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72D CONGRESS
1st Session

HOUSE OF REPRESENTATIVES

DOCUMENT
No. 204



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U.S. War Dept.
FORT FISHER, N. C.

LETTER

FROM

THE SECRETARY OF WAR

TRANSMITTING

REPORT DATED DECEMBER 29, 1931, FROM THE CHIEF OF ENGINEERS, UNITED STATES ARMY, ON THE STUDIES AND INVESTIGATIONS OF THE BEACH EROSION AT FORT FISHER, N. C. X

JANUARY 5, 1932.—Referred to the Committee on Rivers and Harbors and ordered to be printed, with illustrations

WAR DEPARTMENT,
Washington, December 31, 1931.

The SPEAKER OF THE HOUSE OF REPRESENTATIVES,
Washington, D. C.

DEAR MR. SPEAKER: I am transmitting herewith a report dated December 29, 1931, from the Chief of Engineers, United States Army, with accompanying report on the studies and investigations of the beach erosion at Fort Fisher, N. C., made by the Beach Erosion Board in cooperation with the North Carolina Department of Conservation and Development, as authorized by the rivers and harbors act approved July 3, 1930.

Sincerely yours,

PATRICK J. HURLEY,
Secretary of War.

WAR DEPARTMENT,
OFFICE OF THE CHIEF OF ENGINEERS,
Washington, December 29, 1931.

Subject: Beach erosion at Fort Fisher, N. C.
To: The Secretary of War.

I submit, for transmission to Congress, my report, with accompanying papers, on the studies and investigations of the beach erosions at Fort Fisher, N. C., made by the Beach Erosion Board in cooperation

EAST CAROLINA UNIVERSITY
GREENVILLE, N. C. 27834

with the North Carolina Department of Conservation and Development as authorized by the rivers and harbors act approved July 3, 1930.

Fort Fisher, N. C., is located on the ocean front on the narrow neck of land between Cape Fear River and the Atlantic Ocean, about 9 miles north of the point of Cape Fear. It was built by the Confederate Army during the Civil War to guard the entrance to Wilmington, N. C.

The shore along the ocean front of the old fort has been eroded to such an extent that the sand mounds which compose the structure of Fort Fisher are now threatened with destruction. On account of its location and history, local interests desire to protect the remains of the fort.

The studies of the board, based on past records and maps and investigations in the field during the past year, indicate that the shore line has in the past eroded, though not continuously, so as to destroy certain historical landmarks and is now eroding at a rate that threatens to destroy other such landmarks.

The board reports that the most economical form of construction which could be safely counted on to protect the existing shore line at Fort Fisher is the construction of a bulkhead and four groins at an estimated cost of \$71,600.

After due consideration of these plans, I concur in the conclusions of the board. The expenditure, while desirable in the interest of the protection of an historic work, is not justified in any Federal interest of navigation.

In view of the general value of the material contained in the board's report and the public interest involved therein, it is recommended that the report be published with its accompanying plates.

LYTLE BROWN,
Major General, Chief of Engineers.

WAR DEPARTMENT,
BEACH EROSION BOARD,
Washington, D. C., November 10, 1931.

Subject: Shore protection of Fort Fisher, N. C.
To: The Chief of Engineers, United States Army.

SYLLABUS

The Beach Erosion Board, appointed by paragraph 3, Special Orders, No. 72, Office of the Chief of Engineers, September 18, 1930, is of the opinion that the most economical method of protection for the north portion of the shore line of Fort Fisher, N. C., that gives promise of success, consists of a bulkhead and groin system as hereinafter described.

The initial cost of such protection is estimated to be \$71,500.

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| B. Location and description. | E. Corrective measures and recommendations. |
| C. Field and office studies. | |

A. INVESTIGATION ORDERED

1. *Project.*—A cooperative study of the beach erosion at Fort Fisher, N. C., has been made by the Beach Erosion Board and the State of North Carolina, as authorized by section 2 of the river and

harbor act of July 3, 1930, and directed by the Chief of Engineers in an indorsement dated June 5, 1931. (E. D. 6604-44.) Formal application for the investigation was made by the North Carolina Department of Conservation and Development, the official State agency, May 15, 1931. The study involves an investigation and a report on the extent of the beach erosion, with recommendations as to method and cost of protecting the shore from further attack by the sea. It covers the following items:

(a) Historical investigation of all existing new and old maps and reports dealing with this section of North Carolina coast, to determine the changes which have taken place in the past in order to utilize the results as a guide to what may be expected in the future.

(b) Extension of the Carolina-Kure Beach base line previously established by the State of North Carolina and cross sections to a point 1,000 feet south of Fort Fisher.

(c) Preparation of a contour map of the area comprised between points 1,000 feet north and 1,000 feet south of Fort Fisher, extending at least 300 feet west of the high-water mark.

(d) Investigation of foundation conditions by borings or test pits located at appropriate locations within the area described in (c) above, as a guide to location and type of protective works.

(e) Aerial photographs of the shore line from Carolina Beach to Corncake Inlet.

2. The estimated cost of the cooperative investigation was \$2,000. It was decided that the State of North Carolina, through the department of conservation and development, should assume responsibility for items (a), (b), and (c), outlined above, at a cost of approximately \$1,000, which had been made available by the county commissioners of New Hanover County, and that the United States, through the Beach Erosion Board and the district engineer at Wilmington, N. C., should be responsible for the conduct of items (d) and (e).

3. *Inspections by the board.*—The area under investigation has been visited at frequent intervals by various members of the board. Mr. Thorndike Saville has visited Fort Fisher at least once each month since the application was made by the State of North Carolina. In May, 1931, Col. Earl I. Brown, Col. E. J. Dent, Mr. Thorndike Saville, and the recorder visited and examined the beaches in the vicinity of Fort Fisher. On October 22, 1931, the board convened in Wilmington, N. C., and visited the vicinity of Fort Fisher, located the proposed site of the structures, and made such changes in design as the configuration in the terrain indicated.

B. LOCATION AND DESCRIPTION

4. Fort Fisher, N. C., is located on the ocean front on the narrow neck of land between Cape Fear River and the Atlantic Ocean, about 9 miles north of the point of Cape Fear. (See Pl. I.) The locality, known as Federal Point, was on the north shore of New Inlet, now closed. Fort Fisher was constructed by the Confederate Army during the Civil War. It has been proposed by local interests that the Federal Point area shall be administered either by the National or State Government as a public reservation commemorating the Battle of Fort Fisher. Included in this area is "Battle Acre," formerly a

United States lighthouse reservation, which was conveyed to the State of North Carolina by act of Congress dated December 21, 1928 (Public 642), as a memorial to commemorate the Battle of Fort Fisher. A paved highway leading from the mainland to Federal Point has been constructed.

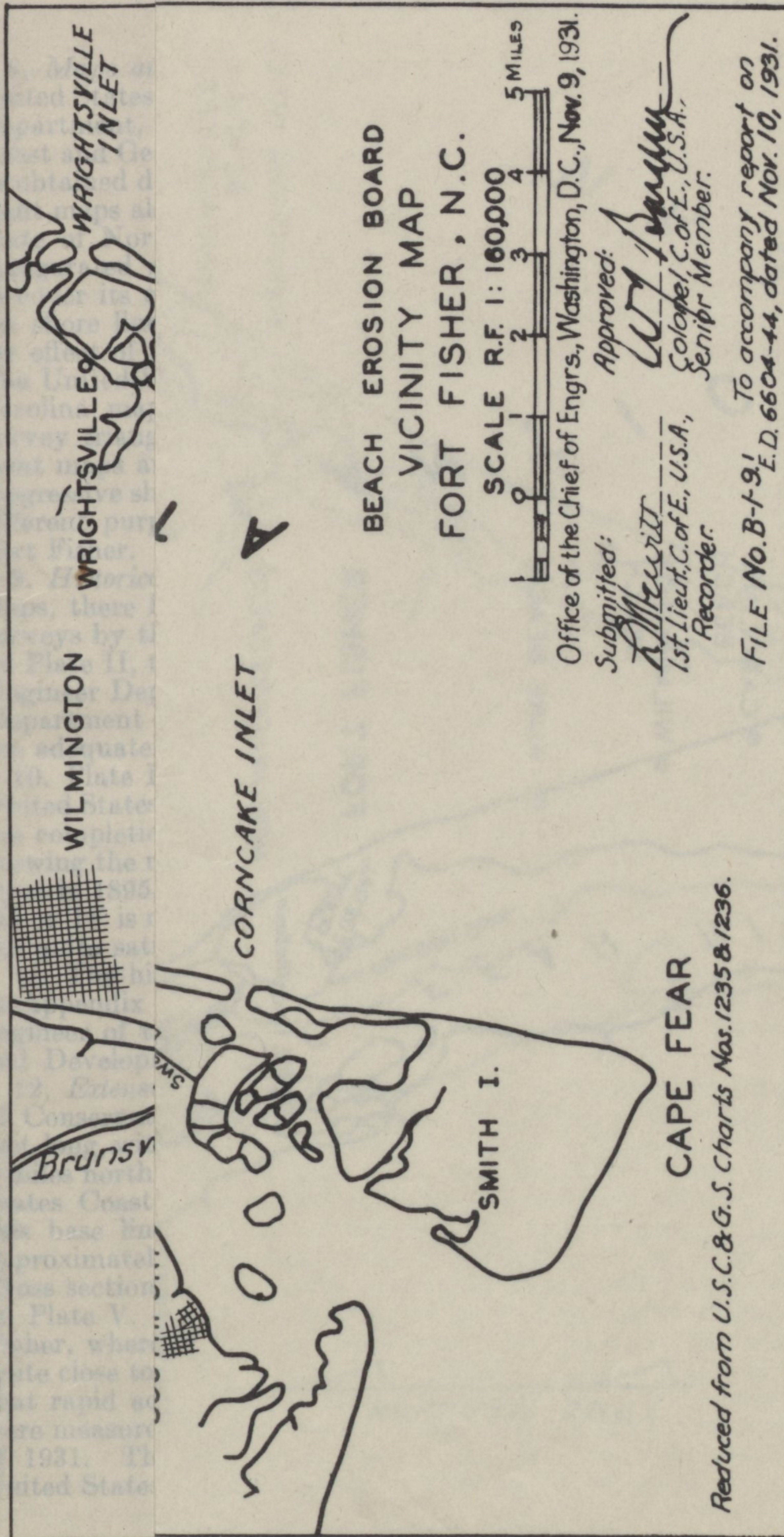
5. The shore along the ocean front of the old fort has been seriously eroded. The beach, although comparatively flat, contains a considerable amount of heavy material, indicating either the wearing away of headlands in the vicinity or abrasion of the sea bottom taking place immediately offshore. Small patches of outcropping coquina are visible at low tide at a point where, at one time, the high-water line was some 600 feet seaward of its present location. The wave attack has extended inshore to the foot of the sand dunes and to the bottom of the earthworks of Fort Fisher.

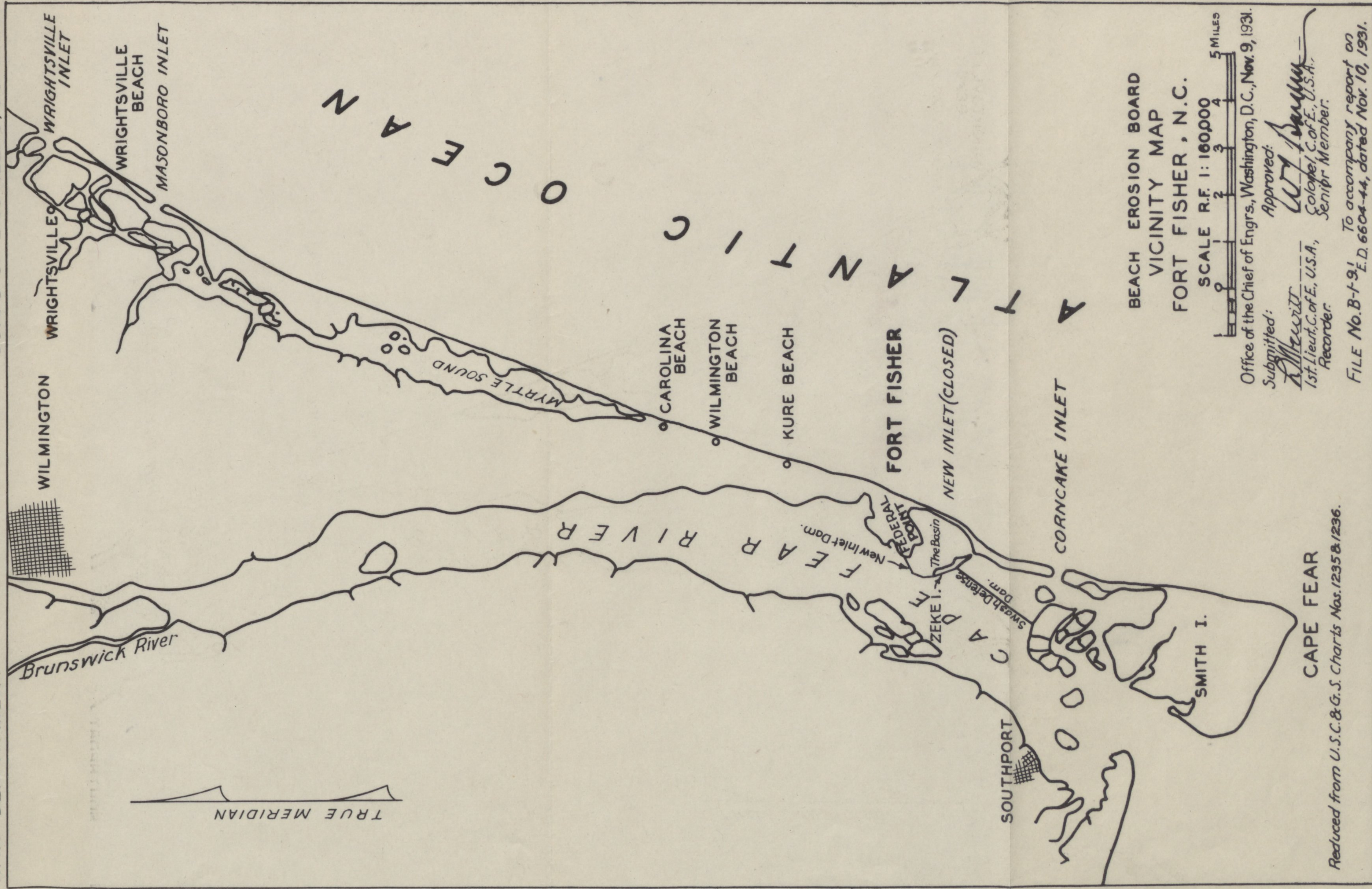
6. The locality has considerable historical interest. During the Civil War Wilmington was an important port of the Confederacy, to which supplies necessary to the prosecution of the war were brought by blockade runners. Its importance increased toward the end of the war, as the Federal forces progressively extended their control of the sea and reduced the importation of war material to the Confederacy through other ports. Fort Fisher, lying near the navigable entrance to the Cape Fear River, was the key to the port. Late in December, 1864, it was attacked by Federal forces, the purpose being to eliminate the running of the blockade at the entrance to the port of Wilmington. A feature of the attack was the explosion of a powder ship at a point opposite the fort, followed by a bombardment and land attack which was unsuccessful. The Federal forces then withdrew to Beaufort. On January 13, 1865, they renewed the attack. The fleet under command of Rear Admiral Daniel D. Porter commenced a bombardment which continued until 3 p. m. January 15, when the assault was made. Eight thousand troops under Maj. Gen. Alfred H. Terry made a flanking attack on the rear defenses at the same time that 2,150 sailors and marines made a frontal attack on the northeast angle of the fort. The naval forces were unsuccessful in gaining an entrance to the fort, but the land forces succeeded in capturing it at 8 p. m. that evening after a hard-fought and bloody action. The fort was defended by 1,800 troops under command of Col. William Lamb. Additional Confederate forces were in the neighborhood but took no part in the battle. The naval bombardment preceding the attack was one of the most intense in American history.

7. On account of its location and history, local interests are anxious to protect what remains of the fort, by restoration, construction of roads, etc., so as to make it a point of attraction for visitors. A delegation of interested parties appeared before the board at its meeting in Wilmington and set forth their views as to the historical importance of the site and the desirability of preserving it. A further evidence of definite interest is shown by the fact that the North Carolina division of the United Daughters of the Confederacy have raised a sum of \$10,000 for the construction of a granite monument at Fort Fisher, work upon which will be started in January, 1932.

CORPS OF ENGINEERS, U.S. ARMY

WAR DEPARTMENT





BEACH EROSION BOARD
VICINITY MAP
FORT FISHER, N.C.

SCALE R.F. 1:160,000
0 1 2 3 4 5 MILES

Office of the Chief of Engrs., Washington, D.C., Nov. 9, 1931.

Submitted:

R. M. Hewitt
1st. Lieut., C. of E., U.S.A.,
Recorder.

Approved:

W. J. Banham
Colonel, C. of E., U.S.A.,
Senior Member.

Reduced from U.S.C. & G. S. Charts Nos. 1235 & 1236.

FILE No. B-1-91 To accompany report on
E.D. 6604-44, dated Nov. 10, 1931.

C. FIELD AND OFFICE STUDIES

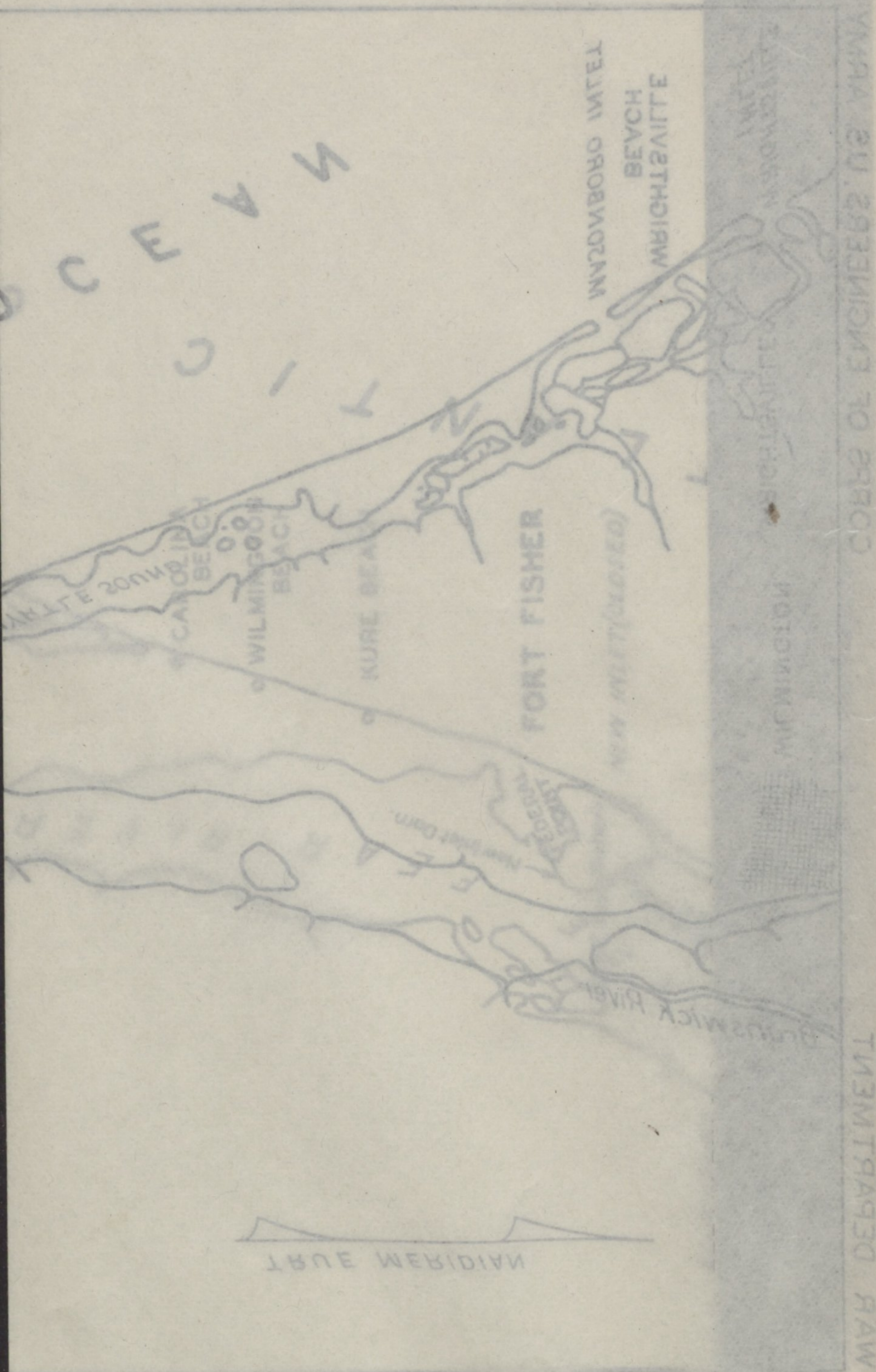
8. *Maps available.*—Maps exist based on periodic surveys of the United States Coast and Geodetic Survey, the United States Engineer Department, and the State of North Carolina. The United States Coast and Geodetic Survey maps from which reliable information can be obtained date back to 1852. The United States Engineer Department maps also cover a considerable period. The maps made by the State of North Carolina date from 1927, in which year the State inaugurated a systematic study of its beaches, intended eventually to cover its entire coast, for the purpose of determining changes of the shore line, the amount and destination of eroded material, and the effect of the littoral drift on the migration and closure of inlets. The United States Coast and Geodetic Survey maps and the North Carolina maps are tied into the United States Coast and Geodetic Survey triangulation system. The United States Engineer Department maps are not thus tied in, but are satisfactory in showing the progressive shore-line changes; unfortunately, as they were made for a different purpose, they do not extend north of the south point of Fort Fisher.

9. *Historical investigation.*—Based upon the study of the above maps, there have been prepared Plates II, III, and IV. Results of surveys by the United States Coast and Geodetic Survey are shown on Plate II, together with the 1926 shore line from the United States Engineer Department and the 1931 shore line by the North Carolina Department of Conservation and Development. All of these surveys are adequately tied into the triangulation system.

10. Plate III is an overlay, showing the results of surveys by the United States Engineer Department in 1882, 1884, and 1887, following the completion of New Inlet Dam in 1881. Plate IV is an overlay showing the results of surveys by the United States Engineer Department in 1895, 1897, and 1901. None of the surveys shown on Plates III or IV is completely tied into the triangulation system, but they are quite satisfactory in showing progressive shore-line changes.

11. The historical investigation ordered is covered in fuller detail in Appendix I, herewith, which is a report submitted by the chief engineer of the North Carolina State Department of Conservation and Development.

12. *Extension of base line.*—In 1927 the North Carolina Department of Conservation and Development established a base line 22,983.5 feet long, with its southern end at a point called Kure's Pier, about 2 miles north of Fort Fisher. This base line was tied into the United States Coast and Geodetic Survey triangulation system. In 1931 this base line was extended under the present project to a point approximately 3,000 feet south of the northern end of Fort Fisher. Cross sections of the beach were taken at selected stations as shown on Plate V. In the immediate vicinity of the northern end of Fort Fisher, where erosion has been severe, five cross sections were made quite close together. During the period of field work it was observed that rapid accretion was taking place, and therefore, cross sections were measured in this vicinity in June, July, August, and September, of 1931. The last two series of cross sections were made by the United States Engineer Office at Wilmington, N. C.



13. It will be observed that at section 338+00 the low-water line (elevation 0) moved seaward 35 feet during the period June 28–July 21, at an average rate of over 1 foot per day. Its position remained constant thereafter at this station, although at station 335+19.7 the movement of the low-water line continued into September, having moved a total distance eastward of 75 feet in the period June 28–September 3, at an average of 1.12 feet per day. The accretion, observed from June to September, in total quantity of sand moved is considerable.

14. It will be noted that erosion occurred at station 324+00 north of the rock ledge. During the period of observation the wind was almost constantly from the southwest and no storms occurred. It will be observed that there is no indication of an offshore bar in the area under observation south of the rock ledge, but that one does exist, in general, north of this point.

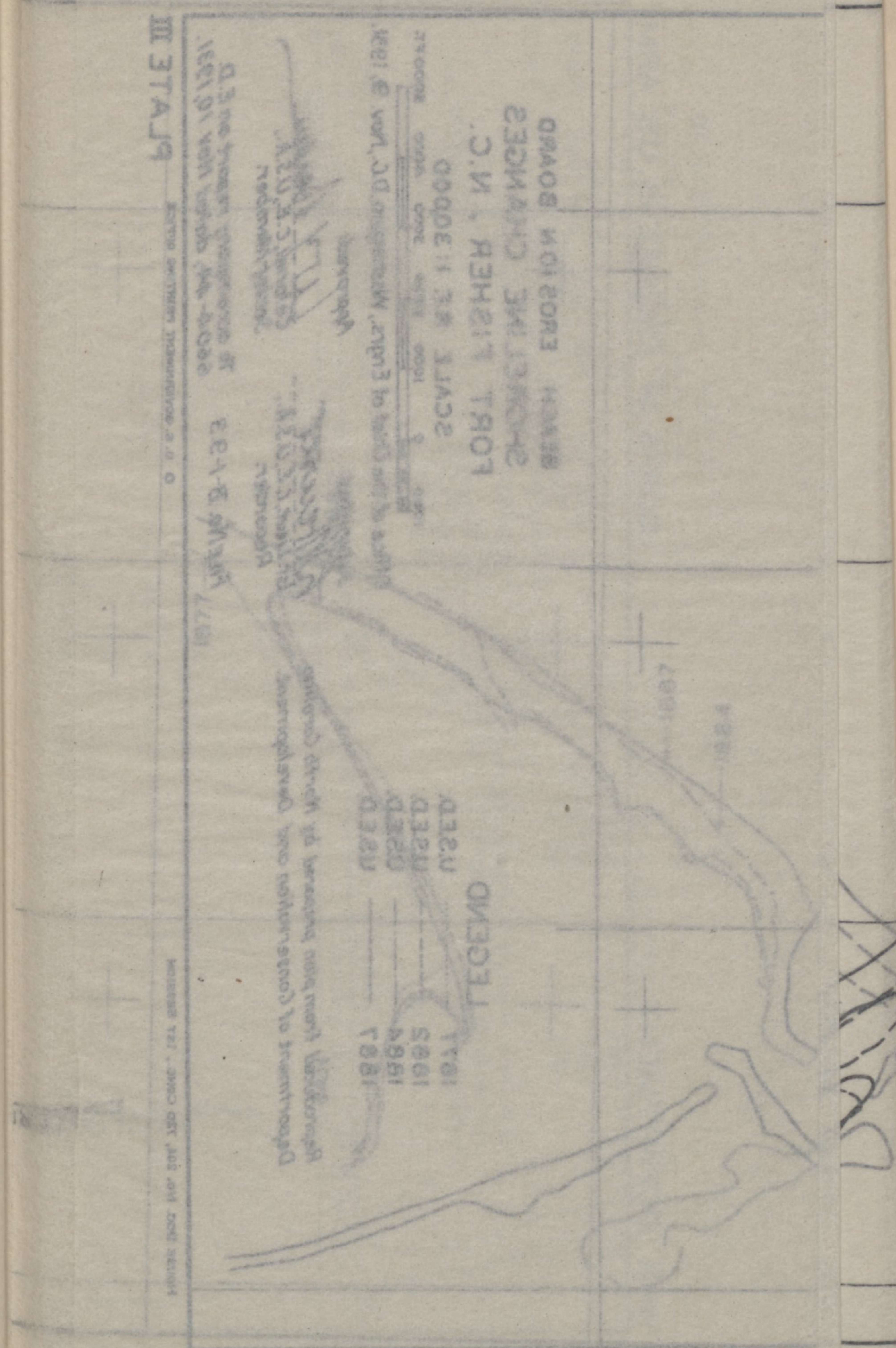
15. *Contour map.*—The North Carolina Department of Conservation and Development had prepared a contour map of Fort Fisher and vicinity. The map is to a scale of 1:1,200 horizontal and the contour interval is 1 foot on the beach from elevation 0 to elevation +10 and 2 feet westward of elevation +10. A reproduction of this map, scale 1:2,400, is attached (Pl. VI). This survey was carefully tied into both horizontal and vertical control systems of the United States Coast and Geodetic Survey. The map is amply accurate for studies of location of beach-protection structures. The contours below elevation +10.0 are subject to rapid change and are to be considered as accurate only as of June 10–16, 1931.

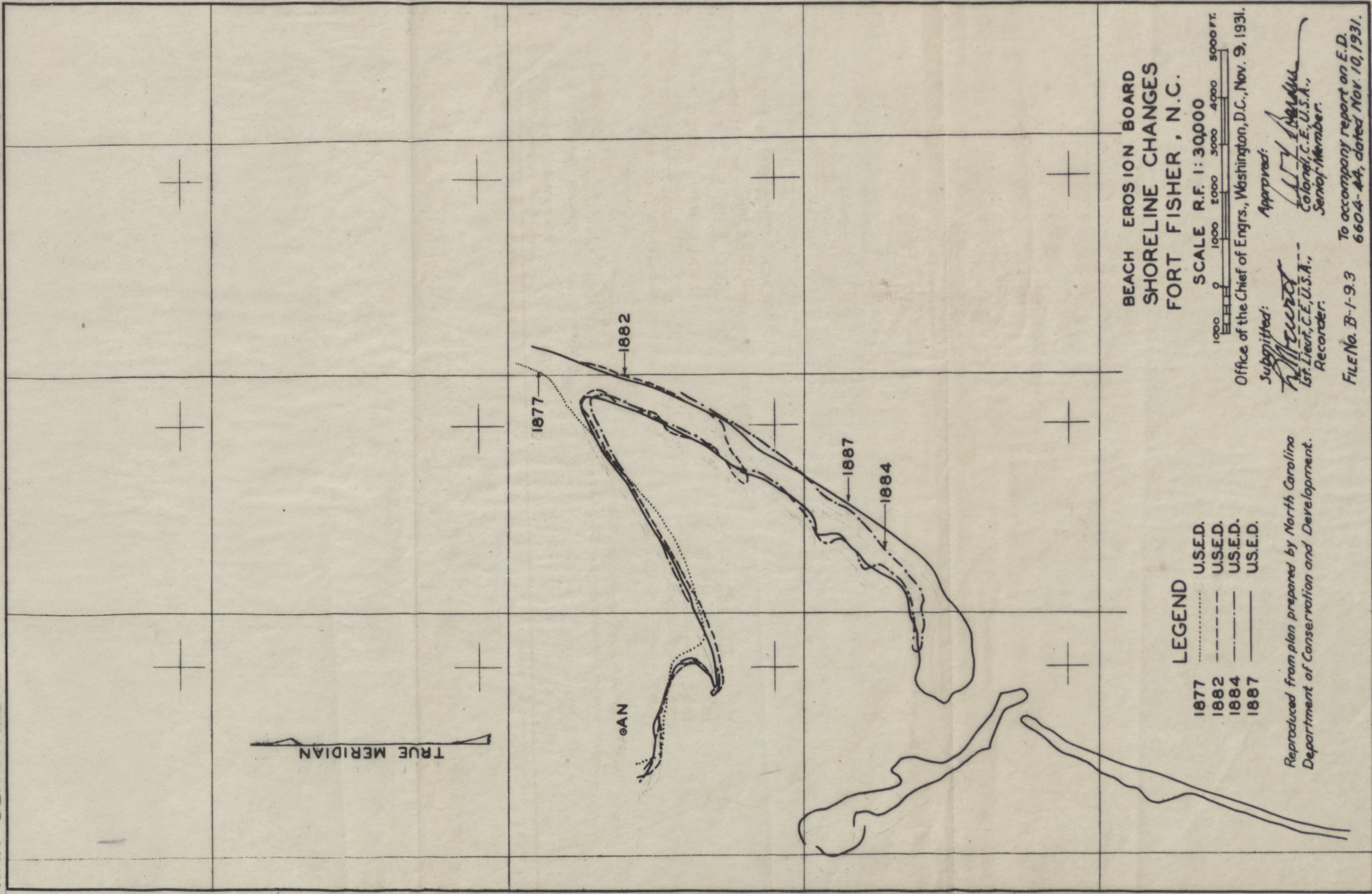
16. *Foundation conditions.*—In order to determine the character of the underlying materials of the beach at Fort Fisher for the purpose of designing and locating protective structures, wash borings were made at many points along the shore line. The borings were made by contract under the direction of the United States district engineer, Wilmington, N. C., and were completed August 11, 1931. Report of the district engineer is included in Appendix II. Samples were obtained of all materials encountered in each hole for a depth of about 20 feet below the surface of the beach. The profiles and locations of the borings are shown on Plate VII. Coquina was found in the majority of the holes. There is no indication that it occurs as continuous strata, but it occurs at irregular intervals and in separate deposits which may or may not be continuous. In general, the quantity and the hardness of the coquina tend to decrease as its elevation and distance from the ocean increases. From the samples obtained, the district engineer at Wilmington believes that no difficulty will be encountered in driving piles through any of the underlying material.

17. *Aerial photographs.*—An aerial mosaic, Appendix III,¹ of the shore line including the beach from a point north of Carolina Beach to Corncake Inlet, a distance of about 12.5 miles, shows its location in the vicinity of Fort Fisher as it existed in September, 1931. The map shows the narrow beach at Fort Fisher and the beaches north and south of this point, and also the complete closure of New Inlet.

18. *Tidal variations.*—The mean range of tide for this section of the coast of North Carolina is given by the United States Coast and Geodetic Survey as 4.2 feet and the range of springtides as 4.8 feet. Inasmuch as the heights of storm tides are dependent on the direction and velocity of the winds producing them, it is impossible to predict

¹ Not printed.





LEGEND

1877	U.S.E.D.
1882	----	U.S.E.D.
1884	----	U.S.E.D.
1887	----	U.S.E.D.

Reproduced from plan prepared by North Carolina Department of Conservation and Development.

**BEACH EROSION BOARD
SHORELINE CHANGES
FORT FISHER, N.C.**

SCALE R.F. 1:30,000

0 1000 2000 3000 4000 5000 FT.

Office of the Chief of Engrs., Washington, D.C., Nov. 9, 1931.

Submitted:

H. Howard
1st Lieut., C.E., U.S.A.,
Recorder.

Approved:

W. J. Anderson
Colonel, C.E., U.S.A.,
Senior Member.

FILE No. B-1-9.3 To accompany report on E.D. 6604-44, dated Nov. 10, 1931.

TRUE MERIDIAN

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1901

LEGEND

1895 ——— U.S.E.D.

1897 - - - U.S.E.D.

1901 - - - U.S.E.D.

Reproduced from plan prepared by North Carolina Department of Conservation and Development.

BEACH EROSION BOARD
SHORELINE CHANGES
FORT FISHER, N.C.

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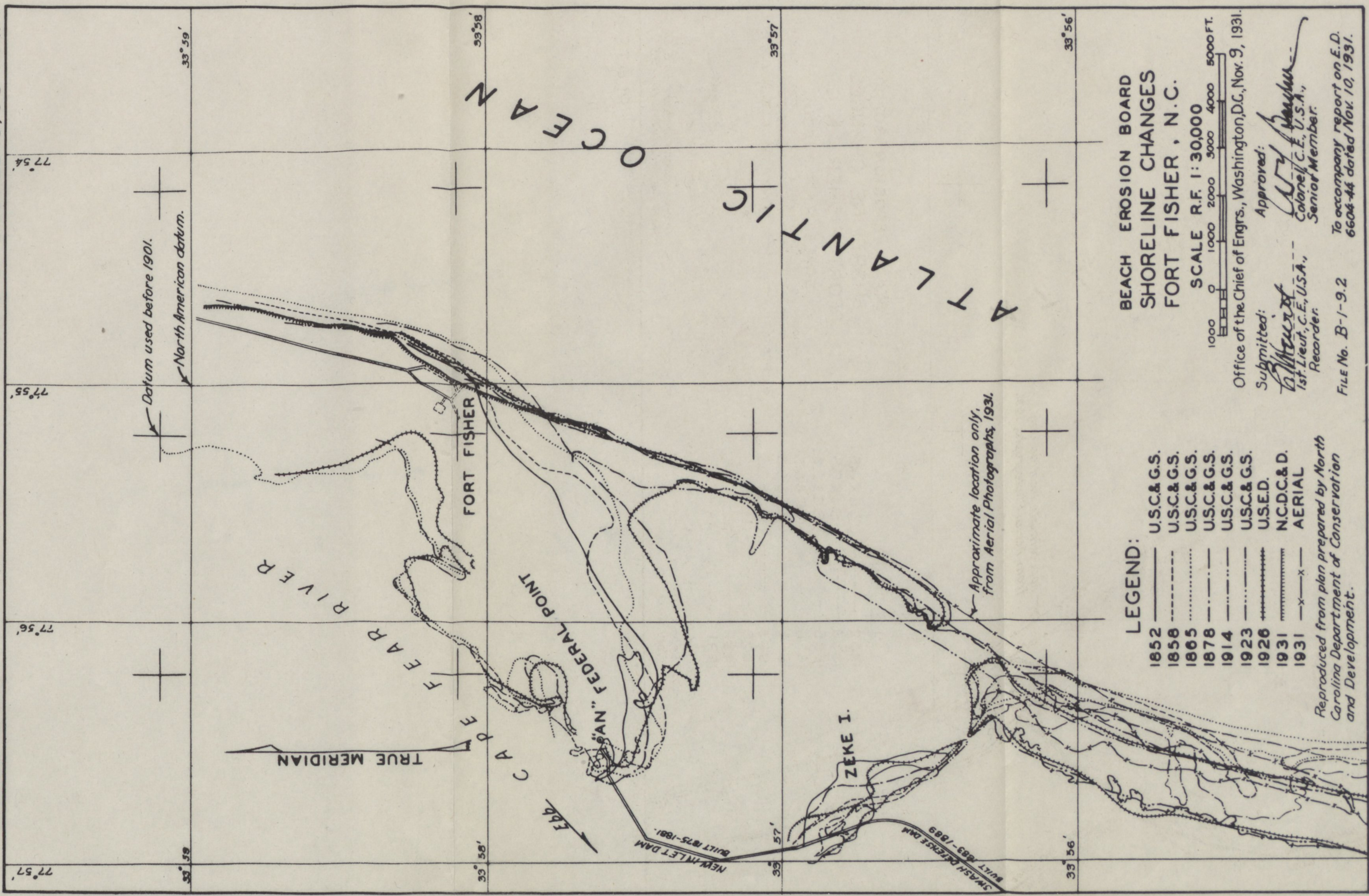
Office of the Chief of Engrs., Washington, D.C., Nov. 9, 1931.

Submitted: Approved:

E. D. Fisher
1st. Lieut., C.E., U.S.A.,
Recorder.

W. J. ...
Colonel, E.E., U.S.A.,
Senior Member.

FILE No. B-1-9.4 To accompany report on E.D. 6604-24, dated Nov. 10, 1931.



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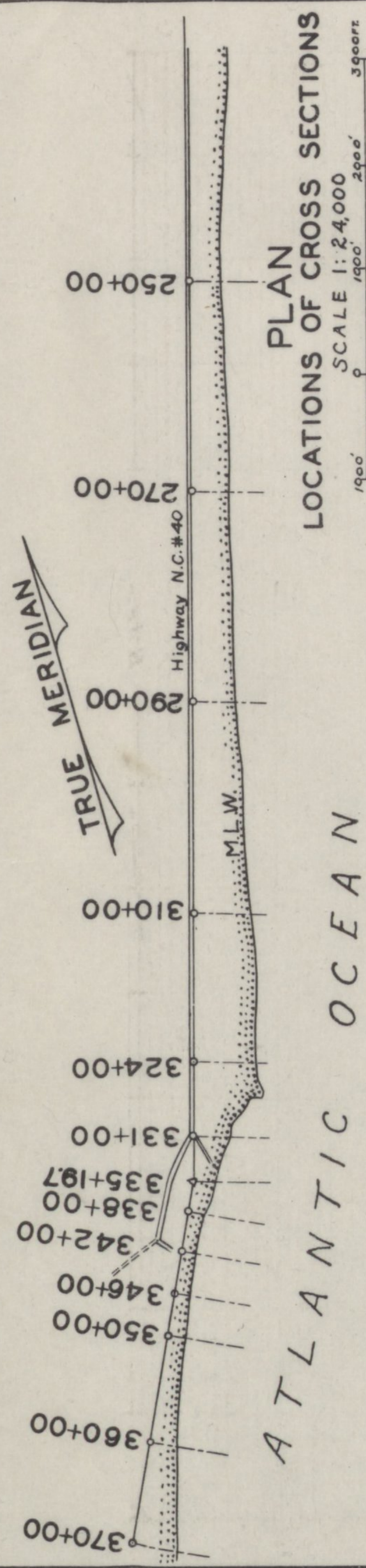
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1865	U.S.C.&G.S.
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1914	U.S.C.&G.S.
1923	U.S.C.&G.S.
1926	U.S.E.D.
1931	N.C.D.C.&D.
1931	AERIAL

Reproduced from plan prepared by North Carolina Department of Conservation and Development.

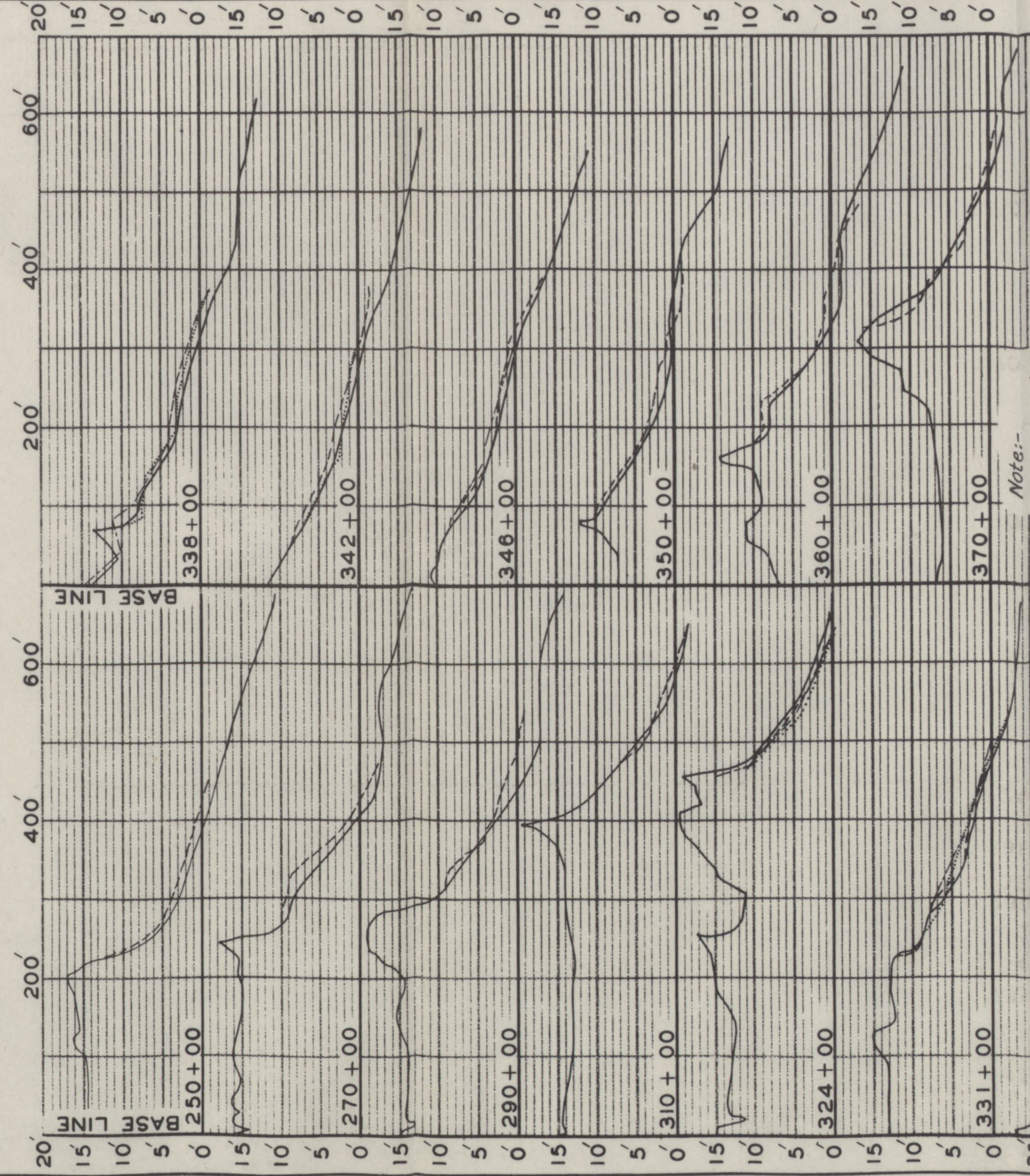
**BEACH EROSION BOARD
SHORELINE CHANGES
FORT FISHER, N.C.**

SCALE R.F. 1:30,000
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Office of the Chief of Engrs., Washington, D.C., Nov. 9, 1931.
Submitted: *[Signature]*
1st Lieut., C.E., U.S.A., Recorder.
Approved: *[Signature]*
Colonel, C.E., U.S.A., Senior Member.
File No. B-1-9-2 To accompany report on E.D. 6604-44 dated Nov. 10, 1931.



PLAN
LOCATIONS OF CROSS SECTIONS
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 August, 1931,
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Elevations refer to mean low water.

Note:-
 Reproduced from cross sections
 furnished by North Carolina Department
 of Conservation and Development.

BEACH EROSION BOARD
 CROSS SECTIONS
 FORT FISHER, N.C.

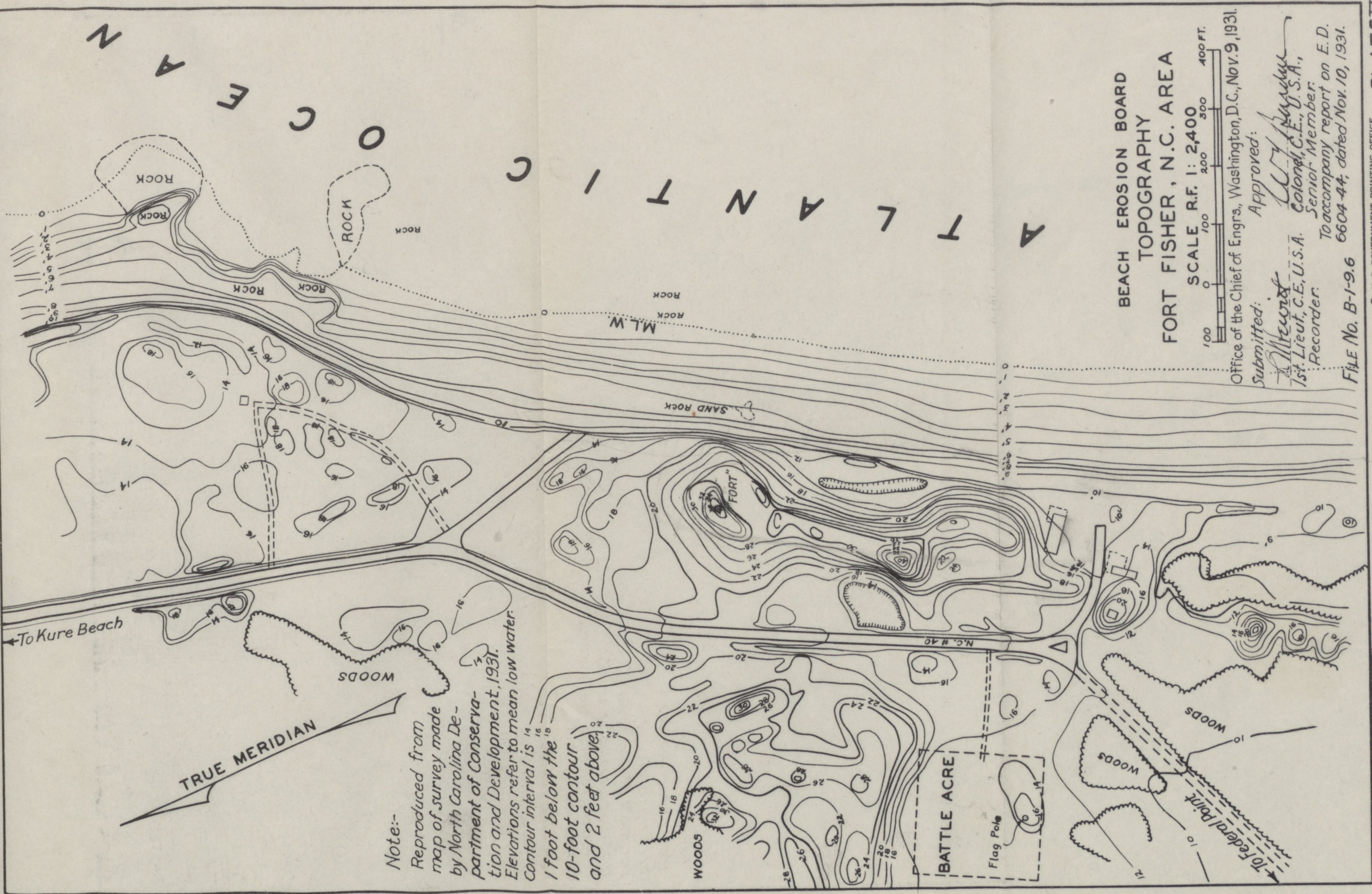
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Office of the Chief of Engrs., Washington, D.C., Nov. 9, 1931.

Submitted:
A. M. Howard
 1st. Lieut., C.E., U.S.A.,
 Recorder.

Approved:
W. F. Naudon
 Colonel, C.E., U.S.A.,
 Senior Member.

To accompany report on E.D.
 6604-44, dated Nov. 10, 1931.



TRUE MERIDIAN

Note:-
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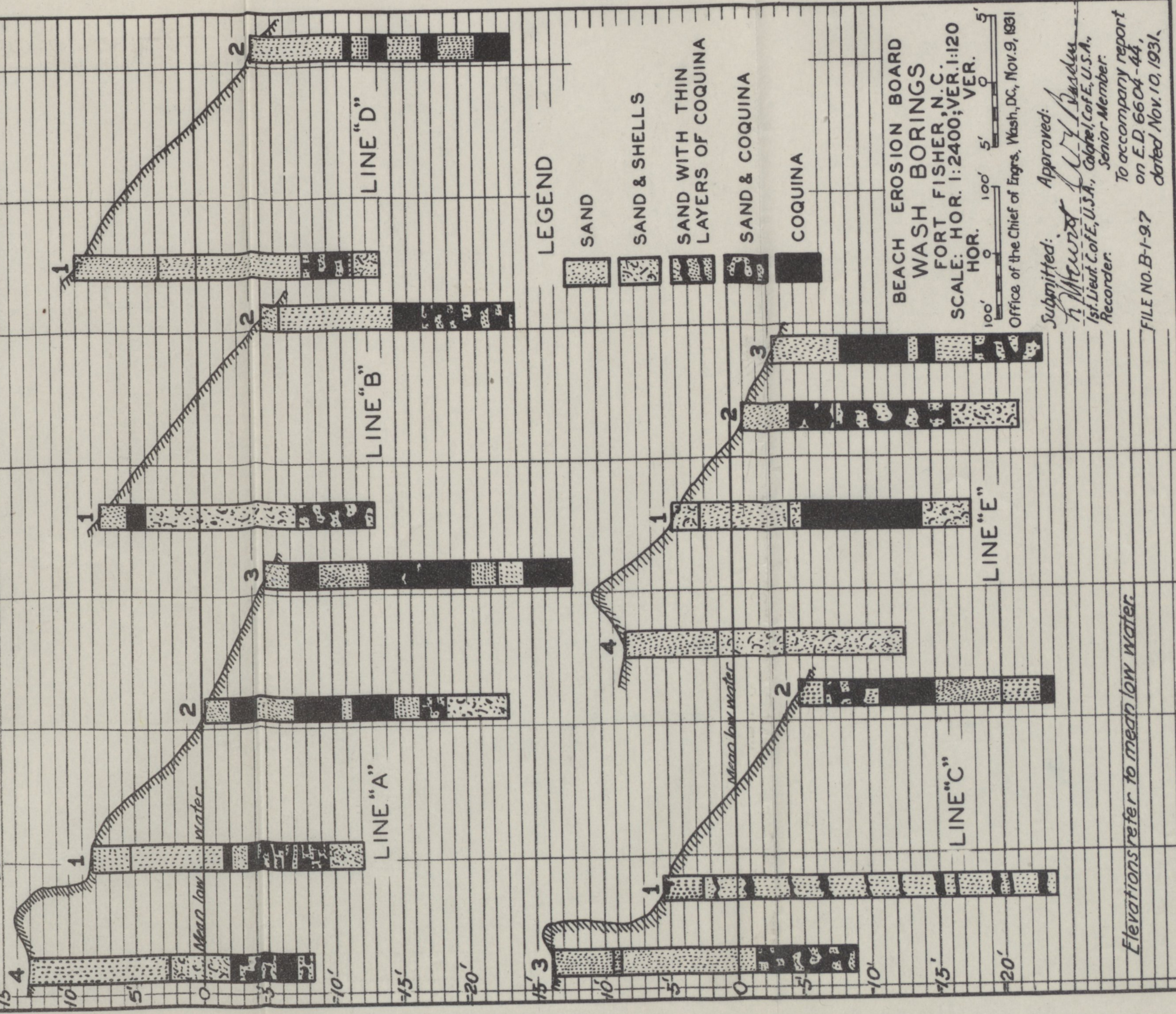
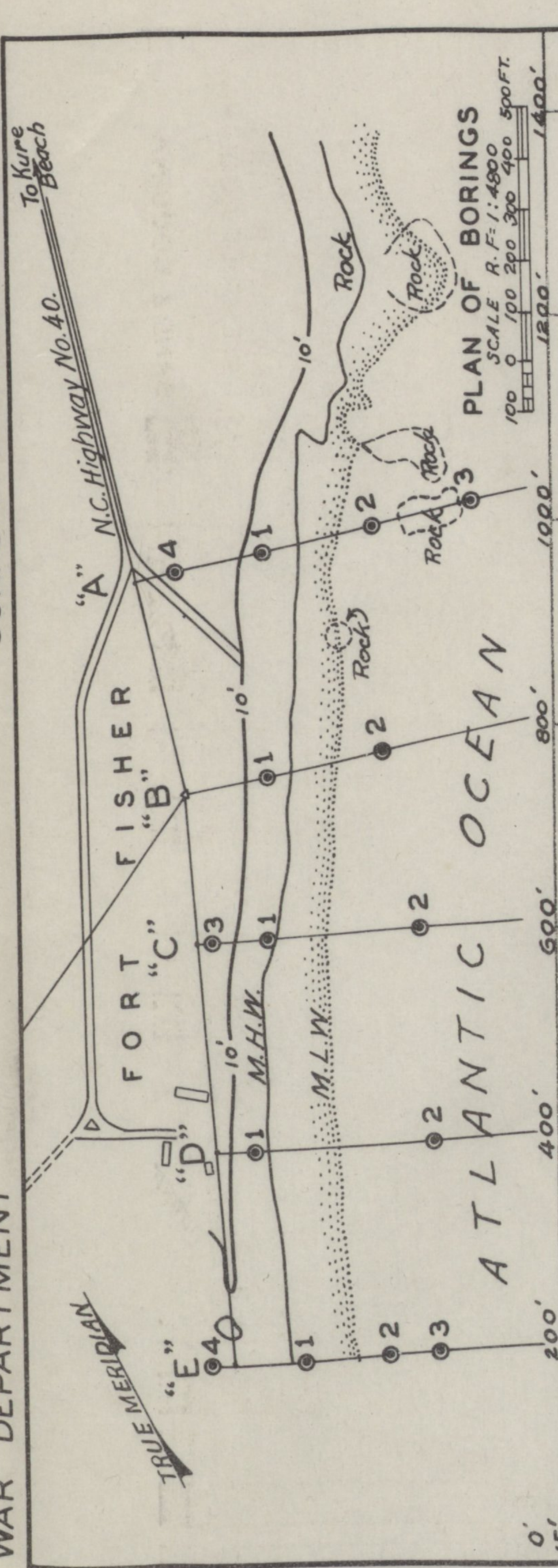
BEACH EROSION BOARD
 TOPOGRAPHY
 FORT FISHER, N.C. AREA

SCALE R.F. 1: 2400
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Office of the Chief of Engrs., Washington, D.C., Nov. 9, 1931.

Submitted: *A. M. Stewart*
 1st. Lieut., C.E., U.S.A.
 Recorder.
 Approved: *W. J. ...*
 Colonel, C.E., U.S.A.,
 Senior Member.
 To accompany report on E.D.
 6604-44, dated Nov. 10, 1931.

FILE No. B-1-9.6



what their height will be. However, it is recorded that on October 13, 1893, the elevation of the tide in the river at Zeke Island was 7.8 feet above mean low water. This height was probably 0.2 to 0.5 feet less than the height of high water in the ocean.

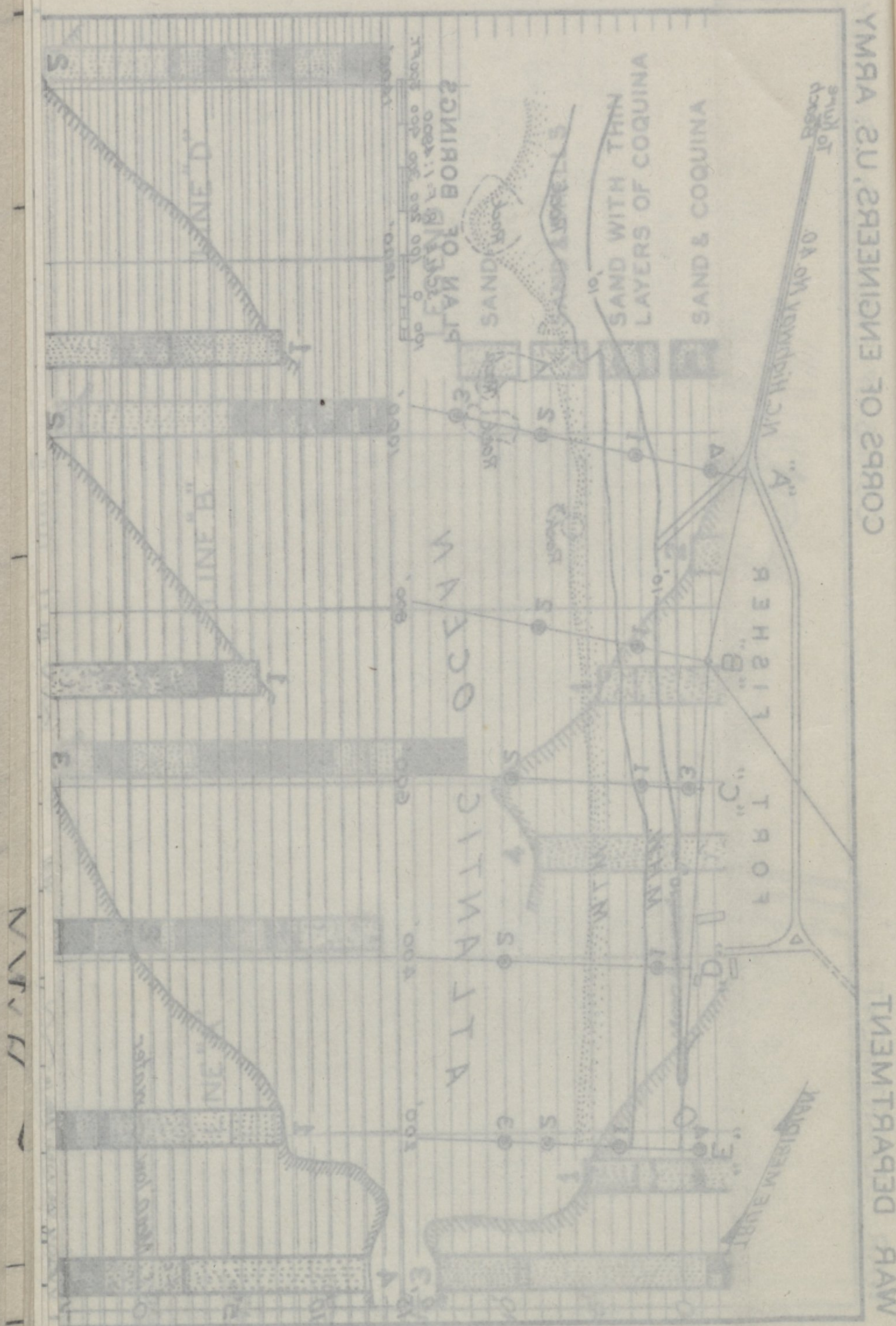
19. *Wind data.*—The proportionate amount of time during which the wind blew from the various directions during the period between 1923 and 1929, inclusive, is:

	Per cent		Per cent
North	16	Southwest	23
Northeast	12	West	19
East	11	Northwest	4
Southeast	4	Calm	1
South	10		

The records giving the wind velocities and directions for 15 storms between 1894 and 1930 show that the majority of storms come from the west. Westerly storms will not damage the beach. Of the remaining storms during this period, only four have come from the southwest and one from the northeast in which the wind velocity equals or exceeds 48 miles an hour.

20. *New Inlet.*—Southwest of Fort Fisher lies the mouth of the Cape Fear River. An important topographical element of this locality is New Inlet, formerly one of the mouths of the river. The elevation of land formations here, by natural and artificial causes, forms a part of the historical investigation of the locality. The history of New Inlet, indicated graphically in the plates previously mentioned, will accordingly be summarized. The coast of North Carolina, like that of other southern Atlantic seaboard States, consists of a series of offshore barrier beaches separated from the mainland by lagoons of various sizes. Old maps show no inlets in the vicinity of Federal Point or Fort Fisher until a storm, which is said to have occurred in 1761, formed the opening known as New Inlet. It was believed that the opening of New Inlet and the subsequent opening of other inlets in the vicinity of Zeke Island allowed the beach sand to enter Cape Fear River, which in turn caused the main bar channel to shoal.

21. In 1829 the improvement of the river was undertaken. Steps were taken to close the inlets near Zeke Island as early as 1854. At this time a series of cribs was sunk across the inlets with the hope of closing them. The major part of the work was done south of Zeke Island. The work did not close the inlets entirely, though it did result in the deepening of the main bar channel. The works were breached by storms, and in 1870, when the repair of these cribs was undertaken, five holes were found. In 1873 the complete closure of New Inlet was recommended. A structure designed for this purpose, known as New Inlet Dam, was begun in 1875 and completed in 1881. Since that time the dam has been extended to the south across Zeke Island, a distance of 2½ miles; this extension is known as Swash Defense Dam. Since 1852 there has been a practically constant tendency toward the closure of New Inlet by the formation of a sand spit extending in a southerly direction from the southern end of Fort Fisher. This tendency is apparent from the changes in the shore line from 1852 to 1878. (Pl. II.) Immediately after New Inlet Dam was completed in 1881 the growth of the spit was greatly accelerated, as will be seen by comparing the shore line of 1882, 1884,



and 1887 with that of 1877. (Pl. III.) From 1882 to 1887 the southern end of the spit was extended for a distance of about 6,300 feet, at an average rate of about 1,260 feet per year.

22. It is probable that a breach occurred north of the end of the spit between 1887 and 1895 (Pls. III and IV) which resulted in the closure of the old inlet and the opening of a new inlet at the place of the breach. (A similar phenomenon is reported as occurring after a breach which was made during a gale in September, 1857. In this case the breach occurred south of the then existing inlet.) After the formation of the latest inlet, between 1887 and 1895, the end of the spit continuously extended southward. It remained essentially stable between 1923 and 1926, the latter date being that of the most recent survey covering the inlet. The inlet was completely closed in March, 1931, and no evidence of its existence now appears. No survey of that area has been made since its closure.

23. *Fort Fisher.*—The evolution of the shore line at Fort Fisher, shown graphically in the above-mentioned plates, may be summarized in the following table:

TABLE I

Period	Erosion	Accretion	Change per year	Period	Erosion	Accretion	Change per year
	<i>Feet</i>	<i>Feet</i>	<i>Feet</i>		<i>Feet</i>	<i>Feet</i>	<i>Feet</i>
1852-1858		160	+26.7	1923-1926		60	+20.0
1858-1865		325	+46.4	1926-1931	280		-56.0
1865-1878	30		-2.3	Total	740	545	-2.47
1878-1914	430		-11.9				
1914-1923							

Erosion 1865-1931 is 680 feet.

The attention of the board was called, during its inspection, to the fact that, in addition to the erosion occurring on the ocean front of the Fort Fisher Reservation, erosion amounting to 550 feet between 1878-1931 occurred on the rear or Cape Fear River face. Fear was expressed that, if this continued, a new mouth of the Cape Fear River might be cut through the sand spit, with deleterious effects to the regimen of that river, which is a channel for ocean-going vessels. It is understood that the United States district engineer at Wilmington has the situation under observation, and it is presumed that the War Department will take whatever steps are necessary, at the appropriate time, to prevent any injury to navigation interests.

24. Reference is made to the strata of coquina shown in Plate VII. It is reported that four or five years ago the county commissioners removed some of this coquina for road metal. Local information is that it was taken from surface strata just south of the projecting point of coquina northeast of the fort and that a strip perhaps 50 to 100 feet wide was removed for a considerable length of beach over an area that now appears to be at or below mean low water. The estimated amount of material removed is 6,000 cubic yards. This action apparently synchronizes with a reversal in the erosion cycle of Table I above; a net accretion of 60 feet over three years before that date was followed by a net erosion of 280 feet in the five subsequent years.

25. At an inspection of the locality by three members of the board in May, 1931, it was noted that the high-water line was practically

at the base of the parapet mounds of Fort Fisher, or shoreward of its location in the summer and fall of 1931, as shown by the late survey in Plate VI. This points to a tendency to winter erosion and summer accretion.

26. Except for the survey of 1926, it is not known in what months the field work was done for the surveys on the basis of which the erosion and accretion shown in Table I were computed.

27. *Summary.*—Over the period of 80 years from 1852 to 1931, inclusive, there was a net erosion of 195 feet at the north end of Fort Fisher, measured along a line at right angles to the present shore line. The available data indicated four trends in this period—accretion of 485 feet for the first 13 years, erosion of 460 feet for the next 58 years, accretion of 60 feet for the next 3 years, and erosion of 280 feet for the last 5 years. High-water lines taken from Coast and Geodetic Survey charts are probably less accurate than those made for the specific purpose of determining these lines, and the figures in the above table, for accretion and erosion are correspondingly subject to inaccuracy. It can not be certainly stated that these represent the maximum swings of erosion and accretion, since the observations averaged 10 years apart. Neither is it certain how far an annual cycle of erosion in winter and accretion in summer, if such exists, quantitatively affects the figures. It is therefore unsafe to conclude that any continuous tendency has existed over a period of 80 years. It is, however, certain that for the past five years erosion has been going on, and that it is still going on. It is also a fact that previous erosions were sufficient to destroy certain landmarks known to have existed at the time of the Civil War, which, of course, were not restored by any intermediate building up of the natural beach.

28. After 1881 the closure of New Inlet converted what was formerly the mouth of a deep tidal estuary, through which there was undoubtedly a considerable ebb and flow of tide, into a shallow bay, through the mouth of which there was little ebb and flow. The closure of the throat of New Inlet was followed by the rapid building southward of a sand spit which eventually closed the mouth of the inlet. There is little question that this natural closure of the mouth was the effect of the construction of New Inlet Dam; that the material for the natural closure was sand brought from the north, including probably some sand from the outer bar shoals; and that there has always been a tendency for this sand to form a spit across the mouth of the inlet. How far the closure of New Inlet is connected with the erosion of Fort Fisher is, however, beside the present question. The material of which the sand spit at the mouth of the inlet is built greatly exceeds in quantity the net material that has been eroded in the same period from the Fort Fisher front. Some of it, no doubt, came from Fort Fisher and the beaches to the north, where a considerable erosion has occurred over a period of years. Reference to Table I shows that between 1865 and 1878 an apparent accretion cycle at Fort Fisher had ended and an apparent erosion cycle, on a small scale, had begun. The closure of New Inlet was started three years later (in 1881), and over a period of 33 years following this the erosion cycle at Fort Fisher apparently continued. Causal connection between these phenomena is wholly problematical. As nothing can now be done at New Inlet affecting the protection of Fort

Fisher, which is the practical problem before the board, the whole question of the inlet is academic for our present purpose. It is, however, an investigation of much interest in connection with the general study of coastal phenomena.

29. The only other information having a possible bearing on the problem is the removal of coquina a few years ago by the county commissioners. It is conceivable that this, by reducing the quantity of resistant material at a critical point, has accelerated the erosion.

30. The board finds in substance that the shore line of Fort Fisher has in the past eroded, though not continuously, so as to destroy certain historical landmarks, and is now eroding at a rate that threatens to destroy other such landmarks. While the cause can not be definitely stated now, the effects can be remedied. The only practical remedy consists in protective works.

E. CORRECTIVE MEASURES AND RECOMMENDATIONS

31. *Recommendation.*—The board considers that the cheapest form of protection which could be safely counted on to protect the existing shore line of Fort Fisher is a series of four steel sheet-pile groins and a steel sheet-pile bulkhead. The layout for the proposed work is shown on Plate VIII. Detailed estimates are in Appendix IV. The general characteristics of the installation are as follows:

A bulkhead, to consist of a row of steel sheet piles, of $\frac{3}{8}$ -inch web thickness, driven along the 10-foot contour of the beach, with a penetration of 14 feet. Suitable bracing, as shown in section B-B, Plate VIII, is provided by $1\frac{1}{4}$ -inch diameter tie-rods, spaced at every sixth pile and fastened to steel anchor piles, 12 feet in rear of bulkhead. The elevation of the top of bulkhead should be 10 feet above mean low water.

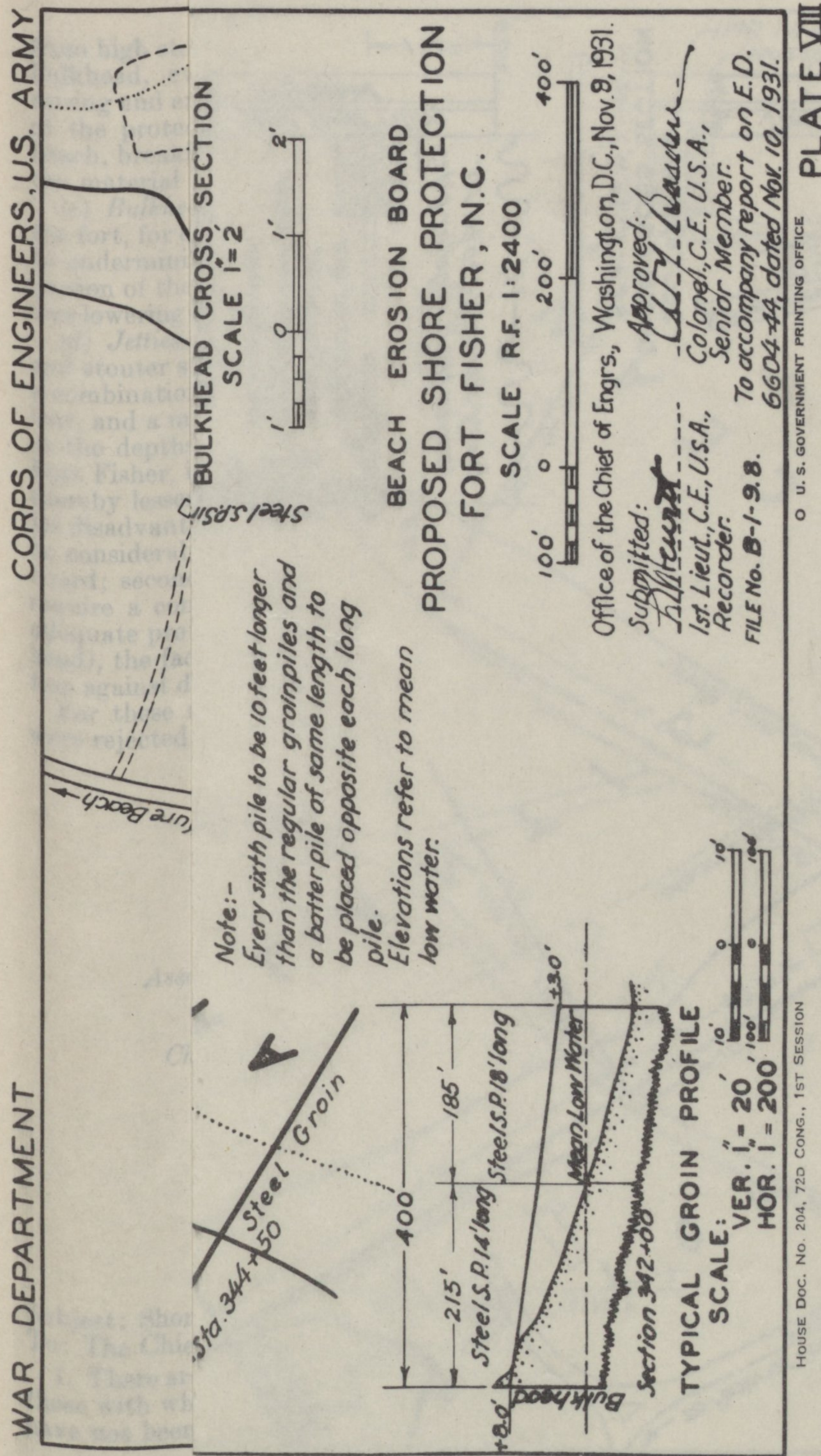
Four steel sheet-pile groins, generally normal to the bulkhead and shore line, tied to the bulkhead at their inner ends, each of a length of approximately 400 feet; to be constructed of heavier type of steel sheet pile, with a minimum penetration of 10 feet; every sixth pile to have a penetration of 20 feet; suitable bracing, as shown in section A-A, Plate VIII, is provided by a long master pile and a batter pile placed at every sixth pile; the inner end of each groin to have an elevation of 8 feet above mean low water, and the groins to slope to elevation +3.0 feet at the seaward end.

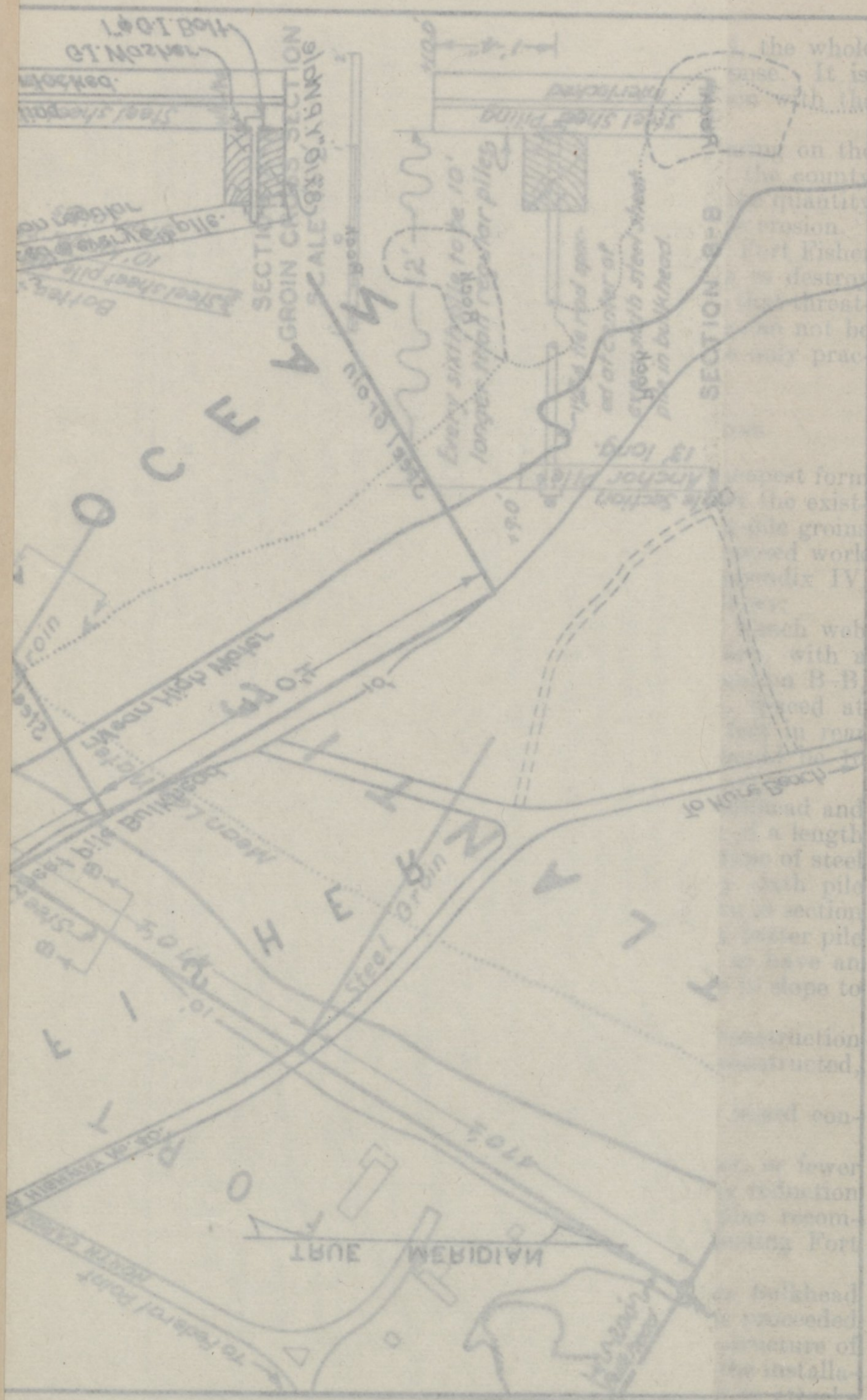
The exact location of the structures and other details of construction may need to be modified if, in the interval before they are constructed, changes of the shore line occur.

32. Before deciding on this type of construction, the board considered carefully possible alternative means. These are:

(a) A cheaper groin system consisting of shorter, lower, or fewer groins. The board was, however, of the opinion that any reduction in the strength of the groin system, below that of the plan recommended, would not give satisfactory assurance of protecting Fort Fisher.

(b) A groin system without bulkhead.—Omission of the bulkhead would effect a saving. The objection is that erosion has proceeded to the extent that the sand mounds, which compose the structure of Fort Fisher, and the protection of which is the purpose of the installation, are practically at the edge of the beach and exposed to attacks





from high storm waves. The board feels that a groin system without bulkhead, even if it accumulated sand between the groins, thus raising and extending the beach, would not give satisfactory assurance of the protection of the fort against high waves passing over this beach, breaking against the face of the fort and tending to drag down the material of which it is composed.

(c) *Bulkhead without groins.*—A bulkhead built along the sea face of the fort, for example, on the 10-foot contour, would always be subject to undermining by the uncontrolled action of waves, especially if the erosion of the beach in front of it continued, with a resultant progressive lowering of the level of the sand on the seaward side of the bulkhead.

(d) *Jetties.*—A jetty differs from a groin in being a longer, higher, and stouter structure extending farther into the water. It is usually a combination of an impermeable core, made of sheet piles or equivalent, and a mound of heavy rock, strong enough to resist wave action at the depths of water in which the jetty is built. A long jetty at Fort Fisher, if successful, would tend to accumulate a broad beach, thereby lessening and transferring seaward the attack of the waves. Its disadvantages are, first, its cost, which even for a single jetty would be considerably in excess of that of the plan recommended by the board; second, the fact that the accumulation of the beach might require a considerable time, during which the fort would not have adequate protection; and third (as in the case of groins without bulkhead), the fact that the fort would still not possess a positive protection against direct action of high storm waves breaking at its foot.

For these reasons the alternatives to the structure recommended were rejected by the board.

W. J. BARDEN,
Colonel, Corps of Engineers,
Senior Member.

EARL I. BROWN,
Colonel, Corps of Engineers.

G. R. YOUNG,
Major, Corps of Engineers.

RICHARD K. HALE,
Associate Commissioner, Department of Public Works,
State of Massachusetts.

VICTOR GELINEAU,
Chief Engineer, Board of Commerce and Navigation,
State of New Jersey.

THORNDIKE SAVILLE,
Chief Engineer,
Department of Conservation and Development,
State of North Carolina.

FORT HUMPHREYS, VA.,
December 11, 1931.

Subject: Shore protection of Fort Fisher, N. C.—Minority report.
To: The Chief of Engineers, United States Army.

1. There are some facts that should, in my opinion, be placed before those with whom the final decision in this case must rest, which facts have not been included in the majority report.

2. The board considered a plan providing for three steel sheet-pile jetties without a bulkhead. This plan is shown on the attached drawings. The estimated cost was \$24,000.

3. The purpose of this plan was to provide for the protection of the existing shore line by impounding part of the littoral drift and thereby building up a beach 50 to 100 feet in width in front of the present high-water line.

4. Should such a project prove successful, there would, of course, be no necessity for the more extensive work proposed by the majority at a cost of \$71,000.

5. The board is unanimous in the belief that there is no certainty that such a lesser project would prove sufficient. Certain members are, however, of the opinion that there is a probability, not merely a possibility, that this work would be adequate.

6. If the lesser project be executed, and, after a brief trial, it becomes evident that it will not be reasonably safe, a bulkhead can be added. If a threatened undermining of that bulkhead develops, two additional short groins can be added. The total cost of all of this work would be about the same as the cost of the project recommended by the majority, and the probability is that all of this work would not be required.

7. In view of the above, it is recommended:

(a) That no work for the protection of Fort Fisher be started until the sum required for the maximum project has been made available. This estimated cost is \$71,000.

(b) That the engineers responsible for the execution of the work build three jetties as shown in the attached plan and that the bulkhead and additional jetties referred to in paragraph 6 be not started until the necessity therefor has been demonstrated.

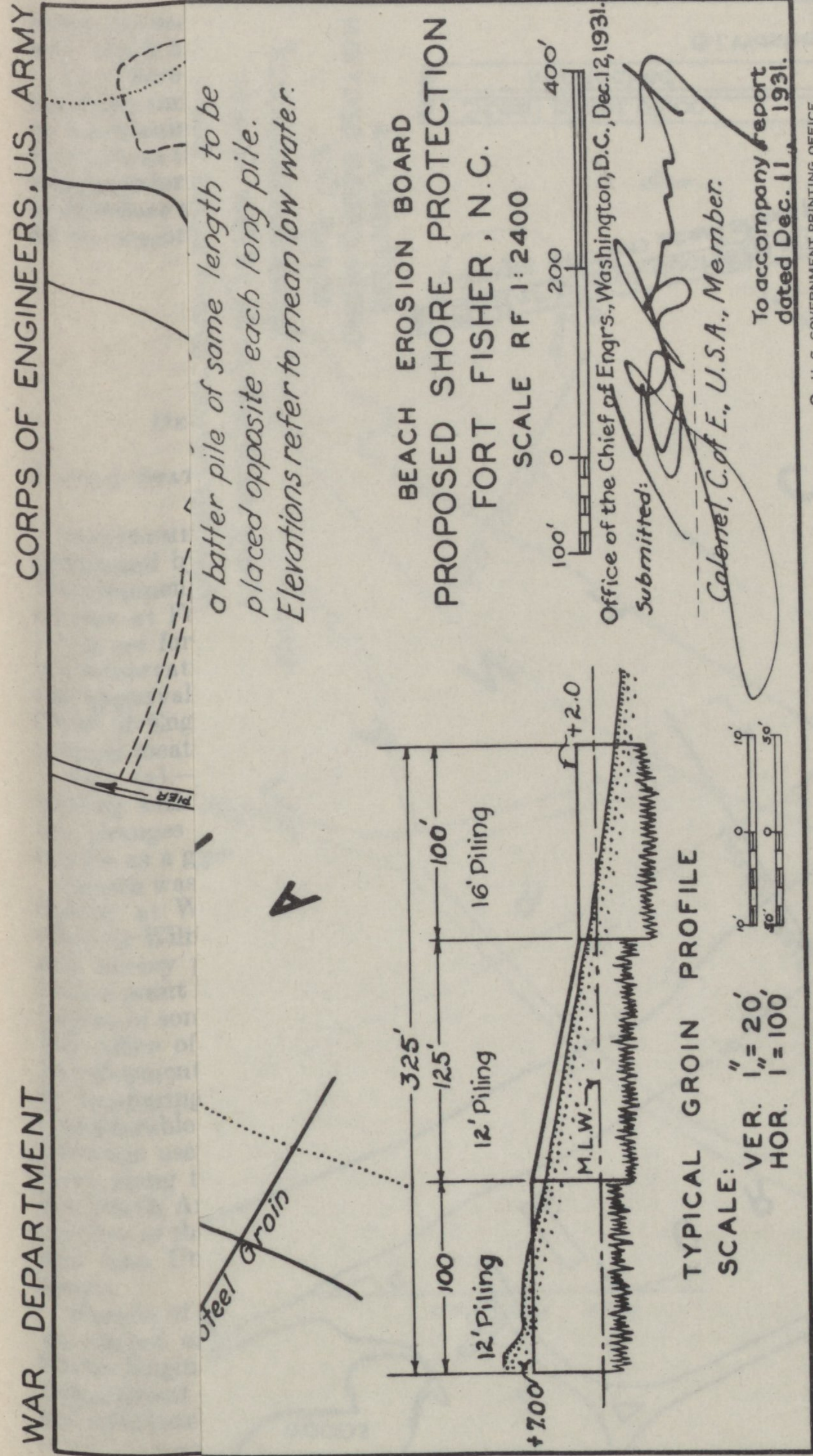
8. It should be emphasized that conditions at Fort Fisher are not similar to those at Fort Screven, Ga., and Coney Island, N. Y., where the problems presented were to retard erosion in localities where no fresh supply of beach material was delivered annually by natural agencies.

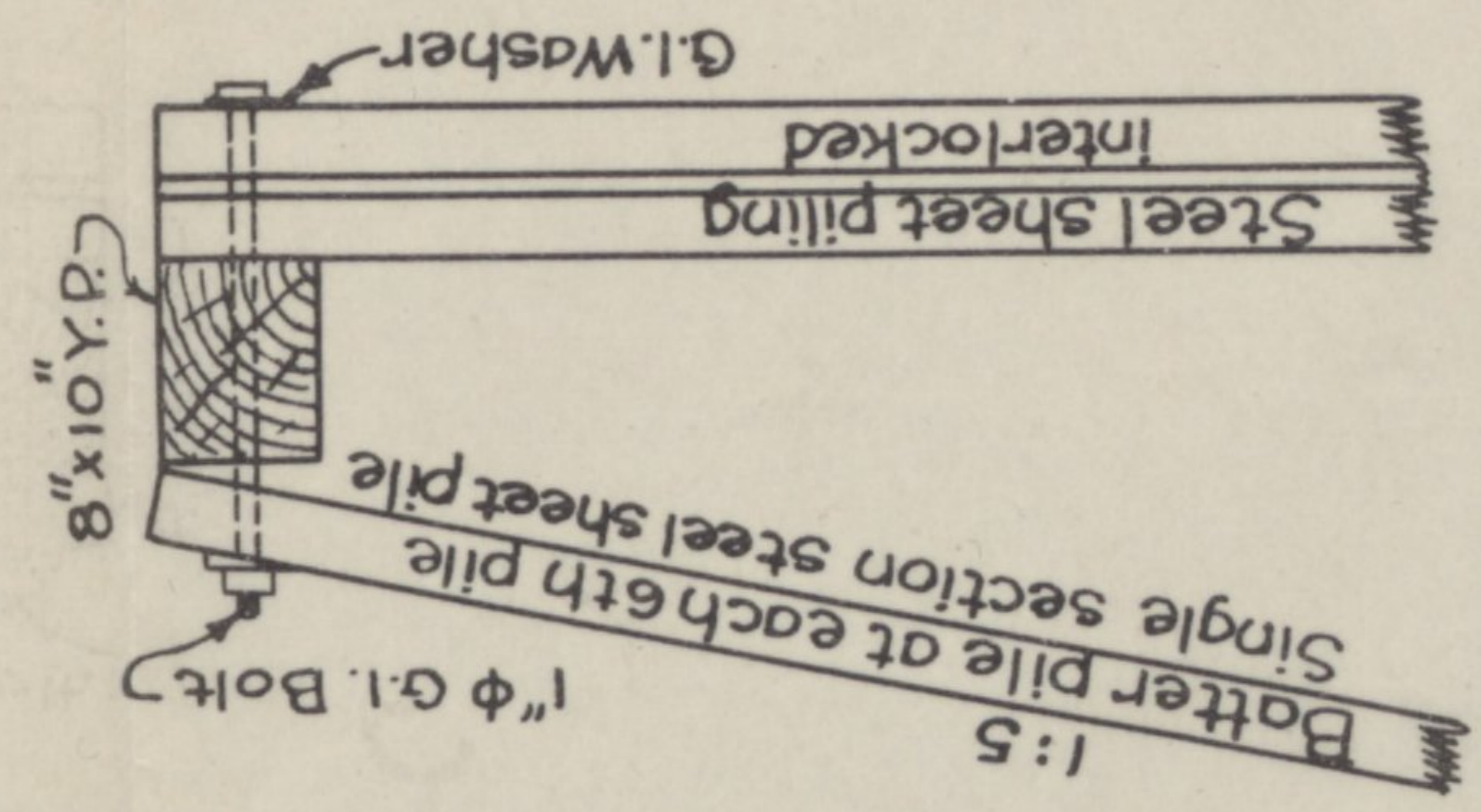
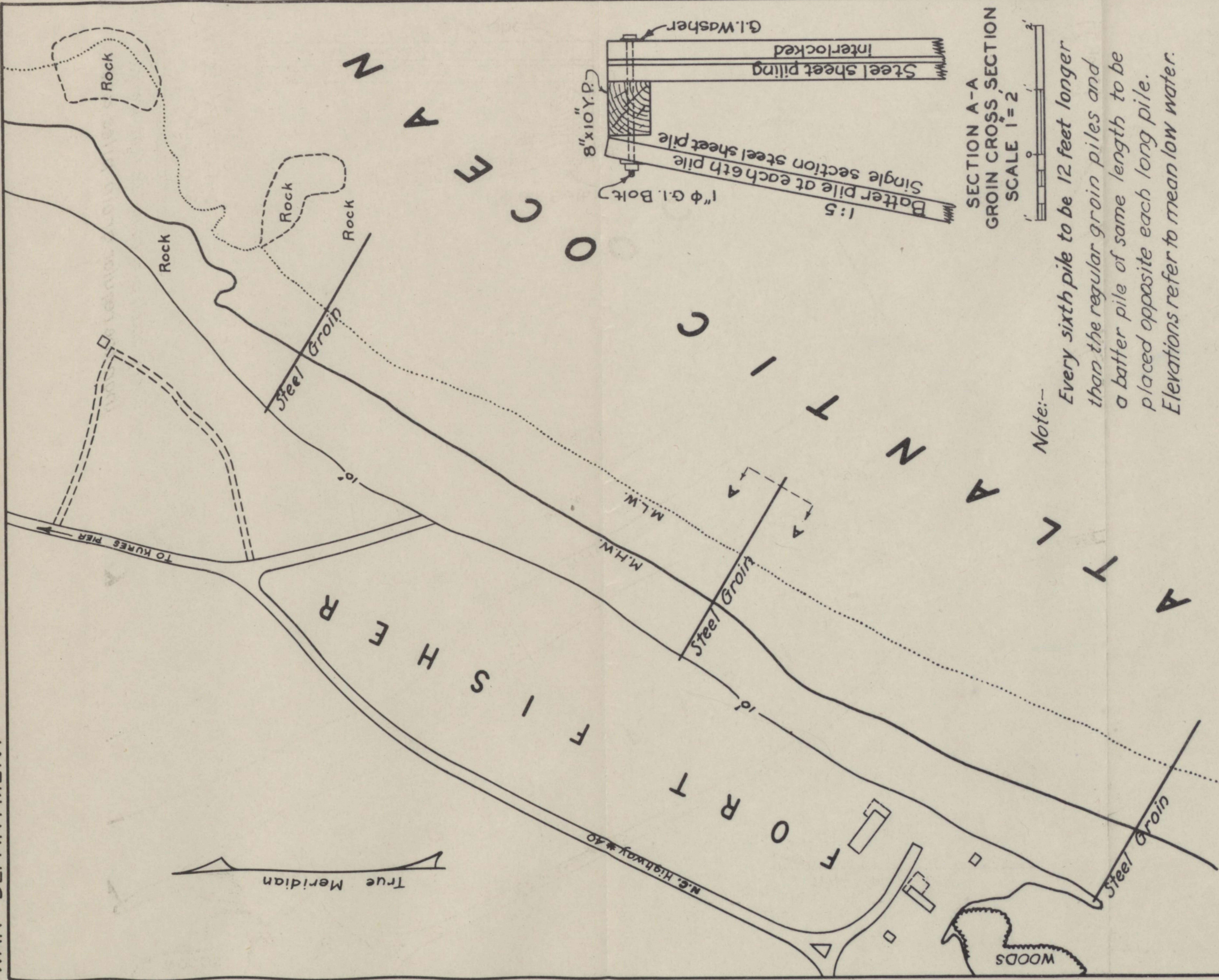
9. At Fort Fisher there is at present a considerable sand movement along the beach. The majority report calls attention to certain extensive changes that occurred during the summer of 1931. The control of such sand movements by the construction of jetties is common practice in other localities.

10. With respect to the length of the proposed jetties, it may be stated that relatively few of the structures along the New Jersey coast are as much as 325 feet in length. Experience along the New Jersey shore indicates that a length of 325 feet should be ample to impound a part of the littoral drift at Fort Fisher and cause an accretion to the beach. The wooden groins built by the Central Railroad of New Jersey to prevent erosion at the toe of the railroad's bulkhead are only 200 feet in length and have served the purpose for which they were built.

11. With respect to the protection that would be afforded by a beach 50 to 100 feet in width, reference may be made to a locality a mile or so south of Fort Fisher where such a beach is at present affording protection to the existing dunes.

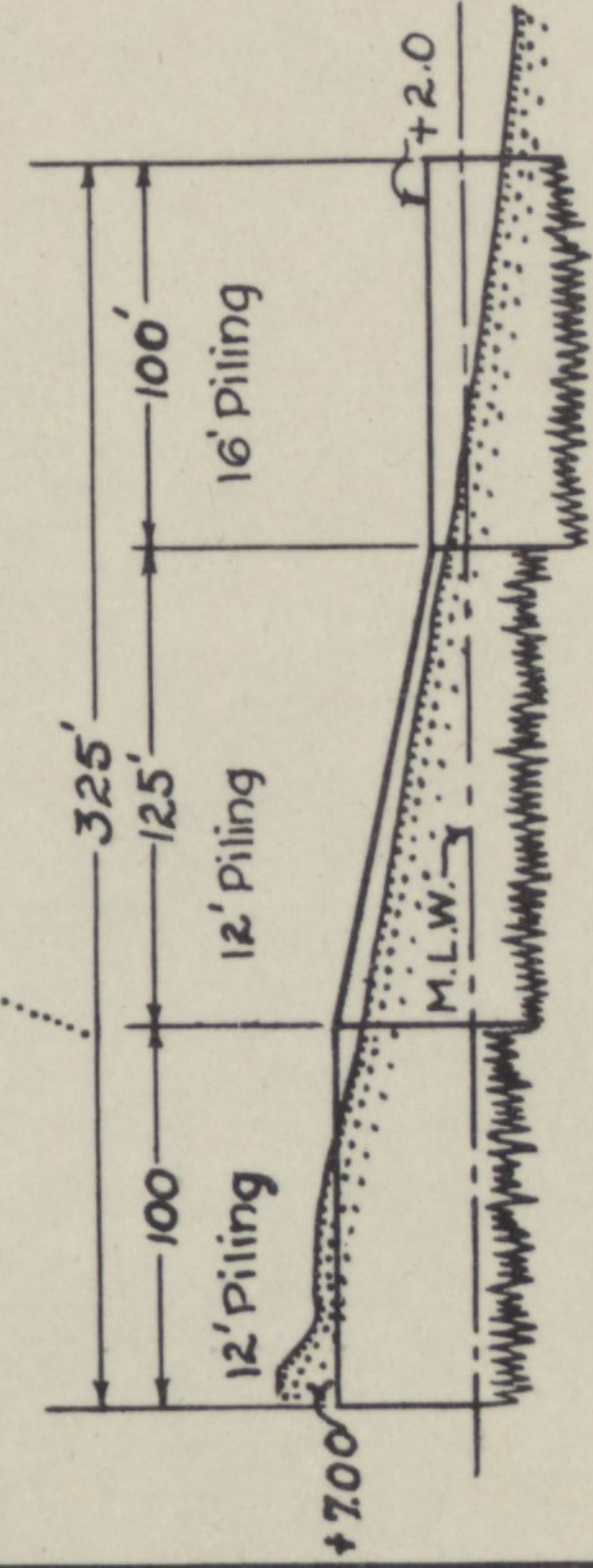
12. With reference to the proposed use of jetties without a bulkhead to prevent their being flanked, attention is invited to the groins





SECTION A-A
GROIN CROSS SECTION
SCALE 1" = 2'

Note:—
Every sixth pile to be 12 feet longer than the regular groin piles and a batter pile of same length to be placed opposite each long pile. Elevations refer to mean low water.



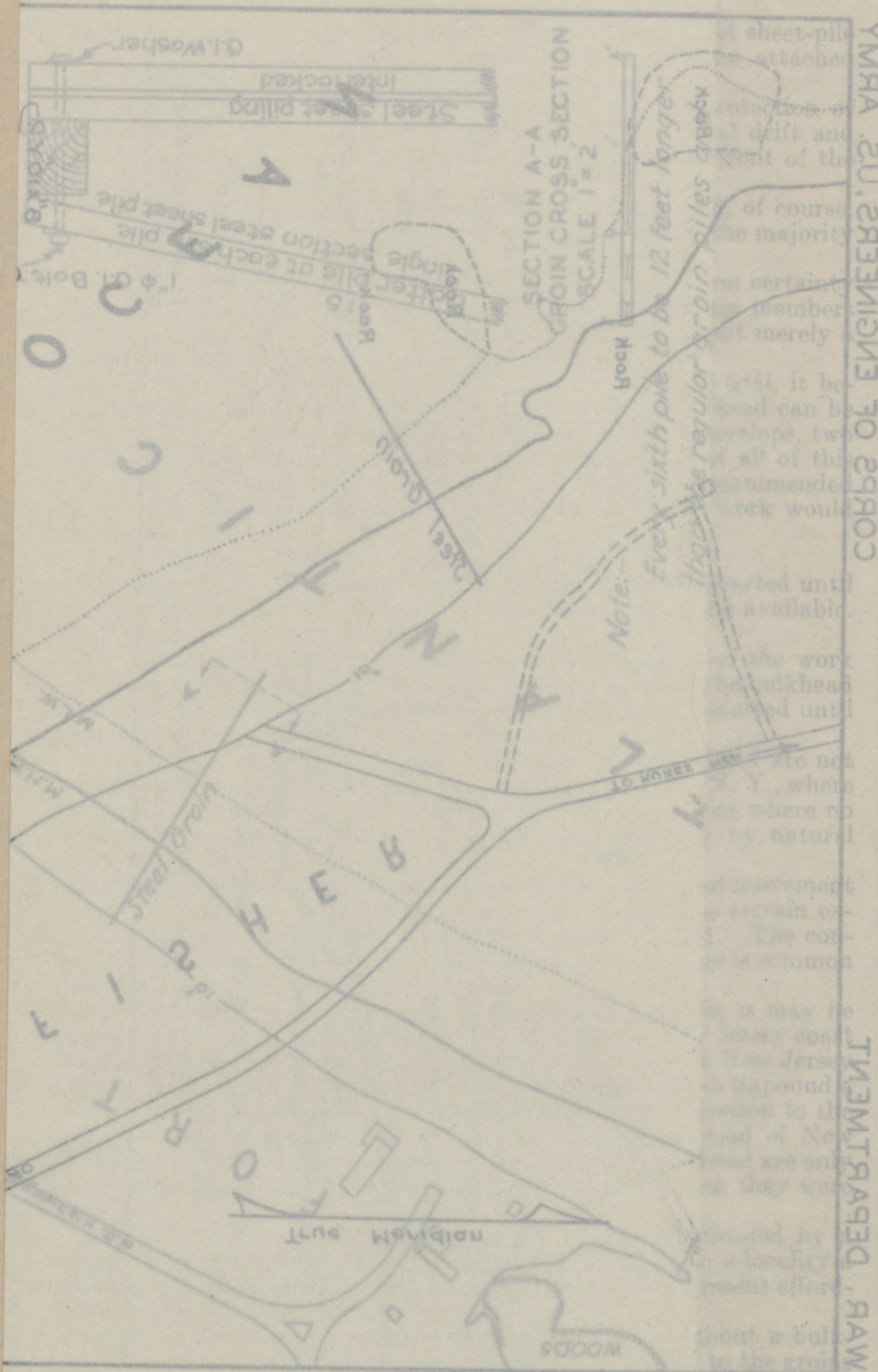
TYPICAL GROIN PROFILE
SCALE: VER. 1" = 20'
HOR. 1" = 100'

BEACH EROSION BOARD
PROPOSED SHORE PROTECTION
FORT FISHER, N.C.
SCALE RF 1:2400

Office of the Chief of Engrs., Washington, D.C., Dec. 12, 1931.
Submitted: *[Signature]*

Colonel, C. of E., U.S.A., Member.

To accompany report dated Dec. 11, 1931.



along the east shore of Sandy Hook which were built many years ago, and which have suffered no material loss on this account.

13. There is in reality but little difference between the views of the majority and minority members except with respect to the advisability of mentioning the fact that a project costing only about one-third as much as the one recommended by the majority will probably prove adequate for the protection of this locality, and no extended discussion is therefore necessary. In most respects I agree with the statements in the majority report.

E. J. DENT,
Colonel, Corps of Engineers.

APPENDIX I

STATE OF NORTH CAROLINA,
DEPARTMENT OF CONSERVATION AND DEVELOPMENT,
Chapel Hill, October 6, 1931.

UNITED STATES BEACH EROSION BOARD,
Washington, D. C.

GENTLEMEN: I beg to submit herewith a report covering the work performed by the North Carolina Department of Conservation and Development as its part of the cooperative investigation of beach erosion at Fort Fisher, N. C. This report covers items (a), (b), and (c) as set forth in the application of the North Carolina Department of Conservation and Development dated May 18, 1931, which received the approval of the Beach Erosion Board on June 1, 1931, and of the Chief of Engineers on June 5, 1931. Plate I¹ has been prepared as a general location map of the area covered by the project.

Item (a).—Investigation of all present and old maps and reports dealing with this section of the North Carolina coast, to determine the changes which have taken place in the past and to utilize the results as a guide to what may be expected in the future.

Search was made in the files of the United States Coast and Geodetic Survey at Washington and in those of the United States Engineer office at Wilmington, N. C., to discover all charts, topographic sheets, and survey plots showing the section of the North Carolina coast from a point north of Fort Fisher to the mouth of the Cape Fear River. Copies of some fifty such charts and drawings were sent to the Chapel Hill office of the North Carolina Department of Conservation and Development. The earliest survey of sufficient accuracy to be of use in comparing shore lines was dated 1852, the latest was of 1931. Considerable difficulty was found in reducing the several drawings to the scale used (1:10,000) due to the fact that the triangulation network along the North Carolina coast prior to 1901 did not refer to the North American datum, the use of odd scales, and the fact that surveys of the Engineer Department prior to 1926 were in general not tied into United States Coast and Geodetic Survey triangulation points.

Results of surveys by the United States Coast and Geodetic Survey are shown on Plate II, together with 1926 shore line from United States Engineer Department, and 1931 shore line by North Carolina Department of Conservation and Development. All of these surveys are adequately tied into the triangulation system.

¹ Plates referred to in Appendix I not printed.

On Plate III, plotted on thin paper so that it can be superimposed over Plate II, are shown the results of surveys by the United States Engineer Department in 1882, 1884, and 1887, following completion of New Inlet Dam in 1881. Surveys by the Engineer Department in 1895, 1897, and 1901 are shown on Plate IIIa, likewise plotted on thin paper. None of these surveys are completely tied into the triangulation system but are quite satisfactory in showing progressive shore changes. Unfortunately they do not cover the shore north of the southern end of old Fort Fisher, and so do not indicate data for the immediate area under study. Shore lines shown on Plates II, III, and IIIa relate to mean high water.

Examination of copies of old maps of the North Carolina coast in the files of the North Carolina Department of Conservation and Development (Mosely, 1733, and Wimble, 1738) shows no indication of the existence of an inlet in the vicinity of Federal Point or Fort Fisher. A detailed account of changes in this vicinity is to be found in the Annual Report of the Chief of Engineers, United States Army, for 1873. Evidence is there presented to show that New Inlet formed during a so-called equinoctial storm on September 20, 1761. It remained essentially stable in location and increased in depth until 1839. Apparently soon thereafter it began moving southward and shoaled slightly. It continued to have as great a depth as the main entrance to the Cape Fear until about 1854, when works for the closure of breaches in Zekes Island were undertaken. These were successively destroyed by gales and rebuilt and extended a number of times between 1854 and 1878. Their effect can be seen in Plate II in comparing shore lines between 1852 and 1878, the general tendency being to produce accretion in the vicinity of Federal Point and as far north as the northern end of Fort Fisher. The accretion at the latter point amounted to about 485 feet between 1852 and 1865.

In 1881 the New Inlet Dam was completed, thus virtually cutting off any tidal flow into the Cape Fear through New Inlet. The results of this were immediate and striking, as shown on Plate III. As might be expected, a spit began to form in the vicinity of the southern end of Fort Fisher, and between 1882 and 1887 it had grown southwestward a distance of about 6,300 feet, or at the rate of about 1,260 feet per year.

By 1895 (Plate IIIa) the inlet had migrated still farther south to a point south of Zekes Island. The northern spit is offset from and overlaps the southern spit. Some time between 1887 and 1895 a new inlet broke through southeast of Lambs Mound. By 1897 the earlier New Inlet had closed and the new New Inlet had migrated southward about 1,400 feet. This southerly migration continued as shown by coast lines of 1901 on Plate IIIa, and of 1914, 1923, and 1926 on Plate II.

Between 1926 and 1931 a phenomenon took place somewhat similar to that described above as occurring between 1895 and 1897. The northerly spit moved southward, overlapping the southerly spit, until the inlet discharged into Corncake Inlet 2 miles below the position of New Inlet in 1926. The narrow winding channel through which New Inlet Basin discharged is clearly shown by the aerial photographs. This channel closed in March, 1931. The approximate outlines of the 1931 shore line south of the surveys of this year by the North Carolina

Department of Conservation and Development are indicated on Plate II and are scaled from the aerial photographs taken in September, 1931, by the Army Air Service.

The phenomena of successive migration of the northerly spit of New Inlet southward, offsetting and overlapping the southerly spit until the inlet closes some miles southward of its original location, appear well authenticated. After the inlet closes, or shortly before it closes, a new inlet breaks through to the north and the phenomenon is repeated. The procedure is typical and is fully described on pages 307 and 308 of Johnson's book entitled "Shore Processes and Shoreline Development."

Evidence from Plates II, III, and IIIa is also to the effect that while sand movement to the southward is large it is by no means constant in amount. During some periods the inlet has migrated rapidly southward and during other periods (as from 1923 to 1926) it has remained practically stable.

A second feature shown by Plates II and IIIa indicates the intermittent nature of the erosion of the shore eastward of and adjacent to the northern end of Fort Fisher. Between 1865 and 1931 the high-water line has moved approximately 680 feet to the northwest. An apparent accretion between 1852 and 1865 is confirmed by the 1858 shore line. Since 1865 there have been surveys by the United States Coast and Geodetic Survey in 1878, 1914, and 1923; by the United States Engineer Department in 1926; and by the North Carolina Department of Conservation and Development in 1931. The results of all surveys indicating changes at right angles to the shore line at the northern end of Fort Fisher are shown in Table I.

TABLE I

Period	Erosion	Accretion	Change per year	Period	Erosion	Accretion	Change per year
	<i>Feet</i>	<i>Feet</i>	<i>Feet</i>		<i>Feet</i>	<i>Feet</i>	<i>Feet</i>
1852-1858.....		160	+26.7	1923-1926.....		60	+20.0
1858-1865.....		325	+46.4	1926-1931.....	280		-56.0
1865-1878.....	30		-2.3	Total.....	740	545	-2.47
1878-1914.....	430		-11.9				
1914-1923.....	0	0	0				

The results of the investigation under item (a) seem to indicate (1) a definite and consistent net movement of sand southward, forming the spit which finally closed New Inlet in 1931, and (2) a series of cycles of erosion and accretion opposite the northern end of old Fort Fisher, with a net tendency at present toward erosion. The erosion cycles have each cut into the mounds forming the northern end of the old fort, and even though cycles of accretion move the high-water line seaward, they can not restore the undermined high land. During 1930 and 1931 the eastern side of the road surrounding the northern end of the fort has been carried away, as indicated on Plate II. Since 1865 surveys indicate accretion of only 60 feet as compared to erosion of 740, or net erosion of 680 feet.

It is also desirable to note on Plate II the tendency toward erosion by the river on the west side of Fort Fisher. The river edge has moved eastward, eroding land toward the fort about 550 feet from

1878-1931. The net reduction in width of this strip of land since 1878 is about 1,230 feet. The definite tendency appears to be to produce an inlet at about this point.

Item (b).—Extension of Carolina-Kure Beach base line and cross sections to a point 1,000 feet south of Fort Fisher.

The North Carolina Department of Conservation and Development in 1927 established a base line 22,983.5 feet long which ended at a point called Kure's Pier, about 2 miles north of Fort Fisher. This base line was tied into the United States Coast and Geodetic Survey triangulation system, and cross-section stations were established every 1,000 feet. Cross sections of the beach were run from many of these stations in 1927, 1928, 1930, and 1931. The results are given on Plates V to XII, inclusive.

This base line was extended to a point approximately 3,000 feet south of the northern end of Fort Fisher. Cross sections were taken at selected stations as shown on Plates XIV to XVIII, inclusive. In the immediate vicinity of the monument and reservation (the northern end of old Fort Fisher) where erosion has been severe, five cross sections were made quite close together, as shown on Plates XVI and XVII. During the period of field work it was observed that rapid accretion was taking place, and therefore cross sections were run in this vicinity in June, July, August, and September. The last two series of cross sections were made by the United States Engineer Office at Wilmington, N. C.

It will be observed that on section 338+00 the low-water line (elevation 0) moved seaward 35 feet during the period June 28-July 21 or at a rate of over 1 foot per day. It remained constant thereafter at this station, although at station 342+00 movement of the low-water line continued into September, having moved a total eastward distance of 64 feet in the period June 28-September 3, or at a rate of 0.68 foot per day.

The accretion observed from June to September is considerable in total quantity of sand moved. It will be noted that erosion occurred at station 324+00, north of the rock ledge. While possibly some of the sand supply came from this source, it is believed that some of it came also from the ocean bottom seaward. During the period of observation the wind was almost constantly from the southwest and no storms occurred. It will be observed that there is no indication of an offshore bar in the area under observation south of the rock ledge but that an underwater bar does exist in general north of this point.

Conclusions from this investigation appear to be tentative only and to indicate a temporary rapid accretion cycle in the vicinity of Fort Fisher during the months June to September, inclusive. This is a usual period of accretion along the coast in the region and equally rapid accretion was observed at Wrightsville Beach during approximately the same period this year.

Item (c). Preparation of a contour map of the area comprised between points 1,000 feet north and south of Fort Fisher and extending at least 300 feet west of the high-water mark.

A field party of the North Carolina Department of Conservation and Development prepared an accurate contour map in accordance with this item. The map is to scale of 1 inch=100 feet horizontal, and the contour interval is 1 foot on the beach from elevation 0 to elevation +10, and 2 feet westward of elevation +10. The map is attached as Plate XIX.

This map is carefully tied into both horizontal and vertical control systems of the United States Coast and Geodetic Survey. It is amply accurate for studies of location of beach protection structures. The contours below elevation +10.0 are subject to rapid change, and as shown on the map are correct only as of June 10-16, 1931.

Respectfully submitted.

THORNDIKE SAVILLE,
Chief Engineer.

APPENDIX II

WAR DEPARTMENT,
UNITED STATES ENGINEER OFFICE,
Wilmington, N. C., August 18, 1931.

Subject: Investigation at Fort Fisher, N. C.

To: Beach Erosion Board, Washington, D. C.

(Through the Division Engineer, South Atlantic Division).

1. Under date of May 15, 1931, the North Carolina Department of Conservation and Development made formal application for a cooperative investigation of beach erosion in the vicinity of Fort Fisher, N. C. It was desired that the "study be prosecuted jointly by the War Department through the Beach Erosion Board and by the North Carolina Department of Conservation and Development through its division of water resources and engineering as provided in section 2 of the river and harbor act for 1930." It was estimated that the total cost of the proposed investigation would be in the neighborhood of \$2,000, of which the North Carolina Department of Conservation and Development would contribute approximately one-half, or \$1,000. This amount was to be the minimum contribution from the State of North Carolina, as it had already been made available to the State for this purpose by the Board of County Commissioners of New Hanover County. It was contemplated that the Department of Conservation and Development would be responsible for the following parts of the investigation, and that its studies in this connection would be prosecuted in cooperation with the United States Engineer Office at Wilmington:

(a) Investigation of all present and old maps and reports dealing with this section of the North Carolina coast, to determine the changes which have taken place in the past and to utilize the results as a guide to what may be expected in the future.

(b) Extension of Carolina-Kure Beach base line and cross sections to a point 1,000 feet south of Fort Fisher.

(c) Preparation of a contour map of the area comprised between 1,000 feet north and south of Fort Fisher and extending at least 300 feet west of the high-water mark.

It was proposed that the United States through the United States Beach Erosion Board be responsible for the conduct of the following items:

(d) Investigation of foundation conditions by borings or test pits located at appropriate locations within the area described in (c) above, as a guide to location and type of protective work.

(e) Aerial photographs of the region comprised in (c) above, preferably to result in a mosaic map.

2. The Beach Erosion Board recommended the approval of the project on June 1, 1931, and on June 5, 1931, it was approved by the

267955

Chief of Engineers. As directed by the senior member of the Beach Erosion Board, the work which the Federal Government was to be responsible for as outlined above has been carried out under the supervision of the district engineer, and the following paragraphs, together with the inclosed blue prints, constitute a report on that portion of the investigation assigned to this office.

3. A contract was entered into for the making of wash borings. These borings were made to a depth of 20 feet below the surface of the ground at points selected by a representative of the Beach Erosion Board and by the chief engineer of the North Carolina Department of Conservation and Development. The borings were made under the immediate direction of a representative of the United States Engineer Office and were completed August 11, 1931. Samples were taken of all the materials encountered in each hole, and a log was kept of the progress of the work, showing the depths at which the various materials were encountered. These samples are now in the custom-house at Wilmington and duplicate samples in the office of the North Carolina Department of Conservation and Development at Chapel Hill, N. C. Locations of the borings in respect to the base line established by the North Carolina Department of Conservation and Development are shown in Plate No. I¹ accompanying this report. The 5-foot contour and the low-water line, as shown on this plate, are no longer correct as the beach changed to some extent after the contours were drawn and before the borings were made. Profiles of the various rows of borings are shown in Plates¹ Nos. II, III, and IV.

4. Coquina in sufficient quantities to support piles was found in the majority of the holes. On row A at least two separate strata of coquina were encountered in each of the four holes. Each of the two holes in row B had a layer of coquina in the upper portion and a mixture of sand and coquina at the bottom. Holes 1 and 3 on row C had small quantities of soft coquina, but in hole 2 it was encountered in larger quantities and was much harder. Likewise on row D, hole 2 contained more and harder coquina than hole 1. Holes 1, 2, and 3 of row E all contained fairly hard coquina in large quantities but in hole 4 none was encountered. Thus it is seen that in general both the quantity and the hardness of the coquina tend to decrease not only with increased elevation but also with distance from the ocean. Piles could be jettied through any of the materials encountered.

5. The Beach Erosion Board has made application to the Army Air Corps for airplane photographs of the area. Targets for the photographs will be placed by the United States Engineer Office upon notification by the Air Corps.

R. A. WHEELER,
Major, Corps of Engineers, District Engineer.

[First indorsement]

OFFICE DIVISION ENGINEER,
SOUTH ATLANTIC DIVISION,
Norfolk, Va., August 21, 1931.

To the CHIEF OF ENGINEERS, UNITED STATES ARMY,
Washington, D. C.

Forwarded.

H. B. F.

¹ See Plate VII, main report.

[Second indorsement]

OFFICE CHIEF OF ENGINEERS,
August 26, 1931.

To the BEACH EROSION BOARD,
Washington, D. C.

Forwarded.
By direction of the Chief of Engineers.

V. L. PETERSON,
Major, Corps of Engineers.

APPENDIX III.—Aerial mosaic. (Not printed.)

APPENDIX IV

Estimate
BULKHEAD

	L. feet	Weight	Tons	Cost
<i>Arch section steel sheet piling</i>				
1,400 feet bulkhead:		<i>Pounds</i>		
171 long piles, at 24 feet, 32.5 pounds per foot bar	4,104			
850 short piles, at 14 feet, 32.5 pounds per foot bar	11,900			
171 anchor piles, at 13 feet, 32.5 pounds per foot bar	2,223			
200 feet cut off bulkhead:				
25 long piles, at 24 feet, 32.5 pounds per foot bar	600			
120 short piles, at 14 feet, 32.5 pounds per foot bar	1,680			
25 anchor piles, at 13 feet, 32.5 pounds per foot bar	325			
Total (cost of steel at \$50 per ton)	20,832	677,040.00	338.52	\$16,926.00
119 pieces 8 by 10 inches by 16 feet creosoted timber, 10.79 M.				
B. M., at \$60		38,000.00		647.40
196 1 1/4 inch by 12 feet tie rods, G. I., at \$0.10 per pound		4,045.50		404.55
485 1 by 18 inch bolts, G. I., at \$0.10 per pound		2,352.25		235.23
485 1 by 12 inch bolts, G. I., at \$0.10 per pound		1,702.00		170.20
392 1 1/4-inch G. I. washers, at \$0.04 per pound		1,647.00		65.88
1940 1-inch G. I. washers, at \$0.04 per pound		3,880.00		155.20
Labor, estimated as 27 per cent of cost of materials				5,023.21
Operating costs estimated as 11 per cent of cost of materials				2,046.49
Hauling charge at \$5 per ton			364.34	1,821.70
Total (estimated cost of bulkhead per foot, \$17.18)				27,495.86

GROINS

	L. feet	Weight	Tons	Cost
<i>Arch section steel sheet piling</i>				
Section I:				
27 long piles, at 24 feet, 33.85 pounds per foot bar	648			
130 short piles, at 14 feet, 33.85 pounds per foot bar	1,820			
Section II:				
23 long piles, at 28 feet, 33.85 pounds per foot bar	644			
115 short piles, at 18 feet, 33.85 pounds per foot bar	2,070			
Batter pile:				
27 piles, at 24 feet, 33.85 pounds per foot bar	648			
22 piles, at 28 feet, 33.85 pounds per foot bar	616			
Total (cost of steel at \$50 per ton)	6,446	218,197.00	109.10	\$5,455.00
30 pieces 8 by 10 inches by 16 feet creosoted timber, 3.14 M.				
B. M., at \$60		9,346.00		188.40
50 1 by 15 inch bolts, G. I., at \$0.10 per pound		209.00		20.90
245 1 by 26 inch bolts, G. I., at \$0.10 per pound		1,626.80		162.68
590 1-inch G. I. washers, at \$0.04 per pound		1,180.00		47.20
Labor estimated as 27 per cent of cost of materials				1,586.03
Operating costs, estimated as 11 per cent of cost of materials				646.16
Hauling charge at \$5 per ton			115.28	576.40
Total cost of one groin				8,632.77
Cost of 4 groins				34,731.08
Estimated cost of groins per foot				21.70

COST

Steel bulkhead	\$27,495.86
Steel groins	34,731.08
Overhead, engineering, and contingencies, 15 per cent (app.)	9,373.06
Total	71,600.00

JOYNER

PORT FISHERY, N. C.

Second Indentment
OFFICE CHIEF OF ENGINEERS
August 20, 1881
of the Beach Erosion Board
Washington, D. C.
Forwarded
By direction of the Chief of Engineers
V. L. PATTERSON,
Major, Corps of Engineers

Appendix III - Dental mosaic. (Not printed)

Appendix II

Table
BULKHEAD

Item	Quantity	Unit Price	Total
1	100	1.00	100.00
2	50	2.00	100.00
3	25	4.00	100.00
4	10	10.00	100.00
5	5	20.00	100.00
6	2	50.00	100.00
7	1	100.00	100.00
8	1	100.00	100.00
9	1	100.00	100.00
10	1	100.00	100.00
11	1	100.00	100.00
12	1	100.00	100.00
13	1	100.00	100.00
14	1	100.00	100.00
15	1	100.00	100.00
16	1	100.00	100.00
17	1	100.00	100.00
18	1	100.00	100.00
19	1	100.00	100.00
20	1	100.00	100.00
21	1	100.00	100.00
22	1	100.00	100.00
23	1	100.00	100.00
24	1	100.00	100.00
25	1	100.00	100.00
26	1	100.00	100.00
27	1	100.00	100.00
28	1	100.00	100.00
29	1	100.00	100.00
30	1	100.00	100.00
31	1	100.00	100.00
32	1	100.00	100.00
33	1	100.00	100.00
34	1	100.00	100.00
35	1	100.00	100.00
36	1	100.00	100.00
37	1	100.00	100.00
38	1	100.00	100.00
39	1	100.00	100.00
40	1	100.00	100.00
41	1	100.00	100.00
42	1	100.00	100.00
43	1	100.00	100.00
44	1	100.00	100.00
45	1	100.00	100.00
46	1	100.00	100.00
47	1	100.00	100.00
48	1	100.00	100.00
49	1	100.00	100.00
50	1	100.00	100.00
51	1	100.00	100.00
52	1	100.00	100.00
53	1	100.00	100.00
54	1	100.00	100.00
55	1	100.00	100.00
56	1	100.00	100.00
57	1	100.00	100.00
58	1	100.00	100.00
59	1	100.00	100.00
60	1	100.00	100.00
61	1	100.00	100.00
62	1	100.00	100.00
63	1	100.00	100.00
64	1	100.00	100.00
65	1	100.00	100.00
66	1	100.00	100.00
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69	1	100.00	100.00
70	1	100.00	100.00
71	1	100.00	100.00
72	1	100.00	100.00
73	1	100.00	100.00
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81	1	100.00	100.00
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83	1	100.00	100.00
84	1	100.00	100.00
85	1	100.00	100.00
86	1	100.00	100.00
87	1	100.00	100.00
88	1	100.00	100.00
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90	1	100.00	100.00
91	1	100.00	100.00
92	1	100.00	100.00
93	1	100.00	100.00
94	1	100.00	100.00
95	1	100.00	100.00
96	1	100.00	100.00
97	1	100.00	100.00
98	1	100.00	100.00
99	1	100.00	100.00
100	1	100.00	100.00

Item	Quantity	Unit Price	Total
1	100	1.00	100.00
2	50	2.00	100.00
3	25	4.00	100.00
4	10	10.00	100.00
5	5	20.00	100.00
6	2	50.00	100.00
7	1	100.00	100.00
8	1	100.00	100.00
9	1	100.00	100.00
10	1	100.00	100.00
11	1	100.00	100.00
12	1	100.00	100.00
13	1	100.00	100.00
14	1	100.00	100.00
15	1	100.00	100.00
16	1	100.00	100.00
17	1	100.00	100.00
18	1	100.00	100.00
19	1	100.00	100.00
20	1	100.00	100.00
21	1	100.00	100.00
22	1	100.00	100.00
23	1	100.00	100.00
24	1	100.00	100.00
25	1	100.00	100.00
26	1	100.00	100.00
27	1	100.00	100.00
28	1	100.00	100.00
29	1	100.00	100.00
30	1	100.00	100.00
31	1	100.00	100.00
32	1	100.00	100.00
33	1	100.00	100.00
34	1	100.00	100.00
35	1	100.00	100.00
36	1	100.00	100.00
37	1	100.00	100.00
38	1	100.00	100.00
39	1	100.00	100.00
40	1	100.00	100.00
41	1	100.00	100.00
42	1	100.00	100.00
43	1	100.00	100.00
44	1	100.00	100.00
45	1	100.00	100.00
46	1	100.00	100.00
47	1	100.00	100.00
48	1	100.00	100.00
49	1	100.00	100.00
50	1	100.00	100.00
51	1	100.00	100.00
52	1	100.00	100.00
53	1	100.00	100.00
54	1	100.00	100.00
55	1	100.00	100.00
56	1	100.00	100.00
57	1	100.00	100.00
58	1	100.00	100.00
59	1	100.00	100.00
60	1	100.00	100.00
61	1	100.00	100.00
62	1	100.00	100.00
63	1	100.00	100.00
64	1	100.00	100.00
65	1	100.00	100.00
66	1	100.00	100.00
67	1	100.00	100.00
68	1	100.00	100.00
69	1	100.00	100.00
70	1	100.00	100.00
71	1	100.00	100.00
72	1	100.00	100.00
73	1	100.00	100.00
74	1	100.00	100.00
75	1	100.00	100.00
76	1	100.00	100.00
77	1	100.00	100.00
78	1	100.00	100.00
79	1	100.00	100.00
80	1	100.00	100.00
81	1	100.00	100.00
82	1	100.00	100.00
83	1	100.00	100.00
84	1	100.00	100.00
85	1	100.00	100.00
86	1	100.00	100.00
87	1	100.00	100.00
88	1	100.00	100.00
89	1	100.00	100.00
90	1	100.00	100.00
91	1	100.00	100.00
92	1	100.00	100.00
93	1	100.00	100.00
94	1	100.00	100.00
95	1	100.00	100.00
96	1	100.00	100.00
97	1	100.00	100.00
98	1	100.00	100.00
99	1	100.00	100.00
100	1	100.00	100.00

Total

Gaylord
PAMPHLET BINDER
Syracuse, N. Y.
Stockton, Calif.

JOYNER
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