

CHAPTER 100

EFFECT OF WAVES ON SAND TRANSPORT BY CURRENTS

by

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The effect of waves on the transport of sand in suspension by currents can be especially important in the outer regions of estuaries and tidal inlets. Two series of field experiments are therefore being carried out to investigate the transport of sand under the combined action of waves and currents.

In the first series of tests, measurements were taken from a specially constructed tower located just off the Maplin Sands in the outer Thames Estuary, England, (Fig.1). The tower stands in about 1.5m of water at lowest tide levels, and the mean spring tidal range is about 4.5m. Average tidal velocities are about 0.6m/s, with peak values up to about 0.9m/s. The tower has a completely open structure (Fig.2) below the water line, with the exception of the four corner piles penetrating the sea bed, and a vertical trackway which stops approximately 1m above bed level. A series of instruments were fixed to a trolley which could be winched up and down the trackway, thus allowing measurements at any height above bed level. The annual wave climate at a waverider buoy position some 900m from the tower is summarised in Fig.3: Fig.3a shows the percentage occurrence of different wave heights, and it can be seen that the tower is at a fairly sheltered site, with less than 2 per cent of the waves exceeding 1m in significant height. Fig.3b shows the percentage occurrence of given wave periods which, as one would expect, are correspondingly short, with less than 2 per cent exceeding 4.5s mean-zero crossing period.

The second series of field tests are presently being carried out at the seaward end of Boscombe Pier, located in Poole Bay, England, (Fig.4). Water depths at this site are about 2.5m at low tide, with a mean spring tidal range of about 1.7m. Maximum tidal velocities are only about 0.3m/s, although during prolonged storms the tidal currents are enhanced by strong wind-induced currents. This site is significantly more exposed than Maplin, which was the reason for the choice of this second location. Annual wave statistics are not available for Boscombe Pier itself, but a waverider buoy some 3000m from the pier (Fig.4) has been operated by the University of Southampton for several years, and Fig.5 shows the percentage occurrence of given wave heights for the year 1977. Some 17 per cent of waves were greater than 1m significant height, and 2 per cent greater than 2m. Fig.6 shows the percentage occurrence of given wave periods: 5 second waves are the most common, but with periods of longer than 10 seconds being recorded. Despite initial appearances, Fig.7, Boscombe Pier is a relatively open structure below the water line, with only vertical columns 0.4 x 0.4m, spaced at 5.5m centres. As at Maplin, a vertical trackway is provided, and an instrument trolley can be winched up and down.

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The actual instrumentation used at Maplin and Boscombe was very similar, (Fig.8). To measure time-averaged and also instantaneous velocities an electro-magnetic current meter was mounted in the horizontal plane, giving the two horizontal velocity components. A sampling nozzle connected to a pump enabled large-volume samples of the suspended sediment to be taken. On its delivery side the pump was connected to a pressure filter which separated off all sediment coarser than $40\mu\text{m}$ (microns), with the volume flow rate being measured by flow-meter. At Maplin these two instruments were augmented by a Braystoke propeller current meter to give time-averaged velocities during the first few months of the experiment when the electro-magnetic current meter was unavailable. At Boscombe the two basic instruments were augmented by a light-extinction turbidity meter, which it was hoped would give a qualitative indication of instantaneous sediment concentrations. At both Maplin and Boscombe wave heights were measured by bottom-mounted pressure recorders. Output from all the instrumentation was recorded in digital form on magnetic tape, and also in analogue form on paper chart.

The experimental procedure at both sites is first to lower the instrument trolley until a bed sensor locates the seabed. At this position the instruments were 0.05m above the bed. Velocities were then measured at this level over a 100s period, and a 20 litre sample of the suspension taken and filtered. The filtered sand was then removed ready for return to the laboratory where it was to be sub-divided into 5 size fractions by dry sieving. The trolley was then unclamped from the trackway and moved up to place the instruments at 0.1m above seabed level. Measurements were then repeated at this level and also at 0.15 , 0.25 , 0.5 , 1 , 2 , 3 and thence every metre up to the water surface. Measurement of the complete profile of velocity and sediment concentration generally takes about 20 minutes. Profiles are taken at about 30 minute intervals during typical calm conditions, and also an attempt was made to man the experiments during periods when storms were forecast. All the field measurements have been completed at Maplin Tower, and the equipment has been removed and transferred to Boscombe Pier. Here a good number of measurements were obtained during the winter of 1977/78 but at the time of writing analysis of these results has hardly begun. The results presented in this paper are therefore based almost entirely on the Maplin measurements.

Each data set consists essentially of vertical profiles of time-averaged velocities of the root-mean-square of the velocity fluctuations and of the suspended sediment concentrations of each of 6 size gradings. For the earlier readings at Maplin, when the electro-magnetic current meter was not available, the rms velocity was calculated from the recorded wave spectrum. When the e.m. current meter finally became available a comparison between the measured and calculated rms velocities could be made: the agreement was remarkably good as the example in Fig.9 shows, indicating that the velocity fluctuations were primarily due to the orbital motion of the waves. Altogether some 250 complete sets of good data were obtained at Maplin: faced with this quantity of information the decision was first taken to sub-divide the data into groups corresponding to the range of the tide during which the particular measurements were taken. Secondly it was decided to try a simple "bulk -flow" analysis of the data. For this purpose a classical

logarithmic expression was fitted to the velocity profile and the profile integrated from bed to water surface to give the depth-averaged velocity. An exponential expression of the Rouse type was then fitted to the sediment concentration profiles for each sediment size grading. The product of the fitted velocity and sediment concentration expressions was then integrated numerically from bed to surface to give the sediment discharge in each size grading. The total discharge of sand-sized sediments ($> 40 \mu\text{m}$) was then obtained by summation. This sand discharge was then plotted against depth-averaged velocity, with the rms of the velocity fluctuations at 0.05m above the bed as the third variable. One plot was prepared for each of the tidal range groups of data, and on each plot it was found that for small values of the rms velocity the sand discharge T (g/s/m width) was uniquely related to the depth-averaged velocity V (m/s) by the expression

$$T = 1400 V^4$$

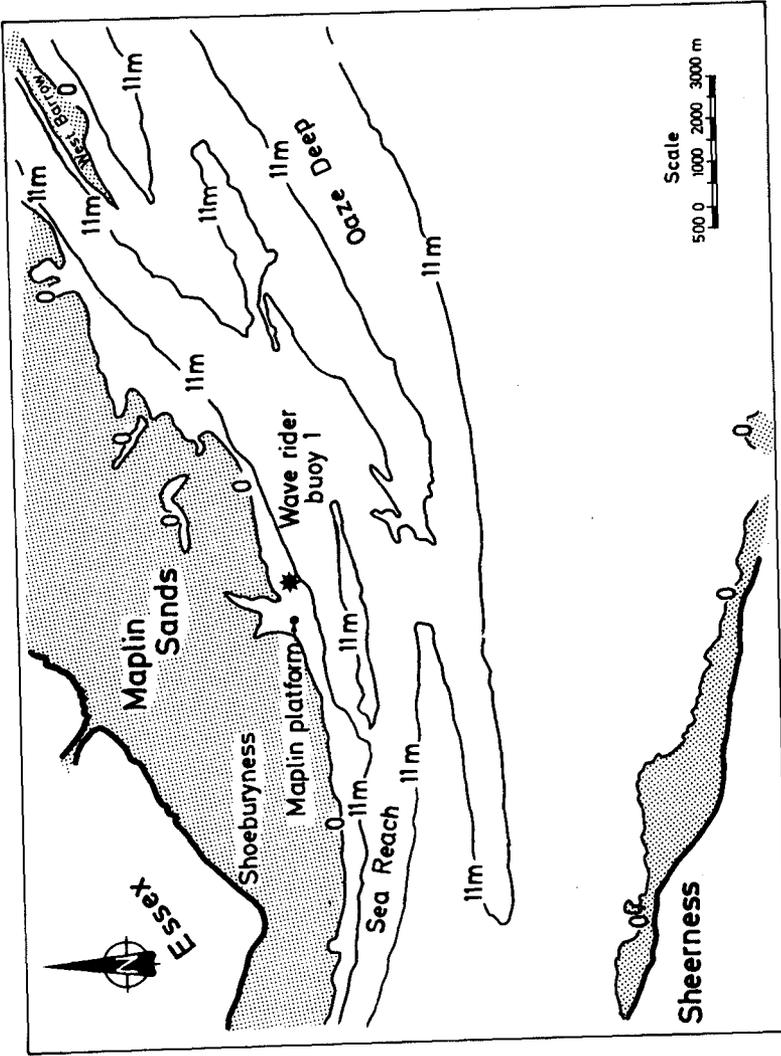
Fig.10 shows the plot for Group A tides - these having a tidal range of about 4.5m and a peak tidal velocity of about 0.8m/s. Neither tidal range, water depth nor rms velocity affected this expression provided that the rms velocity was less than about 50mm/s. Altogether some 210 sets of good data fell within this range of rms velocities. Although there were, inevitably, significantly fewer sets of data with rms velocities greater than 50mm/s it was evident that the sand discharge was substantially increased when there was pronounced wave activity. When lines were drawn on the sand discharge/depth-averaged velocity plot joining points of equal value of rms velocity it was found that they were broadly parallel to the base or 'no-waves' line, Fig.11. In other words, the expression relating sand transport to velocity was still of the basic form $T = \text{const} \times V^4$, but with the constant as a function of the rms orbital velocity. By plotting this constant derived from the various plots against the corresponding rms orbital velocity, Fig.11 it appears that the sand transport can be expressed as

$$T = 1400 \left(\frac{U_{\text{rms}} - 0.05}{0.05} \right)^2 V^4$$

where U_{rms} is the rms value of the velocity fluctuations at 0.05m above the bed, V and U_{rms} are in m/s, and T is in g/s/m width.

It is evident that although such a simple analysis of the data gives a usable expression for sand discharge at the Maplin site, it gives little insight into the actual effect of the waves, for example in possibly enhancing suspended concentrations or in distorting the velocity profile. In addition the analysis does not make use of the data on each size of sediment. Further detailed analysis of the results is therefore presently underway to obtain a better understanding of the processes involved.

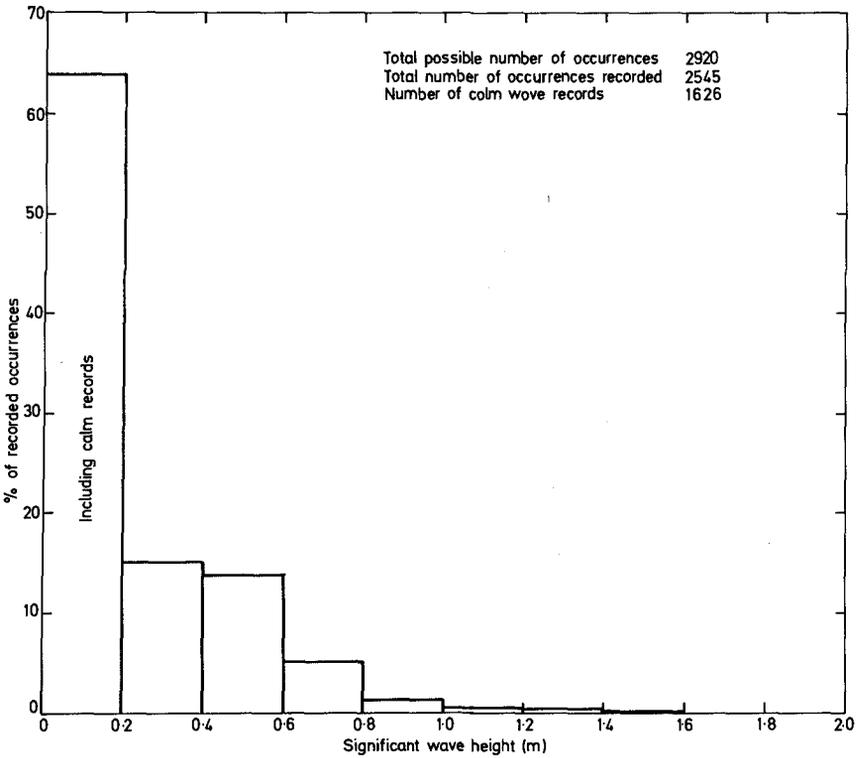
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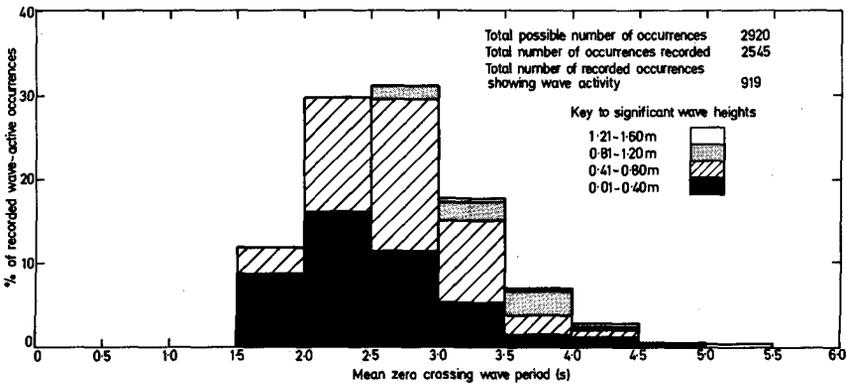
**Fig.1 Maplin Tower
Location map**



Fig 2 Maplin Tower



(a) Distribution of significant wave height, 1st April 1973-31st March 1974



(b) Distribution of mean wave period, 1st April 1973-31st March 1974

Fig 3 Twelve-month wave statistics at wave-rider buoy site 1

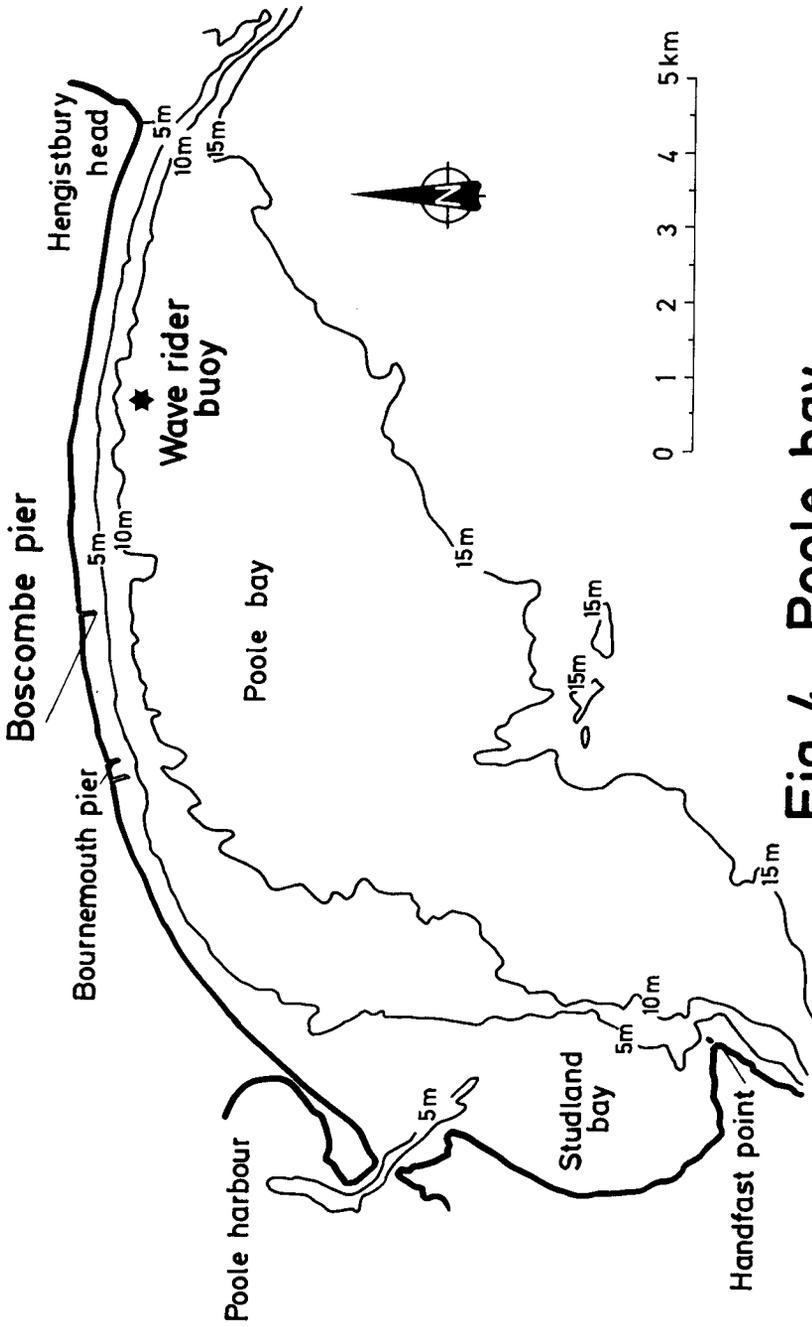


Fig. 4 Poole bay

Location of Boscombe pier and wave rider buoy

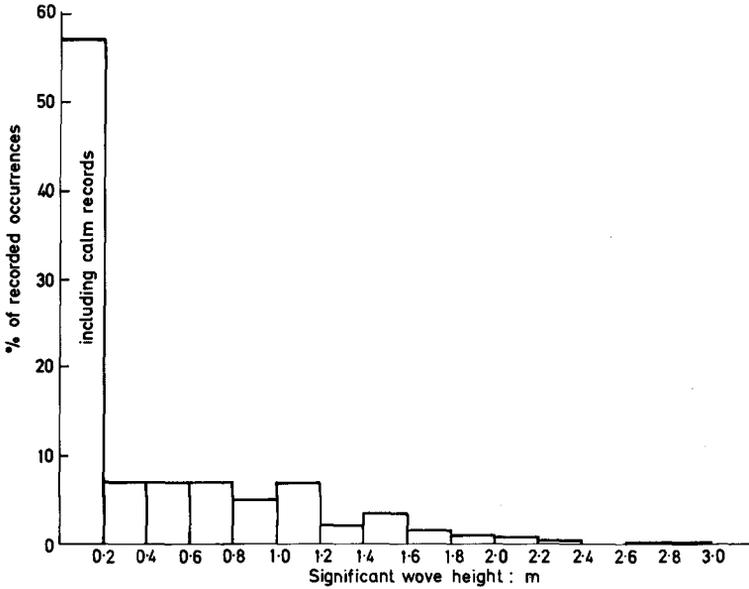


Fig. 5 Poole Bay
Distribution of significant wave height, 1977

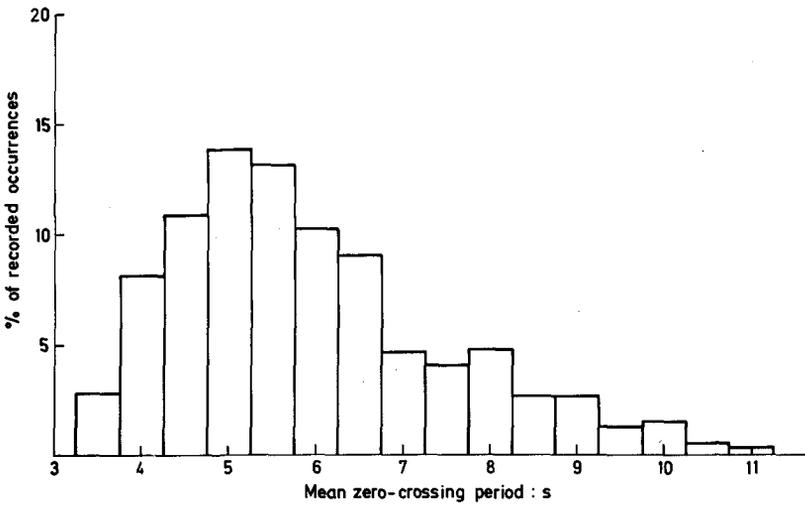


Fig. 6 Poole Bay
Distribution of mean zero-crossing period, 1977



Fig.7 Seaward end of Boscombe Pier



Fig.8 Instrumentation trolley

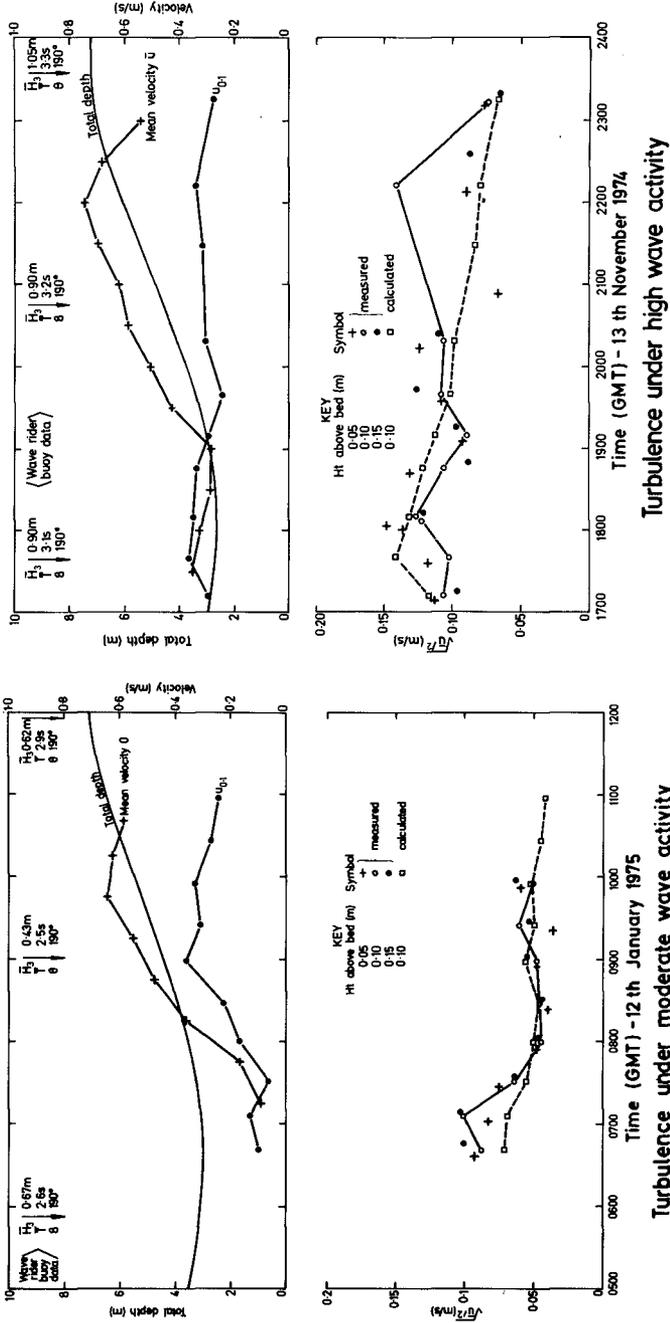


Fig.9 Comparison of measured and calculated turbulence intensities

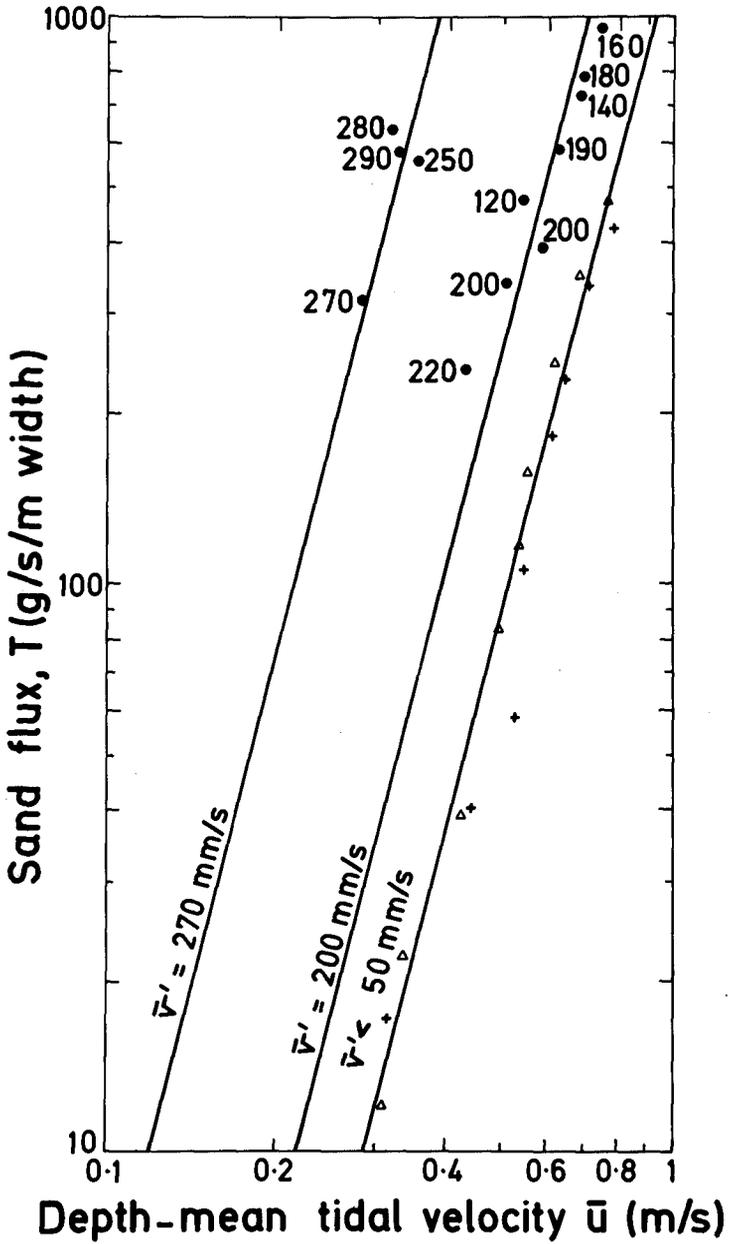


Fig.10 Sand flux for group A tides

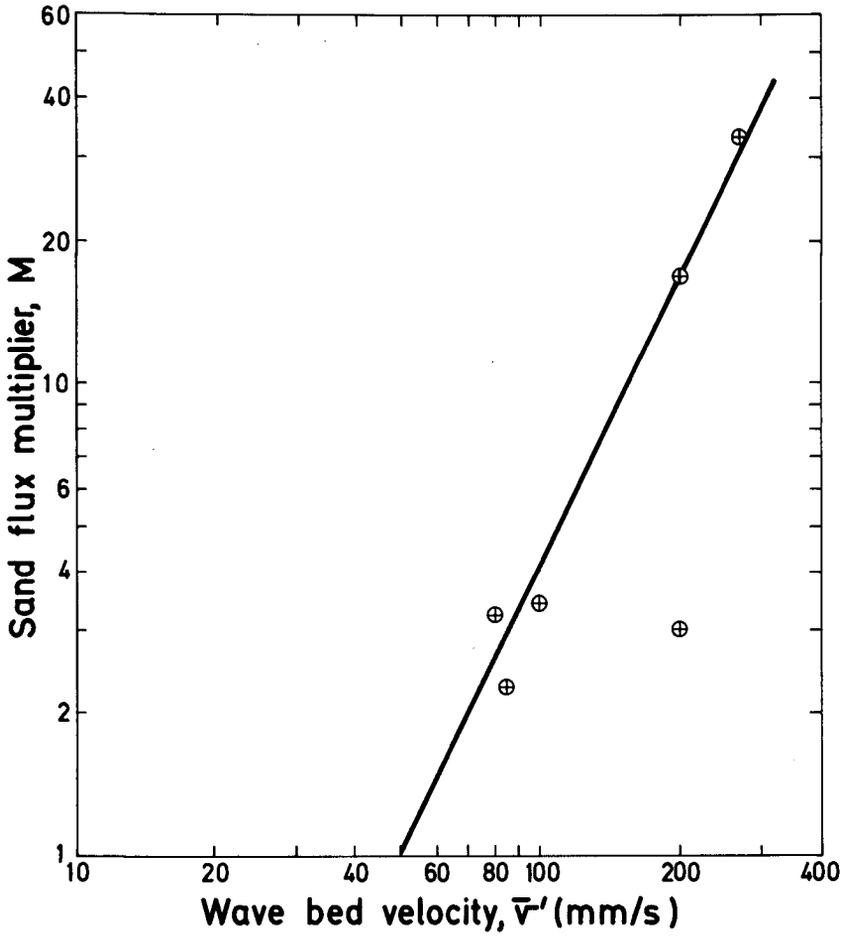


Fig.11 Sand flux multiplier for waves