CHAPTER 112

MORPHOLOGIC EFFECTS OF WESTERLAND BEACH NOURISHMENT 1972

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Abstract

In 1972, a beach nourishment scheme was to delay the steady coast erosion near Westerland (Germany). Morphologic investigations state the development of the fill and its effects to adjacent beaches, and yield recommendations for another nourishment scheme in 1978.

The morphologic analyses are related to two different profile areas. They show that the effects of the nourishment were quite confined in space and time. Particularly the island base and the bar remained unaffected by the fill.

The analysis becomes more instructive and perhaps easier by the use of special means, such as the differential morphometric characteristic and the mean profile depth instead of mass computations or mass balances. The standard mean depth in the morphologic system of the investigation area is found to be NN-4,1 m.

1. Initial Situation

The west coast of the island of Sylt, Germany (fig. 1), is built up of sand and subject to an important erosion. The mean regression rate between 1793 and 1952 was 1,6 to 1,9 m per year. The urban area of the town of Westerland, adjacent immediately to the beach, had been protected by a vertical wall. This wall itself, built between 1907 and 1923, is threatened by the erosion of the shore and foreshore (fig. 2). A beach nourishment in 1972 provided a stock of about 750.000 m^3 of sand, pumped on the beach in the form of a large groyne.

The typical beach profile in this central part of the coast consists in: beach - trough - bar - sea-bottom (fig. 3). It is likely to form a constant morphologic system produced by the specific hydrodynamic conditions. These are characterized by a normally

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Fig. 1. The situation of the investigation area

Fig. 2. Westerland sea-wall and its protection by tetrapods (14.01.76)

medium to high wave impact with variable incident angles, moderate current velocities of changing sense, and a mean tidal range of 1,85 m. The periods of calm sea surface normally do not exceed a total of 6 weeks per year, caused by seaward winds.

2. Investigations

The basic data for the morphologic investigations were collected by a lot of soundings and beach surveys. The soundings included an area till 1000 m offshore and down to a depth of NN-8 to -9 m.

These data were worked up to bathymetric charts and further on to differential bathymetric charts, profiles, maps of contour line shifting, mass calculations, and morphometric diagrams. For checking the reliability of the data obtained, an error estimate took into account especially the possible or existing systematic errors, so those influencing a whole survey or major parts of it in one sense.

It was found that the elevation error in the maps used has the following values:

	maximum	mean values
proportional error	5 %	2,5 %
constant error	0,35 m	0,01 m
+ temporary constant error	0,15 m	0,04 m

Respective error ranges are shown in the diagrams fig. 6 to 8.

The conclusion from this error estimate was, that overall mass balances are no good means to state shore and foreshore evolution. Moreover they suffer from being the result of records of an instantaneous, possibly singular shape and from neglecting the drifting sediments.

To render the statement of mass calculations persuasive, adequate marginal terms have to be chosen. For the present study, two different areas have been defined (fig. 3 and 4):
- the stock comparison area, limited by fixed boundaries or stationary lines, informing about the volume of the available sand masses and their distribution with regard to the coastal structures,
- the system comparison area, limited by defined contour lines (+1,5 m and -7,0 m), thus informing about the volume of sand contained within the morphologic system.

The length of shoreline computed is 1,5 km. The investigation period covers the years 1970 till 1978. Outstanding events during this period were:
- the beach nourishment in 1972
- a series of six heavy storms in November/December 1973, straining the shore with a wave energy superior to that of the whole winter 1971/72 (63100 versus 40700 kWh per 1 m shoreline)
- two heavy storm surges in January 1976, during which the water levels reached those of the catastrophic surges in 1962.

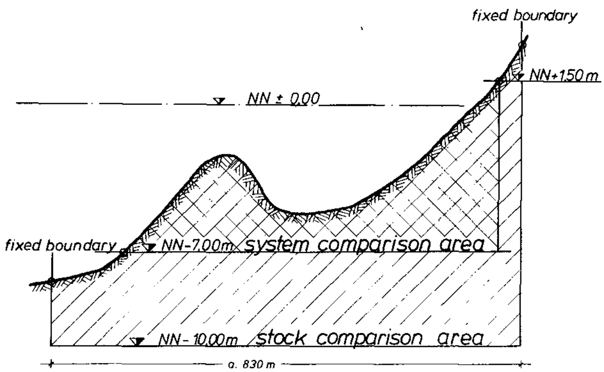

Fig. 3. Morphologic system and mass comparison areas

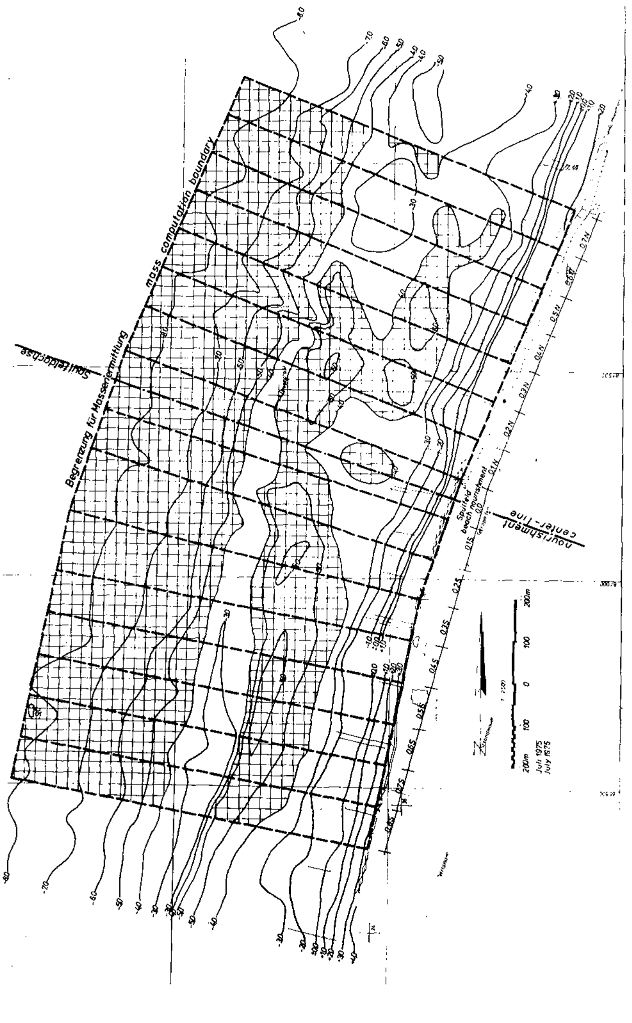

Fig. 4. Bathymetric chart July 1975 and plan of mass computation cells (strips)

3. Sounding and Morphologic Data Analysis

The characteristic phenomena before the filling action 1972 - decreasing beach width, increasing trough dimensions, bar diminution - were partially neutralized: the beach became larger in the immediate vicinity of the fill, and the trough became less wide and deep (fig. 4). But the holes just ahead of the beach continued to exist in their place, though somewhat less deep, and the bar remained unaffected by the fill.

At once after the fill, the situation started to develop towards the former condition, a fact which turns out more evident by the differential bathymetric charts (fig. 5). They show that in 1976 the sand stock in the beach is nearly consumed and the trough is even deeper (by 1 ... 1,5 m) than in 1972. The bar, however, did not change significantly.

The existence of seasonal effects (winter shape - summer shape) is here confirmed, too. They are accentuated by the occurence of winter storms: The shape in March '76, after the January storm-surges, presents clearly a steeper seaward bar slope, a higher bar crest (by 0,5 m against August '76), a deeper trough (by 0,5 m against August '76), and a stronger erosion of the beach (up to 2 m deeper).

The mass computations within the stock comparison area (fig. 6) show a more pronounced erosion in the central part (0 ... 0,2N) of the investigation area before the fill. Towards the ends, at a distance of about 800 m from the filling center-line, the differences between the lines are rather small, meaning that a measurable deposition disappears. The line for February '74 runs near the former lines, meaning that the storm series of 1973 drifted the main part of the fill away.

The mass computations within the system comparison area (fig. 7) show little variation in time, apart from the stations 0 ... 0,2 N before the fill, where even the system had started to dissolve by losing of its specific volume.

But in principle there seems to be a substantial constancy of masses within the morphologic system. On the other hand it prooves a small form variation capability, particularly when comparing it to the conditions at other sand coasts subject to heavy wave attack.

In order to identify the morphologic changes, which occurred nevertheless, in a simple and reliable way, the morphologic magnitude "mean profile depth h_m" is defined:

$$h_m = NN - 7 + d_m \quad [m]$$

with $$d_m = \frac{\text{mass of the profile strip } [m^3]}{\text{surface area of the profile strip } [m^2]} \quad [m]$$

NN = Normal Null, German Normal Chart Datum

The analysis of the mean depth diagram (fig. 8) gives a standard value of NN-4,1 m for the investigation area. In the central part,

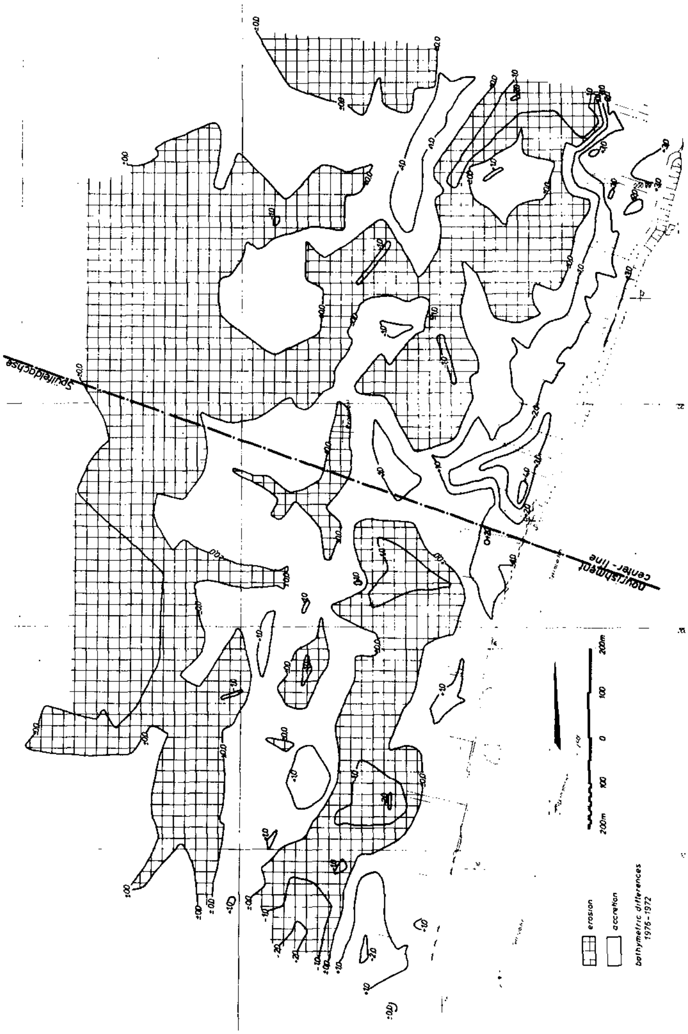

Fig. 5. Differential bathymetric chart 1976-1972 (before the fill). Differences indicated in metre.

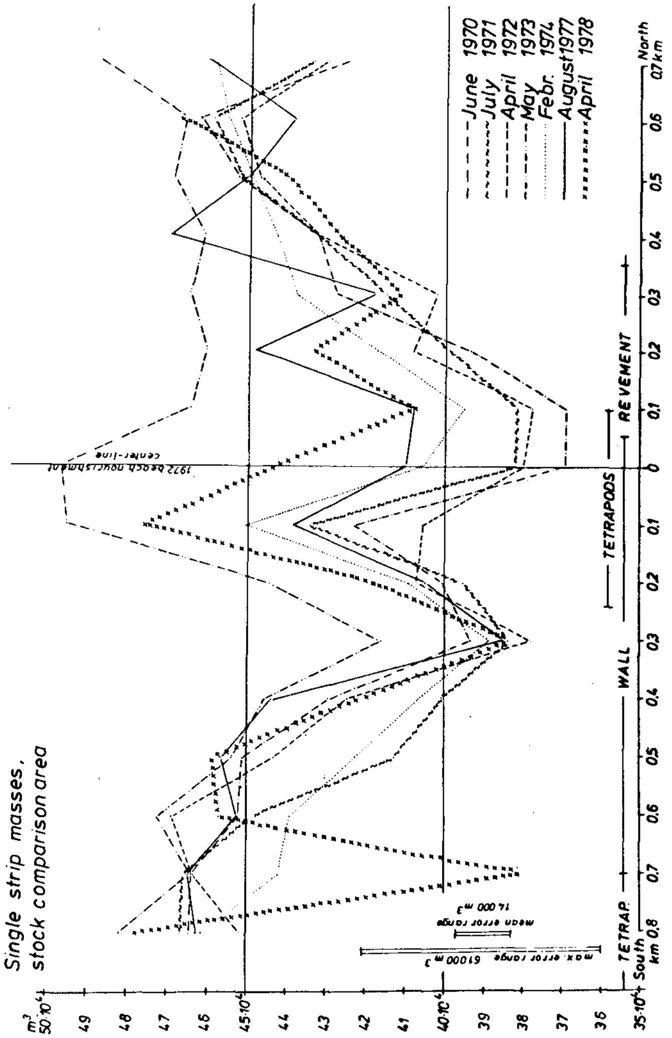

Fig. 6. Distribution of sand masses within the stock comparison area along the coast

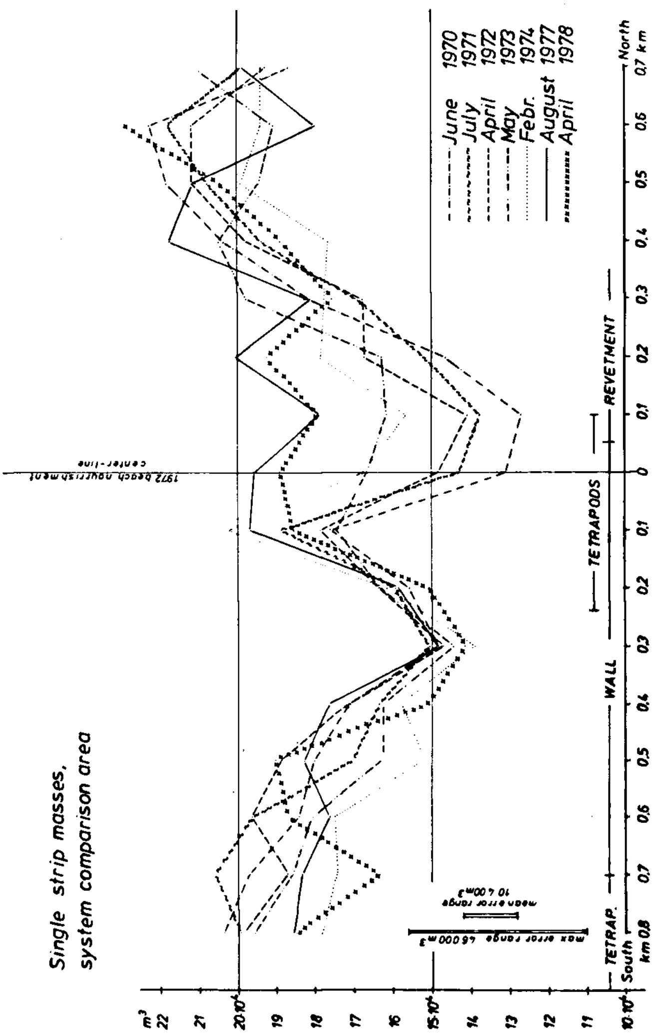

Fig. 7. Distribution of sand masses within the system comparison area along the coast

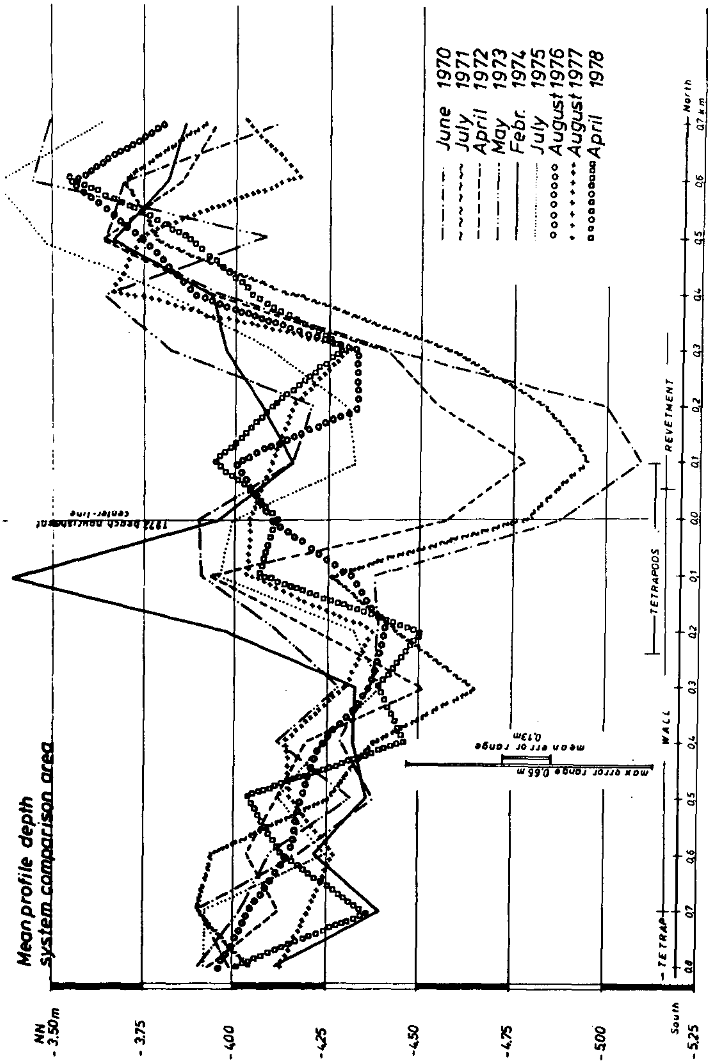

Fig. 8. Mean profile depths of each profile strip within the system comparison area

subject to particular hydrodynamic stress, it increased up to NN-4,85 m before the fill, and afterwards it returned to its normal value again. Two potential danger areas may be indicated in 1975-78 by minima in stations 0,4 ... 0,2S and 0,2 ... 0,3N, and it is here (0,2N ... 0,7S) where the fill 1978 has been executed.

The mean depth informs about the development due to erosion or accretion of this one-bar system and thus indicates the "state of health" of a certain coast section.

The morphometric characteristic (according to RENGER) represents the typical depth distribution by a generalized vertical section (fig. 9). It can be imagined as being obtained by shifting all the horizontal layers horizontally towards the island.

For easier analysis, the differences versus the mean values of the years 1970/71 have been drawn up (fig. 10). The application of this method to the shore and foreshore reveals that the effect of the beach nourishment, increasing the contour line areas, was confined to the zone above NN-5 m. Below NN-6 m, the 1973-line runs in the negative and even deeper than the 1972-line, meaning that the erosion of the deeper island base continued even during the filling action and afterwards. In these depths, accretion can be observed only in the immediate vicinity of the filling site.

The storm surges of November/December '73 caused a considerable erosion, most significantly between NN-3 m and NN-6 m. In the following years, a certain recovery took place in the deeper parts, but the tendency is obvious, that the slope of the overall profile is going to approach the former slope of 1970-72.

4. Conclusions

The simultaneous analysis of the morphologic data suggests the conclusion, that the morphologic effect of the beach nourishment extended only to the beach zone down to a depth of about NN-5 m. Particularly the bar of the central 1,5 km shoreline remained unaffected by the fill. Moreover the actual erosion tendency seems to point now to the southern part of the investigation area, affecting now a good length of the shoreline, where it already caused considerable losses of material.

The recommendation deducted from these analyses for the nourishment 1978 was to realize a longshore fill on a distance of 900 m, and in fact, this plan was adopted for execution.

Information about the development of a sand coast subject to erosion is necessary for planning and design of shore protection works. Reliable information can be obtained, rather than from overall mass balances, from the morphologic variations as found by the analysis of bathymetric charts and, more easily, from the interpretation of morphologic indicators, such as the mean profile depth.

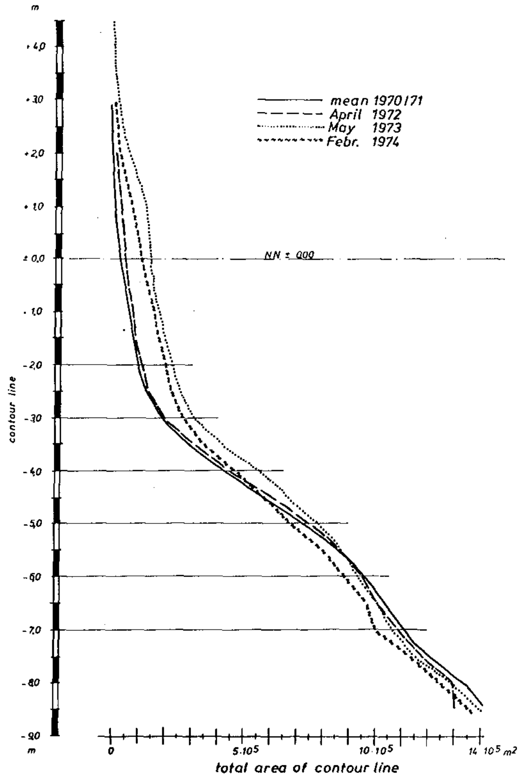

Fig. 9. Adaptation of RENGER's morphometric characteristic to Westerland shore and foreshore, total investigation area

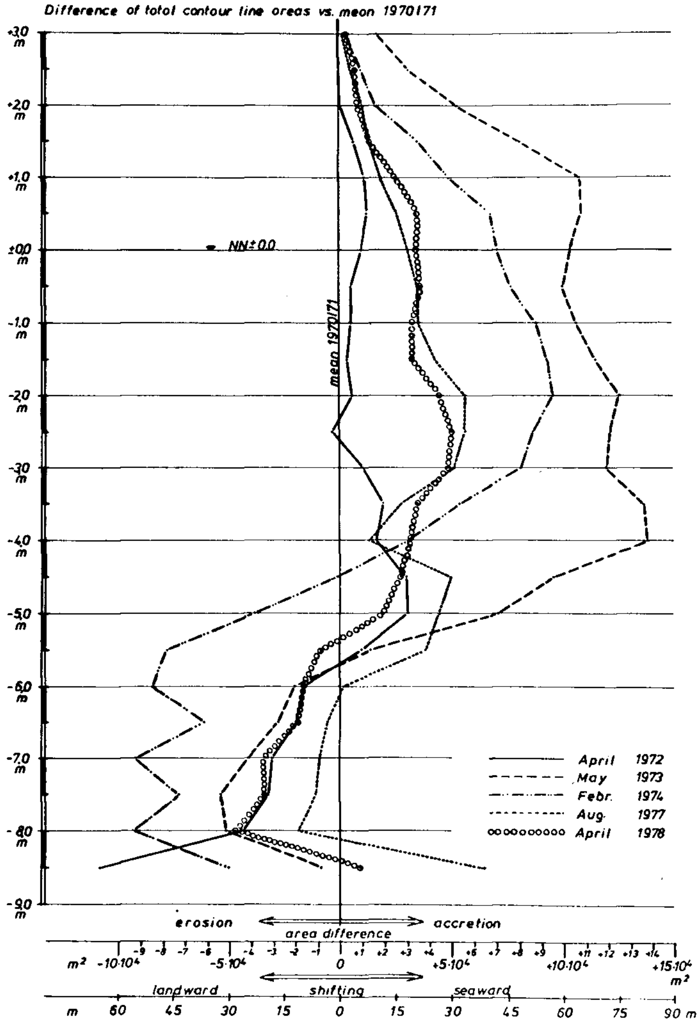

Fig. 10. Differential morphometric characteristic versus mean 1970/71, total investigation area

5. References

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