DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS

THE ANNUAL BULLETIN OF THE BEACH EROSION BOARD

OFFICE, CHIEF OF ENGINEERS
WASHINGTON, D.C.

VOLUME 13 JULY 1959

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BEACH PHOTOGRAPHY

by
Rudolph P. Savage
Hydraulic Engineer, Research Division, Beach Erosion Board
Corps of Engineers, Department of the Army

Introduction

Photography has been proven to be a very useful tool in almost every branch of science and engineering. With pictures, things can be shown, illustrated, and compared with greater ease and brevity than is generally possible with words and drawings. Thus, good photography properly used is an asset to most scientific and engineering reports.

In the course of his investigations, the coastal engineer can profitably use photography to record and compare events and conditions, both from time to time and place to place; and for report illustrations. The beach, however, is a rather special photographic environment and although the general rules of photography apply, the large areas of sand and water create special problems. The purpose of this article is to present some basic photographic information and its application to the special photographic environment created by sandy beaches.

Equipment for Beach Photography

The basic equipment required for beach photography is a camera and a light meter. The camera should be somewhat versatile in that it should have variable lens openings, or f-stops, and variable shutter speeds. F-stops should range from f-3.5 or f-4.7 to f-16 or f-22 and shutter speeds should range from 1/25th to 1/200th of a second. These are considered to be the minimum ranges to properly expose most commercial films but wider ranges of f-stops and shutter speeds are desirable if available. A range finder, a lens which focuses from 6 feet to infinity, and a filter holder which acts as a sunshade are also desirable. Most commercial light meters designed to measure reflected light are adequate for beach photography.

Accessory equipment may include wide-angle and telephoto lenses; K-2, G, and A filters of the Wratten scale; and a polarizing screen. As a minimum, the K-2 filter and polarizing screen are suggested since they cover the basic necessities of filter action for both color and black-and-white film. Wide-angle and telephoto lenses may be used in special situations where the object to be photographed is either too near or too far to be photographed properly with a normal lens. However, their expense and added inconvenience in carrying and using are rarely justified in general beach photography.

Photographic Materials and Techniques

It should be recognized from the beginning that beach photography is ordinary photography under rather special circumstances. Accordingly, the rules and techniques which apply in ordinary photography also apply in beach photography. Some of these are:

1. Expose at a shutter speed sufficiently fast that the picture will not be blurred. Generally a shutter speed of 1/25th of a second or faster is required for a hand-held camera. Longer exposures may be made by using a tripod or some other support.

2. Hold the camera still. If it is moved during exposure, even at reasonably fast shutter speeds, pictures will be blurred and enlargements will not be sharp.

3. Be sure that the lens is focused correctly and, when appropriate, take care to get proper depth of field for the subject, or the general scene.

4. Study your subject. Get the picture that will best serve the purpose by selecting the angle from which the exposure is made, and the lighting on the subject.

5. Use an exposure meter. When a professional photographer considers an exposure meter a necessity in making good pictures, the ordinary photographer should certainly use one.

6. When the rising or setting sun appears red, open the aperture a full f-stop more than called for by the exposure meter.

7. Always load and unload a camera in the shade if possible and be very careful to keep the film wound tightly on the spool. Wrap exposed film to prevent any light from leaking in while awaiting development.

In general, photography may be divided into two types; photography using color film, and photography using black and white film. Color photography is generally used when the end product desired is a positive transparency or a "slide" which may be projected in a slide projector. Because most slide projection equipment is designed to handle 35-mm. or 2-inch by 2-inch slides exclusively, the 35-mm. or "miniature" camera is used almost exclusively for color slide photography. Color, or even black and white prints, may be made from color slides, but this is not generally done since the involved processes required to obtain prints are generally too expensive for routine purposes. This is also true for color prints obtained from negative color films; however, much progress toward making color prints more economical is being made and in the future they should not be disregarded automatically for this reason alone.

When black and white prints are desired, black and white negative materials are used. There are many sizes and types of black and white negative film available commercially. However, in general it has been found that black and white film smaller than 35 mm. prove unsatisfactory for black and white prints and it is usually desirable to use larger black and white film (size 2-1/4"by 2-1/4"or larger) because much less difficulty is encountered in obtaining acceptable enlargements. Of the commercial film available, the most widely accepted is the panchromatic type; that is, film which is sensitive to light of all frequencies of the visible spectrum. In the recent past, orthochromatic film (film which is sensitive to all light of visible spectrum except the reds) was the most popular film especially in box cameras, since this type of film had much wider exposure latitude than the panchromatic film available. However, recent developments in the photographic industry have produced panchromatic film with a wide exposure latitude and these have largely replaced the orthochromatic film used previously, perhaps almost to the exclusion of orthochromatic film for general purpose photography. Most of the panchromatic or orthochromatic films commercially available serve very well for use in beach photography.

All films are assigned an emulsion speed number which is simply a number indicating the relative amounts of light required to properly expose the film. These exposure index numbers are used in conjunction with a light meter to properly expose the film for the lighting of any scene being photographed. The most prominent system of film rating used in this country is a system of relative numbers developed by the American Standards Association. Under this numbering system, any film having an exposure index of 6 or less is considered a slow film; any film having an exposure number between 12 and 50 is considered a medium speed film, and any film having an exposure number from 100 to 800 is considered a fast film.* Films with exposure indexes in the medium to fast range, or having as ratings from 50 to 100, are generally best suited for beach photography.

In the less critical sense, the film exposure, which simply means the amount of light allowed to reach the film, determines whether or not a picture will be obtained. When a film is either extremely over or under exposed, no picture will be obtained. In a more critical sense, a film exposure determines the quality of the final picture in

*Graphic Graflex Photography, 8th edition, W. D. Morgan and H. M. Lester, New York 17, New York, 1950, p. 25.

that a film which has been either slightly over or under exposed will produce a picture of poorer quality than a film which has been properly exposed.

Assuming a film with a particular emulsion speed rating or exposure index, the following three factors affect the exposure of the film: (a) the light intensity of the scene to be photographed; (b) the f-stop or lens opening of the camera; and (c) the shutter speed or the amount of time that the light from the scene is allowed to reach the film. Since photographs are produced by the light reflected from the scene to be photographed, the intensity of this light becomes the important factor in properly exposing the film and it is measured with an exposure meter. The f-stop or lens opening determines the area over which light is allowed to enter the camera, small f-stop values indicating a relatively large area for light entrance and large f-stop values indicating a relatively small area for light entrance. F-stop values on most cameras are arranged so that increasing the f-stop one stop halves the light entering the camera (see Table 1). Here it should be noted that f-2.5 in the U. S. numbers and f-6.3 in the English system are not full stops. Also, some cameras may start with f-4.5 from the Continental system and skip to the f-6.3, 5-11, etc., of the English system, or start with the f-4 of the English system and skip to the f-6.3, 5-9, etc., of the Continental system. Thus, at some point in the lower range of the f-stop values there is more than one full f-stop between the graduations on the camera scale. The shutter speed determines the time that the light is permitted to reach the film. Of the four factors affecting film exposure, the one over which the photographer has the least control is the reflected light intensity from the scene. Hence, the proper film exposure is usually obtained by varying the three other factors in such a way that the proper amount of light reaches the film.

In order to properly expose a film, the ASA rating of the film being used is set on the proper scale on the light meter. The light intensity of the scene to be photographed is then read with the light meter by pointing the photo cell of the meter at the scene and slightly downward to eliminate most of the light from the sky. The light value obtained is then set into the proper scale on the meter. The f-stop scale and shutter speed scale of the light meter will then show combinations of f-stop openings and shutter speeds which may be used to obtain the proper exposure. In determining which combination of f-stop opening or shutter speed which will be used, it is usually better to use a shutter speed of 1/50th of a second or faster and to try to stay somewhere in the middle of the range of the f-stop openings.

TABLE 1

COMMON F-STOP SYSTEMS AND THEIR RELATIVE ILLUMINATION REDUCTIONS*

Illumination Reduction	U.S. System	English System	Continental System
1	-	1	-
2	-	1.4	1.5
4	-	2	2.2
8	-	2.8	3.2
16	1.25	4	4.5
32	2	5.6	6.3
	2.5	6.3	-
64	4	8	9
128	8	11	12.7
256	16	16	18
512	32	22	25
1024	64	32	35
2048	128	45	-

Another important aspect of photography is the focusing of the camera lens to insure that the objects of interest in the scene to be photographed are in focus; that is, clear and sharp in the resulting picture rather than hazy or blurred. The lens on most simple box cameras is preset so that everything is in focus from about 6 feet to an infinite distance in front of the camera. Therefore focusing is no problem with these cameras. However, on most of the more expensive cameras, the focusing mechanism is adjustable and these cameras must be focused for the objects of interest in the scene before the picture is taken. Some cameras have coupled range finders so that when the proper range is found with the range finder, the lens is automatically focused to the proper distance. Other cameras have uncoupled range finders which simply tell the photographer the distance at which the lens must be set in order to obtain a good picture. When there is no range finder, the distance to the objects of interest must be estimated or measured before the lens is focused.

In addition to focusing the camera, one must be sure that the range of distances that are in focus, or the depth of field is adequate to cover all the objects of interest in the scene. The depth of field varies with the properties of the lens being used, the f-stop at which the exposure is made, and the distance from the camera at which the lens is focused. For any particular lens, the depth of field decreases as the

*From Graphic Graflex Photography, 8th edition, W. D. Morgan and H. M. Lester, New York 17, New York, 1950, p. 25.

aperture opening on the camera increases and as the distance at which the lens is focused decreases. Thus, the depth of field is smallest when a large aperture opening is used when photographing an object very near the camera, and the largest depth of field is obtained when photographing an object a considerable distance from the camera with a small aperture opening. On many cameras a depth of field scale is given in terms of the f-stops and distances available with the camera lens. This scale can be used to determine exactly what portions of the scene to be photographed will be in focus and what portions of the scene to be photographed will be out of focus in the resulting picture.

Further information on the basic photographic principles can be found in the references listed in the end of this paper.

Beach Photography

General. Since pictures are produced by the light reflected from objects in the scene to be photographed, the range of intensities of the reflected light from the scene is important. In scenes which include objects which reflect a narrow range of light intensities, no problem is encountered in properly exposing for all of the objects of the scene. However, in the scenes where a wide range of light intensities is produced, care must be taken to properly expose for the most important objects in the scene. When standing at the camera and using a reflected-light-type meter to measure the light on the scene, the light from the total scene is averaged or integrated. Therefore, if there is an especially bright or an especially dull object in the scene, this object will be either overexposed or underexposed if the average or integrated light is used for the whole scene. In beach photography, this principle becomes very important because on sunny days the sandy surface of the beach produces a "beaded screen" effect and light is reflected from the surface of the beach in all directions in relatively large intensities. As an illustration, when such lighting conditions exist, a reflected-light-type meter will measure a larger light intensity when pointed at the sand facing away from the sun than when pointed at the sand facing the sun. Therefore, if the light reading of the general beach is used, objects on the beach will be underexposed and appear as silhouettes (see Figure 1). This picture was made by using the light meter as shown in Figure 2 to take a reflected light reading of the dry surface of the sand. Notice in Figure 2 that the light cell was pointed slightly downward so that the reflections from the sand were measured rather than the brightness of the sky. The use of a light meter to obtain proper exposure for figures or structures on the beach is shown in Figure 3. Here the meter is pointed directly at the person to be photographed and is held relatively close to the person to exclude reflected light from the surrounding sand areas. When the meter is used in this way the persons on the beach will be properly exposed but the background beach area will be overexposed as illustrated in Figure 3.

FIGURE 1. AN EXPOSURE BASED ON THE LIGHT READING IN FIGURE 2. USUALLY RESULTS IN SILHOUETTED SUBJECTS

FIGURE 2. LIGHT READING OFF DRY SAND OF THE BACKSHORE

FIGURE 3. LIGHT REFLECTED FROM THE CLOTHING, FACIAL FEATURES, OR A STRUCTURE, SHOULD BE MEASURED WHEN SUBJECT DETAIL IS REQUIRED

FIGURE 4. THE BEST AVERAGE EXPOSURE READINGS FOR ALL-PURPOSE PHOTOGRAPHS WILL BE OBTAINED FROM THE MOIST, NOT WET, PART OF THE BEACH

The same principles and procedures hold when the subject to be photographed is "back lighted," that is, illuminated by light coming from behind the object. On occasions when the back-lighted object is inaccessible and no light reading can be taken of the object, satisfactory results can usually be obtained by opening the camera aperture two f-stops more than the general light reading indicates.

When taking pictures of the general beach where it is desired to show form or character of the beach itself, an average light reading should be used. When the light meter is used as shown in Figure 2, the general scene will be underexposed and it will be difficult to separate the sand of the beach from the sky and water. It has been found on the Atlantic coast of Maryland and Delaware that the best average exposure readings for all-purpose beach photographs will be obtained from the moist part of the beach just above the zone of wave uprush, Figure 4.

Use of Filters. At times it will be very difficult to separate the sand, water, and sky areas in beach photographs even though the best average exposure is used. This is especially true on hazy or cloudy days. On sunny days, filters may be used to obtain better separation of sand, sky, and water areas. The most useful filters in beach photography are the K-2, G, and A filters of the Wratten scale. These filters eliminate some of the blue light from the sky and thus make the sky appear darker in the photograph. The filters are listed in the order of their ability to filter blue light; therefore, where a small change will be made by a K-2 filter, the A filter will make the sky appear very dark. Since the filters function on the principle of filtering blue light, they will have little effect on cloudy days when little blue light is present. However they act as haze filters, or filters through which greater distances can be photographed, on hazy days.

When filters are used, some compensation must be made in exposure because some of the light from the scene is absorbed by the filter. This is done by assigning factors to the filters which indicate the number of times that the exposure must be increased in order to compensate for the effect of the filter. Manufacturers furnish filter factors with their filters. For instance, if a filter has a factor of 2, the exposure should be doubled to allow enough light through the filter to properly expose the film; if the filter factor is 4, the exposure should be increased four times, or two f-stops. The effect of filters is most easily handled by dividing the filter factor into the ASA exposure index rating and placing the resulting number in the ASA scale of the light meter. This is easier than using the ASA exposure number as given by the manufacturer and trying to compensate for the filter by changing the f-stop or shutter speed.

Another very useful filter in beach photography is the polarizing screen which, when properly orientated, blocks the polarized light reflected from surfaces in the picture. In general, pictures will have better definition and more even lighting can be obtained with a polarizing screen. In using the polarizing screen the manufacturer's recommendations and instructions should always be followed and it should be remembered that the polarizing screen has an absorption factor which must be considered. When using color film, the K-2, G, and A filters should never be used; however, the polarizing screen should be used to produce pictures with better definition and deeper, richer color on sunny days.

Focusing. When taking pictures of a general beach or objects on the beach which are at a moderate-to-far distance from the camera, that is, 20 feet or farther from the camera, it is better to focus the lens at a distance of 30 feet than at infinity. This moves the field of the lens which is in focus closer to the camera and makes objects in the foreground clearer while it does not significantly detract from objects in the distance because they are usually too small to be seen clearly. This is illustrated in Figure 5. Here, the picture on the left was made with the lens focused at 30 feet and almost all of the foreground is in focus. In the picture on the right, the lens was focused at infinity and, while the background is a little sharper than the one on the other figure, the foreground is noticeably out of focus. The post in the figure is about 20 feet along the axis of the groin from the camera lens.

Panorama Exposures. Panorama exposures are excellent for showing structures or large areas that are too large to be photographed in a single picture. This often happens when the physical limitations of the area being photographed will not allow the photographer to stand far enough from the subject to get the entire subject in, or when standing far enough from the subject would produce subject images too small to show required detail. Panoramas are made by taking consecutive pictures from the same spot swinging the camera in the same general horizontal plane and allowing a small overlap to permit matching of the images.

Examples of panorama photographs are shown in Figures 6, 7, and 8. Figure 6 is a two-exposure panorama showing the conditions seaward and landward of the crest of a dune. Figure 7 is a panorama used to show the foreground width of a beach. Included on the figure are suggested guides or aids which can be used to make the beach width more apparent. Figure 8 is a three-exposure panorama of a groin which can be used in conjunction with a "down axis" photograph such as shown in Figure 5, to give very good coverage of the construction details of a structure.

FIGURE 5. COMPARATIVE PHOTOS DOWN THE AXIS OF A GROIN. THE PHOTO ON THE RIGHT WAS MADE WITH THE FOCUS AT INFINITY; ON LEFT, 30 FEET.

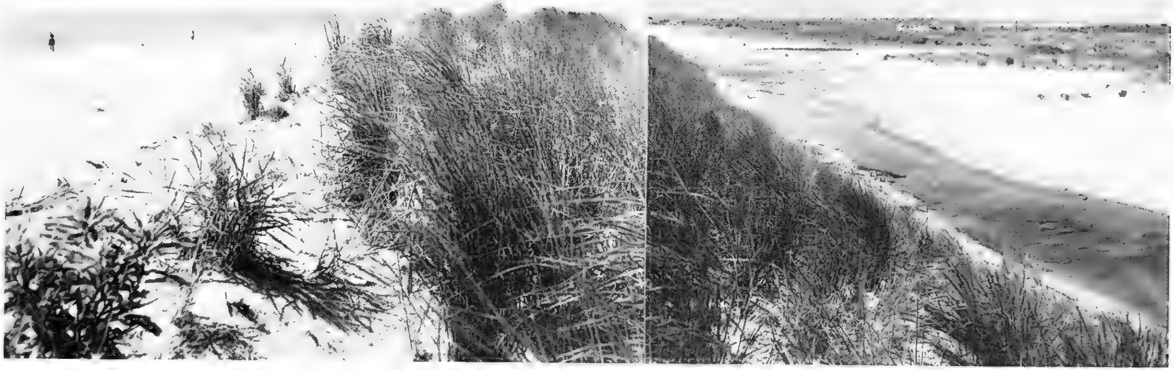


FIGURE 6. TWO-EXPOSURE PANORAMA SHOWING THE CONDITIONS SEAWARD AND LANDWARD OF THE CREST OF A DUNE. THE DUNE IS NOT NATURAL, BUT WAS MADE OF MATERIAL FROM THE EXCAVATION SHOWN IN THE PHOTO ON THE RIGHT. THE DUNE IS STABILIZED BY CLOSELY PLANTED DUNE GRASS. THE TWO-EXPOSURE PANORAMA PERMITS ALL THESE FEATURES TO BE SHOWN IN ONE ILLUSTRATION

FIGURE 7. PANORAMA USED TO SHOW THE FOREGROUND WIDTH OF A BEACH. THE WIDTH IS DECEPTIVE WITHOUT A LINE SHOWN NORMAL TO THE WATERLINE, AND PARALLEL TO THE HORIZON

FIGURE 8. THREE-EXPOSURE PANORAMA OF A GROIN, PERMITTING MOST OF ITS LENGTH TO BE SHOWN WITH DETAIL IN ONE ILLUSTRATION

Conclusion

While the use of the basic principles and techniques presented herein will produce pictures which are technically acceptable, there is an area of photography in which the photographer's individuality and imagination play a large part. This area is usually developed after the photographer has become competent in producing technically acceptable pictures and consists of factors such as the framing of the picture, the angle at which the picture is taken, special use of the lighting available, and special effects. These factors are probably more important to the esthetic photographer, but certainly have a place in technical photography and should be consciously developed and used wherever practical.

Acknowledgment

The author appreciates the ideas and illustrations by Mr. H. A. Ward, former Chief of a Special Studies Branch at the Beach Erosion Board but now retired.

References

Morgan, W. D., and H. M. Lester, Graphic Graflex Photography, 8th edition, Morgan & Lester, New York 17, New York, 1950.

Nibbeling, Don, The Complete Book of Lighting, Midland Publishers, Forest Park, Illinois, 1950.

Kingslake, Rudolph, Lenses in Photography, Garden City Books, Garden City, New York, 1951.

RESEARCH FACILITIES AND SPECIAL EQUIPMENT OF THE BEACH EROSION BOARD

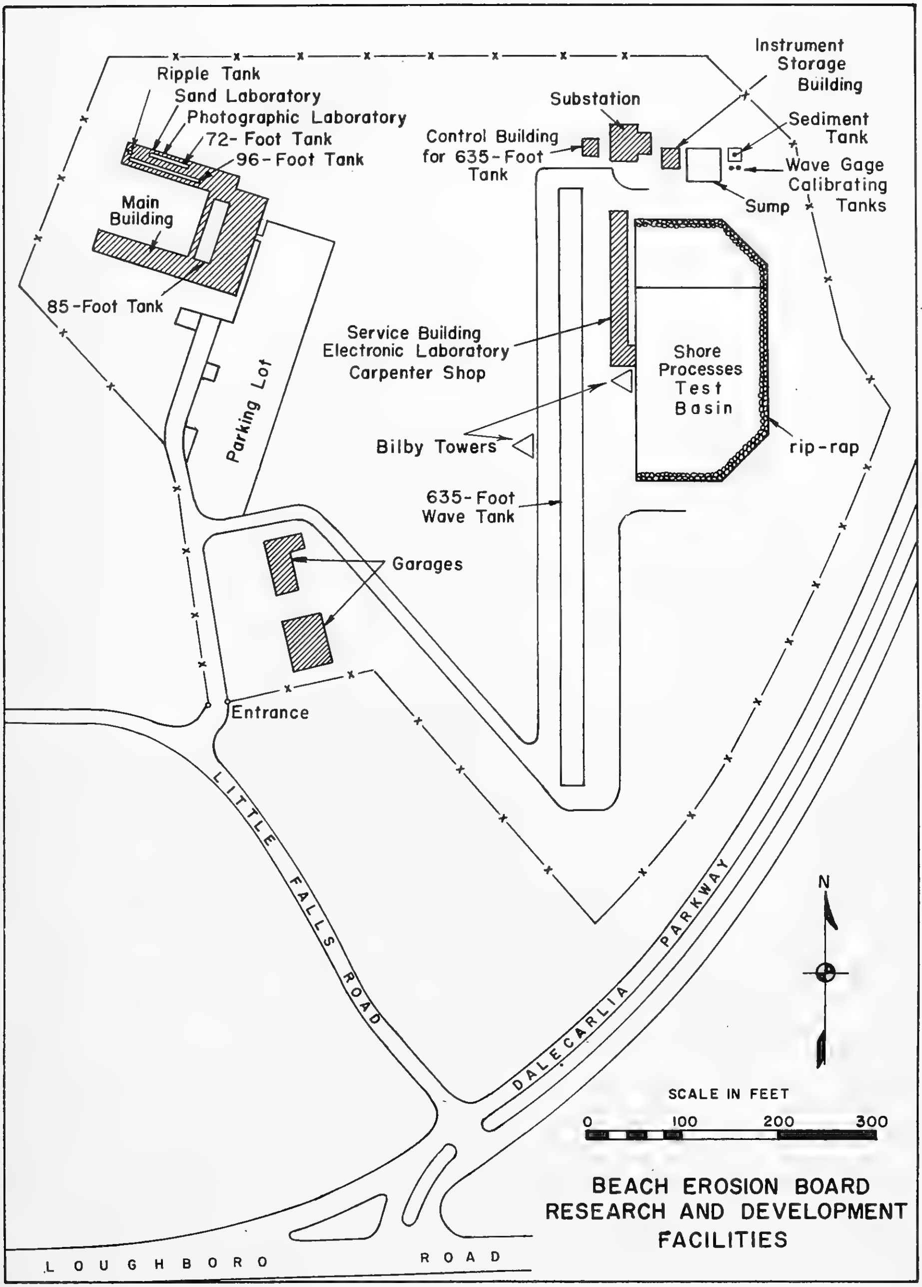
Coastal processes research facilities are of interest to coastal engineers, both from the standpoint of those available in general and also what is available at a particular installation. Since the research facilities at the Beach Erosion Board have been altered or enlarged considerably since publication of the latest description, this article has been compiled by George W. Simmons, Engineering Technician, Research Division, Beach Erosion Board, to provide an up-to-date description of these facilities.

The major research and development facility at the Board is the research laboratory which contains experimental wave tanks, a wave and tide basin, analytical equipment, and instrumentation used in beach and wave studies. Also available are mobile equipment and portable instruments for field studies on the open coast.

The layout of the buildings and wave tanks on the Beach Erosion Board grounds is shown in Figure 1. The wave tanks are described below and a summary of their descriptions and capabilities is given in Table 1.

Ripple Tank. - This tank has a basin constructed of 1/2-inch clear plastic. Its interior dimensions are: length, 4 feet; width, 3 feet; and depth, 4 inches. Waves, or ripples, having a frequency of about 8 cycles per second, are generated at one end and act as lenses to focus light rays from beneath the tank onto a ground glass screen placed above the tank. The wave crests appear as lines of light which may be photographed to record the horizontal position and configuration of the waves in the tank at any time. This tank is especially useful as a demonstration device and in determining qualitatively the wave refractive, diffractive, and reflective characteristics of various natural and man-made shore features (see Figure 2).

"Ninety-six-foot" Tank. - This tank is constructed of steel except for an 18-foot section at the end opposite the generator. This section is constructed of 3/8-inch glass to permit tests in the tank to be observed and photographed from either side. The tank dimensions are: length, 96 feet; width, $1\frac{1}{2}$ feet; and depth, 2 feet. The generator is powered by a 1.5-hp vari-drive unit, which, through a chain drive, rotates a steel disc. A pusher arm, eccentrically mounted on the disc, drives a carriage-mounted vertical bulkhead.


Ripple Tank
Sand Laboratory
Photographic Laboratory
72- Foot Tank
96-Foot Tank
Main Building
85-Foot Tank
Parking Lot
Substation
Control Building for 635-Foot Tank
Instrument Storage Building
Sediment Tank
Wave Gage Calibrating Tanks
Sump
Service Building
Electronic Laboratory
Carpenter Shop
Shore Processes Test Basin
Bilby Towers
rip-rap
635-Foot Wave Tank
Garages
Entrance
LITTLE FALLS ROAD
DALECARLIA PARKWAY
LOUGHBORO ROAD
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0 100 200 300
BEACH EROSION BOARD
RESEARCH AND DEVELOPMENT
FACILITIES

FIGURE 1.

TABLE 1 - WAVE TANKS

Tank	Size	Wave Generator	Maximum Wave Height	Wave Period	Tidal Cycle	Other Features
Ripple Tank	3'x4'x4"	Audio oscillator driving magnetic (loud speaker) impeller.	-	About 8 cps	None	Ground glass and light-reflection system for wave pattern observation.
Indoor Wave Tanks	96'x$1\frac{1}{2}$'x2'	$1\frac{1}{2}$ hp varidrive push-pull type.	8"	0.5 to 5.0 sec.	None	Glass side panels at beach end.
	72'x$1\frac{1}{2}$'x2'	$1\frac{1}{2}$ hp varidrive push-pull type.	8"	0.5 to 5.0 sec.	None	Glass side panels at beach end.
	85'x14'x4'	$7\frac{1}{2}$ hp varidrive 45^{o} scoop-type.	1'	0.5 to 9.8 sec.	40-minute complete cycle for 12" max. fluctuation.	Six 24"x40" glass observation windows with etched height scales. 1-ton personnel and instrument carrier.
Shore Processes Test Basin	300'x150'x3'	$7\frac{1}{2}$ hp varidrives (10)	8"	0.8 to 4.0 sec.	40-minute minimum for complete cycle of 3" max. fluctuation. 2200 gpm system for littoral currents	Simultaneous generation of different wave patterns. 5-ton personnel and instrument carriers. 100-foot observation tower.
Tank for Very Large Waves	635'x15'x20'	510 hp, constant speed motor driving push-pull type generator through (changeable) gears.	6'	1.85 to 16.0 sec.	None	Full-length track for personnel and instrument carrier. Partitions for reducing tank length. Three movable shelter sections to protect portions of the tank from inclement weather.

FIGURE 2. RIPPLE TANK-SCREEN SHOWING EXAMPLE OF WAVE REFRACTION, DIFFRACTION AND REFLECTION

The eccentricity of the pusher arm on the disc can be continuously varied from 0 to approximately 10 inches using a screw-driven connection. The wave generating mechanism (shown on Figure 3) can produce a continuous range of wave heights from 0 to approximately 8 inches, and a continuous range of wave periods from 0.5 to 5.0 seconds. A riprap-type wave absorber behind the generating bulkhead has a face slope of 30° with the horizontal and is held in place by 1/2-inch wire mesh. Figure 4 is a general view of the tank taken near the beach (glass) end.

"Seventy-two-foot" Tank. - This glass and steel tank is 72 feet long, 1-1/2 feet wide, and 2 feet deep. At the opposite end from the generator, glass walls extend 54 feet on one side and 30 feet on the other. The wave generator is a replica of that in the "ninety-six-foot" tank and identical wave characteristics can be obtained. The wave absorber behind the generating blade is also of the same design. Level rods on each side of this tank run the entire tank length and permit measurements from a level base. Figure 5 is a view along this tank taken from the beach end.

"Eighty-five-foot" Tank. - This indoor, reinforced concrete tank is 85 feet long, 14 feet wide, and 4 feet deep. One side is equipped with six glass windows, each 24 x 40 inches, spaced on 10-foot centers. Each window has etched scales graduated to hundredths of a foot. The tank is equipped with a steel-framed instrument and personnel carrier which covers the full tank width and runs on tracks along the entire tank length. Its load capacity is approximately one ton (see Figure 6).

The wave generator (Figure 7) is a steel-scoop-shaped bulkhead with rollers at the bottom driven through two drive shafts by a 7-1/2 hp vari-drive motor. The vertical and horizontal movement of the bulkhead is independently controlled by means of double eccentrics located at each end of the drive shafts. Variation of the eccentricities of the driving arms permits a continuous range of wave heights from 0 to about 1 foot; wave periods may be continuously varied from 0.5 to 9.8 seconds by use of the vari-drive motor and a geared transmission.

A wave absorber consisting of layers of staggered cinder blocks covered with wire mesh is set at an angle of 60° with the horizontal at the extreme rear of the tank a few feet behind the wave generator.

The tank is also equipped with a manually operated tidal system (operated through a constant head tank) which can provide a complete tidal cycle with a maximum 12-inch fluctuation in 40 minutes (or 6-inch fluctuation in 20 minutes, etc.). Stilling well connections at the tank sides permit measurement and control of tidal fluctuations.

Shore Processes Test Basin. - This outdoor, reinforced concrete tank is rectangular except that 50-foot triangular sections are omitted on two corners (see Figures 1, 8, and 9). Horizontal dimensions are 150 x 300 feet, and the depth is 3 feet. The tank is presently subdivided with a removable concrete wall into two basins, 100 x 150 feet, and 200 x 150 feet.

Movable wave generators of the push-pull bulkhead type, nine with bulkhead face widths of 20 feet and one with a width of 15 feet, are available. Each is powered by a 7-1/2 hp A.C. variable-speed electric drive and is equipped with an 8-inch variable eccentric arm for changing the wave height. The machines were designed to give a continuous range of wave heights up to about 8 inches with a period range of 0.8 to 4.0 seconds in 2-1/2 feet of water. Although somewhat larger periods can be generated; wave heights of 8 inches cannot be obtained with periods greater than 4 seconds. The machines may be divided into two sets which may be operated independently to produce simultaneously two separate wave trains of completely different characteristics. The wave machines may also be operated

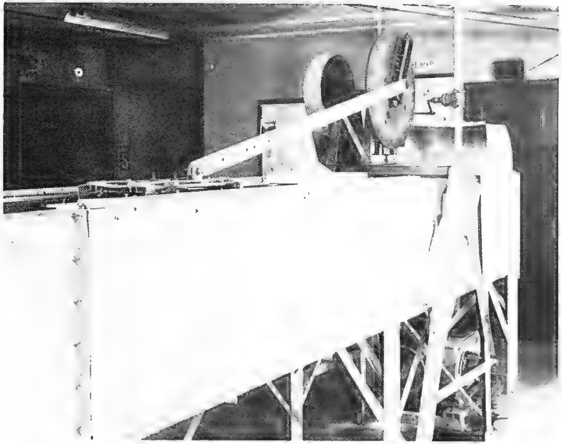


FIGURE 3. WAVE GENERATOR, 96-FOOT TANK

FIGURE 4. VIEW ALONG 96-FOOT TANK

FIGURE 5. VIEW ALONG 72-FOOT TANK

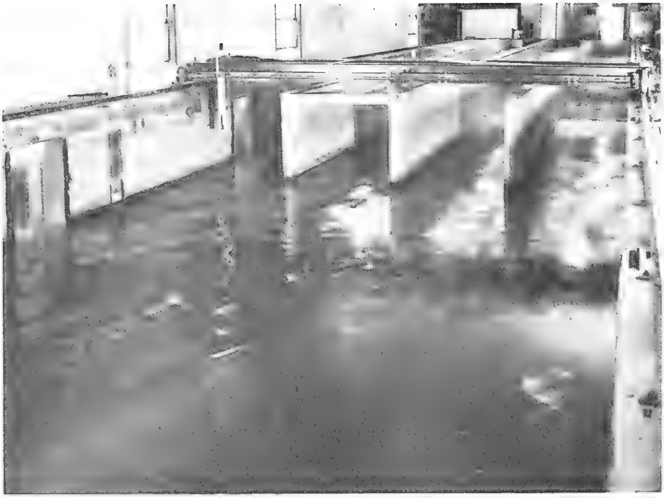


FIGURE 6. 85-FOOT CONCRETE TANK

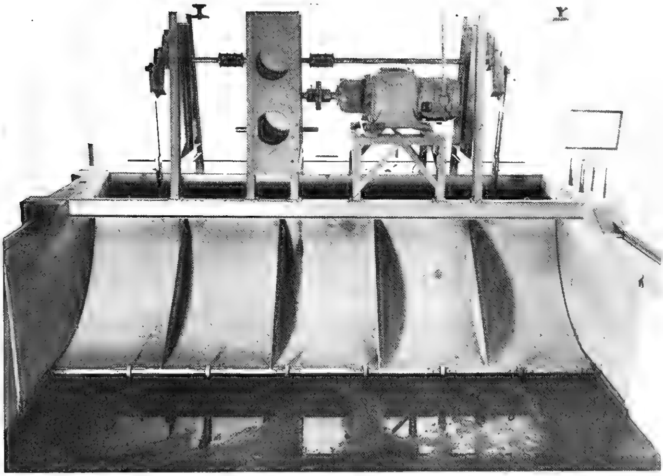


FIGURE 7. WAVE GENERATOR, 85-FOOT CONCRETE TANK

FIGURE 8. SHORE PROCESSES TEST BASIN, CONTAINING NINE SEPARATE WAVE GENERATORS

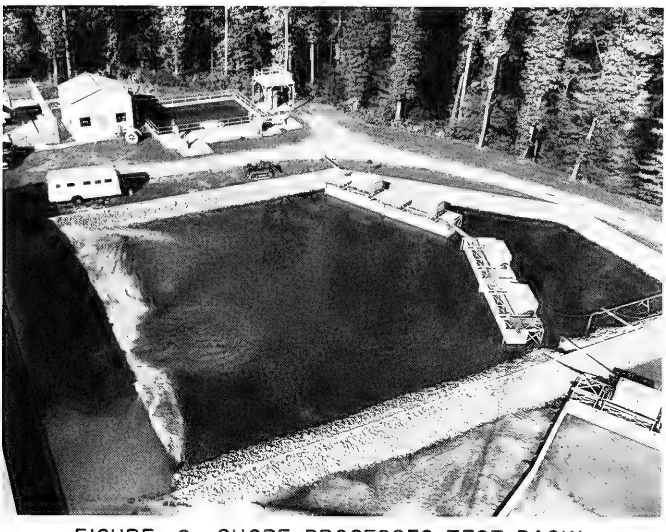


FIGURE 9. SHORE PROCESSES TEST BASIN FROM BILBY TOWER

FIGURE 10. INSTRUMENT AND PERSONNEL CARRIER IN THE SHORE PROCESSES TEST BASIN

FIGURE 11. TIDE SUMP AND PART OF THE PUMPING SYSTEM FOR THE SHORE PROCESSES TEST BASIN

independently to produce simultaneously up to ten wave trains of different heights, directions, and phase, though of only two different wave periods. A gravel wave absorber along three sides of the tank minimizes reflections from the side and rear walls. A planned supplementary tidal system will produce a complete tidal cycle in 40 minutes with a maximum 3-inch fluctuation of water level. The tidal flow from a 40 x 40-foot sump 10 feet deep (Figures 9 and 11) will be introduced through a perforated pipe which runs the length of three full sides of the tank under the gravel absorbing slope. An additional pumping system of 2,200 gpm capacity is available for superimposing a forced littoral current.

The basin is equipped with two motor driven instrument and personnel carriers, one for each of the two existing sections (although Figures 8 and 9 show one only over the larger section, a carriage has now been installed in the smaller section also). The carriers (Figure 10) operate on tracks along the entire length of each section, covering a 100-foot width in the larger section and a 5-foot width in the smaller. A Bilby tower 100 feet high, is located next to the beach side of the tank for photographic use. A number of eductors, an endloader, and a garden scraper-tractor are available for moving sand. Figure 8 is a general view of the tank, with nine of the wave machines installed. Figure 9, a view of the basin taken from the Bilby tower, shows the generating faces of five of the movable wave generators. Figure 10 shows the instrument and personnel carrier for the larger section and the Bilby tower. Shown in Figure 11 is the tide sump and part of the pumping system.

Tank for Generation of Large Waves. - This concrete wave tank is 635 feet long, 15 feet wide, and 20 feet deep. An instrument carriage operates on rails mounted the entire length of the tank on top of both side walls. The instrument carriage is designed to carry personnel as well as instruments required in the performance of tests. Electrical outlets are spaced along the tank wall to provide 110-volt single-phase, and 208-volt three-phase electric power for use with instruments and auxiliary equipment. Another feature of the wave tank is a removable bulkhead and three sets of slots, by means of which the tank may be partitioned into sections of various lengths. A 100-foot Bilby tower is located beside the tank about the midpoint of its length for photographic purposes. Operating at the usual water depth of 15 feet, the tank requires approximately one million gallons of water. The tank is filled through either of two 6-inch lines leading from an 8-inch water supply pipe. Filling normally takes about 8 to 10 hours, but valves may be set to automatically cut off at any predetermined level so that filling may take place during the night without loss of normal work time. Figure 12 is a view of the 6-foot wave in the tank and Figure 13 is a view of the tank looking toward the beach end showing an endloader being lowered into the tank to be used for moving sand.

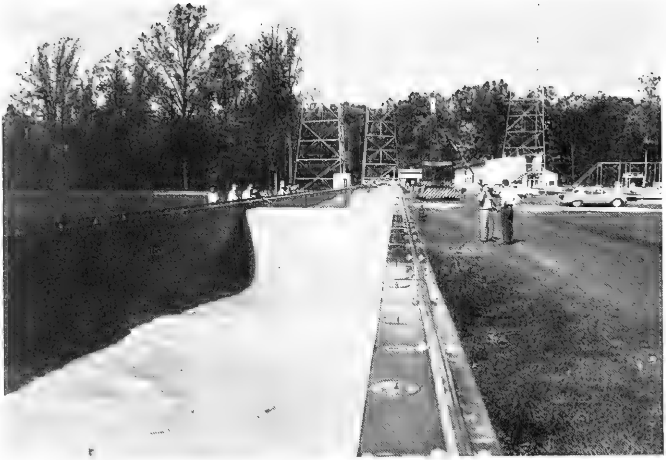


FIGURE 12. A SIX-FOOT WAVE IN 635-FOOT TANK


FIGURE 13. VIEW ALONG 635-FOOT TANK-(AN ENDLOADER FOR MOVING SAND BEING LOWERED INTO THE TANK)

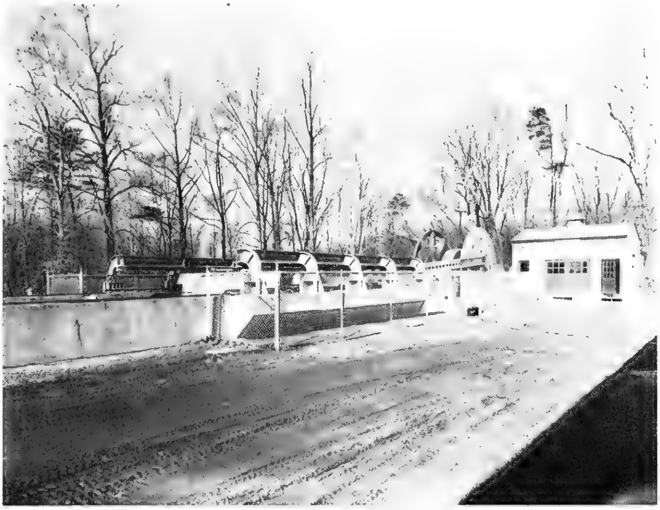


FIGURE 14. GENERAL VIEW OF WAVE GENERATOR, 635-FOOT TANK

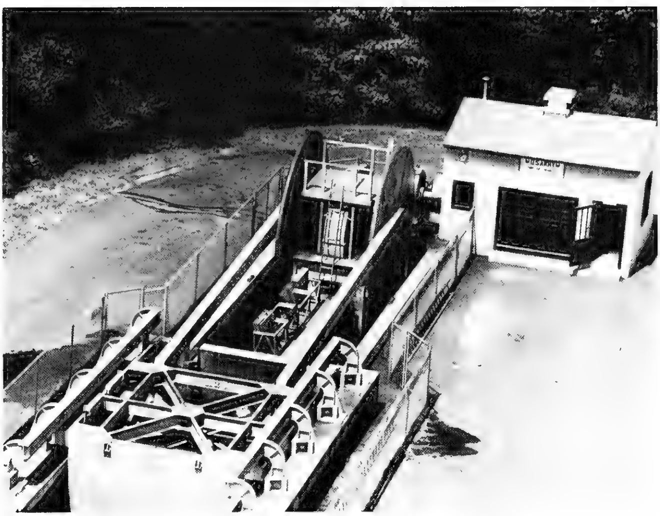


FIGURE 15. TOP VIEW OF WAVE GENERATOR, 635-FOOT WAVE TANK

Three movable Quonset-type cover sections are available to provide protection from the weather for 15-foot sections of the tank during construction or operation. Each of these 4,000-pound galvanized steel cover sections can be used independently or as one continuous length. The three sections protect a total area of about 1,300 square feet including a 6-foot width on each side of the tank. The maximum head room available is 15 feet.

The wave generating mechanism (Figures 14 and 15) consists of a vertical bulkhead 15 feet wide and 23 feet high mounted on a carriage. The carriage moves back and forth on rails mounted on each wall of the tank. Top rails and dual spring loaded wheels are required to prevent lifting of the carriage from the rails during operation. The back and forth motion is transmitted to the bulkhead and carriage by two arms, 42 feet 9 inches in length connected to two driving discs. Each disc is 19 feet in diameter and weighs 14 tons. The discs are driven through a train of gears by a 510 hp, 2,300-volt synchronous motor running at a constant speed of 1,200 revolutions per minute.

Three sets of gears in the first reduction and four sets of gears in the second reduction permit variations in the speed of the discs. The alternative gearing will allow generation of wave periods of approximately 1.85, 2.61, 3.12, 3.75, 4.38, 5.31, 5.60, 6.31, 7.87, 8.92, 11.33, and 16.01 seconds. The maximum usable wave height is approximately 6 feet. The distance that the bulkhead moves can be varied from 2 to 17½ feet by changing the eccentric setting of the connecting arms on the driving discs. The stroke setting may be varied in 3-inch increments through the range from 2 to 8 feet and in 6-inch increments from 8 to 17½ feet. When the connecting arm eccentric setting on the disc is changed, the disc is rebalanced with counterweights. The counterweights required for balancing range from 378 pounds for each disc for the shortest (2-foot) stroke to 3,820 pounds for each disc for the longest (17½-foot) stroke. Normally waves are generated by back and forth motion of the vertical bulkhead. However occasionally lower waves are desired. These can be generated for some of the shorter wave periods (as the smallest eccentric setting possible is 2 feet). Consequently the mechanism has also been adapted to connect to a further bulkhead, hinged to the bottom, which may be installed when desired to give waves with heights about half those available with the vertical bulkhead.

Supporting Facilities. - (a) A library of foreign and domestic documents on coastal engineering, including a file of approximately 30,000 ground and aerial photographs of coastal areas.

(b) A photographic laboratory equipped to process black-and-white and color film, and print contact pictures or enlargements of black-and-white negatives. Included in the equipment of the photographic laboratory are: 4 x 5-inch press cameras, 35-mm cameras, 16-mm movie cameras capable of film speeds from 8 to 3,000 frames per second, oscillograph and oscilloscope recording cameras, and an Omega D-2 enlarger.

(c) A sedimentological laboratory equipped to analyze the size, shape, roundness, surface texture, mineral content, calcium carbonate content, specific gravity, porosity and permeability of sedimentary materials. The laboratory equipment includes: a fixed and a portable motor driven Ro-tap testing sieve shaker, a set of sieves ranging in size from 1 inch to 0.035 millimeter, a Jones sample splitter, a microsplitter, a Brookfield spindle-type viscosimeter, two visual accumulation tube sand size analyzers, a portable electric oven with a variable range of temperatures to 430°F, equipment to make heavy mineral separations and microscope mounts, polarizing monocular microscope and binocular microscope, balance, La Chatelier specific gravity bottles, pipettes, and a permeameter.

(d) Field equipment sufficient to make complete near-shore hydrographic surveys includes: two amphibious vehicles (DUKW), two sonic sounders (Bludworth N-K-2) which will operate in depths up to 180 feet, radio equipment for ship-to-shore communication, topographic and hydrographic survey instruments and equipment, ocean bottom sediment samplers, a mobile field office, salt and fresh water step-resistance wave gages and programmers, and pressure-type wave gages. Recently the Beach Erosion Board completed the development of an in-place sediment density gage designed for obtaining the sediment density in soft bottom materials. The gage is 16 inches long $1\frac{1}{2}$ inches in diameter and weighs 15 pounds. After the gage is lowered into the water and made to penetrate the bottom material, radioactive particles and gamma rays are emitted from a weak radium source in the gage head. The gamma rays which are reflected from the sediment surrounding the probe are picked up by a detector also located in the gage head. The number of ionizing events reaching and being detected by the detector is transmitted to a nuclear counting device at the water surface. The number of counts per unit of time is a measure of the density of the material in a doughnut-shaped area approximately 1 foot thick and 2 feet in diameter with the gage source at the approximate center. The gage has been calibrated for use in most common sediments and gives the density in grams per liter.

(e) Equipment of original design for special requirements. Since it is necessary to test and calibrate the field and laboratory wave gages (step-resistance type) after repair or development, two water tanks are available for this operation: one containing fresh water and the other salt water (simulating sea water). Concrete culvert pipes, 3 feet in diameter and 12 feet in length, placed on end and sealed at the bottom, give sufficient depth for testing and calibrating any existing gages. Calibrating equipment is also available for testing and calibrating ordinary pressure type wave gages by the application of static and dynamic pressures equivalent to pressures expected at the proposed gage installation site. The static and dynamic pressures are indicated on a Mercury Manometer during calibration. Also available is a steel sediment tank, 10 feet high and 4 feet in diameter, with a vertical 1-foot wide observation window built into the lower 7 feet of tank wall. Samples from various depths are easily extracted with a 3/4-inch sampling tube, designed to be used in conjunction with Corporation cocks mounted in the tank at 1-foot vertical intervals. An eductor-type draining system is located at the bottom of the tank. The tank has been used to study the behavior of sounding leads of various sizes and shapes in soft bottom materials of varying consistencies. Figure 16 shows the sediment tank along with the two tanks used for calibrating step-resistance type wave gages.

(f) An electronic shop equipped for the repair of electrical and electronic test equipment, and the development of special test equipment for use in both the laboratory and the field. Included in the electronic laboratory are oscilloscopes, audio and radio frequency signal generators, a tube tester, voltmeters, ammeters, five dual-channel Brush oscillographs, ten universal Brush amplifiers, one six-channel Brush oscillograph with associated amplifiers, electric wave height gages, four strain gage pressure cells, several tourmaline pressure cells, water current meters, and an electronic wave analyzer.

(g) A small carpentry shop and machine shop equipped to service the test facilities.

FIGURE 16. TWO TANKS FOR TESTING WAVE GAGES (LEFT) AND SEDIMENT DENSITY TANK (RIGHT)

NOTES ON THE FORMATION OF BEACH RIDGES

by
Rudolph P. Savage
Research Division, Beach Erosion Board

In laboratory experiments involving wave action on sand beaches the beach ridges formed almost always have a characteristic shape. This shape, shown as a solid line in Figure 1, is created from the original slope (shown) by the waves. One explanation of this shape may be obtained by considering the relationship between relative wave run-up (R/H) and beach slope (Figure 2) previously reported (1, 2). As shown in Figure 2, for any constant deep water wave steepness and wave height, the relationship between wave run-up and beach slope assumes a characteristic curve with the run-up increasing as the slope steepens, up to a maximum value, then decreasing somewhat.

If it is assumed that a beach ridge is created by a deep water wave of constant height and steepness, the mechanics of beach ridge formation might then be explained as follows: When the first waves run up the original, say 1 on 20, slope, the maximum run-up is to the point marked by R_{20} (Figure 1). As the waves surge up and down the slope, a small deposit of sand is left by each wave, thus creating a somewhat steeper slope. As the slope steepens, the run-up increases (depositing sand to successively higher elevations) until at the time the foreshore slope has steepened to 1 on 10, the run-up would be to the point marked R_{10} in Figure 1. This process is continued until the slope achieves a steepness which is limited by the size of the sand and the characteristics of the waves creating the beach ridge.

In Figure 1, it was assumed that all the slopes created by the sand deposits would pivot around point A. It is not necessary that this happen, and the slopes could pivot around some other point or different points. Point A' and the dotted line for the 1 on 10 slope are shown on Figure 1 to give some idea of the effect that a variable pivot point could have on the shape of the beach ridge. It appears that as long as point A does not fluctuate too widely the characteristic shape of the beach ridge would be essentially the same.

It should be noted from Figure 2 that if the foreshore of the beach ridge becomes steeper than 1 on 5 for a wave with a deep water steepness of 0.005, the run-up then begins to decrease. For waves with steepnesses of 0.40, the foreshore slope must become steeper than approximately 1 on 2 before the wave run-up begins to decrease. In any event, the maximum height to which a beach ridge can be built would be a function of the maximum run-up for the particular wave steepness under consideration. Under conditions where the slope finally achieved by the foreshore of the beach ridge does not reach the slope of maximum run-up given in Figure 2, the maximum height of the beach ridge would then be determined by the maximum slope of the foreshore and the run-up from Figure 2 for this particular condition.

Also shown in Figure 1 by dashed lines is the mechanism through which a wide beach berm could be formed by the seaward movement of the foreshore of the beach ridge. This, of course, would only happen under conditions which allow an accreting foreshore.

Shown in Figure 3 are the stages in the development of a beach ridge actually observed in the laboratory wave tank tests at the Beach Erosion Board. The development apparently follows the postulated development closely in that as the slope of the foreshore steepens, the height of the beach ridge is increased until a maximum is reached when the slope of the foreshore becomes stable.

The foregoing theory of beach ridge development has many important ramifications for the coastal engineer. Among the most important are: (1) the height of beach berms would always be limited by the imposed wave conditions and the maximum run-up for particular wave steepness given in Figure 2. (2) In cases where the foreshore of the beach ridge would not stand on the maximum slope given in Figure 2 for the particular wave steepness creating the beach ridge, the maximum height of the beach berm would be determined by the run-up given for the maximum stable slope of the beach ridge foreshore.

It is realized that the processes in nature which create beach ridges are much more complicated than those in the simple laboratory illustration. Wave conditions are apt to vary constantly and the tides also impose their variation. Also, things happen much faster in nature where the size of the sand is considerably smaller in relation to the wave height and it may not be possible to see the various stages of development of a beach ridge as given here. Too, in nature, development of a beach ridge would start from conditions left from a previous wave train and would therefore be very unlikely to have the smooth initial conditions from which the laboratory tests started. It is believed, however, that the theory presented herein embodies basic principles involved in beach ridge formation and that knowing the basic conditions involved will lead to a better understanding of the observed phenomenon.

REFERENCES

1. Savage, R. P., "Wave Run-up on Roughened and Permeable Slopes," Paper No. 1640, WW3, Journal of the Waterways and Harbors Division, Proceedings of the American Society of Civil Engineers, May 1958.

2. Saville, Thorndike, Jr., "Wave Run-up on Composite Slopes," Proceedings of Sixth Conference on Coastal Engineering, Council on Wave Research, Engineering Foundation, 1958.

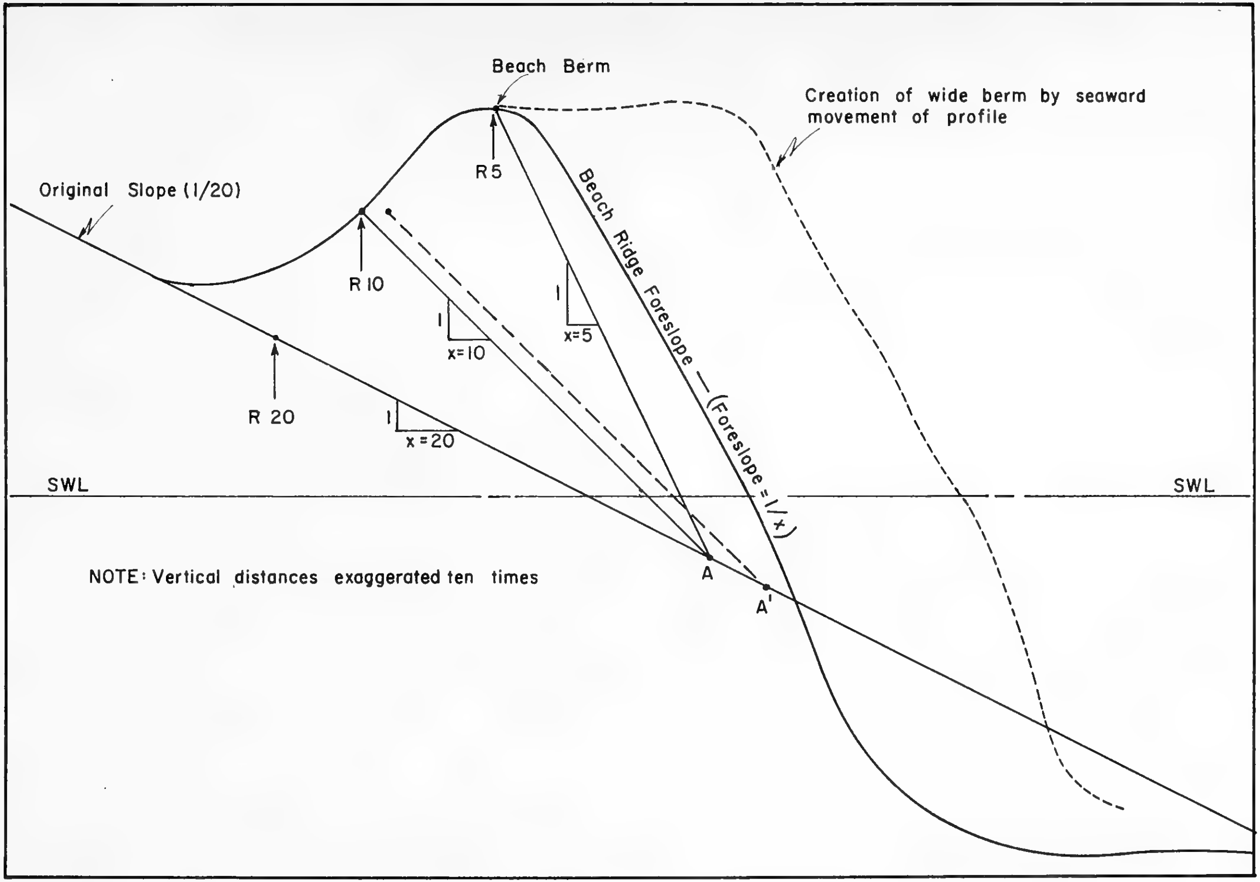


FIGURE 1. POSTULATED STAGES IN THE FORMATION OF A BEACH RIDGE UNDER LABORATORY WAVE CONDITIONS.

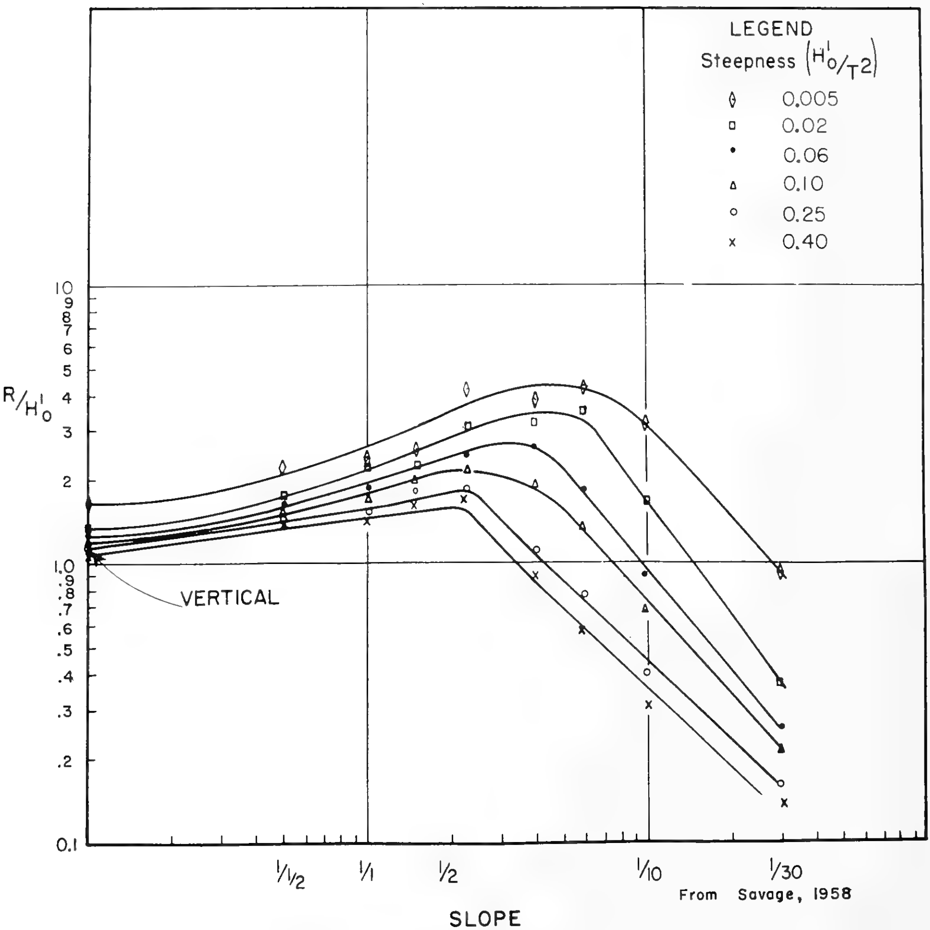
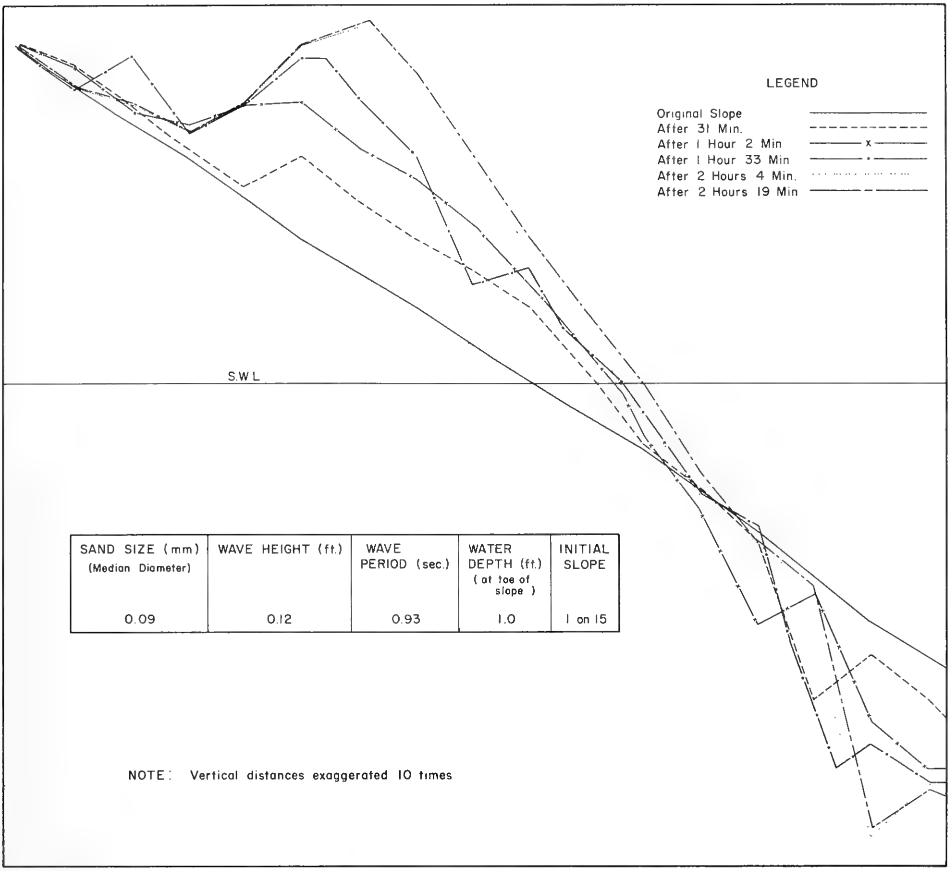


FIGURE 2. WAVE RUN-UP ON SMOOTH SLOPES.



SAND SIZE (mm) (Median Diameter)	WAVE HEIGHT (ft.)	WAVE PERIOD (sec.)	WATER DEPTH (ft.) (at toe of slope)	INITIAL SLOPE
0.09	0.12	0.93	1.0	1 on 15

FIGURE 3. OBSERVED STAGES IN THE DEVELOPMENT OF A BEACH RIDGE UNDER LABORATORY WAVE ACTION

PROGRESS REPORTS ON RESEARCH SPONSORED BY

THE BEACH EROSION BOARD

Summaries of progress made during fiscal year 1959 on the several research contracts in force between universities or other institutions and the Beach Erosion Board, together with brief statements as to the status of some research projects being prosecuted in the laboratory of the Beach Erosion Board, are presented below. These summaries supplement and continue those contained in prior issues of the Bulletin.

I. University of California, Contract DA-49-055-eng-8. Sources of Beach Sand.

Seasonal sampling of Point Reyes Beach and other beaches in the San Francisco area was continued. In addition to Point Reyes Beach, two other beaches north of San Francisco Harbor entrance (the beach at Drakes Bay and Stinson Beach opposite Bolinas Bay) are being studied. Four beaches south of San Francisco Harbor are being occupied. These are the beaches of Golden Gate Park, Fleischacker Zoo, Sharps Point, and Rockaway Beach. These beaches have been occupied at 2 to 6-week periods during the last two years, and a report "Beaches Near San Francisco, California 1956-1957" has been published as Technical Memorandum No. 110 of the Board describing these observations. A further report entitled "Mechanical Analysis of Beach Sands Near San Francisco, California" tabulating the basic data for the previous paper has been prepared for limited distribution as University of California Institute of Engineering Research Report, Series 14, Issue 22. Mineral analyses of some of the samples are now being made in order to obtain further indications of the direction of migration of the sand; measurements of the radioactivity of the sand are also planned in the hope that variations in the content of mazonite (a thorium-bearing mineral) may also indicate the drift direction.

II. Massachusetts Institute of Technology, Contract DA-49-055-eng-16. Sorting of Beach Sand by Waves.

A report entitled "The Damping of Oscillatory Waves by Laminar Boundary Layers" is being published as Technical Memorandum No. 117 of the Board. It discusses the measurements of bottom shearing stress exerted by shallow water waves obtained in a small wave flume. Methods of predicting resistance coefficients are derived. All of the tests indicated a laminar boundary layer, and consequently coefficients are applicable to laminar flow only. Several tests were also made to compare experimentally determined equilibrium profiles with those predicted by the theory previously derived in this study (see Beach Erosion Board Technical Memorandum No. 104). The theoretical description of incipient motion predicts the seaward edge of the initial profile modification within 3 percent for the waves tested. However, the "null" condition or equilibrium condition of established sediment motion was found to predict slopes up to 200 percent too large. The beach shape is qualitatively correct in the offshore region, however, and the cause for the discrepancy may be in the determination of the mass transport velocity distribution within the bottom boundary layer.

III. University of California, Contract DA-49-055-eng-17. Fundamental Mechanics of Sand Movement by Waves.

Certain additional data on the velocity pattern near the bed were obtained with the modified pitot tube. Additional measurements to determine the phase shift constant were also made by taking motion pictures of injected dye. A report describing the motion in the boundary layer near an oscillating plate for the general case has been initiated. This contract was expanded to cover also the mechanism of sand movement by wind. As a part of this portion of the study, various types of sand traps have been calibrated in a wind tunnel, and efficiencies of these various types checked and compared with each other. Five types of sand trap were tested, three of the vertical type and two of the horizontal type. So far only a single grain size has been tested, but tests are planned with other grain sizes to study its effect on sand trap efficiency and on amount of sediment transported.

IV. University of California, Contract DA-49-055-eng-31. Wind Action Over Shallow Water.

This contract was completed with the preparation of a report receiving limited distribution "Transient Wind Tides in Shallow Water", University of California Institute of Engineering Research Technical Report, Series 731, Issue 11. This report is concerned with the surface time history of wind tide conditions, and the transient water motion. It indicates that the water surface set-up may overshoot its steady state value by a factor of 2, being then damped to the steady state condition.

V. University of California, Contract DA-49-055-eng-44. Laboratory Study of Wave Refraction.

A theoretical study was completed on the effect of frictional resistance as a long wave propagates into or through a channel of gradually varying cross-section. This report was published as Technical Memorandum No. 112 of the Board. The work was required in order to enable subtraction of effect of frictional resistance in making studies of long waves, such as tsunamis, refracting over submarine canyons. It is also applicable to the propagation of tidal waves through inlet areas. Studies on secondary formation of multiple crests from a single wave crest as a wave moves into and over shoal water have been made, and are reported on in a preliminary report issued as University of California Institute of Engineering Research Technical Report, Series 89, Issue 4. This report indicates that the theoretical criterion introduced by Miche has been found to be a fairly reliable index of multiple crest formation.

VI. Agricultural and Mechanical College of Texas, Contracts DA-49-055-eng-56-4 and 58-9. Estimation of Hurricane Surges.

Additional work was done on the research problem in Narragansett Bay (eng 56-4), including some adjustments made for the presence of barriers in the bay. This included efforts in connection with the periodic tide problem for complex bay systems such as Narragansett Bay, the aim being to develop a fairly general scheme of analysis which can be employed on other bays and estuaries. Data have been gathered to compare with data obtained from the tidal model at the Waterways Experiment Station at Vicksburg, Mississippi, for ordinary tide conditions within the bay. Computations are also being made on the wind set-up within Narragansett Bay with the barriers closed. Computational methods for determining storm surge estimates in the New York Harbor entrance area have been developed (eng 58-9), and calibrated with historical hurricane data. Predictions have been made for a standard project hurricane, and are being made for a maximum probable hurricane. A report summarizing this work is presently being prepared. Funds for these two studies were provided by the U. S. Army Engineer Division, New England, and the U. S. Army Engineer District, New York.

VII. Dr. W. C. Krumbein (Consultant). Study of Beach Sampling Methods.

A computer program designed to study the application of computing machine methods to the study of factors influencing beach characteristics and stability was initiated.

VIII. Beach Erosion Board Staff.

(a) Wave Forces on Structures

Wave force data obtained in the large wave tank on a vertical 12-inch diameter pile with a 3-foot sensitive (instrumented) section with waves ranging from 2 to 6 feet in height have been reduced and are tabulated in Technical Memorandum No. 111 of the Board. Maximum forces measured ranged from 80 pounds per foot for non-breaking waves to 280 pounds per foot for breaking waves. Forces were measured both for a single pile and for the center pile of a three-pile bent.

(b) Wave Run-Up

A report entitled "Laboratory Data on Wave Run-Up on Roughened and Permeable Slopes" was published as Technical Memorandum No. 109 of the Board. This report presents a somewhat different analysis of the same data that was previously published by the American Society of Civil Engineers. The report gives curves of relative run-up versus wave steepness for different slopes with varying degrees of roughness and permeability. Inter-comparison between the curves indicates the effect of roughness and permeability, at least for laboratory test conditions. A number of large-scale tests involving waves up to $3\frac{1}{2}$ feet in height were made on a 1 on $1\frac{1}{2}$ riprap protected slope using 160-pound rock in an attempt to determine the possible existence of a scale effect. These tests are still underway, but preliminary results indicate the probable existence of a small-scale effect, with run-up being somewhat greater than might be predicted from small-scale model tests.

(c) Study of Sand Bypassing Operations

An attempt is being made to gather all available data on sand bypassing operations (past, present, or planned) for correlation and study. The hydrographic survey data obtained in the Port Hueneme area in June 1958 was analyzed, and another survey was made in June 1959. A study was made of the possibility of adapting a density gage (utilizing a radioactive source) and a magnetic type velocity meter for use on bypass operations by hydraulic pumping to determine quantity and rate of pumping. Several combinations which appear readily adaptable for this use are commercially available, but funds have so far precluded purchase or testing of this equipment.

(d) Laboratory Study of Effects of Groin Field on the Littoral Drift Passing the Field

A report "Laboratory Study of the Effects of Groins on the Rate of Littoral Transport; Equipment Development and Initial Tests" was published as Technical Memorandum No. 114 of the Board. This report describes the instrumentation and methods of measurement, and the tests made through the summer of 1957. Laboratory tests have been continued, being performed with a single groin on the beach located immediately adjacent to the trap area to give an indication of the time history of the rate of material moving past the groin, and the general location of this movement (i.e., whether over the top of the groin or around the seaward end of the groin). These tests were performed for a short-low groin, a short-high groin, and a long-high groin. Tests also were made using two short-low groins placed adjacent to the trapping area and spaced at approximately three groin lengths. Tests were run with different arrangements of side training walls, and complete elimination of one of these training walls, in an attempt to eliminate disturbing reflections from the beach, the side walls, and the generators.

Two tests have been performed on a steeper (1 on 10) beach slope to determine effect of slope upon test results. Results of these tests, not completely analyzed as yet, indicate that the rate of movement on the steeper beach may be in excess of that on the more gentle (1 on 20) slope, depending somewhat on the deep water wave characteristics. Measurements on the steeper slope also indicate that the rate of movement may be increased by including in the transported material a very small portion of silt or mud-sized material; this indication is also in general agreement with results of studies in turbulence tanks and of transport in some rivers. Tests on this beach also involved a period of starving and then overfeeding the beach to determine the rate of movement of the erosion hole and slug of excess material along the beach. Results of the tests made so far with groins indicate generally that considerably more must be known about the movement of material along the unencumbered beach before the effects of the groins can be definitely separated quantitatively. Accordingly, tests now underway are being directed primarily toward studying the relation of rate of littoral movement to the incident wave characteristics and to the beach characteristics.

(e) Measurement of Suspended Material in Laboratory Wave Tanks

A report "Suspended Sediment Sampling in Laboratory Wave Action" was published as Technical Memorandum No. 115 of the Board. This report tabulates and discusses measurements of suspended sediment made under controlled conditions in the laboratory, both with waves of small (several inches) and large (several feet) height. Measurements made on the effect of water temperature on the amount and type of material in suspension, and the rate at which beach deformation takes place, are also discussed in the report.

(f) Wave Theory

Work continued at the Board on basic wave theory with particular emphasis on the determination of design wave criteria. A report describing theoretical distribution functions and comparing them with observed wave conditions is in preparation. This report also indicates analytical functions describing families of wave spectra based on the distribution functions determined. These spectra are compared with others proposed and with observed data.

(g) Equilibrium Profile and Model Scale Effects Studies

Crushed coal having a particle distribution size the same as the 0.2-mm. material previously tested in the large tank, and having a specific gravity of 1.5, was obtained. The specific gravity is scaled to that of the sand in the large tank by settling velocity ratio. A single test has been performed with this coal at a 1 to 10 model of large tank conditions. A preliminary look at the profile results of this test seems to indicate that the coal beach reacted similarly to the sand beach for the first hour or so, but then deteriorated much more rapidly and to a much greater degree than the large-scale test.

(h) Rubble Mound Stability

Large-scale (7.5 to 1) tests on stability of rubble mound structures under wave action are being made to spot-check results of the test program at the Waterways Experiment Station in Vicksburg, Mississippi. These tests are being made on a 1 on $1\frac{1}{2}$ slope rubble breakwater constructed of a sand core with appropriate filter blankets covered with several layers of approximately 1-foot diameter, 160-pound stone. Tests have been completed with four waves to determine the design wave height (i.e., that height of wave which will just initiate damage after $1\frac{1}{2}$ hours of wave attack) for four different wave periods. Although exact analysis has not yet been completed, the design heights for all periods generally seem to be between about 3 and 3.5 feet. A single test with a wave approximately 1.5 times the design height has been run to check the rate and amount of damage caused by waves higher than design.

(i) Wave Measurements and Analysis

Wave records continued to be taken at five ocean gages (Atlantic City, New Jersey; Palm Beach and Naples, Florida; Huntington Beach and Port Hueneme, California). A development model of a wave spectrum analyzer utilizing magnetic tape records and a spinning tape head has been constructed, and is presently undergoing tests. A magnetic tape recorder was installed on the wave gage at Atlantic City, New Jersey, and is recording continuous data; sample analyses of the first of these tapes are being made with the analyzer. Construction of the step-resistance gage has been improved by replacing the neoprene filling previously used in an aluminum channel by a gage composed completely of plastic. Antifouling paint used with this plastic gage at Atlantic City has worked well during the winter months, and is now being tested during the summer season. Three months test of paint at Naples, Florida shows excellent results also. Three years of visual surf observations made at twenty-seven Coast Guard stations along the United States coasts were summarized and published as Technical Memorandum No. 108. This report also includes some observations of hurricane waves on the Atlantic coast.

(j) Regional Studies

Compilation of data on littoral materials for the south shore of Long Island was continued, as was preparation of a report; compilation of data for the coastal sector from Cape Henlopen to Cape Charles is also under way.

(k) Technical Report No. 4 "Shore Protection Planning and Design"

A continuing study is being made to improve and supplement present chapters of this publication. The first printing of this publication is now out of print; however, a revised edition has been drafted, and the revised edition should be available prior to 1 January 1960.

(l) Re-examination of Beach Protection Projects

A continuing program is being carried out on the re-examination of artificially nourished beaches to determine the effectiveness of the fill material within the beach zones, and to better establish the factors upon which the desired characteristics of fill material are based. A study of the behavior of the beach fill and borrow area at Harrison County, Mississippi has been made and published as Technical Memorandum No. 107; a similar study of the beach fill placed at Virginia Beach, Virginia was published as Technical Memorandum No. 113. As a part of the study of the durability of materials in coastal structures, a continuing examination of the asphalt groins at Ocean City, Maryland has been made. Re-examination of other projects utilizing asphalt is presently under way.

(m) Development of In-place Sediment Density Probe

This probe, which enables a rapid measurement of in-place bulk density of bottom sediment and shoals as a guide to improved dredging techniques, has been calibrated by laboratory tests and has been field tested in estuary sediments and shoals in Savannah River, Georgia and Chandeleur Sound, Louisiana, in reservoir sediments in Hulah and Port Supply (Oklahoma) reservoirs, and in bay sediments and shoals in San Francisco Bay. Calibration and testing was generally satisfactory. Preparation was begun on a report on the development of, calibration of, and field experiences with this gage. The gage has the advantage of giving an indication of densities at successive depths without withdrawing the probe. It appears to have proven itself to be a practicable tool for studying sediment deposits. The probe casing is being streamlined to enable easier insertion into and withdrawal from the shoal materials.

(n) Hurricane Studies

The staff of the Board has continued to support the present hurricane study program of the Corps of Engineers. Considerable work has been done by the staff in developing and improving simplified methods for estimating storm surge elevations and wave heights under a variety of shore line conditions. Wave forces, wave run-up, and wave overtopping phenomena connected with seawall, dike, and barrier design under hurricane conditions have also been studied. A generalized study of the effect of offshore slope on the amount of wave and set-up observed with high hurricane waves has been initiated. This study will also test the effect on the wave set-up of submerged offshore barriers, bars, and breakwaters.

IX. Publications

Technical Memoranda published by the Board during fiscal year 1959 are listed below. Copies can be furnished on request to persons within the United States.

TM No.	Title and Date
106	Laboratory Study of Breaking Wave Forces on Piles, August 1958
107	Behavior of Beach Fill and Borrow Area at Harrison County, Mississippi, August 1958
108	Surf Statistics for the Coasts of the United States, November 1958
109	Laboratory Data on Wave Run-up on Roughened and Permeable Slopes, March 1959
110	Beaches Near San Francisco, California 1956-1957, April 1959
111	Large-Scale Tests of Wave Forces on Piling (Preliminary Report), May 1959
112	The Propagation of Tidal Waves into Channels of Gradually Varying Cross-Section, May 1959
113	Behavior of Beach Fill at Virginia Beach, Virginia, June 1959
114	Laboratory Study of the Effect of Groins on the Rate of Littoral Transport; Equipment Development and Initial Tests, June 1959
115	Suspended Sediment Sampling in Laboratory Wave Action, June 1959

Material covered by the above Technical Memoranda is briefly described in the foregoing paragraphs (I to VIII) on Research Progress, except for Technical Memorandum No. 106. That report was prepared at the Wave Research Laboratory of the Institute of Engineering Research at the University of California as a result of work partially sponsored by the National Science Foundation. Because of its applicability to the research and investigation program of the Beach Erosion Board, the report was published in the Board's technical memoranda series. It presents the results of model studies performed to investigate forces of breaking waves on piles located on a sloping beach. A suitable dynamometer developed for these tests is described in the report.

BEACH EROSION STUDIES

Beach erosion control studies of specific localities are usually made by the Corps of Engineers in cooperation with appropriate agencies of the various States by authority of Section 2 of the River and Harbor Act approved 3 July 1930. By executive ruling the costs of these studies are divided equally between the United States and the cooperating agencies. Information concerning the initiation of a cooperative study may be obtained from any District or Division Engineer of the Corps of Engineers. After a report on a cooperative study has been transmitted to Congress, a summary thereof is included in the next issue of this Bulletin. Summaries of reports transmitted to Congress since the last issue of the Bulletin and lists of completed and authorized cooperative studies follow.

SUMMARIES OF REPORTS TRANSMITTED TO CONGRESS

SOUTH KINGSTOWN AND WESTERLY, RHODE ISLAND

The purpose of the investigation was to determine the most suitable method of restoring and stabilizing the shores of Matunuck Beach in South Kingstown and Misquamicut Beach in Westerly, Rhode Island. The study areas comprise the Block Island Sound shores of Rhode Island at Matunuck in South Kingstown and from Weekapaug Inlet to Watch Hill in Westerly. The shore frontage studied has a length of about 1.3 miles at Matunuck and about 5 miles in Westerly. The shores in South Kingstown and Westerly are developed for summer residential use. The permanent population of South Kingstown and Westerly are respectively about 10,000 and 12,000. These populations are about doubled in the summer. The shore of the problem area at Matunuck Beach, about 3,830 feet long, is owned by the State of Rhode Island, and the town of Westerly proposed to acquire a stretch of shore about 3,250 feet long at Misquamicut Beach. Block Island Sound is a relatively open tidal arm of the Atlantic Ocean. Tides are semi-diurnal, the mean range decreasing from 3.1 feet at Point Judith to 2.5 feet at Watch Hill, the west limit of the study area. The spring ranges are respectively 3.9 and 3.1 feet. The maximum tide of record was about 12 feet above mean sea level. Tides 2.5 feet or more above mean high water occur about once a year. Ocean swells entering Block Island Sound affect the shores of the study areas. The waves having greatest energy are those from the southeast quadrant. The shore at Matunuck Beach is sheltered from those waves by the breakwaters of Point Judith Harbor with the result that waves from the southwest quadrant cause an eastward predominance of littoral drift and accretion west of the west breakwater. Minor accretion in the westerly portion of the Weekapaug Inlet-Watch Hill reach indicates a slight net westward littoral drift in that area. The south shore of Rhode Island is characterized by headlands of unconsolidated glacial material with minor rocky outcrops. Wave-built barrier beaches have formed but the headlands which formerly supplied material to the intervening beaches are now generally eroded and protected by structures or consist principally of heavy materials remaining as a result of the erosion, and consequently the beaches have in general slowly deteriorated. The restoration and stabilization of adequate beaches may be accomplished by artificial placement of sand. The rate of loss of fill could be reduced by groins at Matunuck Beach, but groins would not be justified at Misquamicut Beach where the rate of loss has been low.

The Division Engineer and the Beach Erosion Board developed plans for restoring and stabilizing the shores of the problem areas, and made economic analyses of these plans. They found that plans for beach widening, groins and sand fences for Matunuck Beach and for beach widening and sand fences for Misquamicut Beach are justified by evaluated benefits. They recommended that projects be adopted by the United States authorizing Federal participation by the contribution of Federal funds in amount of one-third of the first costs of measures for the restoration and stabilization of the shores at Matunuck Beach and Misquamicut Beach, Rhode Island, substantially in accordance with the following plans of the Division Engineer, with such modifications thereof as may be considered advisable by the Chief of Engineers.

a. Matunuck Beach. Widening approximately 3,830 feet of beach generally to a 150-foot width by direct placement of suitable sand fill, construction of eight groins each about 260 feet long, and installation of sand fences, the construction of groins to be deferred pending demonstration of need except for the most easterly groin and that near the middle of the shore frontage;

b. Misquamicut Beach. Widening approximately 3,250 feet of beach generally to a 150-foot width by direct placement of suitable sand fill, and installation of sand fences.

They further recommended authorization of Federal participation to the extent of one-third of periodic nourishment costs at Misquamicut Beach for a period of 10 years from the year of completion of the initial placement of beach fill. The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

BARNEGAT INLET TO CAPE MAY CANAL, NEW JERSEY

The purposes of the investigation were to develop a comprehensive and unified plan to restore adequate protective beaches and provide recreational beaches adequate for prospective beach use, and to formulate a program for providing continued stability to the shores within the study area. The study area comprises the Atlantic Ocean shore of New Jersey from Barnegat Inlet to the Delaware Bay entrance of the Cape May Canal, a length of about 82 miles. The principal communities along this shore are Atlantic City, Ocean City, Sea Isle City, Wildwood and Cape May. The estimated permanent population (1955) of the communities within the study area is about 113,000. The estimated summer population is about 700,000. The tributary area from which visitors are principally drawn comprises New Jersey and portions of New York, Pennsylvania and Delaware with a total population of about 17,000,000. However, visitors come from all States of the Union. About two-thirds of the shore frontage is publicly owned. From Barnegat Inlet to Cape May the coastal area consists of barrier beach islands. From Cape May to the Delaware Bay entrance of the Cape May Canal the coastal plain extends to the shore. The barrier beach is broken by many inlets. From Barnegat Inlet southward there are the large inlet with two channels known as Beach Haven Inlet and Little Egg Inlet, thence Brigantine, Absecon, Great Egg Harbor, Corson, Townsend, Hereford and Cold Spring Inlets. The principal shore erosion problems are associated with irregularity of transport of littoral drift southward past the inlets.

The erosion problems at Atlantic City, Ocean City and Cape May had previously been studied by the Corps of Engineers, resulting in authorization of Federal projects as follows:

a. Atlantic City (House Doc. No. 538, 81st Congress). Artificial placement of fill to widen the ocean and inlet beaches, groins on the ocean and inlet shores, a jetty on Brigantine Island, extension of the Oriental Avenue jetty, revetment and a steel bulkhead on the inlet shore. Under this project, fill has been placed, the Brigantine jetty has been partially built, groins, revetment and the bulkhead have been constructed.

b. Ocean City (House Doc. No. 184, 83d Congress). Artificial placement of fill to widen the beach and groin extensions. Under this project the beach widening has been partially completed and the groins at 5th and 9th Streets have been extended.

c. Cape May (Cold Spring Inlet - House Doc. No. 206, 83d Congress). Artificial placement of fill to widen the beach and to provide a feeder beach, and groin construction and extension of existing groins. Part of the groin construction and extension under the project has been completed.

Tides in the area are semi- diurnal, the mean range being about 4 feet. The spring range is about 5 feet. The maximum tide of record at Atlantic City, 7.6 feet above mean sea level (9.5 feet above mean low water), occurred during the hurricane of September 1944. The shore of the study area is exposed to ocean waves from the northeast, east and southeast, those with the greatest energy approaching from east-northeast. As a result the predominant direction of littoral drift is southward.

The District and Division Engineers developed plans for protecting and stabilizing the shores of the study area, and made economic analyses of the proposed protective and improvement measures. They found that the plans of protection and improvement for Barnegat Light, Long Beach Island, Ventnor, Margate and Longport, Ocean City, Stone Harbor, North Wildwood and Cape May City are justified by evaluated benefits, and recommended adoption of a project authorizing Federal participation, subject to certain conditions, in the costs of measures for restoration and subsequent periodic nourishment of specified portions of these shores, in accordance with the provisions of Public Law 826, 84th Congress.

The Beach Erosion Board concluded that plans developed by the District Engineer for each present problem area constituted the extent of improvement which warranted consideration at the time. While the works recommended were considered as a step toward a "comprehensive and unified plan" such as was desired at the inception of this study, they were not considered as meeting the objective fully. The Board stated that comprehensive treatment would require stabilization of the inlets with provision for sand bypassing at a cost which does not appear to be justified at this time for the entire area. The Board concurred in the recommendation that the present study be supplemented by an investigation to develop measures to meet the long-term needs of the area.

The Beach Erosion Board recommended that projects be adopted by the United States authorizing Federal participation in the costs of the following plans of restoration and protection, substantially as proposed by the District Engineer:

a. Barnegat Light. Constructing 180 feet of stone revetment and 90 feet of timber bulkhead, reconstructing and extending one stone groin, constructing two new timber groins, and widening 1,200 feet of beach by artificial placement of suitable sand (the beach fill to be deferred pending demonstration of need), and periodic nourishment by placement of suitable sand on the restored beach as necessary.

b. Long Beach Island. Widening 3,500 feet of beach at Ship Bottom, 6,900 feet at Brant Beach and 3,000 feet at Beach Haven by artificial placement of suitable sand to provide a berm width of 50 feet at an elevation of 10 feet above mean low water, construction of four groins in Long Beach Township, and periodic nourishment by placement of suitable sand on the beach at appropriate locations.

c. Ventnor, Margate and Longport. Widening 5,500 feet of beach at Longport by artificial placement of suitable sand to provide a berm width of 50 feet at an elevation of 10 feet above mean low water and periodic nourishment by placement of suitable sand on the beach at appropriate locations.

d. Stone Harbor. Widening 8,400 feet of beach by artificial placement of suitable sand to provide a berm width of 50 feet at an elevation of 10 feet above mean low water and periodic nourishment by placement of suitable sand on the beach at appropriate locations.

e. North Wildwood. Widening 2,700 feet of beach by artificial placement of suitable sand to provide a berm width of 50 feet at an elevation of 10 feet above mean low water and periodic nourishment by placement of suitable sand on the beach.

The Board also recommended Federal aid in periodic nourishment of the foregoing localities for a period of 10 years from the year of substantial completion of the initial beach fill.

The Board further recommended that in lieu of remaining work on the existing projects for Ocean City and Cape May City (Cold Spring Inlet) modified projects be adopted authorizing Federal participation in the following plans of restoration and protection:

a. Ocean City. Artificial placement of suitable sand to provide a beach 300 feet wide between the boardwalk or bulkhead and the mean high water line and 10,100 feet in length between the Atlantic Avenue groin and 15th Street, extension of seven existing groins, and periodic nourishment by placement of suitable sand on the restored beach as necessary.

b. Cape May City. Artificial placement of suitable sand to create a beach 100 to 200 feet wide above mean high water and 12,700 feet in length between Wilmington Avenue and a point 3,300 feet west of Windsor Avenue, artificial placement of approximately 300,000 cubic yards of suitable sand on the adjoining shore to the east, construction of three new timber groins and extension of two existing stone groins with the groin construction to be deferred pending demonstration of need, and periodic nourishment by placement of suitable sand on the restored beach as necessary.

The Board also recommended authorization of Federal participation in the costs of the remaining work under the projects in accordance with the provisions of Public Law 826, 84th Congress, including Federal aid in the costs of periodic nourishment of the restored beaches for a period of 10 years from the year of substantial completion of the initial fill. The Chief of Engineers concurred in the views and recommendations of the Beach Erosion Board.

COMPLETED COOPERATIVE BEACH EROSION STUDIES

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	PUBLISHED IN CONG.	FEDERAL PROJECTS RECOMMENDATION	FEDERAL PROJECTS AUTHORIZED BY CONGRESS
	ALABAMA				
Perdido Pass (Alabama Pt.)	18 Jun 54	274	84	Unfav.	
	CALIFORNIA				
Santa Barbara - Initial	15 Jan 38	552	75	Unfav.	
Suppl.	18 Feb 42				
Final	22 May 47	761	80	Unfav.	
Ballona Creek & San Gabriel R. (Partial)	11 May 38			Unfav.	
Orange County	10 Jan 40	637	76	Unfav.	
Coronado Beach	4 Apr 41	636	77	Unfav.	
Long Beach	3 Apr 42			Unfav.	
Mission Beach	4 Nov 42			Unfav.	
Pt. Mugu to San Pedro BW	27 Jun 51	277	83	Fav.	3 Sep 54
Carpinteria to Pt. Mugu	4 Oct 51	29	83	Fav.	3 Sep 54
Oceanside, Ocean Beach, Imperial Beach & Coronado, San Diego County	26 Jul 55	399	84	Fav.	3 Jul 58
Santa Cruz County	13 Sep 56	179	85	Fav.	3 Jul 58
Humboldt Bay (Buhne Pt.)	29 Mar 57	282	85	Fav.	3 Jul 58
	CONNECTICUT				
Compo Beach, Westport	18 Apr 35	239	74	Unfav.	
Hawk's Nest Beach, Old Lyme	21 Jun 39			Unfav.	
Ash Crk. to Saugatuck R.	29 Apr 49	454	81	Fav.	17 May 50
Hammonasset R. to East R.	29 Apr 49	474	81	Fav.	3 Sep 54
New Haven Hbr. to Housatonic R.	29 Jun 51	203	83	Fav.	3 Sep 54
Conn. R. to Hammonasset R.	28 Dec 51	514	82	Unfav.	
Pawcatuck R. to Thames R.	31 Mar 52	31	83	Unfav.	
Niantic Bay to Conn. R.	11 Jul 52	84	83	Unfav.	
Housatonic R. to Ash Creek	12 Mar 53	248	83	Fav.	3 Sep 54
East R. to New Haven Hbr.	15 Nov 55	395	84	Fav.	3 Jul 58
Saugatuck R. to Byram R.	14 Nov 56	174	85	Fav.	3 Jul 58
Thames R. to Niantic Bay	17 Jun 57	334	85	Unfav.	

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	PUBLISHED IN CONG.	FEDERAL PROJECTS RECOMMEN-DATION	FEDERAL PROJECTS AUTHORIZED BY CONGRESS
	DELAWARE				
Kitts Hummock to Fenwick Is.	11 Feb 57	216	85	Fav.	3 Jul 58
	FLORIDA				
Blind Pass (Boca Ciega)	1 Feb 37	187	75	Unfav.	
Miami Beach	1 Feb 37	169	75	Unfav.	
Hollywood Beach	28 Apr 37	253	75	Unfav.	
Daytona Beach	15 Mar 38	571	75	Unfav.	
Bakers Haulover Inlet	21 May 45	527	79	Unfav.	
Anna Maria & Longboat Keys	12 Feb 47	760	80	Unfav.	
Jupiter Island	13 Feb 47	765	80	Unfav.	
Palm Beach(1)	13 Feb 47	772	80	Fav.	17 May 50
Pinellas County	22 Apr 53	380	83	Fav.	3 Sep 54
Palm Beach County (Lk. Worth Inlet to S. Lake Worth I.)	12 Jul 57	342	85	Fav.	3 Jul 58
Key West	10 Mar 58	413	85	Fav.	
	GEORGIA				
St. Simon Island	18 Mar 40	820	76	Unfav.	
	HAWAII				
Waikiki Beach	5 Aug 52	227	83	Fav.	3 Sep 54
Waimea & Hanapepe Bay, Kauai	17 Jan 56	432	84	Fav.	3 Jul 58
	ILLINOIS				
State of Illinois	8 Jun 50	28	83	Fav.	3 Sep 54

(1) A cooperative study of experimental steel sheet pile groins was also made, under which methods of improvement were recommended in an interim report dated 19 Sep 1940. Final report on experimental groins was published in 1948 as Technical Memo. No. 10 of the Beach Erosion Board.

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	PUBLISHED IN CONG.	FEDERAL PROJECTS RECOMMENDATION	FEDERAL PROJECTS AUTHORIZED BY CONGRESS
	LOUISIANA				
Grand Isle	28 Jul 36	92	75	Unfav.	
Grand Isle	28 Jun 54	132	84	Unfav.	
	MAINE				
Old Orchard Beach	20 Sep 35			Unfav.	
Saco	2 Mar 56	32	85	Unfav.	
	MASSACHUSETTS				
South Shore of Cape Cod (Pt. Gammon to Chatham)	26 Aug 41			Unfav.	
Salisbury Beach	26 Aug 41			Unfav.	
Winthrop Beach	12 Sep 47	764	80	Fav.	17 May 50
Lynn-Nahant Beach	20 Jan 50	134	82	Fav.	3 Sep 54
Revere Beach	12 Jan 50	146	82	Fav.	3 Sep 54
Nantasket Beach	12 Jan 50			Unfav.	
Quincy Shore	2 May 50	145	82	Fav.	3 Sep 54
Plum Island	18 Nov 52	243	83	Unfav.	
Chatham	22 Oct 56	167	85	Unfav.	
Pemberton Pt. to Cape Cod Canal	13 Jan 59			Fav.	
Wessagusssett Beach, Weymouth	6 Jul 59			Fav.	
	MICHIGAN				
Berrien County (St. Joseph)	17 Jun 57	336	85	Fav.	3 Jul 58
	MISSISSIPPI				
Hancock County	3 Apr 42			Unfav.	
Harrison County - Initial	15 Mar 44				
Harrison County - Suppl.	16 Feb 48	682	80	Fav.	30 Jun 48

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	CONG.	FEDERAL PROJECTS RECOMMENDATION	AUTHORIZED BY CONGRESS
	NEW HAMPSHIRE				
Hampton Beach	15 Jul 32			Unfav.	
Hampton Beach	14 Sep 53	325	83	Fav.	3 Sep 54
	NEW JERSEY				
Manasquan Inlet & Adjacent Beaches	15 May 36	71	75	Unfav.	
Atlantic City	11 Jul 49	538	81	Fav.	3 Sep 54
Ocean City	15 Apr 52	184	83	Fav.	3 Sep 54
Sandy Hook to Barnegat Inlet	24 Mar 54	361	84	Fav.	
Review Report - Sandy Hook to Barnegat Inlet	6 May 57	332	85	Fav.	3 Jul 58
Barnegat Inlet to Delaware Bay Entrance to Cape May Canal	22 Sep 58			Fav.	
	NEW YORK				
Jacob Riis Park, Long Island	16 Dec 35	397	74	Unfav.	
Orchard Beach, Pelham Bay, Bronx	30 Aug 37	450	75	Unfav.	
Niagara County	27 Jun 42	271	78	Unfav.	
South Shore of Long Island	6 Aug 46			Unfav.	
Selkirk Shores State Park	21 Oct 53	343	83	Fav.	3 Sep 54
Fair Haven Beach State Park	18 Jun 54	134	84	Fav.	3 Jul 58
Hamlin Beach State Park	20 Sep 54	138	84	Fav.	3 Jul 58
Braddock Bay State Park	15 Apr 55			Unfav.	
Fire Island Inlet to Jones Inlet	10 Feb 56	411	84	Fav.	3 Jul 58
Fire Island Inlet to Montauk Pt. (combined coop. BEC & Hurr.)	30 Jun 59			Fav.	
	NORTH CAROLINA				
Fort Fisher	10 Nov 31	204	72	Unfav.	
Wrightsville Beach	2 Jan 34	218	73	Unfav.	
Kitty Hawk, Nags Head & Oregon Inlet	1 Mar 35	155	74	Unfav.	
State of North Carolina	22 May 47	763	80	Unfav.	

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	CONG.	FEDERAL RECOMMEN-DATION	PROJECTS AUTHORIZED BY CONGRESS
	OHIO				
Erie County - Vic. of Huron	26 Aug 41	220	79	Unfav.	
Michigan Line to Marblehead	30 Oct 44	177	79	Unfav.	
Cities of Cleveland & Lakewood	22 Mar 48	502	81	Fav.	3 Sep 54
Chagrin River to Fairport	22 Nov 49	596	81	Unfav.	
Vermilion to Sheffield Lake Village	24 Jul 50	229	83	Fav.	3 Sep 54
Fairport to Ashtabula	1 Aug 51	351	82	Unfav.	
Ashtabula to Penna.St.Line	1 Aug 51	350	82	Unfav.	
Sandusky to Vermilion	7 Jul 52	32	83	Unfav.	
Sandusky Bay	31 Oct 52	126	83	Unfav.	
Sheffield Lake V. to Rocky R.	31 Oct 52	127	83	Unfav.	
Euclid to Chagrin Rivér	25 Jun 53	324	83	Unfav.	
	PENNSYLVANIA				
Presque Isle Peninsula, Erie					
(Interim)	3 Apr 42				
(Final)	23 Apr 52	231	83	Fav.	3 Sep 54
	PUERTO RICO				
Punta Las Marias, San Juan	5 Aug 47	769	80	Unfav.	
	RHODE ISLAND				
South Shore (Towns of Narragansett, South Kingstown, Charles-town & Westerly)	4 Dec 48	490	81	Fav.	3 Sep 54
South Kingstown & Westerly	27 Jan 58	30	86	Fav.	
	SOUTH CAROLINA				
Folly Beach	31 Jan 35	156	74	Unfav.	
Pawleys Is., Edisto Beach & Hunting Island	24 Jul 51			Unfav.	

LOCATION	BEB REPORT COMPLETED	PUBLISHED IN H. DOC.	CONG.	FEDERAL PROJECTS RECOMMENDATION	AUTHORIZED BY CONGRESS
	TEXAS				
Galveston (Gulf Shore)	10 May 34	400	73	Unfav.	
Galveston Bay, Harris County	31 Jul 34	74	74	Unfav.	
Galveston (Gulf Shore)	5 Feb 53	218	83	Unfav.	
Galveston (Bay Shore)	19 Jun 53	346	83	Unfav.	
Bolivar Peninsula (Gulf Shore & Rollover Fish Pass)	8 Jun 59			Unfav.	
	VIRGINIA				
Willoughby Spit, Norfolk	20 Nov 37	482	75	Unfav.	
Colonial Beach, Potomac R.	24 Jan 49	333	81	Fav.	17 May 50
Virginia Beach	25 Jun 52	186	83	Fav.	3 Sep 54
	WISCONSIN				
Milwaukee County	21 May 45	526	79	Unfav.	
Racine County	5 Mar 52	88	83	Unfav.	
Kenosha	16 Sep 54	273	84	Unfav.	
Manitowoc County	15 Apr 55	348	84	Fav.	3 Jul 58

CURRENTLY AUTHORIZED COOPERATIVE BEACH EROSION STUDIES

CALIFORNIA

STATE OF CALIFORNIA. Cooperating Agency: Department of Public Works, Division of Water Resources, State of California.

Problem: To conduct a study of the problems of beach erosion and shore protection along the entire coast of California. The current studies cover the Orange County and San Diego County areas, Pt. Delgada to Pt. Ano Nuevo, and a review for the entire area from Point Conception to the Mexican Boundary.

FLORIDA

PALM BEACH COUNTY. Cooperating Agency: Board of County Commissioners, Palm Beach County.

Problem: To develop the most economical means of restoring the beaches along the Atlantic Ocean shore of Palm Beach County to a satisfactory condition and protecting the restored beaches and shore property from future erosion. The current study covers the area north of Lake Worth Inlet and south of South Lake Worth Inlet.

FERNANDINA BEACH (AMELIA IS.). Cooperating Agency: City of Fernandina Beach.

Problem: To determine the best method for restoring and retaining an adequate beach for recreation and protection of oceanfront properties and improvements.

VIRGINIA AND BISCAYNE KEYS. Cooperating Agency: City of Miami.

Problem: To determine the best method of preventing further erosion and maintaining such sand as now exists along the City and County-owned frontages on the easterly side of Virginia and Biscayne Keys.

LOUISIANA

BELLE PASS TO RACCOON POINT. Cooperating Agency: Department of Public Works, State of Louisiana.

Problem: To determine the best methods of stabilization and future protection of the Gulf shore along the section of the southeastern Louisiana coast between Belle Pass and Raccoon Point, including the chain of islands, East Timbalier, Timbalier, Wine and Isles Derniere.

MAINE

HILLS BEACH, BIDDEFORD. Cooperating Agency: City of Biddeford.

Problem: To determine the best method of restoration of protective and recreational beaches and protection of shore property.

MASSACHUSETTS

CAPE COD CANAL TO PROVINCETOWN. Cooperating Agency: Department of Public Works.

Problem: To determine the most suitable methods of shore protection, prevention of further erosion and improvement of beaches. Current study covers the shore from Cape Cod Canal to Provincetown in Cape Cod Bay where detailed study is desired for problems at Town Beach, Spring Hill Beach, East of Sesuit Harbor, Brewster Bluffs, Griffin Island, Pilgrim Beach, and shore immediately south of Hatches Harbor.

NEW BEDFORD. Cooperating Agency: City of New Bedford.

Problem: To determine the best method of restoring and stabilizing the public beaches to protect the boulevard and provide public bathing area.

FALMOUTH. Cooperating Agency: Division of Waterways, Massachusetts Department of Public Works.

Problem: To determine the best method of restoring and stabilizing beaches and stabilizing bluff areas along the shore of the town between Nobska Point and the east town line.

ROCKPORT. Cooperating Agency: Division of Waterways, Massachusetts Department of Public Works.

Problem: To determine the best method of restoring the beach and protecting the beach and cottage development.

SALISBURY BEACH. Cooperating Agency: Division of Waterways, Massachusetts Department of Public Works.

Problem: To determine the best method of restoring and protecting the beach and protecting the beach development.

NEW HAMPSHIRE

ATLANTIC OCEAN SHORE. Cooperating Agency: New Hampshire Department of Public Works and Highways.

Problem: To develop plans for stabilization and restoration of adequate recreational and protective beaches and for protection of bluffs or headlands, and to determine amount of Federal participation warranted for nourishment of beach fill under the authorized Federal project at Hampton Beach.

NEW JERSEY

STATE OF NEW JERSEY. Cooperating Agency: Department of Conservation and Economic Development.

Problem: To determine the best method of preventing further erosion and stabilizing and restoring the beaches, to recommend remedial measures, and to formulate a comprehensive plan for beach preservation or coastal protection. Current studies cover the shore from Cape May Canal to Maurice River in Delaware Bay, and from South Amboy to Shrewsbury River in Raritan and Sandy Hook Bays.

ATLANTIC CITY. Cooperating Agency: City of Atlantic City.

Problem: To determine the effect of Public Law 826, 84th Congress on the existing authorized project for beach erosion control.

NEW YORK

ATLANTIC COAST OF LONG ISLAND BETWEEN JONES INLET AND NORTON POINT, AND STATEN ISLAND. Cooperating Agency: Long Island State Park Commission.

Problem: To determine the best method of restoring adequate recreational and protective beaches and providing continued stability to the shores of Nassau County between Jones Inlet and East Rockaway Inlet, the shores of New York City between East Rockaway Inlet and Norton Point, and the shores of Staten Island between Fort Wadsworth and Arthur Kill.

NORTH CAROLINA

CAROLINA BEACH. Cooperating Agency: Town of Carolina Beach.

Problem: To determine the best method of preventing erosion of the beach.

OCRACOKE ISLAND. Cooperating Agency: Department of Conservation and Development, State of North Carolina.

Problem: To determine the best method of protecting the ocean and Pamlico Sound shores of the island against erosion by waves and currents, and providing protection to State highway and other property.

FORT MACON - ATLANTIC BEACH. Cooperating Agency: Department of Conservation and Development, State of North Carolina.

Problem: To develop permanent solutions to halt erosion and protect resort improvements at Atlantic Beach and protect park facilities and historic Fort Macon.

OHIO

MICHIGAN LINE TO MARBLEHEAD. Cooperating Agency: Division of Shore Erosion, Department of Natural Resources, State of Ohio.

Problem: To determine the best method of protecting the shores of the study area, including typical methods of protection for publicly and privately owned shores, especially to determine whether any changes should be made in recommendations contained in H.D. No. 177, 79th Congress in view of changed conditions and additional data; and to develop specific plans of restoration and protection of the shores of Metzgar Marsh, Crane Creek State Park and East Harbor State Park, and general plans for the protection of privately owned property.

SHEFFIELD LAKE VILLAGE. Cooperating Agency: Division of Shore Erosion, Ohio Department of Natural Resources.

Problem: To determine the best method of restoring and improving the beach fronting Sheffield Lake Community Park to provide a public bathing beach and to protect the upland property against erosion.

PENNSYLVANIA

PRESQUE ISLE. Cooperating Agency: Department of Forests and Waters, Commonwealth of Pennsylvania.

Problem: To determine rates of loss and movement of sand fill, the nourishment requirements of the existing shore protection project and its eligibility for Federal participation in the cost of periodic beach nourishment in accordance with provisions of Public Law 826, 84th Congress.

PUERTO RICO

PT. SALINAS TO PT. VACIA TALEGA (SAN JUAN). Cooperating Agency: Department of Public Works, Commonwealth of Puerto Rico.

Problem: To determine most practical and economical method of preventing further erosion of the shore and stabilizing or restoring the beach, especially aimed to protect existing upland properties and future recreational, industrial or residential development areas.

VIRGINIA

VIRGINIA BEACH. Cooperating Agency: Virginia Beach Erosion Commission.

Problem: To determine to what extent assistance from the Federal Government may be extended under the provisions of Public Law 826, 84th Congress, in carrying out the periodic nourishment program of the existing beach restoration project at Virginia Beach.