The Preservation of Sandy Beaches*

Studies Made in the Vicinity of New York

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THE object of this paper is to set before the Society the results of the writer's study of the effect of wave action on the sandy beaches skirting the south shore of Long Island and the New Jersey shore north of Asbury Park, to call attention to the means by which improved beach property may be protected, and to emphasize the damage that must inevitably result to the beaches as a whole if the erection of structures that interfere with littoral drift is allowed to continue.

The paper treats of such subjects, only, as are considered of primary importance in the particular locality under consideration. It is subdivided into sections, and the contents and conclusions are described by sections:

Tidal Currents and Ocean Currents.—These currents are of no effect except in the vicinity of inlets, and receive only brief mention.

Waves.—The behavior of deep-sea and shallow-water waves prior to the plunge receives a brief mention. The phenomena accompanying the plunge, the up-rush and the back-wash of the wave, and the phenomena accompanying the undertow are discussed and illustrated in some detail.

The Origin of Beach Sand and Gravel.—A brief discussion is given, and the conclusion is reached that the principal source of such material is not the grinding up of cliffs, etc., but the sorting out of particular sizes from the soil formed by the decomposition of the primary rocks.

Typical Beach Forms.—Typical beach forms are discussed and illustrated, particular emphasis being placed on the distinction between the temporary berms and the more permanent dunes, etc.

Constructive and Destructive Power of Waves.—The transporting power of the up-rush, back-wash, and undertow are discussed. The conclusions are arrived at that wave action always causes a transfer of material from the beaches to deep water, that in the normal case berms are constructed during stormy weather and eroded by undermining during quiet weather.

Littoral Drift, and Jetties and Groins.—Littoral drift is described, and the effect thereon of inlets, jetties, and groins is discussed. The conclusions are reached that, for beaches such as those under consideration, inlets, jetties, and groins interfere with littoral drift and increase the quantity of material permanently lost to the beaches.

Bulkheads.—The proper functions of bulkheads and sea walls, their proper location with respect to the berms, and the absence of extensive erosion due to back-wash, are discussed. The conclusions are reached that such structures, when their strength is commensurate with their exposure, will afford a real protection to lands in their rear, that their existence will not prevent the formation of berms when other conditions are favorable, that if not placed too far seaward they will not interfere with littoral drift, and that when used to extend the uplands beyond their natural limits such structures may cause a serious loss to the beaches to their leeward.

The increasing value of ocean beach property has led many investors to build nearer and nearer the shore line, relying on the erection of shore-protection works to guard their investments against damage from the sea. Under-estimates of the forces to be resisted and over-estimates of the efficacy of certain types of shore-protection works have resulted in extensive property losses in the immediate vicinity of New York City. In view of the importance of such beach colonies as Coney Island, the Rockaways, and Long Beach, on the south shore of Long Island, and in view of the existence of similar colonies extending in a nearly continuous line along the New Jersey coast from Seabright to beyond Asbury Park, the writer has been tempted to prepare this paper, setting forth such of the general principles of beach formation and erosion as apply to these localities.

The first time he was required to report on plans for the protection of a portion of one of these beaches, he advocated the erection of a system of groins. The direction of the littoral drift was well established, and, in the literature on the subject, no doubt was expressed as to the efficacy of such structures "when properly designed." The case in point appeared to be so simple

that the writer had no doubt as to his ability to design the structures properly.

Subsequently, the writer spent much of his time for two summers walking the beaches around New York City. Occasional beach trips were made during the

FIG. 1.—As a deep-water wave passes, each particle of water moves in a circular orbit; the radii of the orbits decrease with increased depth below the surface; when the wave has passed, each particle is left in its original position.

FIG. 2.—In a shallow-water wave, the orbits of the various particles of water are ellipses; the focal length of all orbits is a constant, $A B$; near the bottom the orbits approach a straight line as a limit; the velocities accompanying the forward and backward swings are equal.

FIG. 3.—When the plunge occurs, orbital motion ceases, and a boiling mass of water rushes up the beach; when the kinetic energy has been entirely dissipated, or transformed, the back-wash begins, and the water flows down the slope in a smooth sheet; the transporting power of the up-rush on the up grade must, for equilibrium, be equal to the transporting power of the back-wash on the down grade.

FIG. 4.—Near the shore, as a result of the undertow, the closed orbits are replaced by spirals; near the surface, there is a progressive landward movement, and near the bottom there is a seaward movement.

FIG. 5.—Beach at San Juan, Porto Rico, September 19th, 1915. The coconut grove stands on semi-permanent sand dunes; berm A represents the remains of a much wider berm built up during the preceding winter and eroded back to the scarp during the summer; berm B was formed during a storm, about September 15th, 1915.

winter, and certain beaches around San Juan, Porto Rico, with which the writer was familiar, were revisited during the summers of 1914 and 1915. At the same time the literature on the subject was quite thoroughly examined. Memoranda made during these visits

furnished the foundation of observed facts on which the discussion herein presented has been based.

There are certain general principles of wave and current action that apply to all beaches, but in one instance the controlling force may be very different from that in another. An effort will be made to state quite fully the principles in regard to the major forces at work on the sandy beaches around the entrance to New York Harbor. Some of the forces emphasized in this paper may be of little or no importance in some other particular locality; and phenomena which, in that other locality, may be of controlling importance may be entirely ignored in this paper. As an illustration, it may be stated that the problem of shore protection at the foot of the caving bluffs along the north shore of Long Island is totally different from that to be faced along the sandy beaches of the south shore; the latter is discussed in this paper.

TIDAL CURRENTS.

On an open coast, far away from any inlet, there is a semi-daily landward and a semi-daily seaward current. If the tide is rising at the rate of 1 foot per hour, and if the mean depth is 1 foot at a point 3,600 feet off shore, there will be a shoreward current at that point having a mean velocity of 1 foot per second. As the slope of the foreshore, in the locality under consideration, is much greater than 1 in 3,600, the subject of currents due to the flood and ebb tides may be dismissed except in the vicinity of inlets.

OCEAN CURRENTS.

The Gulf Stream directly east of the mouth of Chesapeake Bay has a surface velocity of about $2\frac{1}{2}$ feet per second. If a steady current of equal velocity flowed along the New Jersey coast, in shallow water, with a loose sandy bottom, we might expect to find sand waves, deep pools, and shallow bars, all subject to frequent changes in position. Such conditions do not exist along the shores under consideration, and, so far as this paper is concerned, no discussion of ocean currents is necessary.

Wave action is an important factor in the construction or destruction of ocean beaches. A few of the general principles will be given here, and the reader may consult the various works on the subject if further information is desired. The writer has followed the paper "Wave Action in Relation to Engineering Structures."¹

The form of a wave is normally that of a common or prolate cycloid. If we assume several filaments of water, parallel to the direction of travel of the wave, and at certain selected distances below the surface of the water, we shall find that there is no tendency of these filaments to cross as the wave passes by. The passage of a wave does not mix the surface water with the deeper water, or *vice versa*.

In deep water each particle of water coming within the influence of a wave moves in a circular orbit. (Fig. 1.) The orbital velocity is uniform, and in the upper half of the orbit the motion is in the direction of wave travel. When the wave has passed, each particle is left in the position it occupied before the wave arrived. The radii of the orbits decrease with increases of depth below the surface.

In shallow water (Fig. 2) the orbits are elliptical in form. The semi-axes of the orbits decrease with increases in depth below the surface, but the focal distance of all orbits is constant. The horizontal or major semi-axis approaches one half of the focal distance as a limit. The vertical or minor semi-axis approaches zero as a limit. A particle of water very near the bottom moves in what is, to all intents and purposes, a straight line. It is important to note the orbital velocity of such particles.

If a circle is described, concentric with the elliptical orbit, and with a diameter equal to the major axis of the orbit; if a point moves along the circumference of the cycle with a uniform velocity, such that the time required to complete the circle is the same as that required by the particle of water to complete its orbit, then the orbital velocity of the particle of water will be such that it will at all times lie vertically above or below the point on the circumference of the circle.

The orbital velocity of the particle of water is at a maximum as the trough or the crest of the wave passes

¹By the late Col. D. D. Gaillard, Corps of Engineers, U. S. Army, published as *Professional Paper No. 31*, Corps of Engineers, U. S. Army.

*A paper presented before the American Society of Civil Engineers, June 7, 1916, and published in the *Proceedings of the Society*, vol. xlii, p. 625.

over it. As the trough passes, the orbital motion is opposite in direction to the travel of the wave; as the crest passes, the orbital direction is with the wave travel. The velocities in the direction of wave travel and in the opposite direction are equal.

With a moderately sloping foreshore, deep sea waves approaching the beach are diverted in direction. The tendency is to change direction until the travel is perpendicular to the beach. Waves seldom strike the beaches under consideration at an angle of 45 degrees from the perpendicular, or greater.

Assume for the moment that one is observing the effect of a heavy swell following a storm. In deep water a large rounded wave would be seen, its surface section corresponding approximately to the curve of a prolate cycloid; as the water becomes more shallow, the wave rises higher, becomes more pointed, and the section corresponds more closely to that of a common cycloid. When a certain depth is reached, the wave breaks and the upper point falls over, striking the front slope. Depending on the character of the bottom, the magnitude of the wave, etc., this first break may occur in depths exceeding 20 feet.

After the first break, a new wave is formed and travels shoreward until it in turn breaks when it reaches a certain depth. This process continues until water only a few feet in depth is reached, and then the wave breaks for the last time. (Fig. 3.)

This final break is called the plunge, and the point at which it occurs is called the plunge-point.² When the plunge takes place, orbital motion ceases, and a boiling, foaming sheet of water rushes up the beach. This will be referred to as the up-rush. As the wave flows up the beach, the boiling diminishes until a relatively quiet sheet of water has been formed. When the kinetic energy has been entirely wasted, or transformed into potential energy, due to the increase in elevation, the back-wash begins, and the water flows down the slope in a smooth sheet. The velocity during this back-wash constantly increases, and, except for a few feet near the upper margin, the back-wash has, in sand, a considerable transporting power.

On sandy beaches, the height of the wave at the time it reaches the plunge-point is not great. A height of 5 feet is not infrequent, but the writer does not recall having seen breakers as high as 8 feet. The depth of water corresponding to the plunge is seldom more than 3 feet.

An after-effect of the plunge that requires special notice is the undertow. When the back-wash reaches a certain point, normally about the line of the still-water level, a new wave is encountered. The water from the earlier wave must find some escape to sea, and it is a matter of common knowledge that an off-shore current, hugging the bottom, is formed. This current is known as the undertow.

Where the undertow exists, therefore, there must be a new condition of wave action, as shown by Fig. 4. Instead of moving in closed orbits, the particles of water move in spirals. Near the surface there is a progressive movement shoreward, and near the bottom there is a corresponding movement seaward. If, where there is a good surf running, a bather will raise his feet from the bottom and float on the surface, he will almost invariably drift toward the beach. If he is standing on the bottom, the nearly constant pressure of the undertow will frequently outweigh the occasional thrust of the wave and a considerable effort may be necessary to avoid being carried seaward. The undertow normally concentrates into streams of considerable velocity, and in such places the lower spiral of Fig. 4 is replaced by a current of varying velocity, but always flowing seaward.

The foregoing discussion of waves has been somewhat idealized. Waves ordinarily approach the shore from a diagonal direction, and the undertow leaves the beach by a diagonal on the opposite side of the normal. The undertow may concentrate into a stream nearly parallel to the beach and break out to sea at intervals. Such phenomena will be observed by any one making a study of a particular beach, and it will readily be understood that they are modifications of the idealized case.

THE ORIGIN OF BEACH SAND AND GRAVEL.

The grinding away of rocky headlands and the accompanying reduction of ledge rock to gravel and sand is frequently referred to in print. Similarly, the wearing away of boulders as they are carried along by mountain torrents is a constantly recurring theme, attractive to the imagination. If, however, the prosaic engineer will pause for a moment to consider, it will be apparent that these are relatively unimportant sources from which beach sand is derived.

The constant agitation of a gravel beach must in-

evitably wear away the stones and gradually reduce their size. The rounded form of the pebbles is due to this wearing process. Each pebble is constantly reduced in diameter by the conversion of its outer skin into dust, but, by the time any given quantity of gravel

FIG. 6.—The depth of water at the plunge point is indicated by the dimension, x ; the form of the beach before it is attacked by waves plunging at the depth, x , is shown by the full line, and the New Form assumed is shown by the broken line.

Case (a) illustrates the erosion of a beach by waves of less magnitude than those by which the beach was built up. Case (b) illustrates the upbuilding of a berm by heavy waves when the still-water level is at its normal elevation. Case (c) illustrates the readjustment of the beach formed in case (b) when attacked by waves of the same magnitude as those assumed in case (b), but striking the beach at a time when the still-water level is abnormally raised.

FIG. 7.—Littoral drift is mainly due to up-rush, back-wash, and undertow. A particle of sand at B is disturbed by the up-rush to B_1 , by the back-wash to B_2 and by the undertow to B_3 and B_4 .

FIG. 8.—A groin inevitably concentrates the up-rush and the back-wash, and drives the littorally drifting sand into deeper water than would be the case on an unobstructed beach.

FIG. 9.—At Sandy Hook, N. J., the remains of an old berm were seen well up on the face of the sea-wall; back-wash from the sea-wall could not have caused the erosion under way at the time.

can, by the attrition process, be reduced to grains of sand, there will remain only a small percentage of the original volume.

The principal source of sand in America is the verdure-covered mountain, hill, and valley. Wherever rain

falls and vegetation grows the primary rocks are undergoing a process of disintegration. Certain components are carried away in solution, other constituents are transformed into clay, and the quartz crystals remain nearly unchanged. Let some of this decomposed rock, which is called soil, fall into a stream of running water, and the various sizes are quickly sorted out. The clay may be carried to deep water in the ocean without a halt, the finest sand may travel hundreds of miles before it is temporarily deposited, the coarser sand may be deposited within a few miles, and some fragments of rock may be rolled only a few feet during each freshet, and may, in traveling a few miles, be converted into typical rounded pebbles.

The nature of the sand found in most rivers and on most beaches is proof of its origin. It is the friable but insoluble quartz which has survived, and the grains are much more angular in form than pebbles formed by the attrition process. In the immediate vicinity of rocky cliffs, exceptions may be noted, and the writer has seen large areas covered with volcanic sand, but the beaches to which this paper particularly refers are no exceptions to the general rule.

TYPICAL BEACH FORMS.

If all except wave action could be eliminated, the normal form of beach would be a series of berms. Several such berms are sometimes found in the case of gravel beaches. In the case of sand beaches, two berms are often noticeable.

Fig. 5 shows a beach of the general character at San Juan, Porto Rico, as noted on September 19th, 1915. This beach builds up every winter during the stormy season. During the summer or quiet season, it cuts away, the limit of the cutting being indicated by the location of the coconut grove. Berm A, at Elevation +6, was formed during the winter of 1914-15. By September, 1915, the beach had cut away as far as the scarp which, on September 19th, marked the limit of that berm. During a three-day storm about the middle of September, a new berm, B, was built up in front of Berm A, and at a lower level. The high bank on which the coconut grove stands represents a relatively permanent formation; the lower berms are temporary in character.

On September 26th, at a point about one-quarter mile west of that represented by Fig. 5, erosion was under way, and the berm was eroded by the undermining action of waves of less height than those by which it was built. The older and higher berm was formed at the foot of the dunes, which represent relatively permanent formation. Almost identical conditions existed at Long Beach, Long Island, on July 25th, 1915, and at Mattituck, Long Island, where the material was gravel, three berms were formed, but information as to the form of the beach below the low-water line at Mattituck was not as complete as could be desired. In general, there is some depth at which the beach quite suddenly assumes a much flatter slope than it has at and above the level of mean tide. Around New York City, with a mean tidal range of about 4.5 feet, this change appears to come at about the level of mean low water. At San Juan, Porto Rico, where the tidal range is about 1.1 feet, the change of slope is very sharp, and occurs in water from 2 to 3 feet deep. A beach noted by the writer on the Island of St. Thomas was similar to that at San Juan.

CONSTRUCTIVE AND DESTRUCTIVE POWER OF THE WAVES.

Just before the plunge, a wave, by virtue of the orbital velocities of its component parts, possesses a considerable store of energy. After the plunge, this energy is largely dissipated, due to the turbulent flow accompanying the up-rush. To preserve the equilibrium of the beach, the turbulent up-rush must have a sand-carrying capacity on the up-grade equal to that of the back-wash on the down-grade. Shoreward of the plunge-point, the constructive power of the up-rush is greater than the destructive power of the back-wash and undertow. The slope of the beach, taken in connection with the character of the beach material, is an indication of the extent of this difference. It would seem that, seaward of the plunge-point, the destructive agencies are more powerful than the constructive agencies. Referring to Fig. 4, it is seen that, near the bottom, the resultant movement is seaward. Unless the sand can be carried to the top of the wave, there is no force to carry it shoreward. The ultimate effect of wave action, therefore, is a constant transfer of sand from the beach to deeper water in the ocean.

As already stated, there is, in the beaches near New York City, a change in slope near the line of mean low water. Above that line, the slope is the measure of the difference in transporting power, for the particular material under consideration, of the up-rush and the back-wash of the wave. In coarse sand at San Juan and at Seabright, N. J., this slope averages perhaps 1:12; at Long Beach, N. Y., with fine sand, the

²The terms "plunge," "up-rush," and "back-wash" are borrowed from "Coast Erosion and Foreshore Protection," by John S. Owens and Gerald O. Case, Assoc. M. Am. Soc. C. E.

slope is perhaps 1:40. For any locality, this slope is nearly constant, regardless of the magnitude of the waves that have created it and regardless of whether it is the result of an addition to, or a denudation of, the beach. Seaward of the foot of this slope, the inclination of the bottom is much less.

An explanation of the observed fact that berms, built up during stormy seasons, are eroded by the less violent wave action of the calmer seasons, and that berms attacked by storm waves may be either built up or eroded according to circumstances, may be obtained from Fig. 6, in which three typical cases are indicated.

Case (a) represents conditions such as exist when the winter berms are attacked by the summer waves. The plunge-point is at some depth, x , and this is the point of maximum disturbance. Shoreward of the plunge-point, the waves maintain a nearly fixed slope, as described in a previous paragraph. Seaward of that point, the slope of the bottom is steeper than required for equilibrium. The result is a transfer of sand from the berm to the under-water section, and the summer beach indicated by the broken line is formed.

If now, Case (b), waves of greater magnitude attack the summer beach of Case (a), the plunge-point, in the average case, will be moved seaward to water of some depth, x . Shoreward of the plunge-point the slope of the beach is flatter than required for equilibrium, and a transfer of sand toward the beach commences. The ultimate result is a new berm such as shown by the broken line. It should also be noted that at the plunge-point there is also a transfer of sand seaward, and as this sand is carried into deeper water than that where it lay in the summer beach, the probability of its eventual return to the beach has been diminished. In other words, though the berm has been rebuilt, a certain quantity of beach material has been wasted in the process.

In Case (c) it is assumed that the beach formed under Case (b) is, in turn, attacked by waves plunging in water of the same depth as in Case (b), but that the attendant circumstances are such that the still-water level has been raised. Under these conditions, the berm will be built to a higher level, but the sand used in this elevating process is taken from the face of the berm itself, and the width of the berm is correspondingly decreased.

Many other conditions might be assumed and discussed, but those chosen will show why the beaches around New York City, throughout the summer, present to the eye of a visitor a scarp indicative of erosion; they will show why, in many cases, if not in the majority, the berm at the beginning of the summer is wider than it was at the close of the preceding summer; they will also show why the maximum damage to beach structures usually occurs during an extraordinarily high tide.

The foregoing refinements might have been omitted, and the writer might have limited himself to a brief statement to the effect that, above a certain hydrographic contour, the waves exercise a powerful scouring effect on the bottom; that the sand composing the bottom is constantly agitated and can find no rest until it has reached deep water, or until it has been cast on the beach above high-water mark; that the greater the magnitude of the waves, the wider the zone of agitation, the higher the beach to which part of the material escapes, and the greater the depth to which other material is carried.

Along the south shore of Long Island, the waves, for the greater part of the year, beat on the shore from a direction slightly east of the normal to the shore line. This shore is protected from the northerly storms, and, if the northerly winds are eliminated, the remaining storms will come mainly from an easterly direction.

When a wave strikes the beach from a diagonal direction (Fig. 7), the up-rush carries sand along with it in a diagonal direction. The back-wash also follows a diagonal course, but on the opposite side of the normal. The undertow frequently concentrates into a stream nearly parallel to the shore line, flowing out to sea at irregular intervals.

With the assumed conditions, a particle of sand disturbed by the plunge at B might be carried up the beach as far as B_1 . At B_1 , the force of the up-rush having been nearly expended, the particle is dropped until the returning back-wash has acquired sufficient velocity to set it once more in motion. The back-wash carries it as far as B_2 , where the undertow takes charge. The latter is assumed to be nearly parallel to the beach as far as B_3 . At B_3 , the undertow turns seaward, and the particle is carried into deep water.

The course followed by any individual grain of sand is an interrupted one, but, in the normal case, certain particles are at all times following each phase of the

route shown in Fig. 7. The majority of the sand grains actually make many journeys up and down the slope, with a progressive movement to leeward, before they are finally taken to deep water by the undertow, or are carried to the semi-permanent uplands above the reach of the waves.

A study of the geology of Long Island indicates that during the glacial epoch enormous quantities of sand and gravel were deposited near the easterly end of the island, in a position where they were subject to wave attack. The prevailing direction of the waves has caused part of this material to be carried along the south shore for a distance of 100 miles, and has built up a nearly continuous beach along that shore.

The foregoing description of littoral drift applies to a continuous beach, and attributes the phenomenon of drift to wave action and undertow. It should be noted that any break in the continuity of the beach eliminates these forces. At such breaks, normally, there are tidal currents of considerable strength to be dealt with. Wave action keeps the bottom more or less agitated, and thereby assists the tidal currents in moving the sands.

It would seem that the question whether littorally drifting sand will be carried across an inlet to the leeward beach, to deep water outside, or into the harbor, is largely a matter of accident. In any event, inlets must result in a waste of beach-forming material, for there are strong tidal currents there which are capable of carrying the material far away from either the windward or the leeward beach.

JETTIES AND GROINS.

As used by the writer, the term "jetty" will refer to structures reaching well out into deep water; the term "groin" will be applied to structures reaching only slightly beyond the low-water line. Wherever there is littoral drift, and jetties have been constructed, beaches have accumulated on the side from which the drift comes. Such is not the case with groins.

Referring to Fig. 7, it is noted that the littoral drift takes place largely below the still-water level. Above that level the sand movement is principally up and down the slope, with only a small component parallel to the shore line. A jetty cuts off the littoral drift, both above and below the still-water level. A groin has little effect on drift due to undertow, and, so far as the drift above still-water level is concerned, a groin is effective for a limited distance only.

One effect of groins deserves serious consideration. Consider a groin so high that no water will over-top it. Such a structure (Fig. 8) will inevitably concentrate both the up-rush and the back-wash of the wave. With a low groin a lesser concentration is effected. It has been the writer's observation that, in the normal case, the berm will be cut back, and a valley will be formed in the vicinity of a groin.

In the vicinity of an inlet, a training dike may be of great value in aiding the formation of a beach, even though it does not reach below the low-water line. At points where channels parallel to the beach (sometimes called swills) are formed, temporary dams across such channels may be of benefit, but, as the channels are transitory, permanent dams are unnecessary.

In order that littorally drifting material may pass a jetty, or a groin, it is necessary for it to travel into deeper water than would be the case on an unobstructed beach, and this deflection reduces the probability of its ever being returned to the beach. For these reasons jetties and groins must inevitably cause a wastage of beach material.

BULKHEADS.

When an engineer is required to build a bridge over a torrential river, he first searches for marks indicating the highest points reached by floods. Using the information thus obtained, he builds to resist the forces that must be encountered. Similarly, when erecting structures along a beach, he should take note of the signs showing what part of the beach is transitory and what part is fairly stable. The level of the coconut grove at San Juan, Porto Rico, and of the sand hills at Long Beach, Long Island, previously mentioned, represent formations that have remained in their present location for many years, and, in the ordinary run of events, may be expected to last for many years. Who builds in front of these stable formations should build strong.

Confronted by a wide berm, such as that at Long Beach, Long Island, the property owner is tempted to erect some form of bulkhead in advance of the line of dunes. The strength of the bulkhead is proportioned to resist the final attack of the waves after most of their force has been spent in crossing the berm. An unfortunate combination of seasons may entirely remove the protecting berm, as it has been removed in former years, and the bulkhead will then be subjected to forces for which it was not proportioned. The result is that the sea takes back its own.

The effect on the berm and foreshore of such substantial sea-walls as are represented by the rip-rap walls guarding the Edgemere Club, the Manhattan Beach Estates, and the neck of land connecting Sandy Hook with the mainland, and of such substantial bulkheads as guard the tracks of the Central Railroad of New Jersey, from Highland Beach to Seabright, should be considered. It is often stated that such structures cause an erosion of the beaches in front of them. The writer believes that this erosion is much less than is commonly thought. The destruction of the berm is usually brought about by the undermining of the other faces, as indicated in Fig. 6 (a), or by a rearrangement of the berm material, to obtain a higher berm of less width, as indicated in Fig. 6 (c). In the former case the quantity of material above mean low water is diminished; in the latter case it is increased. In both cases the width of the berm is diminished.

Under certain conditions, the back-wash from a sea-wall may tend to undermine its toe by scouring out the bottom for a few feet in front of the wall, but the writer does not recall seeing a single instance of this kind along the many miles of bulkheads near New York City. To erode a berm like that at Long Beach, forces must work far to seaward and must carry the beach material to deep water, or must, by littoral drift, take it to another part of the beach. A seawall would have no material effect on such forces.

The wall in front of the Manhattan Beach property has stopped the erosion of that property, and there is no evidence that it has caused a deepening of the water in front of the wall. There is at the present time a large shoal between Rockaway Inlet and the Manhattan Beach Estates. That shoal is moving steadily westward, and there is no reason to believe that the existence of the wall would prevent the shoal some day from making a contact with the Manhattan Beach property and forming a beach in front of the wall, should other conditions be favorable to such a movement.

The records show that the beach in front of a considerable portion of the sea-wall at the south end of Sandy Hook builds out and cuts away. The sea-wall limits the extent of the erosion, but does not prevent the formation of a new beach when conditions are favorable for such a growth.

In connection with this Sandy Hook wall, the writer on one occasion noted casually a condition that should have been carefully recorded and photographed. Its significance, however, was not realized until later. From memory, the conditions were about as shown in Fig. 9. The beach had eroded perhaps 200 feet in less than a year. The inspection was made in May, 1915, during calm weather. Well up on the wall were the remains of the old berm, just as they had been left by the caving away of the outer part. The corners were sharp, and the caving may have taken place only a few hours before the inspection. It is highly improbable the sand scarp would have stood as it was for more than two or three days, yet the beach had already receded many feet from this particular deposit. The essential facts are that the beach in question was being eroded at a rapid rate by waves that were too small even to splash the old berm. Certainly, back-wash from the wall was not the cause of the erosion, nor was the erosion due to the action of storm waves.

A sea-wall having strength commensurate with its exposure will effectively protect the property in its rear. The location of such a wall, however, should be a matter for serious consideration. If placed so as to include permanently a portion of the temporary berms, the sand thus confined must be deducted from the supply that might otherwise be counted on for the maintenance of the beaches to leeward. The right of a property owner to take permanent possession of beach material temporarily deposited in front of his property may well be questioned. A fair compromise would seem to be that the improvement of the semi-permanent formations be encouraged, and their protection by any means not interfering with the littoral drift be permitted, but that no structures having in view the fixation of the materials composing the temporary berms should be authorized unless the work is on such a scale as to constitute a public improvement, taking care of the beach as a whole.

If used to protect an isolated portion of the waterfront, a bulkhead should be placed at about the line separating the temporary berms from the semi-permanent dunes, or in rear of that line. If the protection of the beach as a whole is undertaken, the bulkhead, sea-wall, or detached breakwater may be placed so as to include the temporary as well as the more permanent formations.

It should be understood that the construction of a detached breakwater or a sea-wall inclosing the berms will effectually stop the littoral drift along that frontage until a new beach has been formed outside of the sea-

wall or breakwater. If there are beaches to the leeward the effect on them may be disastrous.

Detached breakwaters should afford protection to the beaches in front of which they have been placed. They should create along those beaches conditions similar to those existing in protected bays and harbors. So far as the protected beaches are concerned, rapid changes due to wave action will be done away with, and the beaches may be extended by dredging and filling if desirable.

CONCLUSION.

It would appear that along each mile of open beach there is a constant transfer of sand from the shore to deep water. When littoral drift is the source from which the supply necessary to maintain the beach is obtained, the quantity of material brought to the section must, in order to maintain the beach, be at least equal to the material carried into deep water plus that carried away by littoral drift.

Assuming a section of beach where the littoral drift is exactly sufficient to replace the wastage, no checking

of the sand at any point will benefit the beach as a whole. The valuable part of water-front property is the part corresponding to the level of the cocoanut grove in Fig. 5, but the value of this portion is somewhat dependent on the existence of a sufficient berm at a lower level. Uplands may be protected by sea-walls and bulkheads, but bathing beaches must necessarily lie outside of such structures.

The writer knows of no means by which exposed sandy beaches for surf bathing may be preserved except by feeding fresh beach material to them as rapidly as the old material is carried away. The rate of growth of Rockaway Point and Long Beach would indicate that many millions of cubic yards per year are required by the beaches of the south shore of Long Island to counterbalance the demands of the littoral drift. There are no data, so far as the writer is aware, by which the quantity of sand carried annually into deep water can be approximated. At all events, it is safe to say that, if the natural supply of beach maintenance material was to be cut off, any attempt to make up the deficiency by

dredging or other artificial means would be a stupendous undertaking.

Along the New Jersey shore north of Asbury Park there remain to-day only a few isolated temporary berms. Along most of that shore the waves are eating into the semi-permanent formations or are battering against the bulkheads. It would seem that the only salvation for many sections of that beach lies in the construction of sea-walls of sufficient strength to combat the waves until such time as new berms are formed, if such time ever comes.

A study of the littoral drift on the south shore of Long Island and the disastrous results to certain beaches that have followed temporary stoppages of that drift would be well worth while. The stoppages in the past have been brought about by natural causes, but the works of Man will play an important part in the future, and we may well take warning while there is yet time and see to it that the interests of the millions who annually visit the beaches of the south shore are properly safeguarded.

The History of Condensed Milk*

With a Note on Its Therapeutical Uses

By Paul Bartholow, M.D.

THE history of condensed milk emerges bit by bit from beneath the records of kindred industries, as, for example, the refining of sugar and the evaporation of fluids and substances liable to decomposition. It deals with important subjects in physics and chemistry which have been stowed away from sight and have therefore been unduly neglected. It is almost essential in understanding the uses of condensed milk that we should know something of the principles upon which it is made, yet this knowledge has hitherto ended at the "curtain" or peroration of the lecturer or manufacturer when introducing condensed milk as a food for children and babies. The mere mechanics of the subject should preserve us from a view so superficial.

Some of the contributions to this science do not demand much notice. The dissertation of Braun, and the brief history of Hosford in the *Milch. Zeitung* several decades ago, come to nothing, or next to nothing, for they describe methods of manufacture that have long since gone to pieces. Mohan, indeed, has given us something more in a brief reference to the patents of Newton and of Green, but it is not clear whether he has read the original specifications or not. For, as to Green's patent, it cannot be stretched to cover any method related to the manufacture of condensed milk.

The invention of the process really originated with Howard, whose vacuum pan recalls some names illustrious in science and trade. It was invented, wrote Maumené in his "Fabrication du sucre," t. i., 3, in 1816. The account of the apparatus was given by Howard's friend, Thomas Thomson, in the *Annals of Philosophy*, 1816, Vol. 8, p. 209, which was translated and published in the *Annales de chimie et de physique*, 1816, p. 373. "In the ordinary way of boiling sugar, the temperature is so high that a considerable portion of the sugar is converted into treacle. Mr. Howard's vessels are globular, and of copper, and connected with an air pump, which is wrought during the whole time the boiling goes on. The consequence is that a vacuum is formed within the boilers. This enables the boiling to take place at a temperature so low that there is no risk of destroying any of the sugar. The vacuum is such as to support a column of mercury from 1 to 4 inches in height. There is a thermometer attached to each boiler, and likewise a mercurial gage to give the degree of rarefaction." (From "A Short Sketch of Mr. Howard's New Process of Refining Sugar.") Manufacturers of sugar and of condensed milk have made full use of this invention. The vacuum pan described in Thomson's memoir is virtually the same as the globular and cylindrical apparatus in use to-day. According to Foster ("Treatment of Evaporation") "the vacuum pan is quite as old, even older than the multiple apparatus . . . it has the same unpractical globular form, low and confined evaporation space, small heating surface."

These passages describe the vacuum pan used in refining sugar and condensing milk; they show that the two industries are inseparably connected. Even the multiple system of Wellner-Jelinek, by which large surfaces of milk or sugar are exposed to evaporation, is used by some manufacturers, in making evaporated milk, which

in this context must not be confounded with condensed milk. It is certainly important that Howard's vacuum pan has given such an impulse to the manufacture of condensed milk.

What must be regarded as the most valuable feature of Howard's system is generally found in the manufacture to-day. In nearly all factories the vacuum pans are worked upon the general principle of Howard's. The air is kept, by the working of an air pump, at such a state of rarefaction that the milk boils at a temperature too low to cause browning, and the other changes incident to exposure to a temperature of 100 deg. Cent. By carefully regulating the supply of heat to the pan, and of cold water to the condenser, the progress of the operation being watched through a glass plate in the roof of the chamber, the condensation is carried on at a rapid but uniform rate until completed. The milk after sugar is added is raised to such a temperature that it may begin to boil immediately when brought into the rarefied atmosphere of the vacuum pan.

Richmond in his "Dairy Chemistry" refers to the multiple evaporation system, without, however, telling us where it is employed. A vacuum pan with a fairly large vapor space is used by the best manufacturers in America. The heat is carefully regulated, as well as the cold water to the condenser, and the milk is boiled at an even, rapid rate until concentration is sufficient, a point easily told by an experienced operator. The pans have a large heating surface, fitted with coils, as in the Wellner-Jelinek system. There is a high vapor space and low boiling level, unlike many pans in which the steam coils occupy most of the space, leaving little or no room for the charge. In a really good and modern pan the full charge is only 0.1 to 0.12 meters above the top row of tubes, which are copper. These tubes are placed in 2, 3 or 4 rows, according to the size of the pan, and heated separately with steam. A high vapor space in the pan is indispensable to the manufacture of a good brand of condensed milk, since it allows the dispersion of gases from the mass of boiling milk. Such a system, however, is in my experience not often seen, the proof being the low standard of condensed in the constituents of the original milk. According to Tibbles, these variations in the composition of condensed milk are so great that it is essential that some standard should be fixed. Now, a medium quality of cow's milk would contain before condensation 3.3 per cent of fat, and condensed to one-third its bulk 10 per cent of fat. Such milk should also contain 8.5 per cent of solids-not-fat before evaporation, and the condensed substance at least 25 per cent of solids-not-fat. It has therefore been an established custom of the British Government to stipulate that it should contain not less than 10 per cent of fat and 25 per cent of solids-not-fat. The Board of Agriculture made the following regulation under Section 4 of the Food and Drugs Act, 1899:

"That any condensed milk (other than that labeled 'Skimmed Milk' in conformity with provisions of Section 2, Food and Drugs Act, 1899) in which the amount of milk-fat is less than 10 per cent, or the amount of solids-not-fat is less than 25 per cent shall be deemed to be so deficient in some of the normal constituents of

milk as to raise a presumption until the contrary is proved, that it is not genuine."

This English rule is a good one and should be followed.

It is now more than 50 years since Gail Borden first manufactured condensed milk on a commercial scale. In 1856 he received a patent for a "process for concentrating sweet milk by evaporation in vacuo, having no sugar or other foreign matter mixed with it." Readers of advertisements naturally conclude that he invented condensed milk; at least that is the impression these advertisements make until corrected. But there is no doubt in the minds of those who have studied the history of condensed milk in detail that it was a Frenchman who first thought of it, and an Englishman named Newton who perfected it. The Frenchman was Appert, who in 1809 published his "L'art de conserver toutes les substances animales et végétales." This little book, which is now extremely rare, was dedicated to Gay-Lussac. At the time Gay-Lussac was a member of the Board of Arts and Manufactures. His opinion of Appert's method is of particular interest. "The Board of Arts and Manufactures," he wrote, "has reported to me the examination it has made of your process for the preservation of fruits, vegetables, meat, soup, milk, etc., and from that report no doubt can be entertained of the success of such a process. As the preservation of animal and vegetable substances may be of the utmost utility in sea voyages, in hospitals and domestic economy, I deem your discovery worthy of an especial mark of the good will of the government."

Appert tells us how he condensed milk, "reducing it to two-thirds of its original volume." He sweetened it with sugar, though sugar, he says, is "hurtful to the patient." Evidently he disliked sugar. Indeed, his opinion on its use for preserving milk might have been written at the present day. I quote it at length: "A second inconvenience is this, that a large quantity (of sugar) is required to preserve a small quantity of milk; and hence the use of it is not only very costly, but even in many cases pernicious."

It is clear that the original idea in condensing milk was to preserve it, and its appropriate uses are equally distinct. Preserved or condensed milk was intended for armies, fleets and hospitals and not at all for children or babies. An English translation of Appert's work was published in London in 1811. Englishmen followed Appert in his process, and a patent for evaporating milk in a vacuum pan, it is stated vaguely by Mohan, was granted to Green in 1813. I have been unable to find this patent in the Specifications of British Patents. But there is a patent that was granted to Green in 1850 for the "preservation of substances liable to decomposition and destructive agencies." (Eng. Pat. 13,420.)

There is no doubt, however, that the process of condensing milk in vacuo was fully developed in 1835 in the patent granted to Newton. (Eng. Pat. 6,787, 11 March.) As the words of the specification tell the story of the original condensed milk, it is worth while to repeat them. (Specifications of British Patents, 1830-1835.) "A method for preparing animal milk and bringing it into such a state as shall allow of its being pre-

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