

CHAPTER 199

A COMPARISON BETWEEN GERMAN AND NORTH AMERICAN TIDAL INLETS

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ABSTRACT

Initial results are presented relating to an investigation of geomorphological parameters from 26 of a total of 28 tidal inlets and 11 coastal structures similar to inlets along the German Bight. The following parameters were investigated:

- tidal prism - inlet area relationship,
- cross-sectional form and depth,
- location of the channel within the cross-section,
- ebb tidal deltas and
- the structures of the back barrier regions.

The most important parameter governing the shaping process of these coastal structures is considered to be the tidal volume. The results of the investigations were compared with data from American publications. Despite the differences between the regions studied, in overall terms, surprisingly good agreement was obtained between the parameters investigated. Notable differences exist only in relation to the morphological structure of the back barrier regions (tidal flats, salt marshes, open water lagoons). In respect of the latter differences, a short account is given of the biological and climatological influencing factors.

1. INTRODUCTION

Barrier islands and inlets are one of the most commonly occurring coastal formations worldwide. In particular, the American barrier island - inlet systems are widely dealt

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with in literature. In contrast, the corresponding inlets along the coast of the German Bight have not as yet been geomorphologically investigated in their entirety. An exception to this are three inlets on the southern North Sea coast (WALTHER, 1972; LUCK, 1976; FITZGERALD et.al., 1984).

Initial results will be presented concerning a comprehensive investigation of 26 from a total of 28 tidal inlets and 11 inlet-type structures along the coast of the German Bight between Den Helder in the Netherlands and Skallingen in Denmark.

Basic differences between the coast of the German Bight and the southeast American Atlantic coast are highlighted by NUMMEDAL and FISCHER (1978). In this context, it should be noted that the German Bight lies on the same latitude as the southern part of Hudson Bay (James Bay) in Canada.

2. TIDAL INLET SYSTEMS ALONG THE GERMAN BIGHT

2.1. COASTAL OVERVIEW

Over a length of 450 km, the inner part of the German Bight is bordered by a large tidal flat area of 7,500 km² (see Fig. 1) with a barrier island chain in front of it.

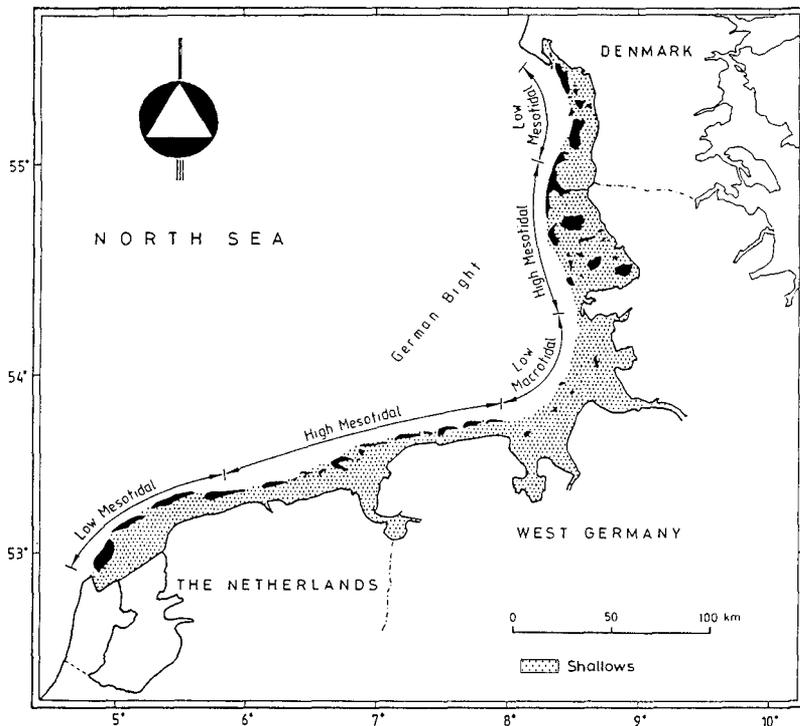


Fig. 1: Map of the German Bight

If one considers the investigations by HAYES (1979) concerning the relationships between coastal morphology, tidal range and wave climate, it becomes evident that the coast of the German Bight is a typical barrier island - inlet region.

According to the tidal and wave conditions, the majority of the German Bight region belongs to the "tidally dominated mixed energy coasts". The barrier islands on the south coast frequently have a well-defined drumstick shape with distinct ebb tidal deltas owing to the littoral drift. Flood tidal deltas, on the other hand, are not present as usual under meso- and macrotidal conditions. Along the south coast, a downdrift offset configuration is apparent, whilst in the case of the east coast, a negligible or small updrift offset is detectable.

The inlets on the south coast are strongly influenced by natural forces. Owing to the action of westerly winds, waves and currents parallel to the coastline, the islands and hence the inlets undergo continuous displacement from the west to the east. Since about 1890, the westerly heads of the islands have been fortified to avoid further drift. The east ends of the islands, however, remain exposed to natural forces and are thus in a continuous state of change. The currents in the inlets are so large as to prevent sedimentation and there are no jetties available which might reduce or alter the direction of the littoral drift.

On the east coast, the tidal inlets are less clearly defined and little is known concerning the barrier island - inlet systems on the east coast. Preliminary depth chart evaluations indicate however that these inlets are relatively stable. Consequently, the need to fortify or protect the heads of the islands has never arisen.

2.2. DATA COLLECTION

A total of 37 inlets and inlet-type coastal structures along the German Bight were investigated. For each inlets investigated, a data set containing the following information was established:

- tidal heights at MHW, MLW and the half-tide water level (HTWL),
- cross-sectional area of the inlet at MHW, MLW and HTWL,
- width of the inlet at MHW, MLW and HTWL,
- drainage area size at MHW, MLW and HTWL,
- maximum and mean depths of the inlet,
- tidal volume.

Since each inlet of the German Bight has a precisely defined drainage area, the mean tidal volumes (tidal prisms) could be obtained with high accuracy from the drainage basin hypsometric curves. The evaluation technique used for this purpose is described in detail in DIECKMANN & PARTENSKY, 1985.

3. US AMERICAN TIDAL INLETS

In relation to US American tidal inlets, a vast amount of material has been published. A comprehensive review is given in the GITI Reports published by the US Army, Corps of Engineers and Waterways Experiment Station as well as in "Stability of Tidal Inlets" by PER BRUUN (1978). Further details will be given there.

4. COMPARISON OF RESULTS

4.1. TIDAL PRISM - INLET CROSS-SECTIONAL AREA RELATIONSHIP

Relationships between the minimum throat cross-sectional area below mean tide level and the tidal prism of an inlet were first reported by O'BRIEN (e.g. 1969). More recent evaluations were presented by JARRETT (1976). On the basis of such relationships, estimates may be made of the long-term changes in the inlet cross-section up to the point at which a mean state of equilibrium is attained.

In Fig. 2, data relating to the inlets of the German Bight are presented in the form of diagrams after JARRETT. All data points lie within the 95% confidence limits and very close to the regression curve given by JARRETT.

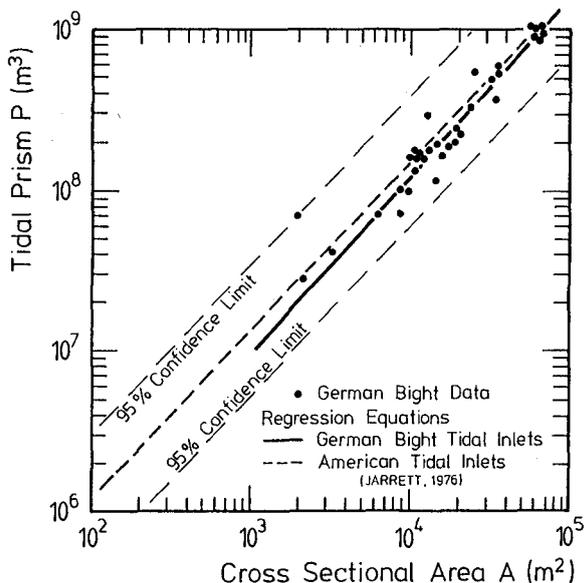


Fig. 2: Tidal prism vs. cross-sectional area for American inlets and inlets along the German Bight.

The corresponding regression equations in metric units are as follows:

$$\text{German Bight:} \quad A_C = 3.720 \cdot 10^{-4} \cdot p^{0.915} \quad (1)$$

$$\text{Atlantic coast:} \quad A_C = 3.039 \cdot 10^{-5} \cdot p^{1.050} \quad (2)$$

$$\text{Gulf coast:} \quad A_C = 9.311 \cdot 10^{-4} \cdot p^{0.840} \quad (3)$$

$$\text{Pacific coast:} \quad A_C = 2.833 \cdot 10^{-4} \cdot p^{0.910} \quad (4)$$

where:

A_C = minimum cross-sectional area below MSL = HTWL (m^2)

p = tidal prism (m^3)

As a result, the best agreement is achieved between the inlets of the German Bight and the Pacific coast as may be seen from the equations (1) to (4). The good agreement between the above relationships indicates that the minimum cross-sectional area of an inlet is primarily determined by the inflowing and outflowing tidal volume. For the German Bight no particular influence of the different coastal and tidal range regions could be detected. This result is surprising in so far as significant differences exist between the US American inlets and tidal flats and the corresponding regions in the German Bight.

4.2. GEOMETRIC PARAMETERS

4.2.1 SHAPE AND DEPTH OF THE INLET CROSS-SECTIONS

An inlet is characterized in the terms of its geometry by the shape of its cross-section and the mean or maximum depth. The cross-sectional shapes of the inlets in the German Bight may be subdivided into 3 groups (see Fig. 3):

- the wide synclinal profile will tend to form in the case of small tidal volumes in combination with relatively wide inlets,
- the triangular profile is characteristic of narrow inlets exposed to large tidal volumes and
- the composite profile may be taken to represent the normal case.

		shape of tidal inlet		
				
occurrence	-	5	12	20
width/depth ratio	-	>300	50-150	90-250
mean depth	m	3-8	>9	>7
maximum depth	m	5-16	12-48	10-37

Fig. 3: Different types of tidal inlet shape.

An account of American inlet cross-sections by VINCENT & CORSON (1980) indicates that the triangular shaped cross-

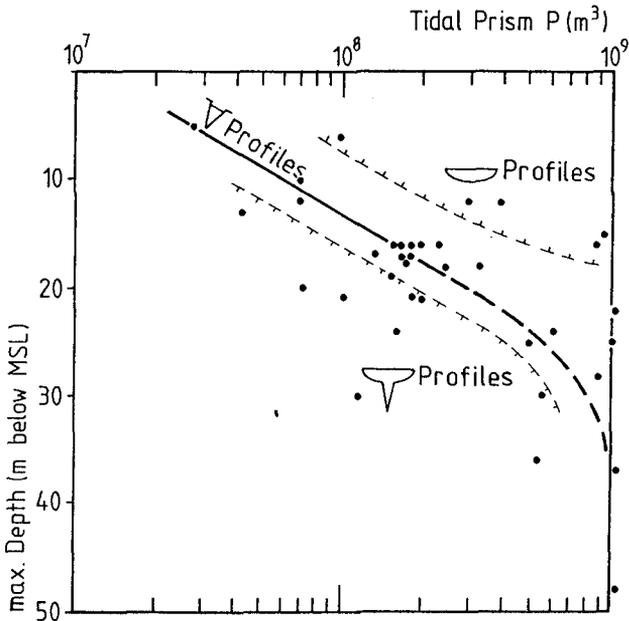


Fig. 4: Relationship between the tidal volume and the maximum depth of inlets in the German Bight.

section is clearly predominant whereas the synclinal shape seldom occurs.

The maximum water depth is also dependent upon the tidal volume. The corresponding relationship for the inlets of the German Bight is illustrated in Fig. 4.

Furthermore, a relationship also exists between the mean and maximum depth in an inlet cross-section. The data for the German Bight inlets have been added to another diagram of VINCENT & CORSON, as shown in Fig. 5. As may be seen in the Figure, the scatter in the latter data is much larger than that of the American data. On the whole, the German Bight inlets are characterized by larger maximum depths.

An interesting aspect concerns the ratio of the tidal volume to the inlet cross-sectional area which lies between $1.0 \cdot 10^4$ and $1.8 \cdot 10^4$, i.e. with a mean value of $1.4 \cdot 10^4$. From a total of 37 inlets investigated, only 5 showed a deviation from the latter ratio. Deviations above this value clearly characterize wide inlets with several channels, whilst deviations below are indicative of narrow inlets with a composite cross-section and a narrow, deep channel (> 20 m). Further investigations may quite possibly lead to the characterization of inlet cross-sections by simple numerical values.

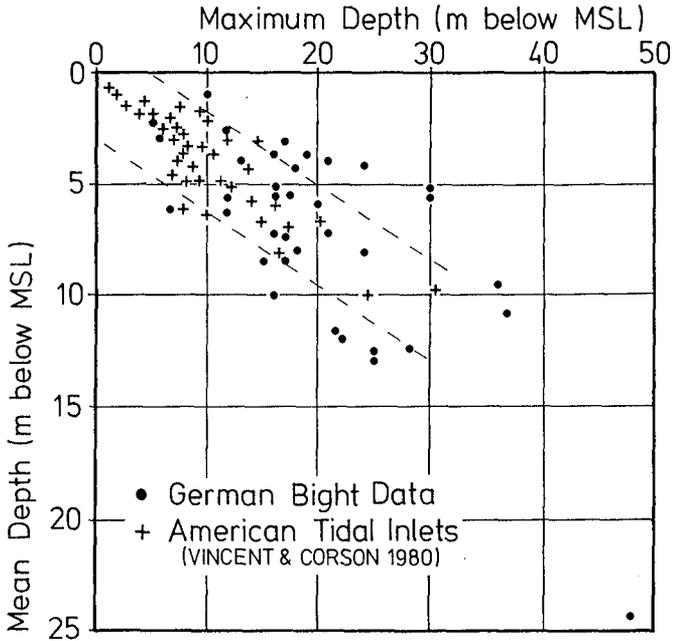


Fig. 5: Relationship between the mean and maximum depth in an inlet cross-section.

4.2.2. LOCATION OF THE CHANNEL WITHIN THE CROSS-SECTION

The geometry of the cross-sectional area and the location of the deep channel within the inlet cross-section in the region of the German Bight are different from the corresponding parameters arising from American investigations (FITZGERALD & FITZGERALD, 1977). In the case of the German Bight, these factors are less dependent upon meandering of the channel bed, the form of the coastline outside the inlet mouth and the dominant longshore transport direction, but are mainly governed by the shape of the drainage area and the location of the latter with respect to the inlet. These conditions are particularly noticeable along the south coast of the German Bight in the vicinity of the East Frisian islands. A distinction must be made between the following cases:

- a) The drainage area is located symmetrically behind the inlet and the deep channel lies in the middle of the inlet (symmetrical cross-section).
- b) The drainage area lies for the most part behind an island (barrier island), e.g. in the downdrift direction relative to the inlet, whilst the deep channel of the inlet is orientated in the updrift direction. This situation is due to the fact that the tidal water volume associated with the morphologically active ebb phase must flow behind the barrier island before the

tidal inlet is reached (non-symmetrical updrift cross-section).

- c) In the case of receding coastlines, two main channel arms often meet together within the inlet. One arm usually runs parallel to the barrier island whilst the other runs directly towards the inlet. If the tidal volume of the channel orientated at right angles to the inlet is sufficiently large, the channel running parallel to the island will be forced in a downdrift direction against the barrier island (non-symmetrical downdrift cross-section). The development of inlets with double channel systems is also possible.

On the east coast of the German Bight, the inlet drainage areas are orientated at right angle to the coastline. For this reason and also because of the lower degree of sediment transport, the channels extend a long way seawards and are located centrally within the inlet cross-section. In the water inlets, side channels frequently occur.

4.2.3. EBB TIDAL DELTAS

General forms of ebb tidal deltas, which develop due to differences in flow velocities and longshore sediment transport rates, have been compiled by OERTEL (1975) for the mesotidal coast of Georgia (Fig. 6).

Similar structures are also apparent in the German Bight. Of particular significance are the curved sand bars of the tidal inlets along the East Frisian chain of islands which have been dealt with in detail by LUCK (1976).

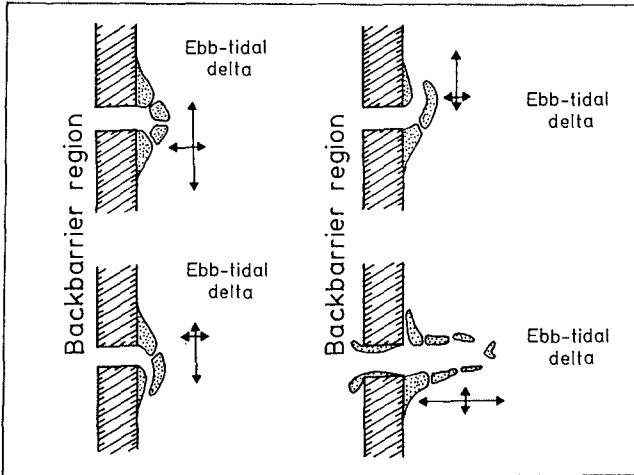


Fig. 6: Ebb tidal deltas of tidal inlets (with arrows indicating the relative magnitudes of onshore, longshore and offshore currents).

4.3. BACK BARRIER BATHYMETRY

The differences between the back barrier bathymetry of the American south coast and the German Bight were first pointed out by NUMMEDAL & FISCHER (1978). The American intertidal salt marshes are mainly comprised of areas overgrown with spartina; only about 20% of the total surface area consists of open water (tidal creeks). In contrast to this, the geomorphological structure of corresponding areas in the German Bight is totally different. Below the MHW line, no vegetation exists. The main factor which governs the morphological structure of the tidal flats is the tidal range (DIECKMANN & PARTENSKY, 1985). Hypsographic curves published in the literature for American coastal sections in the mesotidal range are presented in Fig. 7 together with curves for corresponding regions in the German Bight. As may be seen in Fig. 7, the differences are clearly apparent.

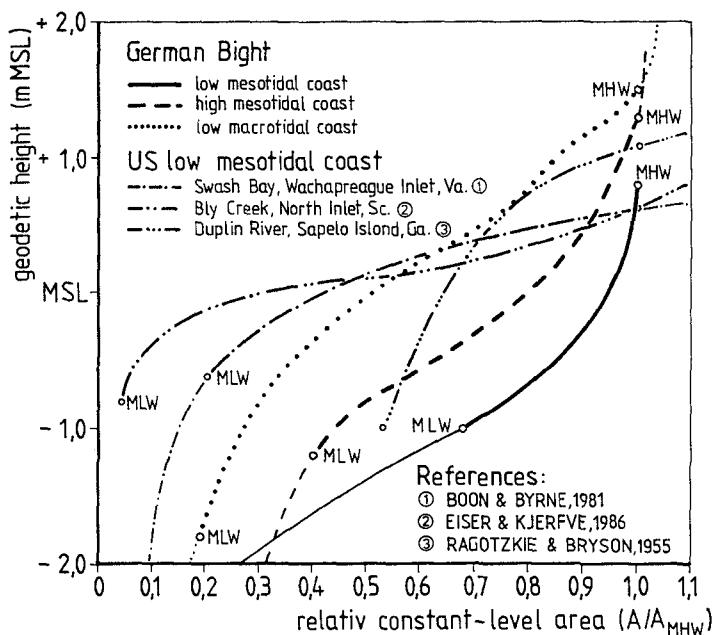


Fig. 7: Hypsographic curves for several American coastal sections (mesotidal range) and the basic types of different tidal range regions in the German Bight.

It should be noted that the given American hypsographic curves represent relatively small coastal sections (0.6 to 27.4 km²) whereas those for the German Bight are derived from larger regions (95 to 260 km²). Differences in the back barrier bathymetry do not govern the size and shape of the tidal inlets, which are themselves determined by the tidal volume, but rather the form of the flow velocity

profiles within the inlets.

4.4. OTHER PARAMETERS

In addition to the parameters mentioned above, there are no doubt other parameters worthy of comparison such as sediments, flows and biological effects relating to different climatic conditions.

For example, NUMMEDAL & FISCHER make mention of the fact that in inlets adjoining open water lagoons in the back barrier region, flood flow dominance is evident whereas for tidal flats and salt marshes in the back barrier region, ebb flow dominance is present. Similar conditions also appear to apply in the case of the German Bight region. For 3 inlets on the East Frisian coast with tidal flats in the back barrier region, a definite ebb flow dominance could be ascertained (PFENNIG, 1978).

5. CONCLUSIONS

From a comparison of American inlets with those in the German Bight, it was found that in the case of all parameters which describe hydrodynamic processes, good agreement exists. In contrast, significant differences were apparent in relation to the morphological structure of the tidal flat salt marshes as well as climatic influences (vegetation). In the context of coastal engineering science, however, these aspects are of no particular importance.

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