MORPHOLOGICAL REACTIONS OF TIDAL SYSTEMS DUE TO NEARSHORE CONSTRUCTION WORKS

by

R. DIECKMANN, H.W. PARTENSCKY, H. SCHWARZE³⁾

1. INTRODUCTION

The nearshore region of the North German North Sea coast is characterised by a large area of tidal flats with a width of 10 to 30 km (Fig. 1).

The development of the structure of this coastal area in the past centuries was mainly determined by several severe storm surges, which have destroyed the formerly existing coastline. In its present state the coastal area is subdived into numerous tidal flats, islands and peninsulas of different size and more or less deep channels and small gullies.

Due to its historical development, this area cannot be expected to be morphologically stable. Once people learnt to build safe dikes, the coastline existing at the time was fixed whilst the islands in the shore belt were protected against flooding during storm surges.

However, the shore belt is furthermore exposed to waves and tidal currents which cause - apart from certain shiftings of gullies - extensive permanent erosion and sedimentation in parts of the shore belt with an increasing tendency in the last decades. The nearshore region at some places on the coast is extremely endangered in its function as part of the shore above MHW and the tidal flat area.

First attempts to achieve morphological stabilisation of the nearshore region consisted in the construction of dams normal to the coastline. However, the shore belt still remained morphologically unstable and could not yet be transformed into a stable system.

1) Senior Research Engineer, Dipl.-Ing.

2) Director, Professor Dr.-Ing. Dr.phys.

3) Chief Engineer, Dr.-Ing.

FRANZIUS-INSTITUT, University of Hannover, Federal Republic of Germany





It was the aim of intensive investigations at the FRANZIUS-INSTITUT, together with the local authorities involved in these problems, to demonstrate the influence of artificial structures on the morphological reactions of well defined drainage areas, consisting of tidal flats and gullies, to a morphological stabilisation of the shore belt.

2. CONCEPT OF INVESTIGATIONS

On the basis of former investigations showing qualitative relationships between geometrical and hydrological parameters, investigations were performed in order to quantify morphological changes to be expected as a result of a variation of a drainage area due to dikes or reclamation works, or in other words, the artificial structures necessary to stabilise a morphologically unstable drainage area.

For instance, a stability criterion was determined for tidal systems, in which the ratio of the tidal prism upstream of a certain cross-section to the area of that cross-section at mean water level is a constant value. According to this criterion, if the tidal prism decreases, the cross-section will decrease proportionally. In a more detailed investigation (RENGER and PARTENSCKY,1974), the evaluation of some 25 tidal systems, in which artificial constructions had not yet been carried out, showed a clear relationship between the tidal prism (water volume between Mean Low Water and Mean High Water Level) VTP (in 10^6 m^3) and the corresponding drainage area E (in km²), as follows (Fig. 2)

$$V_{\rm TP} = 1.65 \cdot E^{1.036} \tag{1}$$

as well as between the volume of the tidal basin below Mean Low Water $V_{\rm MLW}$ (in 10 6 m $^3)$ and the drainage area E (in km $^2)$ (Fig. 3)

$$V_{\rm MIM} = 4.39 \cdot 10^{-2} \cdot {\rm E}^{1.643}$$
(2)

Certain scatter in the data may be explained by the fact that not all selected areas are in a true stable state.

The results of these investigations represent an important step towards solving the problem, since the possibility of generalising the results for all drainage systems has been demonstrated. However, deviations of calculated mean values from actual values for a certain drainage area using the above-mentioned equations provides only an approximate indication of the instability of the overall area. The distribution of erosion and sedimentation to be expected in different parts of the drainage area could not, however, be determined.

3. SUMMARY OF RECENT RESULTS

Recent investigations, carried out on approximately 50 tidal flat systems with different subsystems and subsubsystems along the Dutch, German and Danish coasts, have shown that the above criteria are also generally valid for parts of these basins.

Equations (1) and (2) can therefore be used in a stepwise determination of the increasing volume of the tidal basin from the origin of the main gully towards the sea.

For these evaluations, drainage areas are subdivided into portions as given by the distribution of gullies, branching more and more towards the coast line. Watersheds are determined on both sides of the gullies as boundaries of the drainage area belonging to the gullies (Fig. 4).

For each of these drainage areas, water volumes below MLW, as well as volumes of the tidal prism, are calculated and summarised for the whole drainage area.

The latter calculation results in a summation curve for the tidal volume relating to the surface area of the tidal basin. This curve describes the stable morphological and hydrological state of a drainage system.

This represents an important result of the investigations







with respect to the description of the inner structure of a drainage area.

On the basis of the stability criteria for tidal systems, the stability of a certain area can be evaluated by comparing the measured tidal volume to that determined analytically from the volumetric summation curve based on equations (1) and (2). The deviation from the theoretical curve, which represents the equilibrium state, indicates the degree of instability of the tidal system and subsystems concerned.

In the case of a volumetric deficit, in which the calculated curve lies above the measured curve, erosion may be expected in the tidal basin. In the case of a surplus in tidal volume, a shrinkage of the tidal basin due to sedimentation will occur.

Fig. 5 illustrates a well-balanced tidal basin (Rummelloch-West). In Fig. 6, a tidal basin is presented in which sedimentation is present (Süderau).

The stability criteria show that a given drainage area is associated with a well-defined volume. This equilibrium can be disturbed by artificial measures such as nearshore constructions. The morphological reactions of the tidal system can be determined quantitatively from a comparison of the volumetric summation curves.

In addition, sedimentation in a nearshore region can be caused by the construction of offshore dikes and artificial dams.

Comparisons of water volumes, evaluated on the basis of hydrographic charts and soundings, with calculated volumes, have shown that some of the tidal basins on the northern coast of the Federal Republic of Germany are not in a state of equilibrium, but are rather subject to temporary erosion and sedimentation phases. The erosion of these areas significantly endangers the structural stability of the seadikes as well as of the islands in the vicinity of thecoast.

For instance, in the last 50 years, increasing erosion has occurred in a gully between an island situated approximately 10 km from the coast and the shore line. In 1930 the water depth of this gully was only 0.5 m. Up to now the gully has deepened to nearly 12 m. The adjacent subdrainage areas are also in a state of erosion.

This problem can be overcome by constructing offshore dikes and control-dams between the mainland and the island concerned, thereby reducing the drainage area of the tidal basins. By this means, areas of erosion in a tidal basin may be influenced in such a way as to convert the deficit of volume into a surplus. Plans have been made to stabilise a coastal region of about 450 km² in this manner.

As an example, results of evaluations for a subsystem of the tidal system HEVER in the North Frisian shore belt are given







in Fig. 7. In this case, the summation curve for the water volume below MHW is plotted in relation to the length of the main gully of the subsystem HEVER. Calculations for the determination of the stability criterion were carried out using equations (1) and (2). The measured volume of water is determined on the basis of bathymetric plans.



Fig. 7: Volumetric Summation Curves for Tidal Basin HOLMER FÄHRE at MHW before and after the Planned Offshore Diking Project

The comparison of both curves shows erosion throughout the entire system. The system is unstable and erosion must be prevented by an artificial construction, such as a dike, which reduces the drainage area.

By considering a certain dike, volumetric summation curves calculated both theoretically from equations (1) and (2), and evaluated on the basis of bathymetric plans for the reduced drainage area, are also plotted in Fig. 7. A comparison of the volumetric summation curves shows a change in the morphological behaviour of the system. The former volume deficit could be converted into a volume surplus, which means that sedimentation can be expected to stabilise the nearshore region in all cases.

4. APPLICATION OF THE RESULTS

Such investigations were carried out for all main drainage areas in the latter region of the German shore belt. An example of the results for one of the subareas is illustrated in Fig. 7. On this basis of these results, a system of dams and dikes were planned in order to avoid further dangerous erosion of the nearshore flats (Fig. 8).

The conservation of the belt of foreshore and flats is vitally necessary to ensure stability of the islands distributed in the shore belt as well as the coastline. Nearshore reclamation works involving artificial groynes and trenches will be introduced in order to support and accelerate the natural morphological changes induced artificially.

The results of the investigations indicate the magnitude of volumetric changes to be expected in a tidal system until a morphologically stable state is achieved. The time dependent development of erosion or sedimentation, as well as the time necessary to establish a new final state following the construction cannot be predicted on the basis of the applied method at the present time.



Fig. 8: Offshore Diking Project in the North Frisian Shore Belt

During the period of construction, and particularly after completing the system of dams and dikes, detailed measurements will be carried out in order to monitor morphological development. A minimum necessity is to provide confirmation of the empirically determined basis for estimating such a large impact on a tidal system.

5. REFERENCES	
RENGER, E. and PARTENSCKY, H.W.:	Stability Criteria for Tidal Basins. Proc. 14th International Conference on Coastal Engineering, Copenhagen, Vol.II, pp. 1605 - 1618, 1974
FRANZIUS-INSTITUT:	Stabilitätsuntersuchungen für das süd- liche nordfriesische Wattenmeer. Report No. 422, 1979 Unpublished
PARTENSCKY, H.W. und SCHWARZE, H.:	Wissenschaftliche Gutachten zu den hy- drologischen und morphologischen Aus- wirkungen der geplanten Baumaßnahmen in der Nordstrander Bucht. Unpublished Report, 1980
PARTENSCKY, H.W.:	Neue Erkenntnisse über das Stabilitäts- verhalten und den Sedimenttransport in Watt-Priel-Systemen. Mitteilungen des Franzius-Instituts für Wasserbau und Küsteningenieurwesen der Universität Hannover, Heft 50, 1980