CHAPTER 113

INLET CHANGES OF THE EASTFRISIAN ISLANDS

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ABSTRACT

The seven sandy islands of the Eastfrisian group would appear to be initially formed and now continually supplied with sand from the Westfrisian group and the mainland to the west. The inlets between these islands are in dynamic equilibrium with the strong tidal currents of the near 2,5 m range in the area. Hydrographic information dating back to 1650 permits the development of a hypothetical model which explains the historic changes and might predict future trends. The installation of coastal defence structures on the eroding western extremities of some islands in the mid 19th century has greatly influenced the bars by which sand is transported from island to island in an easterly direction.

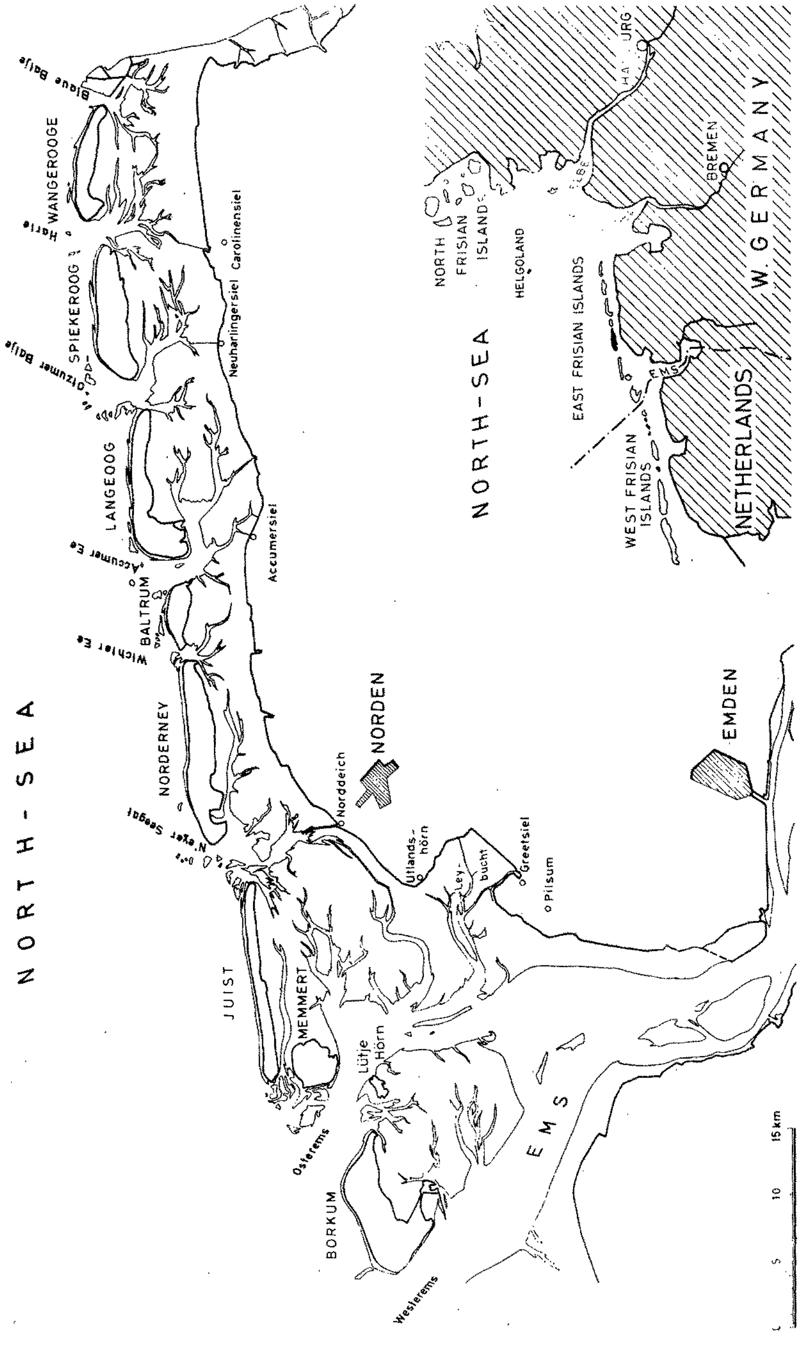
GEOGRAPHY

In front of the southern German North Sea coast between the estuaries of the Jade and Ems Rivers the Eastfrisian Islands are situated; from west to east they are: Borkum, Juist, Norderney, Baltrum, Langeoog, Spiekeroog and Wangerooge (fig. 1). These islands are separated by the tidal inlets Osterems, Norderney inlet, Wichter Ee, Accumer Ee, Otzumer Balje and Harle. Southward, to the coast of the mainland, extend vast tidal flats with sand, silt or mixed soil. The mean tidal range increases from west to east as follows: 2,2 m at Borkum, 2,4 m at Norderney, 2,6 m at Baltrum, 2,7 m at Spiekeroog and 2,9 m at Wangerooge/east.

FORMATION AND AGE OF THE ISLANDS

The islands are completely built of sand and only along their southern borders are more-or-less extensive marsh areas, which have developed by natural siltation. For a long time there have been only very vague notions concerning formation and age of the islands. It was supposed that they were remainders of the former mainland, separated at some stage by storm tides. According to another theory they once belonged to an extended spit of land, which was pierced during a storm tide at several points. However, by the aid of rationalizations, facts and latest findings of the morphological/hydrological processes in the Eastfrisian tidal flats it can be shown, that the islands were formed by the coincidence of current, surf and wind (LÜDERS, 1953).

Fig. 1: EAST FRISIAN ISLANDS



The west to east directed flood current, which is stronger than the ebb current, shifts the sands necessary for the formation of the islands from the Belgian/Dutch coastal area.

Even today the origin of the sands has not been definitly resolved. Mineral explorations prove some sediments are from the big rivers, but also there is erosion material from the British cliffs. More distant sands of the bottom of the North Sea are traceable. These sediments, transported by the tidal currents, are formed into longshore bars by wind and waves and finally the surface is elevated above the high-water-level and is stabilized by vegetation. The influence of plants on the blown sand is to increase the heigth of the bars until they become dune islands. The constant supply of new sea sands provides the nutrients necessary for a strong and healthy vegetation.

The distance between the mainland and the islands is determined by the tidal range. At little or no tidal range the longshore bars and finally the dune islands are formed closer to the coast.

So far it is not possible to determine the exact age of the islands. However, there are references from Greek sailors which permit the hypothesis, that the islands already existed in 300 B.C. As the Atlantic transgression, which led to the formation of the North Sea, commenced about 10.000 B.C. and was interrupted by several phases of regression, a geological determination of the age of the shifting sands cannot be performed and therefore a definite estimate of the age of the islands is not possible.

As the sands are powerless against the forces of current, surf and wind, the islands in the past underwent frequent changes of shape, with long-term developments being overshadowed by short-term events. The tidal flats, tidal inlets and islands are in a state of dynamic equilibrium (WALTHER, 1971) and therefore the changes in the islands and tidal inlets affect also the tidal flats. Only by the construction of the protection works on the islands in the middle of the last century was this process interrupted.

ANCIENT REPORTS

The coast and the adjoining tidal flats were first described by the Roman geographers PLINIUS and STRABO at about the birth of Christ. But the first time the islands were named was in 1398. However, the document did not give further details. Since the 16th century the islands are mentioned more frequently in nautical manuals, and recorded in coastal views for navigation purposes. The first comprehensive descriptions of the islands date from the years 1650 and 1657 (cited in THILO, 1953). For the first time the height and location of the dunes were related to sea level. Narrow beach sections and dune erosion were fully described and measurements were recorded. Following upon these observations inquiries were made as to whether the natural sand supply was sufficient or if there was a necessitiy to protect beach and dunes by artificial means.

These reports are valuable since. With their aid, supplemented by other ancient reports, it is possible to record the island contours relatively well. They provide also the basis for the Historical Map 1 : 50.000 of the Research Station for Island- and Coast-Protection, Norderney (HOMEIER, LUCK, 1969).

The most remarkable phenomenon of the long-term development of the islands, traceable since about 1650, is the fact that at their western ends they underwent a considerable loss of beach and dunes, whilst they built up in the east. This phenomenon, being interrupted by the construction of the protection works, often has been called the "west-east-migration" of the Eastfrisian Islands. The west to east directed "migration" results from the preponderantly eastward directed forces of wind, tide and surf current. With the aid of numerous investigations in the area of the Eastfrisian Islands the mechanism of this west-east-shift could be interpreted.

THE MAP OF GUITET OF 1708

The first map recording the area of the Eastfrisian Islands well enough to be interpreted was drawn by the Dutch Admiral Mathurin GUITET in 1708 (fig. 2). The then existing contours of tidal flat, islands and tidal inlets are preserved in

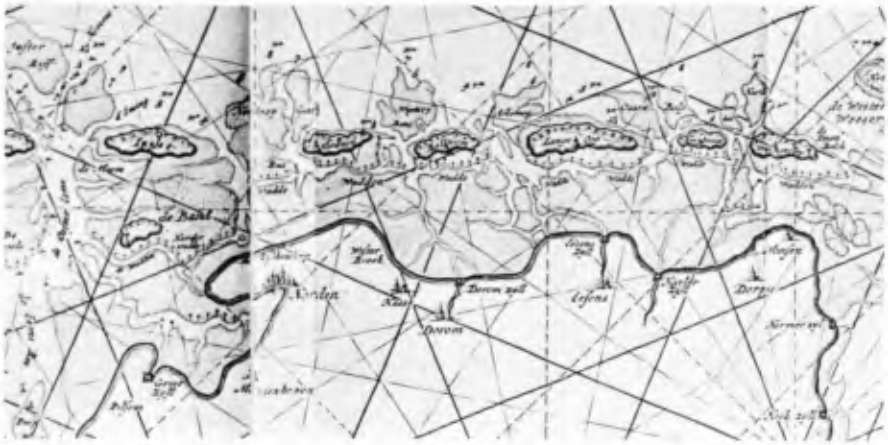


Fig. 2: Wad en buyten-kaart, M. GUITET, Amsterdam 1708/10

Fig. 3: Eastfrisian coast and islands, A. PAPEN, 1843

this map. However, the length of the islands, width of the tidal inlets etc. cannot be measured due to the map's lack of accuracy in scale. For the coastal research the most remarkable phenomenon at that time was the division of the tidal inlets between the islands into two deep narrow channels, which were separated by middle-sands. The first map of accurate scale from the year 1860 (fig. 3), however, shows tidal inlets with only one deep narrow channel. Consequently in most tidal inlets there must have been an alteration from double to single channel profile.

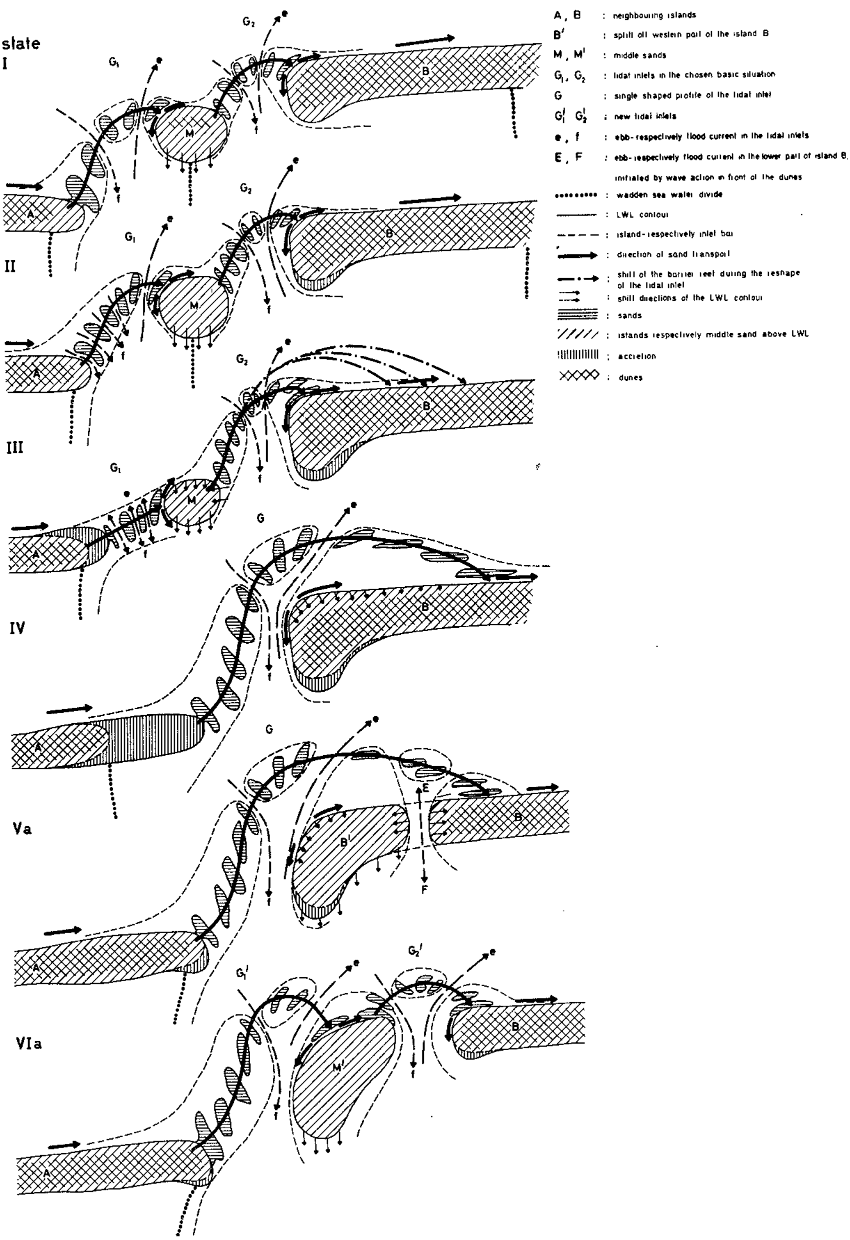
The map of GUITET shows the remains of the once large island Buise, which obviously extended into the present offshore area north of Juist Island. The final phase of the disappearance of this island is recorded relatively well in contemporary maps, discussions, sailing-instructions etc. (LANG, 1955). The well substantiated events in the Norderney inlet, the reduction of the island Buise to a middle-sand and it's final merging at the eastern end of Juist Island, plus the change of the tidal inlet from a double to a single channel profile, made it possible to rationalize these processes on the basis of the findings of modern hydrodynamics. Though the existing information for the other inlets is less comprehensive it is sufficient to prove the applicability of these basic findings.

MODIFICATION OF THE TIDAL INLETS

Though the events in the tidal inlets did not all proceed at the same time, the modifying processes are uniform and can be reproduced in hypothetical models. These explanations can be divided into separate successive stages (fig. 4):

Stage I: The middle-sand M between the islands A and B lies above high-water-level and is being shifted to the south. This southward displacement of M is substantiated by contemporary reports. The tidal inlets G_1 and G_2, which seem to have been hydraulically equal, are located on both sides of the middle-sand. Each one, G_1 and G_2, has it's own intake area separated by the topographical water-divide of the middle-sand M. Northward of the tidal inlets are sands, the spatial order of which evoke the optical impression of a bow, for which reason they are called "sand-reef-bow" or simply "reef-bow". The west-east sand transport within the region of the tidal inlets takes place within these reef-bows. Since their widths correlate more-or-less to the dimensions of the adjoining Wadden-Sea intake areas (WALTHER, 1934) (i.e. small intake area = small reef-bow and visa versa) these reef-bows are relatively flat and reach from A to M and from there to B. As M is small and the sand, coming from A, does not find enough room to spread or build dunes, these sand-supplies do not take hold and M undergoes a loss of material. The

Fig. 4: model of longterm reshape of a tidal inlet
(without scale)



north-western end of B, however, is well provided with sand and correspondingly resistant to erosion.

Stage II: Due to the continuing southern movement of M and the east-directed growth of A the reef-bow of G_1 shortens. As the total sand-supply remains constant over a longer period of time the shoals are moved closer together and consequently the water-exchange in G_1 is reduced. These processes are complementary. Although the water-exchange is now increased in G_2, due to the reduction in G_1, the arc of the reef-bow is still unchanged and the northwestern end of the island B is still well supplied with sand. At the same time the topographical water-divide of M, still effective in Stage I, is gradually reverted and the formerly two separate catchment areas gradually become one.

Stage III: The processes of Stage II continue and M has now become part of the reef-bow of G_1. As the entire intake area between the water-divides of the islands A and B remains constant, changing only minimally over a long period of time, the water-exchange shifts increasingly to G_2. Thus the reef-bow of G_2 is displaced further north and the attachment area of the sands on B is shifted eastward. This produces a sand deficiency on the western end of island B.

<u>Stage IV:</u> The development of the tidal inlet from a double to a single channel profile has been completed. The reef-bow of G has found it's new shape and in the west of island B, which is no longer receiving natural sand-supply, the dunes begin to recede under the influence of the surf. On Norderney Island for instance this state was reached around 1800.

With the Eastfrisian lslands the natural development has not gone beyond Stage IV. The beach and dune erosion, which occurs after termination of Stage IV, was prevented by seawalls and groynes. An uninterrupted development would have allowed the inlets to further change their shape as described in Stage V and Stage VI. ln one case, namely on Wangerooge Island, this process has already begun with the formation of a new deep channel (FÜHRBÖTER, LUCK, LÜDERS, 1973).

<u>Stage V:</u> The dunes of island B are eroded by surf and wind; they recede up to the area of sufficient sand-supply (attachment area) and there remains only a beach B'. At elevated high-water-levels the surf erodes a channel close to the dune base, which gradually becomes deep enough to overflow even at normal tides. With this the preconditions for the formation of a new tidal inlet are fulfilled. On Wangerooge Island, the eastern most Eastfrisian Island, such a development started about 1900. The final development of a new channel was

prevented by the construction of a long and heavy groyne (LÜDERS, 1952).

Stage VI: The channel in front of the dune base of island B has developed into a new tidal inlet. The duneless west-beach of the island B is cut off and has become a new middle-sand M'. By this stage a configuration has been reached, which approximates that of Stage I.

The developments, described in this hypothetical model, apply to the islands Juist to Wangerooge. Borkum Island, due to it's location in the Ems estuary, is influenced by other parameters, which do not allow a transfer of the concepts to the Ems and Easter-Ems inlets.

The investigations, involving developments since 1650, prove that the transitions of the tidal inlets tend to proceed in cycles from double to single channel profile and back to the double version. An unrestricted extrapolation of these phenomena into the future, however, is not possible without consideration of the secular water rise. Over a longer period of time the secular water rise effected a southward shift of the islands, which will continue. At the moment the possibilities are being studied for including the secular water rise into the present models.

DEVELOPMENT OF LENGTH AND WIDTH OF THE ISLANDS AND TIDAL INLETS

Since 1650 the total length of the island chain from Juist to Wangerooge remained constant at about 68 to 69 km, provided that the beach accretions of Juist/west and Wangerooge/east (about 3,5 km) are deducted. However, within the row of islands changes on a large scale took place (see Table I).

Table I: Development of the tidal inlets and islands between the MHW-lines [m]

Year	1650	1750	1860	1960
Juist Island	10470	13010	15810	14970
Norderney Inlet	6800	4730	2600	2770
Norderney Island	8070	9440	13470	13870
Wichter Ee Inlet	2170	2030	710	850
Baltrum Island	8170	7560	5460	5050
Accumer Ee Inlet	3150	2480	1360	1710
Langeoog Island	9600	10280	11230	10920
Otzumer Balje Inlet	2440	2400	2440	2410
Spiekeroog Island	5230	5180	5910	9810
Harle Inlet	5800	5670	4810	2000
Wangerooge Island	7300	7400	7950	8320
Total	69200	70180	71750	72680

All tidal inlets narrowed and the islands, except Baltrum Island, became longer. The shortening of Baltrum Island of about 3 km since 1650 was effected by a simultaneous strong eastward growth of Norderney Island. This development was prevented by the construction of protection works on Baltrum Island, which stopped a further transformation of the tidal inlet Wichter Ee and with this the on-going eastward growth of Norderney Island. Without it's strong protection works Baltrum Island finally would have been completely destroyed, similar to Buise Island, and the last remains would have merged into the eastern end of Norderney Island.

Figures 5 and 6 also illustrate the relations between the transformation process in the row of islands and the events in the tidal inlets. Figure 5 shows the curves of the total length of the islands (without tidal inlets) between the low and high water lines, of the dunes, of the total surface and of the total circumference. Altogether a growth of the islands can be recognized.

Of special interest are the curves of the lengths, which increase slowly in the beginning and then quickly after 1750. At first the construction of the protection works 1860 through 1870 had little effect on the lengths between the high water lines, because the protection works in the beginning were only effective within the reach of the dunes. Therefore at first the MHW lines

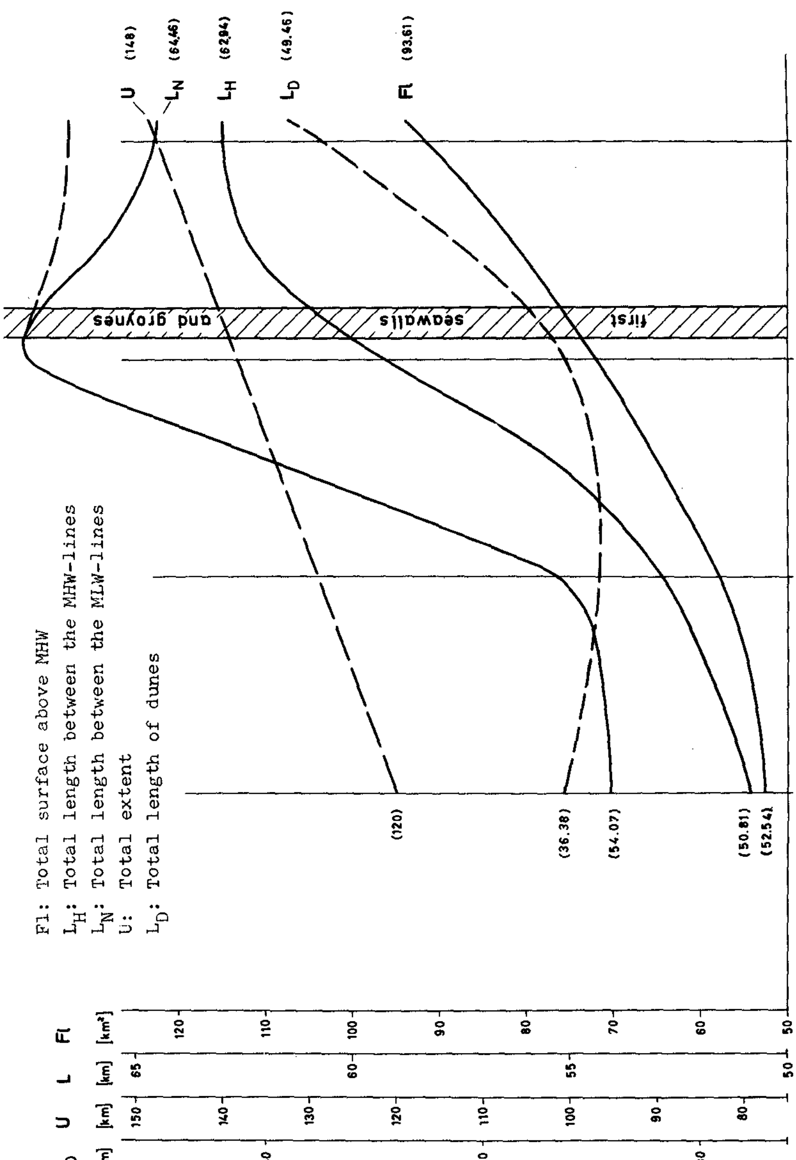


Fig. 5: Development of the row of islands

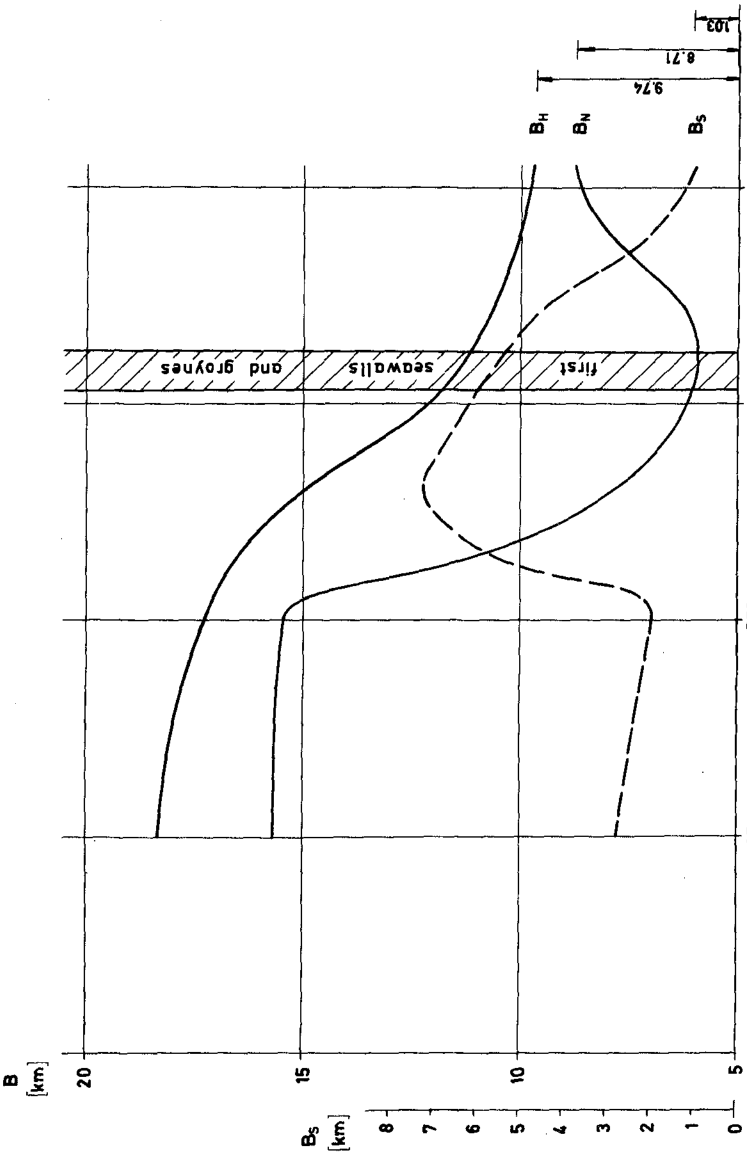


Fig. 6: Development of the width of the tidal inlets km

B_H: Total width between the MHW-lines; B_N: Total width between the MLW-lines;
B_S: Width of the beach between MHW and MLW

had still space to shift backward. The curve of the lengths between the MLW lines, however, falls significantly after the construction of the protection works. These reductions in length occurred at the western ends of Juist Island and Wangerooge Island, the latter being displaced southward since the storm tides of 1854/55.

The curves of the total widths of the tidal inlets (fig. 6) show a complementary development. The more the total lengths of the islands increased, the more the tidal inlets became narrow. Here in the beginning the construction of the protection works had no influence on the curve either, as the MHW and the MLW lines first still had enough space to shift. The rise of the MLW curve after 1860 has to be referred to the southward displacement of the duneless westbeach of Wangerooge Island, which has already been mentioned. The seawalls and groynes, constructed after 1874, served as immediate dune protection and left the large westbeach to the forces of waves and current (LÜDERS, WILLECKE, 1951).

CONCLUSIONS

Under natural conditions (i.e. without protective works) the Eastfrisian Islands tend to shift eastward. On the basis of well substantiated long-term events in the Norderney inlet this tendency could be traced back to morphological events in the tidal inlets and systemized in a hypothetical model. The application of the concepts, gained for the Norderney inlet, to the tidal inlets between Juist Island and Wangerooge Island can be proved by means of old maps, descriptions etc. as well as by consistent reasoning, facts and findings of modern hydrodynamics.

The ancient "west-east-migration" or shift of the Eastfrisian Islands has been effected by the active processes in the tidal inlets, followed passively by the islands. The seawalls and groynes have produced a static condition, which if not present would have been temporary in nature.

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