A SYSTEM OF INVENTORY FOR THE SHOREZONES OF THE GREAT LAKES

Thesis for the Degree of M. S.

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William Franklin Jewell

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This is to certify that the

thesis entitled

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SHOREZONES OF THE GREAT LAKES

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S. R. Schoemann

Major professor

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A SYSTEM OF INVENTORY FOR THE SHOREZONES OF THE GREAT LAKES

By

William Franklin Jewell

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A SYSTEM OF INVENTORY FOR THE SHOREZONES OF THE GREAT LAKES

FOREWORD.

The conservation of the shorezones of the oceans and the Great Lakes is a relatively new idea in the field of natural resource conservation. Shorezone problems have been approached in the past largely in terms of engineering works for the protection of property of high value.

The Beach Erosion Board, established by the River and Harbor Act of 1930, was charged with "making investigations and studies .... with a view to devising effective means of preventing erosion of shores of coastal and lake waters by waves and currents."[1] These studies have been concerned with the dynamics of the shoreline as they affect beach erosion and the need for engineering structures.

The National Park Service has been given the task of location, classification, and purchase of "outstanding stretches of the ocean beaches" as recreational and scenic areas.[2] This classification was on the basis of scenic value rather than shore forms.

Specific problems of utilization have been investigated by civic associations, as in the case of the California Beaches Association.[3] A regional inventory of the number of miles of sand beach available for recreational purposes has been carried out in Florida.[4] Numerous geological and geomorphological studies have been made, notably by Douglas Johnson,[5] and F. P. Shepard.[6] These concerned themselves either with broad genetic classifications or with microforms associated with the beaches.

THE REQUIREMENTS OF A SHOREZONE CLASSIFICATION.

An effective classification of the shorezone must go beyond the prevention of erosion, beyond the selection of recreational sites, and beyond the investigation of gross and minor landforms and processes. It must encompass all of these studies and problems, and must, in its eventual form, supply the basis for answering detailed and specific questions regarding the conservation and utilization of the shorezone.

Classification on the basis of utilization or suitability for use is limited by the viewpoint and objectives of the person making such a classification. The individual seeking a resort location has different requirements than the one interested in locating an ore dock. Accessibility to the water margin from both land and sea is vital to the fisherman, while the man seeking a suburban residential site might be more interested in the view. Each type of utilization requires its own balance of physical and dynamic factors for optimum development. Five basic factors govern all shore utilization. They are Form, Composition, Accessibility, Protection, and Stability. Shorezone types based on these factors will be adequate for the requirements of the land use planner.

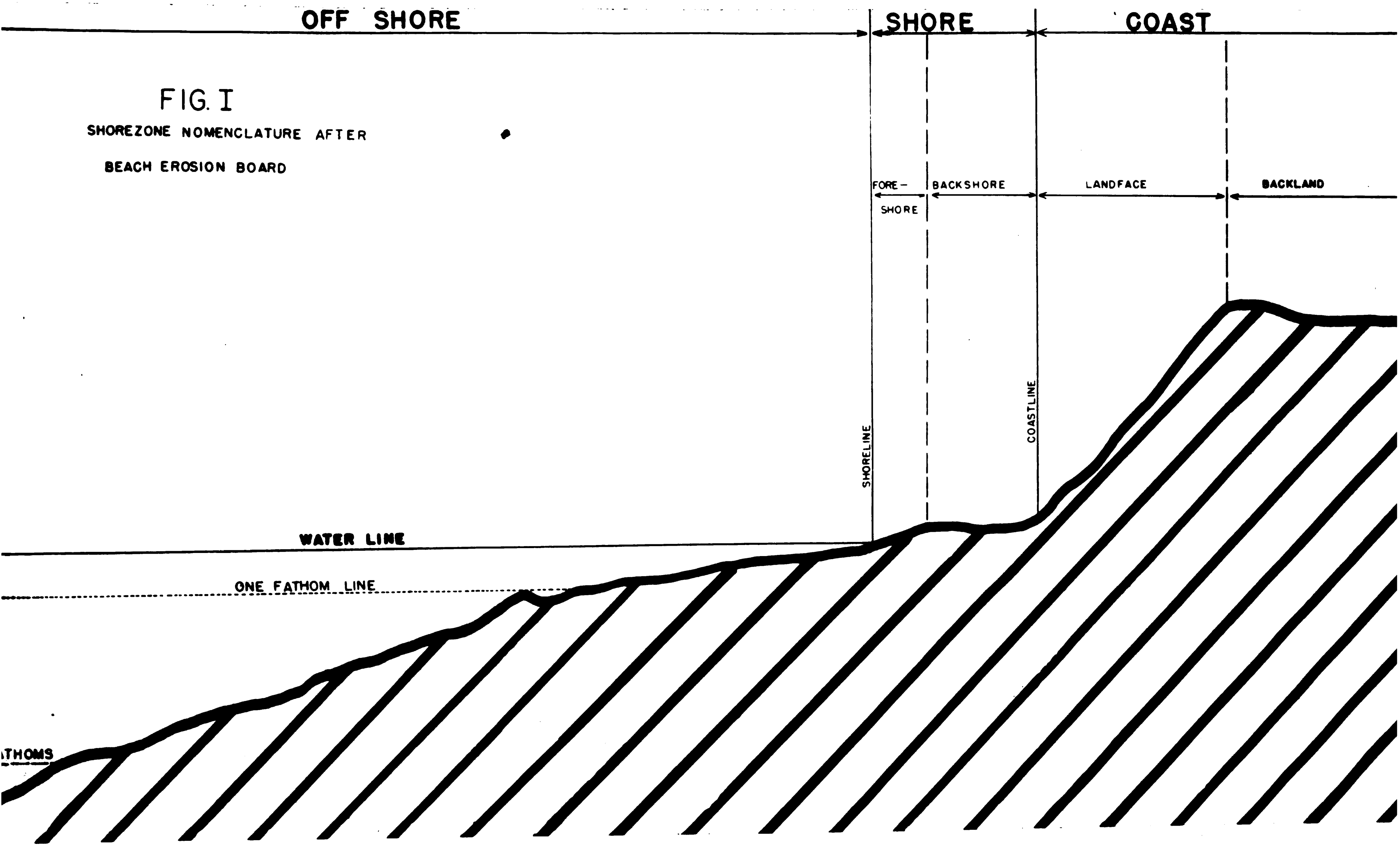
To create such types good factual data is required. This must not only be of a physiographic nature but must include an evaluation of the dynamic factors of the wind, waves, currents, and ice. This information may be derived only from a thorough and precise inventory of the shorezone.

To facilitate this discussion it is necessary to define the terms used. In general, these definitions are in agreement with those of the Beach Erosion Board,[7] although Shorezone, Backland and Landface

FIG. I

SHOREZONE NOMENCLATURE AFTER

BEACH EROSION BOARD



are of the writer's own invention.

SHOREZONE — The zone comprising the Off Shore, the Shore or Beach, and the Coast or Landface.

OFF SHORE — The zone that extends indefinitely seaward from the low water mark.

SHORE OR BEACH	The zone extending from the low water mark to the highest limit reached by storm waves or ice shove.
COAST	The zone of indeterminate width landward from the Shore.
LANDFACE	The zone extending landward from the Shore to the limit of direct influence of the shore processes. Thus, the top of a cliff, the crest of a clay bluff, or the inner limit of active dune formation would constitute the landward margin of the landface. From this it may be seen that the term Coast may be used in land type classifications, while Landface should be used in discussions of slope, materials, and height of land behind the Shore.
BACKLAND	A zone extending indefinitely landward from the inner limit of the Landface.
SHORELINE	The line separating the Off Shore from the Beach.
COAST LINE	The line that forms the boundary between the Coast and the Shore.

From the definition of the term Shorezone, it is obvious that it breaks down quite naturally into its three components, The Off Shore, The Beach, and the Landface or Coast. The basic inventory must consider each component separately.

THE OFF SHORE ZONE.

The four dominant factors of the Off Shore are: 1) the width of the terrace, 2) the degree of protection, 3) the materials composing the bottom, and 4) the dynamic influences operating there.

The condition of the offshore terrace is important in a number of respects. Shoal water will tend to inhibit wave action, which may reduce wave sapping of the shore. The same condition will adversely affect navigation by deep draft vessels. A measurement from the shore to a depth of six feet will indicate the approximate width of bathing beach available. The expression of the condition of this terrace may be in terms of width to a given depth, or in terms of degrees or percent of slope. For the purposes of this inventory, in order to establish the essential conditions in terms that may be readily obtained either from coast charts or by survey methods, the distances to two arbitrarily selected depth curves have been taken as the means of expression. The six foot, or one fathom, and the thirty foot, or five fathom curves have been chosen. The thirty foot curve corresponds to the limiting depth of locks and channels of the St. Lawrence Seaway project. As the maximum draft of the largest lake vessels it is correspondingly the minimum depth of free navigation or the danger line. The six foot depth bears a similar relationship to the small craft of the lakes, also corresponding, as previously mentioned to the practical limit of bathing and swimming. The broad extension of a six foot shoal would have a profound effect on wave action, as waves over three to four feet in height break at that depth, spending the wave energy and reducing the effect of wave action on the shore. Both of these curves are drawn on the charts of the Great Lakes.

The Factors of Protection.

The factors of protection are to be determined in terms of the amount of wave and current attack that will be operating against the shore. This is dependent upon the angle of approach of the waves, the convergence or divergence of waves upon the shore due to submarine topographic conditions, and the limitation of the wave height by the depth of the off shore shelf.

The existence of relatively permanent wind systems during the different seasons of the year allows the oceanographer to predict prevailing wave directions for each season. The wave directions of the stormy season, when the largest waves prevail, are the most important in the determination of the direction of major wave attack upon a coast. Should the shore lie across the path of the storm waves the maximum effect would be felt, while a windward shore would receive the minimum of wave attack.

The configuration of the shoreline and of the bottom contours may greatly alter wave effect. The force of the waves can be concentrated or diminished in a given area under the influence of points and bays as well as submarine ridges and canyons. Waves approaching a coast begin to "feel bottom" as soon as they get within a depth that corresponds roughly to one-half of their crest to crest wavelength. The internal motion of the wave is of considerable amplitude at that depth, enough to retard the progress of the wave should there be any restriction of the oscillatory motion. Thus all waves, when they get within this limiting depth, tend to follow the submarine contours. On a straight shore there will be little tendency for waves to refract in this manner unless the underwater contours are not in the same pattern as those of the land. It may be seen, however, that refraction will cause waves to converge upon points and diverge within bays.

(See Figure 2.) Refraction diagrams can be constructed to show the amount to which this convergence and divergence takes place and to compute the height and force of the waves approaching a given shore, presupposing a given wave height and wavelength in open water. These diagrams are based on the fact that wave energy does not travel along the wave crest but is transmitted with the forward motion of the wave. It is possible to construct theoretical lines delimiting zones of equal wave force. These lines run perpendicular to the wave crests and are called orthogonals. If the orthogonals on a wave entering a bay mouth are 100 feet apart and divergence takes place as the wave conforms to the bottom contours, the orthogonals may be extended until they are 200 feet apart where the wave breaks upon the shore. Correspondingly, the same wave converging upon a point might cause the distance between orthogonals to be decreased to 50 feet. The amount of energy which was contained in 100 feet of wave crest in the open lake would be concentrated along 50 feet of the shore of the point and spread over 200 feet of the shore of the bay. The force of wave attack on the point would be twice that received on a straight coast and four times that received in a bay. In terms of shore erosion such a factor is of tremendous importance. In the system of inventory offered in this paper the means of determining a general protective factor is given.

The Materials of the Off Shore Zone.

The materials of the off shore have an important bearing on the utility of the shorezone. The condition of the holding ground and the material composition of the shoal bottom are of interest to the navigator. Likewise, the near shore bottom type governs recreational

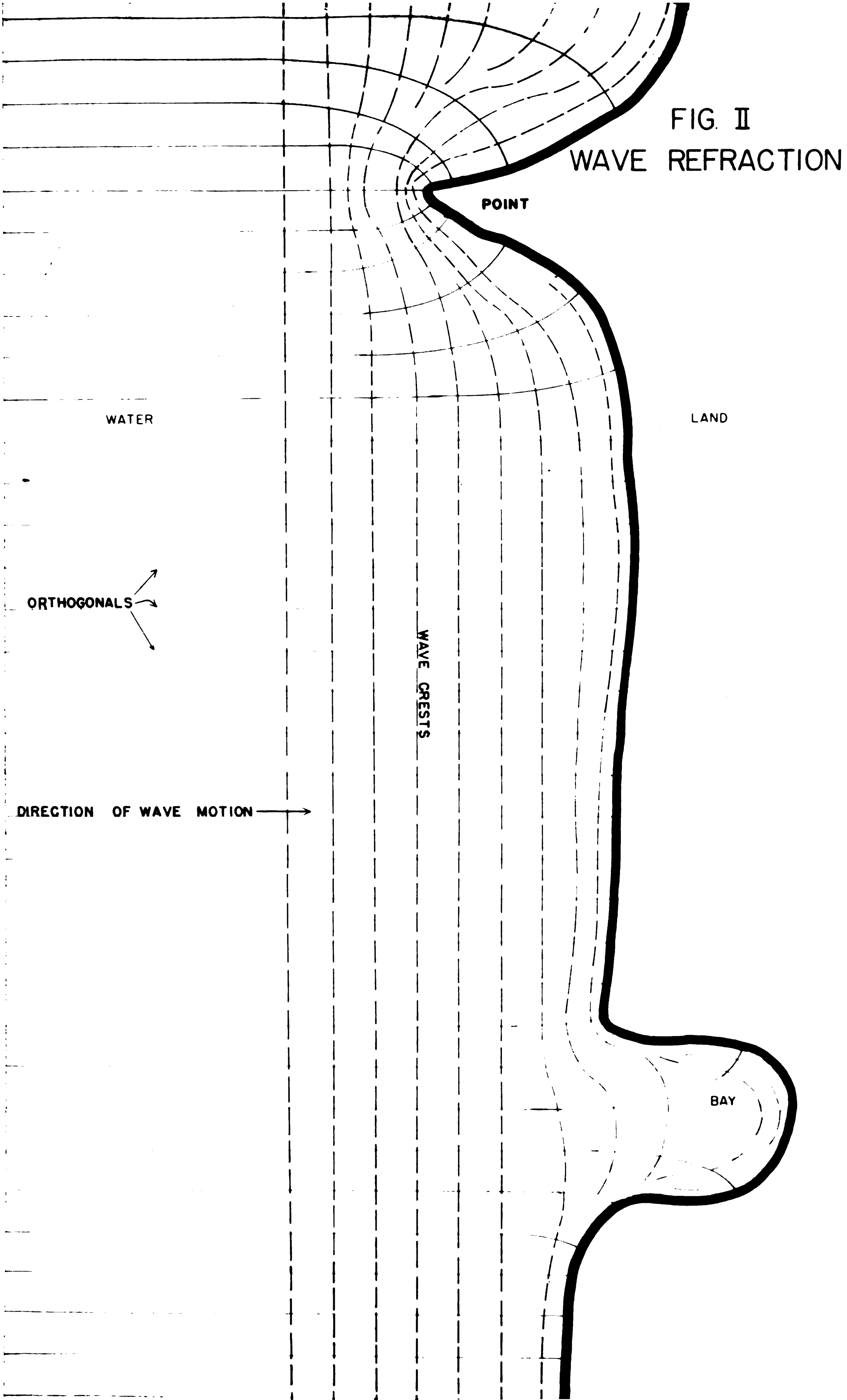


FIG. II
WAVE REFRACTION
POINT
WATER
LAND
ORTHOGONALS
WAVE CRESTS
DIRECTION OF WAVE MOTION
BAY

use of the water. The relationship of the various materials of the off shore area to each other may serve as an indication of the shore processes taking place. Scott[8] has measured ice movement on the shore by studying the tracks gouged in the beach by a boulder caught in the shore ice and moved along by it. Boulder or cobble pavements either on the surface or underlying sand deposits are indications of an erosional process, of either continuous or seasonal nature. Gravel and cobble ridges and cusps may be found on normally sand beaches during the stormy season. Dominant materials, associations of materials, and underlying materials should all be recorded in the inventory.

The Dynamic Influences of the Off Shore Zone.

Dynamic influences are included in this inventory not because they must be recorded always or even in a majority of cases, but because a prograde or retrograde condition of the shore (discussed under Beaches) may require an explanation of its cause or an estimate regarding its continuation. Shore areas exhibiting abnormally high or low waves relative to the average wave height along the shore should be noted as areas of convergence or divergence. Areas of convergence would probably be associated with a considerable amount of erosion, while divergences create optimum conditions for construction of piers and handling of small craft. Of the many dynamic factors that may be checked in a study of the shorezone, the height, direction of approach, and the period of the waves are most important. The force contained within a wave is directly proportional to its height and wavelength. The period is the expression of wavelength in terms of time. The direction of approach of waves, combined with the height will give an indication of the direction and velocity of the along-shore currents, which account for the greater part of the mass transport along the beaches. It is to be emphasized that the information on dynamic influences is of a supplementary nature to be utilized in the solution of definite problems and is not to be attempted unless such a problem presents itself.

THE SHORE OR BEACH.

The first dominant factor of the Beach zone is its presence or absence and its width if present. The total absence of any beach is a characteristic of the Pictured Rocks (See Photo #1). Broad, prograding beaches are characteristic of certain portions of the Lake Michigan shore of Emmet County (See Photo #2). Long time trends in development of the beach can be determined from a comparison of widths revealed by successive periodic measurements.

Coupled with the measurement of width is the estimation of the process which the beach is undergoing. Stability, or prograde or retrograde tendencies can be estimated with a fair degree of accuracy. A cut bluff without cover of trees or grass is quite probably retrograde, while the same bluff, covered by a stand of trees is stable, and has been for at least the life span of those trees. (See Photos #3 and #4.) Undermining of trees and rocks, or overriding of vegetation by beach deposits are all examples of retrograde motion (Photo #5). Broad, extended flats lying below recent beach ridges, development of a new fore-dune ridge in front of an older one, and stream deltas rising above the lake level are all signs of a prograding shore. A beach of medium width, lacking any sign of cutting on its landward side or erosion or deposition on its seaward side may be considered stable. The

Photo #1. The Pictured Rocks. See pages 7 and 24 in text.

Photo #2. A prograding shore in Emmett County. This is an example of the effect of a periodic lowering of the lake level upon an off shore terrace of extremely low slope. See page 7 in text.

Photo #3. The Grand Sable Banks, a former baymouth spit of the Algonquin Lake. Now uplifted and subjected to wave sapping, forming a cut bluff some 300 feet high.

Photo #4. Sable Point, west of Grand Sable Banks, showing relative stabilization of the bluff in the distance, while the water in the foreground is discolored with material in suspension. This indicates active sapping in the area toward the camera from the bare strip on the bluff. Irregular tongues of discolored water are rips.

Photo #5. Ontonagon County. Dead trees in swash zone and on beach together with undermined railroad at right indicate a retrograde beach.

Photo #6. Cobble and boulder pavement on beach in Emmett County. Low traffic utility to the bather, hiker, or person beaching a boat is quite apparent.

Photo #7. Drift beach west of Manistique. The refuse from a saw-mill has spoiled this otherwise excellent sandy beach for bathers.

age of the vegetation on and above the beach is the best indicator of stability.

The Materials of the Beach.

The materials of the beach are an important influence as to its utilization. Cobble and Boulder pavements do not make for high traffic utility. (See Photo #6.) Drift materials, such as the sawdust accumulated on the beach to the west of Manistique (See Photo #7.) may make an otherwise desirable site untenable. As in the off shore zone the dominant material, the associations of materials, and the underlying material should all be known if possible. A sandy beach with some gravel in association underlain by cobble pavement is a possible inventory of the materials of a beach, giving not only the transient character of the beach, but the basic character which will not change over a considerable time. The transience of beach deposits has been a matter of concern to cottagers and resort owners. A cottage bought at the end of August, at the end of the calm summer season, may boast a fine sand beach. That beach may be completely torn out by the fall storms and not build back again until late in the following summer. Sand beaches which are underlain at shallow depth by boulder pavement or bedrock are to be suspect in this regard.

Slope and Form of the Beach.

The slope of the beach has one important aspect to the riparian owner. With the periodic rise and fall of the levels of the Great Lakes, beaches with a low slope, both above and below the current water line, will be subject to considerable migration of the water line. At its highest level the water may be readily accessible to the cottager. In low periods the shoreline may migrate seaward many hundreds of feet, and a long walk over the exposed terrace would be necessary to reach the water. The position of the shoreline on a flat-sloped lee shore subject to wind tides would be most unpredictable, and the shore would be of low utility as a recreational site. Thus the slope of the beach becomes an important consideration of the inventory.

Some notation should be made as to the beach forms present, including both common minor forms and atypical features, in order to properly evaluate the beach. Lagoons, dammed stream outlets, berms, scarps, and ice ramparts are examples of forms deserving inclusion within the study.

THE COAST.

The Coast lies above the direct wash of the waves and currents, but it determines the dominant aspect of the Shorezone. Although it is, in itself, largely a product of those dynamic forces which are active on the beach below, it is a major influence on the development of the shore. In an investigation of the land types associated with the shores of the Great Lakes, eleven Coast Types emerged as being either basic types or complexes which merited differentiation as basic types.

Coast Types.

The cliff and rocky bluff coast is typical of the Lake Superior shores of the Keweenaw Peninsula, the Pictured Rocks, and the Garden Peninsula. The low flat rocky shore, and rock ledge Coast is found in the vicinity of De Tour. The unconsolidated bluff coast occurs at Empire, while Sleeping Bear Dune and Grand Sable Dune are perched dunes above unconsolidated bluffs. Dune coasts are found as the dominant type from the Indiana State Line to Ludington. The plain coast

Photo #8. Cecil Bay, Emmett County, a Marsh type shoreline. See pages 10 and 23 in text, and illustration of its inventory description on Shorezone Survey Form following page 20.

is found in many places along Lake Erie, while its complex form, with superimposed relict beach ridges and low fore-dunesmay be seen near Waugoshance Point. A Terrace Coast, with cut scarps and beach terraces of former higher levels of the lakes may be found in many places. Areas having a fine development of the Nippising bench are near Charlevoix, Mackinaw City and Sault Ste. Marie. The Marsh Coast may be found on the west shore of Lake Erie, in Saginaw Bay, or in less extensive stretches of the shores of all of the lakes. The illustration of Marsh type used in this paper was taken at Cecil Bay, west of Mackinaw City. (See Photo #8.) The Delta Coast is a type created to describe a unique situation.. It occurs on a large scale in but one place, the St. Clair Flats. While it resembles the Marsh type in many respects its structure and its coastal configuration make it worthy of separate mention. The eleventh type is a category created to cover areas not truly within the sphere of this inventory. It is the River Plain type, established to identify the shores of the connecting rivers of the Great Lakes.

Landface Characteristics.

While these land type designations give a broad picture of the nature of the Coast, two other factors of the landface are important to the utilization of the shorezone. They are the slope of the landface and the height of the backland above the beach. These must be determined together, as both are required to determine the accessibility of the beach from the backland. A ten foot cliff with level backland behind would be of more easy access than a twenty-five percent slope three hundred feet high. A third component is a description of the cover of the landface (not of the backland) which can be used as an index of stability.

METHODS OF INVENTORY.

The basic inventory techniques should be the same for the mapping of the shorezone as for other land type methods. Existing maps should be used wherever they are adequate for the task. Aerial photographs, at a scale of not less than three inches to the mile, are ideal for such work, while plane table methods may be used in the absence of other maps or photos. The shorezone mapper is concerned with the factors lying seaward of the inner limit of the landface, the system of inventory of the backland having been adequately developed in the various types of land surveys. Occupance factors which occur within the shorezone, such as piers, jetties, and breakwaters, as well as highways leading down to the shore from the backland, should be mapped. The basic shorezone inventory should be made concurrently with the geographic survey of the shorezone. The shorezone should be broken down into sectors of essential homogeniety, these sectors delimited on the base map, and numbered for identification. The facts determined in the inventory should be recorded on a form provided for the purpose and should be given a corresponding sector number. (See form at end of inventory.)

The following pages are concerned with a detailed presentation of the inventory system, by digits and components, dealing with the complete description of the physical and dynamic features of the shorezone.

BASIC SHORELINE INVENTORY

FIRST DIGIT. THE OFF SHORE

First Component. Width of Off Shore Slope.

I. Numerical System.

Establish distances to one and five fathom depths in feet thus: 50/300. Add as superscript number of bars shallower than six feet which lie beyond the inner one fathom curve. Thus: $50/3000^2$.

II. Complex System. (Alternative).

Type Number.

1) No terrace. Deep water at shore.

2) Narrow terrace. Less than 50 feet to one fathom curve.

3) Narrow terrace. Less than 100 feet.

4) Medium terrace. 100 to 300 feet.

5) Medium terrace. 300 to 500 feet

6) Broad terrace. 500 to 1000 feet.

7) Broad terrace. 1000 to 2500 feet.

8) Very broad terrace. 2500 feet and over.

A) Under 50 feet to five fathom curve.

B) 50 to 100 feet.

C) 100 to 200 feet.

D) 200 to 500 feet.

E) 500 to 1000 feet.

F) 1000 to 2500 feet.

G) 2500 to 5000 feet.

H) 5000 to 10,000 feet.

J) Over 10,000 feet.

NOTE: Read Complex thus: $3D^2$ means 50 to 100 feet to one fathom curve. 200 to 500 feet to five fathom curve. Superscript 2 indicates two bars less than one fathom in depth beyond the first one fathom curve.

FIRST DIGIT.

Second Component. Protection Factor.

1) Exposed position, exposed to wave attack from prevailing wind direction of the stormy season.

2) Open position, not exposed to wave attack from the prevailing wind direction of the stormy season.

3) Broad embayment, providing some protection from storm waves, and permitting limited divergence of waves.

4) Narrow embayment, providing considerable protection from storm waves and permitting great divergence of waves.

5) Protected coast, under lee of barrier or island.

6) Landlocked harbor.

7) Use this symbol for local zones of great convergence of waves.

8) Use this symbol for local zones of great divergence or canyon effect.

*) Directly open to wave attack of stormy season. To modify 3 or 4.

Third Component. Materials of the Off Shore Area.

If symbols are coupled, these types are combined at this station. The type which is listed first predominates. If symbols are written as a fraction, the lower symbol underlies the upper.

a) Sand.
o) Coarse Sand.
b) Gravel.
c) Cobbles.
d) Boulders.
e) Rock Shingle.
f) Clay.
g) Marl.
h) Organic Bottom.
j) Igneous and Metamorphic Rock.
k) Sandstone.
l) Limestone.
m) Shale.
n) Drift Material.
s) Shells.

Fourth Component. Dynamic Influences.

Wave Direction. If facing the sea, a breaking wave strikes the coast first to your right, use the symbol R. If breaking wave strikes first to your left, use symbol L. If approach is normal, use symbol N. If there is an interference pattern, use symbol X.

Wave Height. Estimate height of waves and record value in feet.

Current Direction. If facing the sea, current moves to your right, use symbol R. If current moves to your left, use symbol L. If there is a rip, use symbol V and if there is no observable current, use symbol O.

Current Velocity. The distance a float will travel in feet in the span of one minute is equal to the current velocity in hundredths of a knot. (Drift of 100 feet in one minute equals velocity of one knot.)

Wave Period. Determine time in seconds between passage of crests. Record 12 second interval as T12.

Material in Suspension. A. Bottom visible in more than 6 feet of water. B. Bottom not visible at 6 feet. C. Bottom not visible at one foot.

SECOND DIGIT. THE BEACH.

First Component. Width of Beach.

I. Give width of the beach in feet from low water mark to the highest level reached by storm waves or ice action. If no beach is present use zero.

II. Give estimate of present process.

P. Prograding Shoreline.

R. Retrograde Shoreline.

S. Stable Shoreline.

T. Shoreline stabilized by engineering works.

* Subject to ice action.

NOTE: Write out component thus: 25P* -- 25 foot beach width, prograding, starred for evidence of ice action.

Second Component. Materials.

a) Fine Sand.	e) Rock Shingle.	k) Sandstone.
o) Coarse Sand.	f) Clay.	l) Limestone.
b) Gravel.	g) Marl.	m) Shale.
c) Cobbles.	h) Organic.	n) Drift Material.
d) Boulders.	j) Igneous Rock.	s) Shells.

x) If x is used after j, k, l, or m, broken talus blocks are in the wave washed zone.

*) If second component is starred, vegetation is growing in the wave washed zone. This is to be differentiated from true swamp or marsh conditions.

If symbols are coupled, these types are combined at this station. The type which is given first predominates. If symbols are written as a fraction, the lower symbol underlies the upper.

Third Component. Beach Slope and Beach Forms.

1) Less than 1% slope of the beach in the wave washed zone.

2) 1% to 2%

3) 2% to 3%

4) 3% to 4%

5) 4% to 5%

6) 5% to 7%

7) 7% to 9%

8) 9% to 12%

9) 12% to 15%

10) Over 15%

a) Berm present.

b) Multiple berm.

c) Cut scarp in beach materials. (This is predicated on presence of berm.)

d) Lagoon present behind beach.

e) Dammed stream outlet.

f) Open stream outlet.

NOTE: Add other beach forms as they occur.

THIRD DIGIT. THE COAST.

First Component. The Coast Type.

1) Cliff and Rocky Bluff Coast.

2) Low Flat Rocky, or Rock Ledge Coast.

3) Unconsolidated Bluff Coast.

4) Dune Coast.

34) Perched Dune Coast

5) Plain Coast. Low relatively featureless former lake bed.

55) Relict Beach Ridge Coast. Beach ridges and foredune ridges on plain.

6) Terrace Coast. Cut scarps and abrasion platforms of former high levels of the water plane.

7) Marsh Coast.

8) Delta Coast.

9) River Plain. A special category applied to areas bordering connecting rivers of the Great Lakes.

Second Component. Slope of Landface and Height of Backland.

A) No slope, plain at water level.

B) 0 to 2½% slope. (Flat)

C) 2½ to 7½% slope. (Gently Sloping)

D) 7½ to 15% slope. (Moderately Sloping)

E) 15 to 25% slope. (Strongly Sloping)

F) 25 to 75% slope. (Steeply Sloping, 75% is angle of repose of dune sand.)

G) Over 75% slope. (Bluff and Cliff Slopes)

1) 0 to 5 feet from highest beach level to elevation of backland.

2) 5 to 25 feet.

3) 25 to 50 feet.

4) 50 to 100 feet.

5) 100 to 200 feet.

6) 200 to 300 feet.

7) 300 to 400 feet.

8) 400 to 500 feet.

9) 500 feet and over.

Third Component. Landface Cover Types.

a) Upland Timber (height, type, density).

b) Brushland.

c) Grassland.

d) Marsh (rushes, sedges, bluejoint, etc.).

e) Bog (leatherleaf, bog rosemary, Labrador tea, blueberry, etc.).

f) Swamp (cedar, tamarack, spruce, hardwoods).

x) No cover.

SURVEY REPORT FORM: SHOREZONE INVENTORY

COUNTY: Emmet TOWNSHIP: Wawatam RANGE: 4W TOWN: 39N SECTION: 28

SECTOR	FIRST DIGIT COMPONENTS				SECOND DIGIT COMPONENTS			THIRD DIGIT COMPONENTS		
	ONE	TWO	THREE	FOUR	ONE	TWO	THREE	ONE	TWO	THREE
1	6G	3	a/c	L1R18T4A	OP	h	1m	7	B1	f
2	6G	2	a		100S	a	4	5	C2	a

SURVEYOR: ____________

DATE: ____________

APPLICATION OF THE BASIC INVENTORY TO SHOREZONE CLASSIFICATION

In the determination of the elements selected for the system of inventory given on the preceding pages, every effort was made to preserve scientific objectivity. In certain cases, where a variety of methods of presentation of the same data were possible, the method used was arbitrarily selected on the basis of the broadest utility of the term. Thus, in the case of the Off Shore shelf, its nature was expressed in distances to important controlling depths rather than as degrees or percent of slope or as a ratio. The terms used in each case are given in such form that they may be converted into means of expression suited to a given classification without loss in essential accuracy.

The requirements of three types of classification were anticipated in selecting the elements of the inventory. They are: 1) Physiographic or Geomorphological classification, 2) classification of types of utility of an economic, social, or military nature, and 3) classification of process problems of shore protection. Selected components from the inventory will satisfy the requirements of each of these classifications. In general, the requirements of these classifications tend to increase in the order in which they are given above. In a purely geologic classification only the basic form, the material composition, and an indication of process are needed.. To this the land use classification adds the utility factors of protection, stability and accessibility. The classification of process problems requires a further intimate development of the dynamic factors of the shore processes.

The creation of shorezone types which consist of groups of associated features, which permit prediction in terms of future process and utility, is a prerequisite to planning the use of the shorezones of the Great Lakes.

Natural associations of shore features may be generally grouped under one or another of the eleven Coast types given in the inventory. These establish the dominant aspect of the shore. Subdividing these broad types according to the beach forms associated with them provides the planner with a physical shorezone type, but the factor of predictability in terms of process and utility is still missing. The stability factor, the protection factor, and in some cases the evaluation of the specific dynamic process, must be used to predict the long time process of the shore. The factor of accessibility, both from the land and from the sea completes the picture in terms of utility. A minimum of seven of the factors given in the inventory will be required to make a valid classification of this nature. In their order as they appear in the inventory, they are: the Off Shore slope, the protection factor, the width of the beach, the stability of the beach, the materials of the beach, the Coast type and the slope and height of the landface.

The factors which will not appear in the classification but which are necessary to the solution of process problems are: direction of wave approach, wave height, current direction and velocity, wave period, the slope of the off shore terrace and the beach, and the microforms of the beach which are significant to the process.

DEVELOPMENT OF SPECIFIC TYPES IN ILLUSTRATION.

While it is not the purpose of this paper to classify the shores of the Great Lakes, but rather to provide the raw materials from which such a classification could be made, a number of types selected at random from the shorelines of the upper lakes are presented here as an illustration of the use to which this inventory may be put.

The Cecil Bay Shorezone type is found on the shore of the Straits of Mackinac, in Section 28, Wawatam Township, Emmet County. It is shown in Photo #8, and its inventory description is given as example #1 on the Survey Report Form following page 20. It is a Marsh type shorezone. It has a broad Off Shore shelf, five hundred to one thousand feet to the one fathom curve, and twenty-five hundred to five thousand feet to the five fathom curve. It is in a broad embayment which does not lie open to the prevailing wave direction of the stormy season. The bay has a bottom of fine sand underlain at little depth by cobbles. The dynamic factors were measured, although such would not often be the case in such a protected area. The waves were approaching the shorezone sector from the northwest and were one foot high. There was a distinct alongshore current to the east moving at the velocity of .18 knots. The wave period was four seconds. The water was clear, the bottom being visible in more than six feet of water. No strand has been developed between the marsh and the open water and wave action is so slight at the marsh border that considerable accumulation of decayed vegetation is found along the shore indicating a slight prograde tendency. The material of the beach is largely organic. There is less than 1% slope of the beach in the wave washed zone. The Coast is of the Marsh type with flat slope and less then five feet vertical interval between the level of the shore and the level of the backland.

This is a shore type of limited utility. It is not stable. It has a very low slope which makes it susceptible to flooding during the periodic high water stages. It is in a protected position but has at times been subjected to heavy scouring action (indicated by the underlying cobble pavement). Accessibility from the seaward side is very limited while that from the land would be adequate. The Cecil Bay type would be a subdivision of the Marsh type, having indications of being unstable, of limited accessibility, and of low utility.

The Pictured Rocks type presents an almost complete reversal of conditions. Here there is no significant Off Shore shelf, the one fathom curve being within a few yards of the shoreline and the five fathom curve often within five hundred feet of shore. The shore is an exposed one subjected to the pounding of the northwest storms. The beach is non-existant. The Coast type is a high rocky cliff. The height to the backland is in the order of several hundred feet in many places. The trees growing in crevices of the cliff (See Photo #1) are indicative of its stability. Here the water depth is not a limiting factor in navigation to the shore. However, even if the shore would permit landing of vessels the protection factors would have an adverse effect. Accessibility to the shore from the backland is almost impossible. Here is a shore of high stability, low protection, and low utility, except as a scenic area.

Contrasting with the Pictured Rocks type are two other Rock Cliff types, the Marquette type (Photo #9) and the Burnt Bluff type (Photo #10). The Marquette type is an igneous rock cliff capped by sandstone. There is considerably greater dissection of the cliff by gullies, and the wave washed zone, (there is yet no beach developed) has numerous talus blocks and large boulders. Accessibility from the sea is the same as in the case of the Pictured Rocks while accessibility from the backland is perhaps a little better. There would probably be greater recreational utility in the case of the Marquette type than would be true of the Pictured Rocks type. The Burnt Bluff type is a limestone cliff with a boulder beach developed beneath it. Shoal conditions prevailing off shore make the approach difficult, while the cliffs are breached at intervals to permit access to the backland from the beach. Traffic along the beach is restricted by the size of the boulders but the recreational utility is higher than that of the other two cliff types.

A contrasting shore of high utility as a recreational site might be the Harrisville Type, found along considerable stretches of the Lake Huron Shore. The backland is a low wooded plain. It has a broad Off Shore shelf, five hundred feet to the one fathom line and four thousand feet to the five fathom line. It is on a straight coast and on the windward side of the lake with relation to the prevailing winds. Its Off Shore materials are largely sand. It has a stable beach of sand which averages one hundred feet wide. The beach slope varies up to 4%. The Coast type is low, relatively flat former lake plain. The slope of the landface is less than 7½% and the height of the backland averages less than twenty-five feet above the level of the beach. The inventory description is given as example #2 on the Survey Report Form following page 20. While the broad Off Shore shelf may restrict the utility of the site as a port area, the wide area available for bathers and the effect of the shoal conditions on the height of the breakers enhances its value as a recreational site. Sand beaches and ease of accessibility also add to recreational utility.

Other types may be developed in a similar manner. The Brevort

Photo #9. Presque Isle, Marquette. Rock Cliff type without beach and with talus blocks in the wave washed zone.

Photo #10. Burnt Bluff, near Fayette, Delta County. A Rocky Cliff Coast type, of Niagara Limestone, with development of boulder beach. Note that the boulders still retain their angularity and have therefore not been transported far from their source.

Photo #11. Dune type of Coast west of St. Ignace. Broad sand beach, well developed foredune ridge and low dunes to right of road.

Photo #12. An example of a shelving rock beach, proving that all rock coasts need not be rugged, nor of low accessibility.

Photo #13. An example of a "pocket beach" with the sandy bayhead beach in the foreground and the rocky shore of the headland in the background.

Photo #14. Gravel cusps on a sand beach. An atypical condition of short duration, generally occurring during the stormy spring and fall months.

Photo #15. An example of a stabilized cobble beach in the foreground with an actively retrograding cut bluff in the background.

type is a subtype of the Dune shorezone. It has a broad Off Shore shelf, sandy beach, good development of a foredune ridge and low dunes on a low landface and backland. (See Photo #11.) The De Tour type is a variety of Rock Ledge shorezone. A low flat coast underlain at shallow depth by limestone which comes to the surface at the coastline and is largely exposed on the beach. (See Photo #12.) Other types may be complexes as is the case of the "pocket beach" type. Here, there is development of small but good sand beaches at the head of small bays that indent a rocky coast. The points and stretches of shore between bays may be rock shelf or even cliffs, but the bays having greater protection from waves and alongshore currents develop broad beaches and are highly suitable for recreational use. (See Photo #13.)

In the inventory it is necessary to exercise good judgment as to the permanence of features described. Thus, gravel cusps on a sand beach which result from a period of high waves from a given direction, and which are a temporary condition, should not be mapped the same as a gravel beach, as the permanent or predictable situations would be at great variance from each other and this would destroy the validity of a shorezone type. (See Photo #14.) In the location of boundaries between sectors the point chosen for the separation of two types should be where factors of the highest order change. Thus, a change in the Coast type or a change in process should be followed rather than a change in beach materials or the factors of accessibility. This is illustrated in Photo #15. The boulder beach in the foreground indicates a relatively stable condition, while the shore in the background is definitely retrograde. The sector line should be drawn at the end of the cobble beach.

CONCLUSIONS.

In the past the shorezone has been treated by the planner and conservationist as the water margin of the land types. In few cases has the land type mapper done more than to stop his delineations at the shore. It is to be seen that the shorezone is not the mere end of the land but is a separate entity in itself, to be considered by the planner together with the rest of the landscape, but having its own physiographic forms and dynamic processes as means of evaluation. The classification of the shorezone must be in terms of types which can be related to its conservation and utilization, but the factors governing use are physiographic and dynamic. The creation of such classifications depends upon the existence of good factual data, which is derived only from a thorough and precise inventory.

The inventory here presented will provide the information required by the planner in the development of shorezone types, together with basic facts required in the solution of problems involving shore stability or change. In presenting the problem of shorezone change, and outlining an approach to classification through inventory, this paper provides a point of departure for the planner in the field of shorezone conservation.

GLOSSARY OF TERMS

Refraction	The bending of wave crests related to changes in the depth of the water.
Convergence	The bending of crests inward upon a point of concentration.
Divergence	The bending of crests outward in an expanding curve.
Orthogonal	Lines at right angles to, and delimiting sections of the wave crests.
Prograde	A seaward extension of the land surface.
Retrograde	A landward extension of the water surface.
Cusp	A microform of the shore having a triangular or toothlike projection toward the sea.
Berm	A nearly horizontal formation along the beach caused by deposit of material under the influence of the waves.
Mass Transport	Referring to the preponderant movement of materials along the beach.
Lee Shore	That shore toward which the wind is blowing and upon which the waves expend their force.
Windward Shore	The shore from which the wind is blowing, having characteristicly low waves and little erosion.
Pocket Beach	A beach located at the head of a bay whose headlands are of rocky cliff or bluff type.
Strand	A constructional or depositional feature of the foreshore or swash zone. Often built in front of marsh shores by wave and current action.

Alongshore Current	A current flowing parallel to the shoreline.
Rip	A surface current flowing seaward at a 90^{o} angle to the shoreline.
Swash Zone	Or Foreshore; That portion of the beach lying between the low water mark and the highest point reached by the uprush of the waves breaking upon the shore.
Back Shore	That portion of the shore reached by waves during exceptional storms only, or subject to ice action.

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