CLIMATOLOGICAL WAVE STATISTICS DERIVED FROM FNWC SYNOPTIC SPECTRAL WAVE ANALYSES

Felix Michael Reynolds

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

CLIMATOLOGICAL WAVE STATISTICS DERIVED FROM FNWC SYNOPTIC SPECTRAL WAVE ANALYSES

by

Felix Michael Reynolds

June 1976

Thesis Advisor: W. C. Thompson

Prepared for:
Department of Navigation and Ocean Development.
State of California
Sacramento, California 95815

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NPS-58ReTh76061	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Climatological Wave Statistics Derived from FNWC Synoptic Spectra Wave Analyses		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis Final Report(Jan-Jul 1976
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Felix Michael Reynolds in conjunction with Warren C. Thompson		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS N622716WE00029
11. CONTROLLING OFFICE NAME AND ADDRESS Department of Navigation and Ocean Development, State of California Sacramento, California 95814		12. REPORT DATE June 1976
		13. NUMBER OF PAGES 141
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Spectral Wave Statistics, Spectral Wave Climatology, Wave Climatology

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A summer and winter month of 12-hourly synoptic spectral wave analyses produced by the Fleet Numerical Weather Central, Monterey, California were used to develop three experimental wave climatology formats for a point in the Gulf of Alaska; the analyses were produced by the Spectral Ocean Wave Model at FNWC which computes the wave energy contained in 12 direction bands and 15 frequency bands for a grid point array in the Northern Hemisphere oceans.

The gross climatology format displays frequency of occurrence of significant wave height by period and direction, but does not differentiate between sea and swell. The two-dimensional spectral climatology format is a tabulation of the frequency of occurrence of spectral energy in various frequency and direction bands. The one-dimensional spectral format displays the distribution of spectral wave energy over various frequency bands but contains no directional information. Both of the spectral formats appear to have their greatest potential application in resonance response of floating and fixed structures.

NAVAL POSTGRADUATE SCHOOL
Monterey, California

Read Admiral Isham Linder
Superintendent

Jack R. Borsting
Provost

This thesis was prepared in conjunction with research supported in part by the Department of Navigation and Ocean Development, State of California, 1416 9th Street, Sacramento, California 95814 under standard agreement No. 5-42-96-22.

Released as a
Technical Report by:

Climatological Wave Statistics Derived
from
FNWC Synoptic Spectral Wave Analyses

by

Felix Michael Reynolds
Lieutenant, United States Navy
B.S., University of Washington, 1966

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OCEANOGRAPHY

from the

NAVAL POSTGRADUATE SCHOOL
June 1976

ABSTRACT

A summer and winter month of 12-hourly synoptic spectral wave analyses produced by the Fleet Numerical Weather Central, Monterey, California were used to develop three experimental wave climatology formats for a point in the Gulf of Alaska; the analyses were produced by the Spectral Ocean Wave Model at FNWC which computes the wave energy contained in 12 direction bands and 15 frequency bands for a grid point array in the Northern Hemisphere oceans. The gross climatology format displays frequency of occurrence of significant wave height by period and direction, but does not differentiate between sea and swell. The two-dimensional spectral climatology format is a tabulation of the frequency of occurrence of spectral energy in various frequency and direction bands. The one-dimensional spectral format displays the distribution of spectral wave energy over various frequency bands but contains no directional information. Both of the spectral formats appear to have their greatest potential application in resonance response of floating and fixed structures.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

FIGURE

ACKNOWLEDGEMENT

The author wishes to express his most sincere appreciation to Professor Warren C. Thompson for the many hours spent in consultation, and his immeasurable assistance toward the completion of this thesis. Additionally, the assistance of Sheldon Lazanoff of the Naval Oceanographic Research and Development Activity, and Norman Stevenson and Joe Bottaro of the Development Department of Fleet Numerical Weather Central, is greatly appreciated for the time and effort contributed in producing the spectral wave analyses used in this study. Finally, the author wishes to thank his wife, Margot, without whose periodic inspiration this work might never have been completed.

I. INTRODUCTION

A. OBJECTIVE

The objective of this thesis is two-fold: (1) to examine the properties of the Fleet Numerical Weather Central's (FNWC) Spectral Ocean Wave Model (SOWM) to determine the nature and character of wave information available from this product, and (2) to design and compile three climatological formats using two selected months of SOWM data and to examine their characteristics and potential uses.

B. SCOPE

The FNWC SOWM output provides wave analyses only for specific deep water sites, or grid points, in the Northern Hemisphere oceans. Therefore this thesis deals only with deep water wave climatology and is restricted in application to the Northern Hemisphere. Shallow water wave climatology and transformation processes, i.e., refraction, shoaling, etc. will not be addressed, except to point out the potential applications of the deep-water climatologies in predicting nearshore wave conditions, surf conditions, littoral drift, etc.

The SOWM output is a computer product. Lazanoff and Stevenson (1975) evaluated the SOWM product in some detail by comparison with observed wave conditions from data buoys and shipboard observations, and concluded that the spectral

model is far superior to the previous FNWC non-spectral model. For the purposes of this thesis the wave data is considered to be accurate, and verification of the data with actual wave conditions will not be addressed.

C. BACKGROUND

Existing wave climatologies, often compiled in terms of frequency of occurrence of wave height, direction, and period, may be derived from wave hindcasting techniques, instrument sensors, or visual shipboard observations. These data vary greatly in their time-space sampling, information content, quality, and format. On 19 December 1974 the FNWC put into operational use its SOWM. This approach to analysis and forecasting of the sea surface conditions uses an energy density spectral function which represents the distribution of wave energy over the range of frequencies present in the sea. The two-dimensional spectral analysis routine calculates the total wave energy distribution, or variance, contained in 15 variable frequency bands and 12 direction bands on a twice daily basis (0000Z and 1200Z) for a grid point array covering the Northern Hemisphere oceans, and in the forecast mode can predict wave conditions to 72 hours. This spectral approach is considered to be a significant improvement over previous wave analyses in information content and quality of data. Wave climatologies, then, compiled from these FNWC spectral analyses should be expected to be a significant improvement over existing wave statistics.

D. PROCEDURE

Two months of 12-hourly spectral wave analyses were provided by FNWC for grid point 164 in subprojection 3. The location of this analysis point is shown in Figure 8. One summer month (August 1974) and one winter month (February 1975) were chosen to illustrate the seasonal variability of the wave conditions in the Gulf of Alaska. This point was selected due to its proximity to Ocean Station Papa for possible comparison of the spectral analyses to observed wave conditions. The two months of wave data were extracted from the FNWC historical tapes and printed in the spectral format of which Figure 2 is a sample. A graph of the frequency spectrum showing energy density per equal frequency bandwidth was also computed and plotted for each synoptic analysis by FNWC as shown in Figure 4. From the two month series of analyses, all information potentially useful for the design of the climatology formats was extracted from the SOWM and tabulated in chronological sequence for both months.

The design of the wave climatology formats was initially approached by examining currently existing climatologies for display content and format. To this author's knowledge, spectral climatologies have not previously been formulated; accordingly, the formats for the spectral wave data developed and presented herein are considered to be experimental. These formats present frequency of occurrence statistics. Two of the three experimental formats are similar in design to the widely used statistical tabulations for the California

coast prepared by National Marine Consultants (1960). The third format presents cumulative occurrence statistics in graphical form.

E. WIND REGIME

To better understand the climatological wave statistics for February and August developed for grid point 164, it is instructional to briefly discuss the general meteorological situation which generates the wave fields in this area. This discussion affords a better understanding of the synoptic situations and their associated wind patterns which are responsible for the waves.

During the winter season (January through March) the most severe weather transits through the Gulf of Alaska as strong cyclonic lows which follow a fairly typical storm track. The lows generally originate east of Japan and travel northeastward passing south of Shemya and Adak in the Aleutian Islands and then eastward into the Gulf of Alaska where they recurve to the northeast. These lows develop and deepen considerably as they approach Adak Island, and then move into the Gulf of Alaska at 20 to 30 knots where they stagnate and die out. The low centers generally pass to the northwest of grid point 164, generating a west to southwest wind field at the station. Westerly winds of up to 80 knots are not uncommon during the passage of these storms in the Gulf during the winter months.

During the summer months (July through September) the Gulf of Alaska is influenced by two meteorological regimes:

(1) high pressure centers or ridges south of grid point 164 which generally transit slowly to the east, and (2) weak low pressure centers which move parallel to but to the north of the wintertime lows. Summer season winds at grid point 164 vary from 20 to 30 knots from the west to southwest, but on occasion severe low pressure centers may generate westerly winds of nearly 60 knots over this area (Gerst, 1971).

II. FNWC SPECTRAL OCEAN WAVE MODEL

A. INTRODUCTION

The Spectral Ocean Wave Model (SOWM) is a hindcasting technique which provides a two-dimensional wave spectrum which is composed of a matrix of 12 30-degree direction bands and 15 frequency bands of varying bandwidth. The general hindcasting approach for wave spectra can be applied to historical or real time synoptic surface pressure analyses and to forecasted synoptic conditions as well. The FNWC model presently computes twice daily real-time spectral wave analyses and forecasts out to 72 hours. The SOWM employs a power spectral density function which represents the distribution of total wave energy (sea and swell) at ocean grid points in the Northern Hemisphere. The total wave energy at any location is composed of the energy which is generated by the local wind at that point (sea) plus the energy propagated from the surrounding area (swell) through that point. The SOWM, therefore, consists of two separate parts; the wave energy or growth model (sea), and the wave energy propagation model (swell).

B. WAVE ENERGY GROWTH MODEL

The basic approach for the generation of wind wave energy consists sequentially of obtaining the best estimate of the sea-level pressure distribution, calculating the wind

fields therefrom, and generating the resultant wave field energy. The growth model employs a modified Miles-Phillips technique. When the sea initially begins to grow from calm conditions, the Phillips resonance mechanism predominates, but as wind velocities increase the Miles instability mechanism becomes more dominant. The Phillips theory essentially states that a resonance between the air-sea system occurs when a component of the surface pressure distribution moves at the same speed as a free surface wave of the same wave number. The Miles instability theory states that the mean rate of energy transferred from the parallel shear flow to the surface wave is proportional to the curvature of the wind profile at the height where the mean wind velocity is the same as the phase speed of the wave component (Lazanoff and Stevenson, 1975).

The modification of the Miles-Phillips technique is the result of an alteration of the initial growth portion of the model by Professor Vincent Cardone of New York University. For wind speeds less than or equal to 30 knots, the wave energy will grow at a faster rate during the initial six hours using the Cardone modification than for the unmodified model. The reverse is true for wind speeds greater than 30 knots. After six hours the modified growth rate is always slower than the unmodified one.

Energy input from the growth model is limited by the Pierson-Moskowitz fully developed spectrum for any give wind velocity. This imposes a ceiling on energy output, i.e.,

the fully arisen sea, and precludes unlimited growth of the sea for a given wind speed.

Since energy from a wind field is propagated by the wave field in directions other than the mean wind direction, a partitioning of the wave energy by direction is required. This is accomplished in the SOWM by means of an equation developed by the Stereo-Wave Observation Project which is used to distribute energy in the directional spectra. Since direction bands are computed in 30-degree increments the distribution of wave energy is partitioned as follows: 37.5% in the sector containing the mean wind direction, 25% in the two 30-degree sectors on either side of the mean wind, and 6.25% in the two sectors adjacent to the 25% sectors.

A treatment of the mathematics of the generation model is beyond the scope of this paper; however, more detail is given by Lazanoff and Stevenson (1975).

C. WAVE ENERGY PROPAGATION MODEL

The SOWM propagates wave energy at the group speed of each individual frequency component in accordance with linear wave theory. Swell waves travel across the ocean surface by great circle routes, accordingly the gnomonic projection was selected to simplify mathematical calculations because great circles appear as straight lines on this plane projection. Since great areal distortion would result in attempting to display large ocean areas on one gnomonic projection, the globe was projected onto an icosahedron (a 20-sided polygon with equilateral triangles for its faces) to reduce this

distortion. Each triangle of the icosahedron is a separate gnomonic projection. The icosahedral-gnomonic projection of the globe is shown in Figure 1. Although some distortion remains, it is considered to be within acceptable limits. The projection of the earth's surface onto these planar icosahedral faces alters great circle routes to straight lines (geometrical directions). This fact results in so-called meteorological direction bands (the direction from which wave energy propagates) in which the central direction of each band is different for every grid point. To prevent refraction when wave energy is propagated from one subprojection to another a row of grid points is aligned along each side of the triangle. This scheme precludes discontinuities from existing in the directional propagation of energy.

As a result of computer limitations in storage and computational time, the SOWM is only computed for the Northern Hemisphere. All points south of the equator are treated as land points in the Northern Hemisphere model. Accordingly any swell generated in the Southern Hemisphere will not be included in the Northern Hemisphere wave spectra.

In both the growth and the propagation model, wave energy is dissipated only when the waves encounter land or when swell destructively interacts with the wind. In the later case wave energy dissipation is calculated if the angle between the mean wind direction and the wave direction exceeds 75 degrees. Wave-wave interaction, whitecap generation, and foam streaks are not included in the model as dissipation

mechanisms, although it is felt at least some of these factors may be significant.

D. FNWC SOWM OUTPUT

The SOWM output at a grid point is a two dimensional representation of wave energy. The basic format is shown in Figure 2 and contains the following information:

1. DATE TIME GROUP: DTG 74083100Z

   1974 August 31st 0000Z

2. TAU: The TAU operator denotes the time of computation relative to the DTG.

   TAU = 0 : real time synoptic analysis

   TAU = -6 : hindcast mode

   TAU = 12 to 72: forecast mode from 12 to 72 hours

3. SUBPROJECTION: Denotes the number of the icosahedral triangle in which the grid point is located; in this example it is number 3 (see Figure 1).

4. GRID POINT: Numbered from 1 to 325 in each subprojection. The grid point number is the identifier for the location at which spectral energy is computed. In the sample a number of 0.00 is shown. This is an artifact of the calling routine for the extraction of climatological data. The actual grid point number for this spectral printout is 164.

5. LAT, LONG: The latitude and longitude of the grid point. Latitude is always given in degrees north.

Longitude is always given in degrees east (from 0° to 360°E).

6. WIND SPEED: Given to nearest hundredth in knots.
7. WIND DIRECTION: Given in geographical degrees. It is the direction from which the wind blows.
8. USTAR: Frictional wind velocity computed from the analyzed or computed wind speed. USTAR is the actual input to the wave spectral model growth equations.
9. FREQ: The central frequency of each of the 15 frequency bands. For these frequencies, the frequency bands, frequency bandwidths, scaling factors, and equivalent period values are given in Table I. Note all frequency bands are not of equal bandwidth.
10. DIR: Each coded entry, 1 through 12, corresponds to the MET DIR's listed in item 11.
11. MET DIR: The central direction, called the meteorological direction, is given in geographical degrees in each of the 12 30-degree bands.
12. The matrix of 180 data bits (12 directions times 15 frequencies) will be subsequently referred to as "internal" data. Each entry represents the energy in terms of sea surface variance in dimensions of $(\text{feet})^2$, associated with a particular frequency band and a particular direction band.
13. Item 13 represents the summation of all energy contained in a given frequency band irrespective of

direction, and therefore constitutes a one-dimensional frequency spectrum. These entries will be subsequently referred to as "external" data. The entry of maximum energy will be referred to as E_1, with its associated frequency or period, T_1. The entry containing the second largest amount of energy is designated E_2, with its corresponding period, T_2, etc. The values of E_1, E_2, etc. may or may not be adjusted to equal bandwidths. This adjustment will be discussed in a later section.

14. Item 14 reflects the summary of energy in a given direction band, over all frequencies. These values constitute a one-dimensional direction spectrum, and will also be referred to as "external" data. The entry containing maximum energy from the direction spectrum will be designated as E_a and the corresponding direction band ψ_a; secondary values will be designated E_b, ψ_b, etc. No correction for variable bandwidth need be applied to these data.

15. Item 15 represents the total energy in the frequency spectrum and also in the direction spectrum, and is given by

$$\sum_{f=1}^{15} E_f = \sum_{\psi=a}^{1} E_\psi = E_t .$$

E_t is also given by the total of the 180 energy bits in the internal data. E_t is total variance;

accordingly, the significant wave height is given by: $\bar{H}_{1/3} = 4\sqrt{E_t}$. Other wave height parameters that may be of interest are given in Appendix A; they may be computed in an analogous manner to those listed in H. O. 603.

It should be noted for subsequent reference that the gross characteristics of the sea surface, referred to within FNWC as singular wave data, may be given by $\bar{H}_{1/3}$, ψ_a, and T_1. These parameters describe the significant height of the wave field, the central direction of the band containing the maximum amount of wave energy, and the central period (inverse of frequency) of the band containing the maximum amount of energy, respectively.

E. ONE-DIMENSIONAL FREQUENCY SPECTRUM

Although not routinely produced by FNWC, it is instructional to examine a plot of the external one-dimensional frequency spectrum. The data can be plotted for the bandwidths generated by the SOWM output or for equal bandwidths. Both types of presentations will be examined in some detail.

Figure 3 is a plot of the one-dimensional frequency spectrum using the FNWC variable bandwidths as displayed on the SOWM output shown in Figure 2. The total area under the curve, is not equivalent to E_t. This particular synoptic analysis was selected to illustrate additional information which may be obtained from the SOWM. The lower frequency energy peak of 0.067 Hz clearly represents incoming swell. It may be noted that the swell is fairly narrowly constrained

in bandwidth and significantly longer in period than the sea component that is also present. The apparent peak of energy centered about a period of 7.5 seconds represents wind-generated sea at the grid point. It exhibits the general tendency of sea to occupy a broader period spectrum than swell when plotted on a linear frequency scale.

An FNWC machine-generated plot of the same one-dimensional frequency spectrum is shown in Figure 4. In this plot the energy component values of each FNWC frequency bandwidth have been multiplied by a scaling factor so as to give the energy density per constant bandwidth. The scaling factors are given in Table I. The standard bandwidth used for this computation is 0.0055 Hz. In contrast to Figure 3, the total area under the curve is proportional to the actual total energy in the wave field. The frequency bands from 0.039 Hz through 0.083 Hz, which are of constant bandwidth, retain the same shape as in Figure 3, although the energy scale is magnified by a factor of 180. For periods greater than 12 seconds, alteration of the curve becomes apparent as a result of the variable scaling factors. In Figure 3 there are three points of peak energy, while in Figure 4 there are four. It may also be noted that the period maximum of the sea present does not agree in the two figures. The correct portrayal of the shape of the frequency spectrum is that of Figure 4.

It is not always possible to distinguish between sea and swell in the frequency spectrum, especially under high wind conditions; nevertheless, multiple energy peaks apparently

representing wave energy from different wind areas are frequently present. Figures 5 and 6 show the occurrence of multiple peaks for two selected months of FNWC 12-hourly analyses. Both time series graphs were constructed using the equal bandwidth frequency spectrum plots generated by FNWC. It was initially presumed that it frequently would be possible to identify individual wave trains on the basis of their continuity from a time-series analysis of monthly data. However, the highly discontinuous nature of secondary and lower order peaks for both months appear to preclude this as a possibility. From these data, however, a frequency of occurrence tabulation of period peaks (T_1, T_2, etc.) was generated and is presented in Table II. Examination of Figure 5 shows that for the August data, the primary energy peak, T_1, is with few exceptions confined to periods of 6.1 seconds to 9.7 seconds. The February data in Figure 6, however, shows the primary energy peaks to be contained within a range of periods from 9.7 seconds to about 16.4 seconds. This result is not unexpected as longer period waves are generated under the higher wind conditions which exist during the winter months in the North Pacific.

F. ONE-DIMENSIONAL DIRECTIONAL SPECTRUM

The one-dimensional directional spectrum represents the energy propagated in the 12 direction bands, independent of frequency. Figure 7 is a plot of the directional spectrum for the SOWM printout shown in Figure 2. The energy peak centered about ψ_a = 3 (259.5 degrees true) can be identified

as the same wave energy which was previously identified as swell. As may be seen in Figure 2, this energy is contained in the 30-degree direction band centered about MET DIR 3. The secondary band centered about ψ_b = 5 corresponds to the energy previously identified as sea which, even though of lesser energy content, occupies a somewhat broader directional distribution than does the swell. For the two selected months of 12-hourly FNWC wave analyses mentioned above, the frequency of occurrence of multiple direction peaks was computed and is contained in Table III. It will be noted that the maximum number of peaks never exceeded two in number. For this reason, a time-series analysis for multiple direction peaks was not considered to be of significant value in describing the directional spectrum.

The interpretation of the one-dimensional frequency and direction spectra in the preceding sections is based on some basic principles of wave analysis. First, sea is more broad-banded in both direction and frequency distribution than swell for the same peak energy density, and second, for two or more separate wave trains, the higher frequency energy may be sea or swell, and all other components of lower frequency are swell (Kinsman, 1965). From the application of these principles it may be possible to identify sea and swell components of the wave field which could assist the user in the interpretation of synoptic wave data.

III. CLIMATOLOGY FORMATS

A. INTRODUCTION

The SOWM spectral analyses yield two basic types of wave data: the gross data and the spectral data.

The so-called gross form derives its name from the fact that a single height, period, and direction value give a gross or overall picture of the wave field conditions. Both of these kinds of data may be compiled in several ways to produce wave climatologies. A most useful form for many wave statistics users is a compilation by frequency of occurrence of wave height (or energy) with an associated period and direction parameter.

Three experimental formats were selected to explore and demonstrate several alternatives available for the display of useful wave climatology data: The gross (singular) format, the two-dimensional spectral format, and the one-dimensional spectral format. In all three formats the data entries in the various tables represent the number of specific occurrences during the two representative summer/winter months for grid point number 164. One occurrence represents the wave conditions or parameters which exist at the time of a single 12-hourly analysis; thus, a 30-day month would have a total of 60 12-hourly analyses, or 60 occurrences. It was decided that event occurrences (i.e., number of events) would be a more preferable parameter in which to express the frequency

of occurrence for data display than percentage occurrence or duration of occurrence. This was done because the monthly data are not continuous or complete owing to some missing observations in the FNWC's historical synoptic files for the two months selected. Conversion from number of occurrences to percentage or duration of occurrence can readily be accomplished if desired.

B. GROSS CLIMATOLOGY FORMAT

The data extracted from each 12-hourly FNWC synoptic analysis which were used to built the gross wave climatology is composed of the total energy, E_t (which yields significant height via a simple arithmetic operation), the central direction of the directional bandwidth containing the maximum amount of energy, ψ_a, and the central period (adjusted to the standard frequency bandwidth of 0.0055 Hz) containing the maximum energy, T_1 (adjusted). Using the SOWM printout in Figure 2 as an example, these data were obtained as follows: E_t corresponds to item 15, and equals 3.145 ft^2 (accordingly $\bar{H}_{1/3}$ = 7.09 ft), and ψ_a corresponds to the directional band number 3 or 259.5 degrees. From Figure 4, T_1 (adjusted) is a period of 15.0 seconds, or 0.067 Hz. The basis for selection of E_t and ψ_a as parameters for describing the gross character of a wave field is obvious. It is evident, however, from the discussion in Section IIE, that the identification of the period of maximum energy density per standard frequency bandwidth is somewhat more complex because of the use of variable frequency bandwidths by FNWC. Since the use of

variable frequency bandwidths does not give the energy distribution in equal frequency segments, the energy values composing the frequency spectrum must be adjusted to equal bandwidths by application of the scaling factors listed in Table I in order to allow identification of T_1 (adjusted).

The gross climatology format that has been designed contains a linear wave height scale employing two foot increments up to 40 feet and keyed to coded values from 01 to 21, as shown in Table IV. The selection of the two-foot height increments was subjective, but it was felt that this scale provides adequate definition of the lower wave heights, and should be retained to preserve the accuracy available from the SOWM in the higher wave heights. The 12 directional bands from the SOWM were used in the interest of preserving as much directional definition as is available, as were the 15 central periods (frequencies). The resultant gross climatology format is illustrated in the tables of Appendices D and E.

The actual procedure for data entry into the climatology format amounts to the extraction from each 12-hourly analysis of T_1 (adjusted), ψ_a, and $\bar{H}_{1/3}$, according to the procedures described above. These constitute one synoptic analysis event which is entered in the appropriate table of the gross climatology. Tables D-1 through D-12 of Appendix D contain the gross climatology for the month of February 1975, and Tables E-1 through E-12 of Appendix E is a similar compilation for August 1974. These tables are presented in the appendices because of their bulky size. Because of the

sparcity of data in these tables and in order to better illustrate the nature of the statistical distribution, cumulative totals of event occurrence for all directions were compiled for February and August, and are shown in Tables V and VI. The cumulative climatology for February exhibits an envelope limiting the highest wave heights in each period band. As previously discussed, the growth (sea) portion of the SOWM is energy-limited by the Pierson-Moskowitz fully developed spectrum. The envelope for maximum values of $\bar{H}_{1/3}$, or energy, approximate a fully developed Pierson-Moskowitz spectrum for the stronger winds present during the month. The energy content for a given period may even exceed fully arisen conditions as a result of the superposition of the sea on swell arriving simultaneously at the analysis point. The limitation on wave energy versus period exhibited in the February statistics (Table V) will be addressed in greater detail in Section IIIC.

A comparison of the cumulative statistics shown in Tables V and VI for the months of February and August illustrate some seasonal aspects of the wave climatology at the selected station. As would be expected, the summer month contains far less wave energy and significantly shorter wave periods than does the winter month. However, during February, low energy waves of long period (quite evidently swell) were dominant on at least five occasions and clearly reflect instances where the sea was of lesser consequence than the incoming swell. During August only one case of long-period swell dominance is

immediately evident. It is thus apparent that even though the winds were relatively light throughout August and produced low seas, the swell energy was of even lesser consequence.

Figure 8 is a plot of event occurrence by direction for all frequencies. The February statistics show a maximum occurrence from MET DIR 3, with lesser but significant occurrences along directions 4 and 5. This fact correlates well with the predominant west to southwest wind patterns previously discussed in the meteorological section. The summer wave statistics show a generally similar directional distribution to winter. This is due also to the predominance of west to southwest winds which occur during the summer months and influence the wave analyses at grid point 164.

Wave statistics users may desire to know if sea or swell waves are represented by the statistics in the climatology tables. Wave steepness may be used to distinguish sea from swell and also determine whether swell has had a short propagation distance (young swell) or a longer propagation distance (old swell) from the generating area. Wave steepness for monochromatic wave trains is defined as the ratio of wave height to wave length. For deep water waves this may be written as $\frac{H}{L} = \frac{H}{\frac{g}{2\pi} T^2}$. Since $\frac{g}{2\pi}$ is a constant, the wave steepness may be represented by H/T^2. For a spectrum, steepness will be defined here as $\bar{H}_{1/3}/T_1{}^2$(adjusted). Figure 9 is a plot of the wave steepness parameter computed using Cardone's program for duration-limited and fully arisen energy spectra generated by wind speeds of 20, 30, 40, and

50 knots. The compilations for this figure are given in Appendix B. It may be seen in the figure that for wind speeds greater than 20 knots, seas in all stages of growth have steepnesses in excess of 0.125. Since swell can be presumed to have lower steepnesses than sea, values less than 0.125 may be considered to be swell.

Figure 10 is a plot of the wave steepness envelope in the climatology format for values greater than or equal to a steepness criteria of 0.125. It may be concluded that for wind speeds greater than 20 knots, climatological entries lying to the left of the curve represent sea, and those to the right of the curve are swell. It is evident that the steepness associated with any entry in the gross climatology tables of Appendices D and E can readily be determined.

A cursory examination of Figures 4 and 7 reveal two shortcomings inherent in the gross wave climatologies. For the synoptic wave conditions illustrated in Figure 2, the gross wave statistics indicate a single wave train having an $\bar{H}_{1/3}$ value of 7.09 feet, a T_1 (adjusted) of 15.0 seconds, and a ψ_a of 259.5 degrees (MET DIR 3). However, Figure 4 clearly shows a secondary energy peak in the shorter period bands and Figure 7 shows the same wave train centered about MET DIR 5. The secondary wave train would not be revealed in the gross climatology. A wave statistics user concerned about secondary wave energy maxima would not find this information available in the gross climatology statistics.

C. TWO-DIMENSIONAL SPECTRAL CLIMATOLOGY FORMAT

The two-dimensional spectral format is a tabular representation of the frequency of occurrence by direction and period of the "internal" energy values, or variance components, obtained from the synoptic analyses covering a given time period. The tabulations for all 12 direction bands for February 1975 and August 1974 are contained in Appendix F (Tables F-1 through F-12) and Appendix G (Tables G-1 through G-12) respectively. The "internal" section of the FNWC synoptic analysis (item 12 in the printout of Figure 2) contains 180 energy bits of both zero and non-zero values, the sum of these 180 bits constituting the total energy, E_t. Each non-zero energy value has been extracted from the FNWC analyses and entered into the spectral climatology format to build the wave climatology for the given month. The tables for February 1975 are derived from 45 12-hourly analyses, and the tables for August 1974 from 61 12-hourly analyses.

As in the gross climatology tables, the energy values in the spectral climatology tables are coded according to the key shown in Table VII. The units of the energy values are $(\text{feet})^2$/frequency bandwidth, where the frequency bandwidth may be either the FNWC bandwidths or an adjusted common bandwidth. It may be recognized that while the total energy (E_t) in a given spectral analysis may be equated to some wave height parameter (such as $\bar{H}_{1/3}$ in the gross statistics), the individual energy values which comprise E_t cannot. For this reason an energy scale rather than a height scale is employed in the two-dimensional spectral climatology format. The scale below 2 ft^2 was expanded to provide better definition

of the energy distribution in this lower energy range. This expansion is a result of the fact that of the 2951 non-zero entries in the two-dimensional February Statistics only 1.5 per cent exceeded values of 2 ft^2, and none exceeded this value in the August data. This scale expansion results in a discontinuity at the coded value of 09. The maximum internal energy density value occurring during the two months of data was 8.36 ft^2 (00Z analysis on 19 February 1975).

Two alternatives were available for expressing the magnitude of the energy values associated with the period bands, that of energy density per FNWC variable frequency bandwidth or per constant frequency bandwidth. Table VIII is the two-dimensional spectral format for the month of February 1975 for meteorological direction 3 using the FNWC variable frequency bandwidths. Table IX, for the same month and direction band, reflects the same energy values adjusted to equal frequency bandwidths.

In Table VIII the energy values were obtained directly from the FNWC analyses (e.g., from item 15 of Figure 2) converted to the coded values given in Table VIII, and were entered into the climatology format. These energy values are contained in the FNWC unequal frequency bandwidths, and therefore have units of $(feet)^2$/FNWC bandwidth. The table accurately represents the total energy for February for ψ = 3 but does not give the energy contained in equal frequency bandwidths.

As shown in Table I, the FNWC frequency bandwidths from 0.083 Hz (12.0 seconds) to 0.039 Hz (25.7 seconds) are equal

and have a value of Δf = 0.0055 Hz. At periods shorter than 12.0 seconds the FNWC bandwidths vary. In order to compare the energy density in one frequency band of Table VIII with that in another it is necessary to adjust these energy densities to a common frequency bandwidth. This may be accomplished by multiplication of the energy values coded in Table VIII by the factors listed in Table I, normalized by dividing by 180. Table IX represents the result of this procedure. All values in this table have the units ft^2/0.0055 Hz bandwidth. In Table IX the wave energy values may be compared directly from one frequency band to another, but the total energy in the table does not represent the total energy in the waves for MET DIR 3 for February.

The relationship between Tables VIII and IX can best be understood through the use of a specific example. Table VIII shows one incidence of occurrence in energy level 02 (0.25-0.49 ft^2) contained in the period bands of 8.6 seconds and 20.0 seconds. Assuming an average value for this energy level of 0.37 ft^2, a bar graph for these FNWC bandwidths would appear as in the upper part of Figure 11. Application of the normalized FNWC scaling factors contained in Table I to convert the energy values to an equal bandwidth basis of 0.0055 Hz is shown in the lower part of Figure 11. Examination of the two sets of data in this figure reveals that although the energy contained in the two FNWC bandwidths is equal, from an equal bandwidth point of view, the energy in the 8.6 second period is reduced by a factor of one third from that of the 20.0 second period. This apparent reduction

in energy content in the 0.117 Hz band (8.6 second band) results from the exclusion of the energy contained in the bands from 0.108 Hz to 0.114 Hz and from 0.120 Hz to 0.125 Hz. A comparison of Table IX with Table VIII reveals that the overall effect of adjustment to a common frequency bandwidth is a proportional reduction in the energy values for the period bands of 10.9 seconds and lower.

Both of the two-dimensional climatologies contained in the tables of Appendices F and G were tabulated using the FNWC variable bandwidths. The reason for this choice is that variable bandwidth tables retain more information about the wave energy distribution than do adjusted bandwidth tables. For example, given the FNWC climatology in Table VIII, it is possible by frequency bandwidth adjustment to produce Table IX. However, given Table IX it is not possible to generate Table VIII. Additionally, the total wave energy for the month is shown in Table VIII, while only part of this energy is reflected in Table IX. In the use of these climatology tables the reader is cautioned that he cannot make direct comparisons of the energy levels across the frequency spectrum. In order to do this he must correct the energy values to an equal (common) frequency bandwidth. To perform this conversion the normalized scaling factors listed in Table I would be required.

The envelope of maximum energy versus period illustrated in Tables VIII and IX is the result of energy saturation of the sea surface. As the sea progressively builds, the shorter period bands become energy saturated first, followed

successively by longer ones. Once a period band is saturated, unless the wind velocity increases that band can absorb no additional energy. For a given climatology table the saturation trend is established by the highest wave conditions (i.e., heaviest seas plus swell) occurring during the period covered by the data. For example, Table X shows an energy-period plot for the FNWC analysis of 19 February 1975 at 00Z for ψ = 3, which contained for this direction band a total energy density of 38.15 ft^2. By comparison with Table VIII it may be seen that the data in Table X represents the most nearly saturated condition that occurred during the month of February. All energy values for seas generated by weaker winds (plus swell) are contained inside the envelope of these maximum limiting values.

It is of interest to examine the frequency spectrum of fully arisen seas when plotted on a spectral climatology format. To accomplish this the energy levels in the fully developed spectrum produced by Cardone were reduced to that energy contained in a 30 degree direction bandwidth centered about the mean wind direction. This was done for seas produced by wind speeds of 20, 30, 40, and 50 knots by applying the FNWC 37.5 per cent factor to the energy content of each spectrum. This reduction is shown in Tables C-1 through C-4 of Appendix C. Tables XI through XIV show this information tabulated in a climatology format for these four wind speeds. The fully arisen spectra for these wind speeds are presented for both the FNWC variable frequency bandwidths and equal bandwidths adjusted as described above. Although swell

commonly occurs simultaneously with seas, and is included in the climatological plots for February and August, no swell energy is contained in Tables XI-XIV.

The reduction of the saturated wave energy spectra to a 30-degree direction bandwidth permits direct comparisons with the spectral climatologies of February 1975 and August 1974, and provides a rough estimate of the peak wind speeds responsible for the wave conditions during the month. For example, comparison of the two-dimensional spectral climatology compiled for meteorological direction 3 for August 1974 shown in Table XV with Table XII (using the energy distribution for the FNWC bandwidths) suggests that the maximum winds at the observation point did not exceed 30 knots. In fact, 23.8 knots was the highest analyzed during August.

The effect of the additional energy due to swell which is included in the spectral climatologies can be illustrated by a comparison of Table VIII (the spectral climatology for February 1975 for MET DIR 3) with Tables XIII and XIV. For periods shorter than 12.0 seconds it can be seen that fully arisen sea conditions were not attained for wind speeds of 40 knots. However, for periods greater than 12.9 seconds the 40 knot fully arisen conditions are significantly exceeded by the climatology. Comparison of Table VIII with Table XIV shows that in the 20.0 second period band of the climatology, the energy values exceed even the fully arisen conditions realized under 50 knot winds, even though the maximum winds calculated for February did not exceed 42 knots. Obviously these wind conditions were of insufficient duration to attain

fully arisen status. The additional energy resulted from the simultaneous occurrence of swell with sea and increased the total wave energy to a considerable extent, especially in the longer period bands.

Swell energy is not as easily identifiable in the spectral climatology tables as it is in the gross climatology tables, although in meteorological direction 4 of the August 1974 data (Table G-4 of Appendix G) the event occurrence of 17 in the 16.4 second period band with an energy level of 01 is undoubtedly swell, as are other high event occurrences in the long period bands of the other tables of Appendices F and G.

As in the gross statistics, a comparison of the February and August spectral data (Appendices F and G) reveals that the maximum wave energy in both cases comes from meteorological direction 3 with lesser, but significant, amounts from adjacent directions.

D. ONE-DIMENSIONAL FREQUENCY SPECTRUM FORMAT

The one dimensional frequency spectrum climatology is a tabulation of cumulative energy density versus frequency summed over all directions. The energy density values tabulated from the SOWM analyses are those contained in the frequency spectrum shown in the FNWC printout (item 13 of Figure 2). The tabulations for February 1975 and August 1974 for grid point 164 are shown in Tables XVI and XVII for equal frequency bandwidths (Δf = 0.0055 Hz).

The construction of this format involved the extraction of the external energy values E_1 through E_{15} and their

associated period bands from the FNWC SOWM 12-hourly analyses for the month of interest. Subsequent conversion of the FNWC energy density values to an equal frequency bandwidth basis using the normalized scaling factors in Table I was then accomplished. The energy values for the common bandwidths were then coded with the energy scale from Table VII and entered into Tables XVI and XVII. The entries in the tables represent event occurrence vice duration or per cent occurrence for reasons previously discussed. A total of 45 12-hourly analyses were entered for February 1975 and 61 for August 1974.

Tables XVI and XVII are similar in construction and appearance to the tables contained in Appendices F and G; however, the energy densities are not directly comparable. In the latter tables the occurrence entries for a given period band refer to energy values for each of the 12 direction bands, while in the former, the entries refer to the cumulative energy in all direction bands. The energy values in the former tables, therefore, are larger.

The individual occurrence entries in all of the climatology tables in this thesis could be cumulated so as to show the cumulative occurrence of wave heights or energy densities in any frequency band equal to or higher (lower) than a given value. This has been done for the data contained in Tables XVI and XVII, and the results are shown in graphical form in Figures 12 and 13. These figures show curves of coded energy density plotted versus period and cumulative frequency of occurrence. The period is the reciprocal of the central

wave frequency for a given frequency bandwidth. The coded energy density values may be translated into variance values through the use of Table VII. The 01 energy density category includes zero wave energy. Cumulation through the energy value of 01, therefore, will yield a total number of event occurrences equal to the total number of 12-hourly analyses during the month. This climatology format will yield period/energy event occurrences for any period from 6 to 26 seconds.

In constructing the figures, the individual cumulative event occurrence/period entries for the same coded energy level were plotted for both months. All points having the same coded energy level were then connected to form a curve. Interpolation, when required, was accomplished in a manner consistent with the shape of the data points. Although Figures 12 and 13 contain basically the same information as Tables XVI and XVII, graphical presentation of the statistics in cumulative form is easier to visualize and to use. It will be noted that use of the graphs permits determination of the event occurrence for any wave period rather than only for FNWC periods.

The statistical distribution for February 1975 in Figure 12 is seen to have a distinctive appearance that is not unlike a series of nested fully arisen sea spectra generated by a range of wind speeds. The maximum occurrence for all energy density curves, shown as a dashed line, is the counterpart of the curve of energy density maxima, T_{max}, in nested spectra. The curves show a surprising uniformity for the small size of the occurrence sample (45 total events). The

irregularities in the plot for February would be expected to largely disappear if the data base were lengthened to include several years of February spectral statistics.

The most striking difference between the February and August climatologies is the energy content of the two months. The maximum energy level observed in August (Figure 13) occurred at a coded energy level of 04 in the period band of 15 seconds, while a very much greater energy maximum of 26 occurs at 18 seconds in the February statistics. Additionally, the energy in February is contained in longer period bands (greater than 26 seconds) than that of August.

The remaining comments in this section will be directed to use of Figures 12 and 13. Period (or frequency) and energy levels may be used as entering arguments to obtain an event occurrence for that combination for the given monthly climatology. If, for example, a user desired to operate a spar buoy in February whose resonant period was known to be 15 seconds, and the maximum tolerable energy level could not exceed 1.50 ft^2 at this period, a determination of frequency of occurrence of these conditions could be established as follows. From Table VII, 1.50 ft^2 is represented by energy code 07. Entry into the February climatology with a 15 second period and an energy level 07 reveals that energy levels of 1.50 ft^2 or greater occurred 18 times during the climatology base period of 45 total possible occurrences. The same entry arguments in the August data reveal that at no time was the energy content in the 15 second period in excess of energy level 04 (0.75 to 0.99 ft^2).

To determine the frequency of occurrence of a particular energy level in a given period band, e.g., 2.00 to 2.50 ft^2 at 13.8 seconds for February, enter 13.8 seconds to the 09 energy curve and obtain an occurrence of 20 events, then enter the 10 curve for an occurrence of 17. The difference, or 3, is the occurrence in this energy density band at 13.8 seconds. The frequency of occurrence of energy level 01 is determined in the same manner, but the total number of 12-hourly analyses must be known. For example, for the February data with 45 total events the frequency of occurrence of energy state 01 in the 18 second band is 45 minus 17 (the frequency of occurrence of energy level 02), or 28.

IV. APPLICATIONS

It is of interest to compare the experimental gross climatology format and data contained in Appendices D and E of this thesis with similar wave climatologies which are currently available to wave statistics users. One such compilation was made by National Marine Consultants (NMC) for three deep-water stations along the Oregon-Washington coast (NMC, 1961) and seven deep-water stations along the California coast (NMC, 1960). Table XVIII is a sample wave climatology extracted from the NMC data for February (average of three years) at a station located in deep water off the Washington-Oregon border. The formats of the NMC data and the gross statistics presented herein are similar, but there are some significant differences. The NMC data were derived manually (as is the case with all other wave statistics known to the writer) by the hindcasting methods contained in H. O. 603, while the gross statistics presented here were derived from computer produced spectral wave analyses. The frequency of occurrence entries in the NMC statistics are presented in per cent whereas those in the tables herein are given in number of synoptic events. Conversion of one to the other may be easily accomplished.

The NMC data are presented as separate tables of sea and swell while the gross statistics show the total wave energy. Combining the sea and swell tables of the NMC data to obtain

the total wave energy is difficult. One difficulty arises from the fact that while the NMC sea tables always total to 100 per cent (lower portion of Table XVIII) the swell tables (upper portion of Table XVIII) do not. This is a result of the mode of compilation of the NMC swell statistics. The basic problem the user is faced with is how to convert the NMC swell statistics to 100 per cent total occurrence. A second difficulty involves the method by which sea and swell should be combined and is due to the fact that sea and swell may occur simultaneously or separately. These problems do not occur in the gross statistics because the FNWC Spectral Ocean Wave Model generates sea and propagates swell together and does not separate sea from swell. Some resolution between sea and swell is possible in the gross statistics, however, with the use of the steepness criterion discussed in Section IIIB. It was pointed out there that each height-period entry in the climatology format can be converted by the user into a crude measure of wave steepness which will indicate whether the larger waves present approximate steep sea, young swell of moderate steepness, or old swell of low steepness.

The gross wave statistics described in this paper would have similar applications by wave statistics users to those climatologies currently available. A major advantage of wave statistics compiled from FNWC spectral analyses is the ability to lengthen the statistical data base beyond the three years used by the NMC and some other similar statistics. From six-hourly surface pressure analyses archived in FNWC it would be possible to produce wave statistics for approximately a

20 year period. It may be of interest to note that synoptic wave fields are currently being prepared from a 20-year series of synoptic weather maps by FNWC.

No spectral climatologies have previously been produced; therefore, the resulting spectral climatology formats described herein are considered to be experimental in nature. Although the area of application of spectral data appears to be largely unexplored, it is probable that in resonance related phenomenon they will find their greatest use. Ships or ship routers might utilize deep water two-dimensional spectral climatologies to estimate the energy content from both a frequency and direction standpoint for the purpose of planning ship routes. While the actual relationship between energy densities and hull responses requires investigation, increased energy in a critical frequency or direction band may be expected to significantly affect the stability and sea-keeping characteristics of a structure or craft.

For coastal engineering purposes it may be seen that the two-dimensional spectral climatology statistics (Appendices F and G) may be shoaled and refracted into intermediate or shallow water depths where they could be used for prediction of the resonant behavior of piling platforms, floating breakwaters, and other coastal structures. Littoral drift rates may also be computed from computation of the longshore component of wave power derived by shoaling and refracting the deep water climatology. Wave heights in shoal water cannot be calculated from the deep water spectral climatology, however. Near-shore wave-height climatologies can be prepared

only by shoaling and refracting the deep water spectral analyses and recombining the resultant wave heights at a near-shore site.

The one-dimensional spectral data (shown in Tables XVI and XVII and Figures 12 and 13) cannot be transformed by refraction to provide near-shore wave information because no directional information is available in this format. Its potential applications are, therefore, restricted to deep water use, and furthermore have no application to situations which require directional information. The one-dimensional spectral statistics appear to have their greatest potential application with regard to dynamic interaction of moored or stationary structures in deep water which are not directionally sensitive.

LIST OF REFERENCES

1. Cardone, Vincent, 1975. Computer Program for the Spectral Energy Distribution of the Sea Surface, program run at FNWC 26 March 1975.

2. Gerst, Anthony L., 1971. Naval Weather Service Environmental Detachment, Adak, Alaska, Local Area Forecaster's Handbook, 1 February 1971.

3. Kinsman, Blair, 1965. Wind Waves their generation and propagation on the ocean surface, Prentice-Hall.

4. Lazanoff, Sheldon and Norman M. Stevenson, 1975. Fleet Numerical Weather Central Technical Note 75-3, An Evaluation of a Hemispheric Operational Wave Spectral Model, June 1975.

5. National Marine Consultants, Inc., 1960. Wave Statistics for Seven Deep Water Stations Along the California Coast.

6. National Marine Consultants, Inc., 1961. Wave Statistics for Three Deep Water Stations Along the Oregon-Washington Coast, May 1961.

7. Pierson, Willard, J. Jr., Gerhart Neumann and Richard N. Jones, 1955. Practical Methods for Observing and Forecasting Ocean Waves by Means of Wave Spectra and Statistics, H. O. Publication No. 603, U. S. Naval Oceanographic Office.

Table 1

FREQUENCY/PERIOD PARAMETERS FOR THE FNWC SOWM
(modified from Lazanoff and Stevenson, 1975)

Central frequency (Hz)	Frequency band (Hz)	Band-width (Hz)	Central period (Sec)	Period band (Sec)	Band-width (Sec)	Scaling factor
0.164	.164-∞		6.1	6.1- 0.0		10
0.153	.142-.164	.0220	6.5	6.1- 7.0	.9	45
0.133	.125-.142	.0165	7.5	7.0- 8.0	1.0	60
0.117	.108-.125	.0165	8.6	8.0- 9.3	1.3	60
0.103	.097-.108	.0110	9.7	9.3-10.3	1.0	90
0.092	.086-.097	.0110	10.9	10.3-11.6	1.3	90
0.083	.080-.086	.0055	12.0	11.6-12.5	.9	180
0.078	.075-.080	.0055	12.9	12.5-13.3	.8	180
0.072	.069-.075	.0055	13.8	13.3-14.5	1.2	180
0.067	.064-.069	.0055	15.0	14.5-15.6	1.1	180
0.061	.058-.064	.0055	16.4	15.6-17.2	1.6	180
0.056	.053-.058	.0055	18.0	17.2-18.9	1.7	180
0.050	.047-.053	.0055	20.0	18.9-21.3	2.4	180
0.044	.042-.047	.0055	22.5	21.3-23.8	2.5	180
0.039	.036-.042	.0055	25.7	23.8-27.8	4.0	180

Table II

OCCURRENCE OF PERIOD PEAKS FOR AUGUST 1974 AND FEBRUARY 1975

Number of period peaks per analysis	Percentage occurrence August 1974	Percentage occurrence February 1975
0	6	0
1	36	36
2	26	40
3	20	20
4	12	4

Table III

OCCURRENCE OF DIRECTIONAL PEAKS FOR AUGUST 1974 AND FEBRUARY 1975

Number of direction peaks per analysis	Percentage occurrence August 1974	Percentage occurrence February 1975
0	8	0
1	77	42
2	15	58

Table IV

WAVE HEIGHT CODE FOR THE GROSS CLIMATOLOGY FORMATS

Code	$\bar{H}_{1/3}$(ft)	Total variance(ft^2)
01	0.0- 1.9	0.000- 0.249
02	2.0- 3.9	0.250- 0.999
03	4.0- 5.9	1.000- 2.249
04	6.0- 7.9	2.250- 3.999
05	8.0- 9.9	4.000- 6.249
06	10.0-11.9	6.250- 8.999
07	12.0-13.9	9.000-12.249
08	14.0-15.9	12.250-15.999
09	16.0-17.9	16.000-20.249
10	18.0-19.9	20.250-24.999
11	20.0-21.9	25.000-30.249
12	22.0-23.9	30.250-35.999
13	24.0-25.9	36.000-42.249
14	26.0-27.9	42.250-48.999
15	28.0-29.9	49.000-56.249
16	30.0-31.9	56.250-63.999
17	32.0-33.9	64.000-72.249
18	34.0-35.9	72.250-80.999
19	36.0-37.9	81.000-90.249
20	38.0-39.9	90.250-99.999
21	40.0 +	100.000 +

Ψ = ALL DIRECTIONS — FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03									1		2				
04						1				1					
05										1					
06					2	1									
07					6	1									
08					2		2								
09						1									
10						2	2								
11						1		3							
12							2	1		1					
13									3	1					
14								1	1	1					
15										1					
16											2				
17												1			
18											1				
19															
20															
21															

Table V. Gross Wave Statistics for All Directions for February 1975

Ψ = ALL DIRECTIONS AUGUST 1974

SIGNIFICANT HEIGHT (CODED) \ CENTRAL PERIOD (SECONDS)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	6	4		3	5										
02	2	4	1		2										
03		4			1										
04		1	5	3	3					1					
05				6	3	1	1								
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table VI. Gross Wave Statistics for All Directions for August 1974

Table VII

ENERGY DENSITY CODE FOR THE SPECTRAL CLIMATOLOGY FORMATS

Code	Energy Density (ft^2/frequency bandwidth)
01	0.00- 0.24
02	0.25- 0.49
03	0.50- 0.74
04	0.75- 0.99
05	1.00- 1.24
06	1.25- 1.49
07	1.50- 1.74
08	1.75- 1.99
09	2.00- 2.49
10	2.50- 2.99
11	3.00- 3.49
12	3.50- 3.99
13	4.00- 4.49
14	4.50- 4.99
15	5.00- 5.49
16	5.50- 5.99
17	6.00- 6.49
18	6.50- 6.99
19	7.00- 7.49
20	7.50- 7.99
21	8.00- 8.49
22	8.50- 8.99
23	9.00- 9.49
24	9.50- 9.99
25	10.00- 10.49
26	10.50- 10.99

$\psi = 3$

FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/FNWC FREQ BANDWIDTH (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	12	5	3	5	2	11	12	15	13	12	9	7	5	3	5
02	18	20	21	1	5	4	2	3	3	3			1		
03				6	3	1	4	2	2	2	2	2			
04				14	4	2	1	2	1	2	2	2		1	1
05					10		5	3	3	2	1			1	
06						3	5	1	1	1	2				
07						4	2	4	1						
08						7		3	2	2					
09								1	3	1		1	3		
10									2			1			
11										4		2			
12											3			1	
13										1	1				
14															
15											1	1			
16															
17															
18															
19												1			
20															
21													1		
22															
23															
24															
25															
26															

Table VIII. Two-Dimensional Wave Climatology for February 1975 ($\psi = 3$)

Table IX. Two-Dimensional Wave Climatology for February 1975 (ψ = 3) Adjusted for Equal Frequency Bandwidth

$\psi = 3$

FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/STANDARD FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	30	25	24	12	7	15	12	15	13	12	9	7	5	3	5
02				14	7	3	2	3	3	3			1		
03					10	3	4	2	2	2	2	2			
04						11	1	2	1	2	2	2		1	1
05							5	3	3	2	1			1	
06							5	1	1	1	2				
07							2	4	1						
08								3	2	2					
09								1	3	1		1	3		
10									2			1			
11										4		2			
12											3			1	
13										1	1				
14															
15											1	1			
16															
17															
18															
19												1			
20															
21													1		
22															
23															
24															
25															
26															

Table X. Energy Spectrum of FNWC SOWM Analysis for 19 February 1975, 000Z for $\psi = 3$

$\Psi = 3$

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED) \ CENTRAL PERIOD (SECONDS)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															1
02	1	1	1												
03															
04				1											
05					1										
06															
07							1								
08						1		1							
09															
10									1						
11										1					
12														1	
13											1				
14															
15															
16															
17															
18															
19												1			
20															
21													1		
22															
23															
24															
25															
26															

Ψ = MEAN WIND DIRECTION

ENERGY DENSITY/BANDWIDTH (CODED) \ CENTRAL PERIOD (SECONDS)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	0	0	1 0	1 0	1 0	1 0									
02		1													
03	1														
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

1:FNWC BANDWIDTH
0:COMMON BANDWIDTH

Table XI. Energy Spectrum for Fully Arisen Sea for 20 Knot Winds (FNWC and equal bandwidths)

Ψ = MEAN WIND DIRECTION

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	0	0	0							1 0	1 0	1 0	1 0		
02		1		0	0			1 0	1 0						
03	1		1			0	1 0								
04					1										
05				1		1									
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

1:FNWC BANDWIDTH
0:COMMON BANDWIDTH

Table XII. Energy Spectrum for Fully Arisen Sea for 30 Knot Winds (FNWC and equal bandwidths)

Ψ = MEAN WIND DIRECTION

ENERGY DENSITY/BANDWIDTH (CODED)

	CENTRAL PERIOD (SECONDS)														
	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	0	0												1 0	1 0
02			0	0											
03	1												1 0		
04			1		0										
05						0									
06				1											
07					1		1 0					1 0			
08															
09						1		1 0	1 0	1 0	1 0				
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

1:FNWC BANDWIDTH
0:COMMON BANDWIDTH

Table XIII. Energy Spectrum for Fully Arisen Sea for 40 Knot Winds (FNWC and equal bandwidths)

Ψ = MEAN WIND DIRECTION

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/BANDWIDTH (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	0	0													
02			0												
03	1	1		0											
04			1		0										
05															
06															
07				1		0									1 0
08					1										
09							1 0								
10															
11						1		1 0							
12									1 0						
13															
14														1 0	
15										1 0					
16															
17											1 0				
18															
19												1 0	1 0		
20															
21															
22															
23															
24															
25															
26															

1:FNWC BANDWIDTH
0:COMMON BANDWIDTH

Table XIV. Energy Spectrum for Fully Arisen Sea for 50 Knot Winds (FNWC and equal bandwidths)

$\psi = 3$ AUGUST 1974

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	15	19	19	19	18	11	12	10	3	2	3	3	1		
02	15	5	6	4	7	2			1		1				
03				1		1	1	1		1					
04										1					
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Table XV. Two-Dimensional Wave Climatology for August 1974 (ψ = 3)

Ψ = ALL DIRECTIONS

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/STANDARD FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	45	11	6	6	5	5	6	13	15	17	21	28	33	41	43
02		34	10	1	2	3	3	4	1	3	3	3	2		
03			26	8	2	6	1	1	3	3	2		5		
04			3	8	1	2	7	1	1	1	2	2		1	1
05				14	7	4	1	3	3	2		2		1	
06				7	4	1	2			1	1			1	
07				1	7	1	1	1	1	2	4	3			1
08					3	1		1	1	1		1			
09					13	6	3	3	3		1	1			
10					1	4	5	2	3	3	1		1		
11						9	3	2	2		1		2		
12						1	7	3	1	3	2			1	
13						2	3	4	2	2	2				
14							3	3	4			1			
15								3	1	2	1				
16									1	1		1			
17								1	1	1	1				
18									2						
19										1	1	1	1		
20															
21										2					
22															
23											1	1	1		
24											1				
25															
26												1			

Table XVI. One-Dimensional Frequency Spectrum for 0.0055 Hz Bandwidths for February 1975

Ψ = ALL DIRECTIONS

AUGUST 1974

ENERGY DENSITY/STANDARD FREQ BANDWIDTH (CODED)	CENTRAL PERIOD (SECONDS) 6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	61	61	55	49	50	56	59	59	60	59	60	61	61	61	61
02			6	12	11	5	1	1	1		1				
03							1	1		1					
04										1					
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Table XVII. One-Dimensional Frequency Spectrum for 0.0055 Hz Bandwidths for August 1974

TABLE 2.2 AVERAGE Monthly HEIGHT-PERIOD-DIRECTION FREQUENCY DISTRIBUTION (PERCENT)[1] STATION 2 February (1956,1957,1958)

SWELL AVERAGE TOTAL HOURS 933.0

DIR.	NNW 1.5%							NW 5.4%							WNW 22.3%						
T_s / H_s	6-8	8-10	10-12	12-14	14-16	16-18	18+	6-8	8-10	10-12	12-14	14-16	16-18	18+	6-8	8-10	10-12	12-14	14-16	16-18	18+
1-2.9		.6						.3	.3			.3			1.5	2.4	.3	.3			
3-4.9			.3					1.2	.3	.3	.3				2.6	3.5	.3			.3	
5-6.9			.3						.6	.3					.6	2.1	2.1	.3	.3		
7-8.9			.3							.6						.9	1.2				
9-10.9									.3							.6	.6		.3		
11-12.9																	.6				
13-14.9																		.9	.3		
15-16.9										.3									.3		
17-18.9																					
19-20.9												.3									
21-22.9																					
23-24.9																					
25-26.9																					
27 +																					
Σ		.6	.9					1.5	1.5	1.5	.3	.6			4.7	9.5	5.1	1.5	1.2	.3	

DIR.	W 32.6%							WSW 29.6%							SW 18.2%						
T_s / H_s	6-8	8-10	10-12	12-14	14-16	16-18	18+	6-8	8-10	10-12	12-14	14-16	16-18	18+	6-8	8-10	10-12	12-14	14-16	16-18	18+
1-2.9	2.6	2.1	.3	3.5	3.2	.9		2.9	2.9	2.1	1.2	1.8	.9		1.5	2.1			.3		
3-4.9	.9	4.1	.9	1.5	.3			.6	5.0	3.8	2.4	1.5	.3		1.8	2.6	.9	.9	.6	.3	
5-6.9		2.1	.3	.3		.3			.6	.9	1.5					1.8	.9	.6		.3	
7-8.9		1.5	.3		.3				.3	.3						.3	1.2		.3		
9-10.9			1.2	1.2	.9	.3				.3								1.5	.3		
11-12.9			.3	.6	.6		.3														
13-14.9					.3						.3										
15-16.9				.3	.3	.3															
17-18.9																					
19-20.9				.3	.3																
21-22.9																					
23-24.9																					
25-26.9																					
27 +																					
Σ	3.5	9.8	3.3	7.7	6.4	1.8	.3	3.5	8.8	7.4	5.4	3.3	1.4		3.3	6.8	3.0	3.0	1.5	.6	

DIR.	SSW 20.1%							S 7.5%							SSE							Σ
T_s / H_s	6-8	8-10	10-12	12-14	14-16	16-18	18+	6-8	8-10	10-12	12-14	14-16	16-18	18+	6-8	8-10	10-12	12-14	14-16	16-18	18+	
1-2.9	.9	2.1	2.1	.3				.9	.6	.3												41.5
3-4.9	2.1	2.1	1.8		.6			.6	.9	.3												45.9
5-6.9		1.8	1.8	.3				.3	.3	.6												21.3
7-8.9	.3	.3	1.2	.3					.3													9.9
9-10.9		.3	.3						.6	.3												9.0
11-12.9			.6						.3		.3											3.6
13-14.9				.6																		2.4
15-16.9										.9												2.4
17-18.9				.3																		0.3
19-20.9																						0.9
21-22.9																						
23-24.9																						
25-26.9																						
27 +																						
Σ	3.3	6.6	7.8	1.8	.6			1.8	3.0	2.4	.3											137.2

SEA

DIR.	N 0.6%					NNW 1.8%					NW 5.7%					WNW 5.9%					W 7.2%				
T_s / H_s	4-6	6-8	8-10	10-12	12+	4-6	6-8	8-10	10-12	12+	4-6	6-8	8-10	10-12	12+	4-6	6-8	8-10	10-12	12+	4-6	6-8	8-10	10-12	12+
1-2.9	.6					.9					1.5					.3					.9				
3-4.9												1.2				.8	.3				.3	1.8			
5-6.9												1.2					1.2					2.4			
7-8.9													1.2					2.4					1.2		
9-10.9																			.3				.6		
11-12.9																									
13-14.9									.6					.3					.6						
15-16.9														.3											
17-18.9										.3															
19 - 22.9																									
23 - 27																									
Σ	.6					.9			.6	.3	1.5	2.4	1.2	.6		1.1	1.5	2.4	.9		1.2	4.2	1.8		

DIR.	WSW 6.3%					SW 6.2%					SSW 10.1%					S 16.6%					SSE 6.0%					OFFSHORE	CALM[2]	Σ
T_s / H_s	4-6	6-8	8-10	10-12	12+	4-6	6-8	8-10	10-12	12+	4-6	6-8	8-10	10-12	12+	4-6	6-8	8-10	10-12	12+	4-6	6-8	8-10	10-12	12+	5.2	28.4	33.6
1-2.9	1.2					1.5					1.5					1.8					.3							10.5
3-4.9	.6	2.1				.3	.6				.3	1.2					2.4				.3	1.5						13.7
5-6.9		1.2					1.5					.3					3.5					.6						11.9
7-8.9			.3					.9					2.6					3.5					.9					13.0
9-10.9			.6					.3	.3				1.5					1.2					.6					5.4
11-12.9								.8						.3				.6	1.5				1.5	.3				5.0
13-14.9				.3										1.2					.6									3.6
15-16.9																			.6									0.9
17-18.9														.6					.9									1.8
19 - 22.9															.6													0.6
23 - 27																												
Σ	1.8	3.3	.9	.3		1.8	2.1	2.0	.3		1.8	1.5	4.1	2.1	.6	1.8	5.9	5.3	3.6		.6	2.1	3.0	.3		5.2	28.4	100.0

1 Based on 28-1/3 days

2 Includes waves of 0 to 0.9 feet

Table XVIII. National Marine Consultants Sample Wave Climatology (from NMC, 1961)

Figure 1. Icosahedral-Gnomonic Projection of the World Oceans (from Lazanoff and Stevenson, 1975)

```
DTG=74083100   TAU=   0
SUBPROJECTION        3 GRID PT      0.00 LAT 50.900 LONG 214.400
            WIND SPEED  6.30 WIND DIR 205. USTAR  .22
```

FREQ / DIR	.164	.153	.133	.117	.103	.092	.083	.078	.072	.067	.061	.056	.051	.044	.039		
1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	319.5
2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.02	289.5
3	0.00	0.00	.02	.01	.02	.04	.07	.04	.15	.85	.35	.11	.01	0.00	0.00	1.65	259.5
4	.01	0.00	.02	.02	.02	0.00	0.00	.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.09	229.5
5	.01	.20	.27	.37	.29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.14	199.5
6	.01	.12	.10	0.00	0.00	0.00	.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	.24	169.5
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	139.5
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	109.5
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	79.5
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	49.5
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.5
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	349.5
	.03	.33	.41	.40	.33	.04	.08	.05	.15	.85	.35	.11	.01	0.00	0.00	3.145	

Figure 2. FNWC SOWM Output for 74083100Z

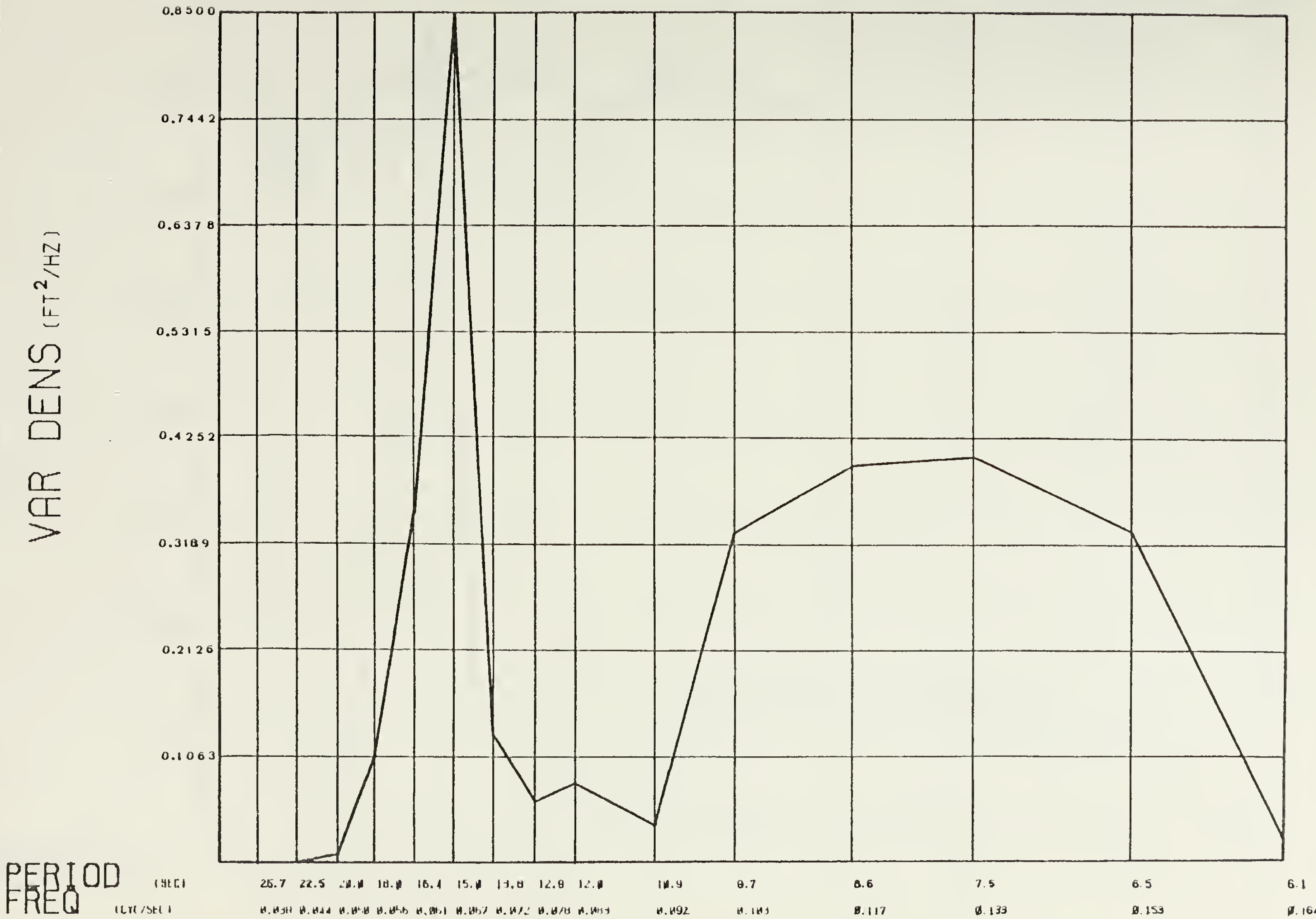

Figure 3. One-Dimensional Frequency Spectrum (FNWC Frequency Bandwidths for 74083100Z)

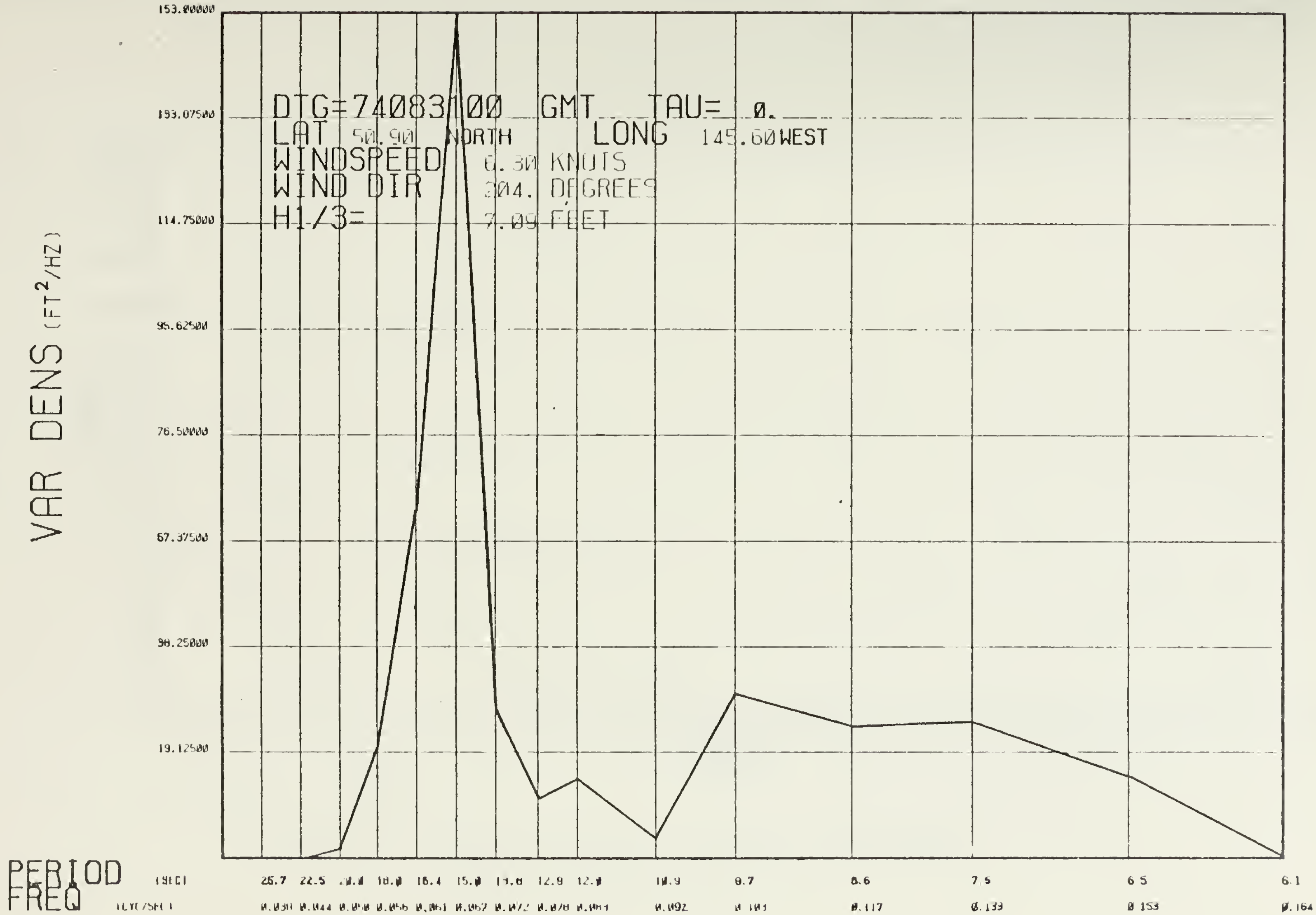

Figure 4. One-Dimensional Frequency Spectrum (Equal Frequency Bandwidths for 74083100Z)

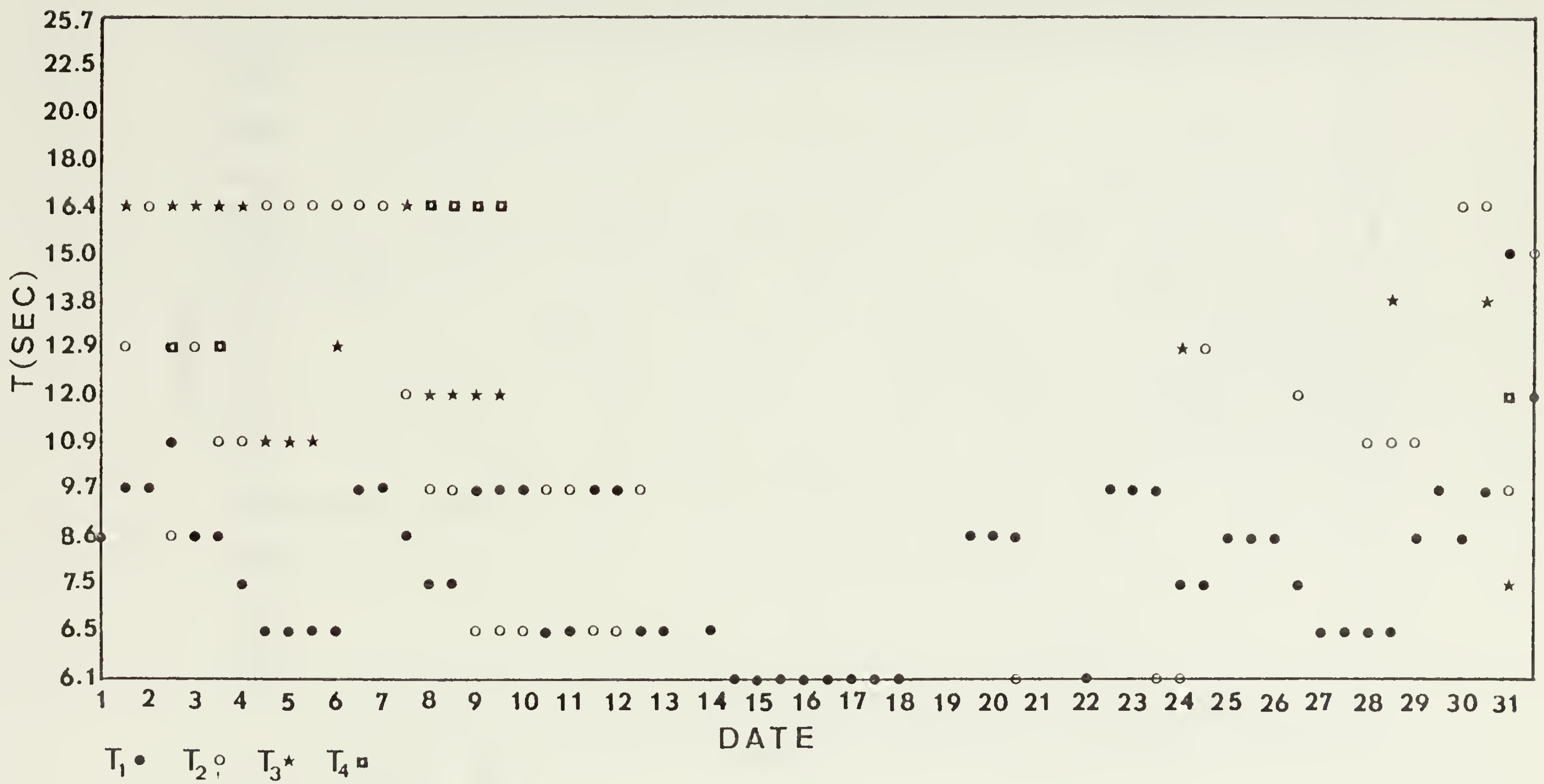

Figure 5. Occurrence of Multiple Frequency Peaks - August 1974

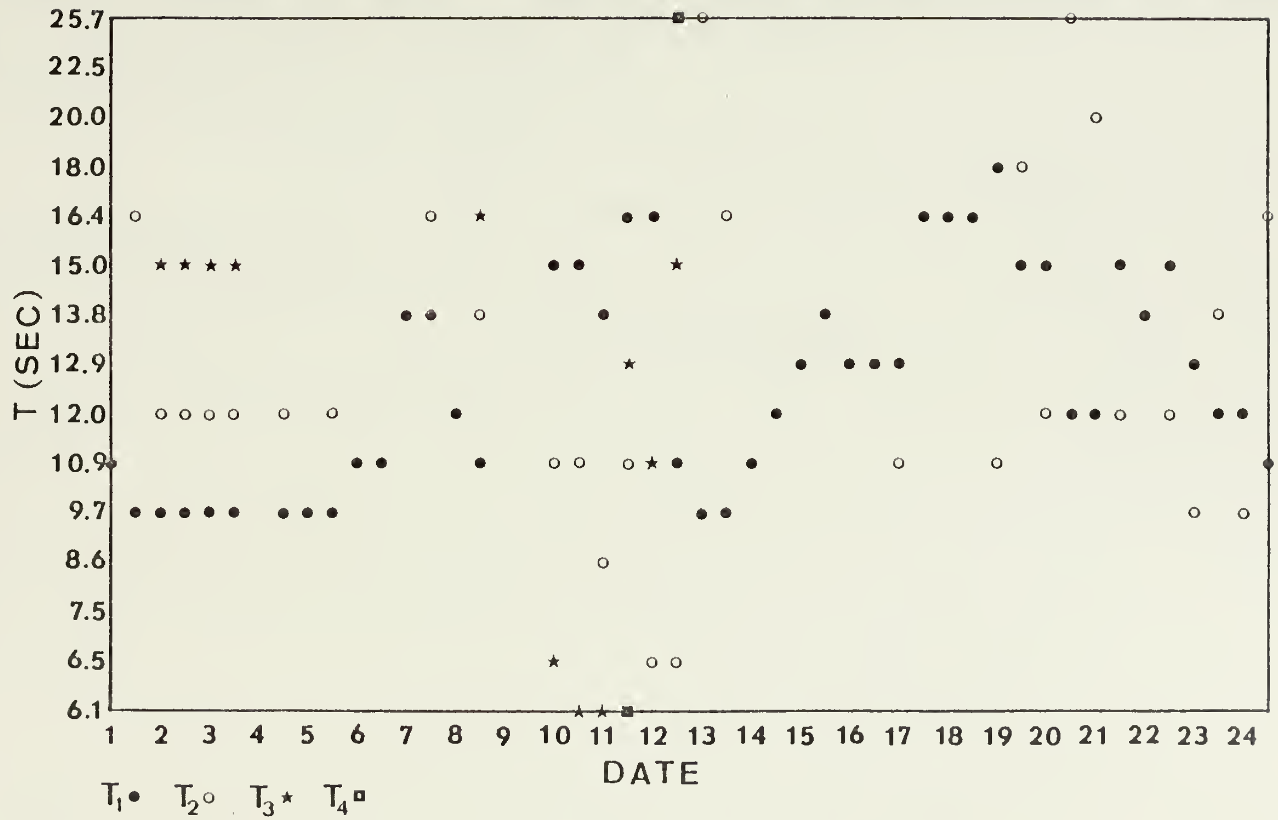

Figure 6. Occurrence of Multiple Frequency Peaks - February 1975

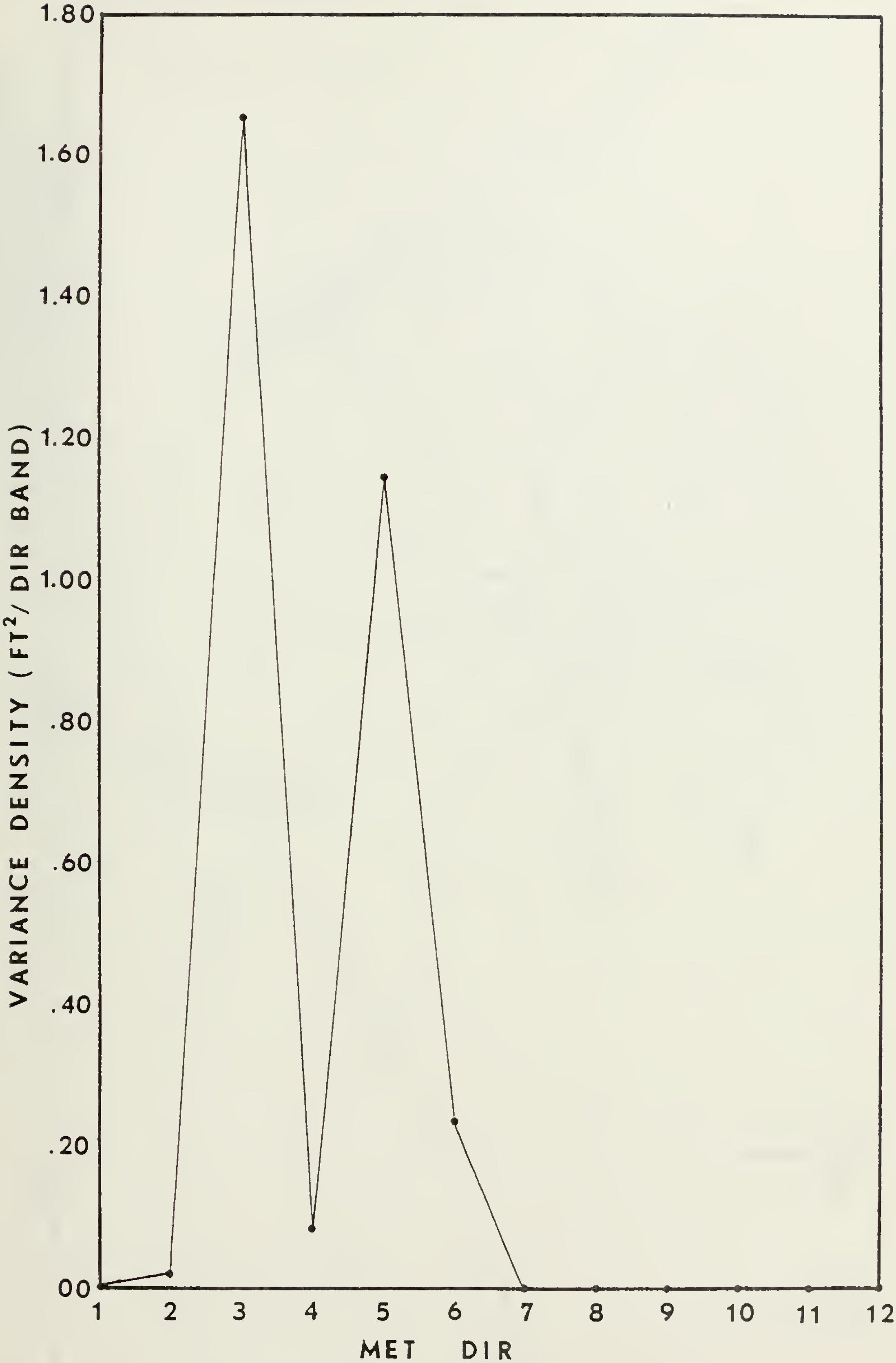

Figure 7. One-Dimensional Directional Spectrum for 74083100Z (Coded directions apply to FNWC grid point 164)

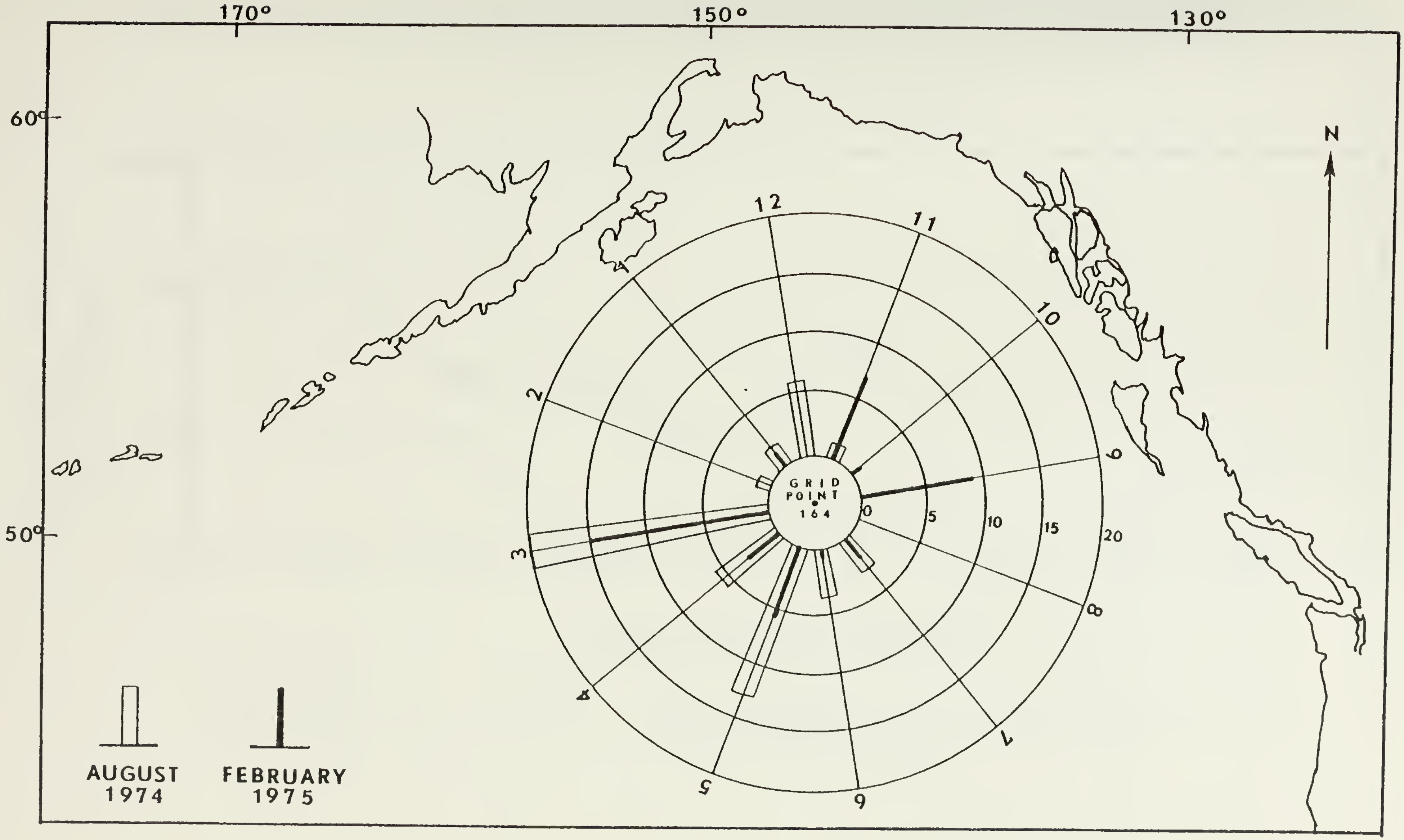

Figure 8. Event Occurrence by Direction for February 1975 and August 1974

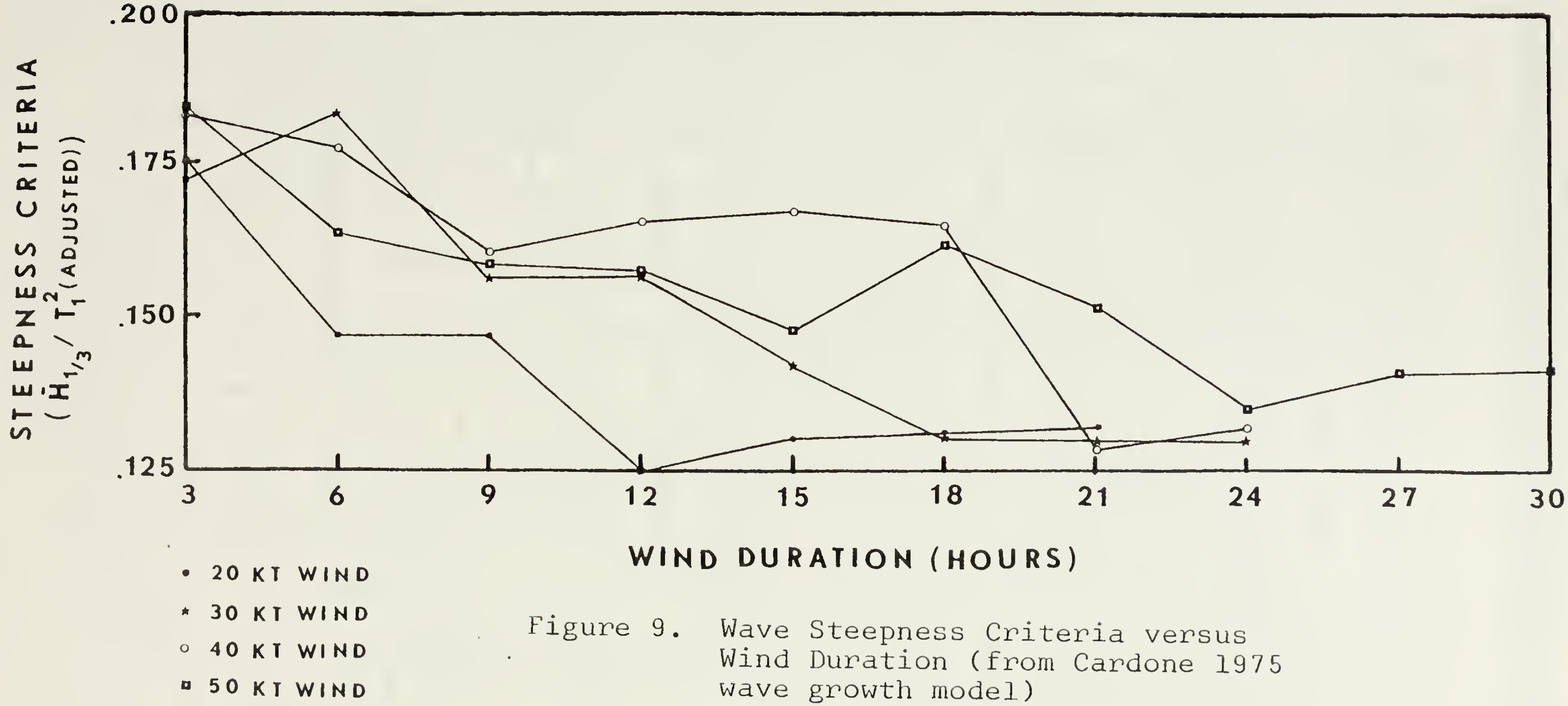

Figure 9. Wave Steepness Criteria versus Wind Duration (from Cardone 1975 wave growth model)

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03	1														
04		1													
05			1												
06				1											
07					1										
08						1									
09						1									
10							1								
11								1							
12								1							
13									1						
14									1						
15										1					
16										1					
17											1				
18											1				
19											1				
20											1				
21												1			

Figure 10. Wave Steepness Criterion Envelope of $\bar{H}_{1/3}/T_1^2$(Adjusted) $\geq$ 0.125

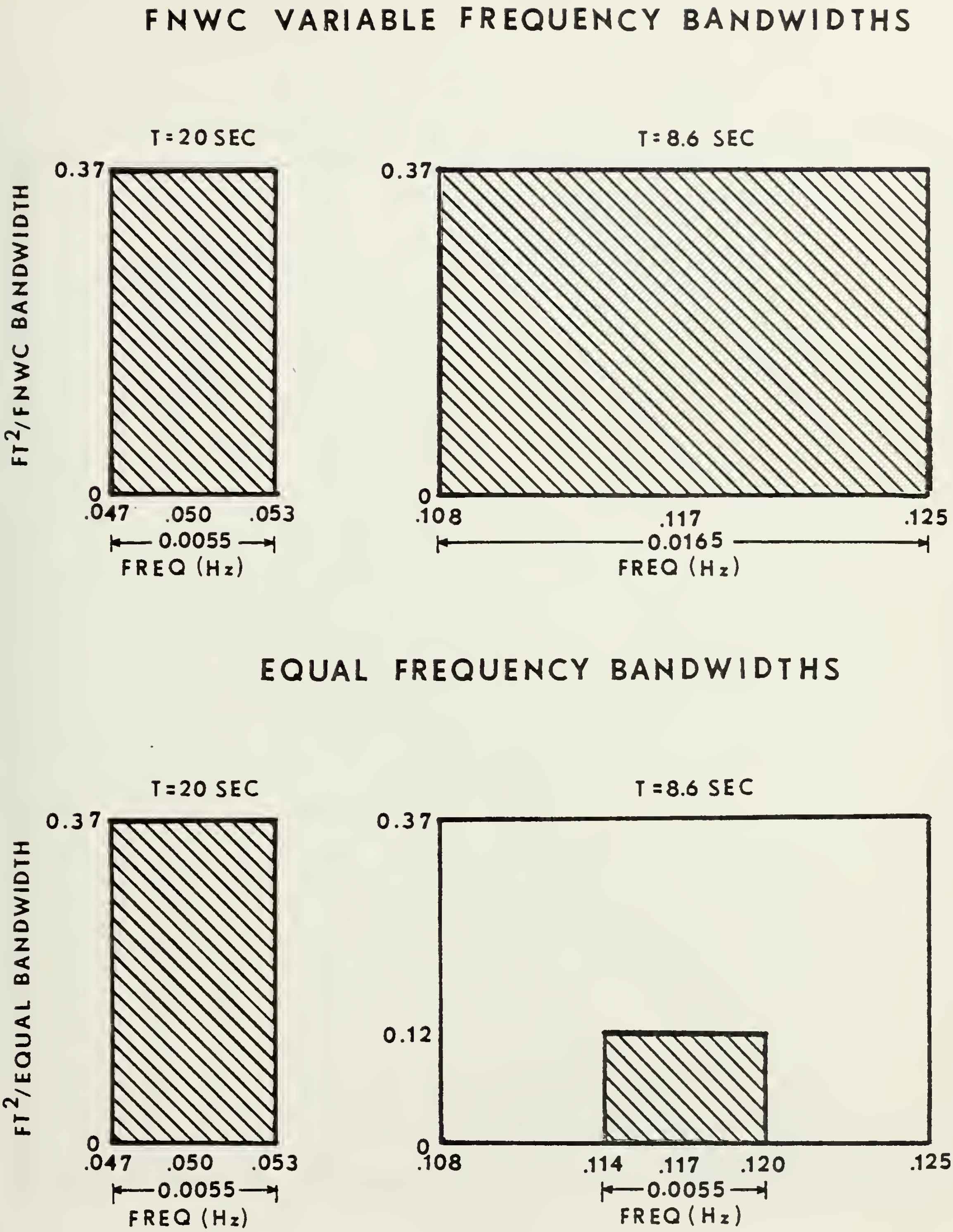

Figure 11. Comparison of Energy Content for FNWC Frequency Bandwidths and Common Frequency Bandwidths of Δf = 0.0055 Hz.

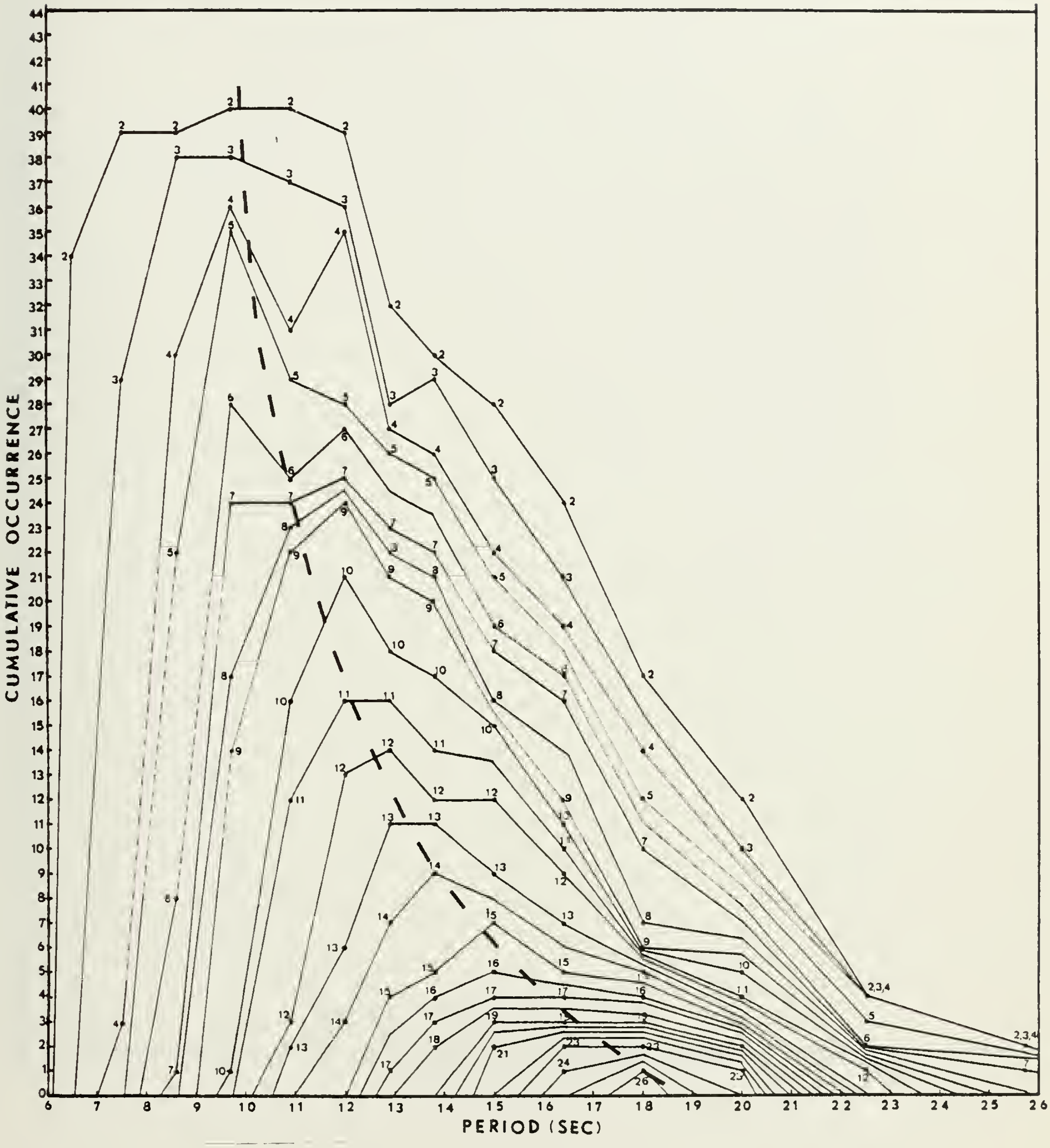

Figure 12. One-Dimensional Frequency Spectrum Climatology for February 1975 (45 total event occurrences)

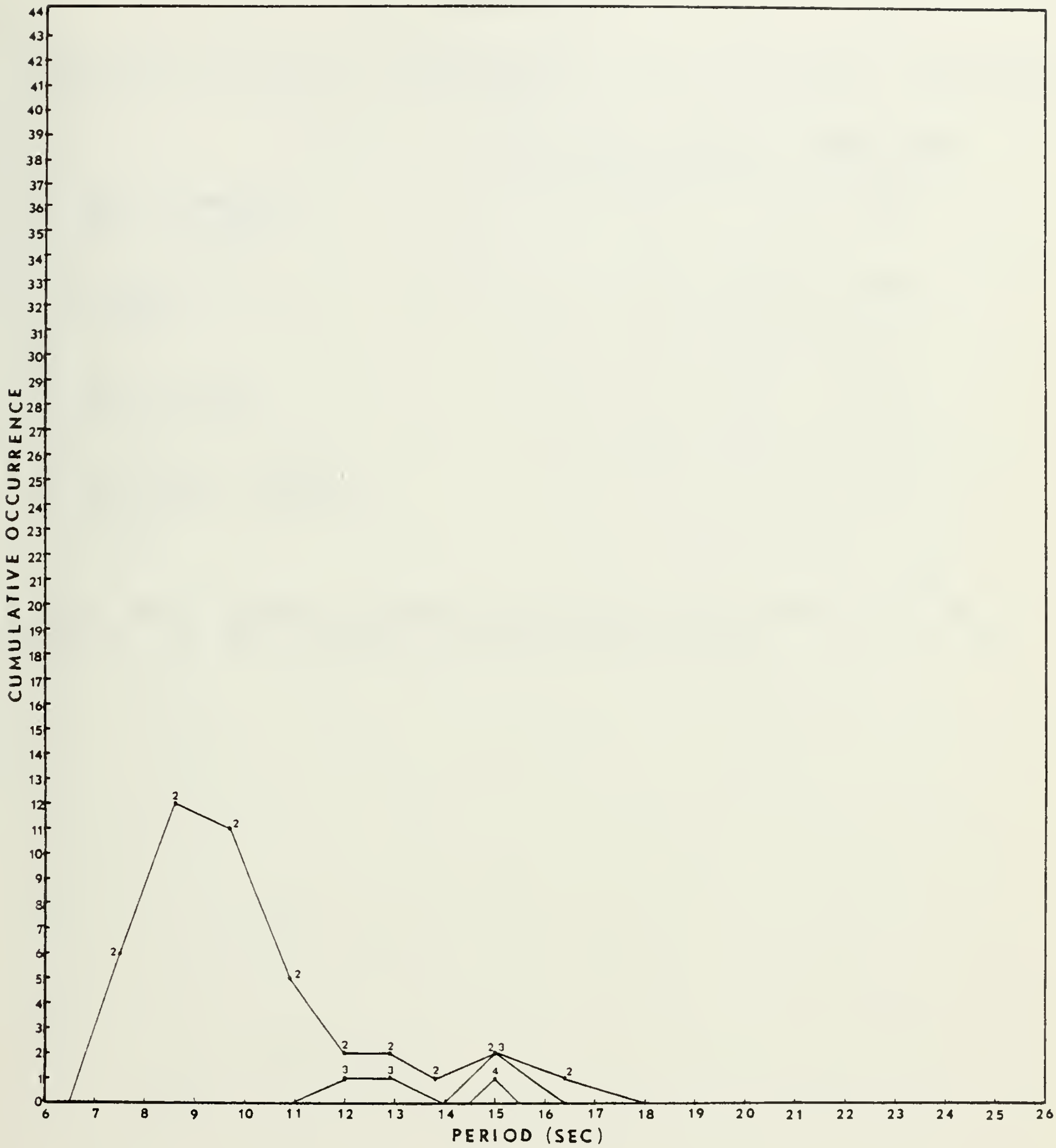

Figure 13. One-Dimensional Frequency Spectrum Climatology for August 1974 (61 total event occurrences)

APPENDIX A

CONVERSION FORMULAE FOR COMMONLY USED WAVE HEIGHT PARAMETERS

	H.O. 603 (1955)	FNWC SOWM
Most frequent wave height	$1.41 \sqrt{E}$	$2 \sqrt{E_t}$
Average wave height	$1.77 \sqrt{E}$	$2.5 \sqrt{E_t}$
Significant wave height	$2.83 \sqrt{E}$	$4 \sqrt{E_t}$
Average heights of 1/10th highest waves	$3.60 \sqrt{E}$	$5.1 \sqrt{E_t}$

In the wave height parameters given in H.O. 603, $E = 2E_t$, where E_t is the variance of the sea surface.

APPENDIX B

SPECTRAL WAVE GROWTH PARAMETERS AND STEEPNESS CRITERIA FOR 20, 30, 40, AND 50 KNOT WINDS
(modified from Cardone, 1975)

Wind Speed: 20 Kts (Fully Arisen Sea at 21 Hours)

Wind duration (hrs)	3	6	9	12	15	18	21
T_1 (adjusted) (sec)	3.53	5.80	6.60	7.50	7.50	7.50	7.50
$\bar{H}_{1/3}$ (ft)	2.18	4.93	6.36	7.03	7.29	7.39	7.42
Steepness	.175	.147	.146	.125	.130	.131	.132
$\bar{H}_{1/3}/T_1^2$ (adjusted)							

Wind Speed: 30 Kts (Fully Arisen Sea at 24 Hours)

Wind duration (hrs)	3	6	9	12	15	18	21	24
T_1 (adjusted) (sec)	5.30	6.90	8.57	9.47	10.59	11.25	11.25	11.25
$\bar{H}_{1/3}$ (ft)	4.90	8.72	11.48	14.02	15.87	16.39	16.47	16.49
Steepness	.174	.183	.156	.156	.142	.130	.130	.130
$\bar{H}_{1/3}/T_1^2$ (adjusted)								

Wind Speed: 40 Kts (Fully Arisen Sea at 24 Hours)

Wind duration (hrs)	3	6	9	12	15	18	21	24
T_1 (adjusted) (sec)	6.90	9.00	10.59	11.25	12.00	12.86	15.00	15.00
$\bar{H}_{1/3}$ (ft)	8.71	14.33	17.94	20.86	23.99	27.31	29.03	29.38
Steepness	.183	.177	.160	.165	.167	.165	.129	.131
$\bar{H}_{1/3}/T_1^2$ (adjusted)								

Wind Speed: 50 Kts (Fully Arisen Sea at 30 Hours)

Wind duration (hrs)	3	6	9	12	15	18	21	24	27	30
T_1 (adjusted) (sec)	8.57	11.25	12.86	13.85	15.00	15.00	16.36	18.00	18.00	18.00
$\bar{H}_{1/3}$ (ft)	13.54	21.30	26.26	29.99	33.36	36.78	40.42	43.81	45.58	46.04
Steepness	.184	.168	.159	.156	.148	.163	.151	.135	.141	.142
$\bar{H}_{1/3}/T_1^2$ (adjusted)										

APPENDIX C

SPECTRAL ENERGY DISTRIBUTION FOR FULLY ARISEN SEAS FROM WIND SPEEDS OF 20, 30, 40, AND 50 KNOTS FOR A 30° DIRECTION BAND (modified from Cardone, 1975)

Tables C-1 thru C-4 contain the spectral energy-period band distribution for wind speeds of 20, 30, 40, and 50 knots respectively. The 30° direction band is centered about the direction of the mean wind. The energy distribution is presented for both the FNWC and the common bandwidths.

Table C-1

Fully Arisen Sea (20 knots)

Wind speed:	20 kts
Time to fully arisen conditions:	21 hrs
Tav:	5.69 secs
U_*:	.74
$\bar{H}_{1/3}$:	7.42 ft
Var:	3.44 ft^2

Frequency (Hz)	Period (secs)	ΔE/FNWC bandwidth	Energy in 30° band	ΔE/0.0055Hz bandwidth
.039	25.7			
.044	22.5			
.050	20.0			
.056	18.0			
.061	16.4			
.067	15.0			
.072	13.8			
.078	12.9	.0003	.0001	.0001
.083	12.0	.0020	.0008	.0008
.092	10.9	.0351	.0132	.0066
.103	9.7	.1614	.0605	.0302
.117	8.6	.5025	.1884	.0628
.133	7.5	.6199	.2325	.0775
.153	6.5	.7074	.2653	.0663
.164	6.1	1.4094	.5285	.0294
		E_t=3.4375		

Table C-2

Fully Arisen Sea (30 knots)

Wind speed:	30 kts
Time to fully arisen conditions:	24 hrs
Tav:	8.18 secs
U_*:	1.26
$\bar{H}_{1/3}$:	16.49 ft
Var:	16.99 ft^2

Frequency (Hz)	Period (secs)	ΔE/FNWC bandwidth	Energy in 30° band	ΔE/0.0055Hz bandwidth
.039	25.7			
.044	22.5			
.050	20.0	.0003	.0001	.0001
.056	18.0	.0131	.0049	.0049
.061	16.4	.1158	.0434	.0434
.067	15.0	.4032	.1512	.1512
.072	13.8	.8177	.3066	.3066
.078	12.9	1.1983	.4494	.4494
.083	12.0	1.4363	.5386	.5386
.092	10.9	2.9903	1.1214	.5607
.103	9.7	2.5722	.9646	.4823
.117	8.6	2.7401	1.0275	.3425
.133	7.5	1.6863	.6324	.2108
.153	6.5	1.2767	.4788	.1197
.164	6.1	1.7370	.6514	.0362
		E_t=16.9873		

Table C-3

Fully Arisen Sea (40 knots)

Wind speed:	40 kts
Time to fully arisen conditions:	24 hrs
Tav:	10.78 secs
U_*:	1.85
$\bar{H}_{1/3}$:	29.38 ft
Var:	53.97 ft^2

Frequency (Hz)	Period (secs)	ΔE/FNWC bandwidth	Energy in 30° band	ΔE/0.0055Hz bandwidth
.039	25.7	.0056	.0021	.0021
.044	22.5	.2749	.1031	.1031
.050	20.0	1.7222	.6458	.6458
.056	18.0	4.0634	1.5238	1.5238
.061	16.4	5.8309	2.1866	2.1866
.067	15.0	6.4152	2.4057	2.4057
.072	13.8	6.0960	2.2860	2.2860
.078	12.9	5.3359	2.0010	2.0010
.083	12.0	4.4611	1.6729	1.6729
.092	10.9	6.5687	2.4633	1.2317
.103	9.7	4.2319	1.5870	.7935
.117	8.6	3.7227	1.3960	.4700
.133	7.5	2.0158	.7559	.2520
.153	6.5	1.4182	.5318	.1330
.164	6.1	1.8043	.6766	.0376
		E_t=53.9668		

Table C-4

Fully Arisen Sea (50 knots)

Wind speed:	50 knots
Time to fully arisen conditions:	30 hrs
Tav:	13.41 secs
U_*:	2.51
$\bar{H}_{1/3}$:	46.04 ft
Var:	132.49 ft^2

Frequency (Hz)	Period (secs)	ΔE/FNWC bandwidth	Energy in 30° band	ΔE/0.0055Hz bandwidth
.039	25.7	4.0088	1.5033	1.5033
.044	22.5	12.5661	4.7123	4.7123
.050	20.0	18.7274	7.0228	7.0228
.056	18.0	19.4475	7.2928	7.2928
.061	16.4	16.9890	6.3709	6.3709
.067	15.0	13.6499	5.1187	5.1187
.072	13.8	10.5468	3.9551	3.9551
.078	12.9	8.0207	3.0078	3.0078
.083	12.0	6.0780	2.2793	2.2793
.092	10.9	8.1547	3.0580	1.5290
.103	9.7	4.8500	1.8188	.9094
.117	8.6	4.0489	1.5183	.5061
.133	7.5	2.1166	.7937	.2646
.153	6.5	1.4595	.5473	.1368
.164	6.1	1.8233	.6837	.0380
		E_t=132.4872		

APPENDIX D

CLIMATOLOGICAL WAVE TABLES OF THE

GROSS STATISTICS FOR FEBRUARY 1975

Tables D-1 thru D-12 contain the coded wave height-equal period band distribution for the meteorological direction bands 1 thru 12 for grid point 164 in subprojection 3 at latitude 50.9° North, longitude 145.6° West. The February 1975 wave statistics were derived from 45 FNWC SOWM 12-hourly synoptic analyses. The wave height codes are found in Table IV. The directional bandwidth codes are contained in item 11 of Figure 2. The tabular entries reflect the number of event occurrences of 12-hourly analyses for February 1975.

$\psi = 1$ FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03															
04						1									
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table D-1

$\Psi = 2$ FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table D-2

$\Psi = 3$ FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03									1						
04										1					
05										1					
06					1										
07					1										
08															
09															
10							1								
11								2							
12															
13									1	1					
14									1						
15										1					
16											2				
17												1			
18															
19															
20															
21															

Table D-3

$\Psi = 4$ FEBRUARY 1975

SIGNIFICANT HEIGHT (CODED)	CENTRAL PERIOD (SECONDS) 6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03															
04															
05															
06						1									
07															
08							1								
09															
10															
11															
12															
13															
14															
15															
16															
17															
18											1				
19															
20															
21															

Table D-4

Ψ = 5 FEBRUARY 1975

SIGNIFICANT HEIGHT (CODED) \ CENTRAL PERIOD (SECONDS)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03															
04															
05															
06															
07															
08							1								
09															
10							1								
11								1							
12								1							
13															
14								1		1					
15															
16															
17															
18															
19															
20															
21															

Table D-5

Ψ = 6

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03															
04															
05															
06															
07															
08															
09															
10															
11						1									
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table D-6

Ψ = 7 FEBRUARY 1975

SIGNIFICANT HEIGHT (CODED) \ CENTRAL PERIOD (SECONDS)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12							1			1					
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table D-7

Ψ = 8

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table D-8

$\Psi = 9$ FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03															
04															
05															
06															
07					2	1									
08					1										
09															
10						2									
11															
12							1								
13									2						
14															
15															
16															
17															
18															
19															
20															
21															

Table D-9

Ψ = 10

FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03															
04															
05															
06															
07					1										
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table D-10

$\Psi = 11$ FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03											2				
04															
05															
06					1										
07					2										
08					1										
09						1									
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table D-11

$\Psi = 12$ FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table D-12

APPENDIX E

CLIMATOLOGICAL WAVE TABLES OF THE

GROSS STATISTICS FOR AUGUST 1974

Tables E-1 thru E-12 contain the coded wave height-equal period band distribution for the meteorological direction bands 1 thru 12 for grid point 164 in subprojection 3 at latitude 50.9° North, longitude 145.6° West. The August wave statistics were derived from 61 FNWC SOWM 12-hourly synoptic analyses. The wave height codes are found in Table IV. The directional bandwidth codes are contained in item 11 of Figure 2. The tabular entries reflect the number of event occurrences of 12-hourly analyses for August 1974.

$\Psi = 1$ AUGUST 1974

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	1														
02	1														
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

CENTRAL PERIOD (SECONDS)

Table E-1

$\Psi = 2$ AUGUST 1974

SIGNIFICANT HEIGHT (CODED) \ CENTRAL PERIOD (SECONDS)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02			1												
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table E-2

Ψ = 3

AUGUST 1974

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02		2			2										
03		2			1										
04			4	2						1					
05				3	2		1								
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table E-3

Ψ = 4

AUGUST 1974

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01		1			2										
02		1													
03															
04			1												
05				1											
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table E-4

$\psi = 5$ AUGUST 1974

SIGNIFICANT HEIGHT (CODED) \ CENTRAL PERIOD (SECONDS)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01		2			3										
02		1													
03		1													
04				1	3										
05					1	1									
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table E-5

Ψ = 6 AUGUST 1974

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01				3											
02															
03															
04															
05				1											
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table E-6

$\Psi = 7$ AUGUST 1974

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03		1													
04		1													
05				1											
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table E-7

Ψ = 8 AUGUST 1974

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table E-8

Ψ = 9

AUGUST 1974

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table E-9

Ψ = 10 AUGUST 1974

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01															
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table E-10

Ψ =11 AUGUST 1974

SIGNIFICANT HEIGHT (CODED)	CENTRAL PERIOD (SECONDS) 6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	1														
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table E-11

Ψ = 12 AUGUST 1974

CENTRAL PERIOD (SECONDS)

SIGNIFICANT HEIGHT (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	4	1													
02	1														
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															

Table E-12

APPENDIX F

CLIMATOLOGICAL WAVE TABLES OF THE TWO-DIMENSIONAL WAVE STATISTICS FOR FEBRUARY 1975

Tables F-1 thru F-12 contain the coded energy density - FNWC period band distribution for the meteorological direction bands 1 thru 12 for grid point 164 in subprojection 3 at latitude 50.9° North, longitude 145.6° West. The February 1975 wave statistics were derived from 45 FNWC SOWM 12-hourly synoptic analyses. The energy density codes are found in Table VII. The directional bandwidth codes are contained in item 11 of Figure 2. The tabular entries reflect the number of event occurrences of 12 hourly analyses for February 1975.

Ψ = 1

FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	24	24	21	20	18	23	19	17	9	21	5	2	1		
02	11	3	7	6	3	3	4	2	2	4	2				
03				4	3	2		1	1	2					
04					1	3									
05						1	1								
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Table F-1

ψ = 2

FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/FNWC FREQ BANDWIDTH (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	15	15	12	13	8	12	19	24	21	25	16	11	6	1	2
02	14	12	15	5	3	4	5	7	3	3	3	1			
03				11	5	2	2	3	5	2	2	1			
04				3	9	1	2	1	1						
05					1	3	1	1	2		1				
06						3		1		2					
07						2			1						
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Table F-2

Ψ = 3 FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/FNWC FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	12	5	3	5	2	11	12	15	13	12	9	7	5	3	5
02	18	20	21	1	5	4	2	3	3	3			1		
03				6	3	1	4	2	2	2	2	2			
04				14	4	2	1	2	1	2	2	2		1	1
05					10		5	3	3	2	1			1	
06						3	5	1	1	1	2				
07						4	2	4	1						
08						7		3	2	2					
09								1	3	1		1	3		
10									2			1			
11										4		2			
12											3			1	
13										1	1				
14															
15											1	1			
16															
17															
18															
19												1			
20															
21													1		
22															
23															
24															
25															
26															

Table F-3

$\psi = 4$

FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	4	3	2		1	6	6	8	10	6	6	8	2	1	3
02	20	21	21	5	5	6	2	2		5	4	1		1	
03	1		1	6	7	2	5	1	2	1	1			1	
04				13	6	1	5	5	1	1	1	1			
05					5	5	4	2	1	1			1		
06						1	1	1	2						
07						3	2	1		1					
08						3			1		1				
09								2		2					
10									3			1			
11										2		1			
12											2	1			
13											1		1		
14															
15															
16												1			
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Table F-4

$\Psi = 5$ FEBRUARY 1975

Table F-5

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/FNWC FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	7	6	5	7	7	7	8	7	6	7	6	5	9	2	3
02	17	17	19	2	5	1	6	3	3	2	2	2			
03				10	6	7	2	3	2	3	1	2	8		1
04				5	6	1	4	2		1	1				
05					3	3	4	1	2	1	2				
06						5	1	3	2		1				
07						3		3	2	1	1				
08						1			3	1	1				
09										1	1				
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Ψ = 6

FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/FNWC FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	14	13	16	13	14	20	17	19	14	8	10	9	2	1	
02	10	6	6	4	6	2	3	4	5	2	1	2	1		
03				4	2	2	1	3	2	4	1	1			
04				4	3	2	2	4							
05					2	2				1					
06						1	1								
07						2									
08															
09						1									
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Table F-6

FEBRUARY 1975

Ψ =7

Table F-7

ENERGY DENSITY/FNWC FREQ BANDWIDTH (CODED) \ CENTRAL PERIOD (SECONDS)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	16	11	12	16	17	14	11	10	11	10	11	8	3		
02	4	3	5	4	4	4	4	4	2	1					
03				1	1	2	1	1	1						
04				3	1	1	1		1	2					
05					2		1	2	1						
06						1									
07						1									
08						1									
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Ψ =8

FEBRUARY 1975

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/FNWC FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	10	12	8	11	14	14	13	13	14	4	4	4	3		
02	5	2	7	2	1	3	3	5	3	5	2	2			
03				5	4	2			1		1				
04				2	2	2	3	1	1	1					
05						1	1		1						
06						2					1				
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Table F-8

FEBRUARY 1975

$\Psi = 9$

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	7	6	12	13	18	22	18	20	10	2	3	1	4	2	
02	8	9	9	1	2	1	4	1	2		1	2			
03					1	3	2	1	1	1	1	2			
04				10	5	2					1				
05					4	2	2	1	1	2	1				
06						1	1	2	1	1					
07						2									
08						2									
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Table F-9

Ψ =10

Table F-10

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED)

CENTRAL PERIOD (SECONDS)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	5	6	5	5	9	10	10	13	9	4	2	1	1	1	
02	12	11	12	2		2	2	3	1	1	1	2			
03				9	8	6	3	1				1			
04				4	5	2	1		1		1				
05					1	1	1	2	1	2	1				
06						1			1						
07						1									
08						2									
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

FEBRUARY 1975

Ψ=11

Table F-11

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED)	CENTRAL PERIOD (SECONDS)														
	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	8	12	4	3	1	1	1	2	2	4	2	2	1		
02	13	8	10	1	1	2	4	2	2	1	1				
03				6	5	2	9	1		1					
04				5	8	1		1	1						
05						1		1	1						
06						2									
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Ψ =12

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/FNWC FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	20	22	22	17	14	13	9	10	10	5	2	2			
02	9	3	5	7	6	1		1	3						
03				3	4	2	1								
04				2	1										
05						1									
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Table F-12

APPENDIX G

CLIMATOLOGICAL WAVE TABLES OF THE TWO-DIMENSIONAL WAVE STATISTICS FOR AUGUST 1974

Tables G-1 thru G-12 contain the coded energy density-FNWC period band distribution for the meteorological direction bands 1 thru 12 for grid point 164 in subprojection 3 at latitude 50.9° North, longitude 145.6° West. The August 1974 wave statistics were derived from 61 FNWC SOWM 12-hourly synoptic analyses. The energy density codes are found in Table VII. The directional bandwidth codes are contained in item 11 of Figure 2. The tabular entries reflect the number of event occurrences of 12 hourly analyses for August 1974.

Table G-1

Ψ = 1 — AUGUST 1974

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY / FNWC FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	16	3	3	2	2										
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Ψ=2 AUGUST 1974

Table G-2

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	23	15	19	14	23	14	6	6	2	1	3				
02	2			2											
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Ψ = 3 AUGUST 1974

Table G-3

ENERGY DENSITY/FNWC FREQ BANDWIDTH (CODED)	CENTRAL PERIOD (SECONDS)														
	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	15	19	19	19	18	11	12	10	3	2	3	3	1		
02	15	5	6	4	7	2			1		1				
03				1		1	1	1		1					
04										1					
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

$\psi = 4$ AUGUST 1974

Table G-4

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	16	27	28	22	27	15	16	15	5	1	17				
02	15	3	4	7	2	1									
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Ψ = 5

AUGUST 1974

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED)	CENTRAL PERIOD (SECONDS)														
	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	26	38	24	16	11	7	7	5	3	1	1				
02	9		5	8	7	4	1								
03				1		2									
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Table G-5

Ψ = 6 AUGUST 1974

Table G-6

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED)

CENTRAL PERIOD (SECONDS)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	26	16	24	11	7	8	7	3	1						
02	2		2	6	3										
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Ψ = 7 AUGUST 1974

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	6	5	5	3	3	1									
02	5	2	1	2											
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Table G-7

Ψ = 8

AUGUST 1974

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/FNWC FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	7	5	4	4	2	1									
02	4														
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Table G-8

Ψ = 9 AUGUST 1974

Table G-9

ENERGY DENSITY/FNWC FREQ BANDWIDTH (CODED)

CENTRAL PERIOD (SECONDS)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	6	4	4	3											
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Table G-10

$\Psi = 10$ AUGUST 1974

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/FNWC FREQ BANDWIDTH (CODED)	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	3	1	2	1		2									
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Ψ=11 AUGUST 1974

Table G-11

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED)

CENTRAL PERIOD (SECONDS)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15 0	16.4	18 0	20.0	22.5	25.7
01	4														
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

Ψ = 12

AUGUST 1974

Table G-12

CENTRAL PERIOD (SECONDS)

ENERGY DENSITY/ FNWC FREQ BANDWIDTH (CODED)

	6.1	6.5	7.5	8.6	9.7	10.9	12.0	12.9	13.8	15.0	16.4	18.0	20.0	22.5	25.7
01	10	3													
02															
03															
04															
05															
06															
07															
08															
09															
10															
11															
12															
13															
14															
15															
16															
17															
18															
19															
20															
21															
22															
23															
24															
25															
26															

INITIAL DISTRIBUTION LIST

		No. Copies
1.	Mr. John S. Habel Department of Navigation and Ocean Development State of California 1416 9th Street Sacramento, California 95814	6
2.	Defense Documentation Center Cameron Station Alexandria, Virginia 22314	2
3.	Department of Oceanography, Code 68 Naval Postgraduate School Monterey, California 93940	3
4.	Library (Code 0212) Naval Postgraduate School Monterey, California 93940	2
5.	Professor W. C. Thompson, Code 68 Department of Oceanography Naval Postgraduate School Monterey, California 93940	2
6.	Professor Edward B. Thornton Department of Oceanography Naval Postgraduate School Monterey, California 93940	1
7.	LT F. M. Reynolds, USN 1307 Fechteler Drive Monterey, California 93940	1
8.	Oceanographer of the Navy Hoffman Building No. 2 200 Stovall Street Alexandria, Virginia 22332	1
9.	Office of Naval Research Code 480 Arlington, Virginia 22217	1
10.	Library, Code 3330 Naval Oceanographic Office Washington, D. C. 20373	1

11. Commanding Officer 1
Fleet Numerical Weather Central
Monterey, California 93940

12. Commanding Officer 1
Navy Environmental Prediction Research
Facility
Monterey, California 93940

13. Department of the Navy 1
Commander Oceanographic System Pacific
Box 1390
FPO San Francisco 96610

14. Director, Naval Oceanography and Meteorology 1
Building 200
Washington Navy Yard
Washington, D. C. 20374

15. Commanding Officer 1
Naval Civil Engineering Laboratory
Port Hueneme, California 93043

16. Dr. Robert E. Stevenson 1
Scientific Liaison Office, ONR
Scripps Institution of Oceanography
La Jolla, California 92037

17. Commanding Officer 2
San Francisco District
U. S. Army Corps of Engineers
100 Mc Allister Street
San Francisco, California 94111

18. Mr. Orville T. Magoon 1
Coastal Engineering Branch
Planning Division
U. S. Army Engineering Division, South Pacific
630 Sansome Street
San Francisco, California 94111

19. Mr. Charles Fisher, Chief 1
Coastal Engineering Branch
U. S. Army Corps of Engineers
P. O. Box 2711
Los Angeles, California 90053

20. Dr. Rudolph P. Savage 1
Technical Director
Coastal Engineering Research Center
5201 Little Falls Road, N.W.
Washington, D. C. 20016

21. Dr. D. Lee Harris 1
Coasting Engineering Research Center
5201 Little Falls Road, N.W.
Washington, D. C. 20016

22. SIO Library 1
University of California, San Diego
P. O. Box 2367
La Jolla, California 92037

23. Department of Oceanography Library 1
University of Washington
Seattle, Washington 98105

24. Department of Oceanography Library 1
Oregon State University
Corvallis, Oregon 97331

25. Dr. James S. Bailey 1
Director, Geography Programs (Code 462)
Office of Naval Research
Arlington, Virginia 22217

Thesis 166625
R3685 Reynolds
c.1 Climatological wave
statistics derived from
FNWC synoptic spectral
wave analyses.