CHAPTER 214

BEACH MAINTENANCE STRATEGIES, A COMPARISON FOR A RECREATIONAL BEACH

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ABSTRACT

This paper describes the morphological and economical evaluation of the beach nourishment maintenance strategy of an eroding recreational beach at the Dutch coast. In addition to the results of this evaluation two alternative strategies were analysed. In order to assess the economical feasibility of the alternatives appeared to be essential to estimate the morphological effectiveness of the alternative strategies. Therefore, an extensive numerical modelling scheme was set up. The numerical modelling played a key role in the understanding of the existing morphological system and subsequently in the assessment of the effectiveness of the alternatives on a long term basis. The morphological effectiveness of the alternatives, being offshore breakwaters and a 450 m long groin, was calculated in terms of reduction of required beach nourishments. The objective of the study was not only to find an optimal coastal morphology strategy but also to find the best strategy which combines a sound beach protection with effects valuable for the specific recreational function of the beach, including an effective way to deal with eventual lee-side erosion. Possibilities were studied to shift the erosion to the dune area in the north which would allow a more flexible and dynamic way of maintenance.

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SITE DESCRIPTION

Scheveningen Beach (Figure 1) is located on the west coast of The Netherlands. Scheveningen Port is located just south of the beach with its breakwaters reaching 550 and 725 m into the sea. During the entire year but especially in summertime, the sandy beach attracts thousands of locals and holiday making tourists.

The beach consists of sand with a characteristic grainsize (D50) of about 200 μm. The slope of the beach is approximately 1:40. The -10 m MSL contour lies about 1300 m offshore. Scheveningen is also protected by a seawall with a length of 2.5 km. The beach level at the toe of the seawall is about +3 m MSL. North of Scheveningen the land is protected by a massive dune area.

Scheveningen Beach is eroding continuously. In the beginning of the century a system of 150 m long groins (spacing 500 m) was built but the erosion was not stopped. Up to now five beach nourishments were carried out starting in 1969 (see Table 1).

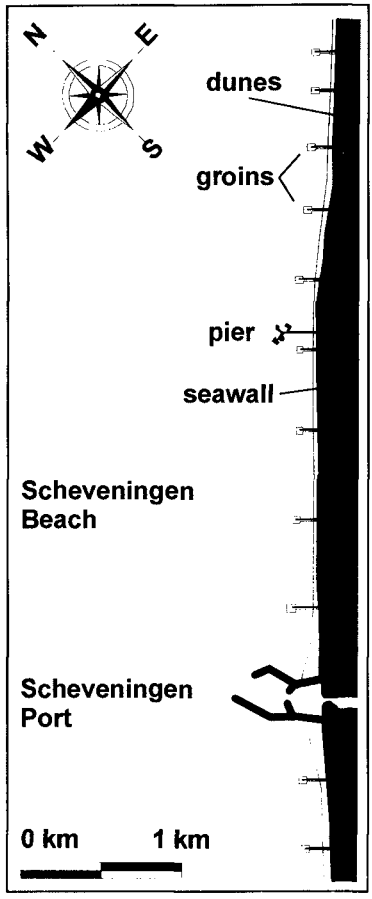

Figure 1 *Scheveningen Beach*

The Dutch west coast is known as a morphological dynamic system. The wave and current climate result in massive longshore sediment transports in northern as well as in southern direction. The average yearly sand transport is directed to the north and is estimated, for this part of the coastline, at 500,000 m^3/year.

year	1969	1975	1985	1991	1996
volume [m^3]	45,000	700,000	330,000	1,000,000	850,000

Table 1 *Beach Nourishment Volumes at Scheveningen Beach*

HYDRAULIC BOUNDARY CONDITIONS

The average wave climate on the southern North Sea is presented as a wave rose diagram in Figure 2. The most persistent conditions develop from south-western directions whereas the highest extreme conditions are to be expected from north-western directions.

The average amplitude of the diurnal tide for this part of the Dutch Coast is 1.7 m. The tidal variation induces a significant tidal flow along the coast. Typical flood currents are in the order of 0.6 m/s, typical ebb currents are 0.4 m/s. Peak flood currents may reach up to 0.9 m/s and ebb currents to 0.75 m/s. However, during extreme south west storms (directed parallel along the shore) the wind-driven current can give a significant contribution to the flow especially in shallow areas (surf zone). Consequently, the longshore sediment transport along this part of the Dutch coast is dominated by the interaction between the waves (disturbance, wave-driven current) and the tidal current. The wind-driven current effect pays a minor but nevertheless a not to be neglected contribution.

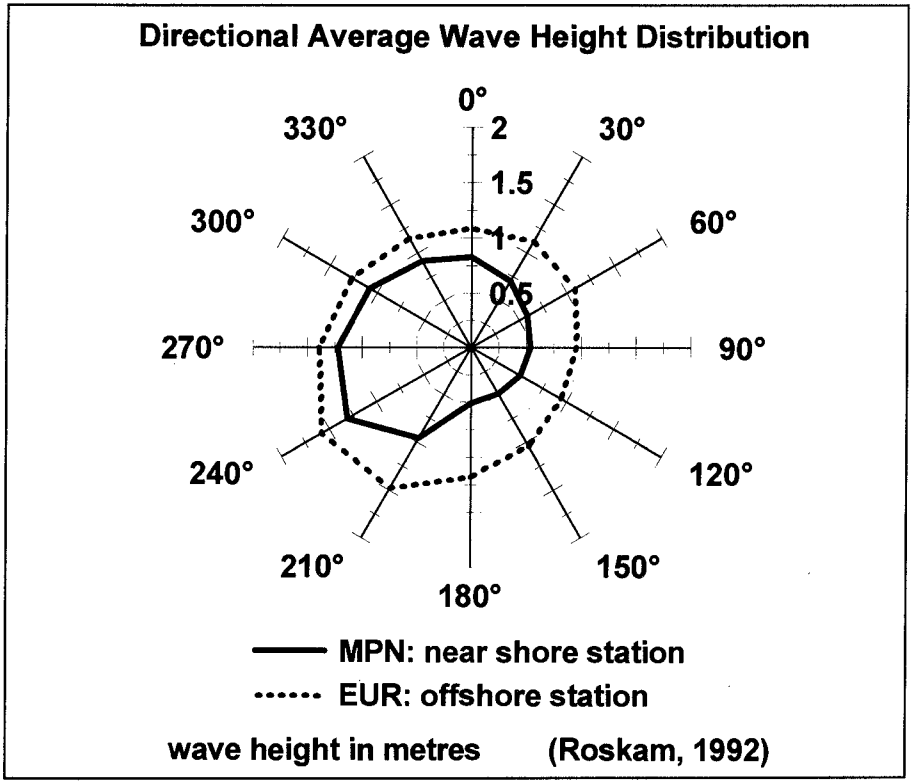

Figure 2 *Directional Average Wave Height Distribution*

EVALUATION PRESENT BEACH NOURISHMENT STRATEGY

The evaluation of the present beach nourishment strategy concentrated on the behaviour of the executed nourishments and the sand transports along the coast. Regular measurements of the Ministry of Transport, Water Management and Public Works were analysed giving insight in the behaviour of the beach nourishments. Based on the measurements and sediment transport calculations it was concluded that (*i*) especially the first nourishments were used as restoration of the steepened cross sectional profile, that (*ii*) the aims of the nourishments were initially met but (*iii*) that the lifetime of the nourishments was almost completely determined by extreme wave conditions, which resulted in a rather random nourishment behaviour. The characteristics of the morphological system do not allow a complete natural restoration of the beach after an erosion causing storm. The unpredictability of the wave conditions results in a capricious development of the beach. This has already led to an unexpected narrow beach in the summer having negative effects on the tourist industry.

NUMERICAL MODELLING ANALYSIS

Based on the conclusions of the beach development evaluation one- and two-dimensional wave, flow, and sediment transport models were applied (DHI, 1995 and DH, 1992). The well calibrated models of the wave- and flow climate were combined in sediment transport simulations using the Bijker sand transport formulae. The model results were used to understand the importance of the various sediment transport mechanisms and to finally formulate a well based hypothesis of the morphological system. After the formulation of the hypothesis simulations were made of alternative coastal protection structures. These were, among others, offshore breakwaters and a 450 m long groin perpendicular to the coastline. The effects of the structures were brought in relation with the hypothesis of the existing system in order to quantify the predicted impacts on the coastal development.

existing situation

The key questions after the evaluation of the nourishment strategy were (*i*) what are the physical reasons for the erosion and (*ii*) where is the sediment going to. It was clear that the position of the beach, the breakwaters of the port, the seawall and the geometry of the beach were essential elements in the morphological system. With the use of the mentioned numerical simulations the following conclusions (schematically presented in Figure 3) could be drawn:

(1) The net north going longshore sediment transport is not blocked by the breakwaters of the port but is passing these obstacles. It was shown that under

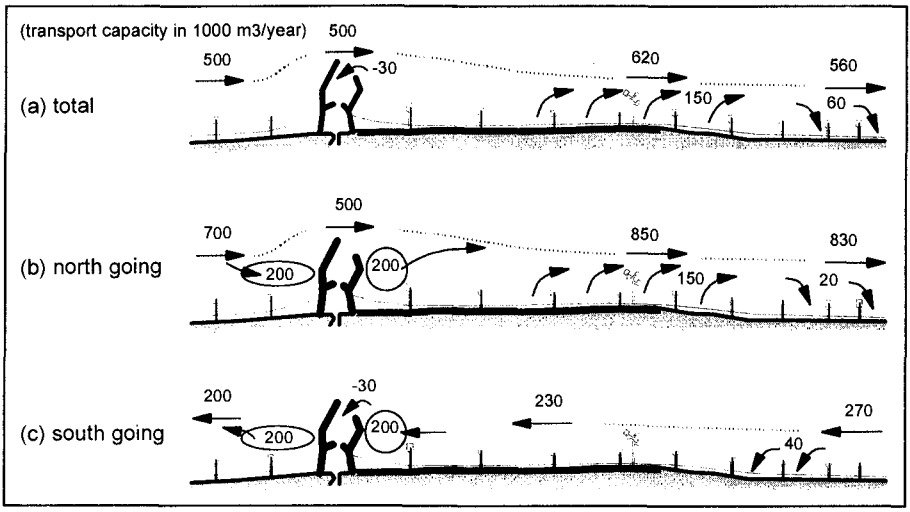

Figure 3 *Sediment Transport Capacities, Existing Situation*

south-western wave conditions the contracted current (tide-, wave- and wind-driven current) in combination with the orbital wave motion result in a substantial sediment transport in front of the breakwaters. This transport is developing in front of the breakwater tips in a water depth of -8 m MSL. Evidence that this process exists is the absence of a sedimentation zone south of the breakwaters. The passing of the net northern transport around the breakwaters is very important for the development of Scheveningen Beach. This transport is the main feeding mechanism of the beach.

(2) It was found the sediment transport north of the port is about 10% higher than south of the port. The reason for this was found in the bathymetry of both areas. The beaches north of the port appear to be more gentle sloping. This results in a wider surf zone north of the port which in this case (transport driven by the combination of waves and tidal current) generates a higher sediment transport. This effect can be observed while standing on the breakwaters.

(3) Because of the forced orientation of Scheveningen Beach by the seawall a strong local longshore transport gradient develops at the northern side of the beach.

(4) The natural beach restoration after a north-western storm is distorted due to the presence of the breakwaters. The timescale of storm events is in the order of hours whereas the timescale of the restoration is weeks to months. In this part of the Netherlands the time averaged flow along the shore is directed to the

north. Sediment deposited on the foreshore during a storm event will therefore contribute to the beach restoration of a beach section somewhat to the north. The presence of the breakwaters of the port distorts this mechanism which results in an incomplete natural restoration of the beach or, in other words, erosion of the beach.

These four main conclusions are the basis of the hypothesis of the morphological system of Scheveningen Beach. The hypothesis is schematically presented in Figure 3. In the figure the annual yearly north going and south going transports are shown as well as the total average yearly transport.

offshore breakwaters

One of the alternative measures which was defined was offshore breakwaters. The impacts were studied on the basis of the developed hypothesis of the existing morphological system. The simulations were repeated for the schematized offshore breakwaters. The main result of the computational effort was that offshore breakwaters do not fit in the morphological system of Scheveningen Beach. Indeed the structure reduces the wave action and thus the sediment transport on the beach. But the structure also redirects the sediment which is transported past the port's breakwaters along the seaward side of the structure. This transport was found to be the most important feeding mechanism of the beach. It is therefore expected that the construction of offshore breakwaters as defined for this study will result in an even stronger erosion on the beach. The predicted sediment transport patterns after the construction of the offshore breakwaters are presented in Figure 4.

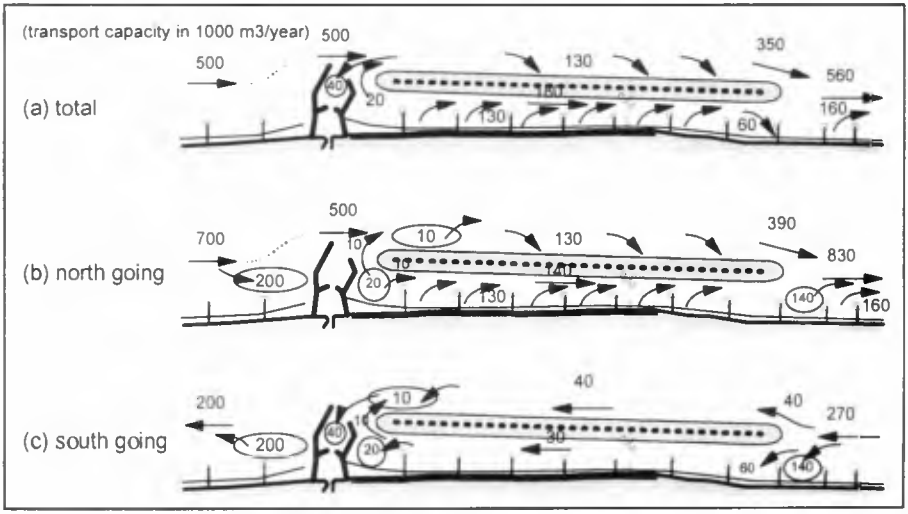

Figure 4 *Sediment Transport Capacities, Offshore Breakwaters*

450 m long groin

Another alternative was the construction of a 450 m long groin at the northern side of Scheveningen Beach. This would prevent the build up of the transport gradient due to the shoreline orientation. The simulations show (Figure 5) that indeed positive results for the beach development are to be expected. The redistribution of sediment due to the local gradient will be prevented and part of the erosion of Scheveningen Beach will be shifted towards the north. This was one of the objectives of the study. A relatively wide dune area is located north of the Beach. Here, the opportunity exists to handle the erosion in a more flexible dynamic way. The construction of a long groin would result in a less frequent nourishment need. This predicted effectiveness of the structure was used to compute the cash flow over a long term period. In this way an economical comparison could be made to the present nourishment strategy including maintenance and re-nourishment needs.

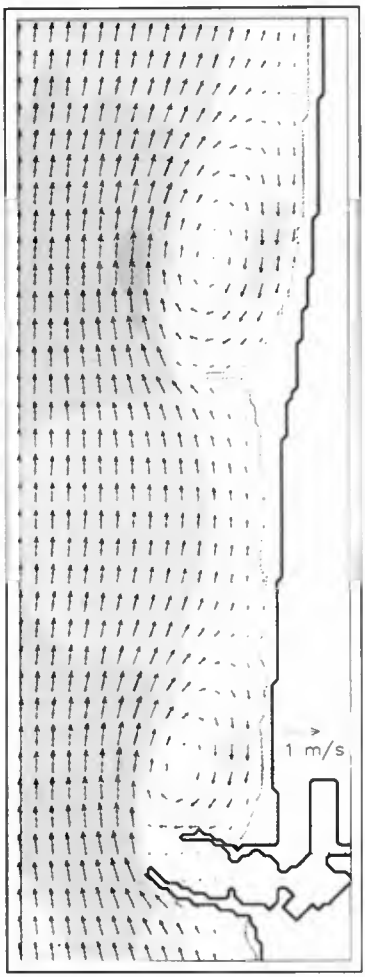

Figure 5 *Flow model result 450 m long groin*

COST COMPARISON

The long term costs of investment of the various beach maintenance schemes were evaluated by means of a Nett Present Value (NPV) computation (Pluijm et al., 1994). In this calculation all the costs of an alternative are capitalized over a period of 50 years. Construction costs, interest, inflation, maintenance but also the nourishment need (the results of the morphological studies) are taken into account in this analysis. The results of the NPV cost comparison are presented in Figure 6. It can be seen that with the present rates for sand it is economically more attractive to proceed with the present nourishment strategy. However, when the prices of sand would increase the construction of a long groin would then become an attractive alternative.

For this cost comparison the extra benefits for the local tourism industry have not been taken into account. The construction of a groin would result into two advantages over the beach nourishment strategy being (*i*) a more predictable development of the beach

(coastline stability) and (*ii*) a wider beach. In view of the recrcational function of the beach this is an important factor.

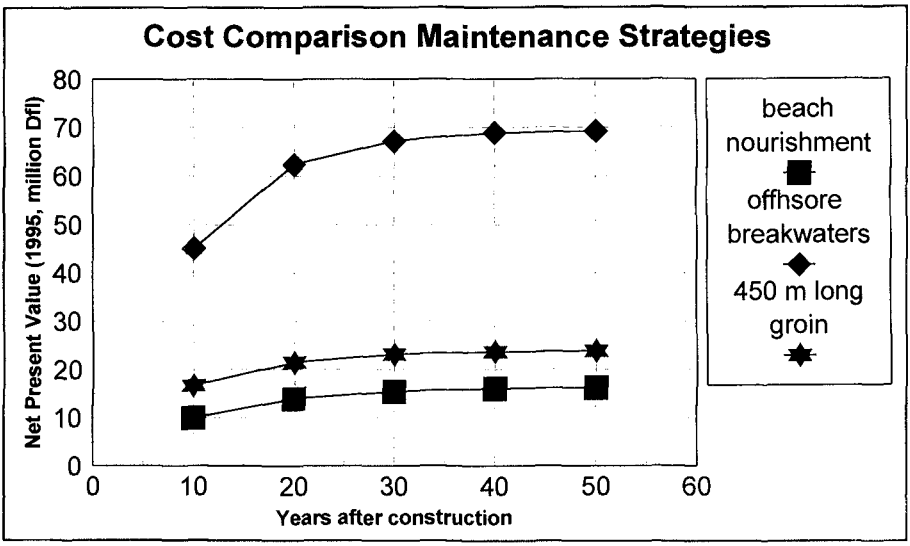

Figure 6 *Cost Comparison Beach Maintenance Strategies Scheveningen Beach*

CONCLUSIONS

Numerical models are of significant importance to develop insight and understanding of the role of each of the morphological processes. The models help to understand the development of a particular beach section, to define the governing processes and to indicate the beach developing sediment transport patterns. Based on this understanding of the morphological system a well-based assessment can be made of impacts of a structure on eaeh of the processes. In many cases this comprehension will allow a reliable prediction of coastline development.

In this paper the methodology has been presented which was adopted to compare alternative beach maintenance strategies. A key element in this evaluation is the nourishment need which will be required when one of the strategies is implemented and which is an important factor in the long term costs. It has been described how numerical simulations models were adopted to assess the morphological effectiveness of the alternatives. These results were then used as input for the cost evaluation resulting in a well based comparison of various beach maintcnance strategies.

ACKNOWLEDGEMENT

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