Economic optimalization of the protection level against erosion in Dutch coastal cities

A.1 Values affected by coastal processes

Overview of the problem

Space in the Dutch coastal towns is sparse, resulting in pressure on the space available for living, working, recreation and mobility. At the same time, it is expected that climate change and ongoing sea level rise causes an increase in the probability of a severe storm which may result in damage to among others buildings and infrastructure. In other words the risk – defined as the probability of coastal erosion and flooding multiplied by the magnitude of the resulting damage – increases.

Flood defences along the Dutch coastline protect the land from erosion and flooding from the sea. The height and strength of the primary flood defence is in the province of North- and South Holland determined by calculating the impact of a representative storm with a yearly probability of 1/10,000. The area landward of this flood defence is protected to the standards of the Law on Flood Defence. However, some parts of coastal towns are situated in unprotected areas on or in front of the primary flood defence (Figure A-1). Activities or functions in these unprotected areas are essentially at the public's own risk, yet the public appears largely unaware of the risks involved. It is debatable whether or not this situation is acceptable and which role public authorities play with respect to the management of this risk to unprotected areas of coastal towns.

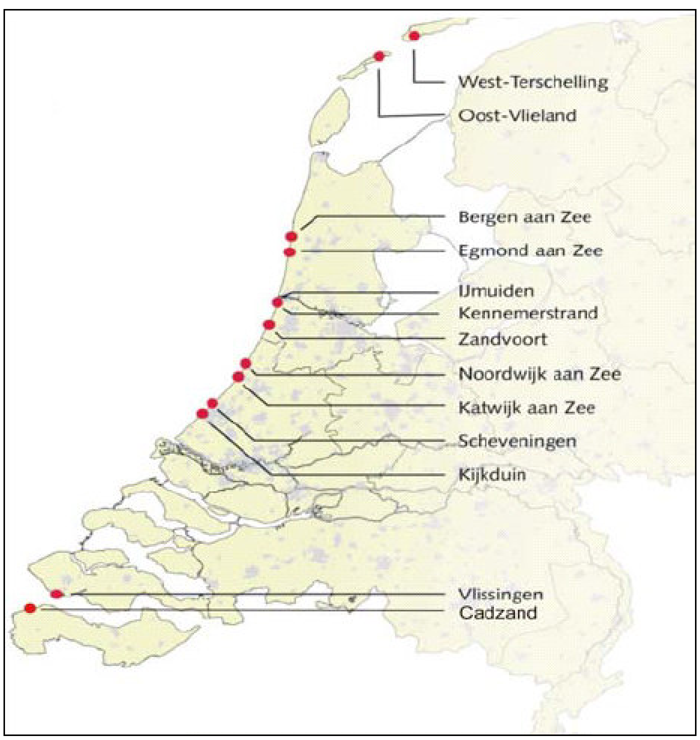

Figure A-1 Coastal towns with unprotected areas (from: Van Nielen-Kiezebrink et al., 2005a).

The result of the rising sea level and increasing storm influence will increase the probability of damage to unprotected buildings and infrastructure, assuming the flood defences remain fixed at the current location. This increase in the risk of damage can be counteracted by protection measures like sand suppletion at the beach or strengthening of the dunes. The costs of these measures consist of the construction costs and maintenance costs, and have the benefit of increased protection for coastal towns. However the question of the balance between costs and benefits remains. In order to gain insight in this problem, an economic cost-benefit analysis can be performed. During this analysis personal hazard risks and victims resulting from dune erosion or flooding are not considered.

The aims of this report are to:

- Develop an overview of costs and benefits information available in literature;
- Determine an economic optimal level of protection for three coastal towns;
- Gain insight into the possibilities and limitations of using a cost-benefit analysis to determine the ideal future protection level of currently unprotected areas.

More information can be found in Kok and Tonk (2005).

General description of the coastline

In order to perform a cost-benefit analysis the spatial boundaries of zones in the coastal transect need to be defined (Figure A-2). From the landward to the seaward side, the cross section consists of a **dune** which changes to a **beach** at the **dune foot** and a **foreshore** near the mean low-tide mark. The location of the **erosion point (P)** is determined by a representative storm characteristic for the **current safety level** (yearly probability of 1/10,000) with associated hydraulic load. The point P is linked to the location of the **boundary profile**. After erosion by a representative storm, the boundary profile has to be unaffected by erosion in order to protect the dune from breaching. The **core zone** is the area between the dune foot and the boundary profile (Van Nielen-Kiezebrink *et al.*, 2005a).

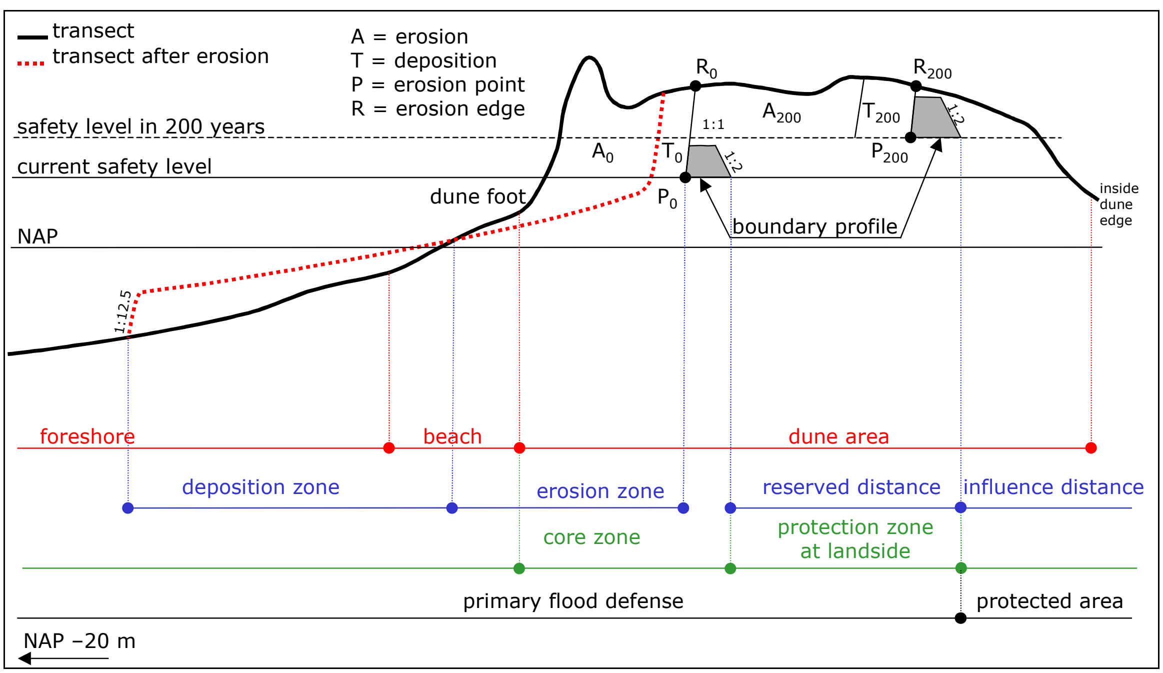

Figure A-2 Definition of zones in a coastal cross section (from: TAW, 2002).:

The Dutch coastal waterboards have reserved enough space in the coastal area in order to be resistant to a representative storm in 200 years time (**reserved distance** or **protection zone at landside**). This way the land is protected from damage caused by future climate change and sea level rise. Given the erosion points determined by the representative storm of the current safety level (yearly probability of 1/10,000), the **erosion line** is determined by connecting the erosion points along the coast. This defines the representative **erosion zone** (Van Nielen-Kiezebrink *et al.*, 2005a).

The location of the erosion line depends on two factors. The primary factor is the hydraulic loads used to calculate the storm representative of a 1/10,000 situation. Given recent insights, the 'old' hydraulic load of the 2001 standard ("HR2001") need to be strengthened due to more severe wave conditions. Changing from 'old' to 'new' hydraulic load will move the erosion lines in landward direction. The secondary factor is the location at the date at which the coastal cross section was measured. The beach and dune areas are subject to a constant change, during which sand is periodically gained or lost to the system. A coastal cross section measured at a specific point in time might have gained a considerable amount of sand to the dune area, causing the erosion point of a representative storm to move seaward compared to the location on a coastal cross section after erosion. Since the erosion line is one of the parameters used in an economic cost-benefit analysis, it is important to keep these uncertainties in mind.

Available information

To get a first indication of the current economic values in the erosion zone, an overview of the information available in literature is given (Table A-1). It is clear that none of the studies are able to estimate the value of buildings at each coastal town. Furthermore, the values according the 'new' and 'old' hydraulic wave conditions differ greatly.

	Value of constructions (million €)			
	'new' hydraulic load		'old' hydraulic load (HR2001)	
Coastal town	Van Nielen-Kiezenbrink *et al.* (2005a)*	Van Nieuwenhuijzen en Planteijdt (2005)*	POK (2004) **	Huizinga (2002) ***
West-Terschelling	10	-	11	-
Oost-Vlieland	48	-	54	-
Bergen aan Zee	51	44	-	8
Egmond aan Zee	96	119	-	13
IJmuiden	-	-	-	-
Kennemerstrand	0	-	-	-
Zandvoort	251	258	-	90
Noordwijk	101	-	-	176
Katwijk	306	-	-	70
Scheveningen	284	-	-	292
Kijkduin	13	-	-	40
Vlissingen	-	-	-	-
Cadzand	0	-	-	-

Table A-1 Overview of the economic value of buildings in the erosion zone.

* values according to Law on Property (values on which property tax is calculated)
** values according to Law on Property, increased with an estimate (%) of damage to home contents (furniture etc.)

*** replacement values

A.2 Alternatives for solving the problem

The current policy concerning the risk management of the unprotected coastal towns is part of debate between the public authorities (on national, regional and local scale, and also the waterboards are involved since they are responsible for the maintenance of the flood defences). Four different policy options for risk management have been formulated. (An extensive description is given in the document "Hoofdrichtingen voor risicobeheersing in kustplaatsen" (Van Nielen-Kiezebrink, 2005b)).

Policy option A: Communication
Maintaining the current coastline, without new building restrictions, and consolidation of the current situation. Communicating the risks to the occupiers of the unprotected area. The dunes can increase by supplementing extra sand in the system, resulting in a coastline keeping up with the rising sea level. However, since the uplifting of the coastal cross section only reaches the foot of the dunes, the erosion line does move landwards. This causes a gradual increase in the probability of damage in unprotected areas of coastal towns.

Policy option B: Consolidation
Consolidation of the current level of safety. Maintaining the current erosion line by sand suppletion of the complete coastal cross section, including the dune area. This way, the probability of coastal erosion or flooding does not increase.

Policy option C: Tailor-made
Further difference in level of protection, where risk-avoidance building is permitted (while considering the local situation). Physical instruments might be the seaward extension of the current flood defences (dune or dike) or building a new secondary flood defence. The most desirable and feasible protection level is chosen by an objective method, like the economic cost-benefit analysis.

Policy option D: Landside scheme
Protect all the buildings in the yet not fully protected areas of coastal towns: the unprotected areas should be included within the chain of primary flood defences as given by the Law of Flood Defence. After this measure no extra construction restrictions of the new buildings will be issued.

These four policies are used as alternative options while choosing a policy, cost benefit analysis being the method for choosing the ideal level of protection for each coastal town; the economic optimum is somewhere between the four options A - D. When choosing option A (maintaining current coastline) the costs of the measures are the lowest but the risk (probability multiplied with damage) is the highest. The opposite is the case for option D (protect all unprotected areas). When using a cost-benefit analysis to determine the ideal policy of coastal protection, it is important to have an insight into the possibilities and limitation of this analysis.

A.3 Socio-economic study: cost-benefit analysis

Introduction

When performing a cost-benefit analysis, the costs and benefits of several physical measures are determined. This information can be used by public authorities when making a decision on the preferred policy of coastal protection. In this report the measures endeavour to decrease the probability of damage by dune erosion to currently unprotected coastal towns. The potential flooding of the land behind the flood defences is not considered, even though this is a possibility at the West Frisian islands and Katwijk (Van Nielen-Kiezebrink *et al.*, 2005a). In the cost-benefit analysis, the costs are the cost of additional measures, and the benefits are the reduction is the risk of damage. In order to calculate the risk we have to know the probabilities and the economic values.

The information needed to perform a cost-benefit analysis depends on the analysis method used and its underlying assumptions. All methods are common inasmuch as the sum of the costs and the benefits should be minimised. All methods also define the risk as the probability multiplied by the economical damage done. This report uses the method developed by the province of Zuid-Holland (Piek, 2002).

Case study: Zandvoort

The coastal town of Zandvoort is located near Amsterdam (Figure A-3). The dune area is two to three kilometres wide and has an alongshore length of 4 km. The total economic value of the area seaward of the 1/10,000 erosion line is over 1 billion € (Van Nielen-Kiezebrink *et al.*, 2005a). This value includes:

- Value of buildings (see table A-1: Euro 251 million)
- Value added of business situated in the area outside the dunes (about Euro 500 million, estimated on the bases of national statistics)
- Indirect value added of business that performs trade with the business in the concerned area (about Euro 250 million, estimated on the bases of national statistics)
- Replacement value of infrastructure (negligible amount)

(these values has been estimated with the programme HIS-KSM. **I will try to get an English description of this**)

The values at several erosion lines are needed in order to perform a cost-benefit analysis therefore it was assumed that:

- There are no buildings seaward of the 1/300 line, thus the value between erosion probabilities of 0 and 1/300 are zero;
- The economic value between the 1/10,000 and 1/100,000 line is estimated as 500 million €, and 500 million € between the 1/100,000 and 1/1,000,000 line.

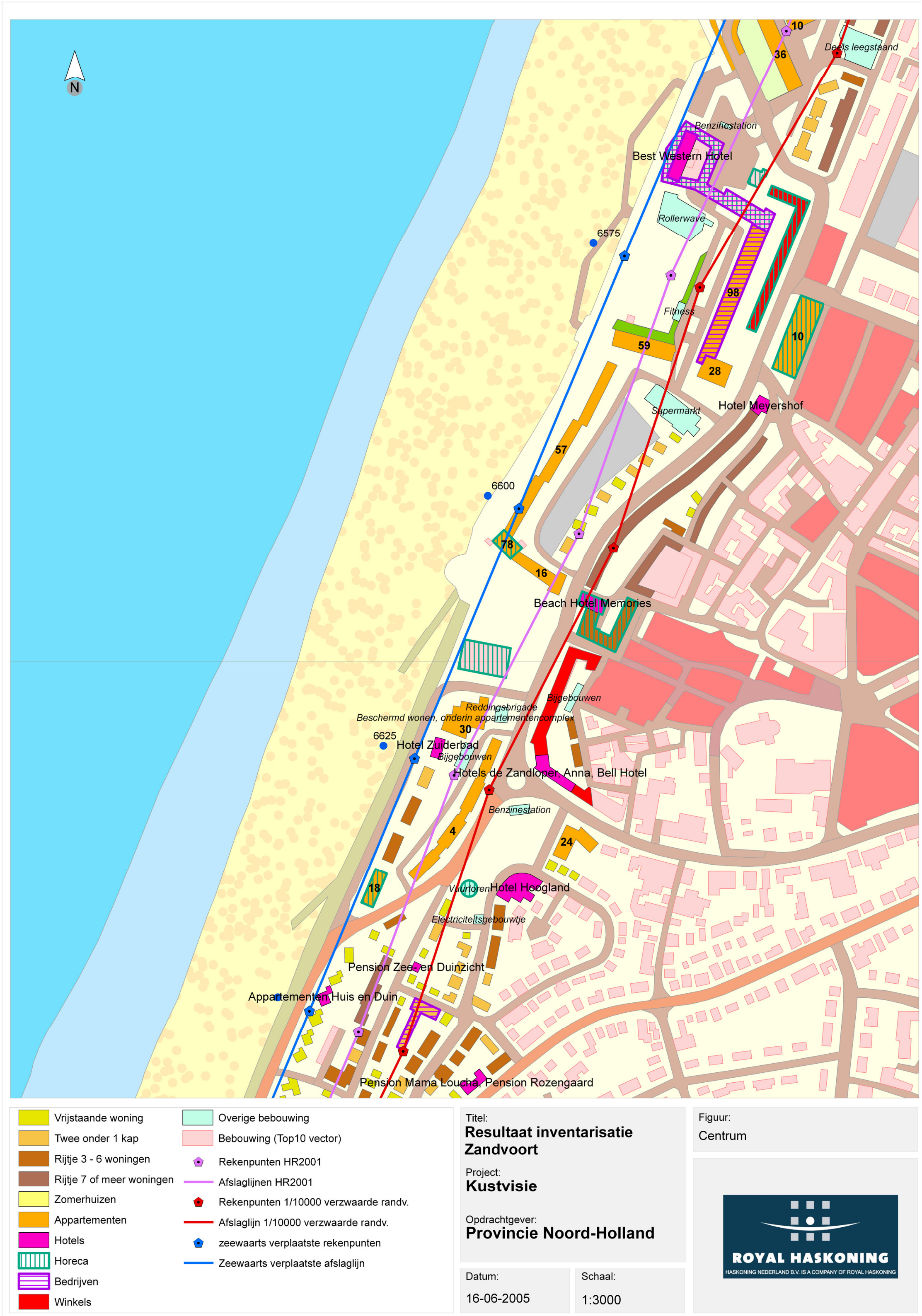

Figure A-3 Erosion lines in Zandvoort (From: Van Nieuwenhuijzen en Planteijdt, 2005).

Yellow and brown (different shades): housing (free-standing, terraced, apartments and holiday houses)
Pink: hotels

Green/white: restaurants and bars
Pink/white stripes: business
Red: shops
Pink line: erosion line “old hydraulic load”
Red line: erosion line 1/10,0000 “new hydraulic load”
Blue line: erosion line on the seaward side

The results of these assumptions can be presented as a value against erosion probability (Figure A-4). The risk can be calculated as the economic value multiplied by the probability of erosion, taking into account an exponential distribution. The cumulative risk as function of the erosion probability is displayed in Figure A-5. The probability of erosion decreases with distance to the coastline, while the cumulative risk increases. The largest increase of the risk is expected in the first metres of from the 1/300-line. The total risk at Zandvoort is 0.7 million € per year. This risk is similar to the yearly “insurance premium” (excluding the costs for the insurer) needed to compensate for the damage over a long time period.

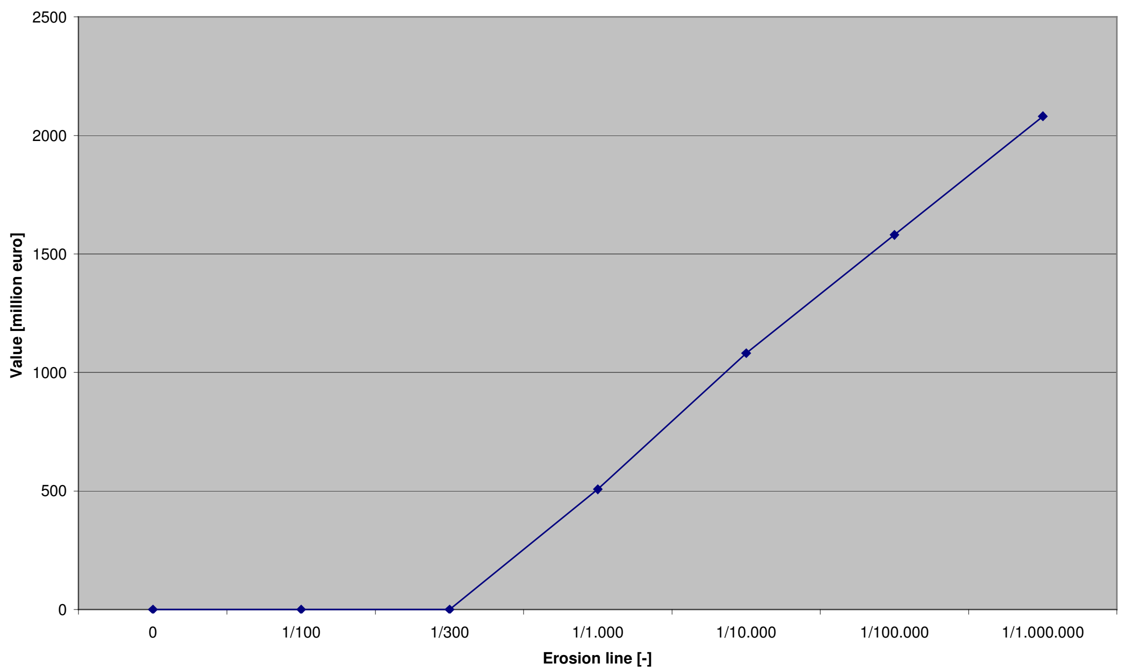

Figure A-4 Economic value in the unprotected area of Zandvoort.

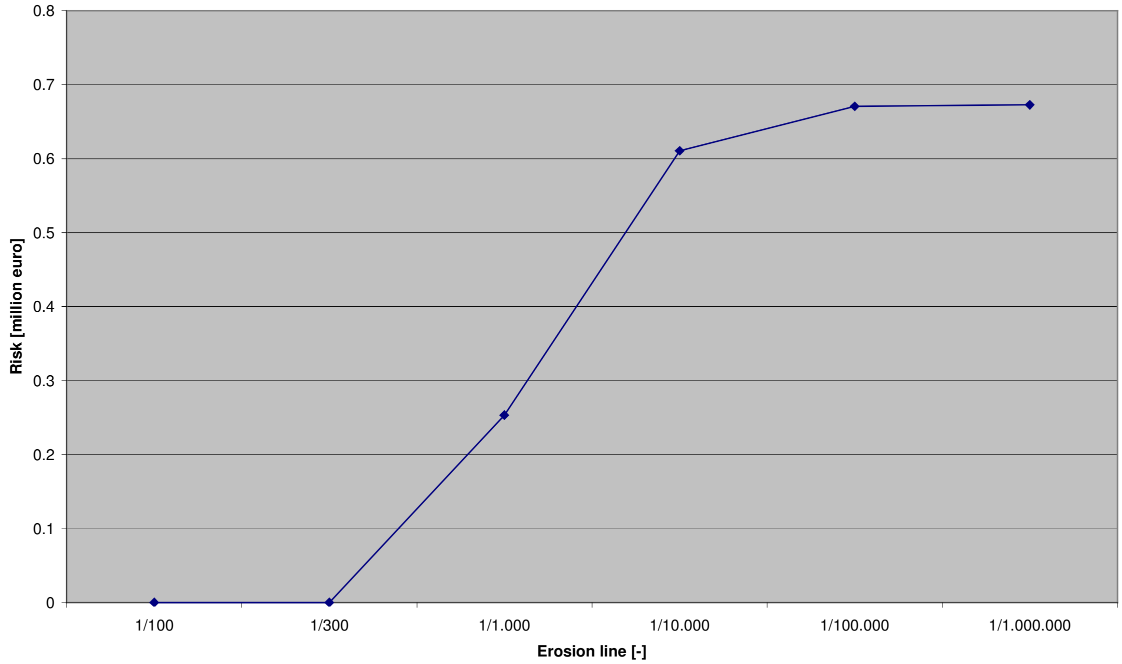

Figure A-5 Cumulative risk as a function of erosion probability.

This study investigates the possibilities of reducing the risk by sand suppletion, the strengthening of the dune at the seaward side in order to move the erosion line (and the associated probability of failure) in a seaward direction. An overview of the costs of sand suppletion to increase the level of safety is given in Table A-2. The costs for increasing the safety of the unprotected areas up to probabilities of 1/4,000 and 1/10,000 are cited in a document of Van Nieuwenhuijzen en Planteijdt (2005). Increasing the probability to 1/4,000 is an instrument in agreement with policy option C (reference?), where the level of coastal protection is tailor-made to the location. The measures by which probabilities are reduced to 1/10,000 conform to policy option D, whereby all unprotected areas are adjusted to the safety standard of 1/10,000 years. The table can be interpreted as follows: Given a location with a current probability of erosion of 1/300, the investment of 30 million € in sand suppletion will reduce the erosion probability to 1/1,000.

	Investment [million €]	Maintenance [million € per year]
1/300	0	0
1/1.000	30	0,1
1/4.000	61	0,2
1/10.000	82	0,3
1/100.000	150	0,5

Table A-2 Costs of sand suppletion (Kok and Tonk, 2005).

According to a cost-benefit analysis the yearly risk can be used to calculate the maximum amount of profitable investments (including additional maintenance costs). Therefore, new risks need to be calculated after moving the probability of the erosion lines with a factor 10, 100, etc. The yearly risk needs to be recalculated to represent the Present Value, in order to make it comparable to the costs of investments. When calculating the Present Value a time horizon of 200 years and a discount rate of 4 % are used (as recommended by the Ministry of Finance).

Figure A-6 displays the total costs as a function of the probability of erosion without taking into account factors such as economic growth and rising sea level. The present value of the risk is equal to 17.5 million €. In this case the ideal situation is to not invest in further increasing the level of safety. Inclusion of economic growth and rising sea level can be accomplished by changing the discount rate. When including factors for economic growth (2 % per year) and rising sea level (1 % per year) it is still not profitable to further invest in safety (Figure A-7). The present value of the risk is equal to 70 million €.

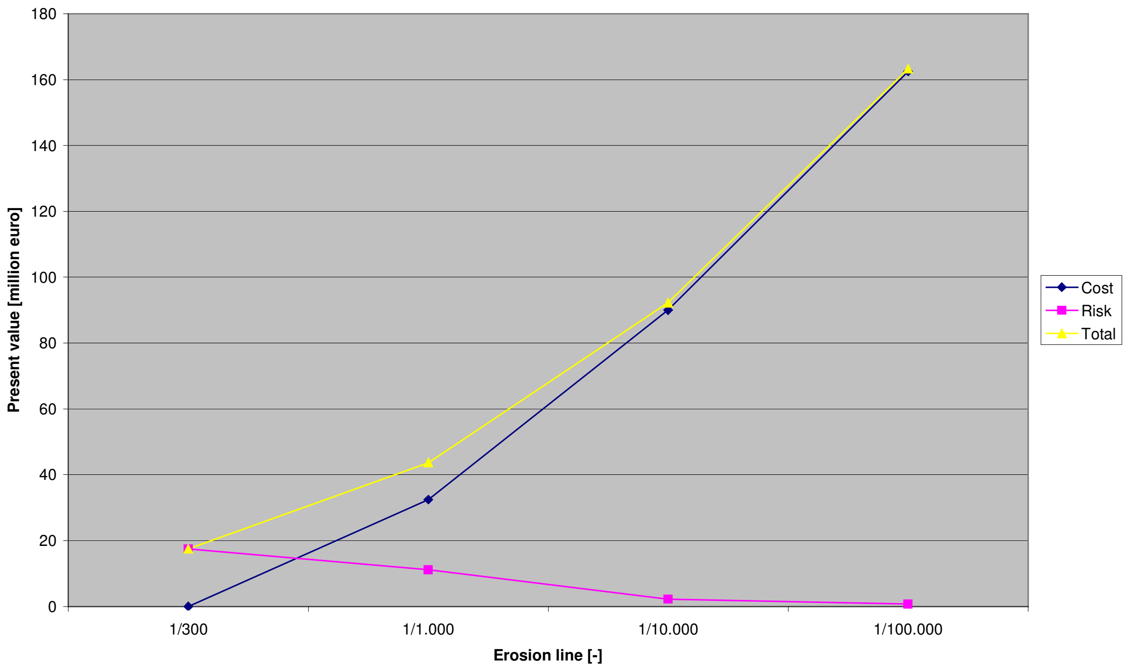

Figure A-6 Costs and benefits of sand suppletion, without economic growth and sea level rise.

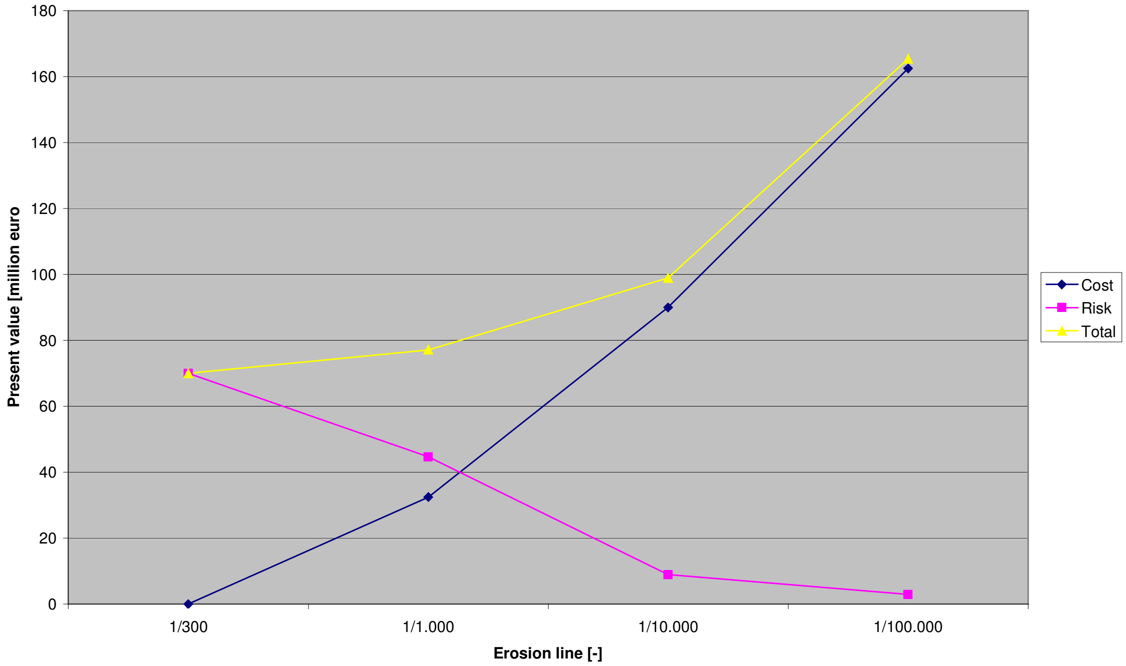

Figure A-7 Costs and benefits of sand suppletion, including economic growth and sea level rise.

A.4 Results and discussion

In the main report (in Dutch) an overview is given of the data available from current studies. The available information is not adequate for a reliable economic optimalization of the protection level of the areas outside the dunes. However, this information can be made available in further studies. The available data included:

- The position of the 1/10,000 erosion line;
- The economic value in the area between the sea side and the 1/10,000 erosion line;
- Costs of measures to maintain the 1/10,000 erosion line and costs of measures to move the 1/10,000 erosion line to the seaward side. (thus, costs to increase the protection level of the area outside the dunes to 1/10,000)

The conclusions on the optimum investment should therefore be considered with great care, since several assumptions were made during the analysis. The following additional data is needed:

- The location of several erosion lines (on top of the 1/10,000 erosion line), with which to define zones of different safety levels;
- An overview of the economic value in each safety level zone;
- The amount of investments needed in order to increase the safety to several different levels. Ideally these are the costs of several methods, for example the costs of beach suppletion, dune suppletion and hard constructions.

In this summary the results of a case study at Zandvoort are discussed, while two more case studies have been discussed in the main report. The case 'Bergen aan Zee' very is similar to the case 'Zandvoort', with the same kind of data used and resulting in the identical conclusion; that it is not profitable to invest in increasing the level of safety. For Scheveningen no information on the cost of investments (sand suppletion) was available. Since only a limited amount of data was used for these case studies, the conclusion cannot be applied directly. Based on these results it is also unfeasible to indicate the economic optimal level of protection for the other coastal towns.

In the main report a subjective estimation of the uncertainty of parameters used in the cost-benefit analyses is given. The costs of the measures and the location of the erosion lines is one of major causes of uncertainty. If the uncertainty of the location of the erosion line is more than tens of metres, the results of a cost-benefit analysis will be unreliable (the considered areas outside the dunes extend to about 100 to 200 metres). Ideally the influence of the parameters on the results of the cost-benefit analysis should be further investigated via uncertainty analysis.

A.5 Reference

Kok, M en A.M. Tonk, 2005. Quick-scan economische optimalisatie beschermingsniveau buitendijkse kustplaatsen. HKV LIJN IN WATER, PR1040, oktober 2005.