CHAPTER 35

THE EFFECT OF WAVE REFRACTION OVER DREDGED HOLES

by

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ABSTRACT

Preliminary results are presented of a study of the beach erosion caused by wave refraction over offshore dredged holes. A mathematical model is used of an idealised sand beach, typical of those on the English Channel and North Sea coasts of Great Britain. Depth and side slopes of dredged area and original water depth before dredging were varied. Beach erosion increased with increasing hole depth and with decreasing original water depth. The effects of side slope and hole depth will be separated in future work, as will the effects of hole shape. Beach erosion due to holes in water depths greater than half the length of "normal" waves, or a fifth of the length of extreme waves, was negligible.

INTRODUCTION

Large deposits of sand and shingle exist off the coasts of Great Britain, and the commercial exploitation of these resources for aggregate and reclamation material has become a major industry. At present approximately 11% of the national requirement for aggregate is supplied from offshore; this is some 15 million cubic metres per year. An additional 5 million cubic metres was won from the offshore seabed for reclamation in 1973.

There is pressure to increase this exploitation. In Ref 1 the Advisory Committee on Aggregates have said:

> "We think it is important that the marine sand and gravel industry should be encouraged to make the maximum possible contribution, especially as increases in the price of land, particularly in the South East, are likely to make land won sand and gravel more expensive, and so diminish the economic disadvantages of marine won aggregates."

We at the Hydraulics Research Station are involved in offshore dredging as expert advisors to the Crown Estate Commissioners, the public body responsible for letting licences for dredging. We examine dredging proposals submitted to us by the Crown Estate Commissioners, and advise whether or not the proposal is likely to have an adverse effect on the adjacent coastline. In forming our opinion we ask ourselves four questions:

1. Is the dredging area far enough offshore so that beach drawdown into the hole will not occur? For this we rely on the work of Watts in Ref 2.
2. Is the dredging in deep enough water that it will not interrupt the onshore movement of shingle? The work of Crickmore, Waters and Price, Ref 3, seems to indicate that this must be in water of depth 18 m or greater for the wave climates experienced on the English Channel and North Sea coasts of Britain.
3. Does the dredging area exclude bars and banks which might provide some natural wave protection to the coast?
4. Is the dredged hole sufficiently far offshore and in deep enough water that refraction of waves over it will not cause significant changes in the pattern of alongshore transport of beach material? This is the subject of the present paper.

A study of this refraction effect is under way, using a mathematical model of an idealised beach. This paper presents the results of the early work on the model, and describes the future programme of testing.

MATHEMATICAL MODEL

The mathematical model is described in Ref 4. It consists of two parts:

1. The beach plan shape model, also presented in Ref 5, which calculates temporal changes in beach shape caused by alongshore sediment transport. This transport is calculated from the breaking wave conditions using the Scripps Formula, as modified by Komar in Ref 6.

$$Q = \frac{0.045}{\gamma_s} \rho g \; H_b^2 \; Cg \; \mathrm{Sin}\; 2\alpha_b$$

where Q = the volume rate of alongshore sediment transport

γ_s = the submerged unit weight of beach material in place

ρ = the mass density of water

g = the acceleration due to gravity

H_b = the breaking wave height

Cg = the group velocity of the waves at breaking

α_b = the angle between the breaking wave front and the beach

2. A simplified version of the Abernethy and Gilbert wave refraction model is used, see Ref 7. By calculating the paths of wave orthogonals over the nearshore seabed, this determines the non-uniform breaking wave conditions from the assumed uniform waves in deep water.

The model performs the following operations:

1. Calculates breaking wave conditions from deep water wave conditions by refraction over the inshore seabed.
2. Calculates rates of alongshore sediment transport on the beach from the breaking wave conditions.
3. Calculates changes in beach plan shape.
4. Distributes accretion and erosion over the inshore seabed.
5. Recalculates refraction and returns to 2.

TESTING PROGRAMME

In order to complete an exhaustive study of the effects on beach plan shape of refraction over dredged holes, it would be necessary to investigate the following 12 parameters.

1. Properties of the beach: plan shape, grain size, profile shape.
2. Properties of the deepwater wave climate: height, period, direction.
3. Properties of the dredged hole: distance offshore, original water depth, depth of dredging, width, length, and side slopes.

Several of these can be eliminated with thought. For example, once the beach profile is specified, so is a relationship between the distance of the hole offshore and the original water depth in which it is dredged. We therefore chose a profile composed from a number of surveyed profiles of the sand beaches at Great Yarmouth, on the East Coast of Britain. The area offshore of Great Yarmouth is one of the most heavily dredged in the country.

This decision also permitted a deepwater wave climate to be specified, typical of that on the North Sea and English Channel coasts of Britain. This is summarised in Table 1 where the datum of direction is normal to the beach.

TABLE 1

DURATION (DAYS)	HEIGHT (M)	PERIOD (S)	DIRECTION (DEGREES)
$1\frac{1}{2}$	2.00	8	10
$88\frac{1}{2}$	0.41	5	20
90	0.36	5	10
90	0.35	5	- 10
$1\frac{1}{2}$	1.79	8	10
$88\frac{1}{2}$	0.47	5	10

For most of the year, wave periods are 5 sec and mean heights are less than half a metre. Initial tests indicated a need for storms in the climate and two have been specified, each of $1\frac{1}{2}$ days duration with heights of approximately 2 m and period 8 sec. Deep water wave directions were selected by trial and error to produce a net alongshore transport of beach material of 30,000 m^3/yr, typical of these coasts. An infinitely long, straight beach was assumed.

Grain size of beach material is not a parameter in the alongshore transport calculation. Komar, Ref 6, believes that the effects of beach slope and grain size compensate for each other. However, in an earlier mathematical model study of the beach at Bournemouth, attempting to reproduce beach build-up against a long groyne, we found transport rates of shingle of approximately 1/10 of those predicted by the Scripps equation. Nevertheless, our idealised beach is sand and we feel justified in using the equation unmodified for grain size.

Dimensions of the dredged hole were examined in a series of preliminary tests. Varying hole length, the dimension parallel to the beach, had little or no effect on the pattern of accretion and erosion on the beach. Hole width simply determined the location of beach erosion or accretion, not the amount. A rectangular hole of 880 m length and 305 m width was therefore chosen arbitrarily.

The important hole dimensions are clearly depth and side slopes. In our mathematical model approach these two are linked by the size of our refraction grid, 176 m. Thus for a 1 m deep hole, the steepest slope we can test is only a quarter of the steepness of the steepest for one 4 m deep.

We are left, then, with only two parameters to test, hole depth and original water depth, if the effect of side slopes is not taken into account. The effect of side slope and hole depth will be separated in future work.

RESULTS

In Fig 1, starting from an original beach on the zero line, the effects on beach plan shape of each element in the wave climate are shown. The positive ordinate indicates seaward accretion and the negative ordinate landward erosion. Clearly the storms, despite their relatively short duration, have a much more serious effect than the long periods of "normal" wave activity. In fact the "normal" waves serve to reduce the damage caused by storms.

The first tests were run for a period equivalent to 10 years, and in each case stability had been almost reached after two years. All subsequent results, Figs 2 and 3, show beach plan shapes after 2 years.

As might be expected, these results show an increase in beach erosion with increasing depth of hole, see Fig 2, and with decreasing original water depth and distance offshore, see Fig 3. On the seaward boundary of the refraction grid, in 18 m of water which represents half a 5 sec wavelength and a fifth of an 8 sec wavelengh, even the deepest hole tested causes only 4 m of beach erosion, see Fig 2.

PRELIMINARY CONCLUSIONS

We believe our results to be conservative, that is predicting larger amounts of erosion than would occur in nature. This is due to the fact that erosion is caused by differences in sediment transport along the beach, and the assumption in the refraction calculation that wave energy cannot propagate along the wave front tends to exaggerate these differences.

At present, dredging is not allowed shoreward of the 18 m depth contour on sediment supply considerations. Our results suggest that for the North Sea and English Channel coasts of Britain, the effects of wave refraction also point to an 18 m minimum depth. This is approximately half the wavelength of the most common wave period, and a fifth of the length of the extreme wave period; hence it may be possible to extrapolate our results to other areas on a wavelength basis.

It has not been possible to separate the effects of hole depth from those of side slopes to date. We wish to examine this problem in the future, to determine which is the most important; this will probably involve the introduction of a much finer refraction grid in the vicinity of the hole. Such a fine grid will also allow the study of holes with shapes other than rectangular.

ACKNOWLEDGEMENTS

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REFERENCES

1. "Preliminary report of the Advisory Committee on Aggregates", Department of the Environment, Great Britain, September 1973.

2. WATTS, G M "Behaviour of offshore borrow zones in beach fill operations" Proceedings of the 10th Congress of the International Association for Hydraulic Research, London 1963, Vol 1 pp 17-24

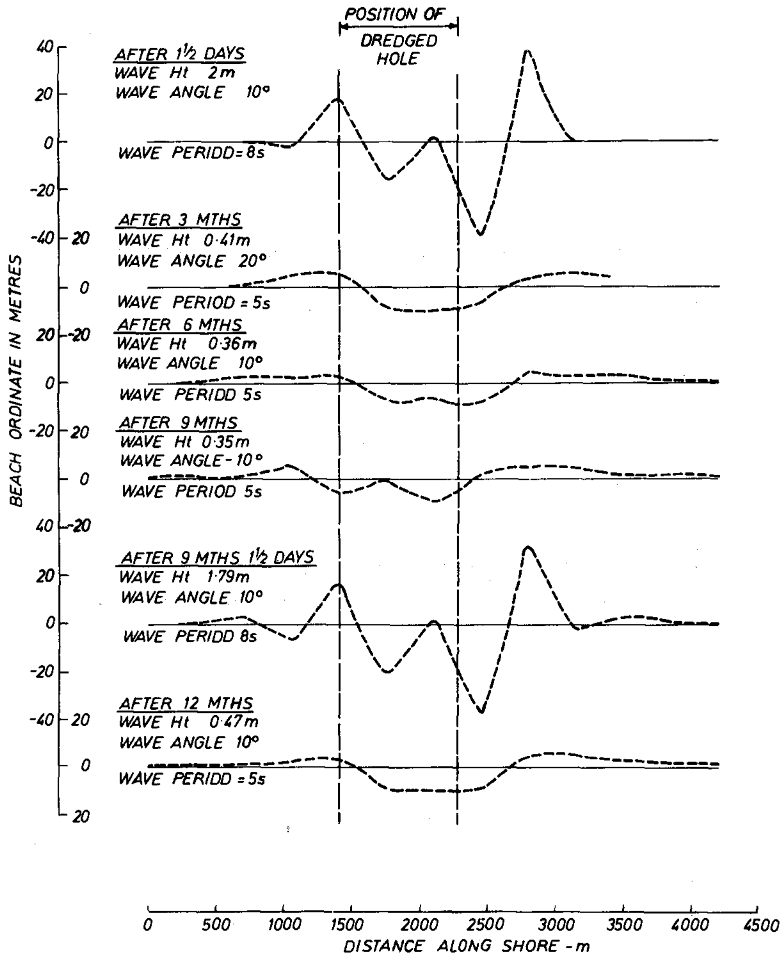
3. CRICKMORE, M J, WATERS, C B and PRICE, W A "The measurement of offshore shingle movement" Proceedings of the 13th Conference on Coastal Engineering 1972, Vol II, pp 1005-1025

4. WILLIS, D H and PRICE, W A "Trends in the application of research to solve coastal engineering problems" in "Nearshore sediment dynamics and sedimentation" edited by Hails and Carr, John Wiley & Son Ltd, in preparation

5. PRICE, W A, TOMLINSON, K W and WILLIS, D H "Predicting changes in the plan shape of beaches" Proceedings of the 13th Conference on Coastal Engineering, 1972, Vol II, pp 1321-1330

6. KOMAR, PAUL D "The longshore transport of sand on beaches" PhD thesis, University of California, San Diego, 1969

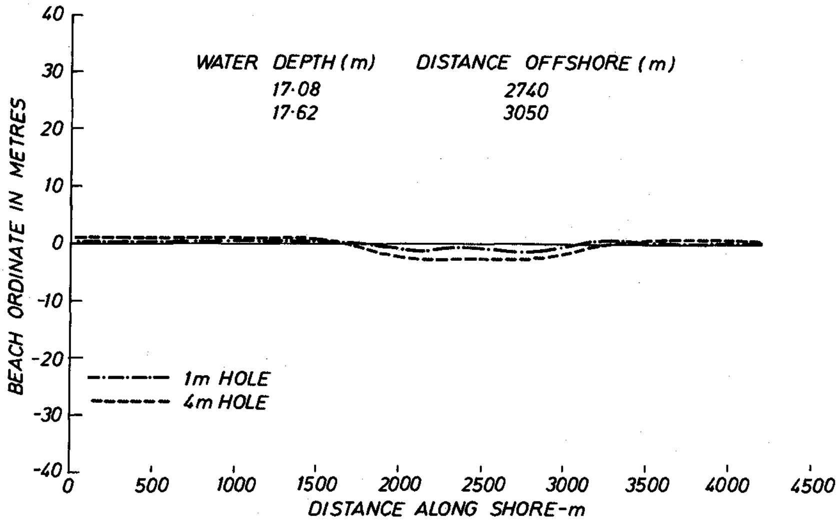
7. ABERNETHY, C L and GILBERT, G "Refraction of a wave spectrum", Hydraulics Research Station, Report No INT 117, in preparation.



BEACH PLANSHAPE

DUE TO REFRACTION OVER 2m DEEP HOLE, 1220m OFFSHORE

FIG 1



PLANSHAPE OF BEACH

DUE TO REFRACTION OVER DREDGED HOLE, 2740 m OFFSHORE

FIG 2

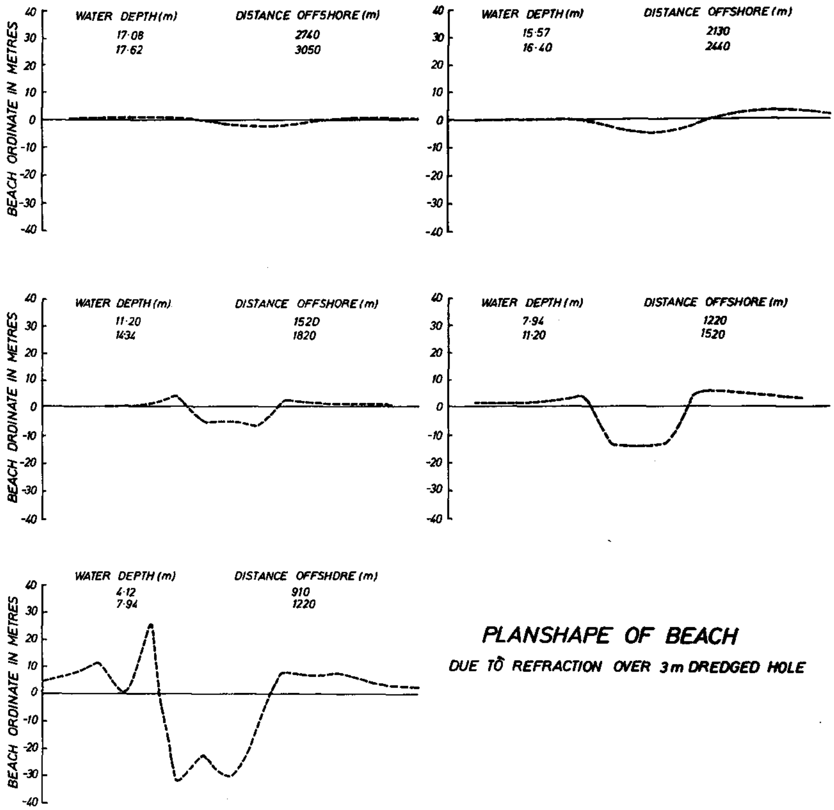

BEACH ORDINATE IN METRES
WATER DEPTH (m)
DISTANCE OFFSHORE (m)
17·08 2740
17·62 3050
15·57 2130
16·40 2440
11·20 1520
14·34 1820
7·94 1220
11·20 1520
4·12 910
7·94 1220
PLANSHAPE OF BEACH
DUE TO REFRACTION OVER 3m DREDGED HOLE

FIG 3