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# General strategy on coastline protection – The Dutch case

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## 1 INTRODUCTION

### *1.1 the Dutch coast*

The 350 km long Dutch coast along the North Sea is generally a dynamic coast. The dynamic coast is characterized by alternating coastal stretches of accretion and erosion resp. resulting in seaward and landward displacement retreats of the shoreline. Places of accretion and erosion also vary in time. Behind the dunes are low lying polders (very often with a ground level even below the low water line), in which millions of people live. The coastal erosion endangers the strength of the dunes as a sea-defence. Erosion of narrow dunes (at some places the dunes are less then 200 m wide) can therefore not be permitted in the Netherlands. At 40 km of coastline the dunes have no more than 10 m extra width available to cope with the erosion problem. A yearly erosion of only 1 m/year causes big problems within a few years. Since life in the Netherlands is so highly dependent of the quality of the coastal defence, structural solution for this problem must be developed and carried out.

In the past the only way to attack the erosion problem was to build groins. Several sections of the Dutch coastline are defended with these constructions (see figure 1). Evaluation of the efficiency of groins as tools for erosion was not stopped by these constructions. More recently (last decades) nourishment of sand beach and front dune has been practiced to compensate for the loss of sand dune to erosion.

For definitions of the various zones in the coastal defence zone is referred to figure 2.

At some places it was not possible to maintain the dunes, and at those places the dunes are replaced by sea dikes, mostly with very extensive bottom protection works (mattresses covered with stones, until a depth of 50 m below mean sea level).

Problems of coastal erosion and the resulting need for coastal defence are not new. Already in the Middle Ages the Dutch felt the need for organization of coastal defence efforts. In this period autonomous and independent authorities were formed with a special task to construct the dikes, to maintain all sea defences and to build and manage all the pumping works. These agencies, the Waterboards, still function. They collect their own taxes and have an own council and administration, which is chosen by the inhabitants of the polder. At this moment de Waterboards are responsible for maintaining the dunes

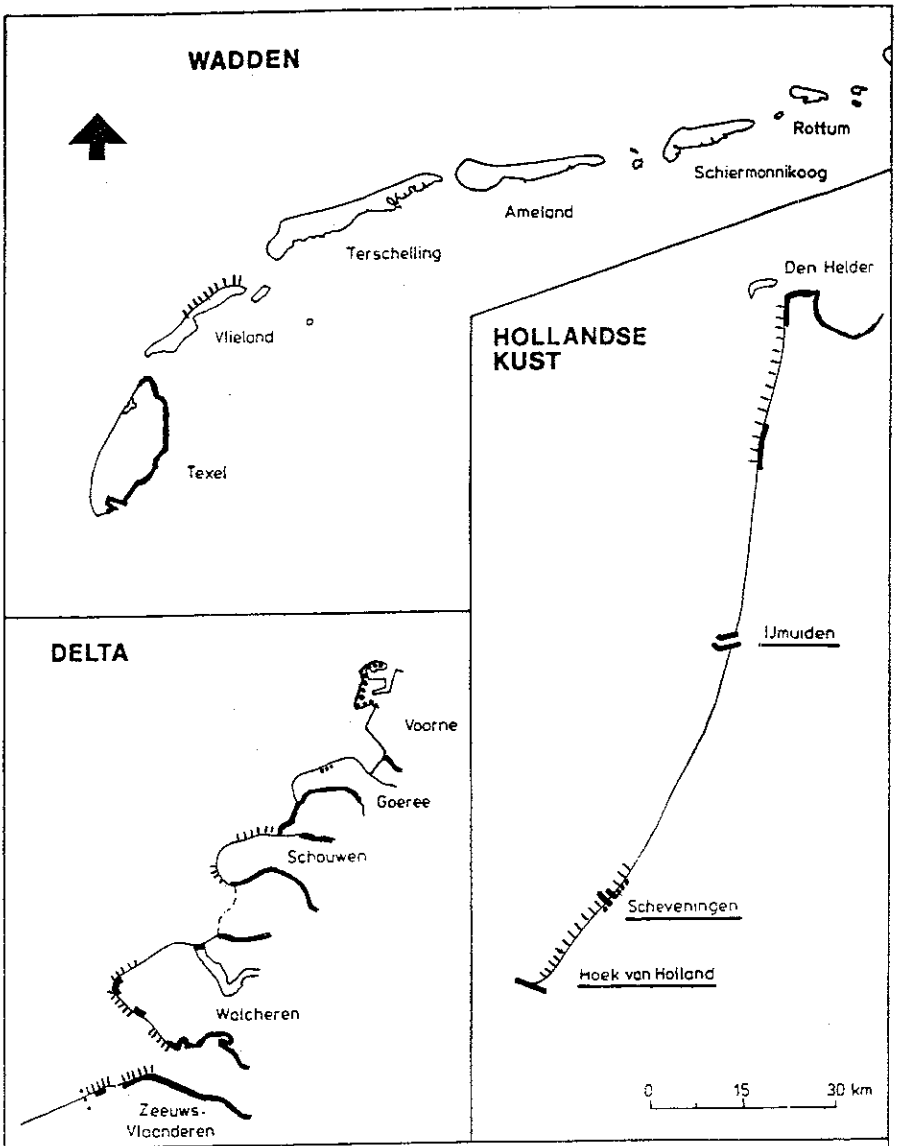


figure 1: various types of coasts along the Dutch coast

- various 27 km
- seadikes 34 km
- dunes 254 km, 62 % undefended
  7 % pile groins
  31 % stone groins

figure 1: different types of coasts along the Dutch coastline

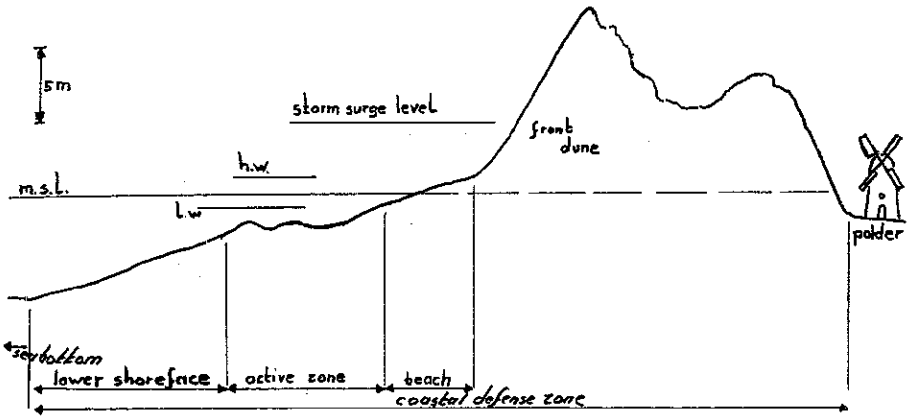


figure 2: definitions in the coastal zone

as a primary sea defence. However, they are not responsible for combating the coastal erosion. Erosion prevention is a task of the national government.

*1 2 legal framework for the coastal defence system*

The protection of land against flooding was based upon a wide variety of regulations, laws, etc. At this moment a Bill is discussed in parliament. This "Bill on sea-defence and river dikes" will also provide a basic legal framework for all coastal defence measures in the Netherlands. In this Bill the low lying part of the Netherlands is divided in so-called dike circles. A dike-circle is a low-lying area, which is surrounded by dikes, dunes and/or high grounds. Failure of one section of the sea-defence usually results in the inundation of a whole dike-circle. Each dike circle has a given allowable probability of inundation. In figure 3 some of the 40 dike-circles of the Netherlands are presented with the allowable inundation frequencies.

The allowable inundation frequencies are laid down in the Bill on Sea-defence The choice of an allowable inundation frequency is fundamentally a political decision.

More recent studies are performed to find the optimal allowable inundation frequency, based upon the economic value of real estate and infrastructure in the dike circle. However, the values of human life, natural environment, historical and cultural values, etc made it impossible to define the optimal value in an objective way.

It is interesting to mention that the results of these studies indicate that the economically optimal values are in the order of $10^{-4}$ to $10^{-5}$ per year. The frequencies proposed in the new Law on Sea-defence are a factor 10 higher.

In this Law it is also stated that the boundary values (such as water-levels) have to be recalculated every five year, and that dike managing authorities have to certify every five years that their dike still fulfills the requirements. So, they have to check the height of

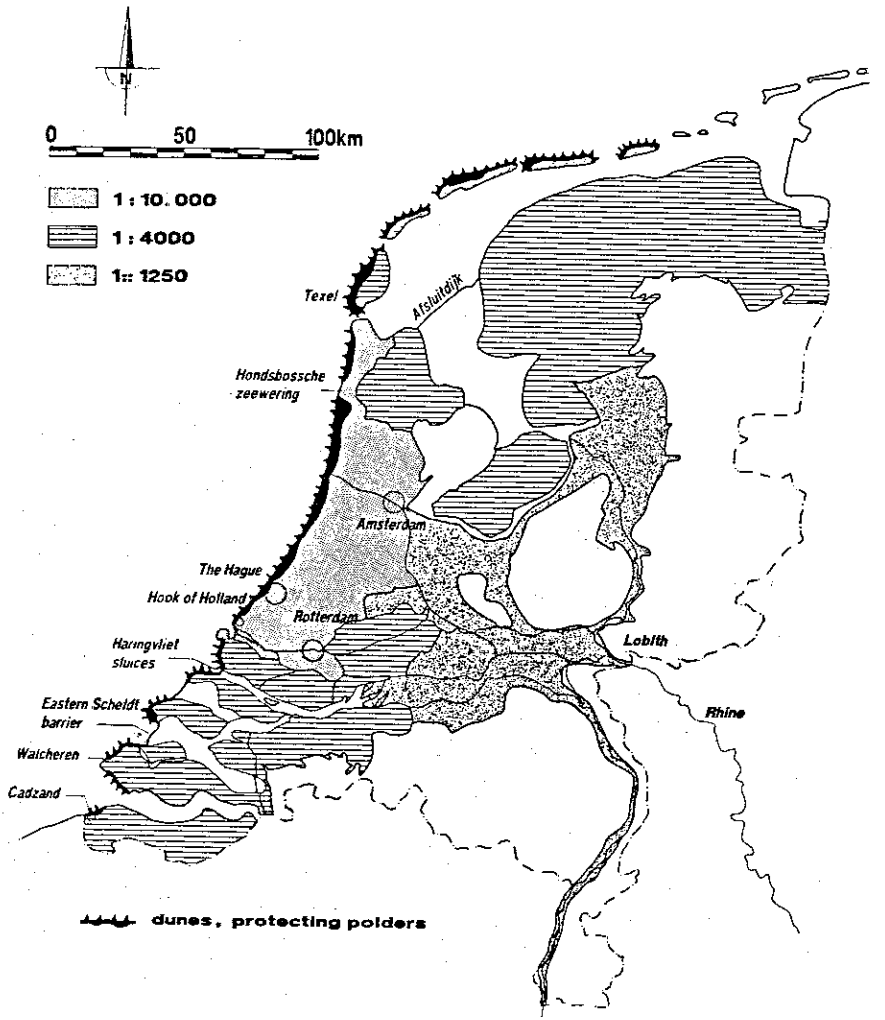


figure 3: levels of protection in the Netherlands; the dike circles are areas separated by dikes (mostly along rivers or estuaries).

the dike, the quality of the slope protection, etc. In this way it its tried to prevent that the effect of climatic changes causes surprises, and dikes have to be adapted to the new situations regularly. This is the main reason that design water-levels, etc., are not given in regulation, but only their probabilities

*1 3 Need for a coastal defence policy in the Netherlands*

As has been already stated, care for the quality of the sea-defence as a means to protect the polders from flooding is the responsibility of the Waterboards. However it is the responsibility of the national government to take care of the "foundation" of the sea defence. With other words, the national government is responsible for the battle against coastal erosion.

Also at locations where the dunes are wide erosion can cause problems. At those points there is of course no danger for flooding of polders during storm surges. The problem here is that the relatively wide dune area often have a very high natural values and besides at various places accommodate a number of human activities or functions. The dunes are considered as a high natural system of high national value that needs to be preserved. It is the longest more or less uninterrupted dune coast of Europe and exhibits a large variety of biotic and abiotic gradients.

Functions accommodated in the dune are: drinking water resourees, recreation, living and such. At a few places people live in the dunes. Historically dunes primary functioned as sea-defence. Therefore, many dunes became the property of the Polder Board. While some dunes are owned by drinking water companies, dunes remain as sea-defences because the Polder Boards have special jurisdiction over them, even if they do not own them. For the most part the Polder Boards do not allow construction of houses in the dunes. At present there is little private property and permanent housing in the dunes. Only temporary buildings were allowed, which must be removed before winter. Because of this policy, the dunes also became important natural reserves, although that was not the original intention.

Dunes valued for ecological important functions, remained in a semi-natural state while the rest of the Netherlands became urbanized, or used for intensive agriculture.

Beaches and dunes have very important recreational value not only for the 14 million inhabitants of The Netherlands but also for the densely populated Ruhr-area in Germany. For them, the Dutch coast is the nearest coastal recreation area. Beaches are generally not affected by coastal erosion. In principle coastal erosion only causes beach problems if a fixed structure such as a sea-wall lies behind the beach. In the dune areas there are recreational facilities such as camp grounds. Structures such as hotels and restaurants in the first dune-row are, of course, endangered by erosion.

Originally, some villages were built just behind (landward) the dunes. As coastal erosion occurred these villages became closer to the sea (several times in history this required the removal of a village to a new location further inland). Today, in The Netherlands, demolishing houses because of coastal erosion is socially and politically unacceptable, although in some cases it would be economically acceptable. Therefore, the presence of villages near the sea requires a policy that maintains the coastline at its present location.

In the Netherlands the dunes are also used for the production of drinking water. Because ground water in large parts of the Netherlands is brackish, is cannot be used for drinking water. In the 19th century the public water works of the big Dutch towns started to pump drinking water from the fresh-water lenses in the dunes. At this moment the natural supply from these lenses is not enough any more, and the lenses are supplied with river water (mainly from the Rhine river), which

is infiltrated in the dunes and recovered later. Coastal erosion endangers the high investments in the drinking water pumping areas.

Since coastal erosion can be a treat for all these functions and for nature preservation, there is a need for clarification and qualification of this problem in relation to coastal defence.

*1.4 history*

In the past only the sea-defence aspect was very important. The authorities responsible for sea-defence therefore improved the dunes by placing more sand behind the dunes on the landward side, causing considerable damage to nature

In order to control the erosion many groins have been build. In some cases the dunes became so narrow that is was necessary to construct a seawall or a sea dike. The consequences of the construction of seawalls and dikes was that the safety of the polders was guaranteed, but the beaches in front of the constructions disappeared. Also the effect of groins was not quite satisfactory In cases where they were located near tidal gullies they were able to keep the tidal current out of the coastline, preventing extra erosion of the beach in that way Near coastal sections where the tidal current is not so strong, the effect of groins in controlling erosion appeared to be minimal.

Erosion continued in spite of the construction of groins and dikes. In the south of Zeeland (southern Netherlands near Cadzand), several polders were permanently flooded due to coastal erosion in the 19th century. In many dune fields it was customary to maintain the dunes at the required strength by moving them landward. This was accomplished by making the seaward slope of the dune-front somewhat more gentle, lowering the dune at the side of the sea, and moving the sand in a landward direction. The principle of this procedure is shown in Figure 2. This procedure does not stop erosion (in some cases it may even increase erosion), but the safety of low lying polders behind the dunes was guaranteed at the cost of the dune area This was not considered to be a problem because of the low economic value of coastal dunes.

*1 5 Changes in Dune Appraisal*

Today attitudes are different and dunes play an important role in coastal zone management. First, better methods for determining safety of dunes were developed. In 1984 the "Technical Advisory Committee on Water-defences" presented guidelines for the evaluation of dune safety as a coastal defence (TAW, 1986). In these guidelines a method is presented to calculate the strength of a dune during a storm surge. This method is based upon a normalized coastal profile after a storm-surge and an equilibrium of sand in this profile (Van de Graaff, 1986).

Also, new techniques have been developed for coastal maintenance. Artificial beach nourishment has become important, partly a by-product of the dredging industry. Prices in the Netherlands are between US $ 1 - US $ 4 per cubic meter placed on the beach (Rijkswaterstaat, 1987). These low prices made it financially possible to switch from dune improvement at the landward side to improvement by beach nourishment

A third important factor is the new regard of dune areas. Dune areas now have a much higher value because they are used as a source of drinking water (by infiltrating river water), they have a very important recreational value (camping grounds, daytime recreation) and they

are critical areas from an ecological point of view (rare plants and animals, breeding grounds, etc.).

In the past years the nourishment projects were executed on a ad-hoc basis by the national government and not by the sea-defence authorities. This is caused by the fact that it are generally big projects and that sea-defence was very often not the main reason for the nourishment plan.

Since sea-level rise must be anticipated (now 20 cm/century, in future it will be more because of the greenhouse-effect) it is to be expected that the erosion problems along the coast will increase.

*1.6 finance*

The waterboard raise their own taxes. From this income they finance the costs of construction and maintenance of dikes and dunes. The coast of combating erosion has to be covered from the National Budget. However there is no structural budget for erosion control measures. Beach nourishments in the past have always been financed on an ad-hoc basis. In order to be able to have a long term policy in this field, it is obvious that money for beach nourishment has to be available also in future. The only way to do that is having a special item on the National Budget for coastal defence. The coastal defence study should bring about the information on the amount of money involved with structural erosion control measures.

*1.7 strategy*

Because in the past all attention was paid to improvement of the sea defence system, and not on erosion control, no general policy was developed regarding coastal maintenance. If the dunes were wide enough, there was no problem. Coastal erosion was only a problem, when the safety of low-lying polders behind the dunes was endangered. Because nowadays the dune areas itself are regarded as vary valuable, erosion is always a problem. From various groups from society there became a strong pressure to stop the erosion. Some 10 years ago it became therefore necessary to nourish a few beaches on places were there was no need for beach nourishment from a strictly "sea-defence point of view". With other words, nourishment had to be done on places were the dunes were wide, and were there was no danger for inundation of polders. The legal framework in the Netherlands formally could not give a basis for these nourishments. Neither there was a component in the National Budget for financing such non-safety related nourishments. Finding money for these nourishments was therefore always a problem. It is clear that in the near future more nourishments will be required. For a long term policy regarding coastal maintenance, it is therefore necessary to have an fixed amount of money in the National Budget.

The real problem is how to get such a fixed amount of money on the National Budget. Otherwise it is not possible to do the job. Therefore the responsible department (Rijkswaterstaat) followed the a step-by-step strategy, using signals from society, leading to a strong public opinion favoring coastal maintenance on a national scale. The following steps were taken:

1. For a case were there was a strong pressure from the public, a detailed policy-analysis was made, to see what amount of money would be realistic to spend on beach maintenance project in relation to the lost values if erosion would continue at that place

2 From that analysis followed that beach nourishment was a socially well acceptable solution for the erosion problem. Also the costs proved to be not excessive.
3 An analysis was made of the costs of beach nourishment projects in the past. Ample publicity was given to the results. Special leaflets were made and distributed to policy makers in society.
4 The next step was that the Minister of Public Works asked for a policy analysis on coastal management. The study for this policy analysis was performed by Rijkswaterstaat, assisted by specialized institutes (like Delft Hydraulics) and universities. An inventory of all available knowledge regarding the Dutch coastline was made, forecast were made on the expected sea level rise and on the development of the coastline for the next century. Maintenance methods and costs were analyzed. This study took approx. one year and resulted in a set of 20 technical reports. On the basis of the technical reports, a discussion memorandum was produced in which 4 different management strategies were presented. These strategies were presented to parliament and other groups for discussion. See also the letter from the Minister to Parliament in the Annex to this chapter. Public hearings were held.
5 After the discussion the minister makes a choice from the alternatives and present the decision to parliament for approval. This has been done in May 1990. During the preparation of the text for this course, the final memorandum was not yet available. However, it is very likely that the chosen alternative is Full Erosion Control, with a few amendments. For example in areas were there is a wide sand bank in front of the dunes, this sand-bank will not be maintained. When approval (and the budget) is granted by parliament, the national coastal management policy is effective.

## 2 PROBLEM OF THE COAST

### *2.1 causes of coastal erosion*

The dune coast is a flexible sea defence against the North Sea. Characteristic is the continuous movement of sand in the coastal zone. There is an exchange of sand between the subaerial and subaqueous part of the coastal profile. Currents and waves move the sand from and to the shore in cross-shore and longshore direction. This process may cause a loss of sand from the sea-defence zone to adjacent coastal sections or to neighboring inlets.

Because of these processes there is a continuous movement of the borderline between land and water. Erosion and accretion alternate both in space and in time. Erosion nearly always causes problems.

There are two types of coastal erosion.

* A fast, sudden erosion of the dune front during storm surges, causing a considerable loss of sand to deeper water;
* A slowly, chronic erosion, which is not so striking, caused by sea level rise and morphological phenomena. Due to chronic erosion sand disappears from the coastal defence zone. An increase in sea level rise may cause an increasing chronic erosion. In that case also the coastal profile will adapt to the new waterlevel by moving in a landward direction.

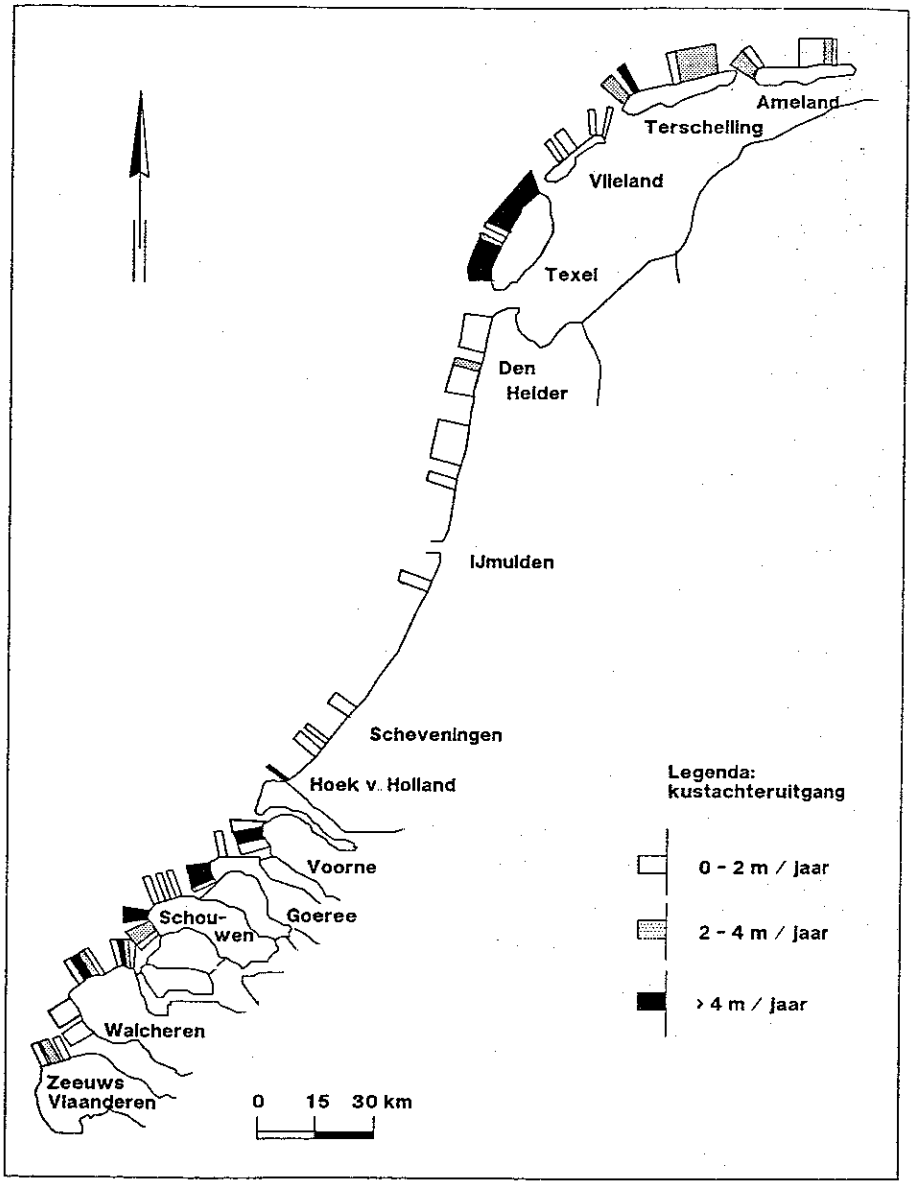


figure 4: coastal erosion in the Netherlands, in m/year

The difference between the two types of erosion will be discussed more in detail by mr Van de Graaff in his contribution to this course.

In the Dutch situation the fast erosion during a storm surge is a problem for the Waterboard, the chronic erosion is a problem for the National Government. Figure 4 shows the present situation of shoreline development. About half of the coast length is eroding. The coast in the Delta area is most severely attacked. The northern part of the Holland coast and Texel exhibit large erosive areas as well. In Texel, in addition is much faster than at other places.

*2 2 impact of sea level rise*

According to our present knowledge the impact of sea level rise on the coast is twofold:

* First it causes a relatively deep underwater shore. In order to compensate that, there is a need of sand on the inshore zone. If this sand is not available from the sea bottom in a large enough quantity, this will cause a loss of sand from the dunes to beach and active zone. The sea-dunes, the row of dunes just adjacent to the beach, becomes narrower and moves in a landward direction: The direct effect of sea level rise. This effect will occur along the entire shoreline.
* The second effect is an increase of some of the erosive processes; the indirect effect. There will be an increasing demand of sand from the coastal sections neighboring tidal inlets. Because of the sea level rise the basins behind the tidal inlets will become deeper. This creates a need for sand to fill up the basins to a new equilibrium level. This sediment will partly be withdrawn from the coast. Especially if an increasing sea level rise is combined with a change in wind climate a significant increase of the erosion of the coastal sections neighboring tidal inlets is expected.

An increase of sea level rise will result in an increase of erosive coast length. Besides the sections that are already eroding now will suffer an increased erosion.

For the areas near tidal inlets we expect an increase of erosion with approx. 0.5 m/year; for the other coastal sections this will be in the order of 0 2 m/year.

*2.3 impact of chronic erosion on safety*

At this moment the dune coast along the entire Dutch coastline fulfill the requirements of a safe coastal defence system. The method of assessment of safety of dunes as a sea defence will be discussed in more detail by mr. Koster in his part of this course. Along the coast of Holland the dunes are able to withstand a one in 10 000 year storm.

However at some places there is hardly any spare width in the dunes where erosion can be awaited. The length of coast where safety can not longer be guaranteed is in the year 2000 about 20 km, rising to about 40 km in 2090 (see figure 5). For the unfavorable scenario of sea level rise an increase oaf about a factor 2 with respect to the present-day sea level rise must be anticipated. These effects are most severe in the Delta area.

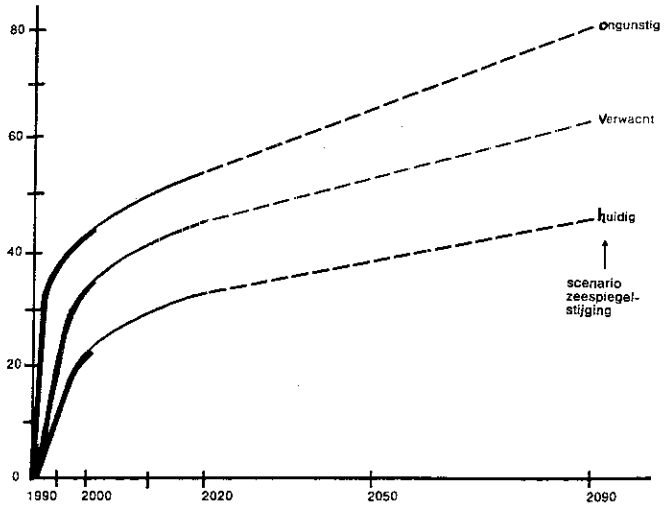


figure 5: The expected length over which the dunecoast becomes unsafe in the next 100 years On the vertical axis is the number of unsafe kilometers. H, V and O are various sealevel-rise strategies (H= present 20 cm/century; V= 60 cm/century; O= 80 cm/century + change in wind climate).

*2.4 impact of chronic erosion on other functions in the dune area*

The dune area covers of approx. 420 $km^2$. The effects of shoreline retreat on the dune area and functions accommodated here are also evaluated (figure 6) In the year 2000 for the present-day value of sea level rise along about 40 km of coast very valuable nature area is lost In 2090 this is increased to about 60 km, which is some 40 percent of coast length where these areas occur in the unfavorable scenario an increase of about 50 percent with respect to the present-day se level rise may be expected.

The effects that have been reckoned with are the loss of land due to the landward shift of the shoreline and the loss of area with a specific value (for instance wet dune valleys) that have been lost due to a landward shift of the back side of the front dune: since a minimum safety level must be maintained, a front dune with minimum dimensions must shift landward with the same pace as the shoreline retreat. Due to the landward shift of the (minimal) front dune a wet dune valley for instance can be replaces by bare sand. This can also happen to functions located behind the front dunes.

Locally and regionally the dune ecological system has a variety of qualities. Dunes with small lakes, (freshwater)marshland, dry areas, shrub, moor and woodlands are varied with "normal" beachgrass or dry grasslands, strongly influenced by human activities

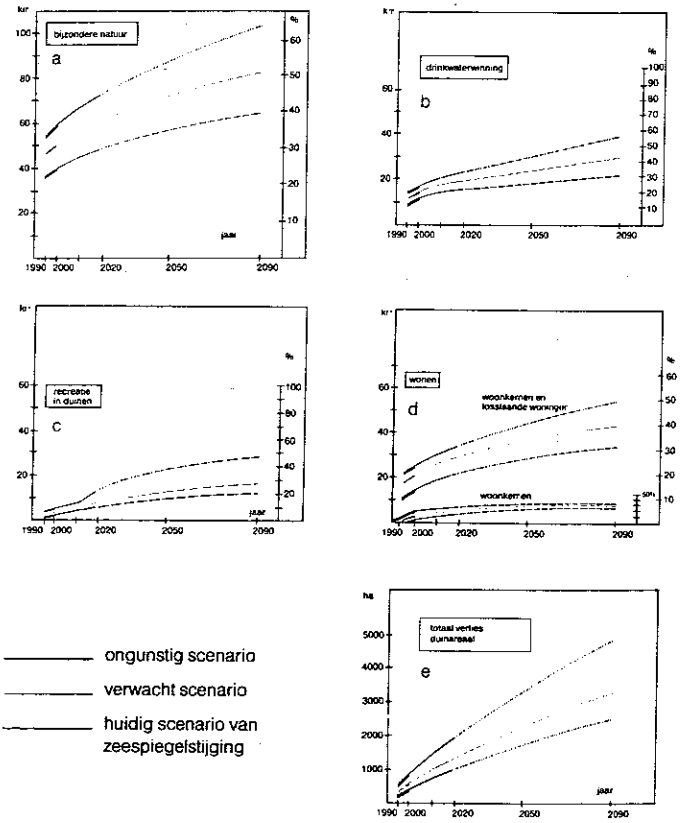


figure 6: Loss of functions in the dune area when coastal erosion is not controlled a= valuable natural reserves; b= drinking water production; c= recreational values; d= housing; e= total loss of dune area. The three curves are the various sealevel scenarios (see fig. 5).

Besides its natural values, the dune area is also of economic value as a production area of drinking water and for recreation. It is used as urban area and (at a few places) as industrial area. Most of these functions are just behind the sea-dunes. Locally one finds in the sea dunes a restaurant of some houses. Fortunately the sea-dunes are urbanized only on a few locations.

*2.5 impact of shoreline retreat on values on the beach*

Although the beach is important for recreational use, we did not succeed in deriving a sufficient reliable parameter to express the value of the beach for this function. Therefore it was assumed that the beaches along the coast would not change as much that considerable affection to this function should be expected.

## 3 ALTERNATIVES FOR COASTAL DEFENCE

Alternatives for a coastal defence policy in any case must meet requirements concerning safety against inundation. Additionally demands concerning protection of other functions in the dunes can be made.

Objectives of coastal defence policy can be:

* To give way to natural development of the coastline where it can be admitted. Only the safety requirements are met.
* To prevent coastal retreat at certain places; safety requirements and demands for a selection of other functions in the dunes are met. In this case the problem is which other functions have to be selected. It can be housing, nature values, drinking water production, or a mixture.
* To prevent overall shoreline retreat; requirements concerning safety and all other functions are met.
* To strengthen coastal defence at weak places along the coast by constructing defence works into the sea; all requirements are met.

Starting from these four points mentioned here, four alternative policies for coastal defence and shoreline management are developed.

In order to work out the strategies several measures have to be taken. In fact the following technical options can be used for implementing the four strategies:

* maintenance of existing constructions and dune profiles;
* nourishment of sand that disappears from the coastal profiles (erosion control);
    - at the front side of the front-dunes
    - at the back side of the front-dunes
* build new constructions for erosion control.

Four alternatives are presented to parliament and public: Withdrawal, Selective erosion control, Full erosion control, Seaward expansion.

**alternative 1: withdrawal** (terugtrekken)

If nothing is done, the shoreline will erode. This is not acceptable at locations where the dunes have only marginal safety. Everywhere where the dunes are wider, erosion can be allowed until the minimal dune width is reached.

This alternative is the minimal alternative. The shoreline of the Netherlands will be determined by the natural processes. Only at those locations were the safety of the polders is in danger, action will be taken. Generally the action will be a beach nourishment, but also other solutions are possible (like the construction of a heavy sea-dike). After some years artificial headlands will be formed along the coast (the coast between the headlines continues to erode). The costs to defend these headlands will increase in due course.

If erosion continues, there is the possibility that villages in the dunes (not in the polder-area) have to be removed to a more inland location. This has happened often in the past centuries. Also damage will be caused to recreational areas, natural reserves and the drinking water production. The loss of land in the next decade will be in the order of 3.5 $km^2$ (800 acres) and 20 km of shoreline has to be defended by beach nourishment or other means.

In a few cases also the dunes has to be improved on the landward side. This improvement will cost approx. 100 ha (220 acres). In this alternative all sea dikes and groins will be maintained in the same way as it was done until today. A landward reconstruction of these structures has proven to be more expensive than maintenance on the present location. This alternative will cost 35 million guilders per year (16 million US $/year).

**alternative 2: selective erosion control** (selectief handhaven)
The second alternative is control the erosion in a selective way. Here also safety is the primary aspect But erosion is not only controlled in case of danger for inundation of polders, but also when important other functions are endangered Because there are many functions in the dune area, some choices have to be made. What has to be protected, what is "important" ? In this alternative the following choices have been made:

- all villages in the dune area will be protected;
- natural reserves with an (international) high value will be protected;
- infiltration and production plants for drinking water production will be protected;
- investments for recreation will be protected (hotels, etc.).

The expected loss of land in the next decade will be approx. 100 ha (220 acres), 60 km of coastline has to be protected and the coast are 45 million guilders per year (20 million US $/year).

The details of this alternative have to be worked out on a regional level.

**alternative 3: full erosion control** (handhaven)
The shoreline of 1990 will be maintained. Erosion will be fully compensated by beach nourishments A small strip will be available for natural fluctuations of the beach. Nourishments will be performed on the beach, but probably also just in front of the beach, on the inshore zone. There will be no loss of land, 140 km of coastline has to be protected by nourishment. The costs are 60 million guilders per year (27 million US $/year)

**alternative 4: seaward expansion** (zeewaarts)
This alternative is a more active one than the other alternatives. In this alternative the dunes which have a marginal safety are improved by making more beach in front of them. This will be done by the construction of very long groins or other constructions in the sea. This alternative has not yet worked out in such detail as the other one The main purpose of this alternative is not the creation of extra land Most of the constructed accretions are on locations were the do not have a high economic value. The purpose is improving the sea-defence.

Also 140 km of coastline requires protection in this alternative The costs are approx. 80 million guilders per year (35 million US $/year).

## 4 METHOD OF ANALYSIS

In figure 7 the various issues linked up with coastal defence management are depicted. Natural development of the coast, resulting in a displacement of the shoreline, will affect utilization of the coast.

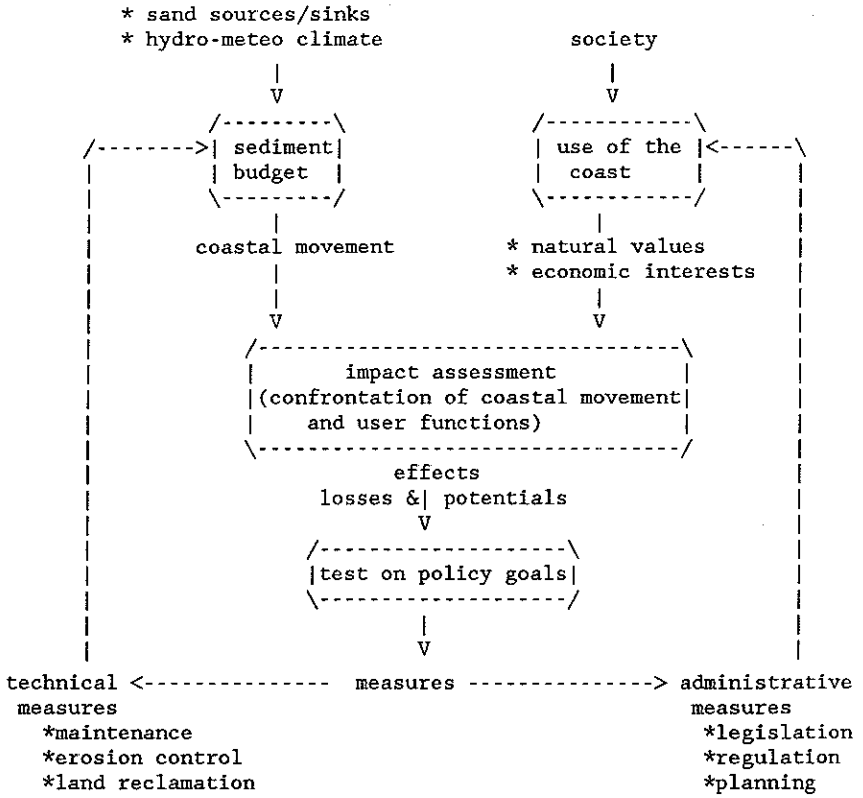


figure 7: Coastal management scheme (coastal defence and coastal development planning

The purpose of the Dutch coastal policy is to control the process, given in the scheme and to build a legal and administrative framework for a good cooperation with all the parties concerned All technical measures have an influence on the use of the coast.

Whether this influence is admitted or not is being prescribed by the alternatives of coastal defence. For instance, if affection of certain recreation activities is not permitted according to the alternative Selective erosion control, further retreat of the shoreline at a location where these activities are endangered is not permitted. In this case measures need to be taken to attain one's objective. This will result in an adaptation of the shoreline position. Costs of measures are computed.

This policy analysis approach was followed for evaluation of the effects of the alternatives. A computer model was developed for this analysis. There were several reasons leading to the decision of developing a model:

* the extent of the whole issue, both in space ant dime (350 grids in longshore direction, more than 10 grids in cross shore direction, 11 time steps) would ask for such a large number of actions, that failures would be easily made, when it was needed tot do it by hand;
* it was foreseen that, before deciding to chose for the alternatives mentioned before, a large number of other alternatives should be investigated;
* since sensibility of the alternatives for variations in basic information is always very important, also in this field a number of evaluations needed to be anticipated.

In the presentation of this course attention will be paid to the steps that were followed in the evaluation of the effects of the various alternatives. Here the steps are shortly mentioned and some interesting issues will be noticed.

a Prediction of shoreline behavior for the next decades (up to 2090) for the various scenarios of sea level rise.
Phenomenological analysis (shoreline, sand budget, long time series, trend analysis). Physical-mathematical and empirical model of coastal behavior; different approaches for central part of the Dutch coast and the northern and the southern part. Explain model in some detail. Integration of phenomenological and model analysis to shoreline predictions.

b Gathering of data concerning utilization of the dune area; choice of resolution; subdivision into a number of classes.

c Identify the consequences of shoreline displacement for safety conditions of the coastal profile along the coast at each time interval; take measures when safety can no longer be guaranteed.

d Identify the consequences of shoreline displacement for functions in the dune area; where will loss of valuable dune area occur ? Show the relation with coastal defence alternatives.

e Compute the amount of sand needed for nourishments. Compute the costs for this sand and for maintenance activities. Dependence of costs for maintenance form type of coast and velocity of shoreline retreat

## 5 EFFECTS OF COASTAL DEFENCE ALTERNATIVES

The various alternatives have different implications for a series of criteria which are relevant for mutual comparison of the alternatives. These criteria are:

* length of the shoreline where measures need to be taken to guarantee safety

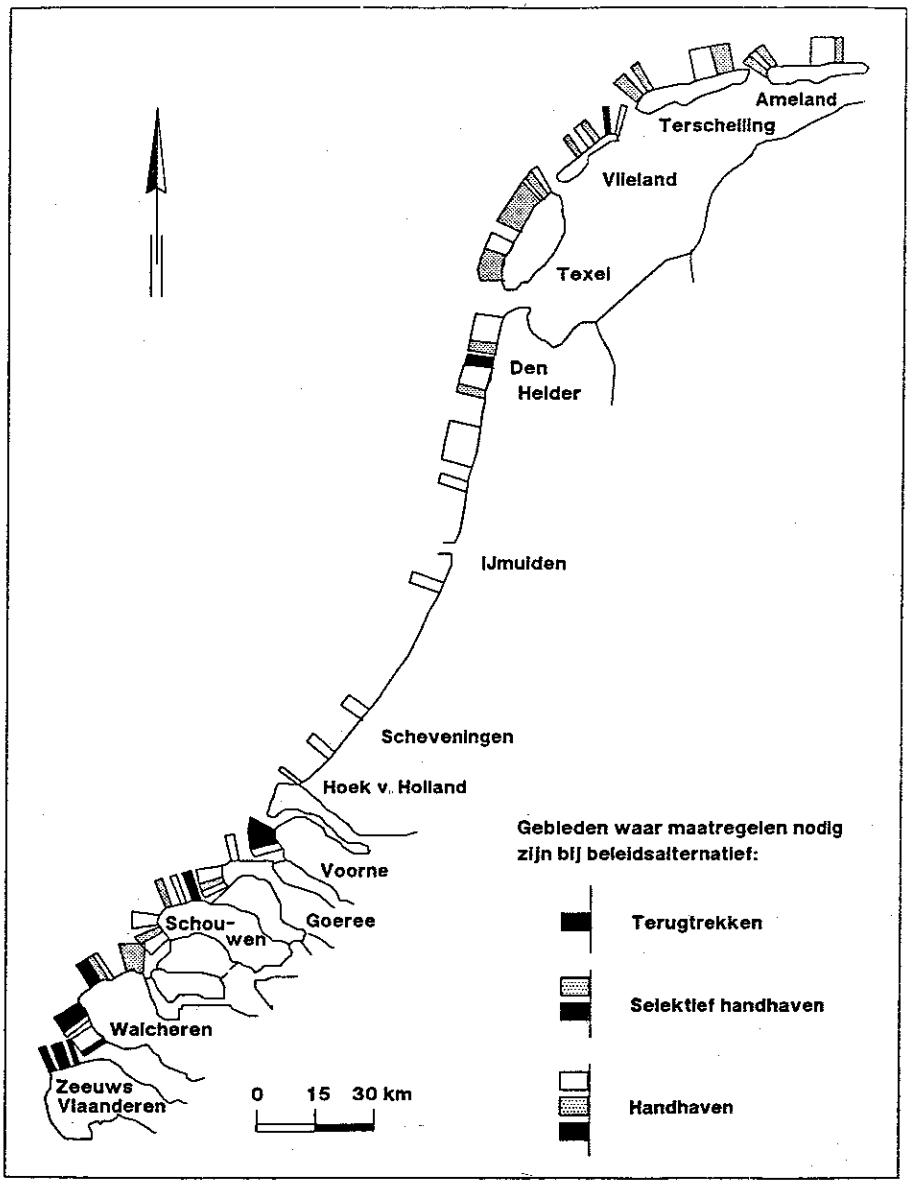


figure 8. Areas where measures are necessary for the various alternatives (T= withdrawal; S= selective erosion control; H= full erosion control; Z= seaward expansion).

* loss of dune area with economic functions of valuable nature area; although the effect of landward displacement of the shoreline will carry over into the total width of the dune, only changes in the position of the front dune, were considered. Other effects, for instance the effect of changes in the ground water level in the dunes, are not described.
* costs for coastal defence measures.

The basic analysis was performed for the present-day sea level rise of 20 cm/century. The other scenario's are discussed separately.

The distinction between the various alternatives with respect to measures needed for erosion control is illustrated with figure 8, where places with measures which are necessary before the year 200 along the coast are indicated. For the alternative Withdrawal (T) the largest effort is concentrated at the Delta coast, where coastal defence is relatively weak. For alternative Selective erosion control (S) places with with measures are located in Wadden (to protect valuable dune area) and Delta (unsafe situation). Full erosion control results (H) in a further increase of locations where measures need to be taken to actually all places that suffer shoreline retreat.

For the year 2000 for alternative T about 20 km of shoreline requires protection; for alternative H this is already about 140 kilometers. The bars indicate the variation between the results under slightly favorable conditions (average values for shoreline prediction, favorable assumptions for analysis procedures) and results under unfavorable conditions (both unfavorable shoreline predictions and assumptions for analysis). The length of coast that needs to be protected increases for alternative T as a function of time (figure 9). They amount to about 18 million US $ per year for alternative T, of which about 5 million US $ for erosion control.

Alternative H shows a rather constant level of length of coast that need to be protected as a function of time (figure 9). The costs of this alternative amount to about 30 million US $ per year in the year 2000 (figure 10). Because all sand that disappears from the coast due to erosion must be replaced in this alternative it is more expensive than alternative T.

Giving berth to shoreline retreat (T) also results in large losses of dune area: about 3.5 $km^2$ in 2000. On the contrary, full erosion control (H) does not lead to any loss of dune area (figure 11).

The alternative Selective erosion control (S) leads to intermediate effects, both with respect to length of coast where measures need to be taken (60 km in 2000), as to costs (23 million US $ per year in 2000) ant losses of area (1.5 $km^2$) in 2000).

The alternative seaward expansion (Z) has not been worked out in such detail as the other alternatives; the estimates of the costs are therefore more tentative and amount to about 40 million US $ per year (in 2000).

Acceleration of sea level rise from 20 to 60 cm/century results in an increase of costs for measures against erosion and loss of dune area of 25 percent. The extra costs and losses of dune area for a scenario of 85 cm/century, including changes in wind and wave climate, amount to 70-100 percent with respect to the case of 20 cm/century sea level rise for the year 2000 (see table). From this table it is clear that for coastal maintenance the rise of the sealevel itself is not a big (financial) problem. However, changes in the wind and wave climate (especially changes in the average wind direction), have considerable financial impacts.

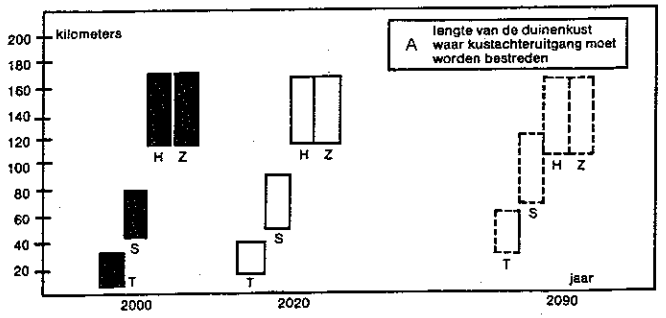


figure 9: Length of the coast where coastal erosion has to be controlled

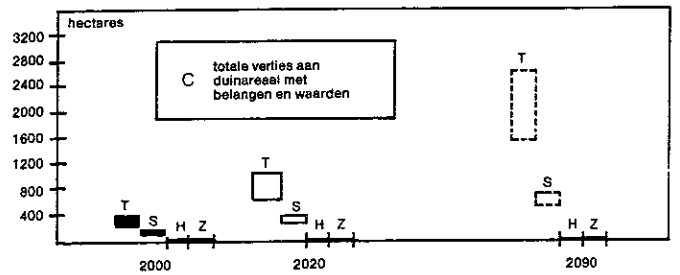


figure 10: Total loss of important dune area

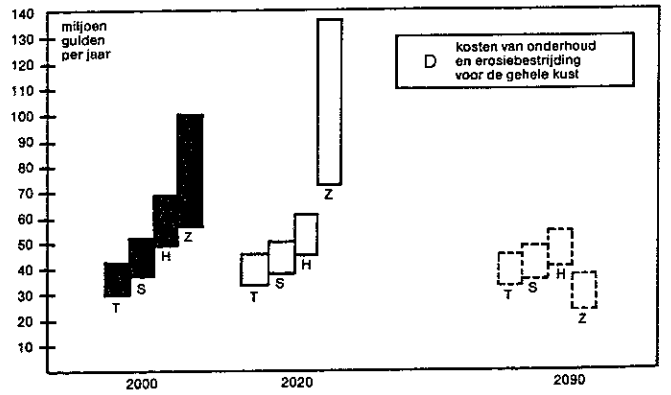


figure 11: Costs of maintenance and erosion control for the total coast (in million guilders per year)

Table:
Increase of several values in percent relative to the sealevel scenario of 20 cm/century. (for example: If the sealevel rises with 60 cm/century, the cost of erosion control in 2090 is 40 percent more than the erosion control costs in 2090 with a sealevel rise of 20 cm/century.)

| year (sealevel rise) | increase in % of amount of km to maintain | cost of erosion control | total cost of coastal maintenance | loss of area |
|---|---|---|---|---|
| 2000 (60 cm) | | | | |
| I | 45 | 25 | 10 | 20 |
| S | 35 | 20 | 10 | 25 |
| H | 40 | 25 | 15 | -- |
| 2000 (85cm +Wind) | | | | |
| I | 80 | 100 | 55 | 70 |
| S | 65 | 80 | 60 | 80 |
| H | 75 | 80 | 65 | -- |
| 2020 (60 cm) | | | | |
| I | 30 | 25 | 10 | 20 |
| S | 35 | 25 | 15 | 30 |
| H | 60 | 30 | 20 | -- |
| 2020 (85cm + Wind) | | | | |
| I | 85 | 100 | 25 | 75 |
| S | 80 | 90 | 35 | 90 |
| H | 95 | 100 | 30 | -- |
| 2090 (60 cm) | | | | |
| I | 60 | 40 | 10 | 25 |
| S | 40 | 45 | 10 | 25 |
| H | 40 | 30 | 10 | -- |
| 2090 (85cm + Wind) | | | | |
| I | 105 | 160 | 30 | 80 |
| S | 80 | 145 | 45 | 75 |
| H | 75 | 120 | 50 | -- |

I - Withdrawal
S - Selective erosion control
H - Full erosion control

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APPENDIX: Letter from the Minister of Public Affairs to parliament, announcing the new coastal policy:

Io:
Ihe chairman of the Second Chamber
of the Parliament ("House of Commons")
1a Binnenhof
2513 AA The Hague

Ihe Hague, May 9th, 1989

subject: Memorandum Sea defence after 1990

Mr Chairman,

Ihe protection of our country against the sea is of greatest importance. This is especially so for the more specific field of protection of the North Sea Coast. Now it becomes more and more clear that the rate of sea level rise will increase in the future years, it is to be expected that also the attack of the sea on our coastlines will increase. First of all the higher waterlevel causes a higher pressure on our sea defence along the coastline. Also follows from recent research that probably also the rate of erosion of the coastline will increase This was one of the arguments of my conclusion that Water Authorities had to manage the sea defence structures along the coast, but that the care of the position of the coastline itself should be the responsibility of the National Government. I informed you on this subject in my letter of May 7th, 1985 (TK 18975, no. 1) In the Commission Meeting of April 6th, 1987 Parliament supported this choice. The task of the National Government related to the care of the coastline will have a legal basis in the Law on the Sea defence and Flood Control (Wet op de Waterkering), on which the High Council of State will advise in short terms

It is necessary that, before the Law on Sea defence takes effect, a long term policy has been developed for the management of the coastline. A strategic choice has to be made regarding the sea defence policy, also regarding the increased rate of sea level rise and the increased erosion rate caused by that fact For that purpose in my department the memorandum "Sea defence after 1990" (kustverdediging na 1990) has been prepared.
The preparation takes place in three phases:

a Production of a discussion-memorandum, in which an analysis is presented of the problems of sea defence and on which basis four policy alternatives are presented.
b Advise by the Advisory Council for Watermanagement and by the Technical Advisory Committee on Water defences. Also there will be discussions with the representatives of the provinces and the Waterboards
c Making a choice by the government from the alternatives. Ihis

choice will be presented tot parliament in a policy-memorandum. This memorandum will be send to you at the end of this year.

Phase a is completed now. Today I have send questions for advise to the Advisory Council for Watermanagement and to the Technical Advisory Committee on Water defences. I have asked the Advisory Council to make arrangements for public hearings on this subject.

**policy alternatives**

The policy alternatives presented in the discussion-memorandum are roughly worked out on a national level. This is done because after selecting one alternative by the government on a national level, further detailing has to be done on a regional level, using local know-how of provinces and water boards. This can be done by preparation of actual coastal plans by specialized regional (discussion) boards. The memorandum "The sea defence along the Dutch coast" (parliamentary year 1976-1977, no. 14481) did already describe these boards and the Law on Sea defence will give them a legal basis.

The policy-alternatives give the boundaries within which the details have to be worked out. By making the alternatives attention has been focused on those parts of the coastline which are eroding. This has been done because the problems of eroding coastlines which possible threat to safety or loss of important dune areas is more important than the problems of accreting coastal sections. For the same reason reclamation is also not placed into the discussion. Reclamation projects require -if demands on a good coastal management are fulfilled- mainly a spatial planning process.

The alternatives can be characterized as follows:

I WITHDRAWAL. Coastal erosion is principally accepted. Only in those coastal sections were erosion may cause inundation of low-lying polders behind the dunes, coastal erosion will be controlled.

II. SELECTIVE EROSION CONTROL. Besides locations were the polders are threatened, erosion is also controlled at those locations where considerable values in the dune area or on the beach are threatened by coastal erosion

III. EROSION CONTROL. Everywhere the coastline will be maintained at its present location.

IV. SEAWARD. On some very eroding areas and relatively weak spots constructions will be build in the sea, which change the eroding trend of the coast into a more accreting trend. Everywhere else the coastline will be maintained at its present location.

Consolidation of the reached level of safety -the purpose of the Bill on the Sea defence- implies that withdrawal is the minimal alternative. The alternative Erosion Control is identical to erosion-stop-policy, sketched in my letter TK18975/3 of March 25th, 1988. The basic thoughts behind the fist three alternatives is that coastal erosion has to be decreased or stopped. De basic thoughts behind the last alternatives is that coastal erosion locally is changes in coastal accretion. This requires specific constructions to be built in front of highly attacked coastal sections. These constructions are also complementary to the other alternatives. These works have the only purpose to protect the coastline against erosion. They may have an interesting "by-product", such as some reclaimed area, like the areas on both sided of the harbor moles of IJmuiden. The constructions can

be build adjacent to reclamation works, which are mainly situated on stable or accreting coastlines; there coastal defence is not the primary objective.

**present policy**

In the following the various alternatives are compared with the present policy. The present policy consists of the components:

1 By the construction of dune improvement works according to the Delta Law (Law which states that all sea defences has to be reinforced in order to guarantee a certain level of safety) always a certain sand-buffer has been formed to cope with the erosion for a number of years. Implicitly the alternative Withdrawal was used in those cases.

2 Additionally on ad-hoc basis a number of beach replenishment projects were executed on coastal sections with high values in the dune area or on the beach. As examples can be mentioned the nourishment works on Texel, near Westerschouwen and additional to the sea defence works near Cadzand.

Both components together form the "bottleneck-policy", sketched in my letter TK18975/3 of march 25th, 1988. The philosophy behind the present bottleneck-policy is equal to the alternative Selective Erosion Control. Executing this policy was limited by shortage of budgets, and had therefore a strongly ad-hoc character. Future policy should have a more structural basis.

**no policy choice yet**

All social effects of the alternatives have to be considered. A choice has to be made between more effort for coastal defence and losing less dunes with high values for society, or making less effort and losing more dunes. Safety against inundation of polders is guaranteed in any case. I have not yet made a choice. To prepare a choice a period of consultation and discussion is foreseen. It is my intention that the council of ministers makes a choice at the end of this year, which choice will be presented to parliament in a policy-memorandum.

Sincerely,

The Minister of Transport and Public Works,

N. Smit-Kroes