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SEA WAVES AT WAGLAN ISLAND HONG KONG

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Contents

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1. Introduction

Observations of wave height and period at Waglan Island have been obtained visually over a fairly long period and the observed wave heights have been analysed by Cuming[1]. In connection with the building of a dam wall in the Kwun Mun inlet for the High Island Water Scheme, a correlation between waves at Waglan Island (Wang Lan) and at Kwun Mun was sought by the consultant engineers for the dam, Binnie and Partners. It was decided to put wave recorders at both Waglan Island and Kwun Mun (see Figure 1) but only for a limited time at the latter site. Correlations established during the common recording period were to be used to refer the Waglan Island data taken over a longer time to Kwun Mun. This paper deals only with the waves recorded at Waglan Island. No distinction has been made between sea waves and swell.

2. Instrument and Installation

The type of wave recorder used at the sites was designed at the National Institute of Oceanography. The design was such that variations with periods in excess of 25 seconds were not recorded. Hence the direct effects of tide and atmospheric pressure variations were eliminated. They still affect the sensitivity of the recorder but to a degree which is negligible. In addition, the response of the shore unit fell significantly when the period to be recorded was less than 4 seconds. This was due to the low torque response of the pen recorder at these short periods.

As a result of computer studies made in London by Binnie and Partners the sea unit of the wave recorder (sensor head) was placed 7.8 metres below the Mean Sea Level in water

28 metres deep, at a point 216 metres from Waglan Light on a bearing of 213° true (172930E, 15220N on the New Colony Grid). This position (Figure 2) was chosen to minimise refraction of waves approaching Waglan Island from the southeast and northeast. In order to ensure that the support for the sensor head was not overturned in the wave conditions expected to be experienced during typhoons, it was a massive construction weighing about 60 tonnes. Figure 3 shows the tower and figures 4 and 5 show the method used to take it to the Waglan Island site several miles by sea from the construction yard. The recorder was housed in the offices of the Marine Department on Waglan Island. The fitting of the sensor head to the submerged tower and laying of the underwater cable connecting the sensor head to the recorder were done by the Royal Navy.

3. Operating Period

Recording started on July 2, 1971. The recorder was out of order due to a lightning strike on August 6, and was repaired on August 14. During the passage of Typhoon Rose on August 16 the cable was damaged by underwater boulders, one of which weighing approximately two tonnes had shifted and fractured the cable and the cast iron pipe protecting it. The cable was repaired and the record resumed on August 24. The record was maintained with minor interruptions until December 17, 1971 when the cable was damaged at the surf line near the rocky shore. Work for adequate protection of the cable had not been completed at this time. The persistence of the northeast monsoon prevented completion of the work, repair of the cable and resumption of recording until well into 1972. The analysis presented in this report covers all the data collected from July 2 to December 17 in 1971.

4. Recording Interval and Recording Period

Recordings were made at 3-hourly intervals for a period

of 15 minutes ending at 0200, 0500, 0800, 1100, 1400, 1700, 2000 and 2300 hours H.K. Standard Time and a 10-minute portion of each of these traces taken for analysis. (There was a period of approximately 2 minutes from the time of switching on during which the recorder switching transient decayed. This, together with an allowance of 3 minutes for possible clock irregularities, limited the period of analysis to 5 minutes less than the nominal operating time.) Eye observations of wave height and period were made independently of the wave recorder by the observers at Waglan Island and instrumental observations of surface wind speed and direction were also recorded by them.

5. Method of Analysis

The method of analysis followed that given by Tucker[2]. H_{max} and H_{rms} were found from H_1, and H_s from H_{rms} using the equations :-

$$H_1 = H_{rms} \cdot 2 \cdot (2\theta)^{1/2} \cdot (1+0.289\,\theta^{-1} - 0.247\,\theta^{-2}), \qquad (1)$$

$$H_{max} = H_1 \qquad (2)$$

$$H_s = 4.00\,H_{rms}, \qquad (3)$$

$$\theta = \log_e N_z, \qquad (4)$$

where H_1 = sum of highest crest height and deepest trough depth (each from the mean water level) during the analysis period,

H_{max} = height, (i.e. the vertical distance from the bottom of the trough to the top of the crest), of the maximum wave, in the analysis period,

H_{rms} = root-mean-square value of wave height in the analysis period,

H_s = significant wave height, (the mean of the highest one-third of all the waves in the analysis period),

T_z = mean zero-crossing period in the analysis period,

T_c = mean crest period in the analysis period,

N_z = number of times the record trace crosses the mean water level in an upwards direction during the analysis period.

Equations (2) and (3) are only strictly true for records containing a narrow range of frequencies, but it has been shown by Tucker[2] that they are very nearly correct over a wide range of values of spectral width. With the technique used it was estimated that values of H_1 as measured had proportional standard errors of 8-11% in records with a narrow spectrum, and 11-15% in records with a wide spectrum, and these proportional standard errors were reflected in the derived values of H_{rms}, H_{max} and H_s.

Corrections were applied to the results to take account of the variation of the sensitivity of the pen recorder with frequency and of the attenuation of the sea waves with depth using the graphs supplied by National Institute of Oceanography[3] (see Figure 6). The correction for attenuation is very large for wave periods of 3 seconds or less.

6. Indeterminate Records

It was found that in the summer months, because the amplitudes involved were usually small, waves at Waglan Island with periods less than 6 seconds rarely produced a record although waves with periods less than 4 seconds and heights of up to 1 metre were observed visually. (Figures 7 and 8 show plots of visual observations of wave height and period at Waglan Island at times when the wave recorder was giving data which was used in the analysis of its results. It also shows the relationship between wave height and period for the steepest theoretical wave.) As a result, a considerable number of the instrumental records during this period were classified as indeterminate in the first instance (referred to as indeterminate for convenience in the rest of this report) and a further number probably gave misleading results for the zero-crossing period and hence for the wave height.

It was necessary to devise some method of treating the indeterminate data in order to obtain a better representation of the frequency distributions obtained from the instrumental records. The smallest departure from the mean water level on the record which can be reliably detected is 0.1 metre. This corresponds to H_1 and H_s at the surface which vary with T_z in the manner shown in Table I below :

Table I

Minimum values of surface wave parameters required to ensure an adequate wave record

Zero-Crossing Period, T_z (second)	3	4	5	6	7	10	15	20	25
Maximum Wave Height at surface H_1 (metre)	5.0	1.4	0.7	0.5	0.4	0.3	0.3	0.2	0.2
Significant Wave Height at surface H_s (metre)	2.9	0.8	0.4	0.3	0.2	0.2	0.2	0.2	0.1

Waves at the sea surface with heights less than those shown in Table I will not be recorded. The significant surface wave heights have been plotted in Figures 7 and 8 as dotted lines. The numerals lying to the left of the lines give an indication of the proportion of time for which the wave recorder would not record the waves although these would be recorded visually. (Visual observations of wave height are close to the significant wave hight). The proportion is large in summer and very small in winter.

A comparison of indeterminate records and those with small recorded amplitudes with the corresponding visual observations showed large discrepancies. There were occasions of very long crossing periods (more than 10 seconds) with small amplitude while the eye observations gave periods of 1 second. Often in the indeterminate cases a best estimate of T_z could be made from a part of the instrumental record where the amplitude was sustained for one or more minutes and from the very nature of the recording this best estimate should be close to the period of the most significant waves. The period thus obtained was never found

to be as short as the eye estimate of the period made at the same time. In fact the shortest crossing period found anywhere in the instrumental record was 5 seconds, and one of 4 seconds or less was never recognised. Thus it was clear that when the wave amplitude was low, the eye observations and the instrumental record related to two entirely different parts of the full wave spectrum in many cases. Also the wave amplitude deduced from the instrumental recorder would have been underestimated due to the use of a smaller correction factor (for attenuation with depth) corresponding to a longer period obtained from the instrumental record. The spectral width parameter (see Section 10) obtained from the instrumental record must also be interpreted as the width in a limited spectral band. However, when the period was greater than about 8 seconds, it could be said that the eye observations and the recorded observations were giving estimates of the same significant wave height and period.

7. Comparison of Instrumental and Eye Observations

A study of the wave height obtained in the same sampling period by the instrumental recorder and by eye when the recorded amplitude was large showed that the maximum wave height in the instrumental record was approximately 1.43 times the height observed by eye (see Section 14). From the instrumental records the maximum wave height was generally about 1.5 times the significant wave height, H_s. This agrees very well with the generally accepted idea that visual observations of wave height are usually close to the significant wave height.

As discussed in Section 6 above it was clear that on some occasions, the record analysed over a ten minute period must have been leading to false results because it was recording at the limit of the sensitivity, i.e. recording only the higher waves and thus reflecting a crossing period determined over the ten minutes recording period which was much longer than the true value. This was

most clearly demonstrated when wave trains of relatively large amplitude were recorded in an otherwise quiet period. On the other hand, it did appear on some occasions to include a true swell not included in the eye observation of the waves. The comparisons of both mean zero-crossing periods, T_z, and mean crest periods, T_c, obtained from the instrumental record with the eye observation of the wave periods (Figures 9, 10, 11, 12) confirmed that the instrumental recorder was recording a restricted spectrum, but wave recorder and eye observation agree on the T_z values for long periods. This implies that the observer normally assesses the longest period waves as dominant. The T_c frequency distribution showed that the instrumental recorder was including waves with shorter periods than those considered by the eye observation as dominant in these circumstances.

After careful consideration it was decided that best use of the indeterminate cases would be made by using the height observed by eye as the significant wave height, H_s, and the period that could be best estimated from re-scrutiny of the instrumental record as the zero-crossing period, T_z, in plotting the results in the final form (Figures 13 to 24 inclusive).

8. Scatter Diagrams

The year in Hong Kong can be divided into two main parts. That from mid-October through December to mid-April is dominated by the winter monsoon to a lesser or greater extent, and the period from mid-April to mid-October by the summer monsoon and tropical cyclones. In this report, summer season contains all data collected from July 2 to October 15, 1971, and winter season, from October 16 to December 17, 1971.

Scatter diagrams relating significant wave height, H_s, to mean zero-crossing period, T_z, were constructed separately from

the wave recorder as shown in Figures 13 to 15 for

(a) the whole recording period,

(b) the winter season alone and,

(c) the summer season alone.

The numbers of occurrences were expressed in parts per thousand. The indeterminate cases have already been included in the scatter diagrams by using the method described in Section 7.

The dashed lines in these diagrams show the steepness of the significant wave which is defined as the ratio of significant wave height to wave length. The theoretical limit of the steepness for a progressive maximum wave is 1/7.

These diagrams indicate that, for the winter season, the most common wave conditions were those with an H_s of between 1 and 1.5 metres and a T_z of between 8 and 8.5 seconds. For the summer season, H_s usually varies between 0.5 and 1 metre with T_z between 8 and 9 seconds. Generally speaking, waves in winter season are steeper than those in summer. However, during the passage of tropical cyclones in summer, the waves can be very steep indeed.

The occasions of very high waves in Figure 15 were associated with the passage of tropical cyclones. Those of long period and low amplitude were from the swells generated by large tropical cyclones, either in the central part of the South China Sea or to the east of the Balintang Channel.

9. Cumulative Distribution of Wave Heights

Irrespective of wave period, the number of occurrence of significant waves in each height range at every half metre interval were added, starting from the greatest height, to give the numbers of occasions when the significant wave height exceed a given height.

These accumulated numbers of occasions were expressed as percentages and plotted in Figures 16 to 18 for each season. From these graphs the proportion of time for which any significant wave exceeding a given height may be determined.

As the recorder only operated for 15 minutes during each 3-hour interval, it was probable that the largest wave for each recording interval (3 hour) might not be detected. However, the most probable height of this wave could be estimated from the available record using the method of Draper[4]. The results are also shown in the diagram for each season and are summarised in Table II below.

Table II

Distribution of Wave Heights

Percentage Exceedance %	Significant Wave Heights H_s (metre)		Most Probable Highest Waves H_{max} (3 hour) (metre)	
	Winter	Summer	Winter	Summer
5	2.4 or higher	3.0 or higher	4.6 or higher	6.0 or higher
10	2.1 or higher	2.5 or higher	4.1 or higher	4.8 or higher
25	1.8 or higher	1.6 or higher	3.5 or higher	3.3 or higher
50	1.5 or higher	1.0 or higher	2.9 or higher	2.0 or higher
75	1.2 or higher	0.7 or higher	2.3 or higher	1.3 or higher

Waves in Winter season were generally higher than those in Summer. However, during the passage of tropical cyclones, much higher waves have been detected in Summer season.

10. Distribution of Zero-Crossing Periods and Spectral Width Parameters

The mean zero-crossing period, T_z, was computed from the following equlation :

$$T_z = \frac{\text{Length of the analysis period (sec)}}{N_z} \qquad (5)$$

The distribution of this parameter is shown in Figures 19 to 21. It is seen that the range of periods in summer was wider than that in winter. The most frequent values were 8-9 seconds in winter and 9-10 seconds in summer.

Spectral width parameter, E, is defined as :

$$E^2 = 1 - \left(\frac{T_c}{T_z}\right)^2$$

It serves as a measure of the range of frequencies present relative to the mean wave frequency. E will be large if T_z is much greater than T_c. This occurs when the wave components cover a wide range of frequencies so that the long waves carry short-wave ripples on top of them and there will be many more crests than zero crossings. On the other hand, if the wave is simple and contains only a narrow range of frequencies, then T_z will be approximately equal to T_c, and E will be small.

Distributions of the spectral width parameter, E, for winter and summer are shown in Figures 22 and 23. The range of its variation was greater in summer than in winter but the most frequent value in summer (0.36) was smaller than in winter (0.53).

11. Persistence of Waves of a given Significant Height

For shipping operations and for other purposes, it is often required to know how often and for how long a certain wave condition will last in one year or season. The persistence diagram of the significant wave height, H_s, during the operational period of the wave recorder is presented in Figure 24. Table III summarises these results.

Table III

Persistence of a given Significant Height

Persistence Period (hours)	Number of Occurrences				
	3 metres or above	2½ metres or above	2 metres or above	1½ metres or above	1 metre or above
5	2	5	14	31	40
10	2	3	7	19	25
20	1	2	4	10	15
30	1	2	3	7	11
40	1	1	2	5	9

12. Wave Height and Wind

A Dines pressure-tube anemometer was installed at Waglan Island with the wind vane 75 metres above the Mean Sea Level and an attempt was made to find a relationship between the wind speed recorded by this instrument and wave height.

It has already been mentioned that waves during the winter monsoon are generally higher than those during the summer moonsoon, except during the passage of tropical cyclones. In the winter season, it was observed that waves associated with the easterly winds were usually higher than those with the northerly winds. This was to be expected as the fetch with northerly winds is small.

In the summer months, it was observed on many occasions that a swell of moderate height and relatively long period was recorded at Waglan Island with only light winds. This usually occurred when a tropical cyclone was developing or intensifying over the central part of the South China Sea or to the east of the Balintang Channel. During the passage of tropical cyclones, the largest waves usually arrived at Waglan Island well before the winds there started to increase.

Little correlation was found between the wind speed at Waglan Island and the wave height for the summer season and a similarly small correlation was found for the winter season as well. That there was a slightly higher correlation in the winter was probably due to the greater persistence of the wind from the same direction. An empirical relation :

$$H = 0.006\ U^2 \qquad (6)$$

where H is the maximum wave height in metres and U the hourly wind speed in knots at Waglan Island was found for the winter period. By using this empirical relation, waves at Waglan Island in winter can be roughly estimated from the winds e.g.

Winds at Waglan Island	Maximum Wave Height
10 knots	0.6 metre
20	2.4
30	5.4

Equation (6) applies to wind speeds of 30 knots and below and tends to under-estimate the maximum wave height at light or moderate wind speeds especially when the winds are blowing from an easterly direction.

No attempt was made to relate wave height to fetch or duration of winds.

13. Predication of the Most Severe Wave

For the design of a maritime structure it is often required to predict the most severe wave conditions which might occur over a long period of time. The method of estimating the most severe wave has been described by Draper[4].

During the operating period of wave recorder in 1971, the highest wave recorded occurred around 1037 hours Hong Kong Standard Time on August 16 when Typhoon Rose was centred about 100 miles south of Hong Kong (Figure 25).

The maximum wave height after corrections had been applied was 10.4 metres. The typhoon subsequently moved closer to Hong Kong, but unfortunately the underwater cable was damaged and no records were available thereafter.

Based on the available data, the probable highest waves for various return periods were plotted on logarithmic - normal probability graph paper and are shown in Figure 26. The points generally clustered along a straight line which could be represented by the following equation :

$$y = 0.0764 + 0.3186x \qquad (7)$$

where x was the plotting position corresponding to the probability of different return period and y the common logarithm of the probable highest wave in metres. The coefficient of correlation is 0.99.

Based on this regression line, probable maximum waves for different return periods have been computed and are shown in Table IV :

Table IV

Probable Maximum Waves

Return Period	Probable Maximum Wave Height
(years)	(metres)
10	22.1
25	27.1
50	29.2
100	33.6

14. Waves at Waglan Island during the Passage of Tropical Cyclones

During the operating period of the wave recorder in 1971, 8 tropical cyclones (Severe Tropical Storm Kim, Typhoons Jean, Lucy and Nadine in July, Typhoon Rose in August, Typhoon Della in September, Typhoons Elaine and

Hester in October) moved close enough to Waglan Island to influence the wave height there. A comparison of the recorded maximum wave height and visual observations shows that the former was about 1.43 of the latter.

The first eye observation of wave height at Waglan Island was made at 1400 hours Hong Kong Standard Time on July 17, 1959. Thereafter wave height was estimated by eye twice daily regularly at 0700 and 1400 hours Hong Kong Standard Time until December 1963. From January 1964 onwards eye estimates of wave height were made every three hours at 0200, 0500, 0800, 1100, 1400, 1700, 2000 and 2300 hours Hong Kong Standard Time. Since the longer period waves are observed equally well by eye and by the wave recorder, this data was used to supplement the analysis of the variation in wave height with the approach of a tropical cyclone.

Tropical cyclones affecting Hong Kong can be generally divided, according to their tracks, into three groups :

Group 1 : Passing to the south of Hong Kong with west or west-northwest movement,

e.g. Typhoon Wanda in August - September, 1962,
Typhoon Ida in August, 1964,
Typhoon Ruby in September, 1964,
Typhoon Shirley in August, 1968,
Typhoon Rose in August, 1971.

Group 2 : Crossing the coast east of Hong Kong,

e.g. Typhoon Viola in July, 1969,
Tropical Storm Ruby in July, 1970,
Typhoon Lucy in July, 1971.

Group 3 : Northward movement in the South China Sea,

e.g. Typhoon Mary in June, 1960,
Typhoon Alice in May, 1961,
Typhoon Dot in October, 1964,
Typhoon Rose in August, 1971.

Typhoon Rose in August 1971 was moving in the South China Sea on a west-northwest track after crossing Luzon from the Pacific. When it was about 100 miles south of Hong Kong it turned onto a northerly track. Tropical cyclones like Typhoon Rose (e.g. Typhoon Shirley in August 1968) which moved on a west-northwest track in the South China Sea at first, but turned onto a northerly track later have been included in both Group 1 and 3.

Values of wave height observed by eye at Waglan Island during the passage of tropical cyclones between July 1959 and July 1971 were multiplied by 1.43. These values, together with those recorded by the instrument in 1971 were plotted in Figures 27 to 32. The value in each square represented the maximum wave height observed at Waglan Island when a tropical cyclone was centred in that square. The top figure in each square was the greatest wave height observed and the bottom, the average maximum height.

Each group contains two categories. Category 1 is for all the tropical cyclones with typhoon or severe tropical storm intensity and Category 2, with tropical storm or tropical depression intensity.

The highest wave height recorded during the period 1959-1971 was 10.4 metres recorded instrumentally during the passage of Typhoon Rose in August 1971.

In Section 7 it was noted that the correlation between the eye-observed wave period and the instrumentally recorded T_z or T_c was poor. No attempt has therefore been made to use the data observed by eye during the past 13 years as a supplement for a analysis of wave period on the same lines as that used for greatest wave height used above.

15. Conclusion

Most of the analysis presented in this report were based on the data collected during the operating period of the wave recorder in 1971, i.e. from July 2 to December 17. In the United States of America, it has been found that, while the annual variation of wave height in coastal waters is small, the seasonal variation is sizeable [5]. Due to its exposure to tropical cyclones the number of which affect Hong Kong varies considerably from year to year, the annual variation in Hong Kong could also be sizeable. The results contained in this report should therefore be treated as preliminary and should be up-dated when more data have been collected.

16. Acknowledgements

Staff in the Meteorological Instruments Section extracted the basic data from the wave record under the supervision of Mr. N.Y. WONG, Mr. S. CHENG wrote the programme for Olivetti Programma 101 for equations in Section 5. Figures 4 and 5 are by courtesy of Binnie and Partners Ltd.

17. References

(1) M. J. Cuming — Wave Heights in the Southeast Approaches to Hong Kong Harbour, Technical Note No. 25, Royal Observatory, Hong Kong (1967).

(2) M. J. Tucker — Analysis of Records of Sea Waves, Proc. Intn. Civ. Engrs, 26, 305-316 (1963).

(3) L. Draper, A.V. Maxted — Graphs of Attenuation of Waves with Depth, NIO Internal Report, No. A17.

(4) L. Draper — Derivation of a Design Wave from Instrumental Records of Sea Waves, Proc. Intn Civ. Engrs, 26, 291-304 (1963).

(5) E.F. Thompson and D.L. Harris — A wave climatology for U.S. Coastal Waters, U.S. Army, Coastal Engineering Research Centre, (1972).

Appendix

The underwater cable was repaired in early July 1972 and the record resumed on July 8. However, on August 13, a thunderstorm caused damage to the electronic components in the sea unit and records were again lost.

During the period from July 8 to August 14, 1972 Typhoon Susan formed over the South China Sea and dissipated over the Taiwan Strait while drifting northeastwards. Tropical Storm Winnie passed to the east of Taiwan and dissipated over eastern China. Neither of these two tropical cyclones caused high waves at Waglan Island.

A scatter diagram and diagrams of the cumulative distribution of wave height and the distribution of zero-crossing period for this period are shown in Figures 33-35.

List of Diagrams

Appendix

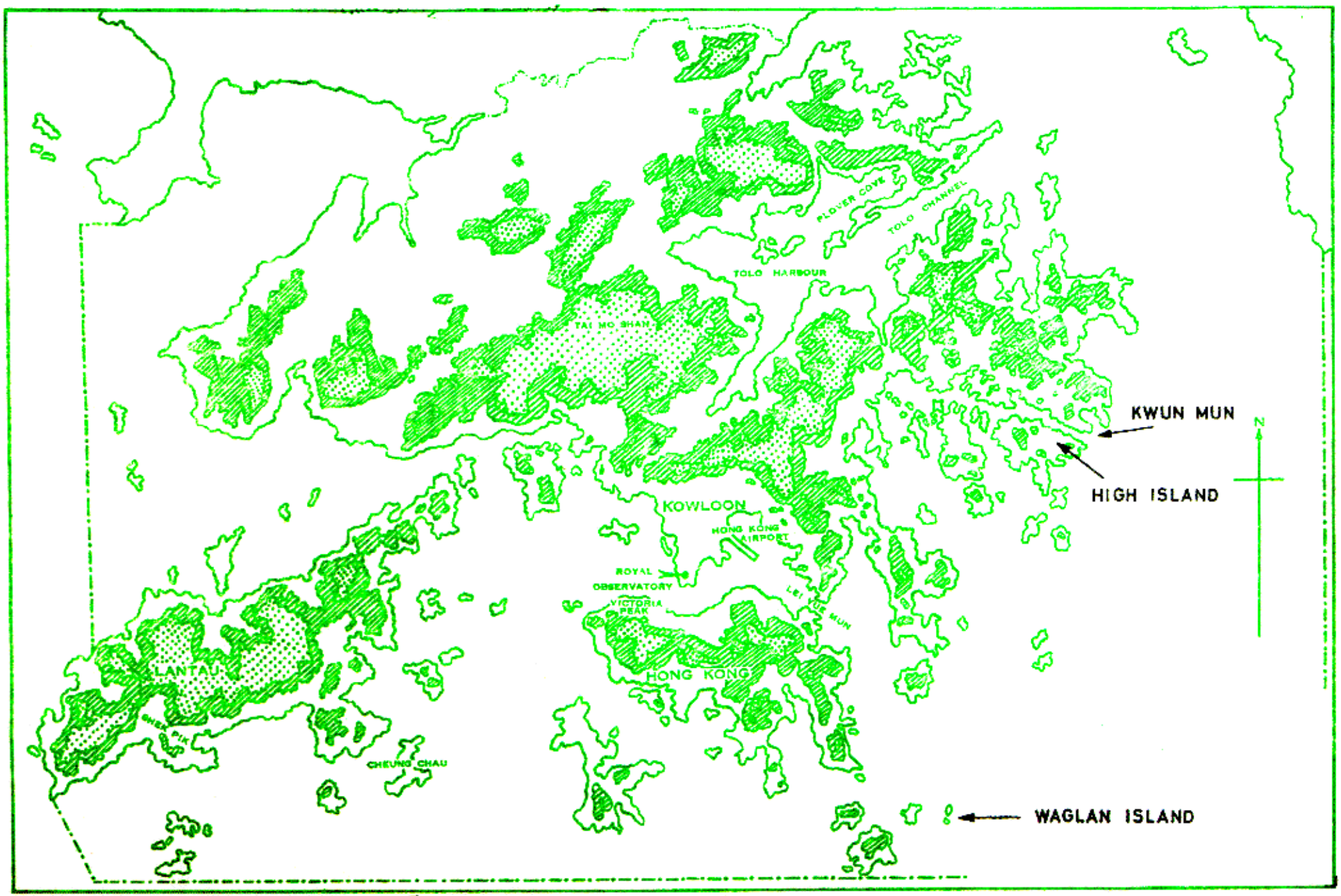
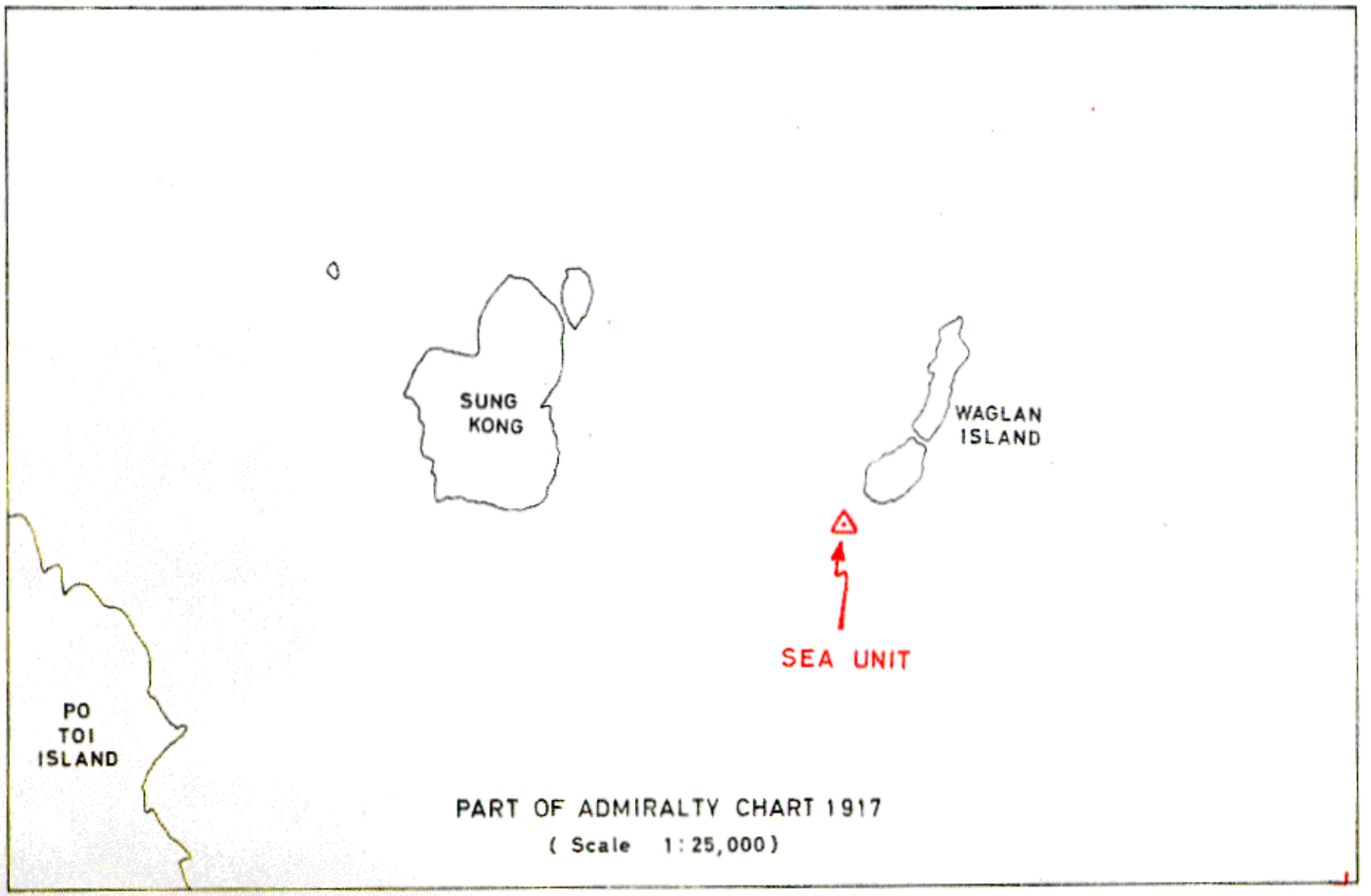


Figure 1 LOCATION OF WAGLAN ISLAND AND KWUN MUN

Figure 2

LOCATION OF THE SEA UNIT



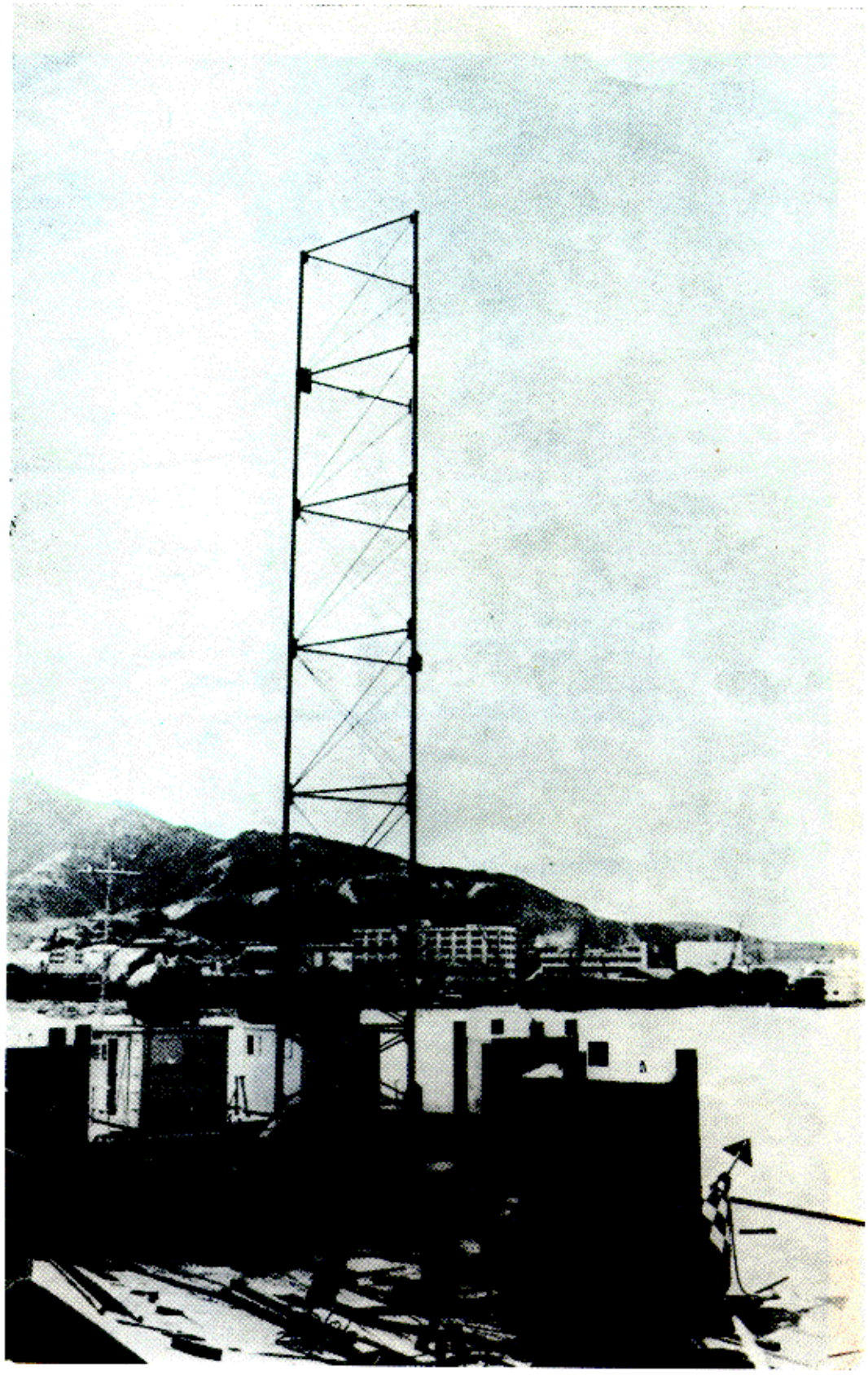


Figure 3

SUPPORT TOWER FOR THE SEA UNIT

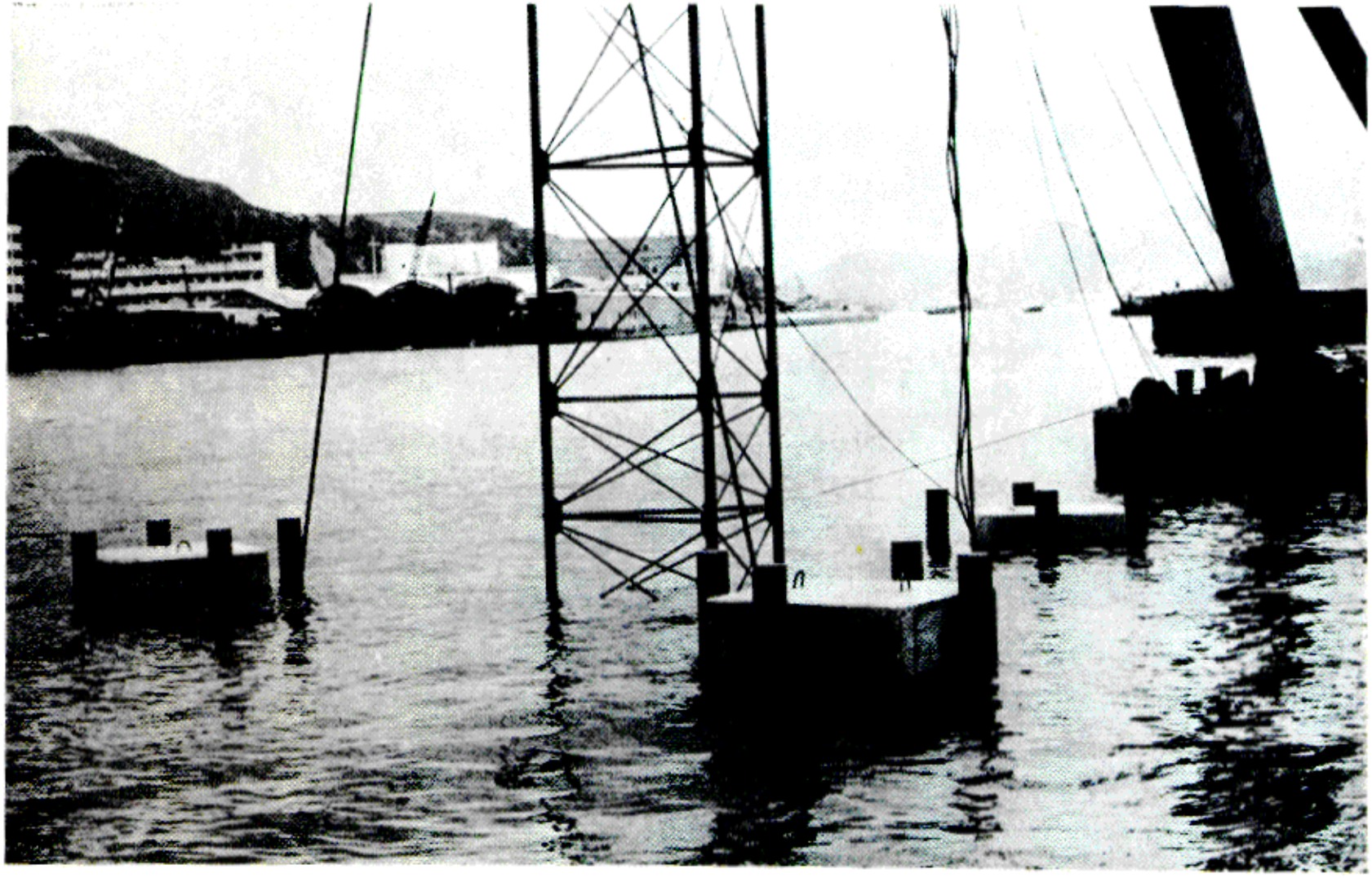


Figure 4

SUPPORT TOWER READY FOR TRANSPORTING TO WAGLAN ISLAND

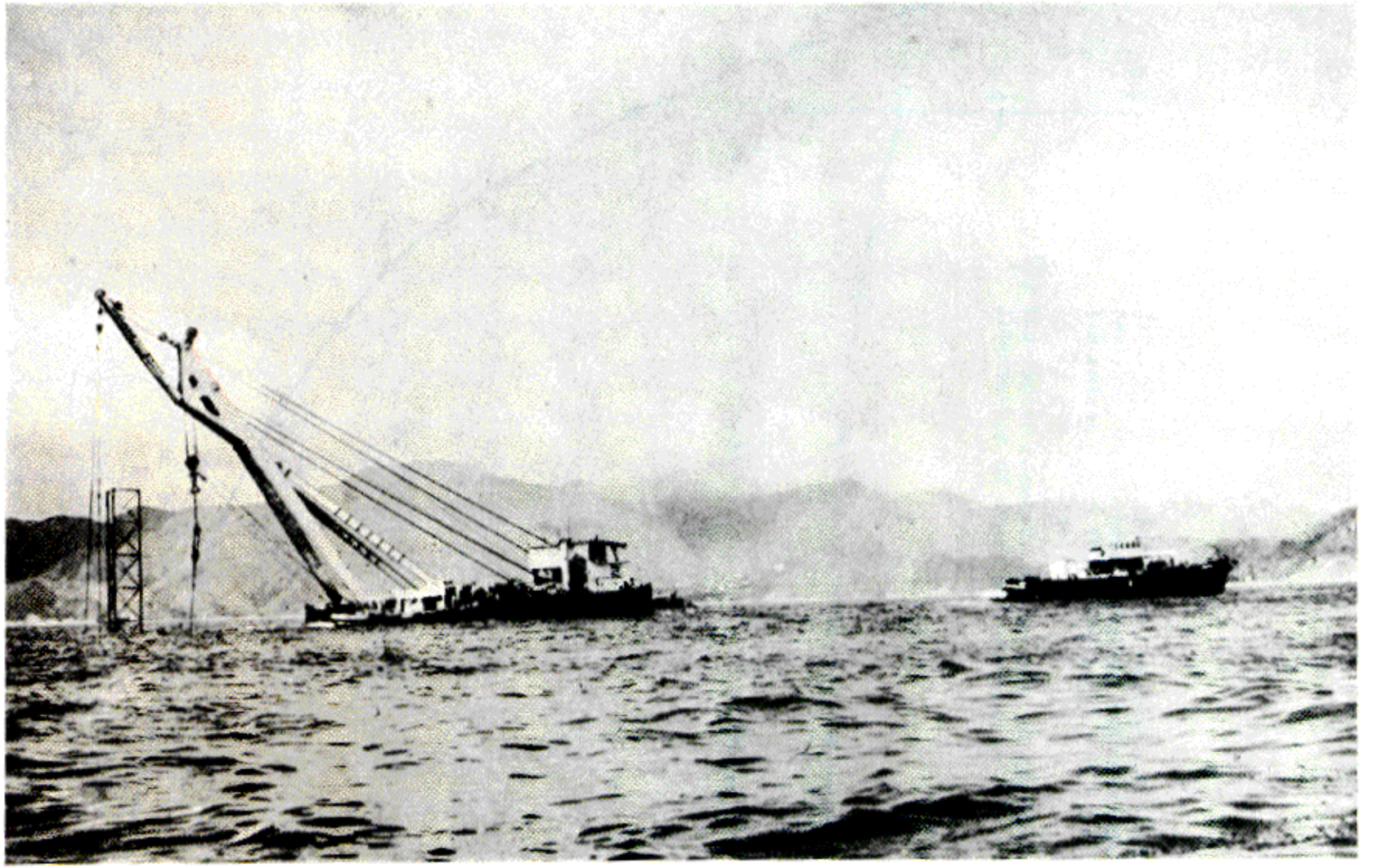


Figure 5

SUPPORT TOWER ON THE WAY TO WAGLAN ISLAND

Figure 6

WAVE HEIGHT CORRECTION FACTOR

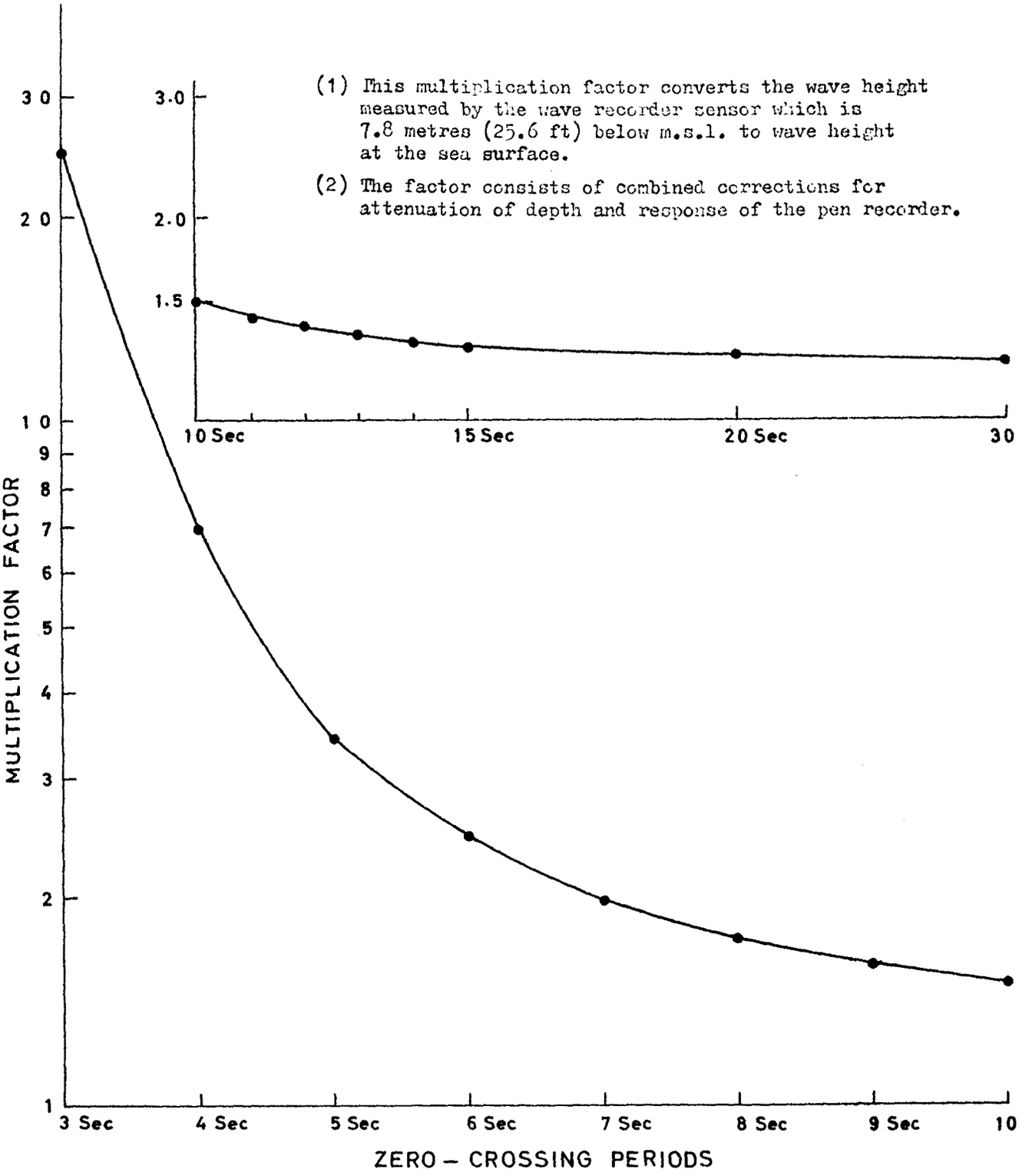


Figure 7

WAVES OBSERVED BY EYE
AT WAGLAN ISLAND
(WINTER)

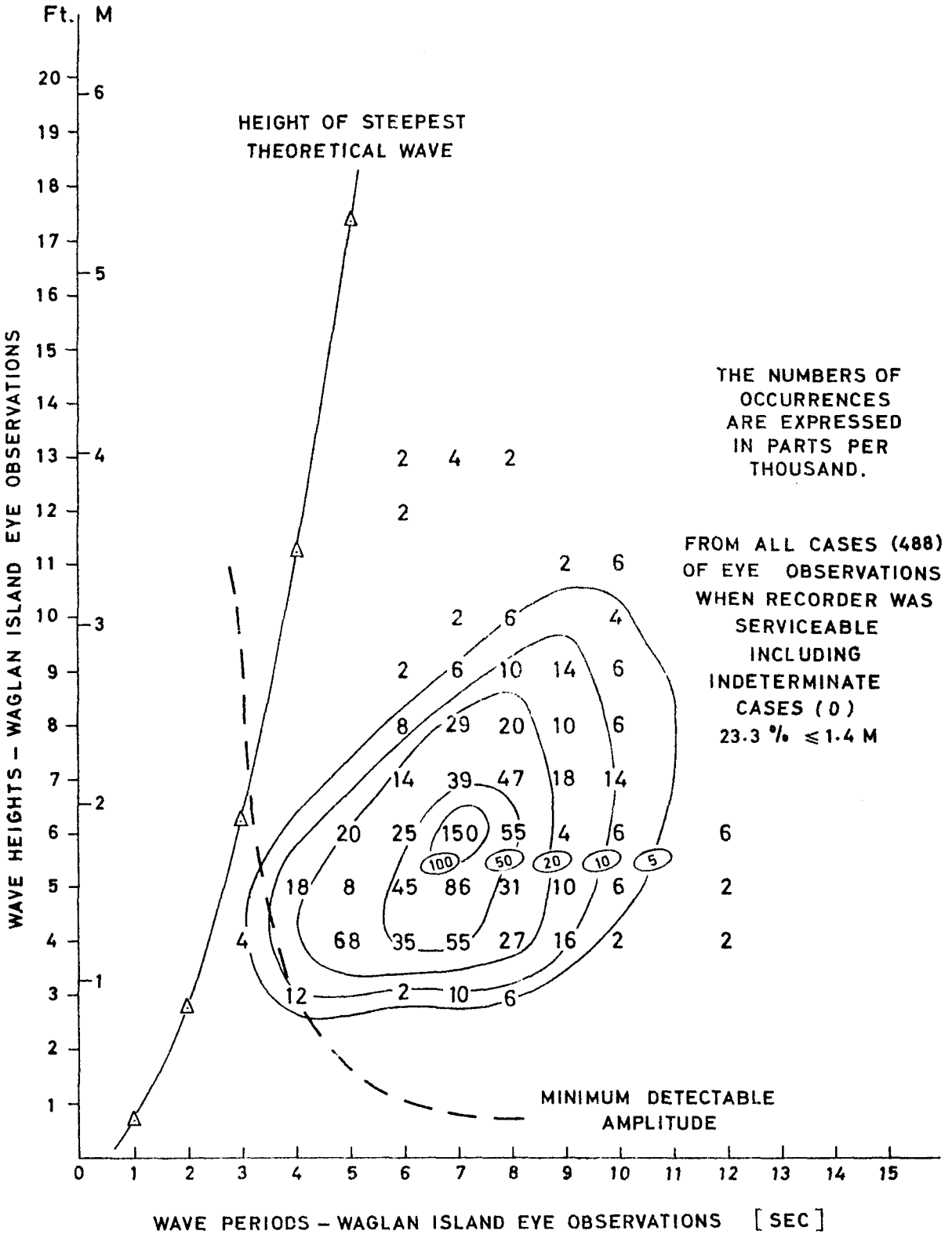


Figure 8

WAVES OBSERVED BY EYE
AT WAGLAN ISLAND
(SUMMER)

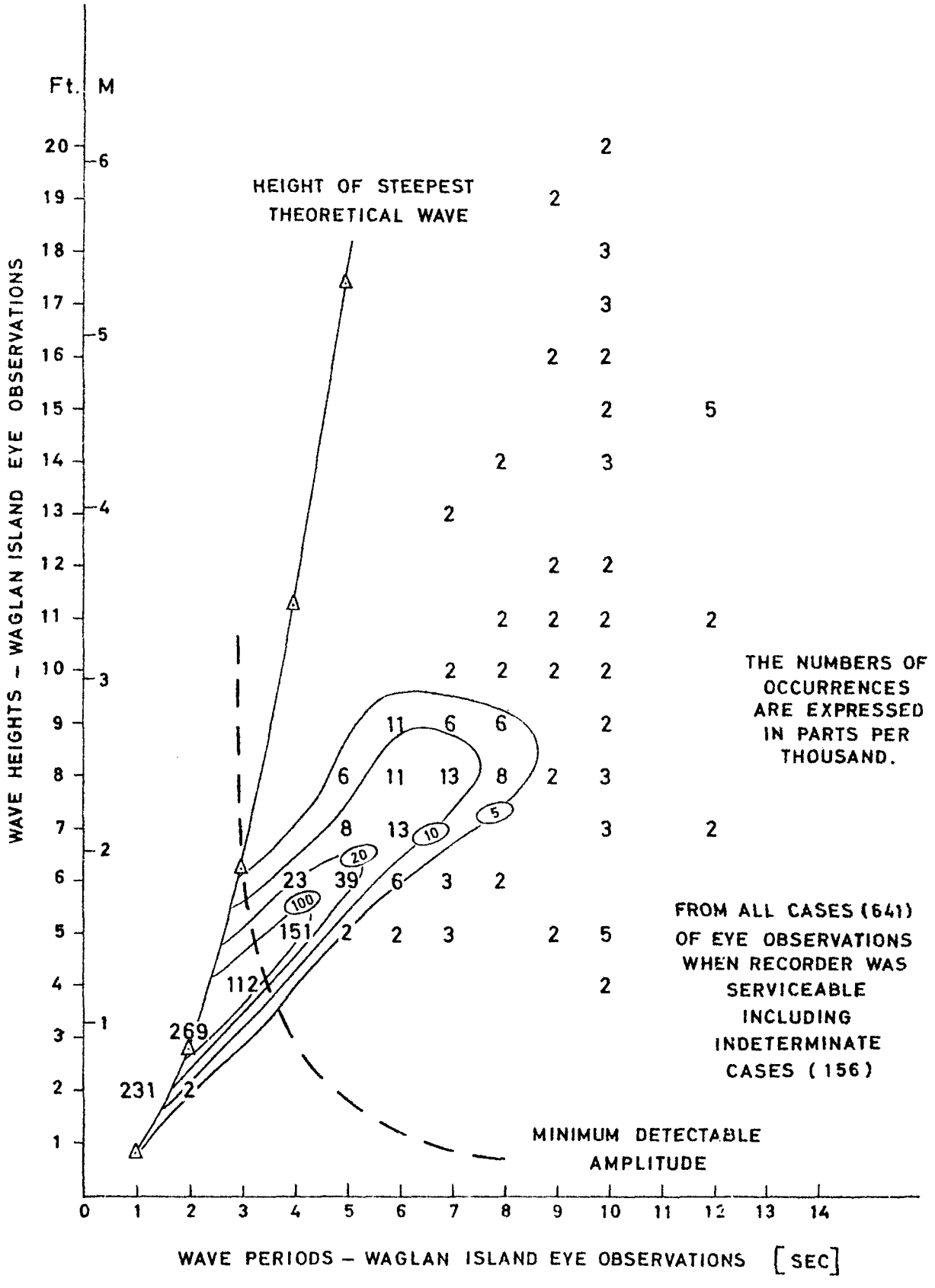


Figure 9

COMPARISON OF EYE – OBSERVED WAVE PERIODS
WITH ZERO – CROSSING PERIODS FROM INSTRUMENTAL RECORD
(WINTER)

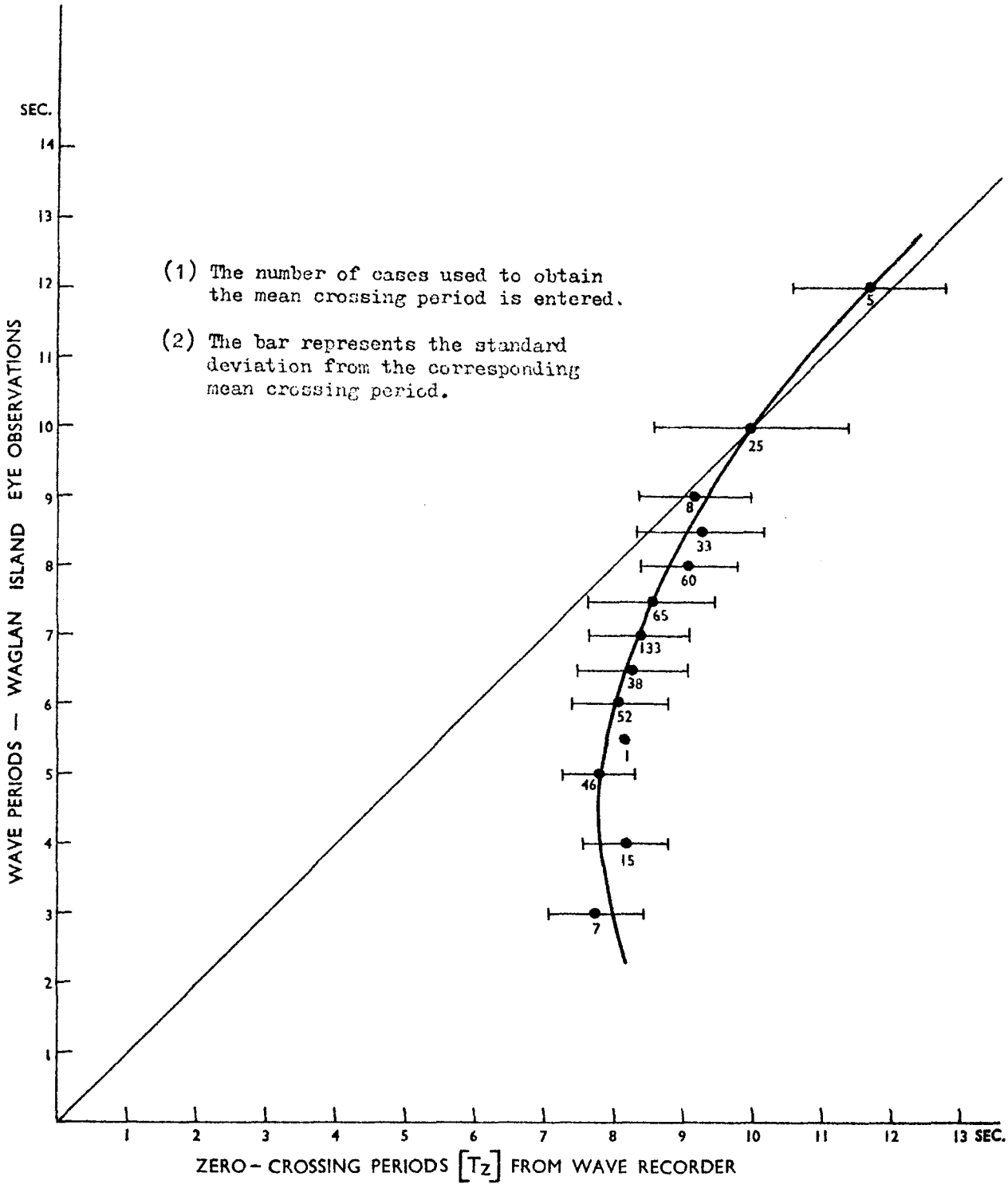


Figure 10

COMPARISON OF EYE – OBSERVED WAVE PERIODS
WITH ZERO – CROSSING PERIODS FROM INSTRUMENTAL RECORD
(SUMMER)

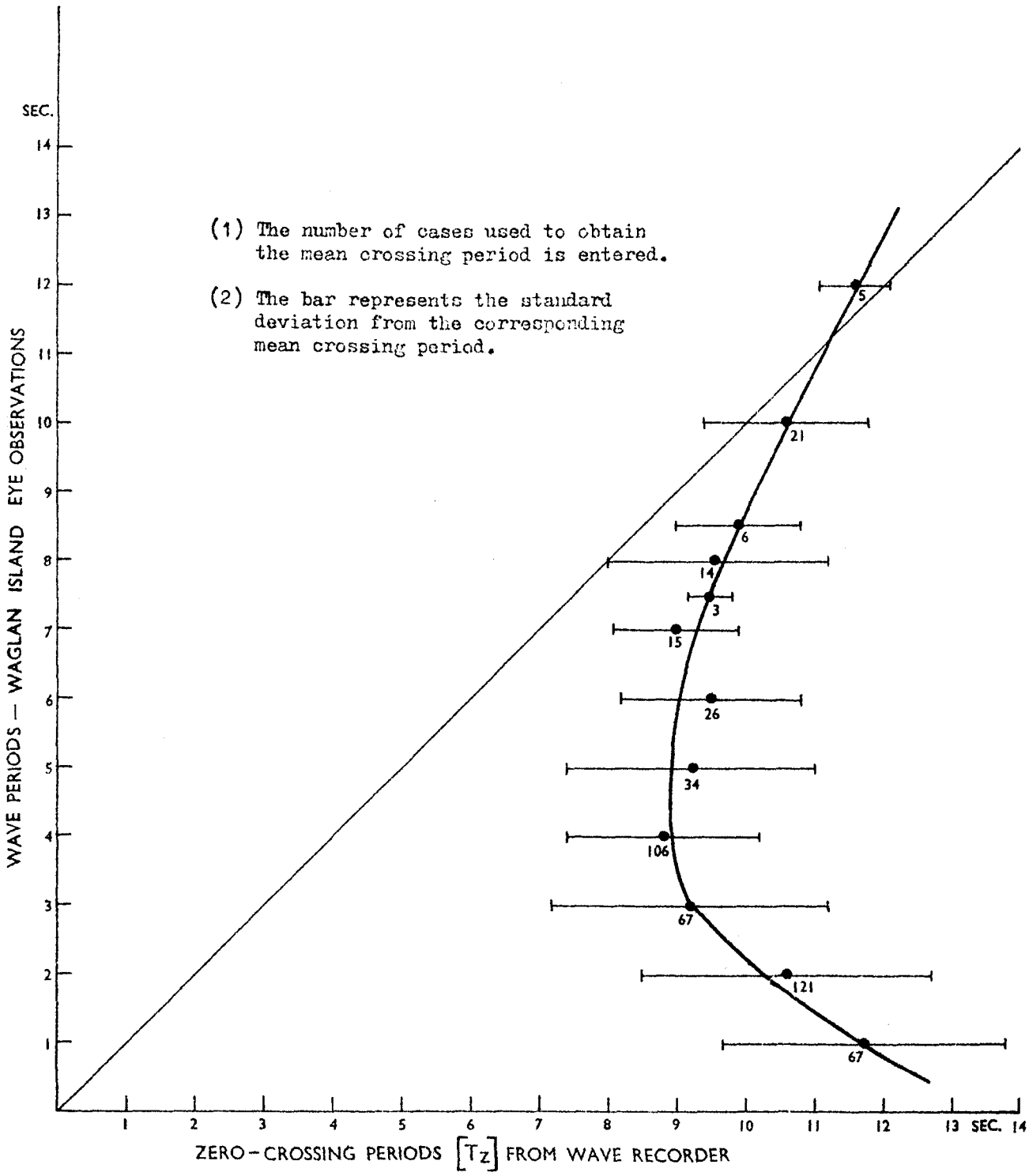


Figure 11

COMPARISON OF EYE – OBSERVED WAVE PERIODS
WITH CREST PERIODS FROM INSTRUMENTAL RECORD
(WINTER)

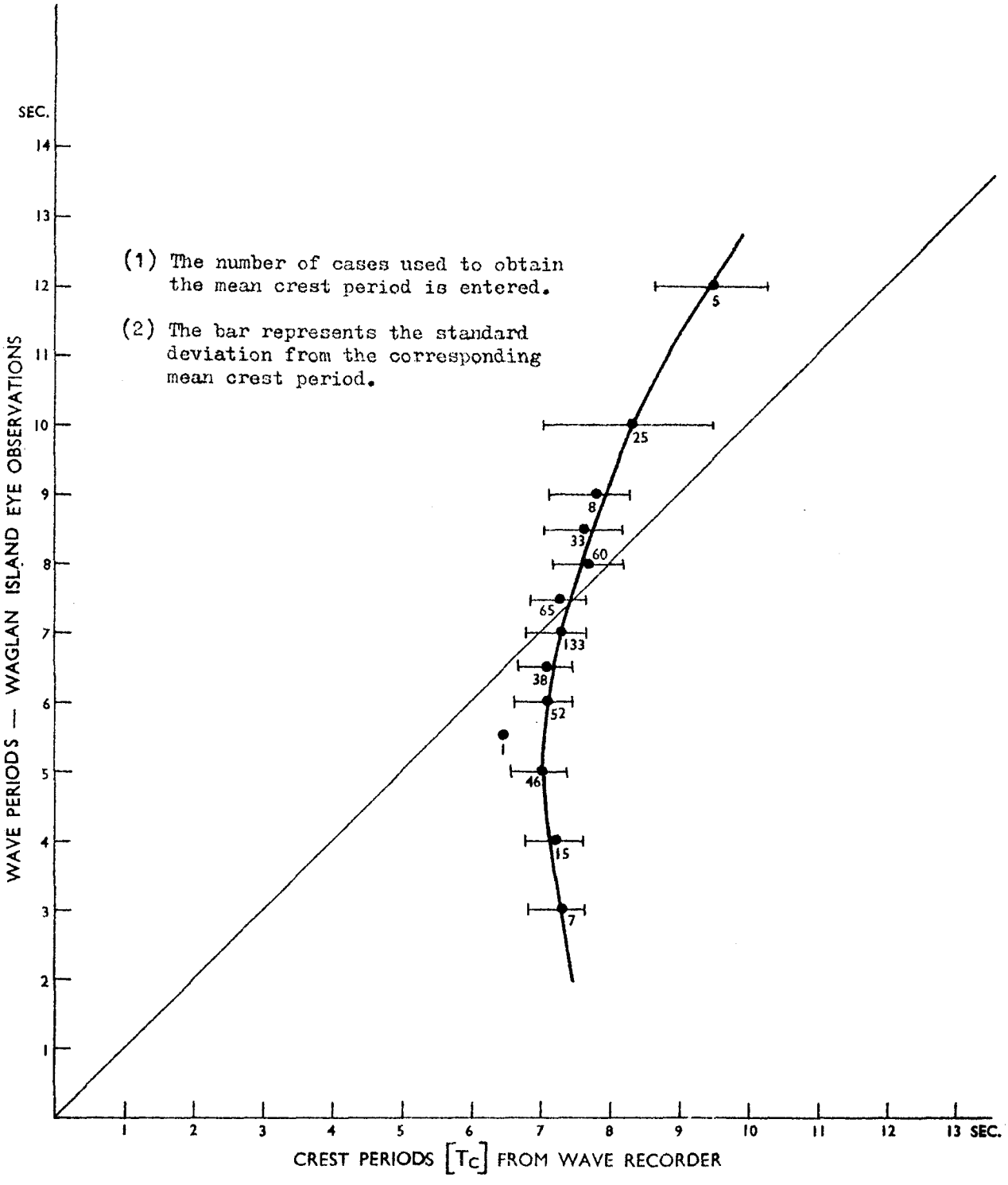


Figure 12

COMPARISON OF EYE – OBSERVED WAVE PERIODS
WITH CREST PERIODS FROM INSTRUMENTAL RECORD
(SUMMER)

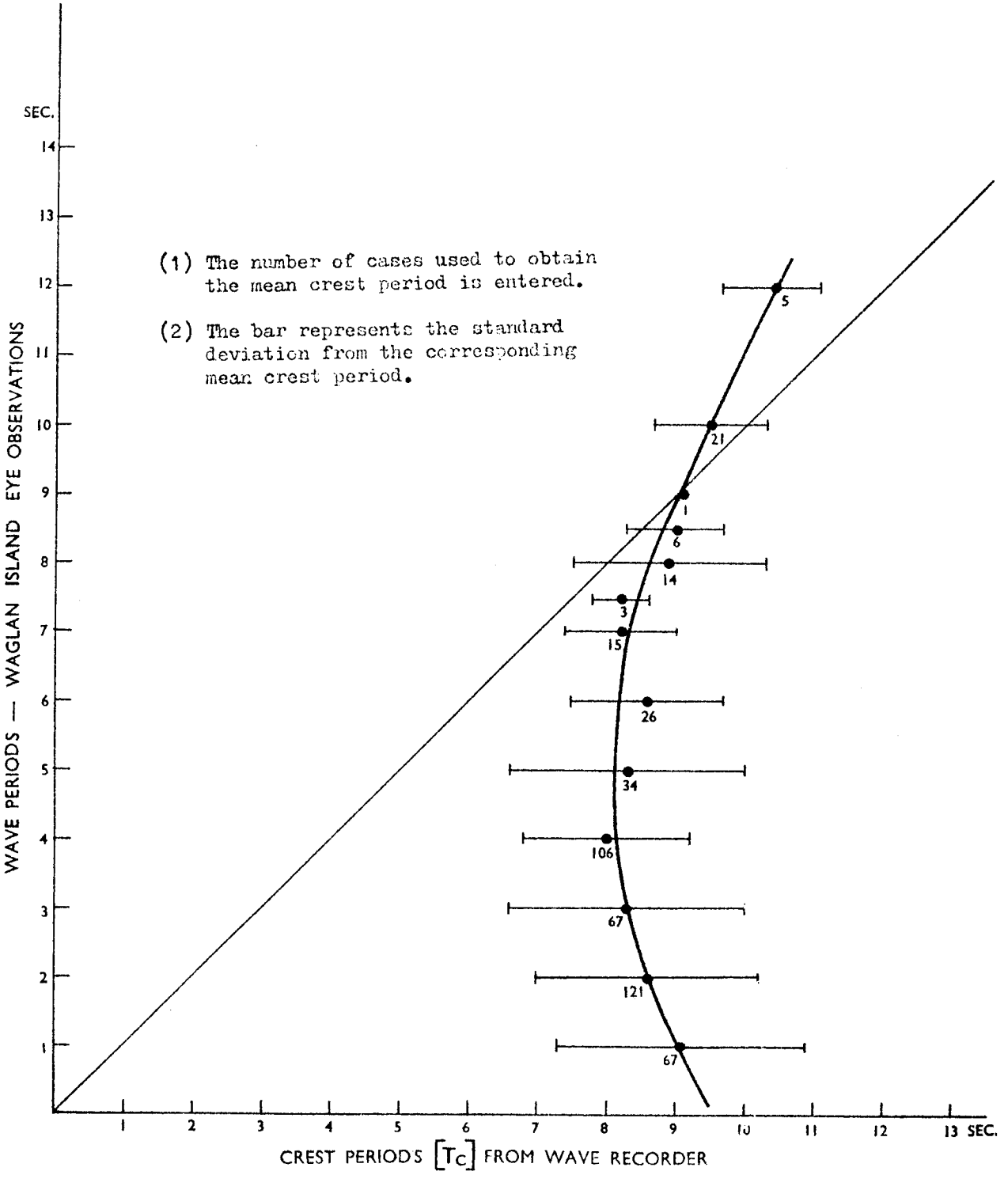


Figure 13

SCATTER DIAGRAM OF SIGNIFICANT WAVE HEIGHTS (WHOLE YEAR)

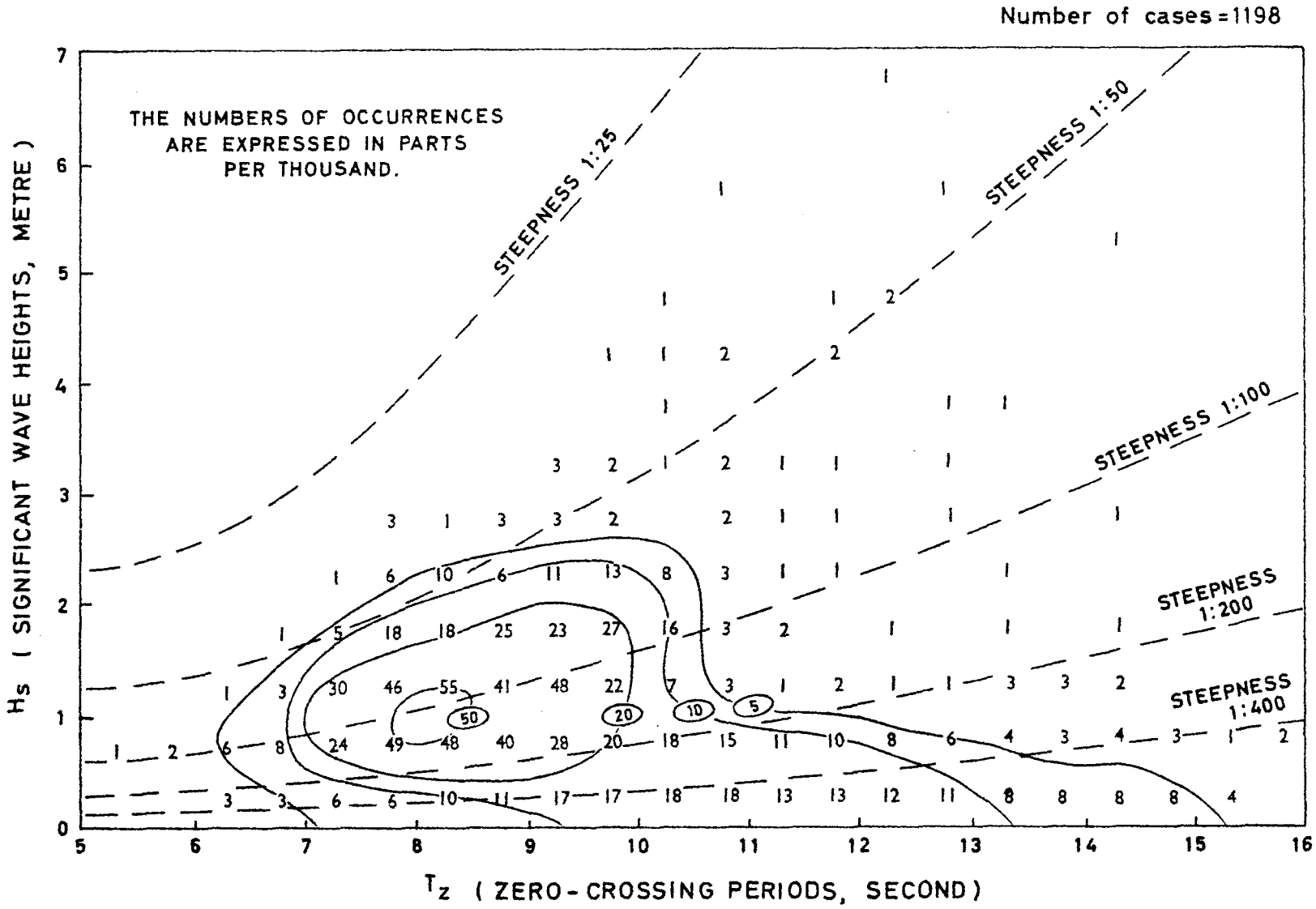


Figure 14

SCATTER DIAGRAM OF SIGNIFICANT WAVE HEIGHTS (WINTER)

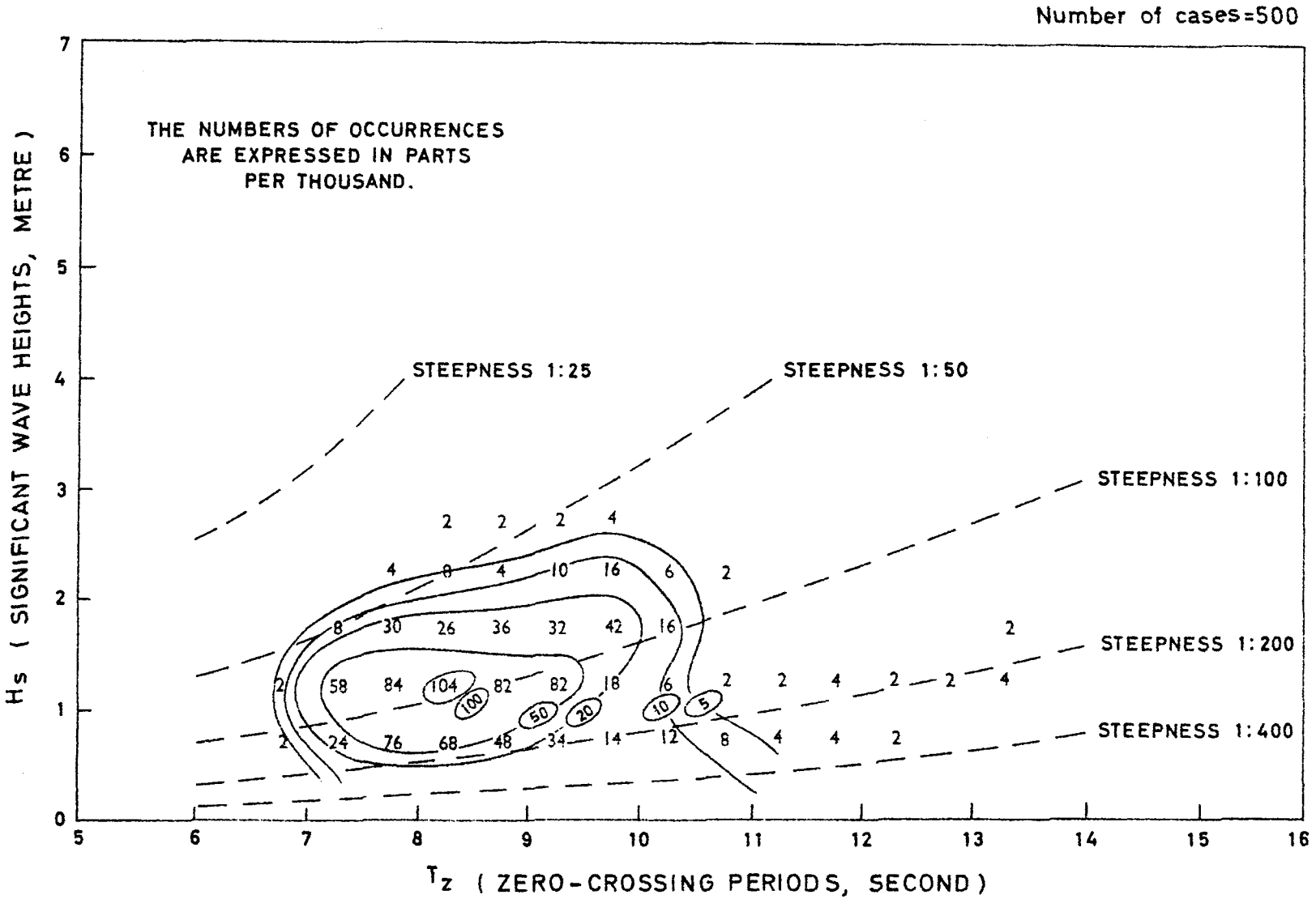
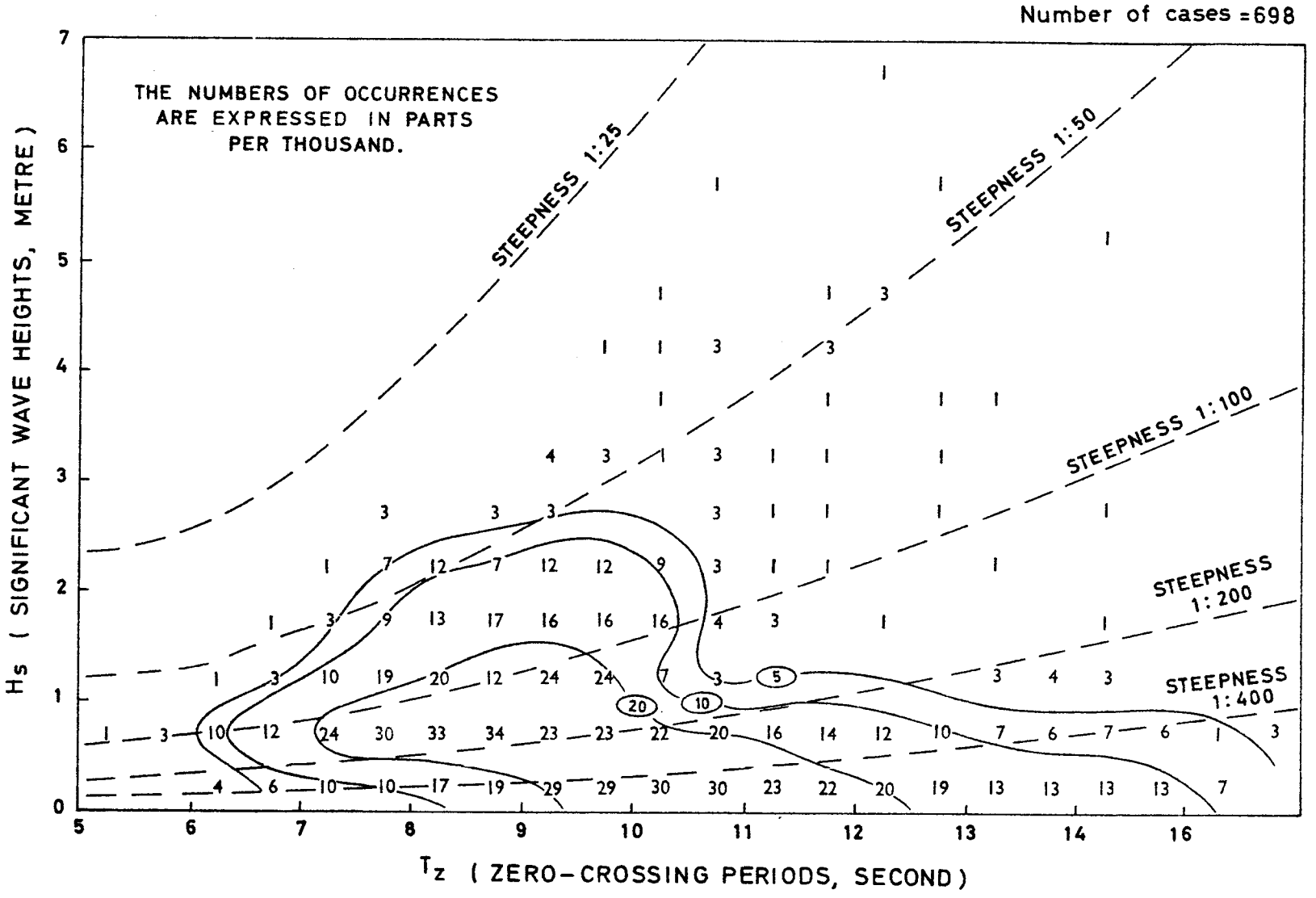


Figure 15

SCATTER DIAGRAM OF SIGNIFICANT WAVE HEIGHTS (SUMMER)



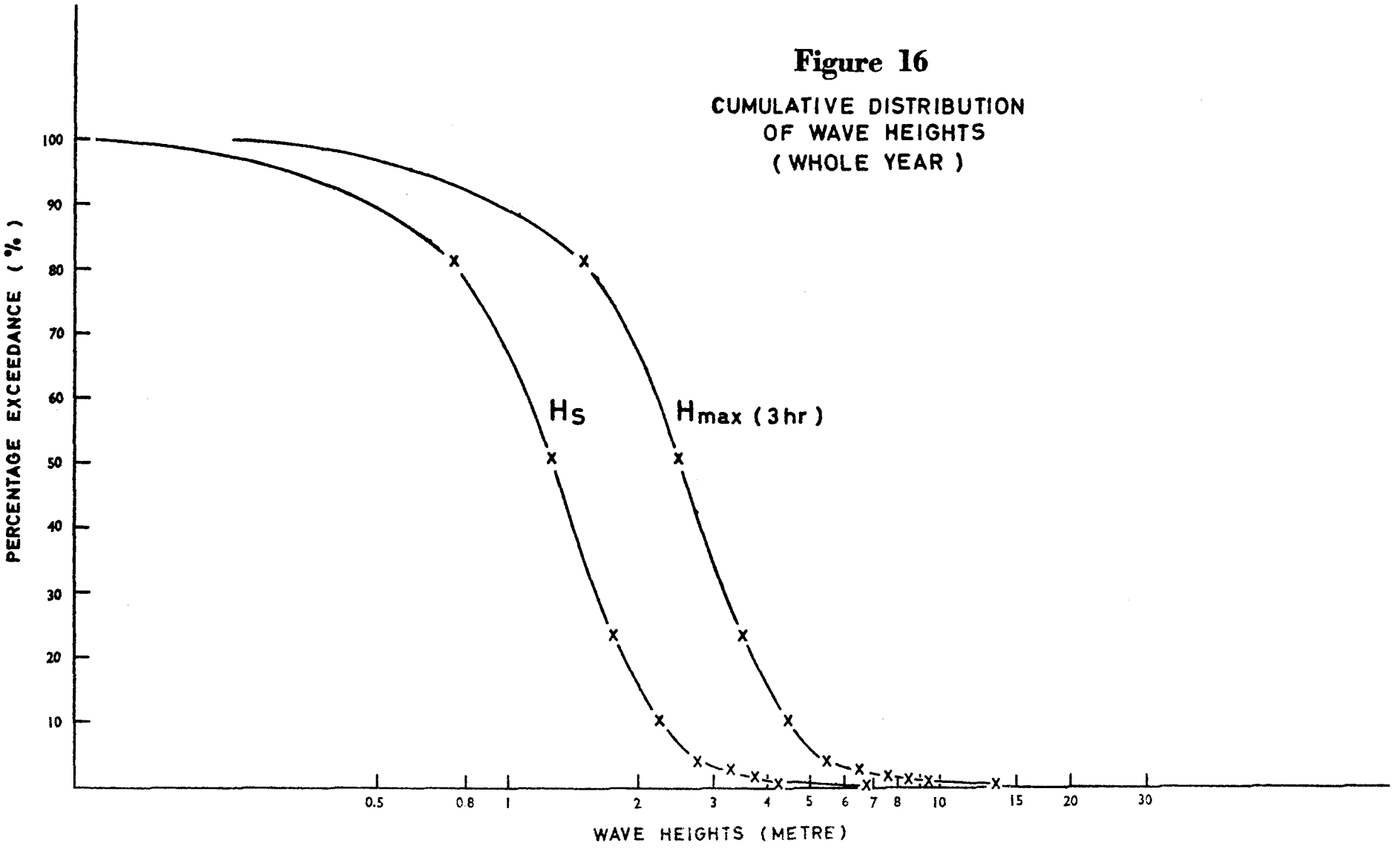
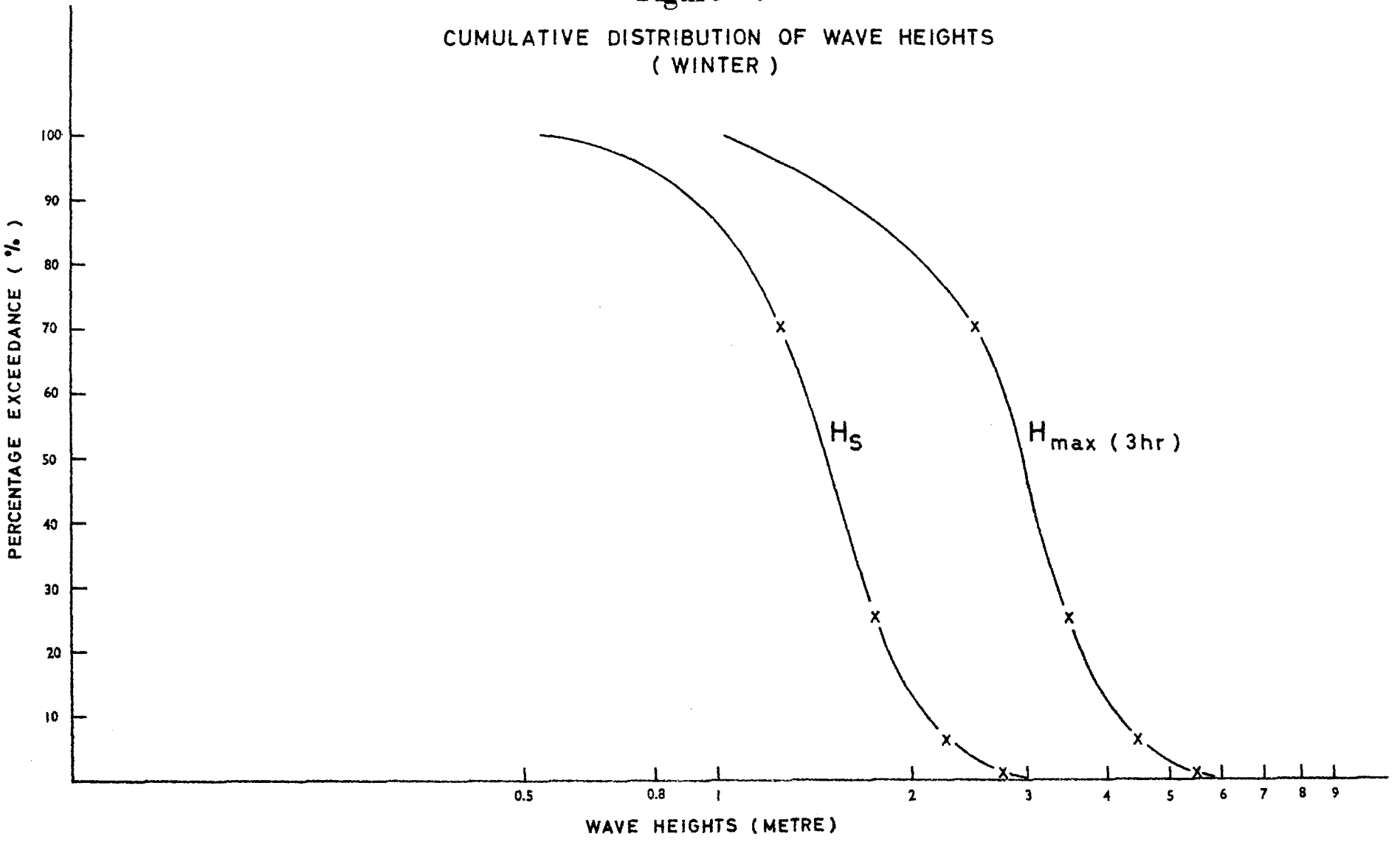


Figure 16
CUMULATIVE DISTRIBUTION
OF WAVE HEIGHTS
(WHOLE YEAR)
PERCENTAGE EXCEEDANCE (%)
100
90
80
70
60
50
40
30
20
10
Hs
Hmax (3hr)
0.5
0.8
1
2
3
4
5
6
7
8
10
15
20
30
WAVE HEIGHTS (METRE)

Figure 17


CUMULATIVE DISTRIBUTION OF WAVE HEIGHTS
(WINTER)
PERCENTAGE EXCEEDANCE (%)
100
90
80
70
60
50
40
30
20
10
Hs
Hmax (3hr)
0.5
0.8
1
2
3
4
5
6
7
8
9
WAVE HEIGHTS (METRE)

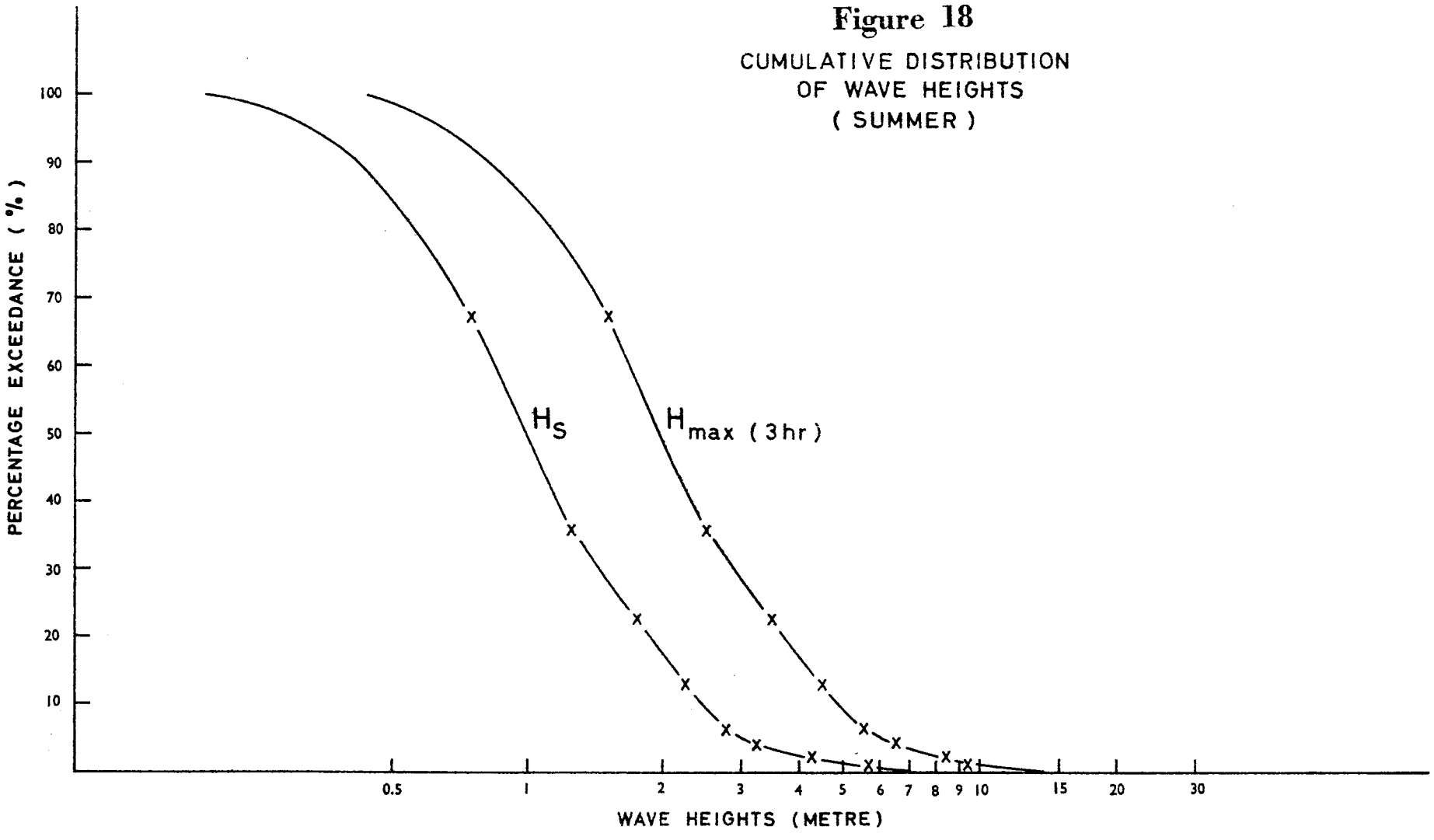


Figure 18
CUMULATIVE DISTRIBUTION
OF WAVE HEIGHTS
(SUMMER)
PERCENTAGE EXCEEDANCE (%)
100
90
80
70
60
50
40
30
20
10
H_S
H_{max} (3hr)
0.5
1
2
3
4
5
6
7
8
9
10
15
20
30
WAVE HEIGHTS (METRE)

Figure 19

DISTRIBUTION OF ZERO-CROSSING PERIODS

(WHOLE YEAR)

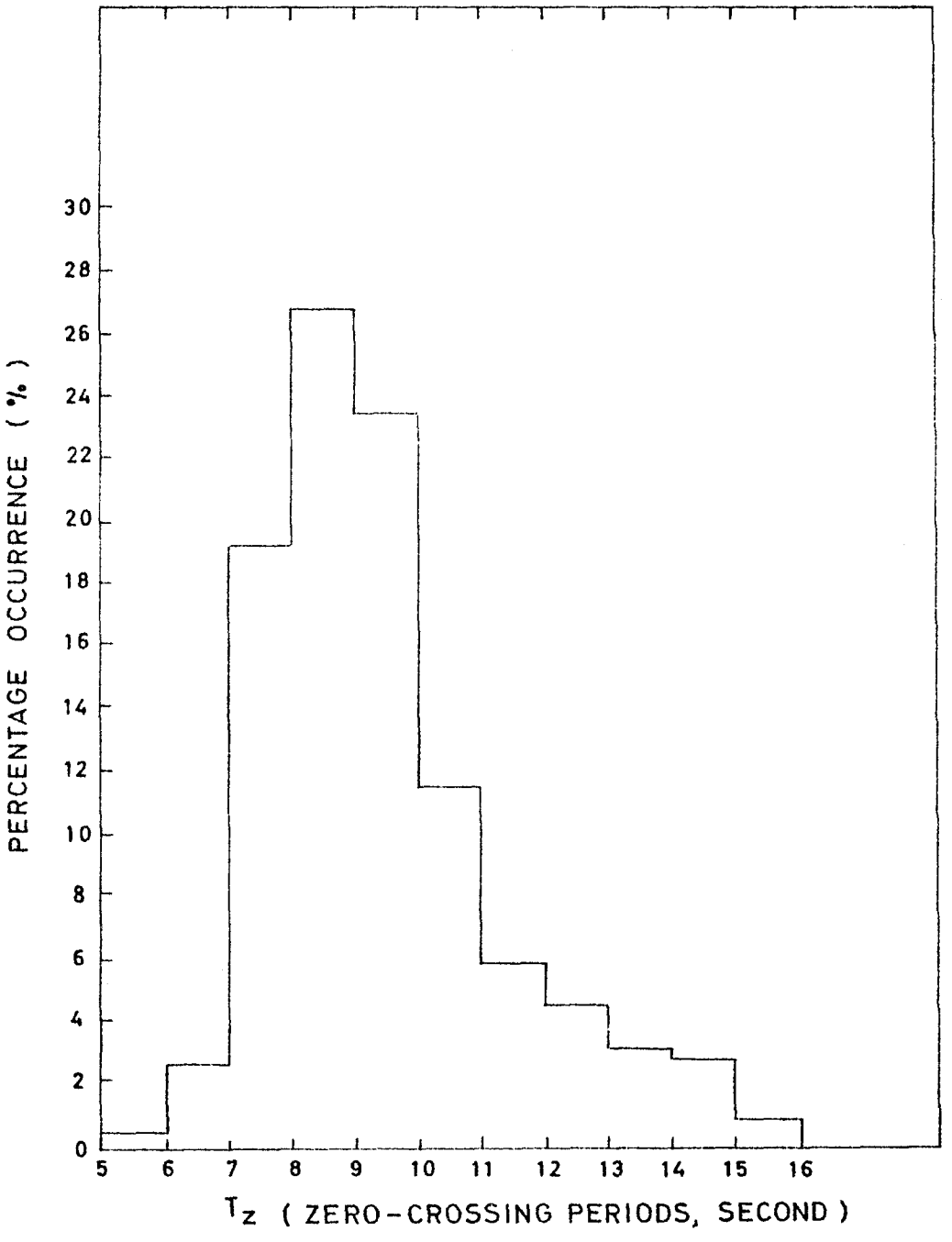


Figure 20

DISTRIBUTION OF ZERO-CROSSING PERIODS

(WINTER)

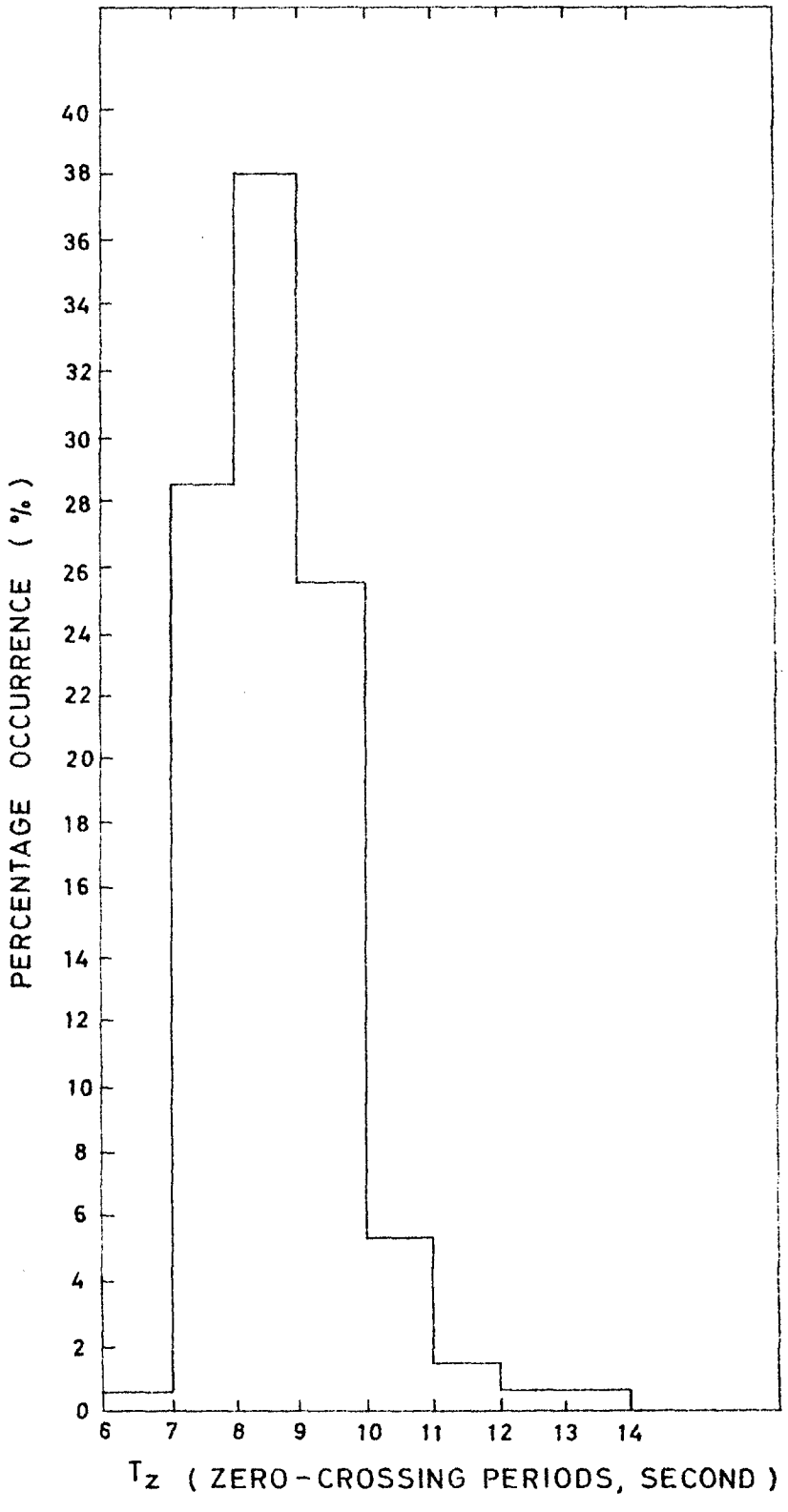


Figure 21

DISTRIBUTION OF ZERO-CROSSING PERIODS

(SUMMER)

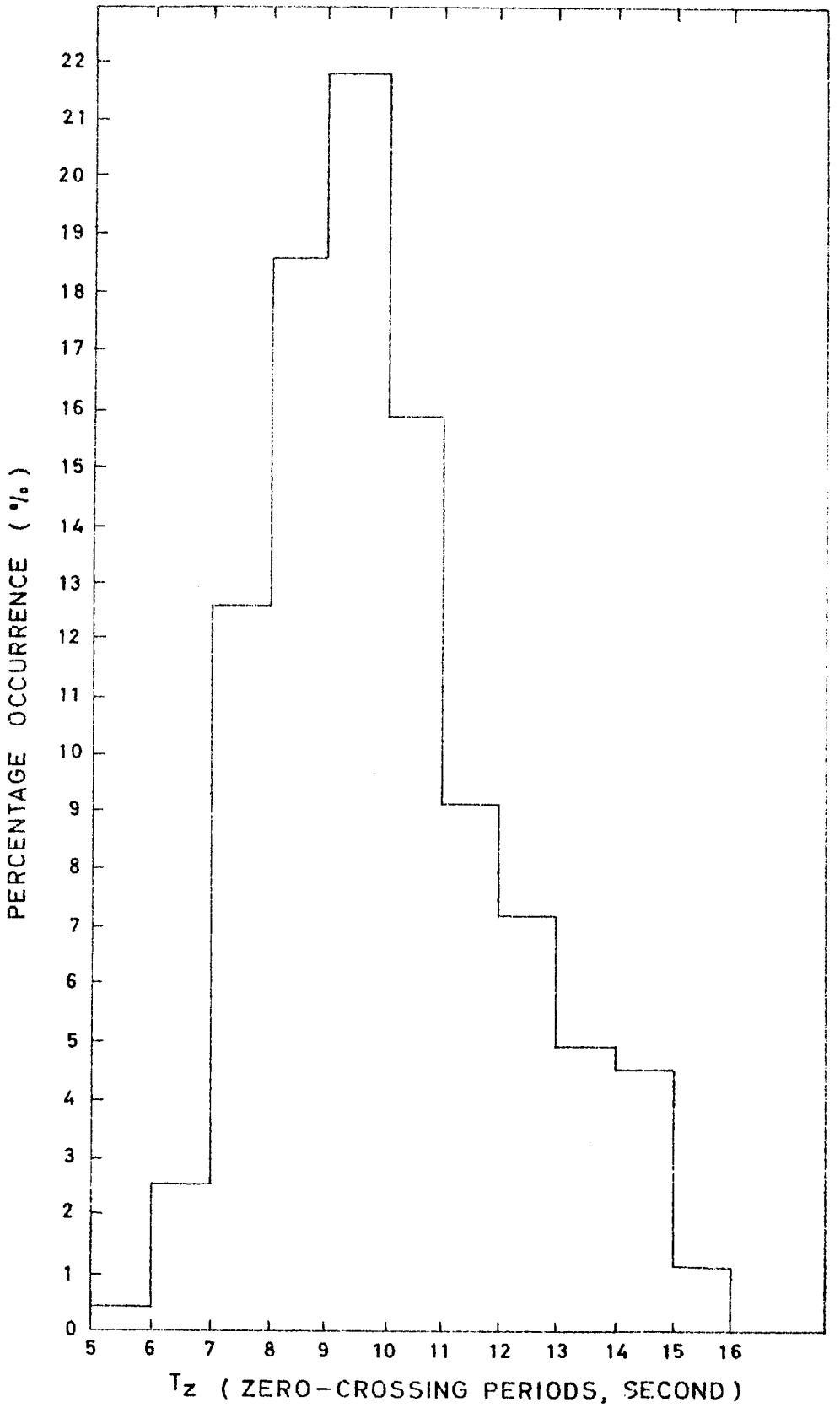


Figure 22

DISTRIBUTION OF SPECTRAL WIDTH PARAMETERS

(WINTER)

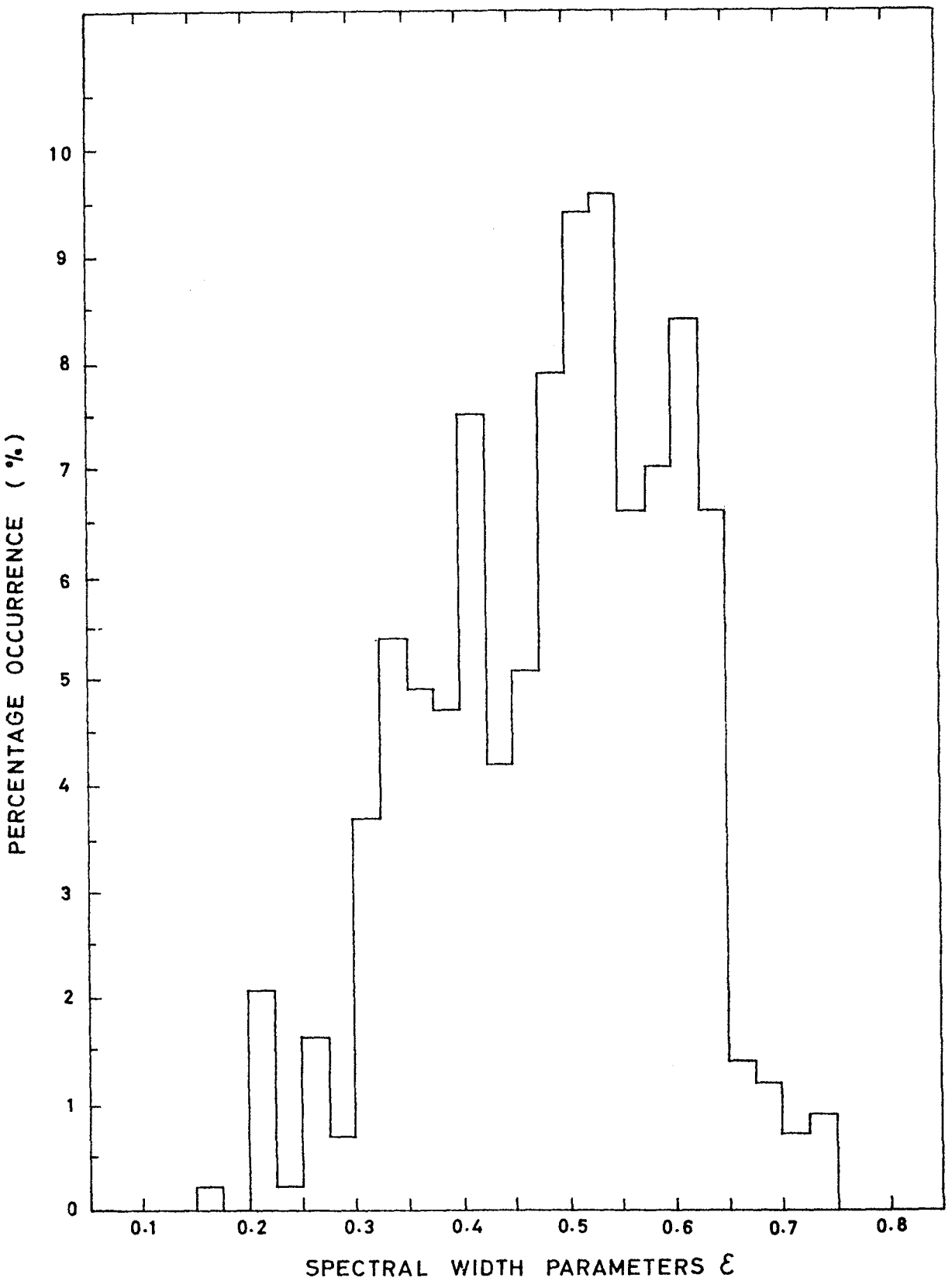


Figure 23

DISTRIBUTION OF SPECTRAL WIDTH PARAMETERS

(SUMMER)

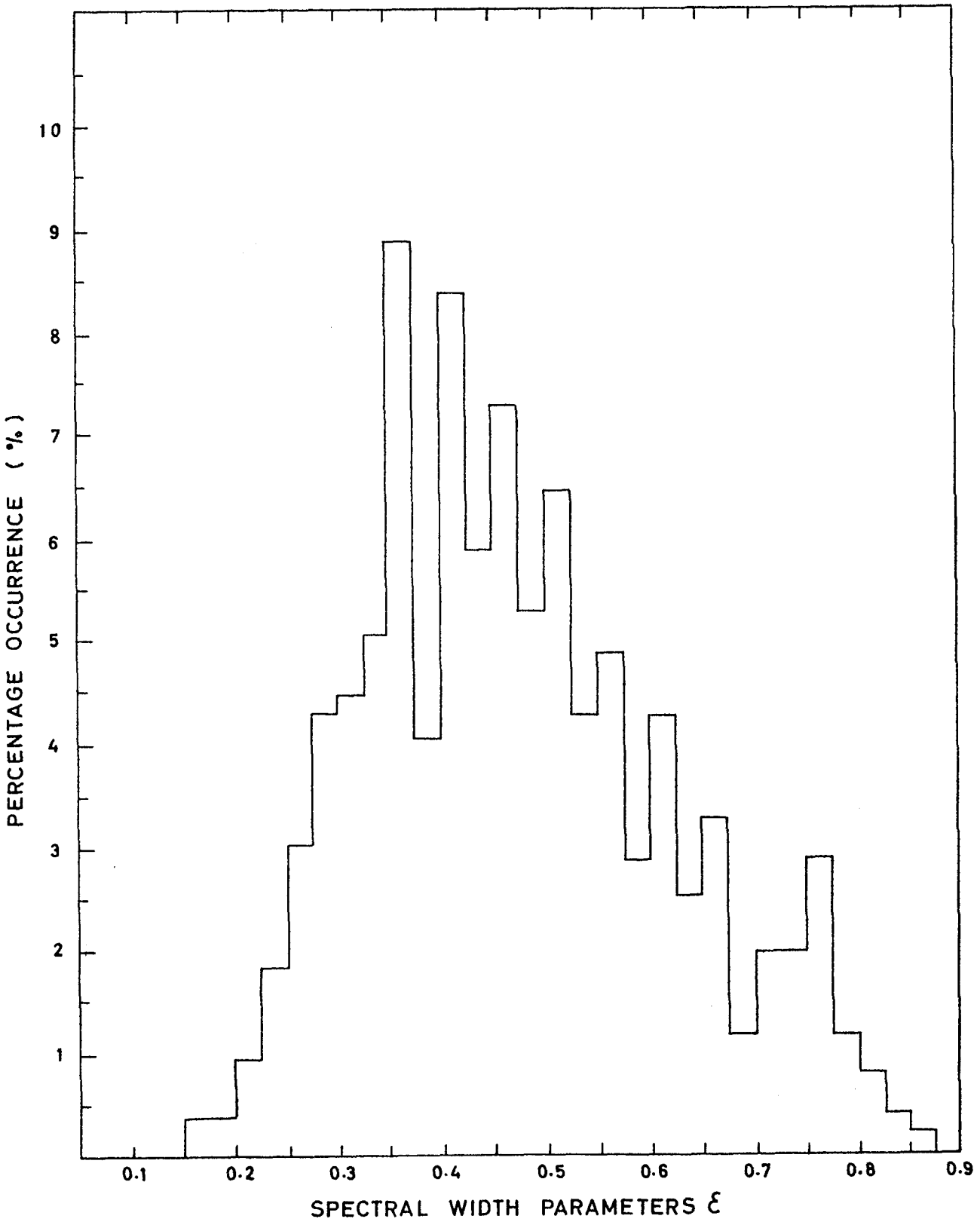
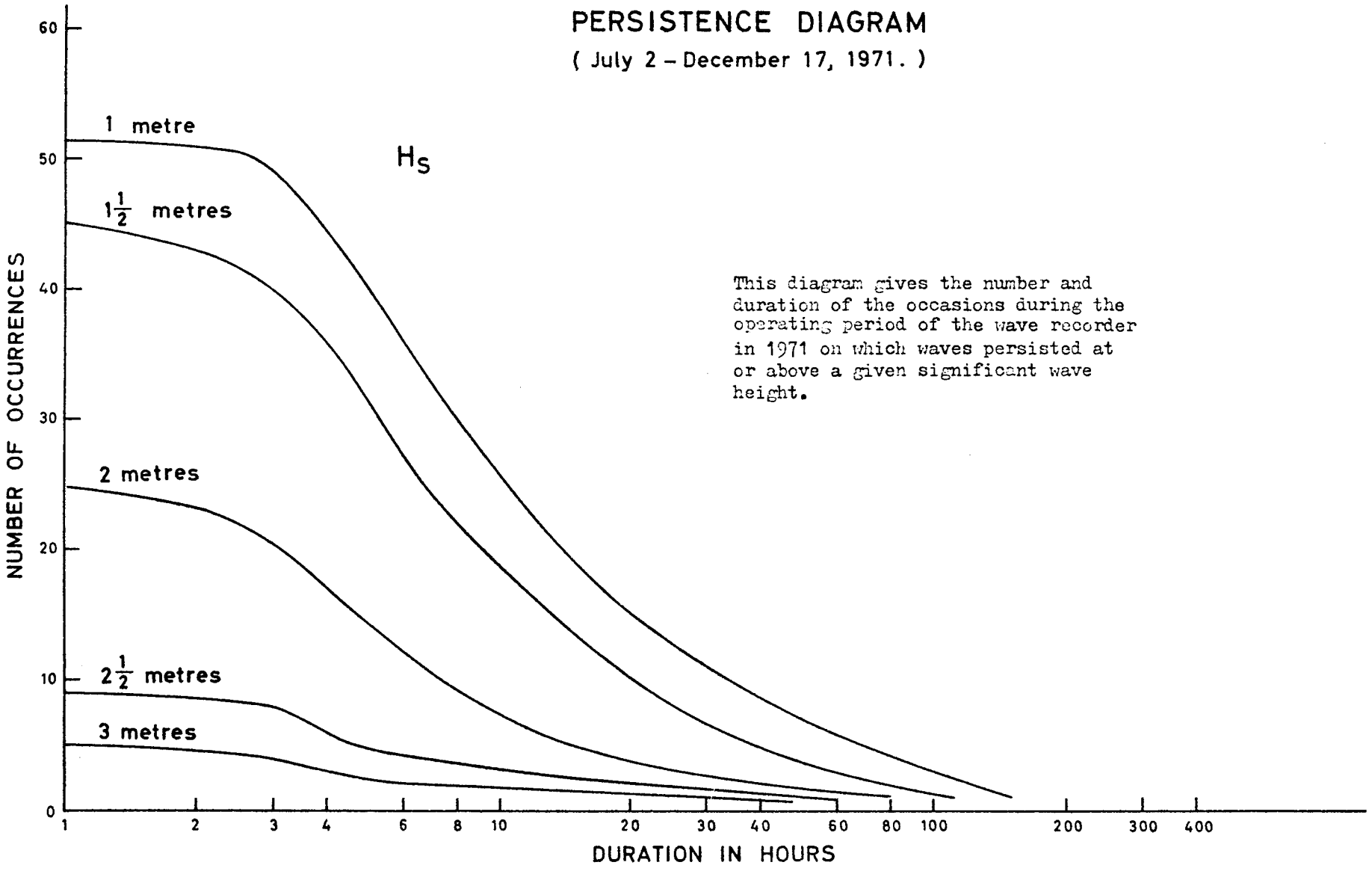


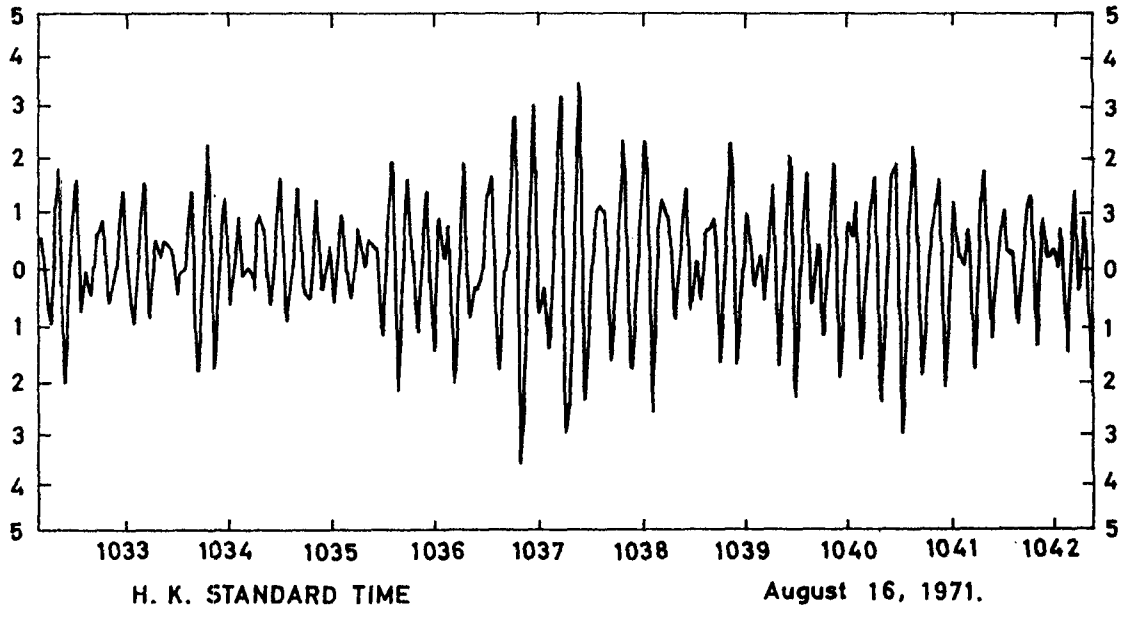
Figure 24



This diagram gives the number and duration of the occasions during the operating period of the wave recorder in 1971 on which waves persisted at or above a given significant wave height.

Figure 25

WAVES RECORDED DURING THE PASSAGE OF TYPHOON ROSE



Waves off Waglan Island recorded on Aug. 16, 1971 when Typhoon Rose was centered about 100 miles south of Hong Kong. The wave height (vertical distance from the lowest trough to the highest crest), after the corrections for attenuation due to depth of the sensor unit below the water surface and the response of the pen recorder have been applied, was 10.4 metres recorded around 1037 H.K. Standard Time (above); and 9.7 metres recorded around 1101-1102 H.K. Standard Time (below).

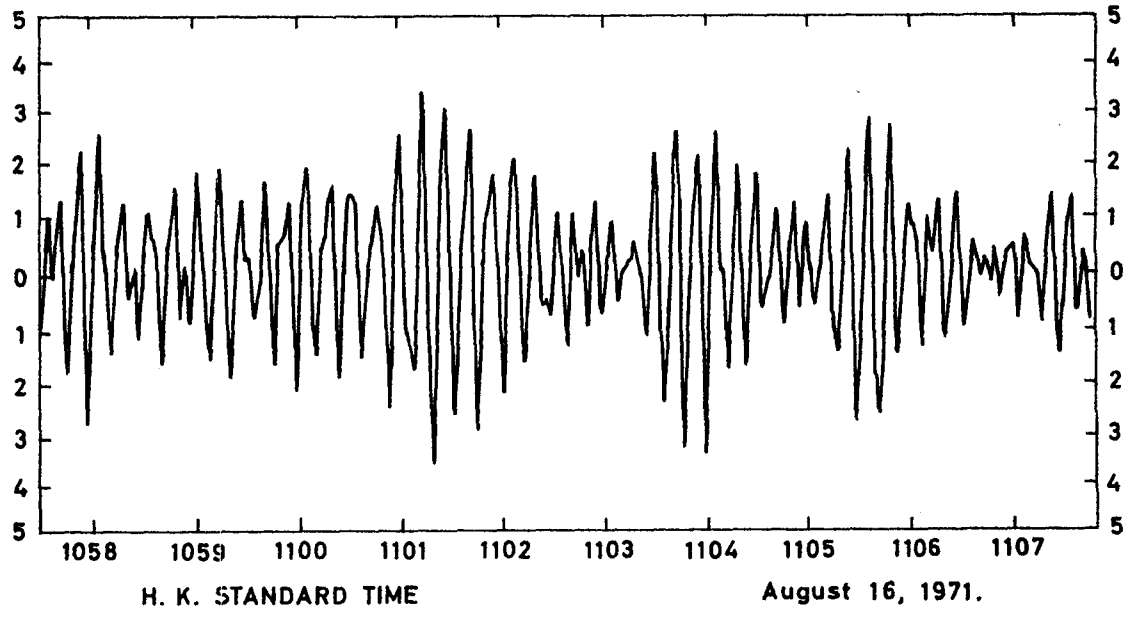
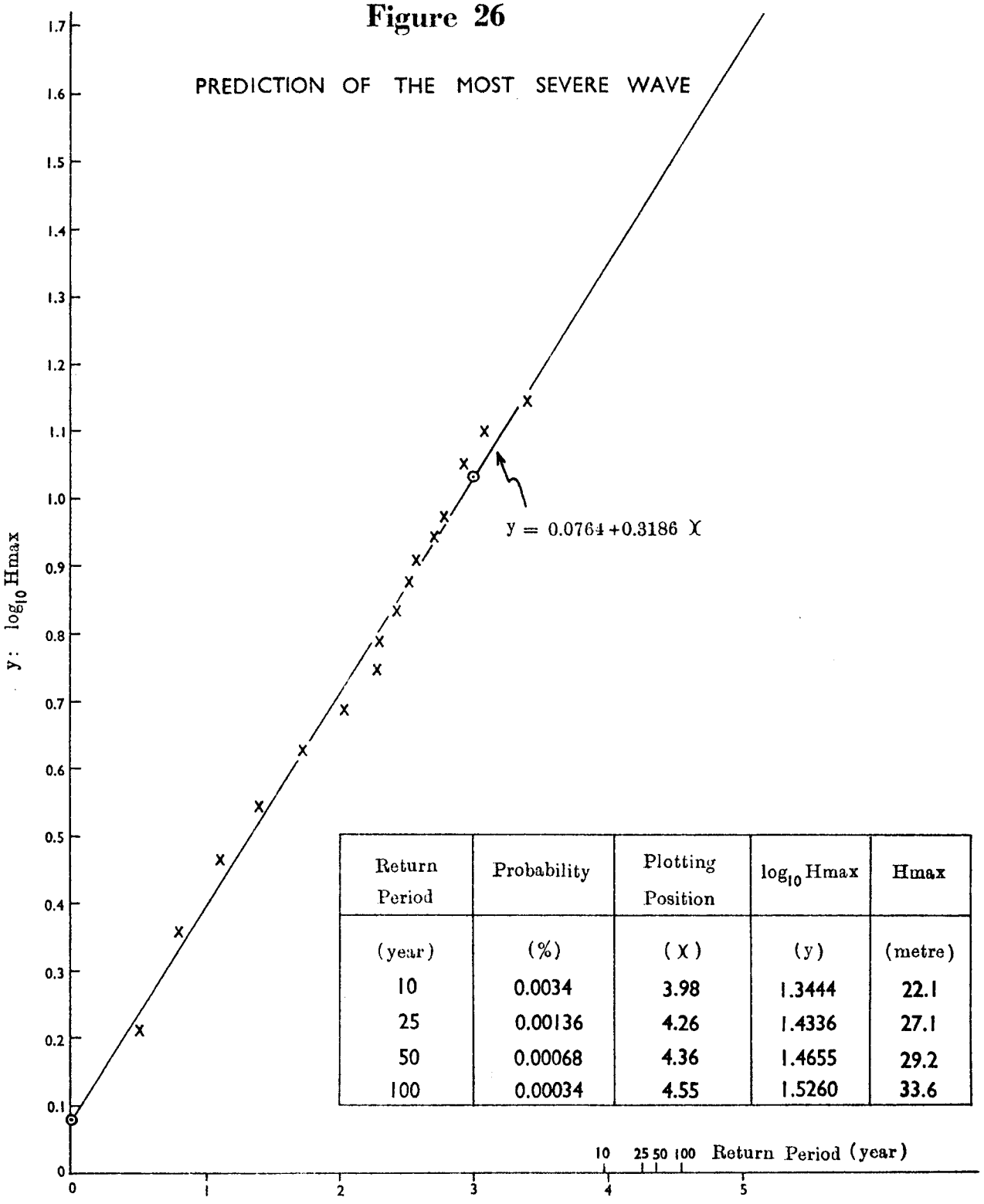


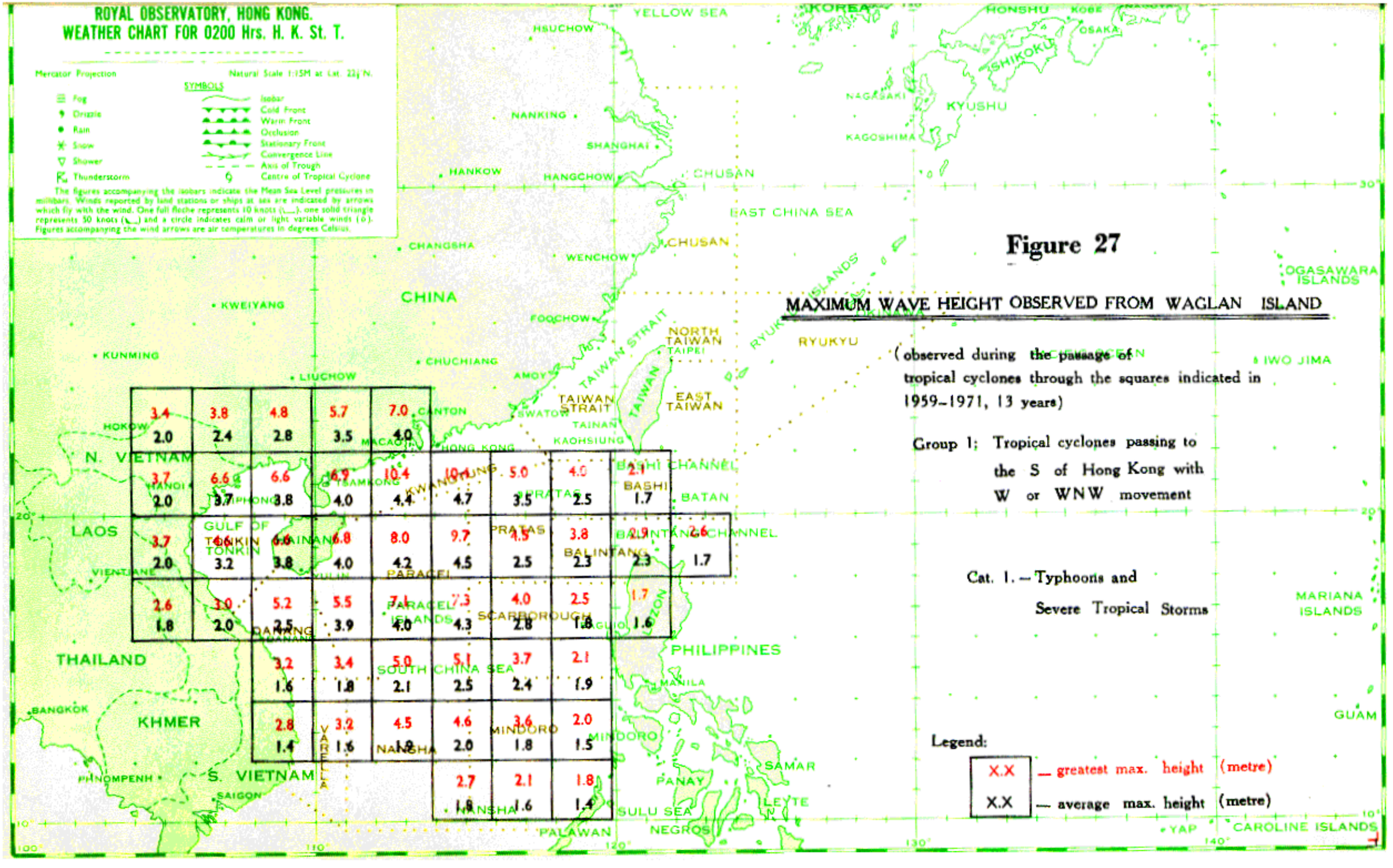
Figure 26

PREDICTION OF THE MOST SEVERE WAVE



Return Period	Probability	Plotting Position	$\log_{10}$ Hmax	Hmax
(year)	(%)	(X)	(y)	(metre)
10	0.0034	3.98	1.3444	22.1
25	0.00136	4.26	1.4336	27.1
50	0.00068	4.36	1.4655	29.2
100	0.00034	4.55	1.5260	33.6

X : PLOTTING POSITION FOR NORMAL PROBABILITY


ROYAL OBSERVATORY, HONG KONG.
WEATHER CHART FOR 0200 Hrs. H. K. St. T.
Mercator Projection
Natural Scale 1:15M at Lat. 22½°N.
SYMBOLS
Fog
Drizzle
Rain
Snow
Shower
Thunderstorm
Isobar
Cold Front
Warm Front
Occlusion
Stationary Front
Convergence Line
Axis of Trough
Centre of Tropical Cyclone
The figures accompanying the isobars indicate the Mean Sea Level pressures in millibars. Winds reported by land stations or ships at sea are indicated by arrows which fly with the wind. One full fleche represents 10 knots, one solid triangle represents 50 knots and a circle indicates calm or light variable winds. Figures accompanying the wind arrows are air temperatures in degrees Celsius.
YELLOW SEA
KOREA
HONSHU
KOBE
OSAKA
SHIKOKU
NAGASAKI
KYUSHU
KAGOSHIMA
HSUCHOW
NANKING
SHANGHAI
HANKOW
HANGCHOW
CHUSAN
EAST CHINA SEA
CHANGSHA
WENCHOW
CHUSAN
OGASAWARA ISLANDS
CHINA
KWEIYANG
FOOCHOW
NORTH TAIWAN
TAIPEI
RYUKYU
KUNMING
CHUCHIANG
IWO JIMA
LIUCHOW
AMOY
TAIWAN STRAIT
TAIWAN
EAST TAIWAN
CANTON
SWATOW
TAINAN
KAOHSIUNG
HOKOW
MACAO
HONG KONG
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HANOI
TSAMKONG
KWANTUNG
PRATAS
BASHI
BATAN
LAOS
GULF OF TONKIN
HAINAN
PRATAS
BALINTANG CHANNEL
BALINTANG
VIENTIANE
YULIN
PARACEL
PARACEL ISLANDS
SCARBOROUGH
LUZON
MARIANA ISLANDS
THAILAND
DANANG
PHILIPPINES
SOUTH CHINA SEA
MANILA
BANGKOK
KHMER
VARELLA
NANSHA
MINDORO
GUAM
SAMAR
PHNOMPENH
S. VIETNAM
SAIGON
PANAY
LEYTE
SULU SEA
WANSHA
PALAWAN
NEGROS
YAP
CAROLINE ISLANDS
100°
110°
120°
130°
140°
10°
20°
30°
3.4 2.0
3.8 2.4
4.8 2.8
5.7 3.5
7.0 4.0
3.7 2.0
6.6 3.7
6.6 3.8
6.9 4.0
10.4 4.4
10.4 4.7
5.0 3.5
4.0 2.5
2.1 1.7
3.7 2.0
4.6 3.2
6.6 3.8
6.8 4.0
8.0 4.2
9.7 4.5
4.5 2.5
3.8 2.3
2.9 2.3
2.6 1.7
2.6 1.8
3.0 2.0
5.2 2.5
5.5 3.9
7.1 4.0
7.3 4.3
4.0 2.8
2.5 1.8
1.7 1.6
3.2 1.6
3.4 1.8
5.0 2.1
5.1 2.5
3.7 2.4
2.1 1.9
2.8 1.4
3.2 1.6
4.5 1.9
4.6 2.0
3.6 1.8
2.0 1.5
2.7 1.8
2.1 1.6
1.8 1.4
Figure 27
MAXIMUM WAVE HEIGHT OBSERVED FROM WAGLAN ISLAND
(observed during the passage of tropical cyclones through the squares indicated in 1959–1971, 13 years)
Group 1: Tropical cyclones passing to the S of Hong Kong with W or WNW movement
Cat. 1. — Typhoons and Severe Tropical Storms
Legend:
X.X — greatest max. height (metre)
X.X — average max. height (metre)

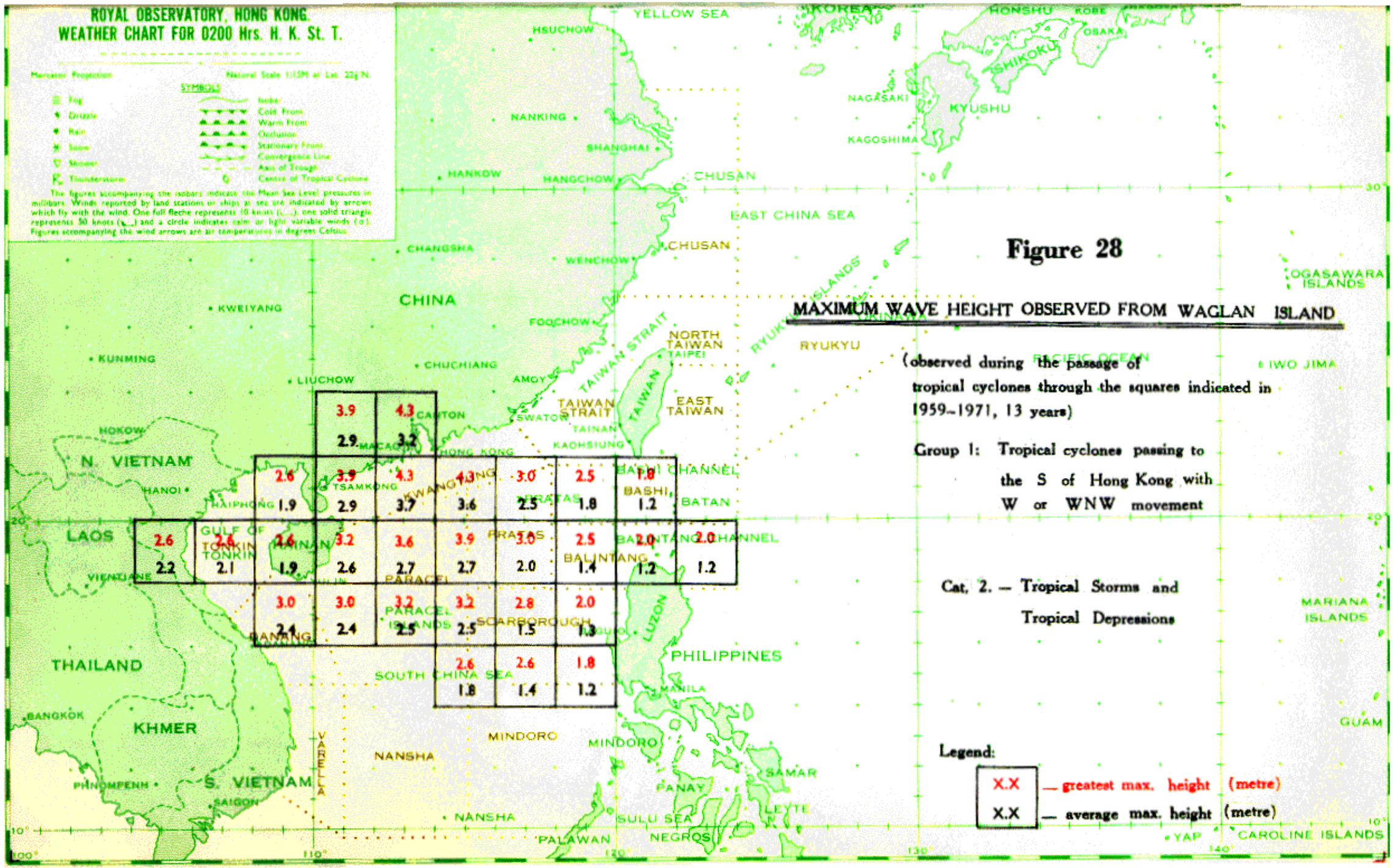


Figure 28

MAXIMUM WAVE HEIGHT OBSERVED FROM WAGLAN ISLAND

(observed during the passage of tropical cyclones through the squares indicated in 1959–1971, 13 years)

Group 1: Tropical cyclones passing to the S of Hong Kong with W or WNW movement

Cat. 2. — Tropical Storms and Tropical Depressions

Legend:

X.X — greatest max. height (metre)

X.X — average max. height (metre)

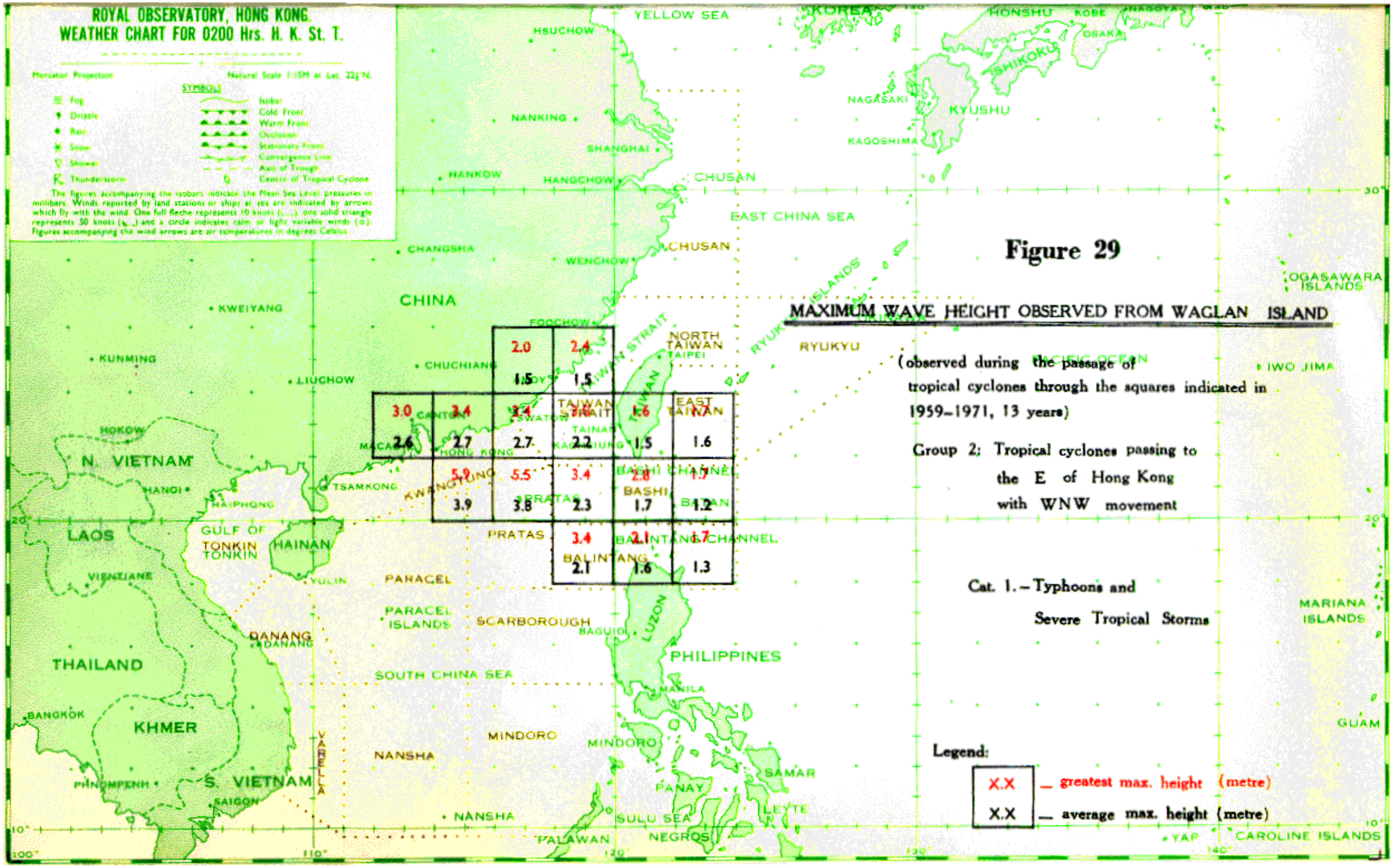


Figure 29

MAXIMUM WAVE HEIGHT OBSERVED FROM WAGLAN ISLAND

(observed during the passage of tropical cyclones through the squares indicated in 1959–1971, 13 years)

Group 2: Tropical cyclones passing to the E of Hong Kong with WNW movement

Cat. 1.—Typhoons and Severe Tropical Storms

Legend:

X.X — greatest max. height (metre)

X.X — average max. height (metre)

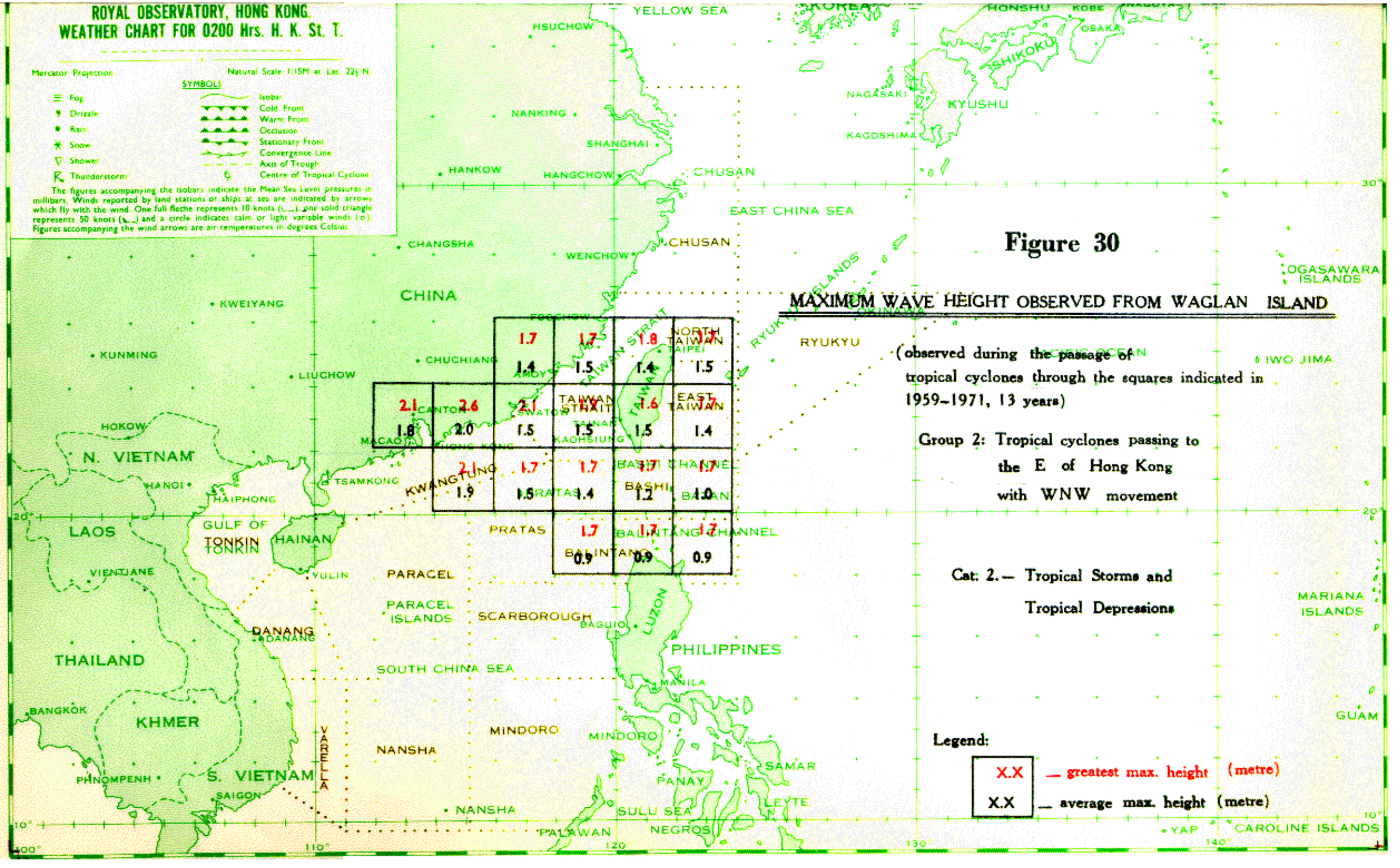


Figure 30

MAXIMUM WAVE HEIGHT OBSERVED FROM WAGLAN ISLAND

(observed during the passage of tropical cyclones through the squares indicated in 1959–1971, 13 years)

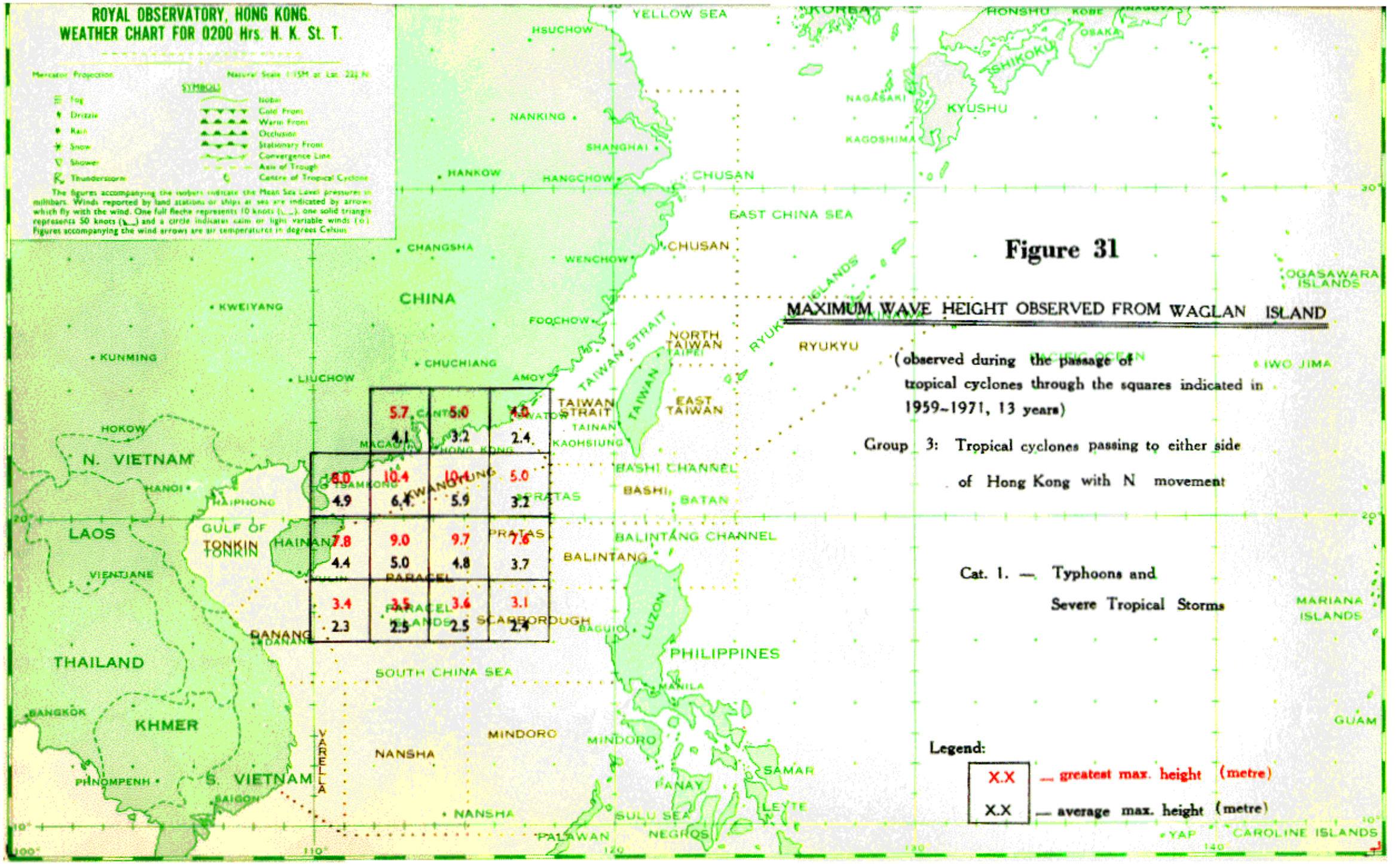
Group 2: Tropical cyclones passing to the E of Hong Kong with WNW movement

Cat: 2.— Tropical Storms and Tropical Depressions

Legend:

X.X — greatest max. height (metre)

X.X — average max. height (metre)


ROYAL OBSERVATORY, HONG KONG.
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SHANGHAI
HANKOW
HANGCHOW
CHUSAN
EAST CHINA SEA
CHANGSHA
WENCHOW
CHINA
KWEIYANG
FOOCHOW
KUNMING
CHUCHIANG
LIUCHOW
AMOY
TAIWAN STRAIT
NORTH TAIWAN
TAIPEI
TAIWAN
EAST TAIWAN
TAINAN
KAOHSIUNG
HOKOW
N. VIETNAM
HANOI
HAIPHONG
GULF OF TONKIN
HAINAN
LAOS
VIENTIANE
THAILAND
BANGKOK
KHMER
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S. VIETNAM
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NANSHA
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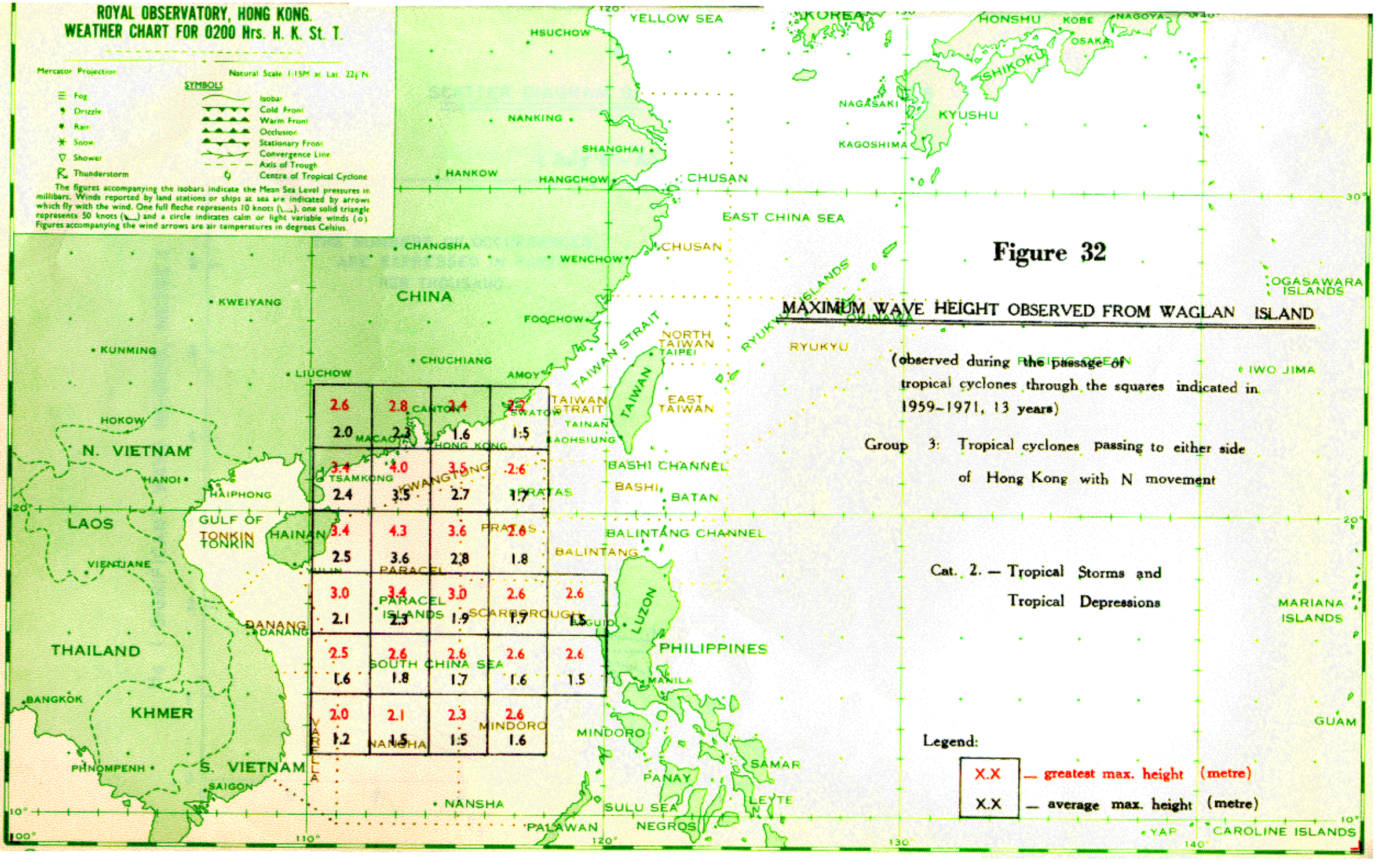
VARELLA
BASHI CHANNEL
BASHI
BATAN
BALINTANG CHANNEL
BALINTANG
LUZON
PHILIPPINES
MANILA
SAMAR
PANAY
LEYTE
SULU SEA
NEGROS
PALAWAN
HONSHU
KOBE
OSAKA
SHIKOKU
NAGASAKI
KYUSHU
KAGOSHIMA
RYUKYU
OGASAWARA ISLANDS
IWO JIMA
MARIANA ISLANDS
GUAM
YAP
CAROLINE ISLANDS
5.7 4.1
5.0 3.2
4.0 2.4
8.0 4.9
10.4 6.4
10.1 5.9
5.0 3.2
7.8 4.4
9.0 5.0
9.7 4.8
7.6 3.7
3.4 2.3
3.5 2.5
3.6 2.5
3.1 2.4
Figure 31
MAXIMUM WAVE HEIGHT OBSERVED FROM WAGLAN ISLAND
(observed during the passage of tropical cyclones through the squares indicated in 1959–1971, 13 years)
Group 3: Tropical cyclones passing to either side of Hong Kong with N movement
Cat. 1. — Typhoons and Severe Tropical Storms
Legend:
X.X — greatest max. height (metre)
X.X — average max. height (metre)


ROYAL OBSERVATORY, HONG KONG.
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Mercator Projection
Natural Scale 1:15M at Lat. 22½ N.
SYMBOLS
Fog
Drizzle
Rain
Snow
Shower
Thunderstorm
Isobar
Cold Front
Warm Front
Occlusion
Stationary Front
Convergence Line
Axis of Trough
Centre of Tropical Cyclone
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HANGCHOW
CHUSAN
EAST CHINA SEA
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WENCHOW
CHUSAN
CHINA
KWEIYANG
FOOCHOW
KUNMING
CHUCHIANG
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TAIWAN
EAST TAIWAN
TAINAN
KAOHSIUNG
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N. VIETNAM
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TSAMKONG
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PRATAS
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GULF OF TONKIN
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SHIKOKU
NAGASAKI
KYUSHU
KAGOSHIMA
OGASAWARA ISLANDS
RYUKYU ISLANDS
OKINAWA
RYUKYU
IWO JIMA
MARIANA ISLANDS
GUAM
YAP
CAROLINE ISLANDS
2.6 2.8 2.4 2.2
2.0 2.3 1.6 1.5
3.4 4.0 3.5 2.6
2.4 3.5 2.7 1.7
3.4 4.3 3.6 2.6
2.5 3.6 2.8 1.8
3.0 3.4 3.0 2.6 2.6
2.1 2.3 1.9 1.7 1.5
2.5 2.6 2.6 2.6 2.6
1.6 1.8 1.7 1.6 1.5
2.0 2.1 2.3 2.6
1.2 1.5 1.5 1.6
Figure 32
MAXIMUM WAVE HEIGHT OBSERVED FROM WAGLAN ISLAND
(observed during the passage of tropical cyclones through the squares indicated in 1959–1971, 13 years)
Group 3: Tropical cyclones passing to either side of Hong Kong with N movement
Cat. 2. — Tropical Storms and Tropical Depressions
Legend:
X.X — greatest max. height (metre)
X.X — average max. height (metre)

Figure 33

SCATTER DIAGRAM OF SIGNIFICANT WAVE HEIGHTS

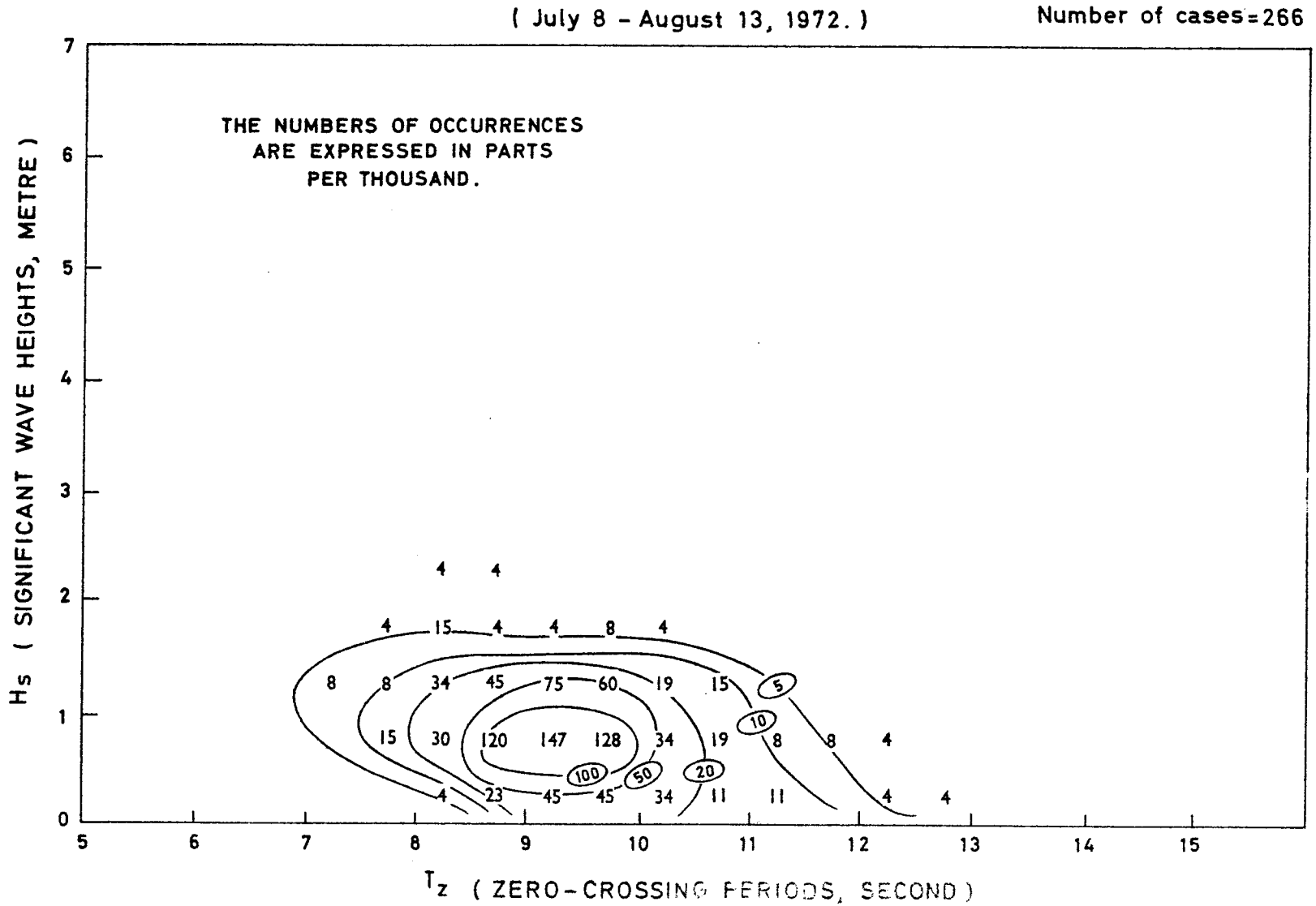


Figure 34

CUMULATIVE DISTRIBUTION OF WAVE HEIGHTS
(July 8 – August 13, 1972)

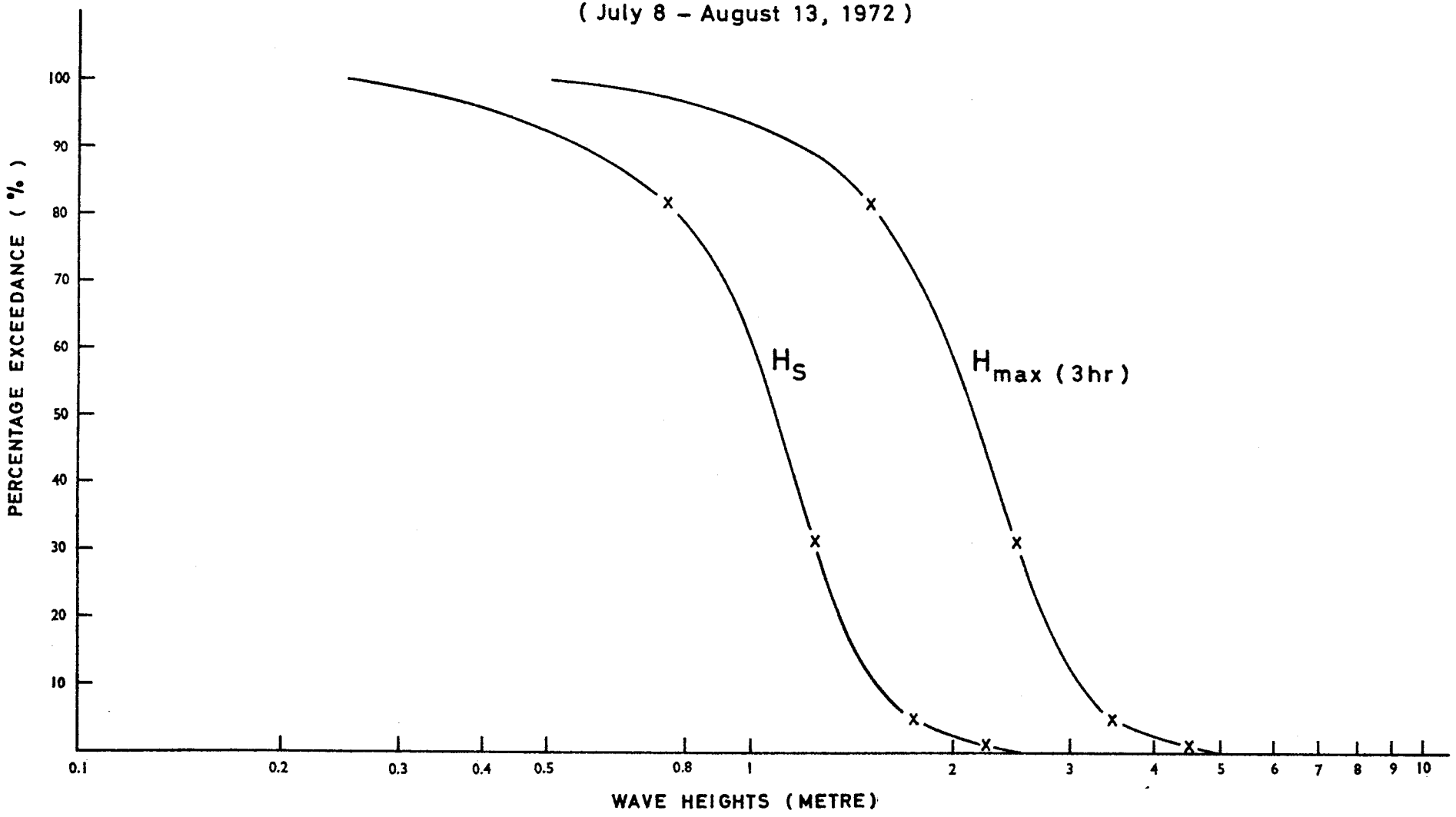
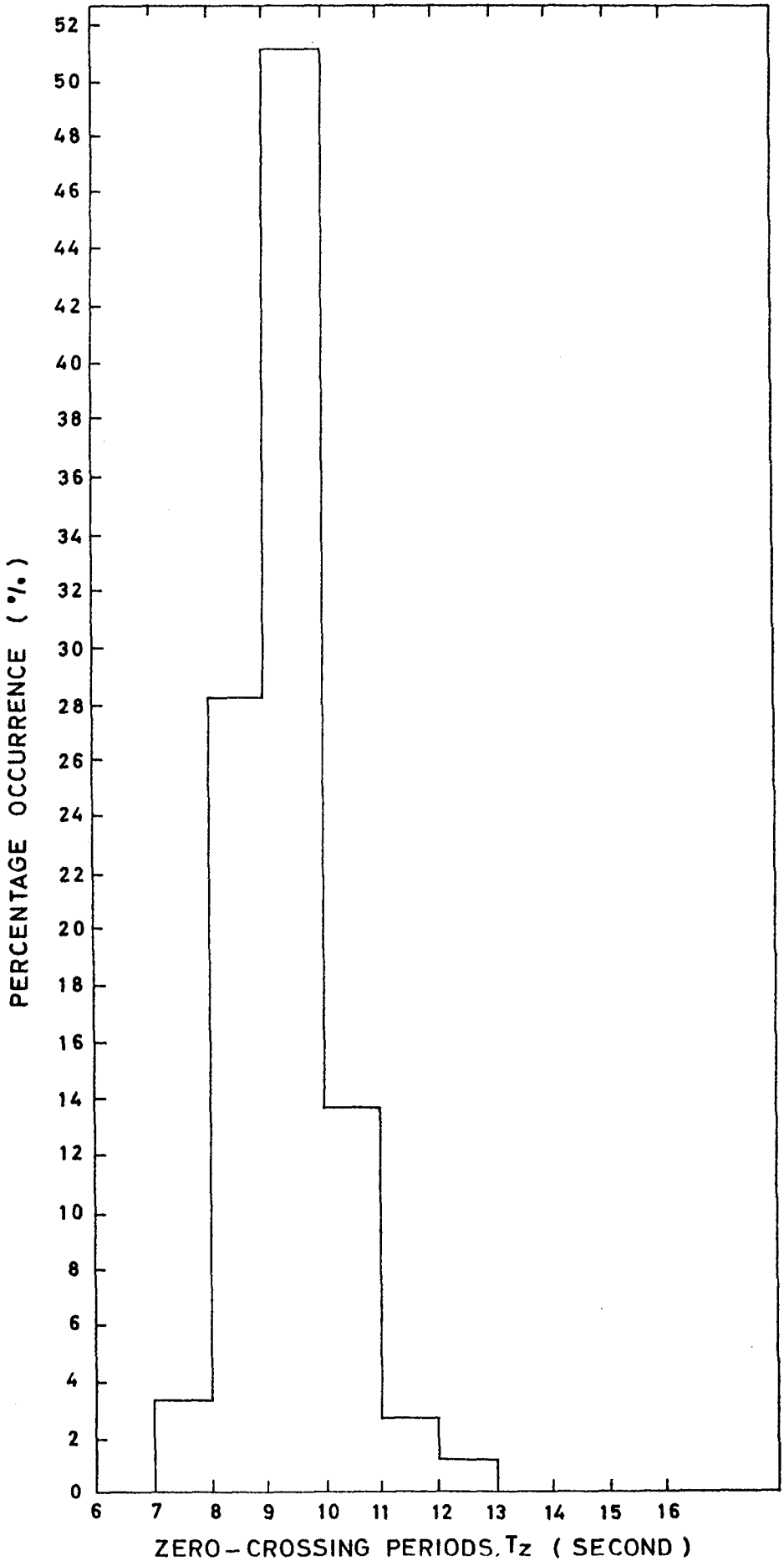


Figure 35

DISTRIBUTION OF ZERO-CROSSING PERIODS

(July 8 – August 13, 1972)



R.O. Technical Notes

No.	Title	Author	Year
*1	Synoptic situation associated with strong winds at the Royal Observatory	R.C. Bannister	1949
*2	Meteorological observations in connection with the Deep Bay airport project	—	1950
*3	Fogs at Waglan Island & their relationship to fogs in Hong Kong harbour	K.R. Hung	1951
*4	Frequency distribution of summer rain duration at Hong Kong	G. Ma	1952
*5	Upper winds determined by radar 1949 - 1951	G.J. Bell & H.Q. Loo	1953
6	Intensity & duration of rainfall in Hong Kong	G.S.P. Heywood & H.C. Huang	1953
7	Evapotranspiration measurements made in Hong Kong, Oct. 1951 - May 1953	C.S. Ramage	1953
*8	Meteorological aspects of scheme D, airport development plan	G.S.P. Heywood	1953
*9	Storm microseisms in Hong Kong (preliminary report)	G.S.P. Heywood	1954
*10	Hong Kong forecaster's manual	C.S. Ramage	1955
*11	An analysis of low cloud & poor visibility at Hong Kong airport, 1949 - 1954	E.T. Baker	1955
*12	Median & quartile upper air temperatures at given pressure levels at Hong Kong 1949 - 1955	R.F. Apps & Y.Y. Lo	1955
*13	Artificial & orographic stimulation of rainfall in Hong Kong	C.S. Ramage & G.J. Bell	1955
14	Solar data for Hong Kong	J.E. Peacock	1955
15	Results of experimental radiosonde ascents carried out during the partial solar eclipse of 20th June, 1955 at Hong Kong	R.F. Apps	1956
16	An analysis of low cloud & poor visibility at Sek Kong, May 1951 - Apr., 1955	E.T. Baker & R.G. Hughes	1956
17	The rainfall of Hong Kong (1st edition) (2nd edition)	P. Peterson P. Peterson	1957 1964
*18	Modification of the normal lag & radiation corrections for the Kew type radiosonde in the troposphere	R.F. Apps	1958
19	Results of the experimental radiosonde ascents made at Hong Kong during the solar eclipse, April 19, 1958	R.F. Apps	1959

R.O. Technical Notes

No.	Title	Author	Year
*20	An analysis of surface winds at the new runway of Hong Kong airport, 1956 - 1958	P.C. Chin	1959
	Supplement - an additional analysis of surface winds & associated temperatures at Hong Kong airport, 1956 - 1958	P.C. Chin	1961
*21	Errors of upper-wind forecasts	P.C. Chin & H.C. Leong	1964
*22	Total solar & sky radiation in Hong Kong	P. Sham	1964
*23	Natural beta-radioactivity & beta-activity of fallout in Hong Kong, 1962 - 1965	R.F. Apps	1965
24	A statistical study of heavy rainfall in Hong Kong, 1947 - 1965	S. Cheng & W.H. Kwok	1966
25	Wave heights in the southeast approaches to Hong Kong harbour	M.J. Cuming	1967
26	Storm surges in Hong Kong	T.T. Cheng	1967
27	Effect of cool season tropical disturbance in the South China Sea on the weather of Hong Kong	M.J. Cuming	1968
28	Cold surges over south China	P.C. Chin	1969
29	Meteorological aspects of air pollution in Hong Kong	G.J. Bell, P. Peterson & P.C. Chin	1970
30	The "Control Point" method for the prediction of tropical cyclone movement	P.C. Chin	1970
31	Comparison between the results obtained with the Kew MK IIB and the Vaisala RS 13 radiosondes under operational conditions in Hong Kong	R.F. Apps	1971
32	Markov chains and sequences of wet and dry days in Hong Kong	J.E. Peacock	1972
33	Seismicity in Hong Kong	R. Lau	1972
34	Radar climatology of Hong Kong for the years 1967 - 1969	T.T. Cheng & W.P. Kwong	1973
35	Quantitative forecasting of the winter monsoon in Hong Kong	A.M. Morrice	1973

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