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Dynamic preservation of the coastline in the Netherlands

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Abstract. In 1990, the Government and Parliament of the Netherlands decided on a new national policy for coastal defence. To ensure the enduring safety of the low-lying polders as well as the sustainable preservation of the coastal dunes, it was decided to maintain the coastline in its 1990 position.

The main method for coastline preservation in the Netherlands is beach nourishment. Since 1991, approximately 7 million m^3 of sand is added to the Dutch beaches annually. From an evaluation study of sand nourishment projects it is concluded that nourishment is an effective and efficient method to preserve the coastline. The evaluation study also proves that nourishment projects should be 'tailor-made', taking the local morphological and hydraulic conditions into account. The first results of an experimental shoreface nourishment are discussed.

The choice for nourishment as the principal method to combat erosion is well in line with the intention to restore the natural dynamics of the dune-coast in the Netherlands. The key probably is a less strict policy with regard to the maintenance of the foredunes. Plans for the development of typical coastal features such as slufters*, wash-overs, blow-outs and mobile dunes are currently under discussion.

Keywords: Coastal dune; Coastal erosion; Coastline management; Natural dynamics; Sand nourishment.

Introduction

The Netherlands are among the most densily populated countries in the world. The country is protected from the sea by natural sand dunes and 11-14 m high dikes. Large rivers - Rhine, Meuse and Scheldt - are flowing through this low-lying area into the North Sea. In fact, the Netherlands are part of a large delta system which has been occupied by man ever since about 5000 years ago. At first, people lived on the higher elevated grounds such as beach barriers and river levees. Later they colonized the marshes behind the dunes. The new inhabitants drained the marshes and started a process of subsidence which is still going on since it started 20 centuries ago. For that reason they had to build mounds and - since 1000 years - dikes to protect themselves against flooding by the sea and the rivers. At present, more than 8 million people - about 60% of the Dutch- are living in their polders up to 6 m below mean sea level. Nevertheless, the country is considered safe from flooding by storm surges.

The Dutch have always been fighting the sea; often winning this struggle, sometimes losing. The last flooding disaster occurred in 1953, with more than 1800 casualties and a damage of approximately 14% of the gross national product. After this event the national parliament adopted new safety standards against flooding. These standards are defined in the Water Defence Bill which provides a basic legal framework for all coastal defence measures in the Netherlands. For the coast of central Holland, for example, the sea defences - dunes and dikes- are able to withstand a storm surge level which is exceeded only once in ten thousand years on average. For other parts of the coast lower safety standards apply, basically depending on the economic value - real estate, infrastructure - of the polderland.

The coastline of the Netherlands is approximately 350 km long; 254 km consist of dunes, 34 km of sea dikes, 38 km of beach flats and 27 km of boulevards, beach walls etc. The width of the coastal dunes varies between less than 200 m and more than 5 km. On the *uninterrupted* coast, in the western part of the country, the position of the coastline is more or less stable. Average erosion/accretion rates are limited to a few m per year. On the *interrupted* coast, in the north and southwest where (former) islands are separated by tidal inlets, the Dutch coast is more dynamic in character. Generally, erosion prevails on the central parts of the islands, and erosion and accretion patterns near the tidal inlets vary strongly in time. On the beach flats at the far ends of the northern islands, coastline shifts of more than 100 m per year are not uncommon.

Because of the importance of the coastal dunes as a

* A slufter is a breakthrough in the first dune-ridge whereby the sea invades former dune slacks or beach plains situated behind the dune-ridge. In this way a tidal marsh is formed within the dune zone.

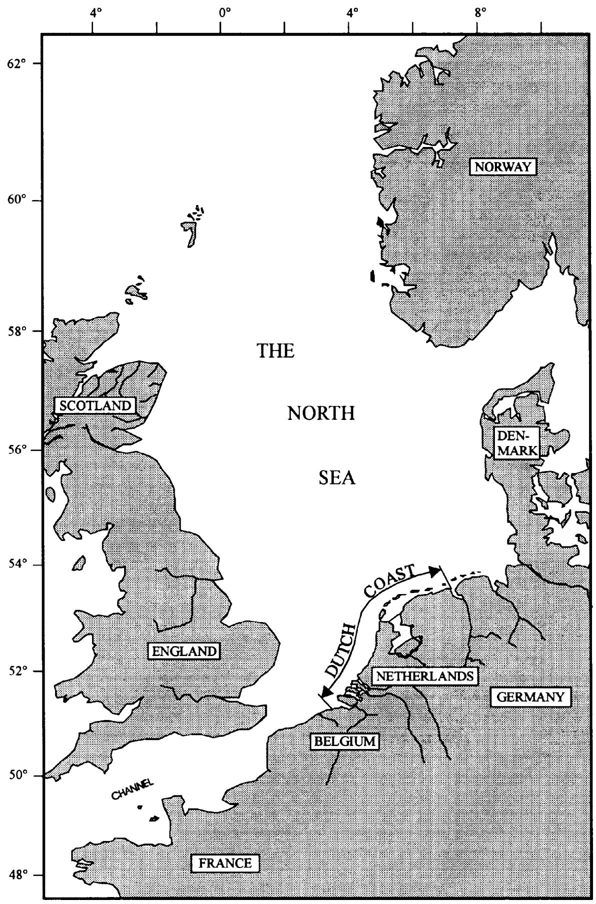

Fig. 1. Location of the Dutch Coast.

sea-defence and as drinking water resources, only a limited number of residential and industrial settlements were allowed in the past. In comparison to the coastal dunes in neighbouring countries, the Dutch dunes have kept much of their natural value. The entire area of coastal dunes is part of the *ecological main structure* of the Netherlands (Anon. 1990a).

Since the middle of the 19th century the position of the dune-foot and the high- and low-water lines have been measured every year. For this purpose, fixed reference poles - beach posts - have been set up on the beach at intervals of 200-250 m. Since the middle of the 1960s, the annual coastline measurements have been performed through a combination of remote sensing (onland) and sounding techniques (nearshore). At every beach post a coastal profile is measured, extending from approximately 200 m landward of the beach post to approximately 800 m seaward. The result of this annual coastal monitoring is a unique data-set available to all types of coastal research and evaluation (van Heuvel & Hillen 1992).

Examples of the application of the monitoring data are the sand budget studies of the Dutch coastal system on different temporal and spatial scales. Based on that information, shoreline predictions are made, indicating locations where accretion and erosion can be expected in the coming decades. Knowledge of erosion/accretion patterns is indispensable for combatting erosion effectively.

Aims

On the basis of a proposal by the Government, the national Parliament decided in 1990 on a new coastal defence policy: *dynamic preservation of the coastline*. Sand nourishment was selected as the principle method to combat all structural erosion of the coastline. The policy choice was directed at lasting safety against flooding by the sea and at safeguarding values (e.g. nature) and interests (e.g. recreation) on the beaches and in the coastal dunes.

Recently, the first evaluation report on *dynamic preservation* has been published (de Ruig 1995). Some major conclusions from the evaluation report are:

- Since 1990, structural erosion along the Dutch coastline has been brought to a standstill;
- In practice, sand nourishment appears to be an efficient method to combat erosion on the sandy coast of the Netherlands;
- The possibilities for restoration and development of natural dynamics in the coastal zone are not yet fully used;
- For a sustainable development of the coastal zone, methods directed at preservation of the coastline should be brought into a broader perspective. There is a need for a coastal *zone* management approach rather than a coast*line* approach.

During 1995, the results of the evaluation will be discussed throughout the country. The conclusions of this discussion will be summarized in a governmental document at the end of the year.

In this paper some aspects of the evaluation report are discussed. Emphasis is on two characteristic elements of the management of a sandy coastline: sand nourishment and natural dynamics. The experience gained in the Netherlands over the past years might be of interest to coastal scientists and managers of sandy coasts.

After a brief explanation on the policy of *dynamic preservation*, the results of evaluation studies on sand nourishment are discussed and an overview is given of the possibilities for the development and restoration of

year	nr	location	Mm³
1991	1	Texel - De Koog	2.0
	2	Callantsoog	0.5
	3	Petten	0.4
	4	Scheveningen	1.0
	5	Hoek van Holland	0.3
	6	Schouwen - Kop	2.5
	7	Westk. - Zoutelande	0.8
1992	1	Ameland -midden	1.6
	2	Den Helder	0.9
	3	Egmond - C'duin	1.5
	4	Hoek van Holland	0.6
	5	Slufterdam	1.1
	6	Domburg	0.7
	7	Zoutelande - Vijgeter	0.9
	8	Vijgeter - Vlissingen	0.2
1993	1	Terschelling - midden	2.0
	2	Texel - zuidwest	1.5
	3	Kijkduin - Ter Heijde	1.1
	4	Hoek van Holland	0.2
	5	's-Gravenzande	0.7
	6	Noord - Beveland	0.4
	7	Walcheren - Veerse Dam	0.2
	8	Walcheren - Oranjezon	0.1
	9	Breskens	0.1
1994	1	Texel - zuidwest	0.8
	2	Bloemendaal / Zandvoort	0.5
	3	Hoek van Holland	0.3
	4	Domburg	0.4
	5	Schouwen - noord	0.1
	6	Texel - Eierland	1.3
	7	Adornispolder	0.9
	8	Rijnland - zuid	0.7
	9	Ameland - west	0.2
	10	Bergen - Egmond	0.2
	11	Goeree - noord	0.5

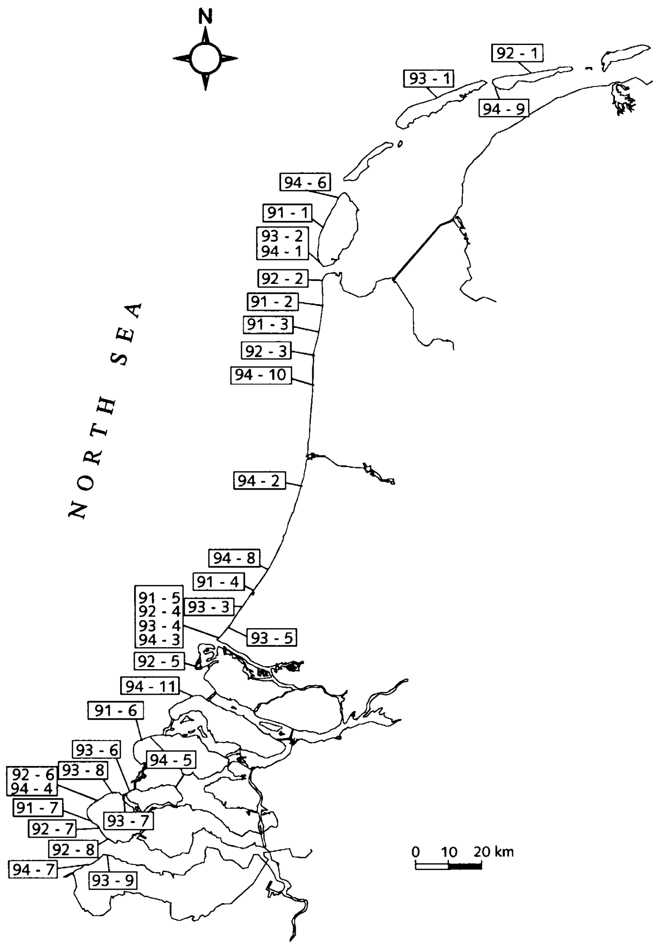

Fig. 2. Nourishment sites along the Dutch coast (1991-1994).

natural dynamics in the coastal dunes. In the discussion section at the end of the paper a look into the future is given: what are the challenges of *dynamic preservation* in the coming decades?

Dynamic preservation

Public discussion on a new national policy for coastal defence started in the 1980s (de Haan 1991). Until 1991 an ad-hoc policy was followed: measures were only taken when the safety of the polderland was at stake or when special values in the dune area – e.g. drinking water areas, nature reserves – were threatened. After the 1953 floods, the dikes and dunes along the North Sea were strenghtened to meet the required safety level, thereby ensuring the safety of the polders. However, if no measures are taken against ongoing coastal erosion, tens of kilometres of coast will become unsafe and hundreds of ha of valuable dune area will be lost every decade. An accelerated rise in sea level will enhance this problem even further.

In 1989, the *Discussion Document* on coastal defence was presented including four policy alternatives (Anon. 1990b):

1. *Retreat*: coastal recession will only be counteracted at those locations where erosion threatens the safety of the polders;
2. *Selective preservation*: intervention will not only be

pertinent to those locations where the safety of the polders is threatened, but also where major interests in the dunes or on the beach may be lost;
3. *Preservation*: the entire coastline will be maintained at its 1990-position;
4. *Expansion seaward*: at locations of concentrated erosion, artificial defences extending into the sea will be built, bringing coastal recession to a standstill. Elsewhere along the coast, the 1990-coastline will be preserved.

Benefits and costs for all policy alternatives were calculated for the period 1990-2090 (Louisse & Kuik 1990; Anon. 1990b). In 1989 and early 1990 an extensive public discussion was initiated among national, provincial and local authorities, scientists, environmentalists and other people concerned with the dune and beach areas. Out of the four policy alternatives the preservation alternative was almost unanimously preferred by all parties. This preference is not surprising, since giving up stretches of coast as a result of continuing erosion became more and more unacceptable in such a densily populated, low-lying country. In November 1990, the national Parliament decided in favour of the *preservation* alternative. This policy choice is primarily aimed at enduring safety against flooding and sustainable preservation of the values and interests in the dunes and on the beaches. To emphasize the wish for the preservation of the natural dynamics and character of the dune coast, the chosen alternative was specified and called *dynamic preservation*.

The policy choice in 1990 marked a new era in coastal defence policy in the Netherlands. The most important aspect of this choice is that from that moment onward all structural erosion of the coastline is to be counteracted. The 1990-coastline is the *basal coastline*, which should not be transgressed (Hillen & de Haan 1993). Until 1990, large sections of the Dutch coast were eroding, at some locations resulting in a retreat of 5 km in four centuries. From 1990 onward all structural erosion is counteracted, thereby creating a basic provision for other functional uses in the coastal area: e.g. housing, recreation, drinking water supply and nature. Another important aspect of the adopted policy was the choice for sand nourishment as the main method to combat erosion.

Sand nourishment

Sand nourishment has been a common measure to combat coastal erosion in the Netherlands since the end of the 1970s. When a nourishment project is carried out, sand excavated from the bottom of the North Sea (outside the – 20 m depth contour), is added to the nearshore zone (i.e. landward from the – 8/– 6 m depth contour). Over the years sand nourishment has proven to be an effective, flexible and financially sound method (Roelse 1990). Prior to the policy choice of 1990, sand nourishments were mainly carried out to repair the damaged coastline at selected locations. Since 1990, the nourishments are no longer repair works, but they are meant as a buffer: preventing transgression of the basal coastline. The sand is placed on the beach, thus creating a transient coastline in a more seaward position. The nourished sand forms a buffer against the ongoing erosion and will be placed on the eroding beach before the basal coastline is transgressed(van Heuvel & Hillen 1992).

Since 1990 about 7 million m^3 of sand has been added to the Dutch beaches annually (Fig. 2). For this purpose a yearly budget of 60 million Dutch guiders (35-40 million US$; March 1995) is available. In fact these costs can be considered the maintenance costs for the coastline. Just for comparison: the average costs for the maintenance of one km of sandy coastline is less than the average maintenance costs of one km of motorway (de Ruig 1995).

Early 1995 an assessment report on the policy choice

Table 1. Characteristics of the 10 nourishment projects for the evaluation study.

Project		Area characteristics			Nourishment characteristics			
		Tidal channel	Groynes	Breaker bars	Volume Mm^3	Mm^3/Mm^1	Design lifespan (yr)	Nourishment type
1. Ameland	1980			x	2.20	365	8 - 10	dunefront
2. Eierland	1979			x	3.05	510	5	beach/dunefront
3. Eierland	1985			x	2.85	480	5	beach/dunefront
4. De Koog	1984			x	3.02	500	10	beach/dunefront
5. Callantsoog	1986		x	x	1.30	440	13	beach/dunefront
6. Zwanewater	1987		x	x	1.70	400	15 - 20	beach/dunefront
7. Goeree	1977	x			1.27	420	5	beach/dunefront
8. Goeree	1984/1985	x			0.86	290	5	beach
9. Schouwen	1987	x			1.83	1080	5	beach/foreshore
10. Cadzand	1988	x	x		1.02	560	5	beach/foreshore

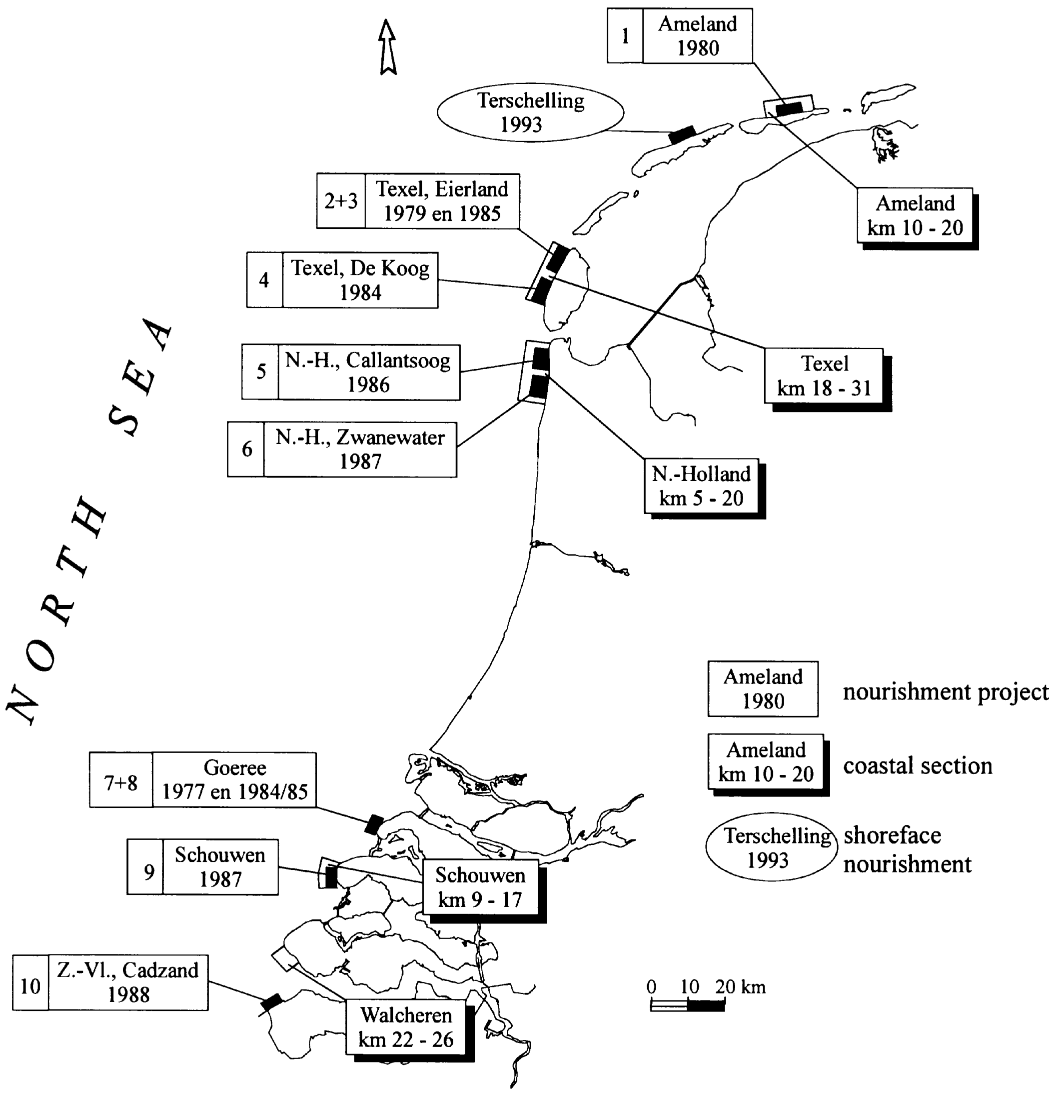

Fig. 3. Location of selected nourishment projects and coastal sections for the evaluation study.

for *dynamic preservation* has been prepared. Important contributions to this assessment report are the evaluation studies of the morphological aspects of sand nourishment (Roelse & Hillen 1993; Roelse 1995). The evaluation studies are concerned with both the performance of individual nourishments - at small temporal and spatial scales - and the combined effect of a series of successive nourishments at larger scales.

For the study of local effects, 10 'older' nourishments (prior to 1990) were selected on the criteria size, type of nourishment and geographical location (Fig. 3). The characteristics of the locations as well as the individual nourishments are given in Table 1. An impression of the different types of nourishments used in the Netherlands is given in Fig. 4. Nourishments performed later than 1990 cannot be evaluated yet as the experience time is considered too short and data-sets are limited.

The performance of a sand nourishment can be looked upon in different ways. A policy maker will judge the success of a nourishment in terms of effectiveness, cost-benefit and side-effects. A coastal manager is interested in the planning and budget aspects, design and monitoring. Contracters are interested in costs, technical execution and planning of the nourishment. Scientists look for opportunities to increase their knowledge of coastal processes.

For the evaluation study, the performance of the 10 nourishments has been described with scores on the following aspects: coastline preservation, erosion compensation, design method, effectiveness nourishment sand, beach width, volume dune erosion zone and dune foot stability.

Table 2. Overall results of the evaluation study of 10 sand nourishment projects (Roelse & Hillen 1993). For explanation see text.

Project	Result	Effort	Functions
1. Ameland 1980	++	++	++
2. Eierland 1979	+	-	+
3. Eierland 1985	+	+	+
4. De Koog 1984	-	-	+
5. Callantsoog 1986	+	--	+
6. Zwanenwater 1987	+	+	-
7. Goeree 1977	++		
8. Goeree 1984/1985	++		
9. Schouwen 1987	++	+	++
10. Cadzand 1988	++	--	++

++ = very good; - = moderate;
\+ = good; -- = poor.

The overall results of the evaluation study are summarized in Table 2 (Roelse & Hillen 1993). The nourishments, although performed before 1990, have been evaluated with regard to the aims of *dynamic preservation*, i.e. enduring safety against flooding and sustainable preservation of values of dunes and beaches. The score for 'result' indicates to what extent the coastline was held in place and whether the autonomous coastal erosion was sufficiently compensated. The score for 'effort' reflects the ratio between the volume of nourishment sand that has left the nourishment area and the volume of sand that would have left the same area if the nourishment would not have taken place ('autonomous erosion'). The score for 'functions' is a combination of the effects on beach width (recreation), maintenance of the sand volume in the dune erosion zone (flood protection) and dune-foot stability (nature).

For an impression of the effects of successive nourishments on larger temporal and spatial scales, the sediment balance of five coastal sections has been studied (Fig. 3). For these sections, the changes in sediment volume as well as the changes of the average coastline position over the period 1963-1993 are presented in Fig. 5. From this figure it can be concluded that in the Ameland, Noord-Holland, Schouwen and Walcheren sections the negative trends in the sediment balance could be stopped through successive nourishments. In the Texel section, the autonomous sediment losses could not be compensated entirely. The coastline recession could be stopped in all five sections.

From the evaluation studies the following conclusions have been drawn with respect to the policy of *dynamic preservation*:

1. On the dynamic coast of the Netherlands, sand nourishment is an effective method of coastline preservation which also serves other functional uses in the beach and dune area;
2. The application of erosion buffers next to the dune-front (*sand banquets*, Fig. 4) is only justified at locations with a moderate wave climate and deep tidal channels in front of the beach;
3. On larger temporal (decades) and spatial (10 km) scales, the rate of coastal erosion is not influenced by successive sand nourishments. However, on the scale of an individual nourishment project, dispersion leads to additional initial erosion. Based on the evaluation of 10 nourishment projects, 20 % extra sand should be added on average to compensate for this additional initial erosion;
4. From a financial point of view, nourishments with long lifespans (≥ 10 yrs) are not desirable. Nourishments with shorter lifespans (≤ 5 yrs) require smaller investments and can better serve local needs. However, other interests (e.g. nature) may profit from long-lasting nourishments because that means less disturbance of natural processes;
5. Nourishments should be tailor-made, taking local hydrodynamic and morphological conditions into account. Examples of tailor-made solutions are: frequent, small nourishments on coastal sections with groynes; sand-banquets near the dune-front on beaches with limited storage capacity; shoreface nourishment at locations with severe wave attack and little influence of tidal inlets; frequent, small-sized nourishments at locations where short-term morphological effects are unpredictable;

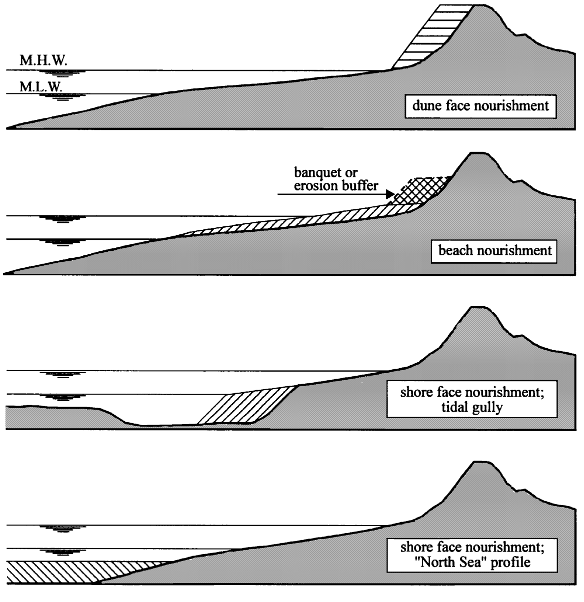

Fig. 4. Types of sand nourishment in the Netherlands.

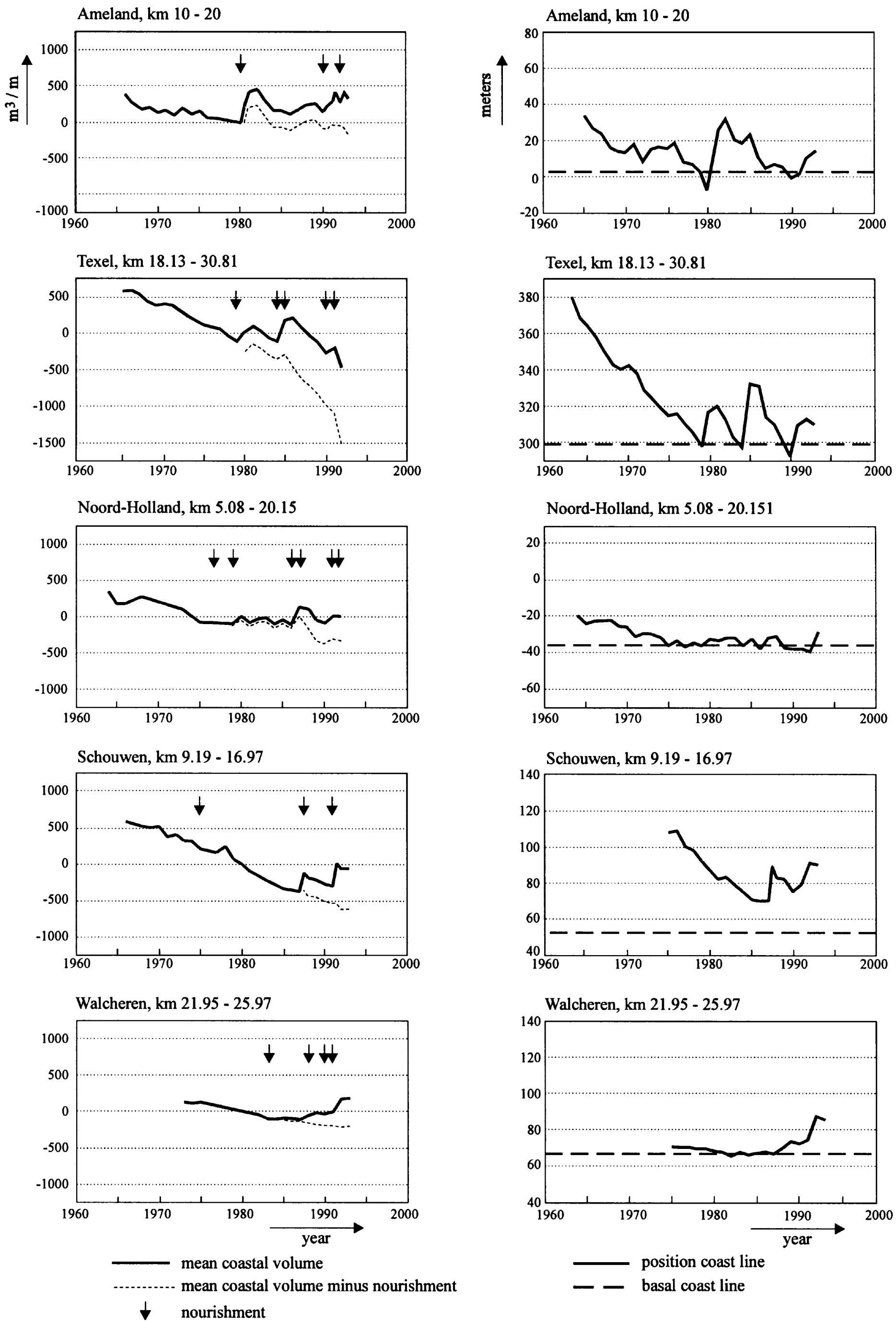

Fig. 5. Changes in sediment volume and coastline position for five coastal sections over the period 1963-1993 (Roelse 1995).

6. The ecological effects of individual sand nourishments, both at the borrow and nourishment site, seem to be of minor importance. Benthic communities recover in a few years. However, the ecological effects of repeated nourishments are up till now poorly known. A study of effects of nourishment sand on dune ecology has started recently.

In 1993 the first large-scale shoreface nourishment was carried out in the Netherlands. The aims of this experiment were to reduce the costs of execution and to minimize interference with recreational activities on the beach. Off the coastline of the island of Terschelling (Fig. 3), hopper dredgers dumped 2 million m^3 of sand at water depths of 5-7 m below mean sea level. In the same

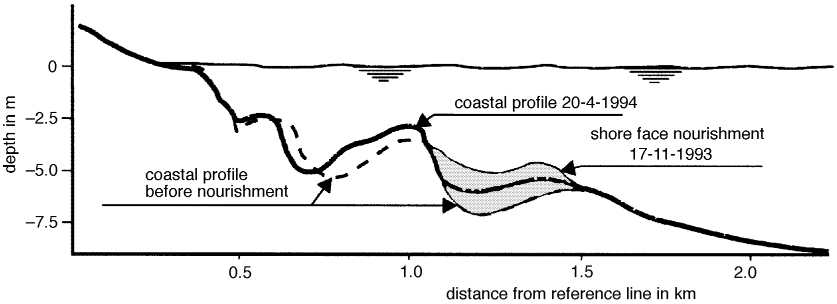

Fig. 6. Shoreface nourishment near Terschelling.

year comparable nourishments were performed in Denmark and Germany. With support of the Marine Science and Technology programme of the European Union, an evaluation study of the three experimental shoreface nourishments (NOURTEC: innovative NOURishment TEChniques) is carried out. The most important question of the NOURTEC study is: will a significant part of the nourishment sand be transported towards the beach?

The first indicative results of the Terschelling study are presented in Fig. 6. After the first storm season, a large portion of the nourishment sand (approximately 0.5 million m^3) was transported in a landward direction. The remaining part is still present at the nourishment site (Biegel 1994). Although the first results look promising, it is yet too early to draw definite conclusions on the Terschelling shoreface nourishment. The overall results from the NOURTEC study are expected by the end of 1996.

Natural dynamics

The coastal dunes of the Netherlands are of great scenic beauty and represent international biotic and abiotic values (Anon. 1992). However, over the centuries, the dunes have been affected by different types of human activities related to sea defence (e.g. intensive foredune management, planting of marram grass), drinking water extraction (e.g. infiltration of nutrient-rich river water, lowering of the groundwater table) and recreation (e.g. infrastructural and recreational facilities).

Given the fact that in a country like the Netherlands it is socially unacceptable to give up eroding sections of the coast, the majority of the nature conservation organisations and ecologists support the policy choice of preservation of the coastline and the choice for *soft* coastal defence methods, such as sand nourishment.

Several nature conservation organisations are now in favour of a less strict policy with regard to the maintenance of the foredunes. Suggestions for the formation of *slufters* -wet dune valley's influenced by the tides- and dune areas with more aeolian dynamics have been presented recently (Anon. 1992). This is well in line with the national Nature Policy Plan (Anon. 1990a) which identifies the coastal dunes as a part of the *ecological main structure* of the Netherlands. One of the action plans of the Nature Policy Plan is to safeguard the coastal dunes by providing a legal status for the entire Dutch coastal dune area under the Nature Conservation Act.

From the viewpoint of coastal defence, there are possibilities for natural development of coastal areas, but not everywhere and unconditioned. On the beach plains at the far ends of the Wadden Islands, where no population is threatened, no active coastal defence measures are carried out. The natural development of these areas is not interfered with as long as the islands remain intact.

For about 15 % of the length of the Dutch coast, the dunes consist of one single dune ridge. Here, the management aims at protection against flooding only through stabilization of the existing dunes. For the remaining dune areas a less strict stabilization policy could be considered as long as the safety of the polderland behind the dunes is not endangered.

In a reconnaissance study, the Ministries of Transport, Public Works & Water Management and that of Agriculture, Nature Management & Fisheries have identified foredune areas with potentials for nature development (Fig. 7). For this study several boundary conditions have been taken into account, such as minimum width and height of the dunes for coastal protection, minimum size of dune area to allow for undisturbed natural processes, and a minimum distance from urban centres and recreational areas to avoid annoyance by drifting sand (Anon. 1994a).

Nature development in the identified dune areas, which will often imply enhancement of natural characteristics through human manipulation, should eventu-

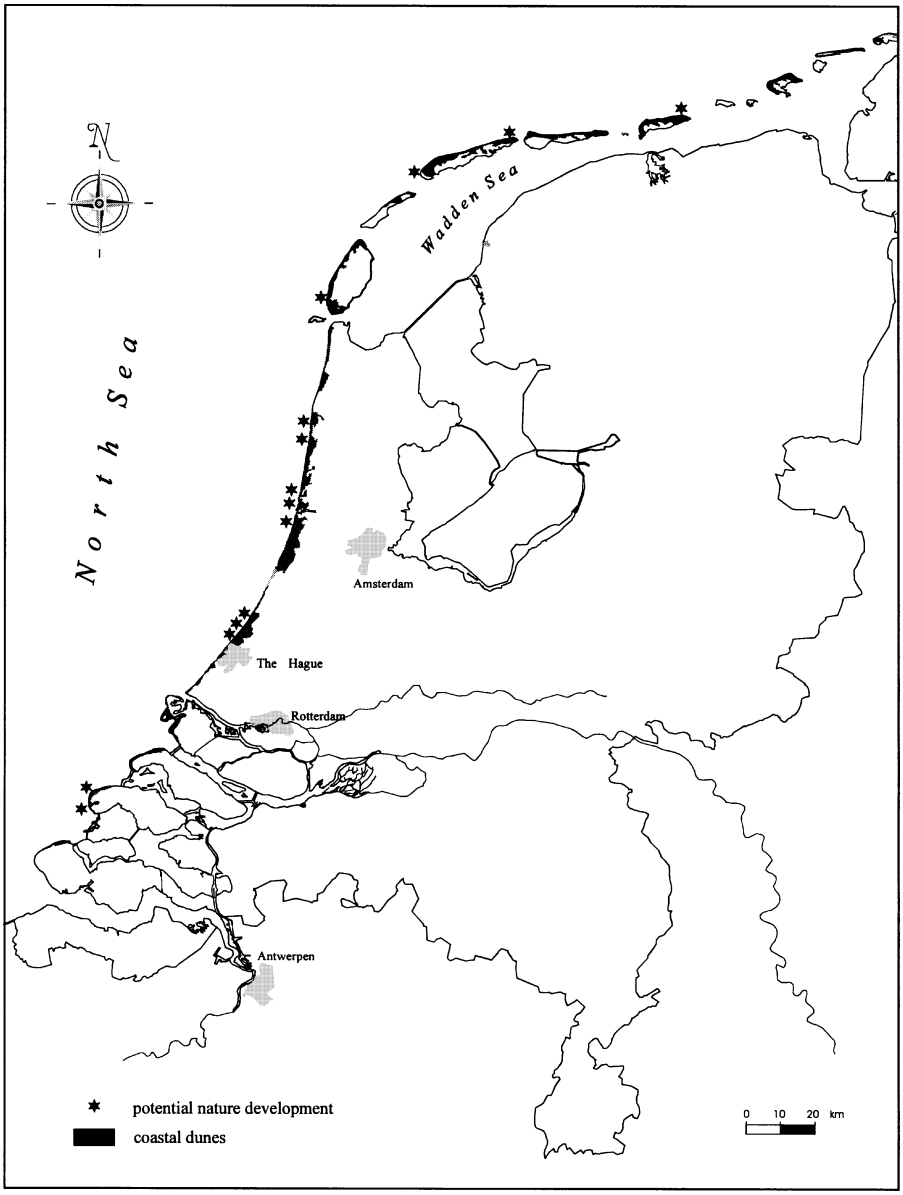

Fig. 7. Foredune areas suitable for nature development.

ally result in typical coastal dune features, such as:

- large-scale aeolian activities: sand drifts, blow-outs, mobile dunes;
- wet dune valleys with typical flora and fauna;
- slufters and wash-overs.

An increase of the natural values of the coastal dunes can only be achieved through a change in management of the foredunes. Up to now, the management at most locations is rather strict: blow-outs are covered to avoid sand drift, marram grass is planted to stabilize the foredunes and screens are placed to catch sand at the dune-foot. At several locations along the Dutch coast this has resulted in a straight 'sand-dike', which only vaguely resembles a natural foredune. Now that the national government guarantees the position of the coastline (*dynamic preservation*) there is no longer need for such strict foredune management at locations where the dunes are relatively wide. The key to the restoration of natural dynamics in the coastal dunes is to extensify management measures in the foredunes. Typical processes in the coastal dunes, often initiated by tides, currents and wind, usually start in the foredunes and proceed inland.

Experiments with dynamic foredune management

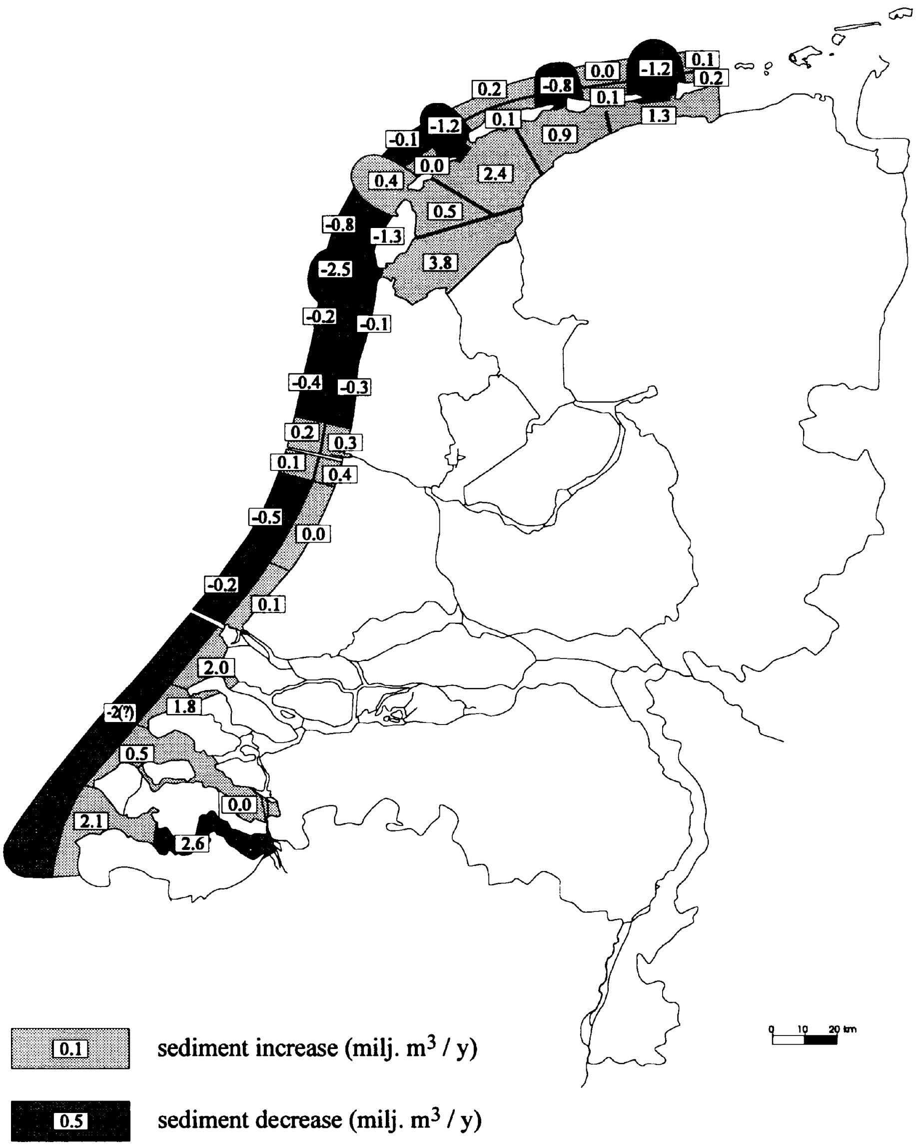

Fig. 8. Large-scale sand budget of the Dutch coastal system (de Ruig 1995).

are presently carried out at several locations on the Wadden Islands in the north of the country.

An increase of the natural dynamics in both the inner and the outer dunes can be achieved also through a more integrated management of the dune area. At present, certain zones of the dunes are set aside to realize the coastal defence requirements, other zones are nature conservation areas or drinking water supply areas. In the future, a more integrated management of the dune areas could be considered (van der Meulen & van der Maarel 1989). Integrated management of dune areas is aimed at larger management units and more room for natural processes.

Since 1990, studies on morphological processes in the nearshore zone (de Ruig 1995), and investigations on aeolian processes on the beach and in the dunes, have been carried out (e.g. Arens 1994). Knowledge on these processes is indispensable to estimate the opportunities for nature development in the coastal zone.

Discussion

Structural erosion of the coastline is the direct consequence of sand deficits in the nearshore zone. Over the past five years is has become clear that sand nourishment is an effective and efficient method to combat structural erosion. When a nourishment is carried out, sand from beyond the coastal system is added to the nearshore zone. On larger temporal and spatial scales, successive sand nourishments form the only structural solution for sand deficits in the nearshore zone. The sand for the nourishments is excavated at the bottom of the North Sea, at water depths of about 20 m.

In the past years, some *hard* coastal defence structures (e.g. dams, groynes) were built to solve local coastal erosion problems (de Ruig 1995). Although these structures may have been successful in solving *local* problems, they do not offer a structural solution to the sand deficit which always is the real reason for coastal erosion. Nowadays, *hard* coastal defence measures are only considered at locations with extreme rates of erosion.

In the period 1991-1994, approximately 7 million m^3 of sand has been added to the nearshore zone annually, enough to compensate the sand losses in erosive coastal sections. It is expected that 6 to 7 million m^3 will be sufficient to maintain the Dutch coastline in its present position for the coming decades.

This statement is confirmed by an assessment of the coastal monitoring results over the past 30 years, resulting in a *sand budget* of the Dutch coastal system between the – 8 m depth contour and the top of the first dune row (Fig. 8; de Ruig 1995). From this figure the following general conclusions can be drawn:

1. In the north there is a structural loss of sand to the Wadden Sea, several stretches of the North Sea beaches are eroding;
2. At the central part of the coastline -the *uninterrupted* coast- sand is being transported from the deeper part of the foreshore to the shallower part resulting in a steepening of the foreshore;
3. In the Delta area in the southwest, sand is deposited in front of the closure dams. As a result of shifting tidal channels close to the coastline, many beaches in the southwest of the Netherlands are subject to erosion.

Based on the assessment of the monitoring data and the sand budget, a prediction of the sediment budget of the nearshore zone for the coming 10 to 30 years has been made. It is expected that more nourishments will be necessary in the area bordering the Wadden Sea in the north of the country. The sand deficits in the southern areas are expected to decrease over the years. The results of the assessment are supported by the evaluation study of nourishment projects, indicating an increase of structural erosion on coastal sections in the north (for example the island of Texel, Fig. 5) and a decrease on southern sections.

It is important to notice here that sand deficits in the nearshore zone do not represent the total sand losses of the coastal system. At deeper water (– 8 to – 20 m), the foreshore and the ebb-tidal deltas in front of the tidal inlets show a distinct sand deficit, resulting in a steepening of the foreshore. In the longer term (40 to 100 years) this will lead to an increase in coastal erosion, especially if there will be an increase in sea level rise due to climate change. More research will be required to identify the best method to combat the sand deficits in deeper water.

Now that a choice has been made for the preservation of the coastline, sand nourishment is considered the best method to ascertain both the safety of the low-lying country against flooding by the sea and a more or less sustainable development of the coastal zone. Measures to maintain the coastline should be brought into a broader perspective, i.e. the long-term effects on the total coastal system should be taken into account. In the coming decades, the coast*line* policy will have to change into a comprehensive policy for the entire coastal zone. Coastal zone management (CZM) is the new keyword, and worldwide many initiatives on CZM are taken (Anon. 1994b). In the Netherlands, no comprehensive CZM-policy exists. But the national policies on physical planning and integrated water management, together with the national nature policy plan and the policy on *dynamic preservation*, form powerful tools for sustainable development of the coastal zone.

Together with rivers and estuaries, coasts are among the most dynamic natural systems on Earth (Anon. 1994b). A healthy coastal system is a dynamic system. When the natural dynamics are threatened, the possibilities for a sustainable development of the coastal zone decrease. It is therefore necessary that all human activities in the coastal zone are judged on their long-term effect on natural dynamics. If adverse effects are expected, compensating measures should be asked for. Examples of compensating measures could be: safeguarding coastal wetlands from human intervention, establishment of shallow marine nature reserves or initiating nature development projects in the coastal dunes.

In the Netherlands, opportunities for restoration and development of the natural dynamics in the coastal system have not yet been fully used. Initiatives for nature development in dune areas are important to increase the natural dynamics of the coastal system. An integrated management of dune areas could also be a step forward in creating more room for large-scale morphological coastal features, such as slufters and mobile dunes.

Developments that are considered harmful for a natural development in the dune areas can possibly be prevented through legislative action. As a follow-up of the national Nature Policy Plan (Anon. 1990b), steps are taken to bring the entire coastal dune area of the Netherlands under the Nature Conservation Act by the year

1998. In this way, the ecological and scenic beauty of the Dutch coast which is unique in Europe, can - at least for a large part - be safeguarded.

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