PART IV

The Dutch Coast

CHAPTER 140

COASTAL DEFENCE ALTERNATIVES IN THE NETHERLANDS

The Dutch Coast : Paper No. 1

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Abstract

Coastal defence is an important issue in the Netherlands since more than half of its territory is situated below sea-level. Coastal erosion causes a permanent threat for this largely natural system. As a consequence flood-protection of the polderland may not everywhere be sufficiently guaranteed in the future. Besides dune area with valuable interests may be lost. These problems will worsen due to sea-level rise.
In 1987 the minister of public works instructed to perform a study to identify these problems and to develope alternatives for an overall coastal defence strategy in the Netherlands and to determine the effects of implementation of the alternatives over a time interval of several decades. The impacts of 4 alternatives have been determined with a policy analysis model, which has been especially developed for this purpose.
Model calculations indicate that the more (structural) measures for coastal defence are taken the less are the losses of dune area and the higher the costs. As time proceeds (up to 2090) the differences in costs between the alternatives decrease, while losses for some of the alternatives rise highly. Accelleration of sea-level rise results in an increase of costs and losses of dune area. A remarkable increase of impacts shows up when a change in wind climate is introduced.

Introduction

About one third of the Netherlands is situated below sea-level and would be flooded if it was not protected by the coastal defence system. This defence system is composed of three major units: in the south the Delta coast, consisting of (former) delta's and islands; between Hoek van Holland and Den Helder a stretch of coast not interrupted by tidal inlets (the Holland coast) and in the north the Wadden Island coast, consisting of a series of coastal barrier islands with tidal inlets in between (Figure 1). The defence system consists of dunes and dikes protecting the polders, and dams closing off large tributaries (Delta coast). The last have been constructed during the last decades (Delta works). In this period, which ends in 1990, also the defence system of the dunes has been improved. This leads everywhere along the coast to an accepted level of flood-protection. This flood-protection level is expressed as the frequency of exceedance of a storm surge

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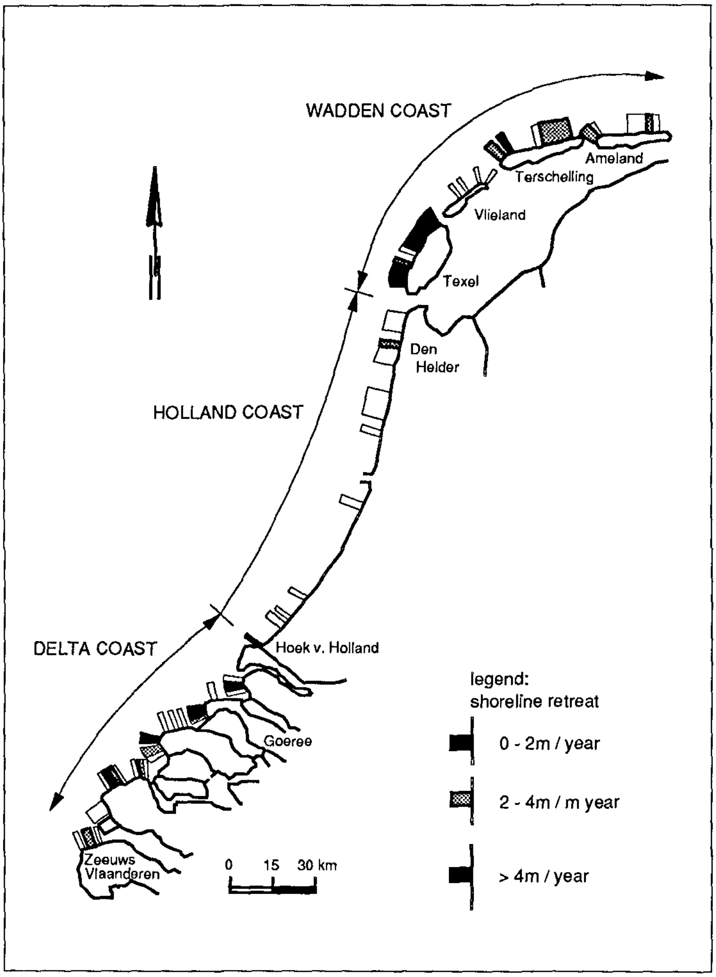

Figure 1. Pattern of erosion and erosion rates along the Dutch coast.

water-level (see Figure 2); dune dimensions are designed in such a way that collapse in these conditions may occur once of a hundred times.

Apart from flood-protection which up till now is the most important function of the dunecoast, the dune area covers a number of communal functions and interests, which also are worthwile maintaining: drinking water supply, recreation, housing, and such like. Moreover the dune area as a whole is being considered as a very valuable natural landscape. It is one of the largest more or less continuous dune areas of Europe with a specific status of protected nature area.

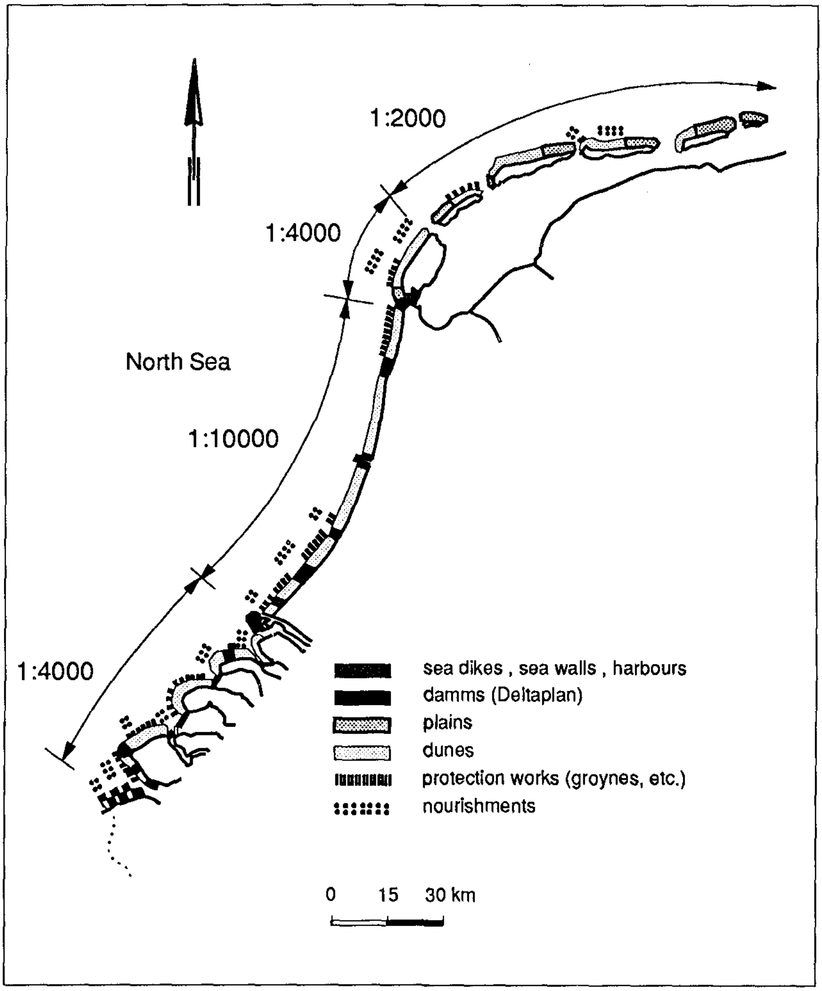

Figure 2. Coastal defence along the Dutch coast and the level of flood-protection along the coast expressed as the frequency of exceedance of a storm surge water-level

However, shoreline retreat due to coastal erosion at various areas along the coast constantly threatens the defensive force of the dunecoast and leads to a loss of valuable dune area. Figure 1 shows the main erosion areas to be situated in Delta and Wadden coast. With the present-day coastal defence policy this process is not being prevented or stopped. The present-day policy is confined to regular maintenance and reinforcement of coastal stretches with a weak defence with sand nourishments. As a consequence at many places shoreline retreat proceeds. Besides, climate changes due to the Greenhouse-effect may worsen or speed up this process.

The major question concerning coastal defence is how to guarantee the level of flood-protection in the future under conditions of continuing shoreline retreat and the threat of an accellerating sea-level rise and climate change. Coastal defence efforts must also as much as possible prevent further loss of dune area and the interests in this area. To investigate precisely the problems of forthcoming coastal erosion under the present-day coastal defence policy and to develope and evaluate new approaches for a coastal defence policy, a policy analysis study of the Dutch coast was performed. In this study three scenarios of sea-level rise are considered: the present-day sea-level rise (20 cm/century), the expected scenario (60 cm/century) and the pessimistic scenario (85 cm/century). The pessimistic scenario also includes a change in wind- and wave-climate (10 % increase of wind force, 10 degrees change of wind direction)

This paper describes the method of the study and presents the results. The study results in a comparison of 4 alternatives for coastal defence.
The policy analysis study has been described in a final report (Rijkswaterstaat, 1989) and in 20 technical documents. Some of these technical studies are presented on this Conference in the session "The Dutch coast". The state-of-the-art of knowledge of coastal development in the Netherlands is described by Zitman et al. (1990), Hoozemans (1990) and Van Vessem et al. (1990). Model analyses and studies on coastal prediction are described by Roelvink et al (1990), Steetzel (1990), Dijkman et al. (1990), Eysink (1990) and Stive et al. (1990). Techniques and strategies for coastal defence are described by Roelse (1990), Van Alphen et al (1990) and Pluym (1990); Terwindt et al. (1990) conclude with a description of implications for future coastal research. Thanks to former and recent coastal research programs like Coastal Genesis and TOW, data and models needed for this study, could be adequately obtained.

Analysis method

The study focuses upon the part of the coast which protects hinterland; dams in the tributaries of the Rhine-Meuse delta are not considered. This part of the coast with a total length of 353 kilometer shows various types of defence against the sea (Figure 2). The dunecoast covers a length of 252 kilometer, 34 kilometer consists of dikes and 27 of other constructions (boulevards, sluices, etc.). The remaining 38 kilometer concern beach plains, located at the extreme ends of the barrier islands of the Wadden coast. These plains do not protect polderland and are merely nature areas.

Since dikes and other constructions are considered as fairly immobile, representing coastal stretches with a fixed coastal defence system at a sufficient level, they are just of marginal importance in this study. From the point of view of flood-protection beach plains are not interesting as well: they do not protect polderland. Concerning nature these plains are most interesting when they can freely develope, thus when coastal management is not too strict. The most interesting part of the coast in this study is therefore the dunecoast.
The main characteristics of the policy analysis study of the dunecoast are on the one hand the sand economy of the coastal morphologic system and on the other the use of the coastal area for communal functions. Both are depicted in the scheme of figure 3. The sand economy describes the movement of sand at large spatial (and temporal) scales and identifies the areas of accretion and erosion and the resulting shoreline movement.

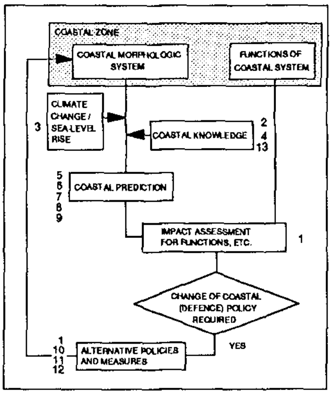

Figure 3. Policy analysis scheme

Evaluation of this shoreline movement (prediction) provides information on future shoreline positions and enables the assessment of the impact on functions of the dunecoast: flood-protection and dune interests. Confronting "autonomous" shoreline behaviour with functions of the dunecoast results in a quantification of the problems, that can be expected when no measures against shoreline retreat are taken (problem analysis).

When this confrontation leads to an undesired number of potential problem's solutions must be developed. For each problem observed, different solutions can be considered, but this leads to ad hoc approaches. A structural approach was needed and led to a process of developement of alternative strategies. These strategies were transferred into a coherent set of measures for coastal defence along the entire coast: alternatives.

Given the alternative policies, next step in the analysis is to run through the scheme again to evaluate the impacts (benefits and costs) of these alternatives. Now the position of the shoreline as a function of time is not just determined by the prediction of the "autonomous" displacement of the shoreline, but also by shoreline behaviour imposed by the coastal defence alternatives. This identifies the places along the coast where measures are needed. The costs of these measures are computed. Where measures are not necessary, while the shore retreats losses of dune area are calculated.

Both for identification of the problems, and especially for the assessment of the impacts, the need for a policy-analysis model was felt. This model, KUSTBEL, enabled analysis of a variety of alternatives with a high resolution along the coast (1 kilometer) for different scenarios of sea-level rise and met the need for sensitivity-analyses for a number of parameters that greatly influence the final results.

In the scheme of figure 3 the technical studies, that have been performed to support the policy analysis study, are indicated by the numbers, which have been given to the papers in the session "The Dutch coast".

The main cause of problems: coastal erosion

Shoreline retreat is caused by coastal erosion. Coastal erosion shows up in two ways, which are clearly related to each other: the sudden, fairly local event of storm erosion and the more gradual chronic erosion. In the first case high water level and waves during storm surges can locally result in a sudden loss of sand from the duneface. The storm erosion will result in a structural loss of sand from the coast on a stretch of coast suffering chronic erosion, because the dune sand will (partly) be used to replenish the sand deficit of the shoreface. Accreting coastal stretches may initially show a serious damage due to storm erosion, but this will be followed by a gradual restoration of the original dune profile in course of time.

Although more gradual and global, chronic erosion at the long run is much more threatening for the dunecoast than loss of sand from the dunes due to storm surges. Due to an often very subtile mixture of hydraulic processes residual transport of sand bodies from one place to another takes place and results in accretion at one place and erosion at others. Long-periodic changes in erosional and accretional processes also occur and result in periodic fluctuations of the shoreline with periods of tens of decades (Verhagen, 1988).

Procedure for problem identification

The problems which arise as a consequence of shoreline retreat are twofold: the threat for flood-protection and for loss of valuable dune area. Problems with flood-protection are concentrated on coastal stretches with a relatively narrow dune area; problems concerning loss of valuable dune area mainly concern wide dune areas.

Flood-protection

The entire coastal profile from shoreface to the landward boundary of the dunes is of interest for the safety of land behind the dunecoast; this whole area determines the strength of the coastal defence system. Mostly the main defence is formed by shoreface, beach and the first dune row, the front dune. The strength of this defence-system can be calculated for each profile and compared with the required strength, derived from design instructions (Vellinga, 1986). The strength is expressed as a dune-width, the storm erosion width A in figure 4. A is the distance from the dunefoot to the point O to where, due to the design storm surge sand from the front dune has been removed (see figure 4). This width A is determined by the assumption that the loss of sand from the duneface during a design storm surge equals the amount of sand that (according to the local geometry) can be placed on the profile of beach and upper shoreface (Vellinga, 1986). Besides some additonal loss must be anticipated, leading to an increase of A to AT (point P). Connecting all points P along the coast leads to the 'storm erosion-line'. The minimum width in a selected profile must at least equal AT plus a residual width (and height) of the "residual profile". When due to shoreline retreat the front dune has become too narrow to contain AT plus the residual profile, reinforcement of the front

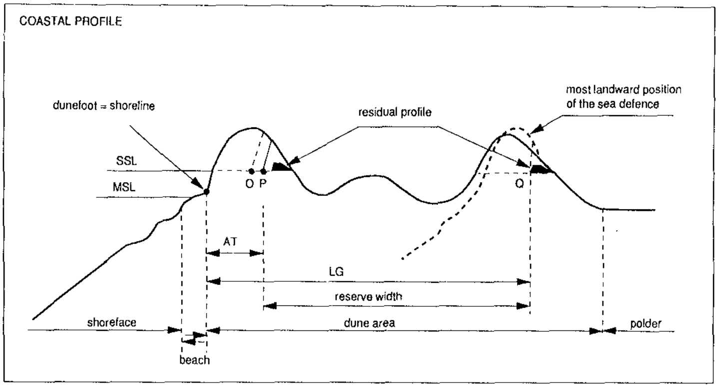

Figure 4 Schematic cross-section of the coastal defence area with definition of the procedure for evaluating problems with flood-protection.

dune is necessary. At present this is often realised by adding sand to the landward side of the front dune, either by activating the natural process of sand blowing or by mechanically replacing sand to the backside. This process results in a narrowing of the dune area. Eventually the dune area may be narrowed to a minimal defence system, consisting of just one row of marginal dunes (AT plus residual profile) at the landward edge of the dune area. Since further landward movement of this row of dunes into the polder is not admitted, potential problems for flood-protection arise when this situation is reached.

In fact at many places along the coast shifting of the defence up to the landward boundary of the dune area is not possible, simply because there is no sufficient volume of sand to contain the residual profile (a height of 2-3 m above the design storm surge level and a width of approximately 25 m). Therefore the ultimate point in the profile to where the backside of the coastal defence (point P) may be retreated is defined as the point (Q) at the landward side of which just the residual profile (related to the local storm surge design level) can be 'constructed' (figure 4). Connecting these points Q along the coast results in a 'most landward residual profile-line', the Q-line. There may be no gaps in this line along the coast. Given this Q-line and the P-line of potential storm erosion damage, the reserve-width for shoreline retreat with respect to flood protection is defined as the distance Q - P. This distance is known for every kilometer of coast.

To evaluate the conditions of flood-protection of the coast it is assumed that the shape of the front dune does not alter in time, even not when the shoreline retreats. When shoreline development as a function of time is known (Stive, et al., 1990), the evolution of the reserve-width due to shoreline development can be identified for every kilometer of coast. Potential flood-protection problems (when the reserve-width equals 0) can now be determined.

Loss of dune area with interests and nature

The economic interests and the nature values of the dune area are presented in table 1. Both economic interests and nature are partitioned to enable a distinction in appraisal within the interests (see table 1). This enabled a more refined analysis. For instance, various levels of appraisal of nature areas are distinguished, so that not just potential

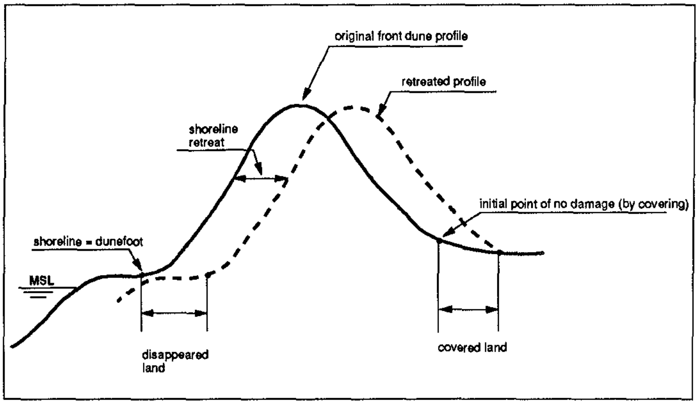

Figure 5. Schematic picture of the effects of shoreline retreat on interests in the dune area.

loss of nature area in general can be determined (which in fact is nearly the entire dune area), but also more specific potential losses of nature values.

	Effects of shoreline retreat		
Function/ Subfunction	Disappearing	Covering	Lowering Ground water table
Nature			
. Wet primary and secondary dunes, moors	+	+	+
. Dry primary dunes	+	+	+
. Dry secondary dunes	+	+	-
. Beach and beach plains	+	-	-
. Remoulde dunes	+	-	-
Water supply			
. Production facilities	+	+	-
. Infiltration infrastructure	+	+	+
. Discharge area	+	-	-
Housing			
. 50% builded	+	+	-
. 10-50% builded	+	+	-
. % builded	+	+	-
Recreation			
. Campings, recreation houses	+	+	-
. Sports-ground	+	+	-
Industrial areas			
. Large plants	+	+	-
. Small facilities	+	+	-
Diverses			
. Infrastructural works (harbours)	+	+	-
. Agricultureal areas	+	+	+
. Military area	+	-	-

Table 1. Sensitiveness of the (sub)functions of the dunes for effects of shoreline retreat (+ = sensitive; - = not sensitive).

Shoreline retreat can threat the interests of the dune area in different ways. Direct and indirect effects are distinguished. Direct effects of shoreline retreat are directly caused by coastal defence ma-nagement and concern (see figure 5):

- a loss of land and the interests accomodated on this land due to displacement of the shoreline (**disappearing**).
- due to shoreline retreat the backside of the front dune must be reinforced to keep the front dune at strength; as a consequence interests located at the backside of the front dune will be covered with sand (**covering**). This may lead to a loss for some interests as for instance housing, recreation, etc.
- shoreline retreat leads to a lowering of the groundwater-table. This may cause damage to nature areas and to groundwater-reserves.

Indirect effects of shoreline retreat are caused by the displacement of the front dune due to coastal defence management measures:

- extra blowing of sand caused by damage of the vegetation of the front dune.
- landward shifting of the zone of salt spray.
- inundation of the dune area when a weak front dune collapses.

In the analysis just 'disappearing' and 'covering' are taken into account. For the other effects supporting information for quantification of the impacts lacked, so they were ignored in the analysis.

The front of the area of potential loss is determined by the two lines which indicate the character of the potential loss: the line-of-disappearance and the line-of-covering.

Identification of the potential losses takes place for every kilometer of coast. To obtain a sufficiently refined analysis each unit of one kilometer of coast is split up in crosshore direction in grids with a width of 50 meter. All interests that are found in a grid are identified. This identification is closely related to the way they suffer loss due to shoreline behaviour.

The problems identified

Shoreline retreat may result in a problem concerning flood-protection of the polderland when safety requirements are no longer met. For interests in the dune area a problem has been defined as a situation of loss of area for these interests either due to disappearing or to covering. The analysis for both issues has been performed at each of the 252 cells (of 1 kilometer length) and results in an expression of the length of coast (= number of cells) where potentially problems may occur. In figure 6A the length of coast where the flood-protection can not longer be guaranteed is depicted for the whole prediction period and for the three scenario's of sea-level rise. For the present-day value of sea-level rise in the year 2000 already more than 20 kilometer are 'unsafe'; this increases to about 40 kilometer in 2090. For the pessimistic scenario an increase with about a factor 2 must be anticipated. The expected sea-level rise causes intermediate effects.

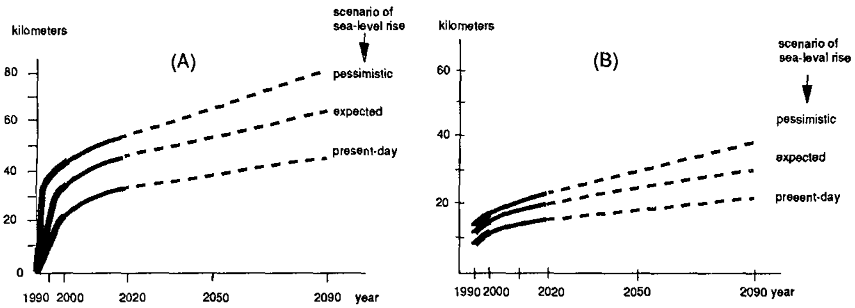

Figure 6. Length of coast where problems for flood-protection (A) and drinking water supply (B) may occur when no measures against shoreline retreat are taken.

The effects of shoreline retreat on the dune area and functions accomodated here can not all be presented here. Just the (potential) loss of area for water supply is shown (figure 6B). In the year 2000 for the present-day value of sea-level rise along about 10 kilometer of coast area for drinking water supply may be lost. In 2090 this is increased to about 15 kilometer. In the pessimistic scenario an increase of about 50 percent may be expected.

Solutions

With the present-day coastal defence policy a gradual increase of places where measures are needed to guarantee safety will occur. Besides due to the absence of a structural approach for protection of dune interests and nature an ever-increasing loss must be anticipated.

A structural approach for coastal defence must mainly be focused on protection of dune interests. Safety of the polderland has already been secured by norms, which vary along the coast (see figure 2). The policy margin here is determined by the distance in cross shore direction along which the defensive front dune can be displaced before the ultimate position has been reached: the reseve width for shoreline retreat (see figure 4). This is also the space within which (extra) protection of dune area and interests can be claimed. The strategies on coastal defence therefore give utterance to the level of protection of the dune area. It will be clear that guarantee of safety against flooding of the low country behind the dunes is a common feature of all strategies. The strategies lead to "alternatives" when they are completed with measures for coastal defence. Four alternatives are distinguished each of which describing the conditions with respect to the initial situation of 1990:

- Withdrawal **W**: admission of further retreat of the shoreline, except for the places where safety can just be guaranteed at the minimum level (norms according to figure 2) and where the reserve width has become zero.
- Selective erosion control **S**: counteract further shoreline retreat at places where dune area with nature and/or functions in this area are threatened; admit shoreline retreat at the other places. Since there is a fair number of interests which all could be separately and in combinations protected, a nearly endless number of alternatives could be defined, which would all fit into Selective erosion control. Just a small selection has been investigated, and the most representative is being presented in this paper. In this alternative the most valuable elements of nature and interests are protected:
  * Housing: concentrations of houses (villages, residential quarters)
  * Nature: wet dune, moors, etc.
  * Drinking water supply: production plants and infiltration works
  * Recreation: campings and recreation parks
  * Industries
- Full erosion control **F**: counteract further shoreline retreat everywhere along the coast

Measures for coastal defence for these three alternatives consist of solutions with sand. In this way the natural character of the coast is not irreversibly affected and there is much experience with this type of defence measures (Roelse, 1990). Except for coastal stretches with a tidal gully close to the coast, groynes and pile-rows, which have been frequently applied in the past, are not considered as promising measures. A study on the effectiveness of these measures indicated a low effectivity for coastal defence objectives.

For Full erosion control, for Selective erosion control at those places where interests of the dune area may not be abandoned, and for Withdrawal at those places where the reserve width has become zero, counteraction of shoreline retreat is prescribed. This is realised by beach nourishments. In specific situations reinforcement of the dunes by supply of sand at the landward side of the front dunes is performed.

The fourth alternative is:

- Seaward expansion **E**; seaward expansion of the shoreline at places where the coastal defence isrelatively weak with the objective of improving

the coastal defence. At those places where seaward expansion measures are not projected, shoreline retreat will be counteracted just like for alternative Full erosion control.

In this alternative structures of hard material, like groins and dams are chosen (Pluijm ,1990). This alternative has just been worked out for the present-day scenario of sea-level rise.
For all alternatives the need for regular maintenance (maintenance of groynes and sea dikes, prevention of sand blowing from the dunefront, etc.) of the coastal defence is discerned. It is clear that the costs for maintenance will differ for the various alternatives: counteracting shoreline retreat will result in a decrease of efforts for maintenance of groynes and other constructions.

Comparison of the alternatives

The various alternatives have different implications for a series of aspects. These aspects are:

- length of coast where measures need to be taken to guarantee safety;
- loss of dune area with economic functions or valuable nature area;
- amount of sand needed for coastal defence;
- costs for coastal defence measures (maintenance and counteraction of shoreline retreat).

The impact of the alternatives on these aspects have been determined. Although regional and local (sectors) variation may be interesting, presentation of the comparison will be focused upon results on a national scale. The present-day scenario of sea-level rise will be discussed first.

Present-day scenario of sea-level rise

In the year 2000 already about 20 km of coast length requires counteraction of shoreline retreat for alternative **W** (see figure 7). The bars indicate the uncertainties in the estimates due to uncertainties in shoreline predictions and analysis method. The coast length where measures are needed to prevent further shoreline retreat for alternative **S** is substantially longer than for alternative **W**: about 60 kilometer. For alternative **F** and **E** an increase to about 140 kilometer is observed.

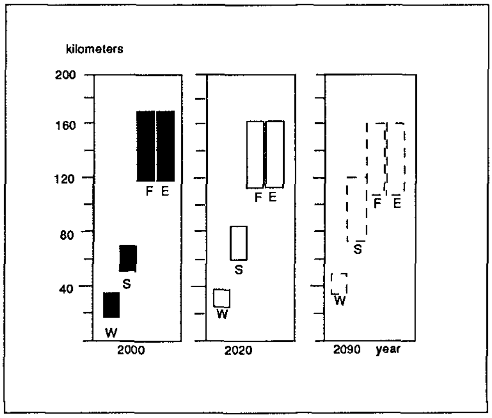

Figure 7 .Length of coast where measures against further shoreline retreat must be taken for the 4 alternatives.

As a function of time there is an increase of coast length that needs to be protected for alternatives **W** and **S** (Figure 7). For alternatives **F** and **E** a slow decrease of this parameter is observed. The explanation for this effect is that the length of coast that suffers erosion has been predicted to be slightly smaller in the far future than in the first decades. This is mainly due to expected favourable periodic behaviour. The increase for the other alternatives has appearently been caused by an increase of coastal places where shoreline retreat leads to 'problems'.
The diagram of the cumulative loss of area shows the same pattern of increase as a function of time for alternatives **W** and **S** (Figure 8). For alternative **W** the loss of dune area amounts to about 3,5 km in 2000 and increases to more than 20 km in 2090. As

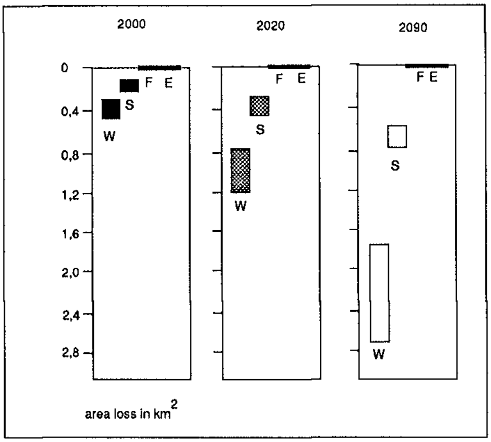

Figure 8. Cumulative loss of dune area for the 4 alternatives

could be expected, for alternative **S** losses of area are considerably smaller: 1,5 km in 2000 rising to about 6 km in 2090. A choice for alternative **F** or **E** does not lead to any loss of dune area. Considering the yearly loss of dune area, a decrease as a function of time is observed (**W** and **S**). This is caused by the fact that in course of time at an ever increasing length of coast (see Figure 7) further shoreline retreat must be counteracted. At these places further loss of dune area does not occur. The loss of area for economic interests in the dunes is just a fraction of the total loss of dune area. For alternative **W** the loss for Drinking water supply for the year 2000 is about 0.15 km, for *housing* about 0.06 km, and for valuable nature about 1.5 km. For alternative **S** these values respectively amount to: 0.1, 0.02 and 0 km. Obviously these interests are better protected with this alternative. As a function of time an increase comparable to the loss of dune area in general is observed.

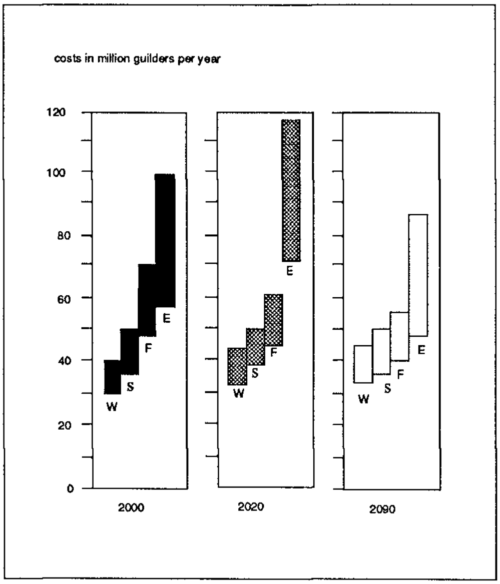

Figure 9. Total costs for coastal defence

The costs show a pattern which is more or less in agreement with the coast length where measures against shoreline retreat must be taken (Figure 9). For the year 2000 they rise from about 35 million guilders per year for
alternative **W** to about 60 million guilders per year for alternative **F**. This rise is caused by the fact that for the consecutive alternatives more sand that erodes from the coast must be replaced. Alternative **E** is somewhat more costly, about 80 million guilders per year. Here the construction costs have been roughly estimated (large uncertainties) and capitalized over 50 years. 20 to 25 million guilders of these amounts are allocated for maintenance (higher costs for maintenance for the alternatives where shoreline retreat is less counteracted). In course of time costs for **W** and **S** have increased and fro

F and E decreased. Obviously the diffrences between the costs for the alternatives decrease in course of time. At the longer term F will just be slightly more expensive than W. However, with alternative W a considerable loss of dune area (about 20 km, Figure 8) must be anticipated, while the loss for F is zero.

More severe scenarios of sea-level rise

Accelleration of sea level rise from 20 to 60 cm/century results in an increase of the impacts for the various alternatives. If in stead of the present-day scenario the pessimistic scenario (85 cm sea-level rise per century, including a change in wave climate) should be reckoned with, a more severe rise of the impacts must be anticipated. Figure 10 gives an overview of these effects for costs and area loss. For the expected scenario (60 cm/century) costs will increase with 10-20 percent, while losses increase with 20-30 percent. The impacts for a more rapid rate of sea-level rise (pessimistic scenario) are more drastically: 25-35 percent increase of costs and more than 75 percent increase of area loss. Here mainly the effect of a change in wind climate (and as a consequence wave climate) is responsible for the extra increase.

One may conclude that accelleration of sea-level rise and especially climate changes will result in a considerable increase of costs for coastal defence and losses of dune interests.

Expected scenario	increase of costs %	increase of area loss %
Withdrawal	10	20
Selective erosion control	15	30
Full erosion control	20	–

Pessimistic scenario	increase of costs %	increase of area loss %
Withdrawal	25	75
Selective erosion control	35	90
Full erosion control	30	–

Figure 10. Effects of sea level rise

Political choice

In june 1990 the gouvernment took the decision on the coastal defence policy for the next 5 years. Erosion will be fully controlled in the near future. This means that yearly on the average 6-10 million cubic meters will be placed upon the coast.

references

1.VAN ALPHEN, J.S.L.J., RIBBERINK, J.S., ROELVINK, J.A., LOUISSE, C.J., HALLIE, F.P. (1990).
Offshore sand mining and nearshore profile nourishment.
These conference proceedings, Session The Dutch Coast: Paper No. 11.
2.DIJKMAN, M.J., BAKKER, W.T., DE VROEG, J.H. (1990).
Prediction of coastline evolution for specific parts of the Holland coast.
These conference proceedings, Session The Dutch Coast: Paper No. 7.
3.EYSINK, W.D. (1990).
Morphologic respons of tidal basins to changes.....
These conference proceedings, Session The Dutch Coast: Paper No. 8.
4.HOOZEMANS, F.M.J. (1990).
Long term changes in wind and wave climate on the North sea.
These conference proceedings, Session The Dutch Coast: Paper No. 3.
5.PLUIJM, M. (1990).
Seaward coastal defence for the Dutch coast.
These conference proceedings, Session The Dutch Coast: Paper No. 12.
6.ROELSE, P. (1990).
Beach and dune nourishments in The Netherlands.
These conference proceedings, Session The Dutch Coast: Paper No. 10.
7. RIJKSWATERSTAAT, (1989)
Coastal defence after 1990, (report in Dutch)
8.ROELVINK, J.A., STIVE, M.J.F. (1990).
Sand transport on the shoreface of the Holland coast.
These conference proceedings, Session The Dutch Coast: Paper No. 5.
9.STEETZEL, H. (1990).
Cross-shore transport during storm surges.
These conference proceedings, Session The Dutch Coast: Paper No. 6.
10.STIVE, M.J.F., ROELVINK, J.A., DE VRIEND, H.J. (1990).
Large scale coastal evolution concept.
These conference proceedings, Session The Dutch Coast: Paper No. 9.
11.TERWINDT, J.H.J., BATTJES, J.A. (1990).
(Implications for research on) Large scale coastal behaviour.
These conference proceedings, Session The Dutch Coast: Paper No. 13.
11.VAN VESSEM, P., STOLK, A. (1990).
Sand budget of the Dutch coast.
These conference proceedings, Session The Dutch Coast: Paper No. 4.
12.VERHAGEN, H.J. (1989)
Sand waves along the Dutch coast. Coastal Engineering, 13, 129-147.
13.VELLINGA, P. (1986)
Beach and dune erosion during storm surges, Thesis, Delft Hydraulics Communications No. 372.
14.WIERSMA, J., ZITMAN, Tj. (1990).
Coastal Genesis I: Geological and historical development of the Dutch coast.