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# SURF FORECASTING

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NORFOLK, VIRGINIA 23511

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## FOREWORD

This report was written under Task 36, "Oceanographic Forecasting Techniques", to give the Navy Meteorologist and Aerographers mate, especially those attached to amphibious forces, a basic background in surf forecasting.

Accordingly, the publication presents a discussion of: (1) Waves, their properties and characteristics; (2) surf, its cause and effect; and (3) forecasting surf conditions for the case of a straight and parallel beach. The concluding section points to the need for further research in this field.

Lt. Gale M. Griswold, USN, former Task Leader of Task 36, wrote the publication. The preliminary edit was performed by Mr. René V. Cormier, the final edit by Mr. John M. Mercer.

This report has been reviewed and approved on 15 January 1965 by the undersigned.

[redacted]

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## 1.1 Introduction

In this era of modern warfare, amphibious operations are still necessary if the Navy is to successfully carry out its mission of implementing the policies of the Nation. Whether it is an actual assault on an enemy beach, the evacuation of personnel from an unfriendly shore, or the supplying of friendly nationals on a remote coast, the amphibious operation is still vital.

One of the factors affecting the accomphishment of an amphibious operation is the condition of the surf which must be navigated. Surf is the name commonly applied to the composite phenomenon when breakers develop in a more or less continuous belt along the shore or over some submerged bank or reef. Very little is known about the action of waves within the surf zone. The University of California made an intensive study of this and other phases of amphibious operations in 1951 but little has been done since that time.

The purpose of this report is to provide a means of forecasting surf conditions, and to describe the work that has been done recently in attempting to improve these forecasts. This report will include a discussion of (1) waves, their properties and characteristics, (2) surf, its cause and effect, (3) forecasting surf conditions, and (4) the need for further research.

## 1.2 Waves--Properties and Characteristics

Any disturbance in water produces waves, that is, a propagated displacement of the surface from normal. The speed with which the wave moves through the water is known as the wave or phase velocity. The speed with which the energy in a group of waves moves through the water is known as the group velocity. The group velocity is one-half the phase velocity for waves in deep water.

Whereas the phase and group velocities of waves are usually measured in tens of knots, the water particles themselves (at any point) have a much smaller average velocity in the direction of propagation of the wave. The exact characteristics of the waves depend on the geometry of the bottom and the nature of the disturbance which produces the waves.

The actual wave patterns can be very complex but we shall limit our discussion to simple sinusodial type waves. Further, we shall assume our waves are two dimensional; that is, the wave height changes only in the direction of propagation, so that the wave crests are all parallel, infinitely long, and oriented at right angles to the direction of propagation. Obviously, real waves are not this simple, but realistic wave patterns may be formed by adding a number of such simple waves traveling in different directions.

With simple sinusodial waves, we can accurately define certain terms: (1) wave length (L), the distance from crest to crest or trough to trough; (2) phase velocity (C), the speed of propagation of the crest; and (3) period (T), the time between crests passing a fixed point (see fig. 1.1). These three quantities are related in that the phase velocity is equal to the wave length divided by the period ($C = L/T$). The theoretical treatment of two-dimensional waves is relatively accurate, provided the wave height, the distance from trough to crest, is small compared to the wave length. However, once the wave attains appreciable height, the simple sine wave is no longer adequate for representation.

The ratio of wave height to wave length can describe the steepness of a wave. As the steepness of waves increases, the waves become less and less sinusodial, and the simple theory breaks down. The curvature of the wave surface near the crest becomes greater than that at the trough until the steepness approximates a value of 1/7, then a peak develops at the crest, the wave becomes unstable and starts to break.

The phase velocity or wave speed of a simple sinusodial wave is dependent on the depth of water through which the wave is moving. The shallower the water, the slower the wave speed. There are three catagories into which water depth is divided when speaking of waves--deep water, intermediate water, and shallow water. These categories are determined by the depth of the water in comparison to the length of the wave. If the depth is greater than half the

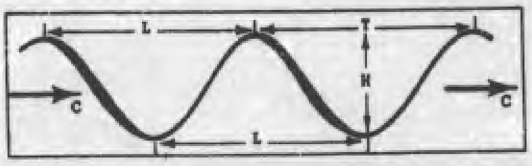


*Figure 1.1. Characteristics of a Simple Sinusoidal Wave.*

length of the wave, the wave is in deep water. When the depth is less than half but greater than one-thirtieth (1/30) of the wave length, the wave is in intermediate water. Whenever the depth is less than one-thirtieth (1/30) of the wave length, the wave is in shallow water. The changes that waves undergo as they move from deep water into shallow water are what determine the characteristics of the surf for any particular beach.

### 1.2.1 *Deep Water Waves*

Waves which result from the wind blowing on the sea surface are called wind waves or sea (fig. 1.2) while they are being developed and swell (fig. 1.3) when they move out of the generating (fetch) area. The growth of these waves is governed by at least three factors: (1) the speed of the wind, (2) the length of time the wind has been blowing (duration), and (3) the distance in the same direction (fetch length) that the wind has been blowing over the water.

After leaving a fetch or generating area, waves travel to a point some distance away — a coast for example — with speeds proportional to their periods. These waves are known as swell and are more uniform and have a longer average period than the original wind waves. The swell loses some of its energy (decays) in its travels to some distant point. The distance which it has traveled from the generating area is known as the decay distance.

When wind waves in a generating area or long trains of swell from some distant storm are observed, a visual estimation of the height or period of the many individual waves will usually result in a single value known as the *significant* height or period. This is the value which the human eye senses as the average, and can be statistically defined as the average height or period of the highest one-third of the waves of the group. This significant height and period is the value reported in synoptic weather reports and is usually the value used when discussing the state of the sea.

*Figure 1-2. Wind Waves or Sea.*

*Figure 1.3. Swell.*

### 1.2.2 *Intermediate and Shallow Water Waves*

When waves enter an area where the depth of the bottom reaches half their wave length, the waves are said to "feel bottom." This means that the wave is no longer traveling through water unaltered, but is entering intermediate water where changes in wave length, speed, direction, and energy, *but not of period*, will occur. These changes are known as shoaling and refraction. Shoaling affects the height of the waves, but not the direction, while refraction affects both; both effects result from the change of wave speed in shallow water.

The shoaling effect is caused by two factors. The first is a result of the shortening of the wave length, as the wave slows down the crests move closer together. Since (considering only shoaling) the energy between crests remains constant the wave height must increase if this energy is to be carried in a shorter length of water surface. Thus, waves can become higher near shore than they were in deep water. This is particularly noteworthy for swell since it has a long wave length in deep water and travels fast. As the swell speed decreases when approaching a shore, the wave length shortens, and a long swell which was barely perceptible in deep water may reach a height of several feet in shallow water (fig. 1.4). The second factor in shoaling has an opposite effect and is due to the slowing down of the wave or phase velocity until it equals the group velocity. As the group velocity represents the speed with which the energy of the waves is moving, the height of the individual waves will decrease with its decreasing speed until the wave and group velocities are equal. The second factor predominates when the wave first feels bottom, decreasing the wave height to about 90 percent of its deep water height by the time the depth is one-sixth of the wave length. Beyond that point, the effect of the decreased distances between crests dominates so that the wave height increases to quite large values close to shore.

When waves arrive from a direction that is

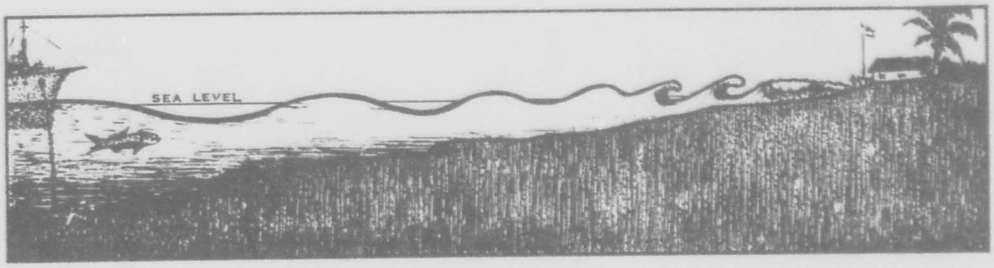


*Figure 1-4 Shoaling.*

normal (perpendicular) to a straight beach, the wave crests will parallel the beach. If the waves are arriving from a direction other than normal to the beach, or the beach is not straight the waves will bend, trying to conform to the bottom contours. This bending of the waves is known as refraction and results from the inshore portion of the wave having a slower speed than the portion still in deep water (fig. 1.5). This refraction will cause a change in both wave height and direction in shallow water. The amount of change is usually determined with the aid of a refraction diagram (fig. 1.6). This diagram may be constructed graphically from hydrographic charts, prepared from aerial photographs, or calculated by numerical (computer) methods.

A refraction diagram may be considered to be a map showing the wave crests at a given time or the successive positions of a particular wave crest as it moves shoreward. Lines at right angles to the wave crests, called wave rays, are constructed to show the direction the waves are moving and to measure the increase or decrease in wave energy. The wave energy between any two rays is considered to remain constant from deep water to shallow water. Thus, spreading rays indicate decreasing wave height and converging rays indicate increasing wave height. For these reasons, only the rays are often shown on a refraction diagram, since these can give an indication of both wave direction and height changes.

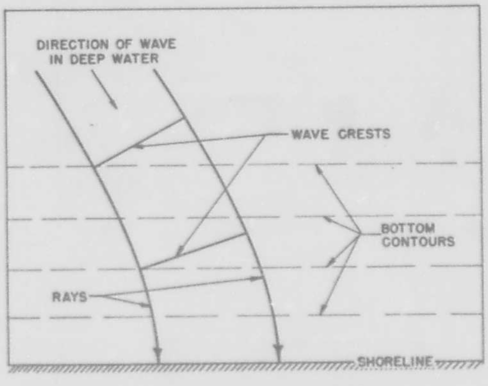


*Figure 1-5. Wave Refraction on a Straight Beach.*

The graphical construction of wave refraction diagrams by either the wave front method, the ray method, or from aerial photographs is described in detail in *H. O. Pub. No. 605* [2]. A refraction diagram indicates the refraction of a wave of a given period and the deep water wave direction. A separate diagram must be constructed for each wave direction and period which may arrive at that particular beach. This could entail up to 600 man-hours or more for any beach, and thus it is usually impossible for amphibious forces to construct refraction diagrams for assault beaches prior to an amphibious operation. By the time the actual landing sites are chosen from the number of possible beaches, there is insufficient time to construct even a few of the required refraction diagrams. For this reason, most surf forecasts for amphibious operations are made without the aid of refraction diagrams.

A computer method, developed at NWRF, is currently being used at FNWF Monterey to predict wave refraction, utilizing the most climatologically probable data for a given beach. This method will allow refraction studies to be made at many pertinent beaches. The refraction of any given deep water wave can be accomplished in minutes. Also, this numerical method can calculate the relative wave height at any point along a ray, incorporating both shoaling and refraction factors. In addition, it is now possible to calculate a *complete* refraction diagram for a given beach with a digital computer; such as, the CDC 1604.

### 1.3 Surf--Cause and Effect

The breaking of waves, in either single or

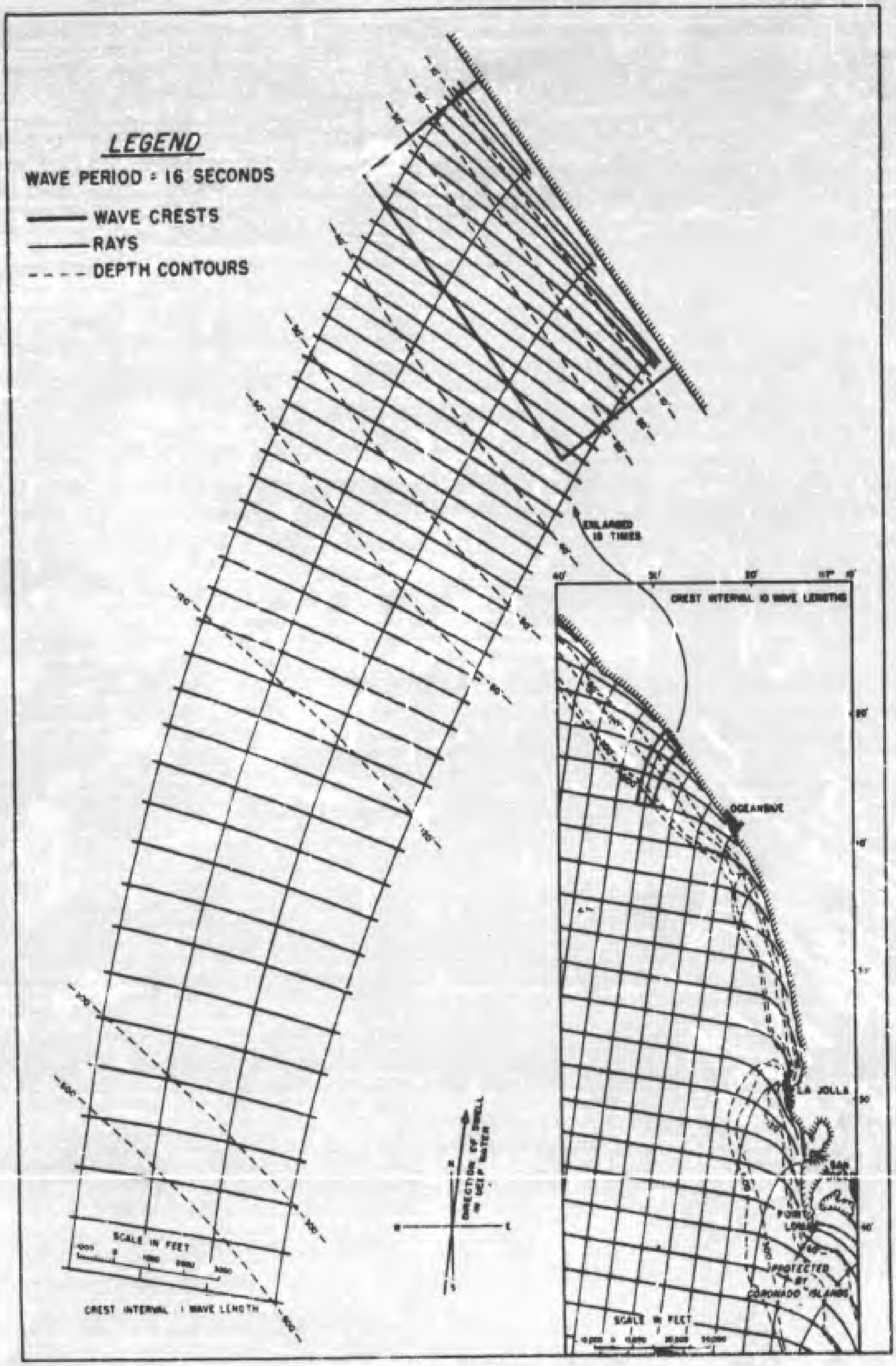


Figure 1.6.   A Wave Refraction Diagram.

multiple lines, on sloping beaches or on rocky promontories is the phenomenon generally known as surf. The surf zone is the areal extent of the breaking waves, from the water up-rush on shore to the most seaward breaker. This zone will vary with the slope of the beach and the characteristics of the deep water waves.

### 1.3.1 *Causes of Surf*

A wave causes appreciable orbital movements of the water through which it is traveling, extending from the surface to a depth equal to half its wave length. When the wave enters water which is shallower than half its wave length, the motion of the water near the bottom is retarded by friction. This causes the bottom of the wave to slow down. As the water becomes more shallow the wave speed decreases, the wave length becomes shorter, and the wave crest increases in height. This continues until the crest of the wave becomes too high and is moving too fast. At this point, usually where the height of the wave equals eight tenths (0.8) of the water depth, the crest of the wave becomes unstable and crashes down into the preceeding wave trough; at this point the wave is said to be breaking. The type of breaker; that is, whether spilling, plunging, or surging, (fig. 1.7); is determined by the steepness of the wave in deep water and the slope of the beach. A gentle gradual slope of the beach bottom usually causes spilling breakers, steeper sloping beaches cause plunging breakers, and very steep beaches may cause surging breakers. Rather perpendicular beaches and cliffs reflect waves which impinge on them, causing a confused surf zone.

The long period waves, or swell, have long wave lengths in deep water and, therefore, concentrate more energy in the crest of the wave as the wave length shortens in shallow water. This causes the wave height to increase much more than for short period waves. The spread, or refraction, of waves in bays causes the waves to spread out along the shore and reduces the height of the surf. Promontories or shoal areas cause a concentration of waves which increase the height of the surf at those points.

Offshore winds, outgoing tides, or opposing currents from river mouths cause the waves to break sooner and may change spilling breakers into plunging breakers. Onshore winds and incoming tides cause waves to break nearer shore and may change plunging breakers into spilling breakers.

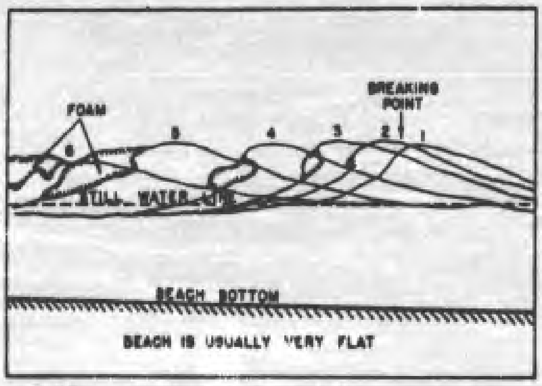
### 1.3.2 *Effects of Surf*

The breaking of waves on beaches dissipates the remaining energy imparted to the waves by the wind during their formation. This concentration of energy on beaches and coasts causes the beaches to be physically changed continuously. These changes are easily noticed on some northern California beaches where low waves and surf build up the beaches during the summer, and high waves and surf remove the sand during the winter. High waves move the sand out to deeper water where it remains until gentle wave action transports it shoreward again.

Longshore currents are often generated by waves breaking at an angle to the beach. These currents themselves or, in addition, the semi-permanent longshore currents will transport sand up and down the beach. Landing craft are vitally affected by these longshore currents as they usually occur between the offshore bars and the beach. This is the area in which landing craft are beaching and retracting and, therefore, most vulnerable. These longshore currents can be forecast for straight, uniformly sloping beaches, with parallel bottom contours, when short period waves are breaking at an angle to the beach. Actual measurements of currents produced by all types of waves show a wide variability in speed, the variations being about equal to the average speed for a number of measurements.

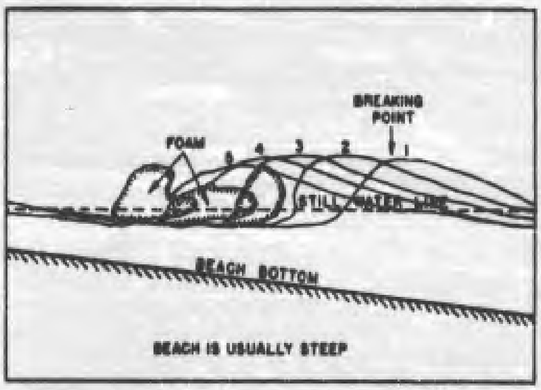
Rip currents, often erroneously called "rip tides", are caused by the return flow of water from the shore back thru the surf zone. This current can be thought of as a small jet or neck which comes back through the breaker zone and fans out into a plume shaped head behind the breakers. The average dimensions of the various parts are shown in figure 1.8. These features can often be recognized by the discoloration of the water caused by its high sediment and bubble content.

The position of a rip current is predictable in some cases. They commonly form at the down-current end of a beach where a headland or a groin deflects the longshore current seaward. These rip currents have a semipermanent location, but on any beach they may be absent, irregularly, or regularly spaced at long or short intervals and persist for a few minutes or a few hours.



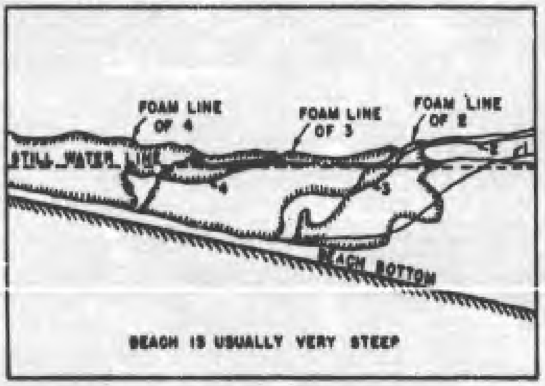
SKETCH SHOWING THE GENERAL CHARACTER
OF SPILLING BREAKERS

(*a*) Spilling Breakers: *The wave becomes unstable at the crest to form white water at the crest. The white water expands slowly down the front face of the breaker. The breaking action is mild.*



SKETCH SHOWING THE GENERAL CHARACTER
OF PLUNGING BREAKERS

(*b*) Plunging Breakers: *The wave crest advances faster than the base of the wave to fall on the front face with a violent action. The resulting white water appears almost instantly over the complete front face. The white water is highly agitated.*



SKETCH SHOWING THE GENERAL CHARACTER
OF SURGING BREAKERS

(*c*) Surging Breakers: *The wave crest tends to advance faster than the base of the wave to suggest the formation of a plunging breaker. However, the wave base then advances faster than the crest, the plunging is arrested, and the breaker surges up the beach face as a wall of water which may, or may not, be white water.*

Figure 1.7. Sketches (Before, During, and After Breaking) of Three Breaker Types.

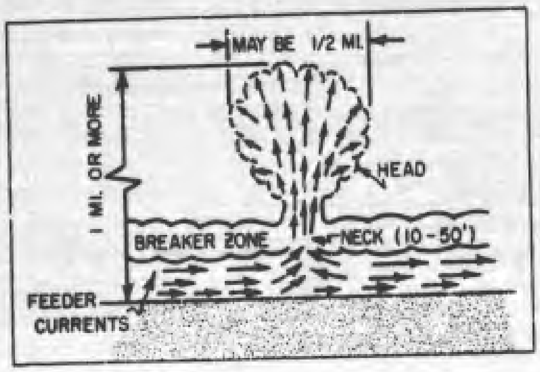


*Figure 1.8. Average Dimensions of Rip Currents.*

Thus, it can be seen that the conditions in the surf zone depend on a number of relationships and are continually changing. Knowing some of the causes and their effects may give the forecaster a better appreciation for the actual changes taking place in shallow water. Forecasting surf is still more of an art than a science, thus any and all factors should be used which might help in estimating the conditions that will prevail at a given time, as well as when these conditions might change.

As in weather forecasting, experience in surf forecasting will give the forecaster an opportunity to develop his own rules and procedures within these general guide lines.

## 2. FORECASTING SURF CONDITIONS

The following graphs and nomograms for forecasting surf conditions are taken from a 1951 study of the University of California. Inasmuch as the data for these graphs were taken from wave tank measurements or studies of surf on California beaches, the forecasts may not always agree with observed conditions. The initial forecast for a given beach will be close enough for determining the feasibility of carrying out the operation, and any additional forecasts should be modified in accordance with any reliable surf observations received from the beach.

A surf forecast should include as many of the elements reported in surf observations as can be forecast. These include significant and maximum breaker height, period and type of breakers, the angle the breakers make with the shore line, longshore current, number of lines of breakers, and the width of the surf zone (see figs. 2.1 and 2.2). Any additional information which may be of value, such as breakers on an offshore bar, should be included.

An example of a surf forecasting worksheet is shown in figure 2.3. A similar sheet should be an aid in compiling a surf forecast. It is assumed that the forecaster will have the beach slope and orientation available, as well as deep water wave conditions, either observed or forecast. The surf forecast is made as follows:

Step 1. Obtain the deep water wave steepness (equivalent to $H_o/T^2$) index from figure 2.4, deep water wave height ($H_o$ in feet) versus period ($T$ in seconds).

Step 2. Enter figure 2.5 with the deep water steepness index ($H_o/T^2$) to obtain the breaker height index ($H_b/H_o$) according to the beach slope. Multiply the deep water wave height ($H_o$) by the breaker height index ($H_b/H_o$) to obtain the significant breaker height.

Step 3. Enter figure 2.6 with the deep water steepness index ($H_o/T^2$) to determine the type of breaker according to the beach slope. As there is usually more than one type of breaker within the surf zone, an estimate of the percent of each type is more informative than stating only the dominant type. Spilling breakers occur on all beaches at the larger wave steepness. The range of spilling breakers is greater for the shallower slopes. At low values of the initial wave steepness, the breakers are plunging or surging. The line of demarcation between the catalogued type of breakers is not definite.

Step 4. Enter figure 2.7 with the deep water steepness index ($H_o/T^2$) and find the breaker depth index ($d_b/H_o$). This value multiplied by the deep water wave height ($H_o$) gives the depth at which the waves start breaking.

Step 5. Enter figure 2.8 with the depth of breaking ($d_b$) to obtain the width of the surf zone according to the beach slope.

Step 6. Enter figure 2.9 with the depth of breaking ($d_b$) and the breaker period (assumed equal to the deep water wave period) to get the breaker wave length ($L_b$). Divide the width of the surf zone (from step 5) by 1/3 of this length ($L_b$). (the 1/3 changes $L_b$ from feet to yards), this will yield the number of lines of surf.

With this information it is possible to complete the surf forecast for the case of a *straight, parallel* beach of uniform slope with *no refraction.* If refraction occurs, the refraction factor ($K_d$) can be determined from figure 2.10 for the case of a straight and parallel beach. This figure is entered with the angle the deep water waves make with the depth contour ($a_o$), and the breaking depth uncorrected for refraction divided by the deep water wave length. The surf forecast values are corrected for refraction by multiplying the deep water height ($H_o$) by the refraction factor ($K_d$) before entering the figure 2.4 to determine the deep water wave steepness index ($H_o/T^2$). This is the steepness the wave would have had in deep water if it had not been refracted. Figure 2.10 also gives the breaker angle ($a_b$) which may be used in figure 2.11 to compute the longshore current. $K_d$ and $a_b$ may be also determined from refraction diagrams, hand calculations, or aerial photographs for beaches which are not straight and parallel. Multiplying the deep water height ($H_o$) by $K_b$ before entering the first graph allows the application of this technique to all types of beaches.

The surf forecast is usually disseminated in a form similar to that used for surf observations in amphibious operations, for example:

SURFCST RED 180600 - 181200R X ALPHA 3.5 X BRAVO 4.5 X CHARLIE 8 X DELTA SPILLING 80 PLUNGING 20 X ECHO 5 RIGHT X FOXTROT WESTERLY 1.2 X GOLF 3 LINES 150 X HOTEL WESTERLY WIND 10 KNOTS BT.

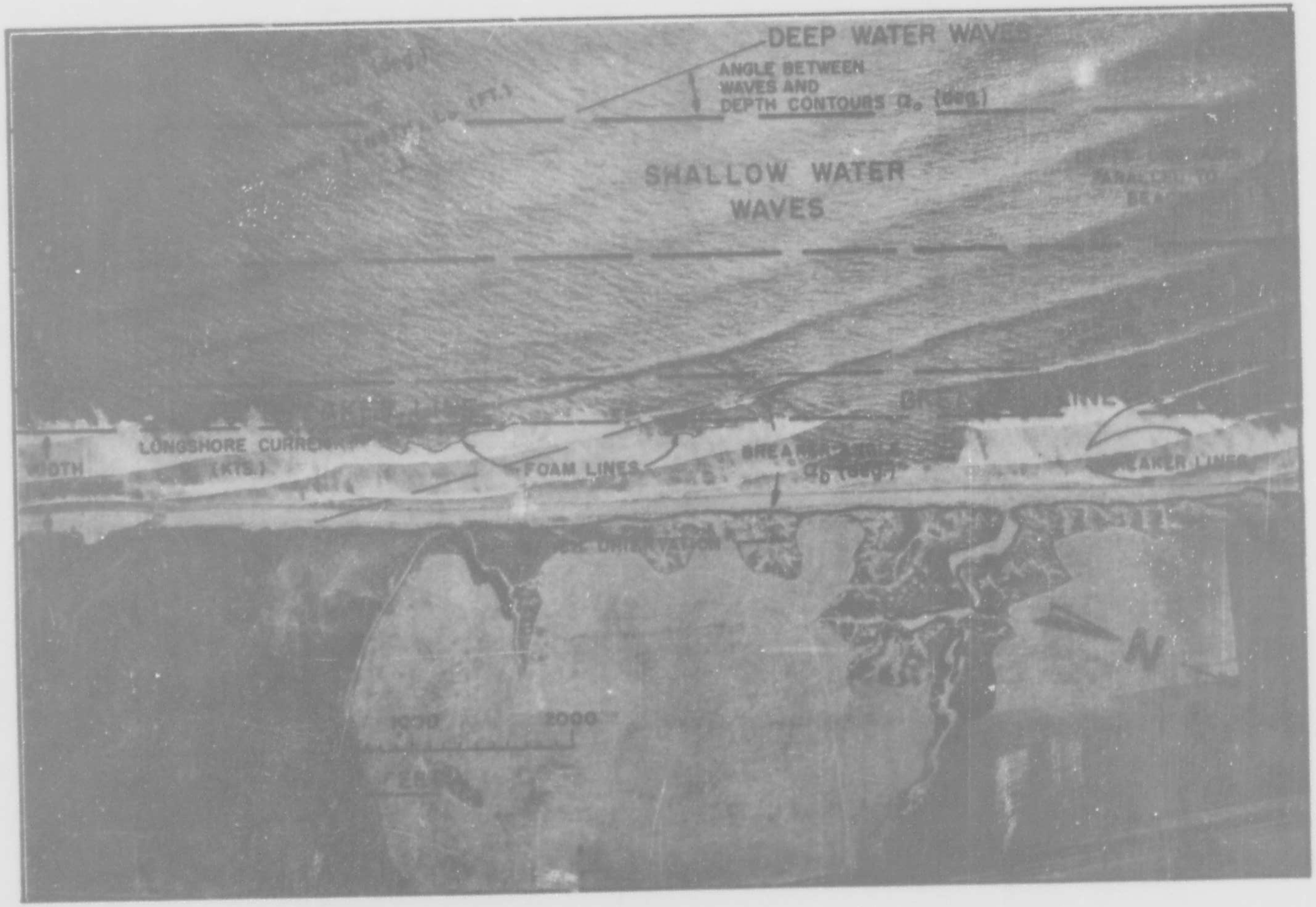
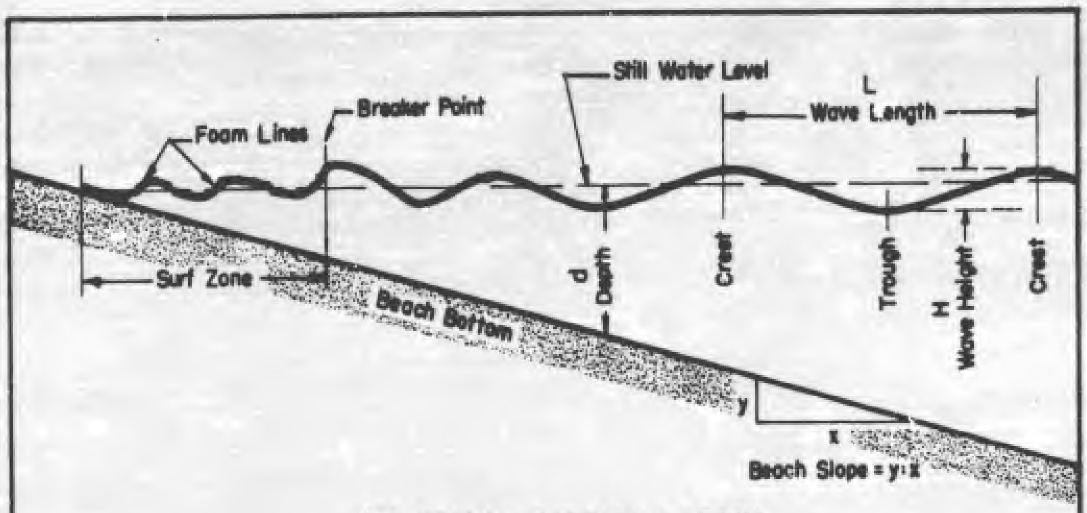
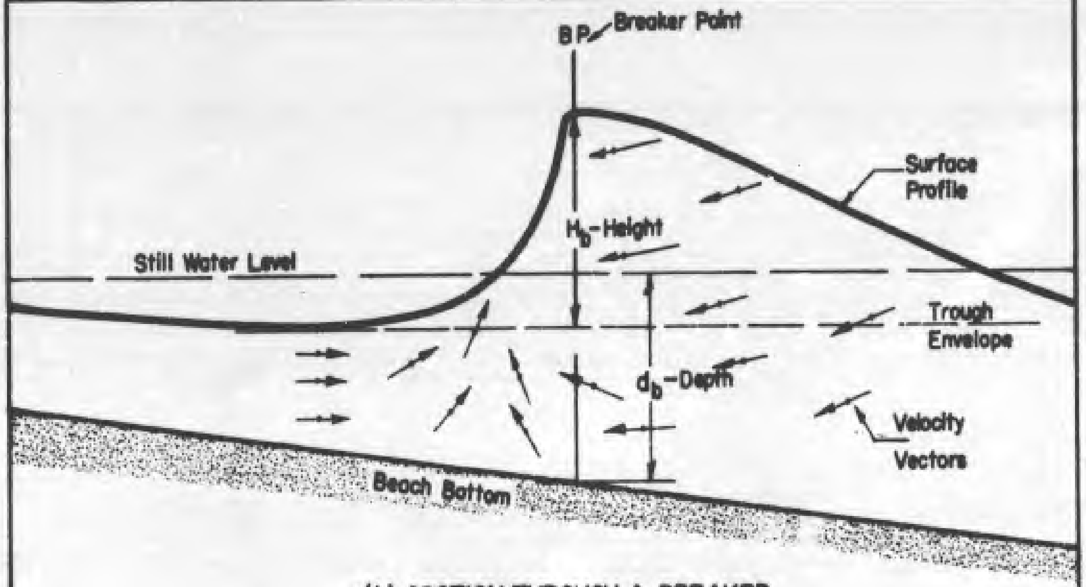


Figure 2.1. Surf Nomenclature.



(a) SECTION THROUGH A BEACH



(b) SECTION THROUGH A BREAKER

*Figure 2-2. Section Through (a) a Beach, (b) a Breaker.*

**Beach** ________ **Date-Time Group Forecast** ________ **Forecast Wind** ________

**Slope** ________ **Forecast Period** ________

**Observed or Forecast**

| | | | |
|---|---|---|---|
| Deep Water Wave Height | $H_o$ | = ________ | ft. |
| Wave Period | $T$ | = ________ | sec. |
| Angle between Deep Water Waves and Depth Contours | $\alpha_o$ | = ________ | deg. |

**Calculations**

| | | | |
|---|---|---|---|
| Deep Water Wave Steepness (Fig. 2.4) | $H_o/T^2$ | = ________ | |
| Breaker Height Index (Fig. 2.5) | $H_b/H_o$ | = ________ | |
| Breaker Height $(\frac{H_b}{H_o} \times H_o)$ = ____ × ____ | | = ________ | ft. |
| Types of Breakers (Fig. 2.6) | | = ____ , ____ | % |
| Breaker Depth Index (Fig. 2.7) | $d_b/H_o$ | = ________ | |
| Depth of Breaking $(\frac{d_b}{H_o} \times H_o)$ = ____ × ____ | | = ________ | ft. |
| Width of the Surf Zone (Fig. 2.8) | | = ________ | yds. |
| Breaker Wave Length (Fig. 2.9) | $L_b$ | = ________ | ft. |
| Number of Lines of Surf (Width × $3/L_b$) = ____ / ____ | | = ________ | |
| Longshore Current (Fig. 2.11) | | = ________ | kts. |

SURFCST ____(BEACH)____ ____(TIME)____ X ALPHA ________ XBRAVO ________ X

CHARLIE ________ X DELTA ________ X ECHO ________ X

FOXTROT ________ X HOTEL ________

A - Significant Breaker Height (ft.)

B - Maximum Breaker Height (ft.)

C - Period of Breakers (sec.)

D - Type of Breakers

E - Angle Breakers Make with Beach (deg.)

F - Longshore Current (kt.)

G - Number of Lines of Surf, Width of Surf Zone (yd.)

H - Remarks

Figure 2.3. Surf Forecasting Worksheet.

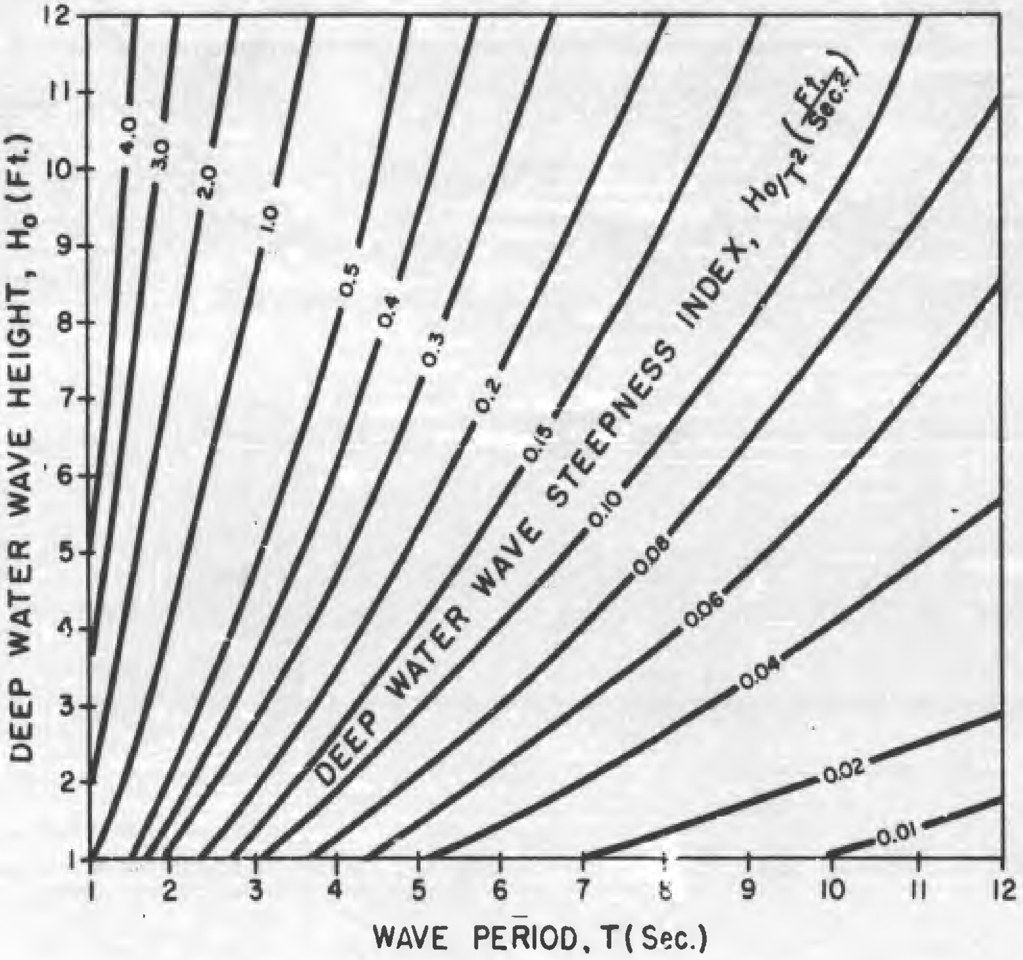


*Figure 2·4. Graph for Determining the Deep Water Wave Steepness Index.*

Where the surf forecast is for Red Beach from 0600 to 1200 on the 18th, usually in local time (X's separate groups; BT, end of message).

| | |
|---|---|
| ALPHA: | Significant breaker height; 3.5 feet. |
| BRAVO: | Maximum breaker height; 4.5 feet. |
| CHARLIE: | Period of breakers; 8 seconds. |
| DELTA: | Type of breakers; spilling, 80 percent—plunging, 20 percent. |
| ECHO: | The angle the breakers make with the beach (less than 90°) from right or left when facing the breakers from shore; 50° from right. |
| FOXTROT: | Longshore current: westerly 1.2 knots. |
| GOLF: | Number of lines of breakers and width of surf zone: 3 lines, 150 yards wide. |
| HOTEL: | Remarks such as wind direction on the beach, breakers on offshore bars, or other significant information not included in ALPHA through GOLF. |

The surf forecast should be sent to all units of the task force which have need of the information. It, like the weather forecast, should not be sent to every unit or to the task force in general if they are not in the vicinity of the beach nor intend to arrive in the vicinity. This often means checking the OP-ORDER to see

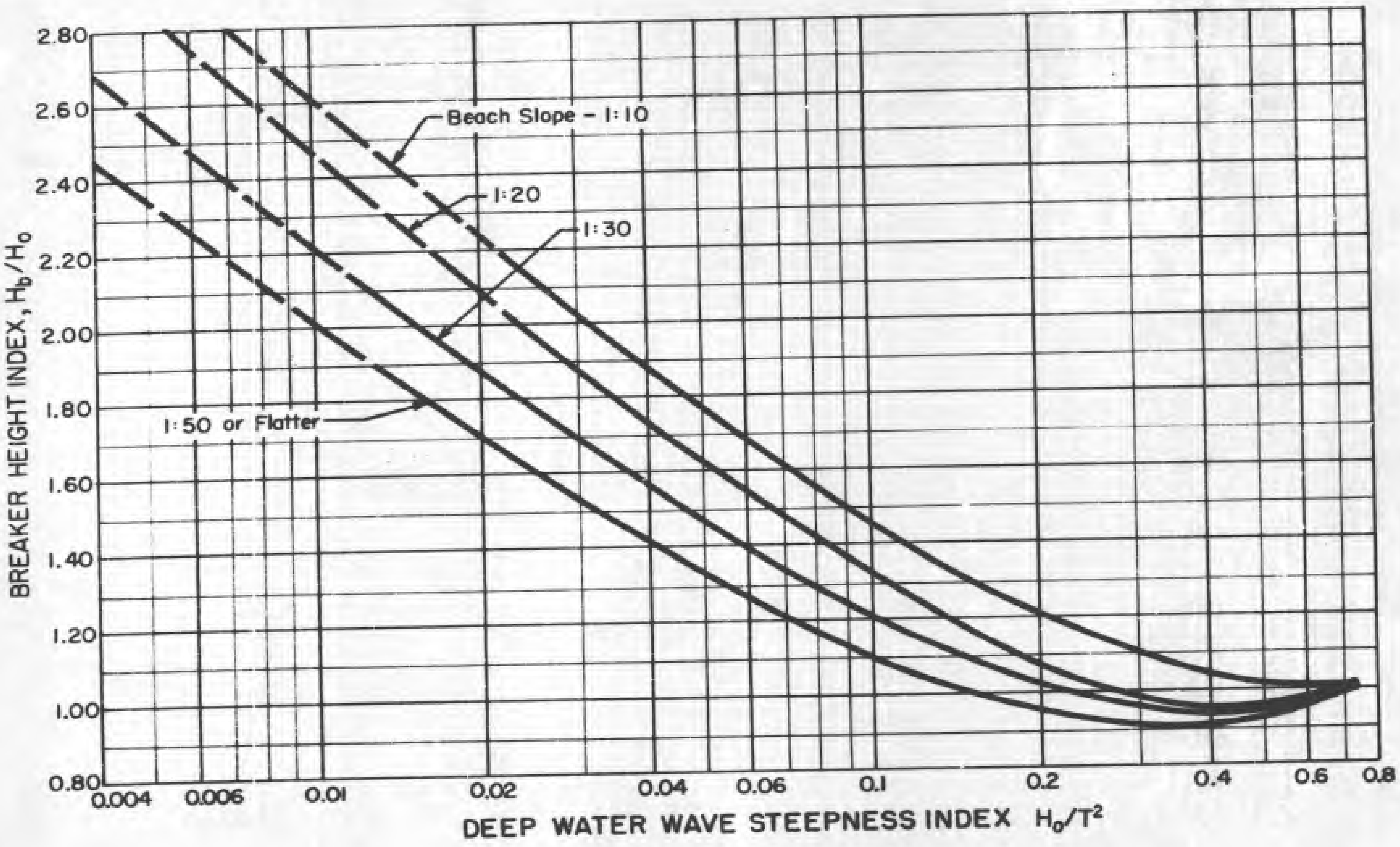


Figure 2·5. Graph for Determining the Breaker Height Index.

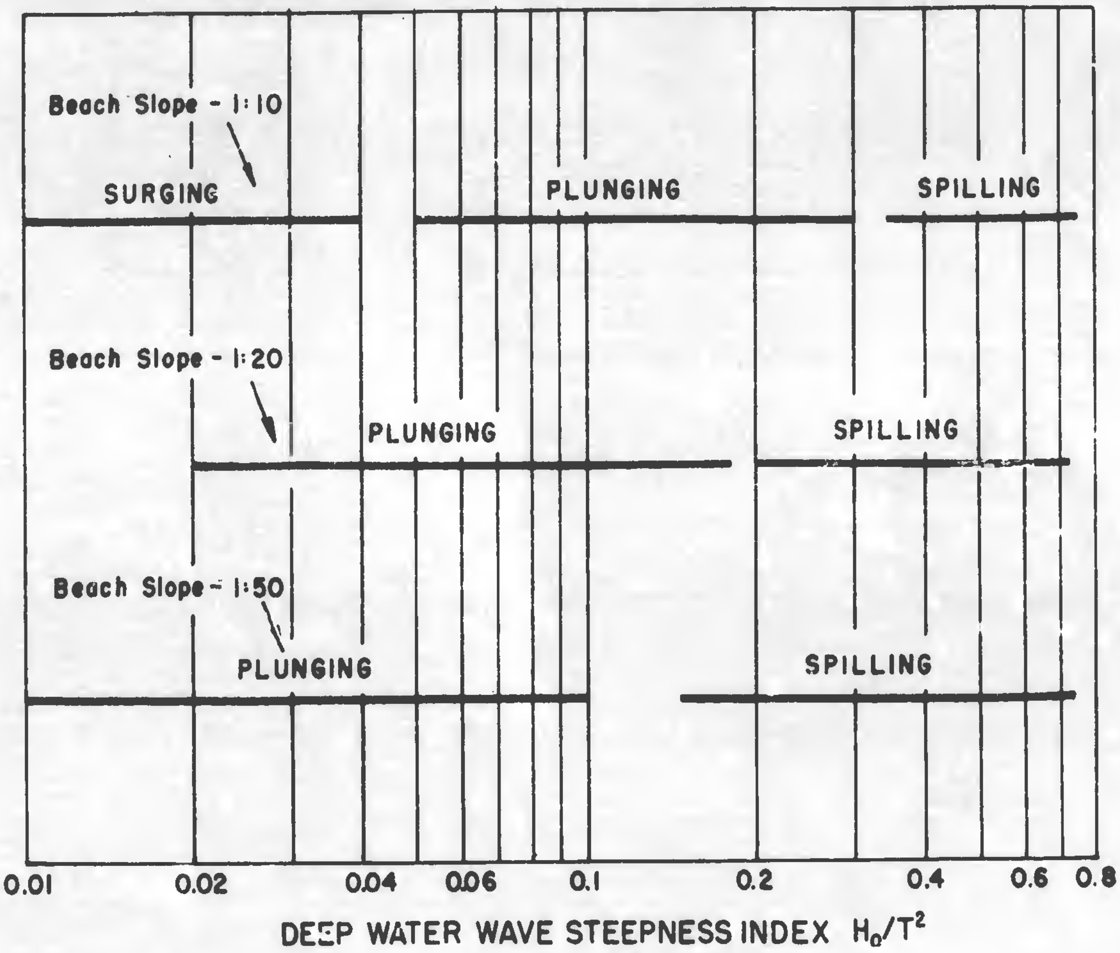


Figure 2·6. Graph for Determining the Breaker Type.

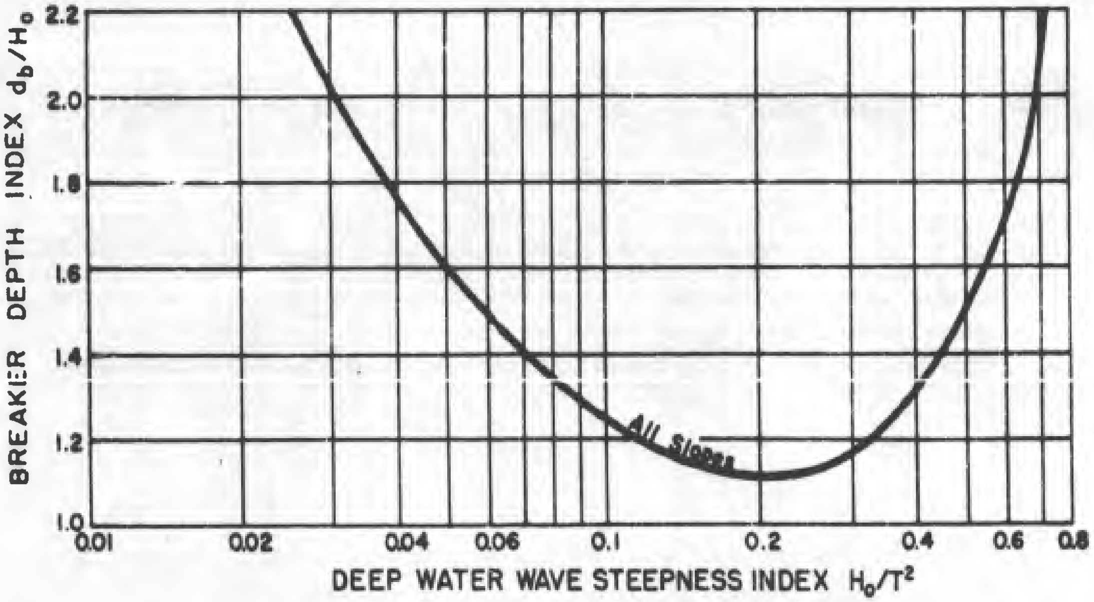


Figure 2·7. Graph for Determining the Breaker Depth Index.

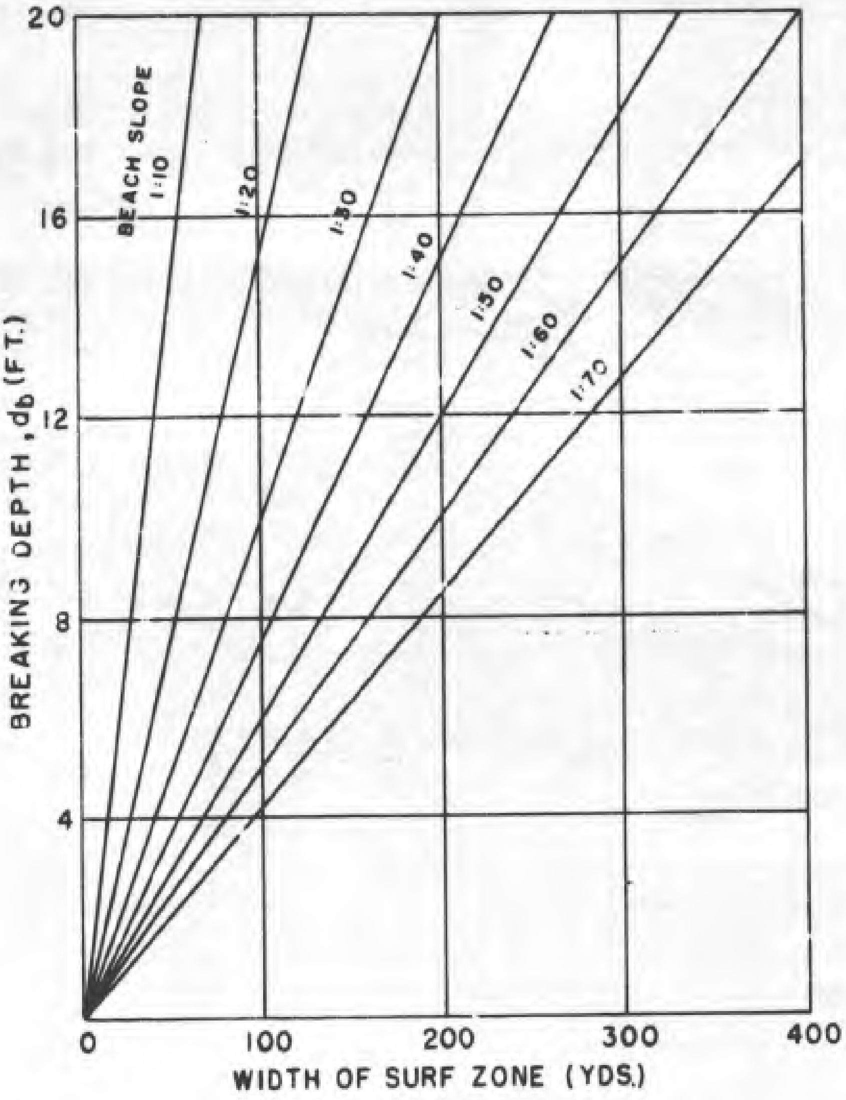


*Figure 2-8. Graph for Determining the Width of the Surf Zone.*

what ships and task units are in the vicinity and which beaches they will use. If two or three beaches are to be used, a surf forecast should be issued for each beach. The forecasts should be made as far ahead as possible, say 24 hours before H hour, and updated when additional information or changing weather conditions warrant. Surf forecasts are just as important after the landing as they are before. Backloading from the beach is as dependent on good surf conditions as is the initial landing and movement of supplies to the beach.

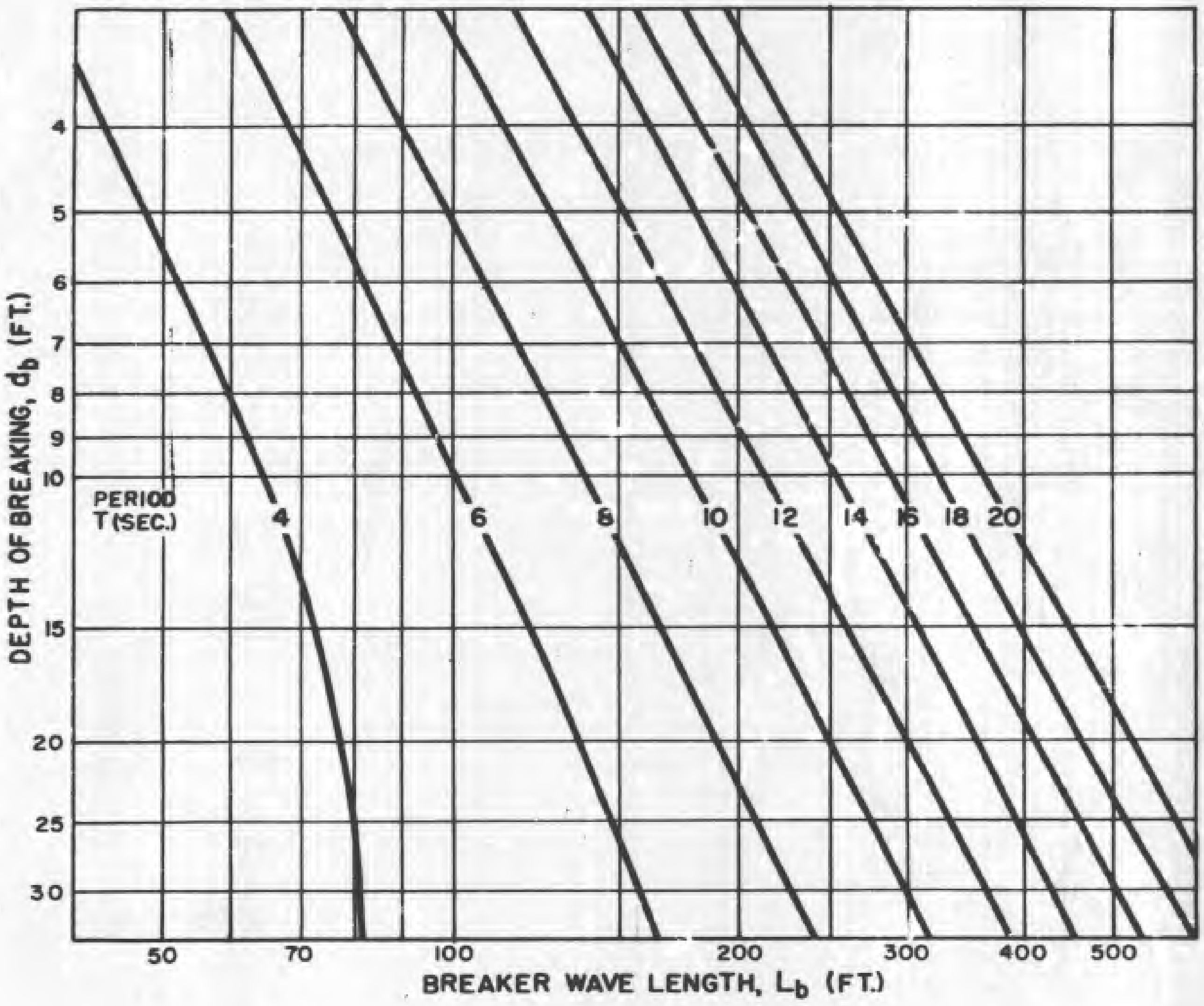


Figure 2·9. Graph for Determining the Breaker Wave Length.

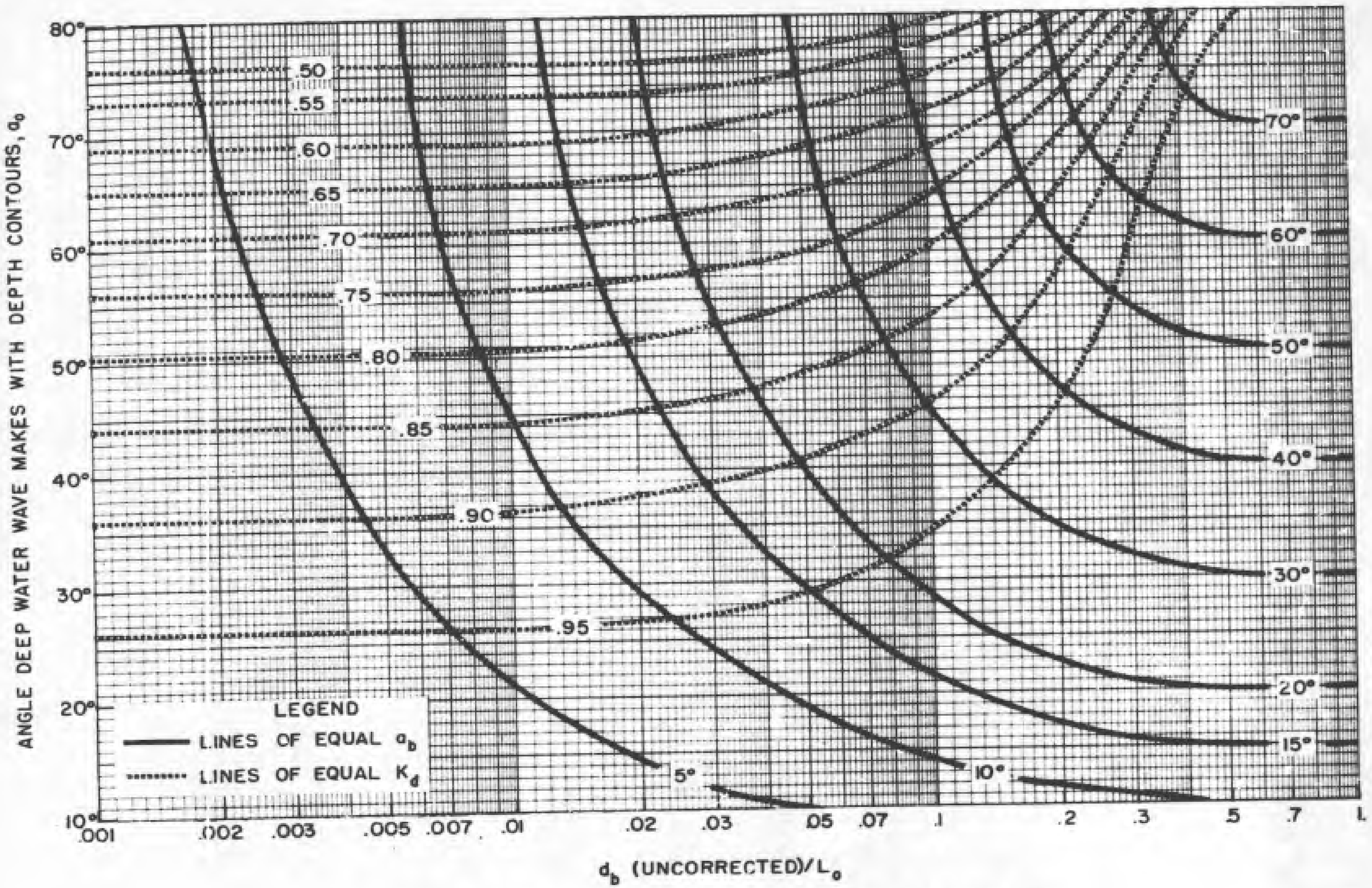
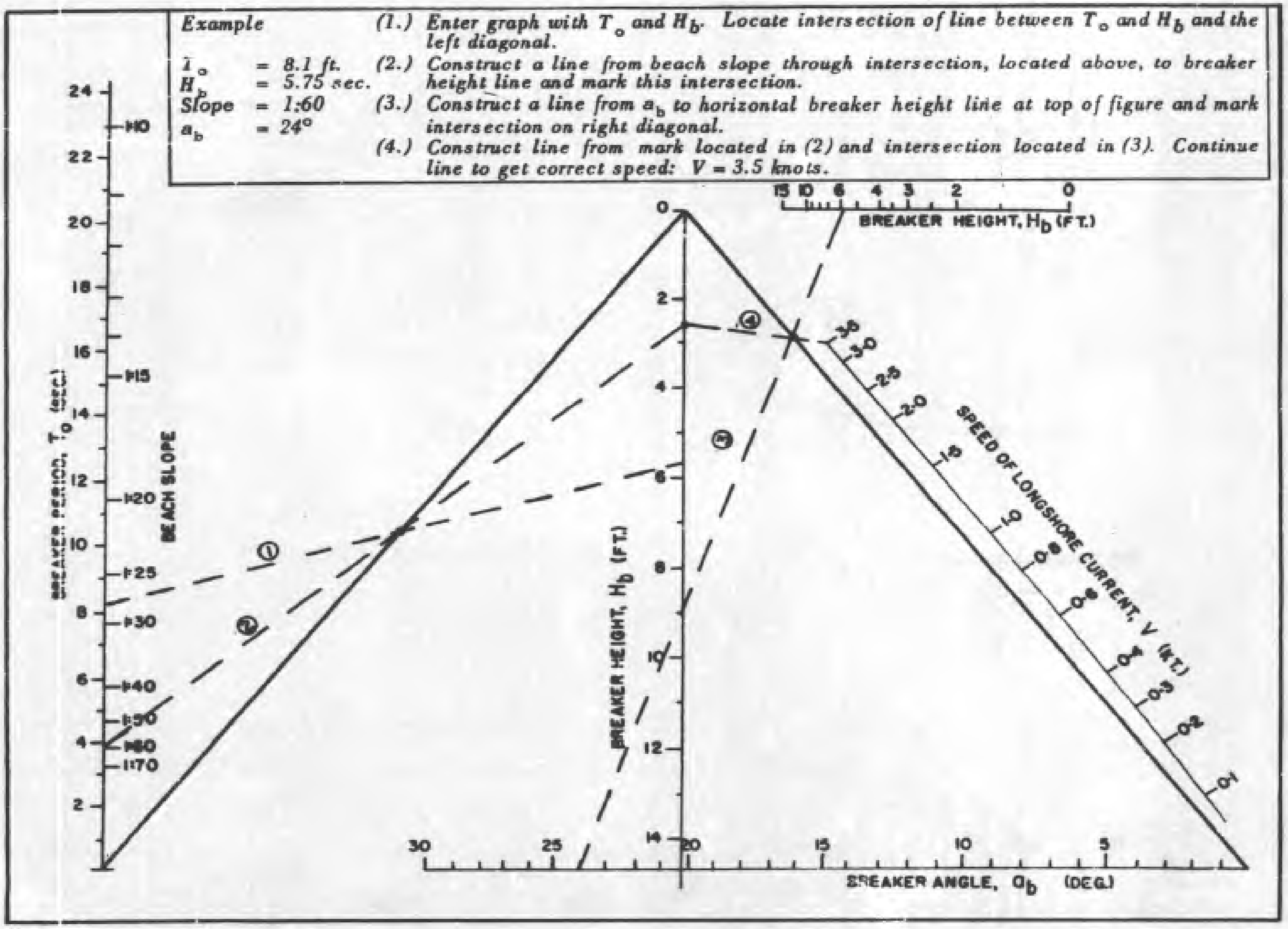


*Figure 2-10. Graph for Determining the Coefficient of Refraction and the Breaker Angle.*



Example

$T_o$ = 8.1 ft.
$H_b$ = 5.75 sec.
Slope = 1:60
$a_b$ = 24°

(1.) Enter graph with $T_o$ and $H_b$. Locate intersection of line between $T_o$ and $H_b$ and the left diagonal.

(2.) Construct a line from beach slope through intersection, located above, to breaker height line and mark this intersection.

(3.) Construct a line from $a_b$ to horizontal breaker height line at top of figure and mark intersection on right diagonal.

(4.) Construct line from mark located in (2) and intersection located in (3). Continue line to get correct speed: V = 3.5 knots.

Figure 2-11. Nomogram for Determining the Speed of the Longshore Current.

## 3. NEED FOR FURTHER RESEARCH

Further research in wave characteristics and their effects is necessary before more accurate forecasts can be made. This forecasting method is based on work that was done on the Pacific coast in 1950 to 1952. Of assistance in this research would be a record of surf forecasts and surf observations for all amphibious operations. These might indicate consistent errors due to erroneous information in the graphs or the lack of some important factor not now included in the forecasting method.

Of equal importance is the need for current information of the effect of surf on the various types of landing craft now used in amphibious landings. The criteria used by both PHIBPAC and PHIBLANT in estimating the effect of various surf conditions on landing craft appear to be in need of updating. In certain cases this *effective surf*, as it is called, may indicate that landing craft can not navigate the surf when in fact there might not even be enough surf to allow the craft to retract after they have beached. The reverse is also possible in that the craft may not be able to negotiate the actual surf when the *effective surf* indicates safe conditions. This is due to the data from which this *effective surf* criteria was derived. The original data was obtained by testing a World War II DUWK on California beaches. Most amphibious craft in use at the present time have much better seakeeping ability than the DUWK as they are primarily boats, not trucks. This is especially true of such craft as the LCU (landing craft utility) with three props and a stern anchor. This data is also biased toward long period waves.

Numerical refraction diagrams for many beaches may be constructed with the program being developed and should improve our ability to forecast surf conditions on these beaches, provided adequate bottom information is available. This will not, however, improve our estimate of the effect of the surf on the various landing craft. A compilation of this data on various amphibious landings would be of great help in establishing a more accurate estimate of the ability of these craft to navigate the various types of surf.

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