CHAPTER 6

EXTREME WAVE CONDITIONS IN BRITISH AND ADJACENT WATERS

LAURENCE DRAPER
NATIONAL INSTITUTE OF OCEANOGRAPHY
Wormley, Godalming, Surrey, Great Britain.

ABSTRACT

Information on extreme wave conditions is needed in the design of offshore structures. This paper present the results of calculations of the parameters in the 50-year storm; the work has been based on extreme wind data and on instrumental wave measurements. The results are complementary, and are combined in two maps, one of extreme wave height and the other of the corresponding wave period.

INTRODUCTION

Systematic measurements of waves in British and adjacent waters have been made during the last quarter of a century. Estimates of extreme wave parameters for specific sites have been required for a number of purposes, but until recently no attempt had been made to produce a coherent picture of conditions in all these waters. The need for such an overall picture has existed for some time, but the study has been precipitated by the imminent government regulations required by the Mineral Workings (Offshore Installations) Act 1971. This Institute was requested by the Department of Trade and Industry to provide guidance on the oceanographic parameters which the installations must be designed to withstand. Of these, probably the most critical single phenomenon is that of wave activity.

Before such a task could begin, certain basic criteria had to be laid down. The first concerns the return period for the parameters being forecast. A typical estimated life-span for many of these structures was in the region of 20 years. The probability of occurrence of, for example, a 50-year return-period wave is 0.332 during a 20-year life-span, whilst there is an even probability of its occurrence in a 35-year life-span (Borgman 1963). This does not mean that the structure can be expected to fail during, say, a 40-year life-span, as safety factors used in the design are likely to reduce the failure probability.

Because of these and other considerations, it was decided, for the governmental 'Guidance Notes' on offshore environmental parameters, to quote the characteristics of the 50-year storm as the minimum acceptable parameters.

The second basic criterion to be decided is that of storm duration. The 50-year storm hourly-mean wind speed is predicted by Shellard (1965), but its duration is not known. The average relationships between that speed and the mean speed over other durations, such as 6, 12, 18 and 24 hours, have been calculated. The average wind speed for a given storm decreases as duration increases, but the ratio of the height of the highest wave in the storm to the significant wave height increases. Because of this, the postulated storm duration is not critical over the range of storm durations likely to occur. A short storm will yield a high significant wave height but the ratio of the likely height of the highest wave to significant height will not be very high; a longer storm (but of lower mean speed over the longer duration) will in practice yield a lower significant wave height but, because of the longer duration, the ratio of likely height of the highest wave to the significant height will be higher. These two effects tend to cancel out. In addition, the number of waves will be slightly different in the two cases. Experience has shown that a 12-hour duration yields marginally higher waves than any other duration when the Darbyshire and Draper (1963) curves are used. Because of this, a duration of 12-hours has been postulated for the 50-year storm.

Methods used in this Study

The primary sources of wave information are forecasts based on

estimates of the 50-year extreme wind calculated by Shellard (1965), and extrapolations of data obtained from instrumental measurements made by Ocean Weather Ships and Light Vessels.

Estimates based on Wind Data

The wind information is applied to established forecasting techniques such as Darbyshire and Draper (1963) which was derived entirely from instrumental measurements in the waters presently considered, or Bretschneider (1970 revision). Because of the large amount of wind data available over the whole country, the wave field can be forecast for most sea areas.

The 50-year hourly-mean wind speed is converted to mean speeds over longer durations using relationships (unpublished) provided by the Meteorological Office. This is applied to the appropriate wave forecasting graphs, from which the required parameters are obtained.

The wave heights derived from the Darbyshire system are of the most probable value of the height of the highest wave in a ten-minute record. These values can be used to derive the significant wave height, and the most probable value of the height of the highest wave in some longer time, very often 3-hours (Draper 1966), but in this case 12-hours as previously stated. The Bretschneider method yields the significant height directly, from which other parameters are speedily derived in the same way. The period forecast by both methods is the significant period, T_s.

Estimates based on Instrumentally-measured Wave Data

The records, which must normally be a sample representative of one or more complete years, are analyzed following the standard N. I. O. routine (Draper 1966). One parameter which is derived is the most probable value of the height of the highest wave likely to have occurred in a 3-hour interval, H max (3 hours). These values are then plotted as cumulative exceedances on log-normal probability paper, and extrapolated to yield an estimate of the 50-year wave height appropriate to a 3-hour interval. Wave period data, in this case zero-crossing period T_z, is usually a best fit on linear probability paper, but it is not always as well behaved as is the height data. This yields an estimate of T_z in the 50-year storm. The value of H max (storm)

for the 50-year storm assuming it lasts for 12 hours is then derived using the number of waves (T_z) expected to occur in the storm, using Longuet-Higgins statistics (Draper 1963). In addition, the methods used by Battjes (1970) are also employed to make a further estimate of H max (storm).

There are two essential checks which must be made on data derived from instrumental measurements. The first is that all the records showing the highest waves of the series must be examined individually and the significant height determined from either the spectrum or by the traditional method of taking the average height of the highest one third of all the waves. The most probable value of the height of the highest wave in a typical record must be determined from this reliably-determined significant height and must be used instead of the value determined by the standard method. This must be done to eliminate the fairly high probability, for such records, of employing an unusually high wave height as a base from which to calculate extremes. Secondly, the wind data for the year in which the wave measurements were made must be compared with some longer-term average to ensure that the deviations from normal can be taken into account. The two simplest comparisons which can be made are of the relationship between the annual mean speed during the year in which wave measurements were made, and that over many years, and also between the number of hours of gale in the year and that in the longer-term average.

Use of this Information

This information has been compiled to give an indication of the likely extreme wave parameters in these waters. Very little account has been taken in this study of the details of the sea-bed topography, except at measurement locations where this information is, obviously, already incorporated in the data. Before any structure can be erected it will be necessary for a detailed study to be undertaken covering a large area around the site to ensure that no focussing of waves, even from large distances, or severe confused seas are likely to occur at the site. Although in principle it might be technically feasible to produce a detailed picture covering all these areas, the cost would be enormous, and in only a few areas would the information be used

before the planned increase in measurement activity yields further data which could modify the picture significantly.

Presentation of Results

Agreement between the two main approaches of derivation has been comfortingly good, more especially so in height. The results are expressed in two maps. Figure 1 gives the height data and Figure 2 the period data. The height map, presenting the most probable value of the height of the highest wave in the 50-year storm, is based largely on wave forecasts, supplemented wherever possible by data derived from instrumental measurements. Heights are now expressed in metres, in accordance with the change to the metric system. Periods are expressed in seconds; the parameter presented is the zero-crossing period T_z derived from instrumental measurements, supplemented where necessary by estimates of T_z derived from forecasts of T_s. The relationship found by Darbyshire between T_s and T_z has been summarized (Draper 1965) and, in general, T_s is slightly larger than T_z. However, in this study no systematic relationship was found between wind-forecast and extrapolated instrumentally-measured period data, although the differences were small.

The basic pattern of wave height is similar to that on the map produced in the spring of 1971. Since that time there has been a significant increase in the amount of data available, the most noticeable change being in the eastern English Channel where more data has resulted in a decrease in predicted extreme wave height of 2 metres. There are minor variations in the positions of some of the contours elsewhere, but the extent of the changes is difficult to discern when comparing this height map with the previous one, because in the previous map the heights are expressed in feet. There was no previous publication of wave period information, except in tabular form.

Location of Reference Points

The locations are indicated by dots, together with a code letter based on the name of the station. With the exception of Dowsing and Royal Sovereign these locations are stations at which instrumental measurements have been made and analyzed. Data from Dowsing are being analyzed at present. To

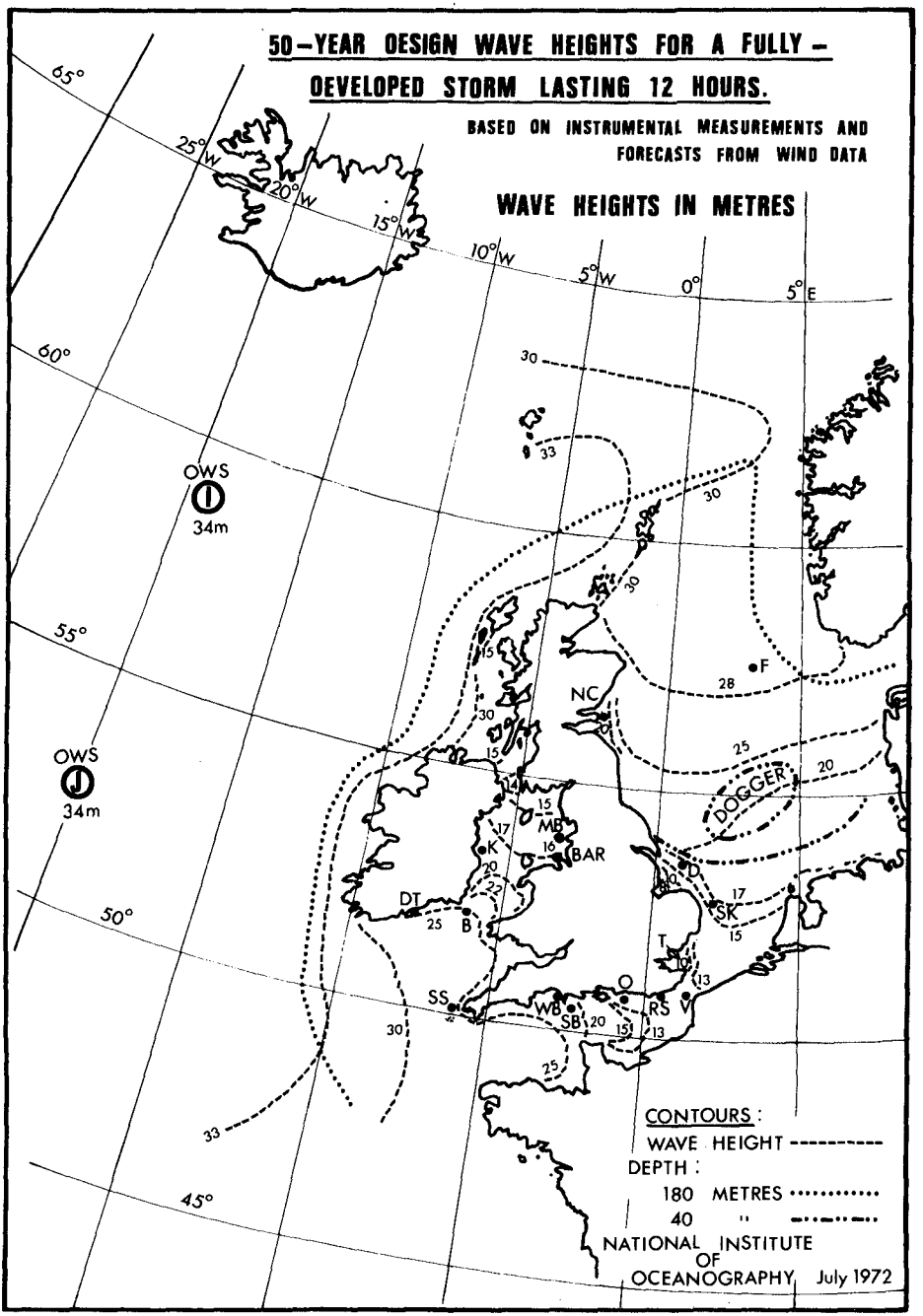

Figure 1: The most probable value of the height of the highest wave likely to occur in the 50-year storm.

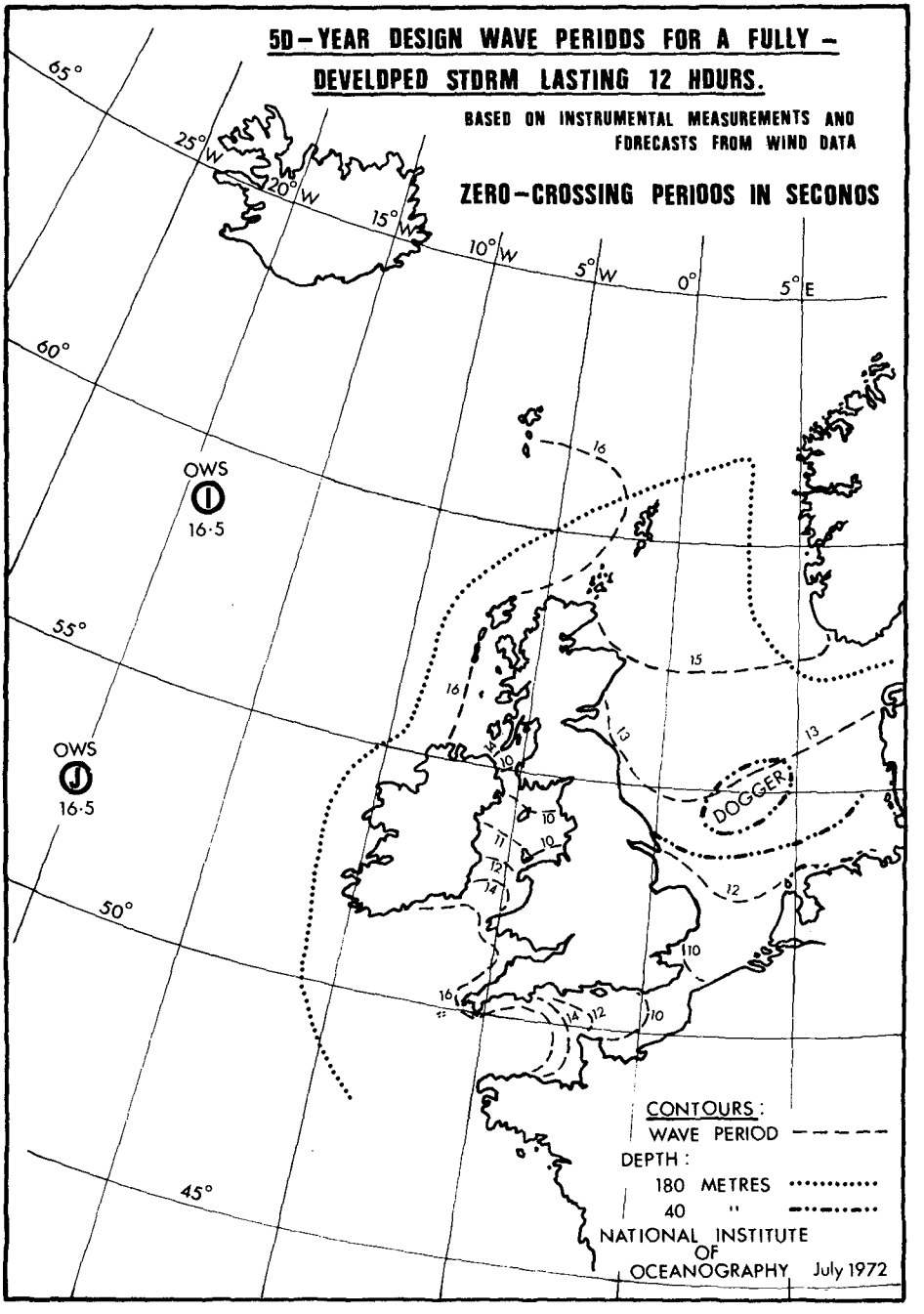

Figure 2: The most probable value of zero-crossing period likely to occur in the 50-year storm.

reduce the length of this paper, details of N. I. O. data publications for these locations are omitted from the Reference, but can be obtained from the author.

B	Barrels L. V.	OWS	Ocean Weather Ship Stations, I and J
BAR	Bar L. V.	RS	Royal Sovereign
D	Dowsing L. V.	SB	Shambles
DT	Daunt L. V.	SK	Smith's Knoll L. V.
F	FAMITA	SS	Sevenstones L. V.
K	Kish Bank	T	Tongue L. V.
MB	Morecambe Bay	V	Varne L. V.
NC	North Carr L. V.	WB	West Bexington
O	Owers L. V.		

Acknowledgements

The author wishes to express his gratitude to all those people and organisations, far too numerous to list, who have contributed to this work. The wave measurements and forecasts have been the responsibility of N. I. O. staff, with the exception of the data from Barrels, Daunt and Kish, for which the author is grateful to Mr. A. D. H. Martin, (Martin 1971) Chief Engineer of the commissioners of Irish Lights, and the data from West Bexington which were obtained by Mr. P. Hardcastle (Hardcastle and King, 1972) of the Unit of Coastal Sedimentation, Taunton.

References

BATTJES, J. A. 1970 Long-term Wave Height Distribution at Seven Stations around the British Isles. N. I. O. Internal Report A44.

BORGMAN, L. E. 1963 Risk Criteria. Journal of Waterways and Harbours Division Proc. ASCE 3607, WW3, August.

BRETSCHNEIDER, C. L. 1970 Forecasting Relations for Wave Generation. Look Lab/HAWWAll 1, 3, 31-34.

DARBYSHIRE, M. and DRAPER, L. 1963 Forecasting Wind-generated Sea Waves. Engineering (Lond) 195, 482-484.

DRAPER, L. 1963 Derivation of a 'design wave' from instrumental Measurements of Sea Waves. Proc. Instn. civ. Engrs. 26 291-304.

DRAPER, L. 1965 Wave spectra provide best basis for Offshore Rig Design. Oil and Gas Internat. 5, 6, 58-60.

DRAPER, L. 1966 The analysis and Presentation of wave data - a plea for Uniformity. Proc. 10th Conf. Coastal Engr. Tokyo, Vol, 1, Chapt. 1.

HARDCASTLE, P. J. and KING, A. C. 1972 Chesil Beach Sea Wave Records. Civil Engineering and Public Works Review, March, 1972.

MARTIN, A. D. H. 1971 Wave Data for Kish Bank L. V., Barrels L. V. and Daunt Rock L. V.
Institution of Engineers of Ireland.

SHELLARD, H. C. 1965 Extreme wind speeds over the United Kingdom for Periods Ending 1963. Met. Off. Climat. Memo. London, No. 50.
This work has recently been substantially extended at the request of the Department of Trade and Industry, but has not been formally published.