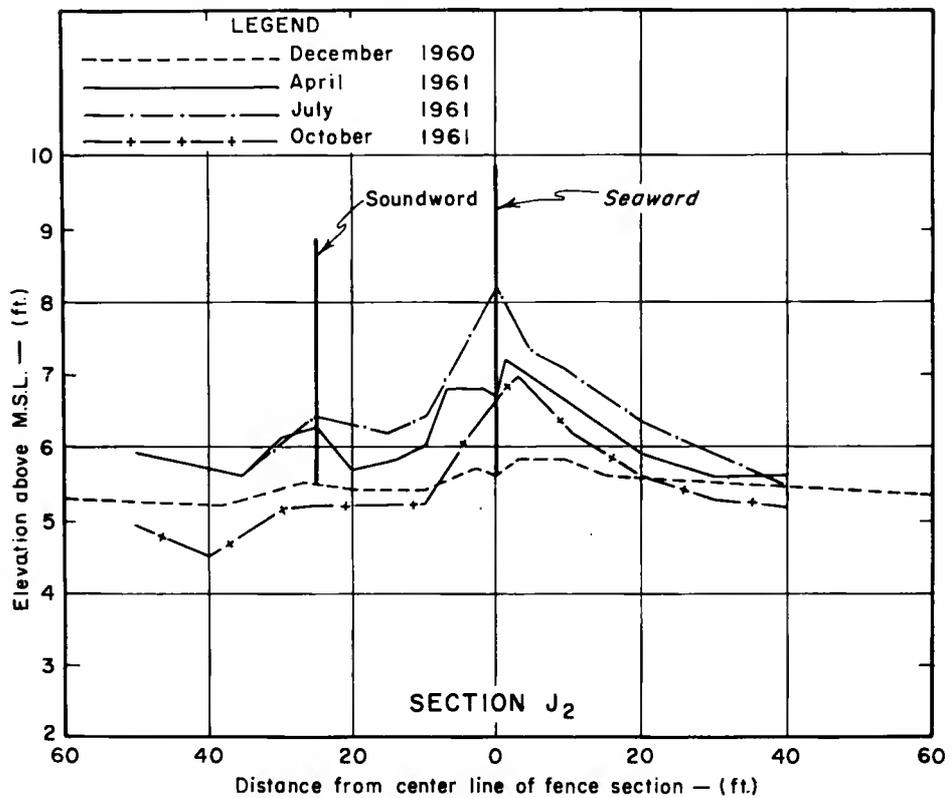


Fig. 9. Typical Sand Accumulation Profiles, Double Fence Section, 25-foot Spacing.

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fence sections compared with the volume of sand trapped by comparable snow fence sections. Since the brush-to-snow ratio averages about 1.05, with one unexplained exception of 0.92, it appears that generally brush fencing traps about 5 percent more sand than comparable snow fencing. However, in this study, installed brush fencing cost about twice as much as installed snow fencing. Therefore, the use of brush fencing would appear to be economically unjustified.

In Table 4, the average volume of sand trapped by three different straight fence sections (Figure 3a) is compared with the volume of sand trapped by single zigzag fences (Figure 3b) and single fence with side spurs (Figure 3c). From this comparison it appears that the straight fences trap and hold more sand than the other configurations, at least in the study area over this period of measurement. Typical sand accumulation profiles for a single fence section are shown in Figure 7, and a filled fence section is shown in Figure 8.

The performance of the multiple-fence sections (double fence rows) which were included in the study to determine if a barrier dune could be built using the method shown in Figure 2a were generally disappointing, in that the center area between the fences did not fill significantly (see Figures 9, 10, and 11). If the area between the fences will not fill, little progress can be made toward heightening the dune by placing new fences on the accumulation between the existing fences. However, some caution should be exercised before this plan is completely abandoned, for the following reason. Comparison of the sand trapped by the single-fence sections and the multiple-fence sections shows that the single-fence sections trapped almost as much sand as the multiple fence sections (about 2.3 compared to 2.8 cubic yards of sand per lineal foot of beach) even though at the end of the year most of the multiple-fence sections had ample sand trapping capacity remaining. A possible and logical explanation for this is that the fences trapped essentially all the sand which was moving during the year, and thus the multiple fence sections had not yet been filled to capacity. If this is true, the multiple-fence sections have not been amply tested in the first year of the study and any conclusions which may be drawn about their total effectiveness would be premature. The first year of the study does indicate, however, that if multiple-fence sections are to be used, the 50-foot spacing between fences is too large. The 25-foot spacing between fences also appears to be too large, but enough doubt about this remains to justify continuing this phase of the tests for another year.

The concept of installing the fences initially on a 2-foot bank appears to have both advantages and disadvantages. One advantage is that under conditions such as those existing on Core Banks, the initial 2-foot bank protects the fence and makes it more difficult for the water to destroy the fencing. However, as a disadvantage, the fencing

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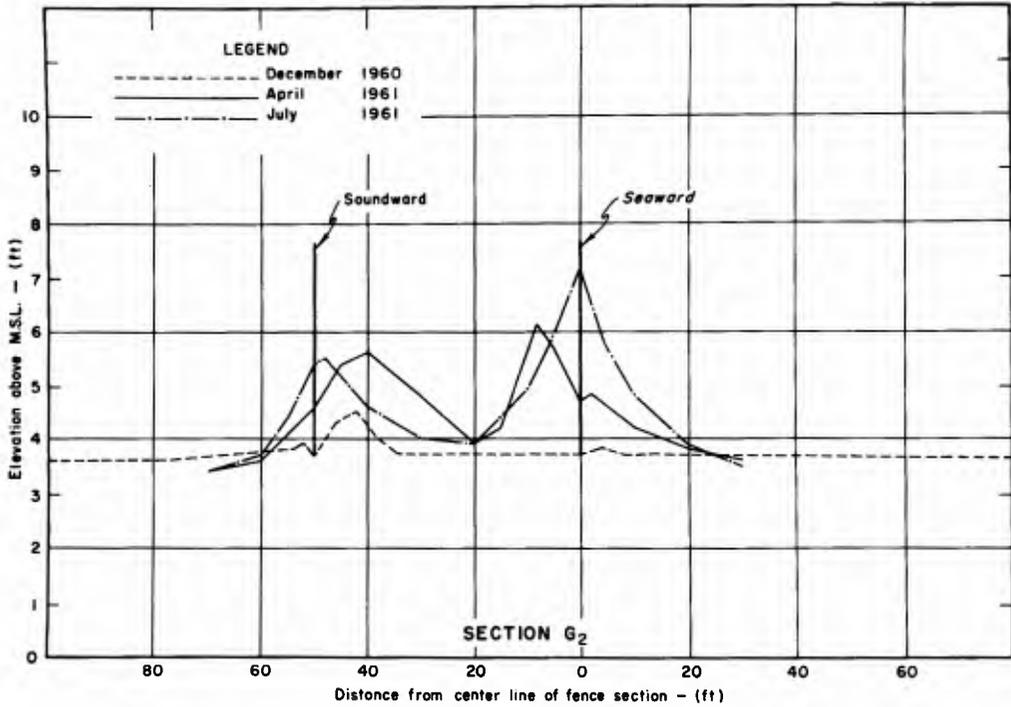


Fig. 10. Typical Sand Accumulation Profiles, Double Fence Section, 50-Foot Spacing.



Fig. 11. Partially Filled Double Fence Section, 50-foot Spacing.

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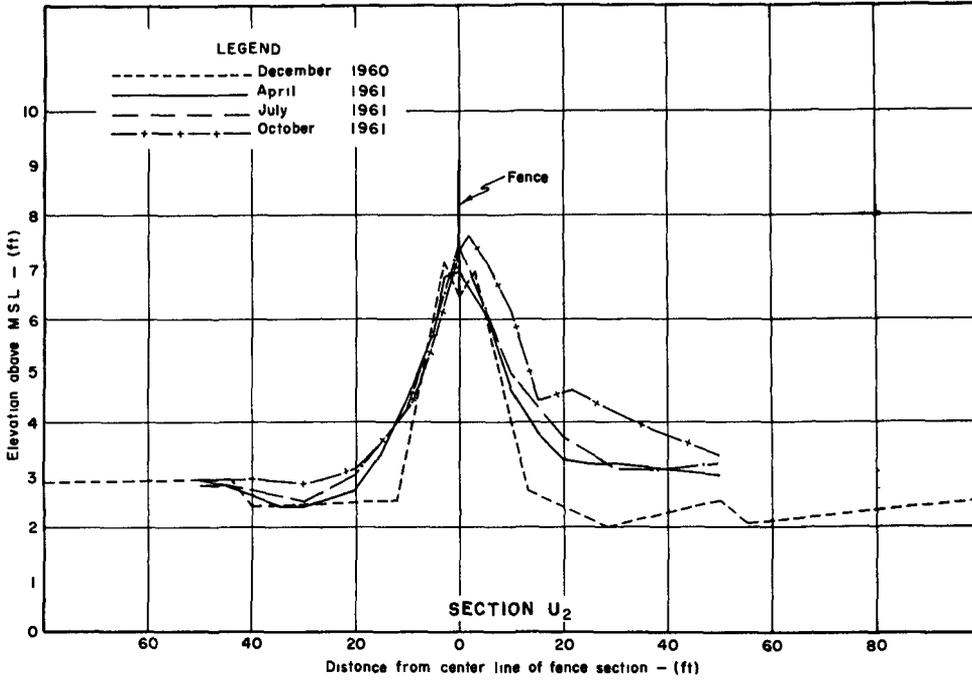


Fig. 12. Sand Accumulation Profiles, Fence on Bulldozed Dune.

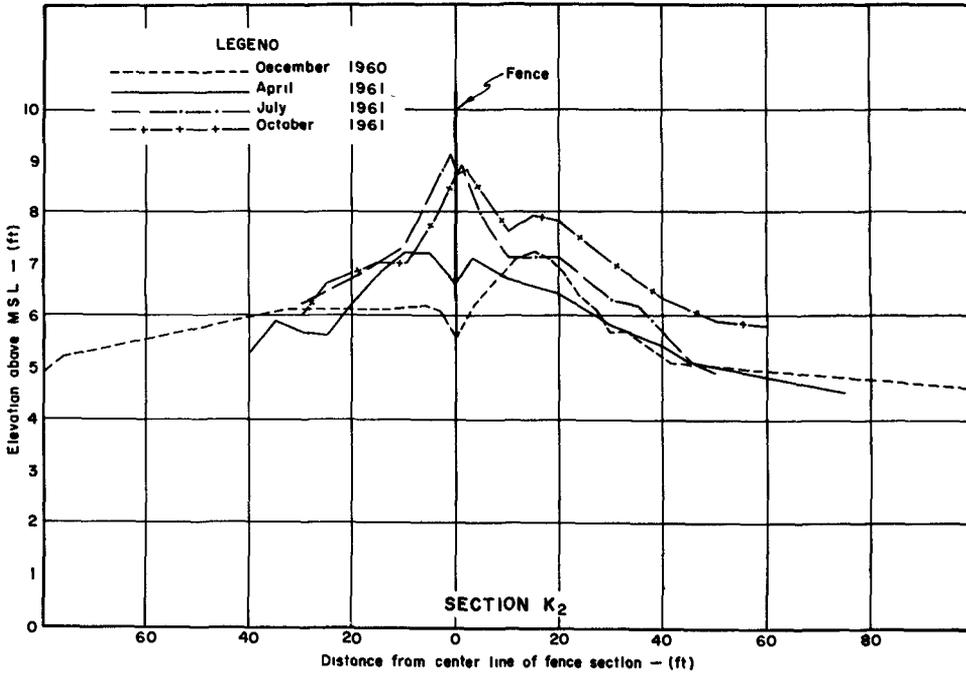


Fig. 13. Sand Accumulation Profiles Single Snow Fencing with Bottom One Foot off the Ground.

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which was installed on the 2-foot bank was among the slowest of the fences in filling and, at the end of the year, was the fence, other than the fences which were completely lost, which had trapped the least of any of the test fence sections. (See Figure 12). The other fences in the immediate vicinity of this fence section had trapped quantities of sand which compare very favorably with those of the other fence sections along the test area. Therefore, it can be concluded that fences which are set at the general ground level fill more quickly than fences which are placed on an initial 2-foot bank.

The one section of straight brush fencing of 25 percent porosity (Section P) trapped more sand than either comparable brush or snow fence sections having a porosity of 50 percent. The fencing of Section P trapped 2.97 cubic yards per foot of beach while the average volume trapped for other comparable test snow-fence sections, all with a porosity of 50 percent, was 2.56 cubic yards per foot of beach (see Tables 1 and 4).

From the performance of Section K, it appears that it is possible to increase the effective height of sand fences one foot by leaving a one-foot space between the bottom of the fence and the sand when the fence is installed (see Figure 13). However, this procedure appears to have certain disadvantages, particularly in this study area, in that the fencing does not fill as quickly as fencing which is initially set on the ground and would be susceptible to loss by water damage for a longer time.

Apparently, increasing the height of the fences by 2 feet is impractical in that the posts must be set much deeper in the sand than the posts of fencing set at ground level. Thus, the advantage gained by having the fence taller may not justify the extra effort involved in setting the posts in the sand well enough to hold the heightened fence section. However, this conclusion must be tentative because the higher fences which were tested did not remain upright long enough to trap sand and, therefore, their efficiency in trapping sand is still not known.

### PLANNED CONTINUATION OF THE STUDY

It is planned that this will be a continuing study and preparations are now being made for the installation of new fencing in the study area in November 1962.

The objectives of the program for the coming year will be:

(a) To establish new fences on top of the existing sand fence accumulations to determine if the desired dune section can be created using the method shown in Figure 2b.

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(b) To establish a dune at least one fence (4 feet) in height along the entire experimental area. Since the indications from the first year of study are that the straight slat-type snow fencing traps essentially as much sand as either the zigzag configuration or the spur-type fencing it has been recommended that only straight snow fencing be used.

(c) To determine to a higher degree of accuracy the conditions which are necessary for significant sand movement. This is believed to be desirable since the people who frequently visit the island report that for perhaps weeks and months the sand accumulation of the fences remains constant. However, over a few hours or days during favorable conditions, large quantities of sand are trapped by the fences.

(d) To test some of the new plastic materials becoming available for use as sand fences.

It appears from the results of the first year of observations that some type of continuous observation and maintenance program will be required to successfully build a barrier dune on Core Banks. Under such a program, any fencing which is lost would be replaced as soon as possible. Thus every favorable sand-moving condition would be utilized to fill in the weak spots in the dune and deterioration of the remaining dune would be minimized.

### CONCLUSIONS

From the results of the first year of the experimental study, the following conclusions appear to be justified:

1. Single fencing which is initially 4 feet high appears to hold about 3 cubic yards of sand per lineal foot of fencing. However, during the first 7 months of this study, the average volume of sand trapped by all of the fence sections, single and double, was about 2.5 cubic yards per lineal foot of beach.

2. Brush fencing apparently traps about 5 percent more sand than comparable snow fencing. However, brush fencing installed costs approximately twice as much as snow fencing installed. Therefore, the use of brush fencing is not economically justified.

3. Straight fencing appears to trap and hold more sand than either straight fencing with side spurs or zigzag fencing.

4. A 50-foot spacing between two fences installed simultaneously is too large if it is desired that the area between the fences fill significantly. A 25-foot spacing appears to be somewhat too

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large; however, this spacing needs to be subjected to further study.

5. The effective height of sand fencing can be increased by installing it with the bottom one foot off the ground. However, fencing installed in this manner fills slower immediately after installation than fencing set at ground level.

6. The rate of filling and final trapping capacity of fencing with a porosity of approximately 25 percent appears to be larger than that of fencing with a porosity of approximately 50 percent.

### ACKNOWLEDGEMENTS

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