CHAPTER 150

BEACH AND DUNE NOURISHMENT IN THE NETHERLANDS
The Dutch Coast: Paper No. 11

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ABSTRACT
In the Netherlands up to the fifties of this century, dike and groyne building were the most important coastal defence measures. Because of the increased awareness of the importance of the sandy coast the demand for a more environmentally friendly coastal protection measure increased. However, artificial beach nourishment was very expensive. In the past two decades the costs of nourishment have decreased as a result of technical developments in the dredging industry, and erosion control by means of sandfills has become in general cheaper than the construction of groynes and dikes. In that period also large volumes of sand have become available from harbour extension and maintenance dredging. These have been the conditions that led to a new coastal defence method. Up till now nearly 50 beach nourishment projects have been carried out, with a total amount of 60 million m^3.
This paper provides a review of the projects carried out in the last 4 decades, with a description of the most important aspects.

1. INTRODUCTION
For centuries severe losses of land occurred along the Dutch coast. Besides local effects such as the shifting of tidal channels and periodical movements of the coastline, the main reasons for the coastal erosion were sea level rise and the effects of decreasing tidal volumes of estuaries. In former days the communal problems caused by coastline withdrawal were small, because of the low economic value of the dune area. The fishing-villages behind the outer dune ridges were simply replaced backwards. Only at some locations where flooding of the land was threatening, people tried to stop the erosion.
In the 19th century the interests in the coastal area increased. Because of the rising value of the land behind the dunes, keeping the land dry became increasingly important. Beach recreation arose, as did settlements for industry and housing. Also the awareness of the natural values and the use as drinking water reservoir increased. All these interests led to the construction of extensive groyne fields in the threatened coastal sections during

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the second half of the 19th century and the first half of the 20th century.

Since the main reasons for the erosion were not removed, however, the coastline withdrawal could not be fully stopped by groynes. In spite of successful applications of artificial beach nourishment to compensate beach erosion in the USA and in Germany, and the availability of the dredging equipment in the Netherlands, the long tradition of dike and groyne building resisted a new soft method of coastal defence. Only during the last 20 years is beach and dune nourishment being practiced more and more in the Netherlands as well.

After the severe storm surge of February 1953, which flooded large parts of the Delta area, new safety standards were developed and dikes were heightened. After intensive investigations on dune erosion during storm surges, leading to a guide-book for the testing of dune profiles, it appeared that many dune stretches had to be strengthened as well.

During the last 20 years, the experience with beach and dune nourishment has grown considerably and led in 1987 to the publication of the "Manual on Artificial Beach Nourishment". In 1988 and 1989 this experience was used in the Coastal Defence Study for the Netherlands (Louisse and Kuik, 1990).

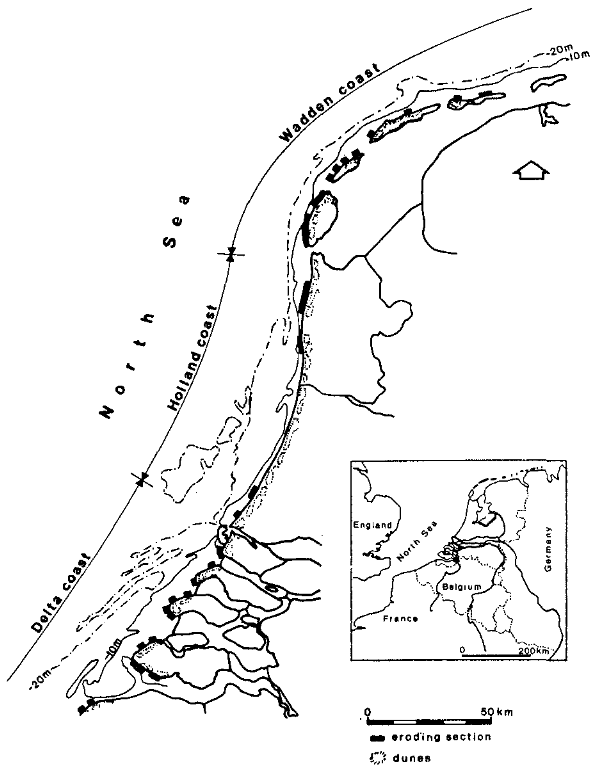

figure 1. The Dutch coast; erosion areas.

2. PROJECTS IN THE PERIOD 1950 - 1989

2.1. Locations, projects

In the Netherlands, 3 coastal types can be distinguished (fig.1):

- The Wadden coast with several tidal inlets. The coastal profile is rather flat, except in the neighbourhood of the ebb-deltas where deep tidal gullies occur. Some of the Wadden islands are protected with groynes.
- The Holland coast with some harbour entrances. The coastal profile is flat. In general the dune area is wide. At both ends of this coast where the dunes are narrow, the beach is protected by means of groynes.
- The Delta coast where most of the tidal inlets are closed. Although the shoals in the ebb-deltas protect the coast against severe wave attack, the shifting of the deep tidal channals caused much erosion. Along these channels very steep shore faces occur. Because of the narrow dune ridges most of the coastal sections are protected with groynes to reduce the coastline withdrawal.

In figure 1 the eroding coastal sections are marked. Figure 2 gives the situation with the nourishment locations. It is obvious that most of the sand fills are placed in locations with existing groynes. Table 1 gives a list of the projects up to and including 1989. In 1990 sandfill projects are running, at various locations, mainly to restore beaches and dunefaces after a period of storm surges.

In the period 1950 - 1989, the mean yearly amount of sand is 1.5 million m^3. However in the fifties and sixties the nourishment efforts were very small. In the period 1970 - 1989 the mean yearly quantity rose to 3.0 million m^3. In table 2 the nourishments are classified by volume. It appears that 67% of the projects had a volume less than 1 million m^3, whereas only one of the project quantities was greater than 5 million m^3 (the dumping of dredged material near Hoek van Holland). In 65% of the years the volume was less than 1 million m^3 or there were no projects at all. Four times the yearly volume succeeded 5 million m^3.

quantity ($10^6 m^6$)	year		project	
	number	perc.	number	perc.
0	40	100	-	-
>0	28	70	48	100
>1	14	35	16	33
>2	12	30	8	17
>3	7	18	6	13
>4	4	10	1	2
>5	4	10	1	2

table 2. Classification after volume.

2.2. Aims

In the Netherlands the major aims of sand nourishment are:

- Safeguarding the land against flooding.
  In the Netherlands the maximum failure frequencies of dikes and dunes have been established at 1/100,000 to 1/20,000 per year, depending on the expected damages.
- Protection of interests in the dunes.

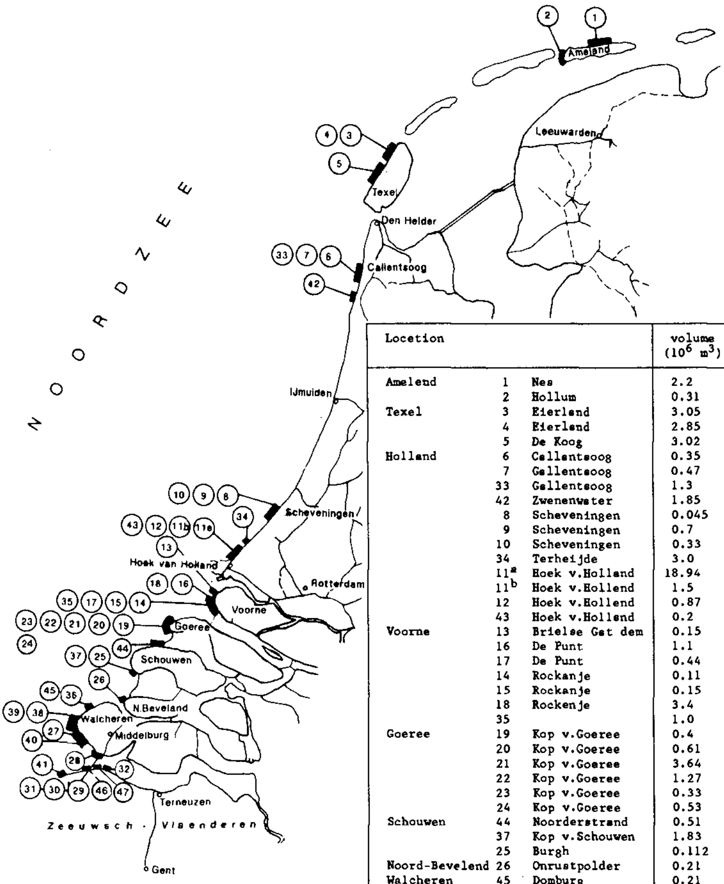

figure 2. Locations of beach nourishment projects.

Location			volume (10^6 m^3)	year/ period
Ameland	1	Nes	2.2	1980
	2	Hollum	0.31	1979
Texel	3	Eierland	3.05	1979
	4	Eierland	2.85	1985
	5	De Koog	3.02	1984
Holland	6	Callantsoog	0.35	1976-1977
	7	Callantsoog	0.47	1979-1980
	33	Callantsoog	1.3	1986
	42	Zwanenwater	1.85	1987
	8	Scheveningen	0.045	1969
	9	Scheveningen	0.7	1975
	10	Scheveningen	0.33	1985
	34	Terheijde	3.0	1986
	11^a	Hoek v.Holland	18.94	1971-1972
	11^b	Hoek v.Holland	1.5	1976-1977
	12	Hoek v.Holland	0.87	1977-1978
	43	Hoek v.Holland	0.2	1988
Voorne	13	Brielse Gat dam	0.15	1979-1980
	16	De Punt	1.1	1977
	17	De Punt	0.44	1983
	14	Rockanje	0.11	1974
	15	Rockanje	0.15	1974
	18	Rockanje	3.4	1984-1985
	35		1.0	1986
Goeree	19	Kop v.Goeree	0.4	1969-1970
	20	Kop v.Goeree	0.61	1971
	21	Kop v.Goeree	3.64	1973-1974
	22	Kop v.Goeree	1.27	1977
	23	Kop v.Goeree	0.33	1984
	24	Kop v.Goeree	0.53	1985
Schouwen	44	Noorderstrand	0.51	1989
	37	Kop v.Schouwen	1.83	1987
	25	Burgh	0.112	1975
Noord-Beveland	26	Onrustpolder	0.21	1973
Walcheren	45	Domburg	0.21	1989
	36	Domburg	0.23	1986
	38	Westkapelle	0.025	1988
	39	Westkapelle	0.41	1988
	27	Westkapelle	0.1	1984
	40	Zoutelande	0.15	1988
	28	Vlissingen	0.775	1952-1959
	29	Vlissingen	0.05	1952
	30	Vlissingen	0.032	1966
	31	Vlissingen	0.045	1975
Zeeuwsch-Vlaenderen	32	Breskens	0.206	1971
	47	Breskens	0.66	1989
	46	Groede	0.44	1989
	41	Cadzand	1.02	1988

table 1. Nourishment projects in the Netherlands 1950 - 1989.

Dune areas are valuable from an ecological point of view, but also represent interests for housing, industrial settlements and drinking water reservoirs.

- Prevention of further loss of land.
  Each year about 0.3 km^2 valuable dune area is being lost to the sea. This appears to be small, but most of the erosion takes place in those coastal sections with the narrowest dune ridges.
- Protection of beach recreational interests.
  Especially in areas where beaches are bound by dikes or dune foot revetments, beach erosion is detrimental to recreational interests.
- Creation of dump sites for dredged material.

From capital dredging, mainly for harbour extension near Rotterdam, large amounts of sand has become available and much of it has been applied to adjacent coastal sections. From regular maintenance dredging the sand is used for beach replenishment.
Figure 3 shows the yearly amounts of sand with an indication of the aims of the projects. It appears that of many projects the choice for beach replenishment had several reasons. Reviewing the main objective, the total volume can be divided as follows:

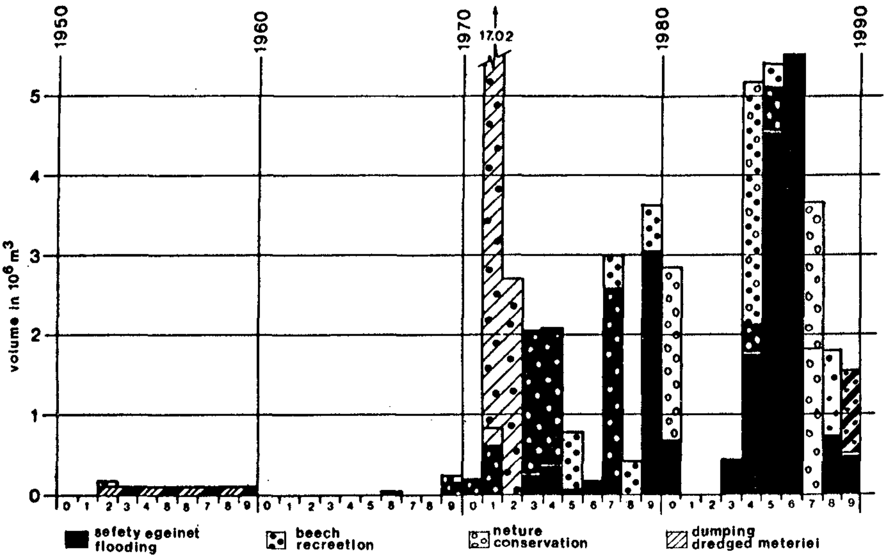

figure 3. Aims of nourishment projects.

Main objective	Volume	
safeguarding the land	24.6 million m^3	(40%)
nature conservation:	12.3 „	(20%)
recreational interests:	5.1 „	(9%)
dumping dredged material:	19.1 „	(31%)
	61.1 million m^3	

The first application of beach nourishment took place on the Walcheren coast in the fifties. Small amounts of sand from maintenance dredging were dumped on the foreshore and the shoreface to safeguard dune and dike revetments after beach erosion. In the period 1969 - 1971, sand fills were placed on the coast of Goeree to strengthen the dunes and to alleviate expected extra erosion after the closure of the tidal inlets. In the years after 1970 large amounts of sand became available from harbour extension works near Rotterdam. In 1971/72 a large part was dumped near Hoek van Holland, creating a recreational and natural area. In the seventies and eighties many nourishment projects have been carried out to strengthen dunes or to maintain their safety-level. Protection of natural values was mainly a secondary goal. Beaches were restored mainly for recreational interests in seaside resorts as Vlissingen, Scheveningen and Hoek van Holland. On the Wadden islands and in the northern part of the Holland coast large amounts of sand have been placed to conserve natural areas.

2.3 Design

In order to define the coastal problem, studies of the morphological processes and of the interests involved have to be carried out. If the problem is considered serious, the appropriate measure can be selected. After making a choice the project design can start.

The design of a nourishment programme mainly depends on the objective(s) and the coastal processes. In addition there are the circumstances for the execution, the aspects of landscape and the costs and benefits. Tools and methods for the design are:

Trend extrapolation. Based on the shoreline movements or lost volumes in the past, by means of curve-fitting an estimation is made of the coastal development in the years after the execution of a sandfill.

Equilibrium coastal profiles/ cross shore transport models. Calculations can be made for short term (dune erosion) and long term (equilibrium profile) profile changes. This is applicable to dune strengthenings and recreational beach nourishments. The effects of massive elements such as a dune foot revetment can also be calculated.

Coastal models. The analytical one-line and two-line models calculate the time dependent wave induced evolution in longshore direction. Two-dimensional coastal models can measure the influence of waves and currents. Presently, however, they are only suited for initial calculations. With both types of models, the influence of groynes and harbour moles can be taken into account.

In the Netherlands, measurements of the shoreline position have been carried out since the middle of the 19th century. Therefore trend extrapolation is the basis of the design of all projects in the coastal area. In the case of dune strengthenings, the dune erosion model (Vellinga, 1986) is used. In general this model is very usable. However the application presents problems in situations with a very steep foreshore or more than one dune ridge and at locations where a dune meets a dike.

Up to now the use of analytical and numerical models for coastline development in longshore direction has not become routine. Because of the complicated morphologic processes in the Dutch situation with tidal inlets and various types of groynes, it is not easy to find the dominant processes and to interpret model results. In most of the cases the sandfills are very long with respect to their width, so longshore deformation is rarely the most important process.

In the last decade the design practice in the Netherlands has been to derive the erosion volume from trend extrapolation and to use the dune erosion model in case of lack of safety. To compensate for dispersion, the volume needed at the seaside of the dune face was added with a certain percentage depending on the local situation. In situations with less tidal influence 25 to 50% was added depending on wave influence and the dimensions of the beach fill. At locations with a steep foreshore sometimes a surplus of 75% was applied. In some cases the choice of the percentage also was based on calculations with coastal models.
In general the textural properties of the borrowed sand were rather similar to those of the native sand. Therefore a fill factor or a renourishment factor based on grain size differences is hardly used.

2.4 Execution, borrowing and transport of sand

Whenever possible the sand was borrowed in the direct neighbourhood of the fill site at a location with a mild current and wave climate. The lowest prices were reached if the sand was pumped directly by the dredger to the shore. In some cases the sand was borrowed from other dredging operations such as harbour extension. In the past decade the possibilities of direct pumping decreased. The main reasons were less capital dredging, the fear for instability of the coastal profile and the prohibition of sand extraction in the closed tidal inlets.
In cases where a shipping channel had to be crossed, where the transport distance was very long or where the sand was borrowed from maintenance dredging, the sand was transported in hoppers. In some projects with small amounts stationary hopper dredgers (hopper volume 500 to 2000 m^3) were used in combination with a reclamation dredger near the beach. Generally trailing suction hopper dredgers (hopper volume 1500 to 8000 m^3) are used at present. Depending on the draught of the vessel, the depth at the mooring point on the foreshore must be MSL -5 to 12 m. Mostly a combination of a flexible floating pipe and a pipe on the bottom is needed for the transport through the surf zone. In case of a flat shoreface the distance can be so long that an extra source of power is needed (fig.4).
Originally the sand for dune strengthenings often was extracted in the dune area itself and transported by truck (fig.5). This process is not considered as nourishment and therefore is not mentioned in table 1. If the sand came by hopper from elswhere two main execution methods were used:
-At the back or on the top of the dunes.
With the use of bunds a depot on the beach was made. After some months of desalination the sand was transported by dumping-carts to the fill site.
-At the dune face.
With the use of bunds in 2 or 3 layers the sand was pumped up to a height of about 10 m above MSL.

In the future mining of sand only will be allowed seaward of the MSL - 20 m depth contour to avoid effects on coastal profile stability as much as possible. Exceptions are made for mining in shipping channels and locations where by means of the sand extraction a better morphological situation can be created.

figure 4. Mooring point at the Holland coast.

figure 5. Dune heightening and sandextraction at Walcheren.

2.5 Costs

The price per m^3 depends on many factors, for example: the amount of sand, the circumstances for the dredging operations, the transport distance and labour market tensions. Therefore it is impossible to obtain absolutely comparable data. Nevertheless a relation has been made between the m^3-price and the quantity of sand, in which the reported project costs have been indexed to a standard price level. Because of the strong labour market tensions, projects in the last 5 years are excluded. Also excluded are projects of which the sand was borrowed from other dredging operations. Figure 6 gives the relation between the sand quantities and the m3-prices, indexed to a 1985 price level. The following general conclusions can be made:

- The lowest prices per cubic meter were attained when relatively large amounts were handled, and by operations where the sand was directly spouted to the fill site.
- The most expensive method was that by which the sand was transported by hopper-dredgers and spouted either by the hopper itself or with assistance of a (barge unloading) dredger, or transported further by dump truck.

It should be remarked that before 1985 no big beach nourishment projects were carried out by means of hopper dredgers. Furthermore the equipment used by the hopper dredgers to bring the sand ashore was less developed than at present, so nowadays the price difference between hydraulic transport and water carriage probably will be less.

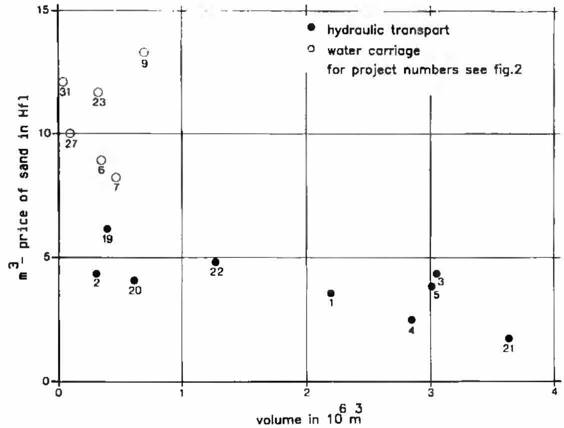

figure 6. Cubic meter price in relation to sand quantity.

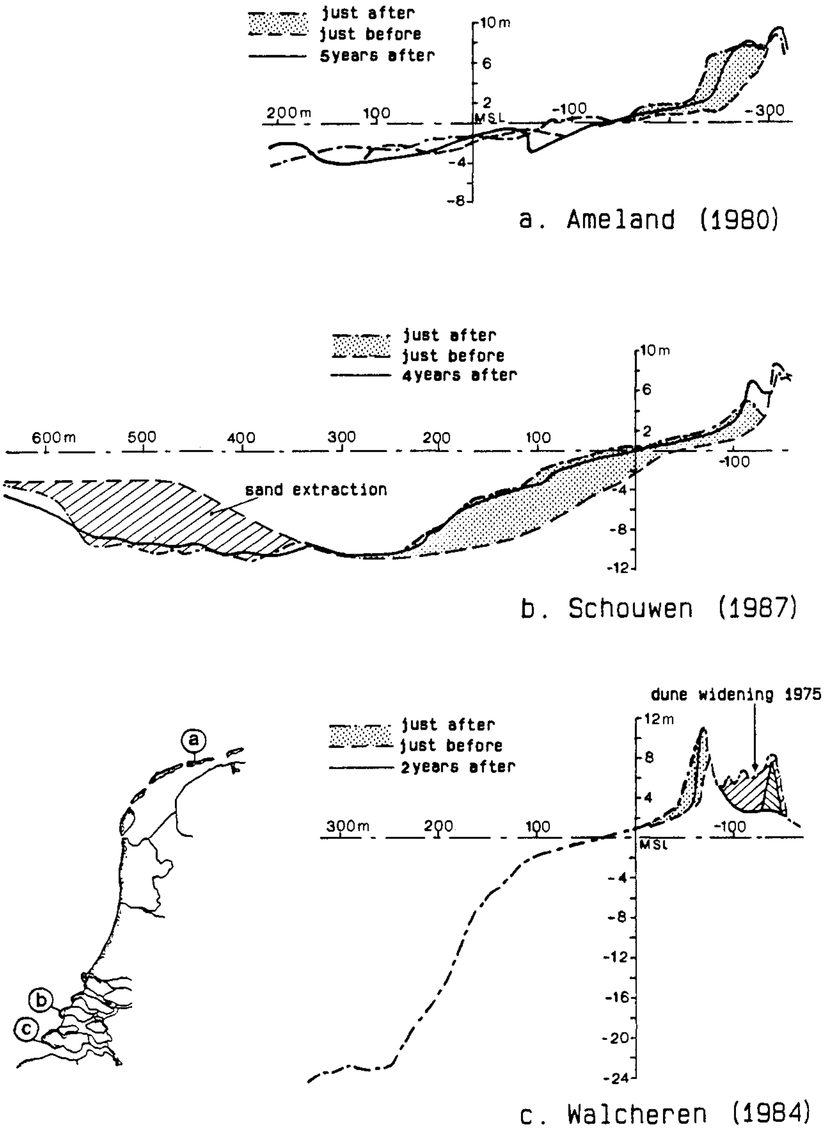

figure 7. Examples of cross shore profiles.

2.6 Examples

To get an impression of the applied types of sand fills in cross shore direction, in figure 7 profiles at some nourishment locations are shown.

Ameland.

Along the North Sea coast of the Isle of Ameland dune erosion occured during storm surges. To protect the valuable dune area, in 1980 6 km of the duneface of the outer ridge were restored with 2.2 million m^3 of sand. The main objective of this type of fill was to have the optimum protection with the available budget. After nourishing of course the profile was out of balance, so in the following years a natural profile was shaped.

Schouwen.

At the Schouwen coast the shifting of a tidal gully caused severe shoreline withdrawal over many decades. To protect the nature of the area and drinking water reservoir in the dune area, in 1987 in a stretch of 2.3 km the gully was artificially shifted in seaward direction. By a stationary dredger 1.5 million m^3 of sand was extracted from the edge of the shoal and pumped through a floating pipe to a pontoon at the shoreface. By means of a booster the shoreface was nourished. The beach was restored by the so-called "rainbow method" (fig.8).

figure 8. Rainbow system at the Schouwen coast.

Walcheren.

Over time the south-western coast of Walcheren was eroded by a shifting tidal channel. Although the erosion of the shoreface nearly stopped, dune erosion went on in spite of a dense groyne field. To maintain a sufficient safety level of the dune ridge, in 1984 a restoration of the backshore and the duneface was carried out. Because of the narrow beach and the fear for losses to the very steep shoreface only 0.1 million m^3 could be placed. The profile development was as expected and it appeares that the required safety level can be maintained by replenishment with intervals of about 5 years.

2.7 Environmental aspects

In general the environmental effects of artificial nourishment in the coastal zone are temporary. In case of sandfills against the duneface, percolation of salt water posed problems to dune vegetation or agriculture at some locations. The effects on the beach fauna were investigated on the Isles of Ameland and Texel (Dankers et al, 1983). It appeared that after 20 months the biomasses returned to a normal level. At the Schouwen coast the influence on the beach was negligible (Adriaanse and Coosen, 1990). In the borrow area there was a temporary influence. Though the benthic community was destroyed, within some months the area was taken over by pioneers and after a year a community had developed, belonging to the new habitat, that was very similar to the nearby gully. At Schouwen as an effect of the rainbow-system during some months, damage to the dune vegetation could be observed.

3. EFFECTIVENESS OF ARTIFICIAL BEACH NOURISHMENT

3.1 Evaluation.

To inform the Minister of Transport and Public Works about the possibilities of coast line maintenance by means of beach nourishment, 9 representative projects have been selected for an evaluation (Pluym, 1988). Figure 9 shows the locations of these projects. In general the aim of these projects was to compensate erosion, in some cases after a

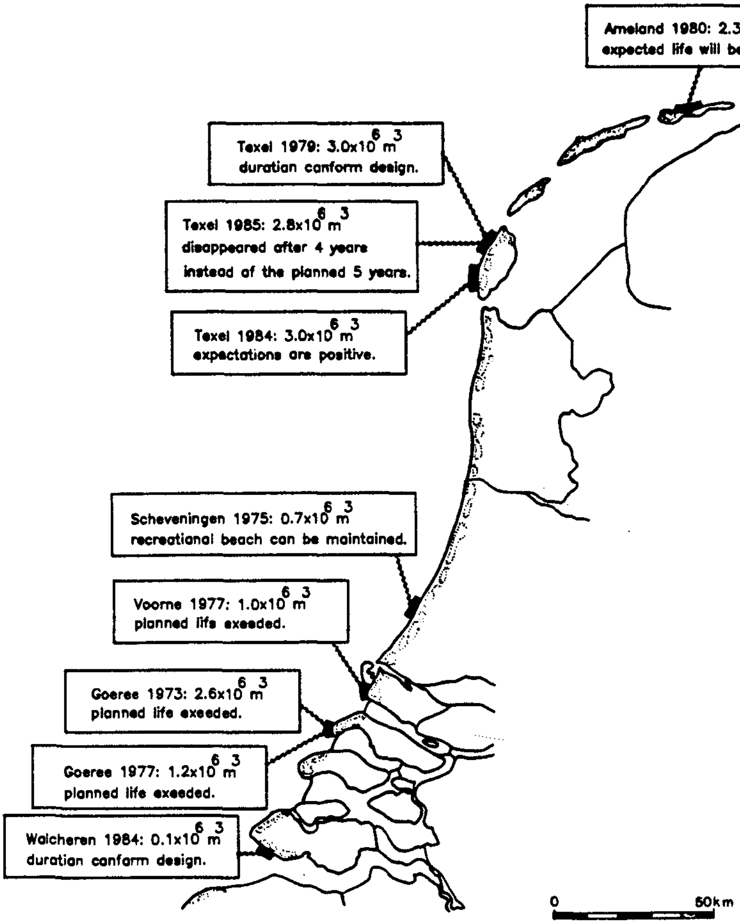

figure 9. Evaluated nourishment projects.

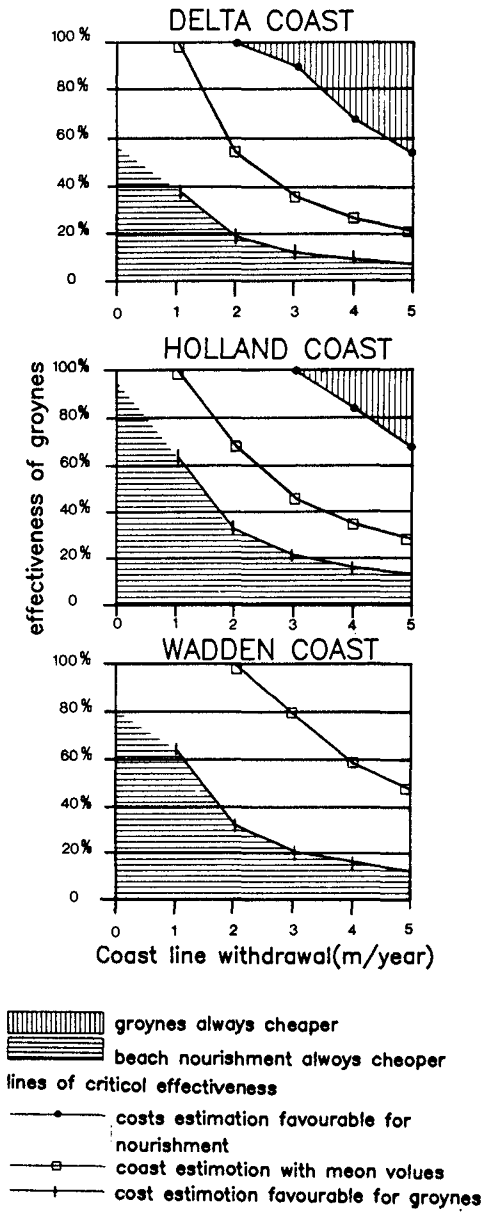

figure 10. Critical effectiveness of groynes.

dune strengthening. One project was carried out in order to create a better recreational beach. The criterium for the evaluation was: Was (or will be) the duration of life of the beach fill as expected?

The main conclusions are:

- 7 of the 9 evaluated projects were succesful and in one case the expectations are positive. Only one project did not meet the expectations. In the tidal inlet north of the island of Texel over a period of 6 years, a large amount of sand was extracted three times. This has likely influenced the behaviour of the 1985 sandfill at the adjacent coastal section. The nourished volume had disappeared after 4 years instead of the planned 5 years.
- It seems possible to design a beach nourishment with a planned duration of life, even in a dynamic coastal situation with a sometimes capricious morphological behaviour.
- Artificial beach nourishment is very effective as a measure for coast line maintenance.

3.2 Relation with groynes

To maintain the present shoreline, sand fills have to be repeated regularly and therefore can be expensive. However, in comparison to the capitalized costs of building and maintenance of groynes , nourishment for the most appears to be cheaper. Furthermore groynes cannot fully stop erosion, so supplementary nourishment is needed. On behalf of the Coastal Defence Study, a costs comparison has been made for several technical solutions for erosion control (Beafort et al, 1989). As an example figure 10

shows the calculated graphs for the 3 coastal types, with the critical effectiveness of new build groynes due to shoreline withdrawal.
The critical effectiveness is defined as the percentage of the erosion that has to be stopped by the groynes to make shoreline maintenance by means of new build groynes and additional nourishment cheaper than shoreline maintenance by nourishment alone. These calculations also have been made for scenario's with maintaining existing groynes and with removing them. Considering the supposed effectiveness of the groynes, the following situations are concluded:
a. Sandy coastline without groynes:
generally, the construction of just groynes is not advisable for reasons of effectiveness and costs;
in the delta area, where landward shifting of tidal channels presents erosion problems, a combination of groynes and nourishment may be cost effective.
b. Sandy coast with groynes:
existing groynes must be maintained for reasons of erosion control;
the costs of nourishing such a coast are relatively low compared to the costs of nourishment in case of removal of the groynes.
The costs of the construction and maintenance of groynes have been derived from prices reported by coastal managers. For future nourishment projects cost estimations have been made. The variable cicumstances for dredging operations along the Dutch coast imply various execution methods with different dredging equipment. Therefore the estimated costs per m^3 (on the beach) differ from Hfl 3.00 in case of large amounts and favourable circumstances, to over Hfl 10.00 in case of small amounts and unfavourable conditions. If the sand has to be transported from the beach into the dune area, the extra costs amount from Hfl 4.00 to Hfl 5.50 per m^3.

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