CHAPTER 146

RESEARCH IN THE HARINGVLIET ESTUARY

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Abstract

After the closure of the Haringvliet estuary, part of the Netherlands Delta Project, morphological changes have occurred. Until now it was impossible to give a completely satisfactory forecast of such changes, however, with the aid of the Leendertse tidal computations a good picture of the tidal flow in the estuary can be obtained. In the paper a short description is given of both the tidal flow and the morphology of the Haringvliet estuary related with some problems of the practising engineers.

Introduction

The socalled Delta region, situated in the south-western part of the Netherlands, consists of a number of islands separated by estuaries with gullies having a depth between 10 and 30 metres. The seaward side of the islands is composed of sand; the gullies, probably being the result of breaches in a continuous dune coast, were formed many centuries ago. In the western part the rivers Rhine and Meuse and in the south the Scheldt river discharge into the delta and North Sea. The sediment transport of these rivers is not large which means that from a geological point of view this coast is not to be classified as a "delta" coast.

The Delta region was often subjected to severe storm surges and the flooding caused by the storm surge of February 1953 was the direct motive for the decision to close the four sea-arms comprised in the Delta Project, with the purpose to protect the low-lying area against future storm surges. The Haringvliet closure (see fig. 1) in 1969 was part of this project. A large sluice complex in the middle of the dam which, apart of negligible discharges during most of the year, can be opened during periods of high discharge of the Rhine river. In this way the original tidal volume in the Haringvliet of 300 million cu.m. was reduced to one eighth. It was expected that the morphological changes resulting from the above reduction would mean increased sedimentation in the entire area with possible scour in some locations.

The need to keep a channel for the discharge of large quantities of Rhine water (at the time of very high discharges) and the requirement to maintain a fairway for shipping towards the locks next to the sluices it was desirable to predict the extent of the sedimentation.

With respect to the coastal protection the possibility of erosion of the adjacent sandy coasts had to be investigated; moreover it was necessary to answer the questions concerning the possibility for the construction of artificial islands and for dredging sand in the area.

In general it can be said that for all morphological changes in this area a better insight was needed. Different methods were used to predict such changes (Dronkers, J.J. 1970)[1] but, as was also recognized by him it is not yet possible to obtain a satisfactory forecast.

Notwithstanding the above enough information regarding hydraulic conditions and morphology could be obtained as to answer the questions of the practising engineers.

Tidal flow

For the research into the tidal flow of the Haringvliet estuary the tidal computations by the Leendertse method)[2] have been used in most cases.

Such computations have been carried out in close cooperation with and the aid of the Rijkswaterstaat Computer Centre in The Hague, the Elliot 503 and Philips P 1400 have been used to this end.

At first the existing situation had to be reproduced.

The computations initially covered a large area along the Delta coast using a net with squares of 1600 m each. Boundary conditions were obtained from simultaneous measurements by anchored ships, "flachsee" remote measuring devices and sea-level measurements by fixed gauging stations also along the coast. With the aid of the large model the boundary conditions for the Haringvliet model were obtained which used a net with squares 400 m each.

From fig. 1 it can be seen that the tidal range increases when going south in the North Sea. The tidal range at the mouth of the Haringvliet estuary is about 1,8 meter.

An overall picture of the resulting maximum ebb and flood flow for Ha 1 (1964 situation) is shown in fig. 2. A detailed comparison of the model and prototype measurements showed that in general a good agreement is reached if the sea bed is reproduced in sufficient detail.

In some places instabilities with the model will occur namely fluctuations of velocities and waterlevels. By reducing the time step these instabilities in general will disappear; if not, a closer inspection of the boundary conditions may reveal that instabilities are generated from the boundaries of the model. This condition however can also appear in prototype.

Fig. 2 also shows the velocities for the Ha 2 model in which the Ha 1 situation is repeated, however with a closed dam and a maximum discharge of 12,000 m3/s through the sluice gates. Fig. 3 shows the Ha 3 model without any discharge.

In order to be able to draw conclusions from the results of the tidal computations it is necessary to know the frequencies of exceedance of the discharges through the Haringvliet sluices. For one of the possible programs (NLP 70), set up with regard to the water control, shipping and safety, the discharges of the Rhine were related to the sluice discharge(s). The result is given below (table 1)

Rhine discharge cub.meters/sec.	Frequency of exceedance of Rhine discharge	Maximum discharge Haringvliet m3/s
3,000	55 days/annum	2,700
5,000	11 "	8,200
6,000	5 "	12,200
12,000	1 day/25 yrs	16,000
18,000	1 day/3000 yrs	19,000

Table 1. Frequency of exceedance of the Haringvliet and river Rhine discharges for program NLP 70.

From the table it is clear that due to the few times that the sluices are used, the discharged water can be disregarded insofar the morphology is concerned almost the entire year. Only in about 15% of the ebb conditions the discharge through the sluices affects the sediment movement.

The table also shows that the maximum ebb discharge no longer reaches the original average value of 23,000 m3/s. Particularly during the recent very low discharge values of the Rhine (1971, 1972 and 1973) the reduction of the discharges was very noticeable.

In the period subsequent to the closure operations up to and including 1973 the discharge values of the Rhine exceeded 3,600 m3/s only during 36 days while the value of 5,000 m3/s was never exceeded.

Insofar the morphology is concerned the results of the Ha 3 model (fig. 3) may be considered a representative average condition.

Fig. 3 also shows the results of computation Ha 22 in which model a sand dam starting at Europort Harbour and extending to the south is used. This model is an example of one of a number of proposed dams, islands and harbour extensions, the effects of which were investigated by means of Leendertse computations. In the Ha 22 model the wide mouth of the estuary is narrowed considerably in order to regulate the tidal flow. The average velocities in the main channel are increased in order to reduce sedimentation and consequently the need for future dredging. In addition to the above advantage the current velocities near the southern Europort beach are reduced which in turn decreases erosion.

At present no final conclusion with regard to the execution of the work can yet been drawn.

Morphology

In the Haringvliet estuary (see fig. 4), just outside the dam two channels are present: Rak van Scheelhoek in the north and Slijkgat in the south. The Rak van Scheelhoek splits up into the northern Gat van de Hawk and in the middle of the outer estuary the Bokkegat. The point of bifurcation moved in the last ten years before final closure between 2,000 and 3,000 meters seaward. (compare figs. 4 and 5).

In the northern part of the outer estuary, during the same 10 year period mentioned before, considerable sedimentation was observed and a large sand flat was formed (see fig. 5).

Figure 6 shows both sedimentation and erosion after the closure of the Haringvliet up to 1974. Considerable sedimentation took place in the inner channels. The sediment is composed of silt and silty sand.

Near the Goeree coast both local scour and sedimentation took place, the overall balance however was stable. The coast of Voorne shows little erosion whereas at the western point A (indicated by arrow on fig. 6) of the coast the scour remained almost constant. Fig. 7, showing the recession of various depth lines with time, clearly illustrates this statement.

This figure also shows that until now no influence can be attributed to the closure of the Haringvliet dam in November 1969 insofar scour on this part of the Voorne coast is concerned.

In the central part of the inner estuary a pit was dredged having a maximum depth of 15 meters (see fig. 6). Sand dredged outside in the North Sea could be dumped there. When required smaller dredgers could reclaim this sand and pump it further inland. This work has been temporarily stopped. The situation of the pit was chosen with regard to both the flow during high discharges and the stability of the sluices.

Conclusion

Although only a general insight could be obtained into the morphology of the Haringvliet estuary after closure of the dam, most questions of the practising engineers could be answered so far. The Leendertse method for tidal computations proved to be a reliable tool. Further work on the forecasting methods mentioned by Dronkers is necessary, especially the relation between tidal flow and sediment movement, and the influence of waves.

References

1. Dronkers, J.J., Research for the coastal area of the delta region of the Netherlands 12th Coastal Engineering Conference Washington, 1970.
2. Leendertse, J., Aspects of a computational model for long-period water wave propagation The Rand Corporation; Santa Monica California, 1967.

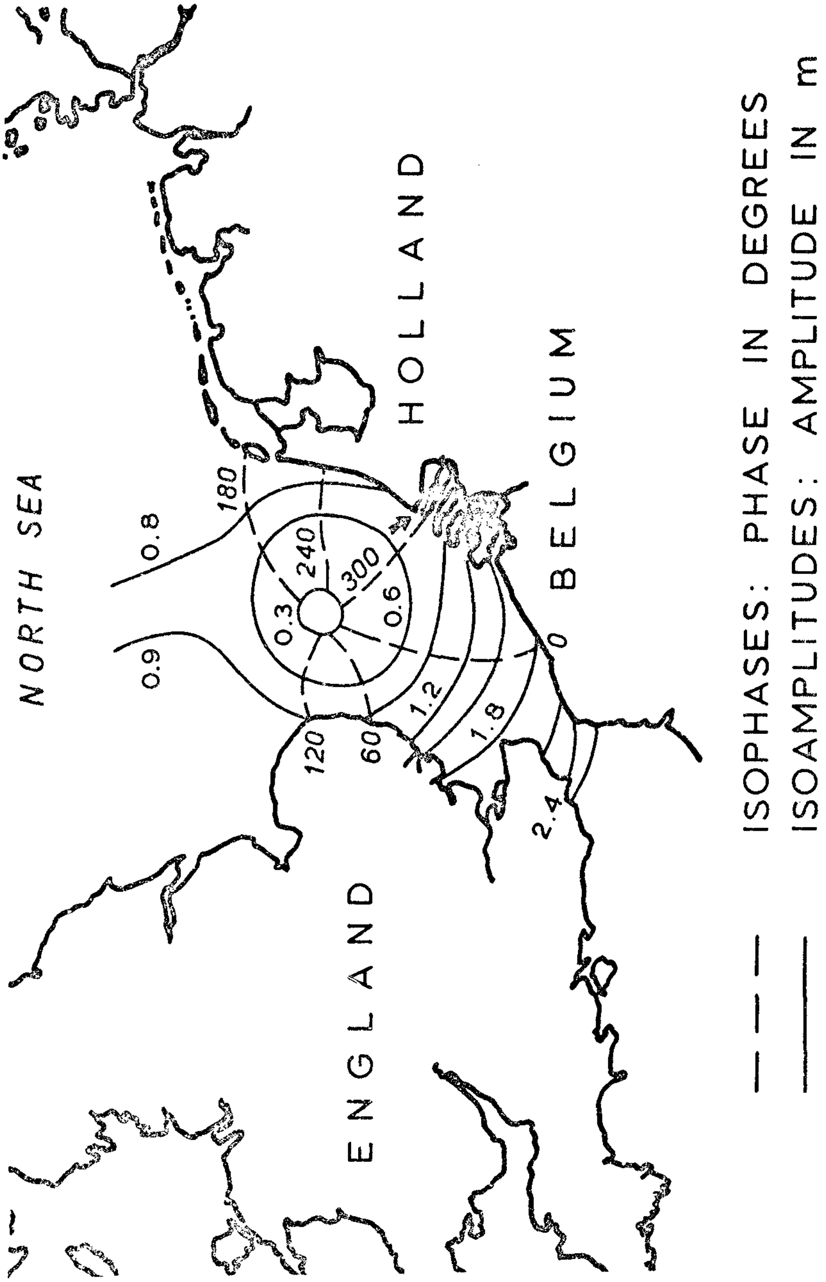
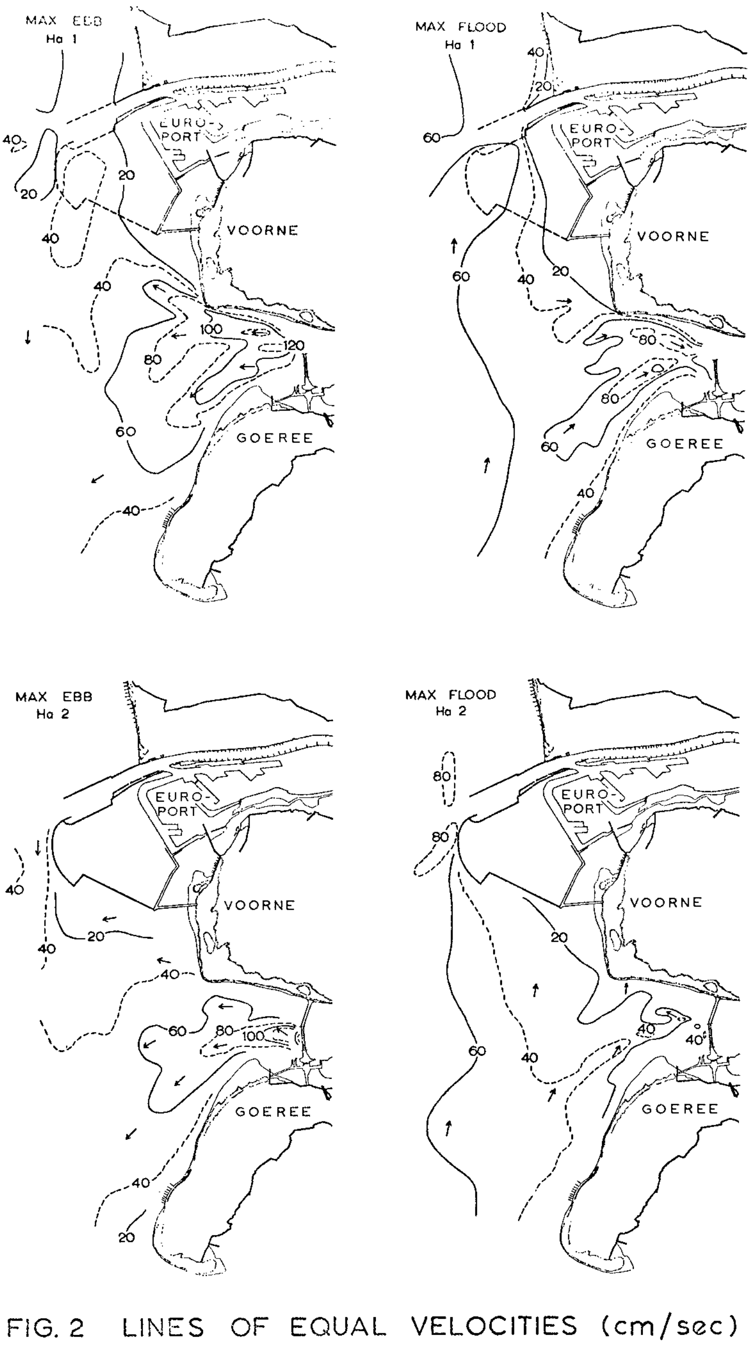


FIG. 1 TIDAL CONDITIONS IN THE SOUTHERN NORTH SEA



MAX EBB Ha 1

MAX FLOOD Ha 1

MAX EBB Ha 2

MAX FLOOD Ha 2

FIG. 2 LINES OF EQUAL VELOCITIES (cm/sec)
Ha 1 AND Ha 2

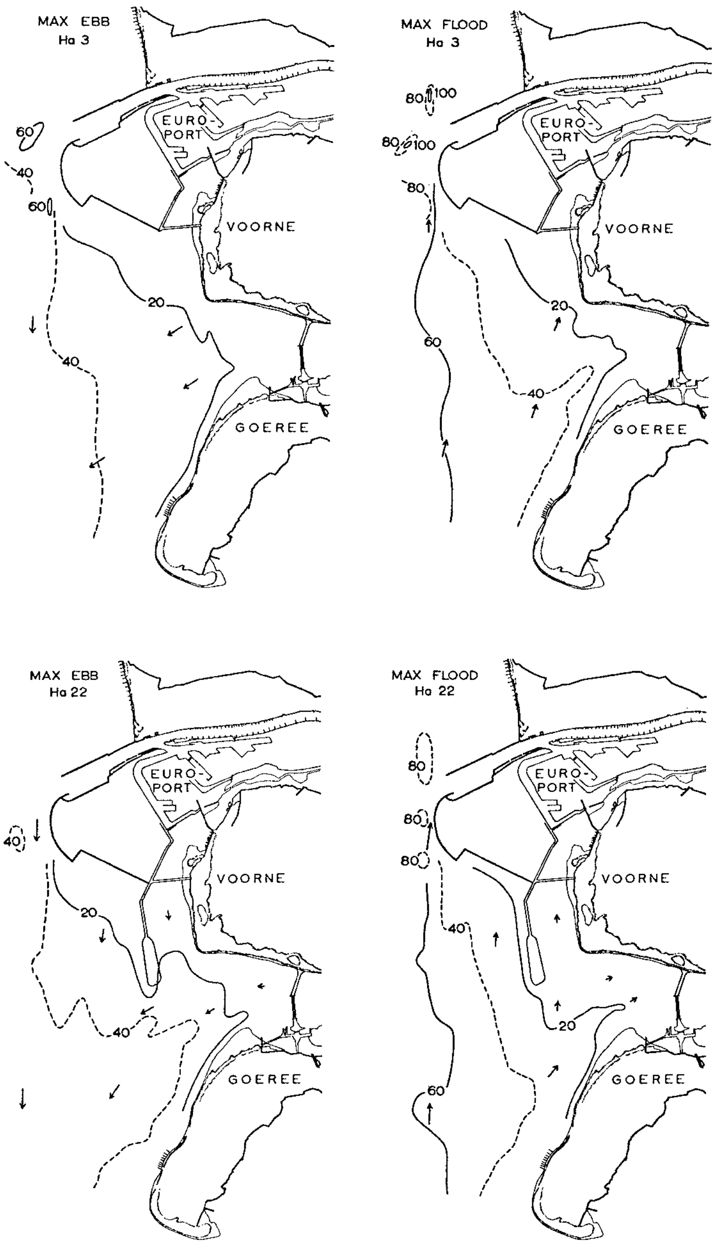


FIG. 3 LINES OF EQUAL VELOCITIES (cm/sec)
Ha 3 AND Ha 22

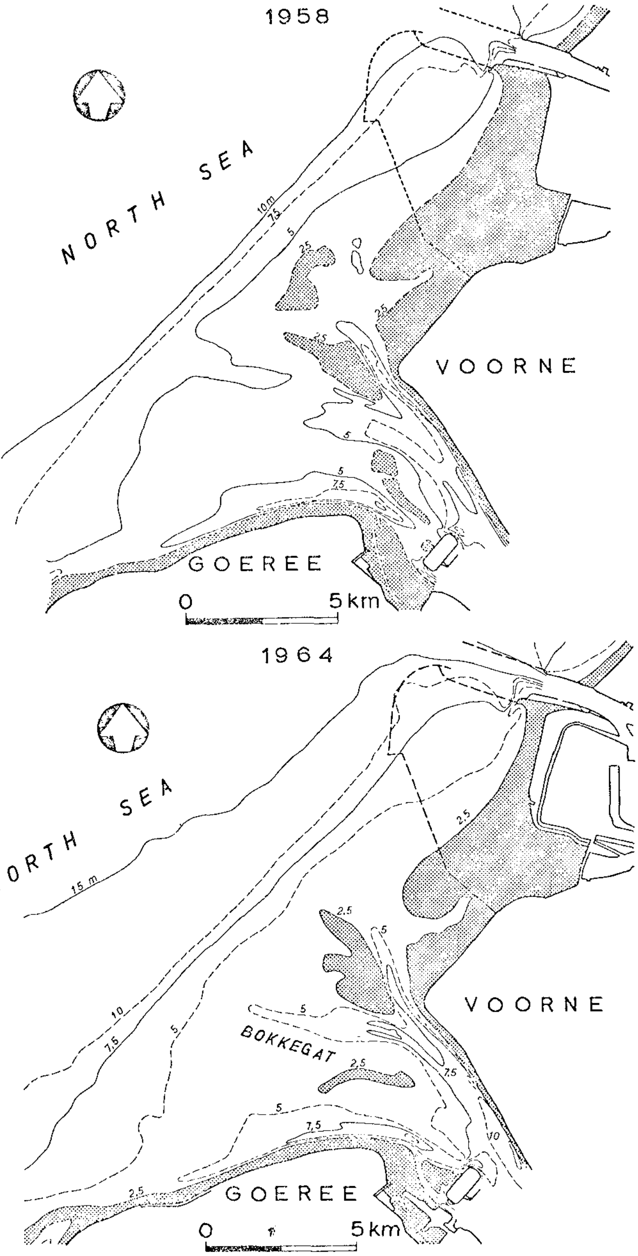
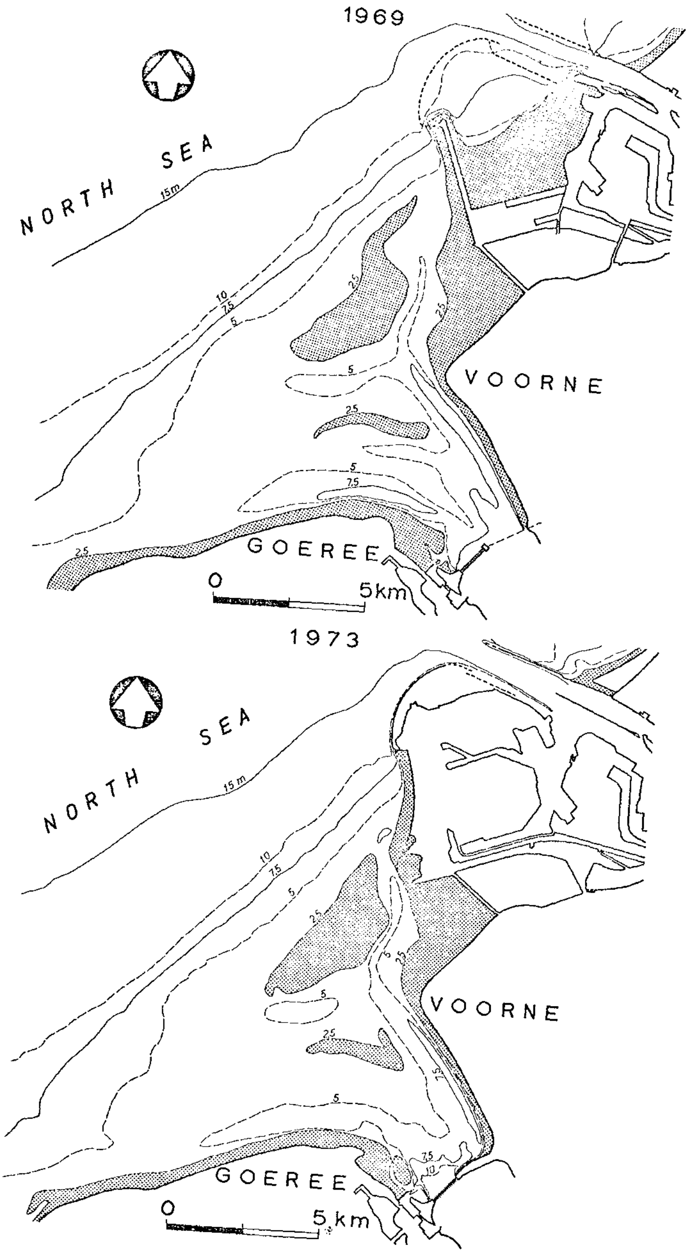


FIG. 4 SITUATION 1958 AND 1964



1969

1973

FIG. 5 SITUATION 1969 AND 1973

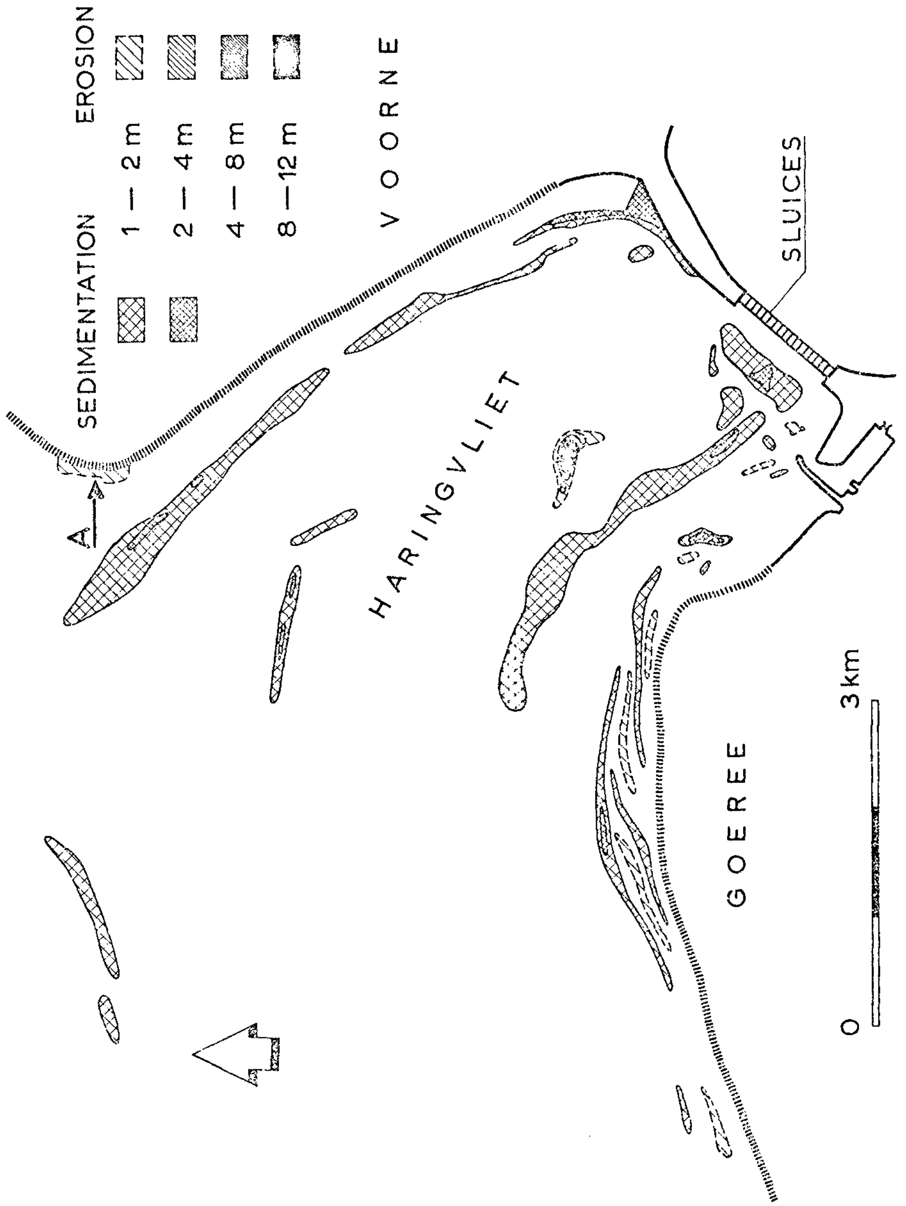


FIG. 6 MORPHOLOGICAL CHANGES 1969 - 1973

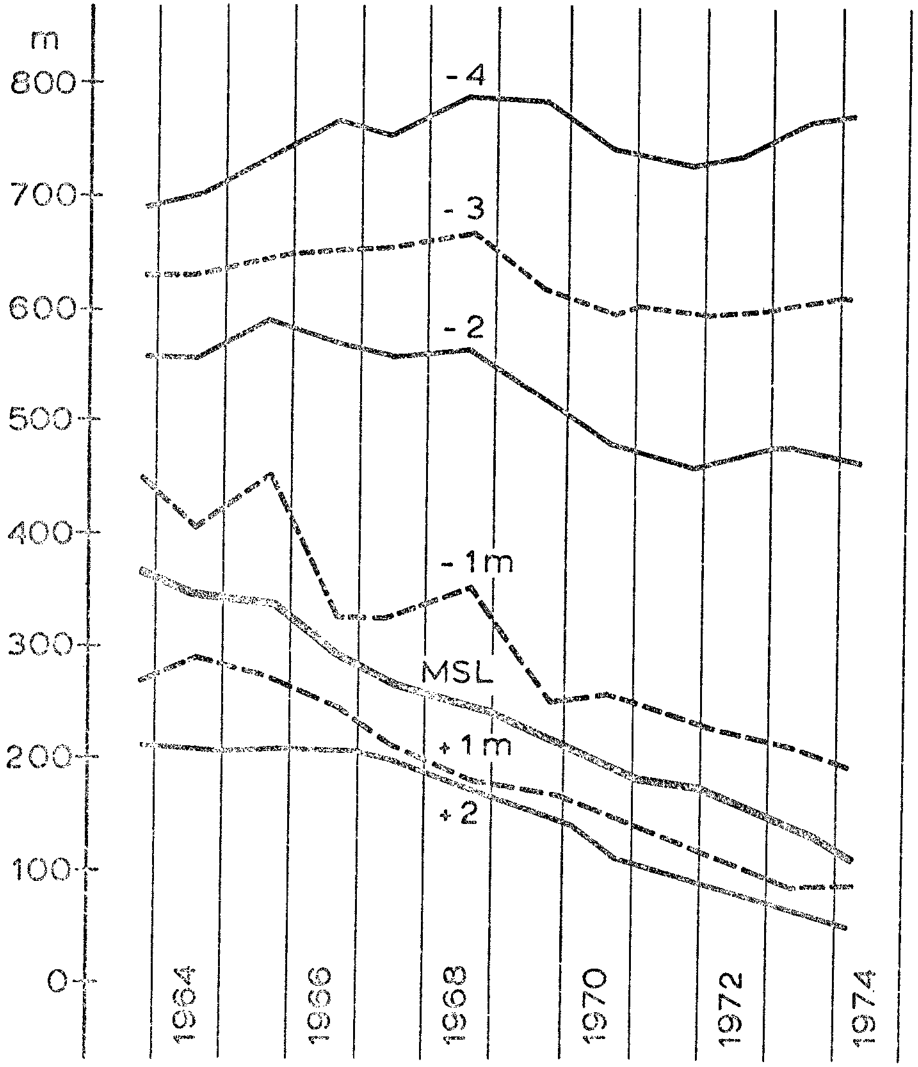


FIG. 7 EROSION OF VOORNE COAST
(POINT A OF FIG. 6)