The Netherlands:
flood, coastal erosion and management

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Summary

The Netherlands is protected against flooding and coastal erosion by natural dunes, dikes, dams and storm surge barriers. Throughout its history, the Dutch have taken advantage of living in a low-lying delta and learned how to adapt to changing conditions.

Population growth, coastal urbanisation, economic development and a changing climate increase pressures on the coastal zone. Designing and evaluating coastal defences, including the effectiveness of sand nourishment requires long term and frequent coastal process monitoring.

Integrated planning addresses the increasing risk of flooding and coastal erosion and is a useful tool to help reduce the risk to the population and capital investments.

The low lying western part of the Netherlands, *sensitive to flooding and coastal erosion, is protected by dunes, in places supported by additional coastal measures. Visible behind the single ridge dune are the capital-intensive industries, towns and horticulture in glass houses. (photo: //beeldbank.rws.nl, Rijkswaterstaat)*

1. Introduction

The Netherlands, a low-lying deltaic country, is the product of interaction between natural and socio-economic processes. Water enters the lowlands from all directions: via the rivers Rhine, Meuse, Ems and Scheldt (river floods), from the North Sea (tides and storm surges), from precipitation and from subsoil seepage. Today, about two thirds of the country's surface is below mean sea level and most of the landscape is man-made. The Netherlands is a prosperous, densely populated and above all dynamic country. Since 1950 the population has grown from 10 to 16 million people, while the Gross Domestic Product has increased exponentially to about € 600 billion (2008, see Figure 2). Most of this growth is concentrated in the low-lying western part of the country.

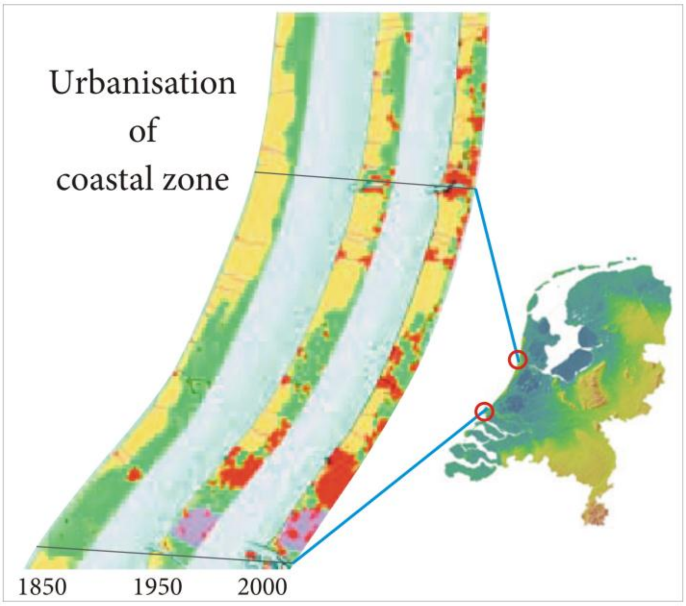

*Figure1: **Increasing urbanisation** (in red) of the sandy Holland coastal zone between Hoek van Holland and Den Helder. (source: Min.V&W , Min.VROM, Min EZ, Min LNV, 2002)*

The coastal zone has considerable economic value. Its sandy beaches and dune fields are both a natural habitat and natural sea defence. These are not the only functions of the coastal zone; many towns and cities are situated here, such as Rotterdam (largest harbour in Europe) and The Hague. Strong urbanisation in the Dutch coastal zone started at the end of the 19th Century (Figure 1).

Where beaches and dunes are absent, dikes, dams and storm surge barriers protect the hinterland from floods.

Flood risk and coastal erosion management in the Netherlands are the concern of public organisations, such as the Ministry of Infrastructure and the Environment (former Transport, Public Works and Water Management = Min. V&W) and the 26 water boards, some having been in existence for more than 800 years.

Today, flood risk and coastal erosion management occur within the legal framework of the Water Act (2008, enacted in December 2009), which incorporates amongst others the Flood Defence Act of 1996. This act holds statutory safety standards and divides responsibilities between national, regional and local governments (including the water boards) with respect to evaluation and reinforcement of flood defences.

2. Historical aspects

Up to the Middle Ages humans moved in response to changes in the coastal zone. People normally lived on the higher dunes and from the 5th century BC on 'dwelling mounds'. Sedimentation from tidal waters allowed the land to keep pace with rising sea levels.

A rising population forced people to move to low-lying areas. Since about 1000 years ago, the Dutch started to structurally affect the coastal landscape (see IGU, 1996). Drainage for agriculture, peat excavation for fuel and salt production caused land subsidence and more serious flooding. Humans responded by constructing dikes improving drainage; first by windmills, later by mechanical means, which exacerbated land subsidence.

In the peat and clay areas of Holland, whereas 1000 years ago the land was almost three metres above mean sea level it now lies three metres below (Figure 2). For other low-lying areas, the situation is more favourable. The increasing flood risk from the sea led to the decision, in the 20th century, to shorten the coastline. This included the construction of the Zuiderzee Works (1932 - Closure Dam and large polders) and the Delta Works (1953 – 1997, dams, sluices, locks, dikes, and storm surge barriers).

Today, most infrastructure developments occur in low-lying polder areas. Although the probability of floods has decreased, the consequences should a flood occur would be far more serious than ever before.

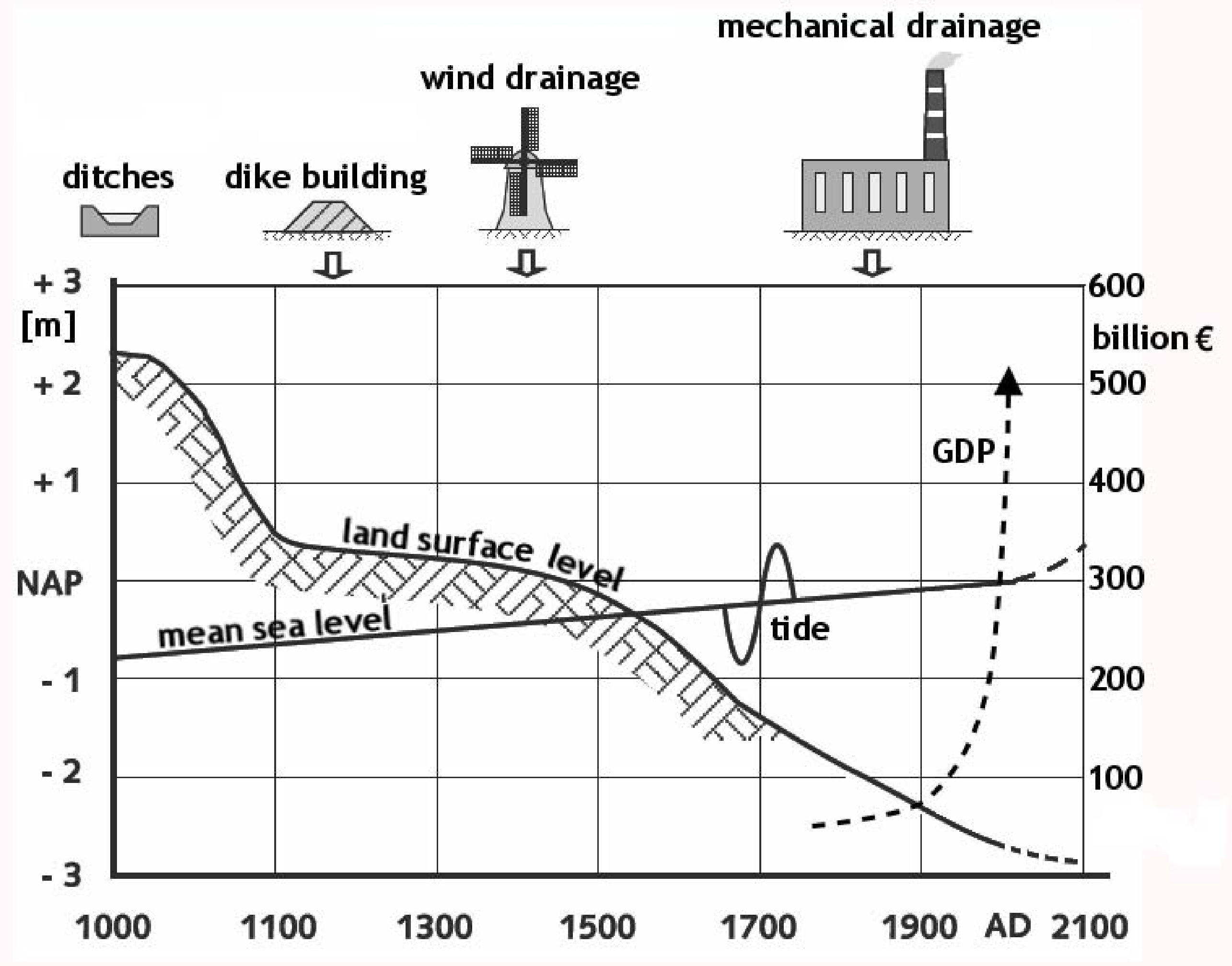

*Figure 2: **Land subsidence** largely by compaction of peat and clayey areas intensely drained, sea level rise and the rise of prosperity indicated by the Gross Domestic Product (GDP) of the Netherlands.*
NAP = Normal Amsterdam Water Level ~ Mean Sea Level. (source: TAW 1998, adapted)

3. Present flood risk management

Overview
The Netherlands has 3500 km of primary flood defences along the coast and rivers and around lakes. An additional 14,000 km of regional (secondary) dikes and embankments exist. The primary flood defences form dike rings. There are 57 larger and smaller dike rings, some are almost the size of a province, others just an island (Figure 3).

Safety standards
Standards for the design and safety of primary flood defences are based on analyses of the 1953 flood disaster. The First Delta Committee (1953) proposed safety standards for flood defences along the Dutch coast and in the estuaries. At a later stage, standards for river dikes based on the work of the Delta Committee were proposed. It was only in 1996 that standards for all primary defences became a legal part of the Flood Defence Act.
A safety standard, defined as the probability of exceeding water levels within a certain return period, range between 1/1,250 (upriver) and 1/10,000 (Holland coast) annually. A design and maintenance of a sea dike should be able to withstand a water level with a chance of occurring once in 10,000 years. For dunes, this means they should have a minimum volume (sand) capable of withstanding predicted storm conditions.

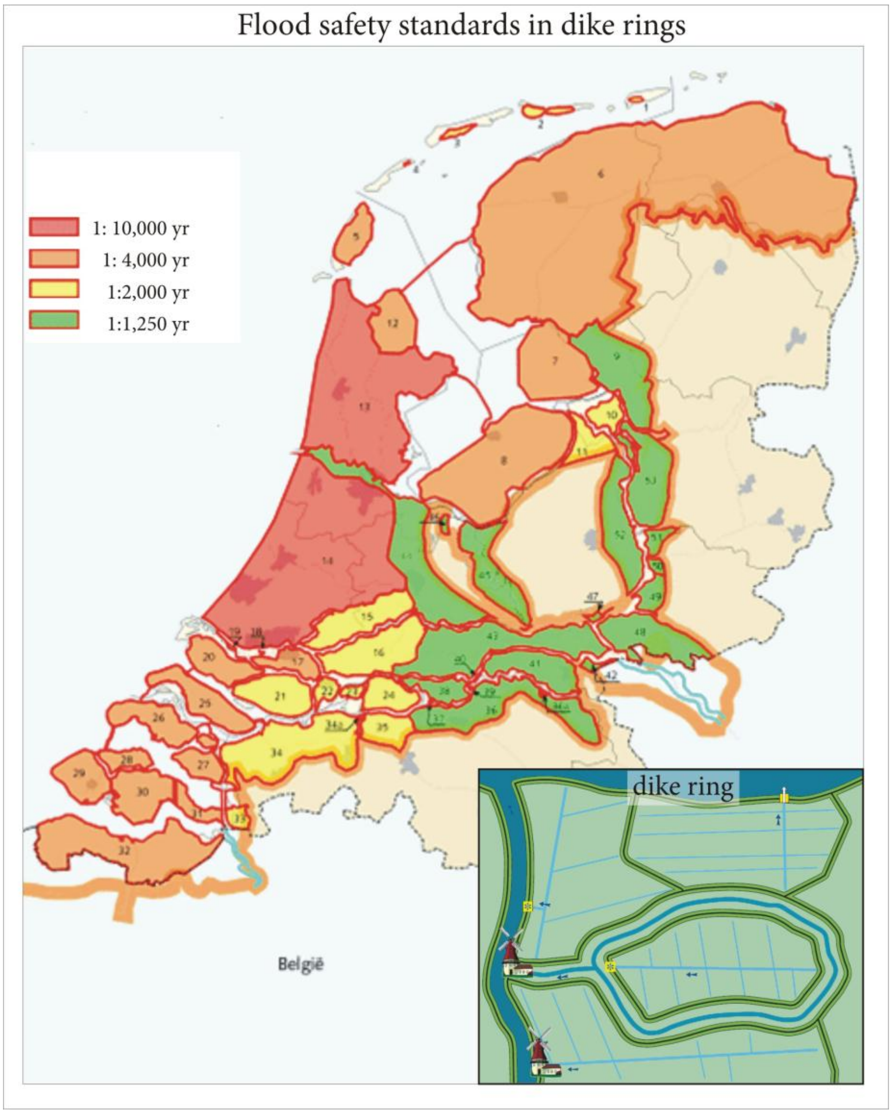

Figure 3: ***Dike rings and flood safety standards in the Netherlands.*** *The western part (red) is most densely populated, with large capital investments, infrastructure, harbours and airport, has the highest safety standard. In this part, the coastal defences (such as dunes, dams and dikes) are designed to be able to withstand a sea level which occurs once in the 10,000 years. (*source: RWS adapted by Robbert Misdorp)

Evaluation

Every 6 years, testing of compliance to statutory safety standards requires state-of-art information of the hydraulic conditions and geo-technical state of the primary flood defences. This information, provides the basis for a nation-wide inventory of the strength of flood defences. Water boards appraise this (legal) technical evaluation with their local judgement and report on the state of their primary flood defences. The reports pass to the provinces and from there to national government and parliament. This step-wise overview has a 6-yearly cycle and has been performed twice (2001 and 2006) since the Flood Defence Act of 1996 (Figure 4).

The most recent evaluation (2006) led to the conclusion that almost a quarter of the flood defences in The Netherlands did not yet comply with the new safety standards. The increase in capital investments and human settlements over the last decades are the main reasons for updating the safety standards in The Netherlands.

In the past, the disastrous floods (1916 and 1953), were the main catalysts for policy change and visionary decision-making regarding the construction of the Closure Dike (1932) and Delta Works (1953 – 1997).

*Figure 4: **Short term testing and improving flood defences** and long-term adjustment to change*

The Ministry of Infrastructure and the Environment (former Ministry of Transport, Public Works and Water Management - Min. V&W) is reviewing the safety standards and looking for alternative approaches (e.g. improved crisis management and spatial planning policy) and addressing the envisaged impacts of climate change. This national assessment includes cost-benefit analysis and a nationwide risk assessment on a 20-40 year cycle (Figure 4).

Flood defence reinforcements

Based on the evaluation of 2001 and 2006 many projects designed to improve flood defences to comply with the 2015 safety standards for rivers and coast, were launched . On average, total government spending on primary flood defences is about € 600 million annually (0.1% of Dutch GDP in 2008), while the protecting capital invested is reaching several times the GDP. This flood defence includes about € 120 million of operational maintenance costs funded (and locally taxed) by the water boards.

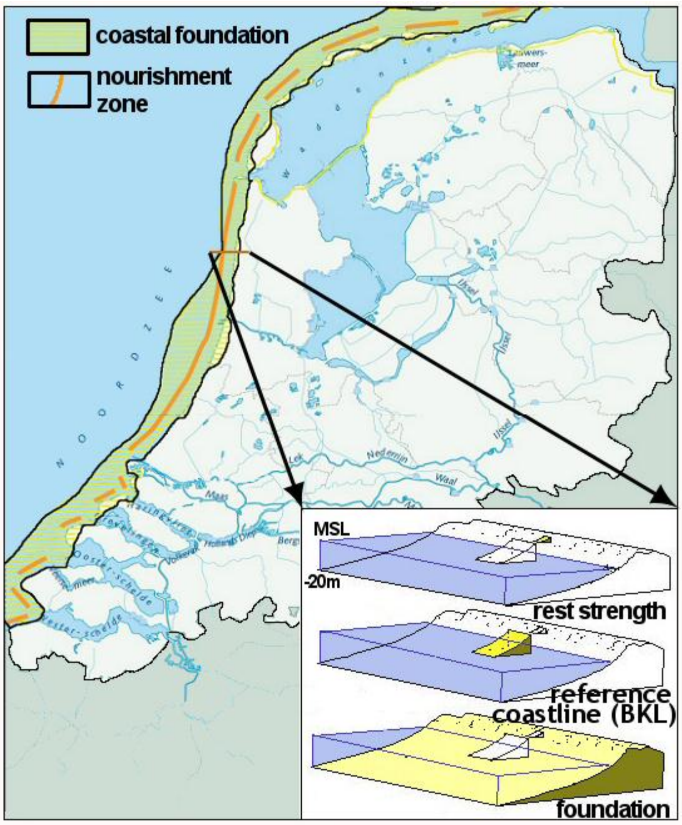

*Figure 5: **The coastal foundation** and nourishment zone.*

4. Present coastal erosion management

Overview

In addition to the system for flood risk management, in 1990 the Dutch government adopted a hold-the-line policy to combat structural (long-term) coastal erosion, and maintain the coastline at its 1990 position. Natural fluctuations are allowed but the management aim is to prevent landward movement of the coast caused by sea level rise.

Standards

For this 'Dynamic Preservation' policy (1990), there is a reference standard for each 250 meter wide coastal section, the 'Base Coast Line' (= reference coastline= BKL, Figure 5). This BKL is a function of the ten-year trend in sand volume for the centre of the profile (between 3 meter above and about 5 meter below Mean Sea Level). Averaging this linear trend over a decade provides a measure of structural, rather than erosion caused by a major storm event.

Monitoring

In the 1960s, an annual monitoring programme (JARKUS) was established to assess the evolution of the near shore zone along the entire, 350 km long Dutch coast. The JARKUS data set represents a key source of coastal information, particularly in combination with historical observations of Dutch coastal evolution dating back to 1840-1850.

JARKUS measures coastal depth profiles from the first dunes up to 1 kilometre offshore, with a profile spacing of 250 meters (see also CCC III-3-3-2). Based on these data a so-called Momentary Coastline (MCL) based on the volume (per unit length) of sand between two horizontal planes is calculated. If the trend of the Momentary Coastline is landward of the Basal Coastal Line this represents a signal to consider intervention (= compensation by sand nourishment).

Compensation

Based on the methodology above, coastline maintenance between 1990 and 2000 required 6 million m^3 of sand annually. Whilst this approach was successful in combating erosion in the short-term, it did not address morphological developments in the deeper parts of the coastal profile (CFZ) over longer *time scales*, such as those associated with sea level rise.

Therefore, in 2000, the Dutch government adopted a wider approach, which involves maintaining the sediment budget of the 'Coastal Foundation Zone' (CFZ = the area extended to the – 20 m depth contour). The primary method is sand nourishment , which led to an increase in volume of supplied sand from 6 to 12 million m^3 (see Figure 6), through beach nourishment and gradually more and more foreshore (underwater) replenishment, which is an cost effective way to nourish sand.

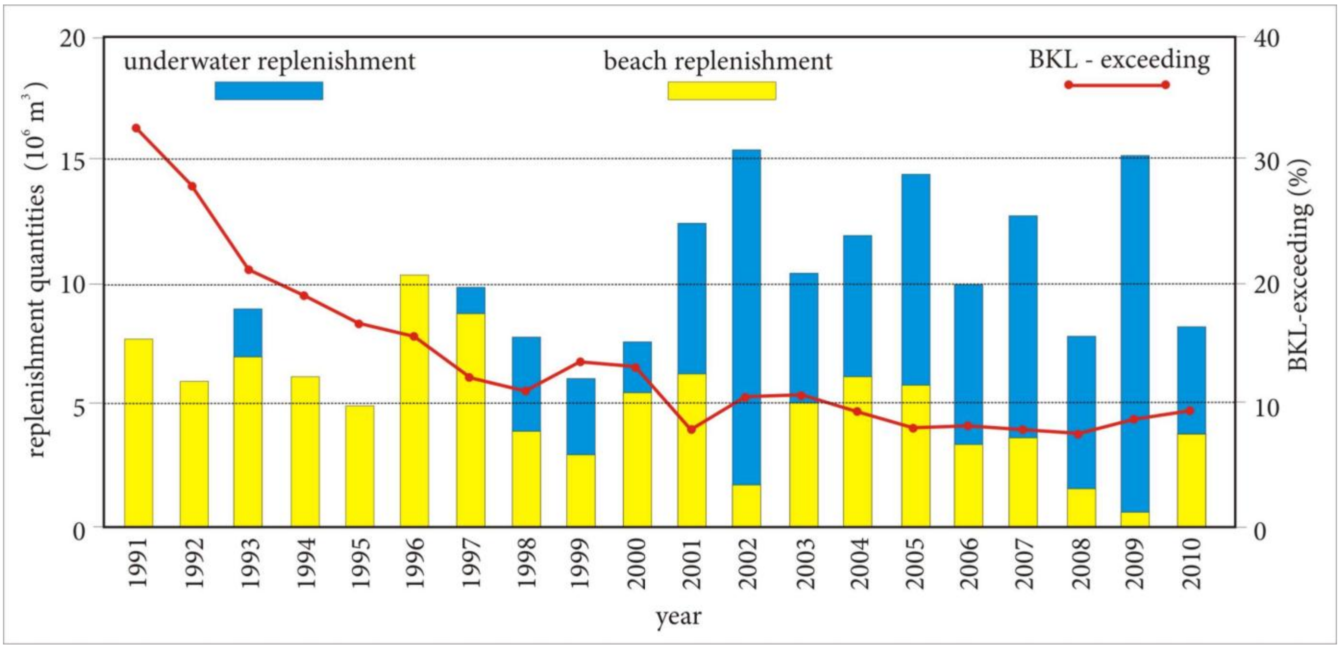

*Figure 6: **Annual sand nourishment volumes** along the Dutch coast to counteract the effects of structural coastal erosion. The structural erosion, expressed in % exceeding the BKL versus the total coastline, is significantly decreased. Since 2000, the volume doubled to compensate for sand losses in the 'Coastal Foundation Zone'.*

Managing the 'Coastal Foundation Zone' (CFZ) provides long-term safety, while maintaining the 'Base Coast Line' provides conditions to preserve the sand volume ('rest strength') of the higher parts of the coastal profiles and addresses smaller temporal and spatial scales.

5. Some ICZM experiences

Turning point in water management

The 1953 storm surge disaster triggered a huge hydraulic undertaking in the south: the Delta Project. At that time the only feasible solution to securing the area against similar extreme disasters seemed to be closure of all sea inlets, except for the Nieuwe Waterweg (entrance to the Port of Rotterdam) and the Westerschelde (entrance to the Port of Antwerp). In 1958, work began on the Delta Project to shorten the coastline by about 700 km.

During the 1970s, public pressure led to a revision of the Delta Project, reconciling safety with environmental issues. Parliament decided (1979) to abandon damming the Eastern Scheldt, and instead sought to preserve its tidal character with tidal currents, flats and salt marshes including their abundant flora, rich fauna and the high-yield shellfish fishery.

*Figure 7: **The Delta Project in SW Netherlands** between the harbour areas of Rotterdam and Antwerp: the primary dams, sluice complex and storm surge barrier in the west - in the three mouths and three series of compartment dams in the east. (photo: //beeldbank.rws.nl, Rijkswaterstaat)*

This was achieved by the constructing a storm surge barrier at the mouth of the Eastern Scheldt tidal basin marking a turning point in the history of Dutch water management (Koningsveld et al, 2008). After a millennium of protection strategies, the completion of the Delta project represented an important step towards an integrated national water policy plan (Misdorp & Terwindt, 1997).

Next steps towards ICZM

The decision in 1990 to adopt a policy of 'hold the line', while preserving the dune habitats and natural coastal dynamics, represents another step towards integrated coastal and water management in the Netherlands.
This policy, confirmed in the Third national Policy Document on Coastal Areas (2000), extended the coastal domain from the deep-water zone to the dune fields. The document also recognised weak links in coastal flood defences and the risk of increasing storm damage to seafront settlements. Integrated planning studies undertaken by relevant provincial authorities, not only looked at ways to strengthen the flood defences, but also to improve the quality of the areas. Environmental impact assessments helped predict the loss of natural values and hence compensation needs.
Some of the issues related to increasing socio-economic developments and impacts of climate change are addressed in a new coastal zone policy. This included strengthening the integrated approach, focusing on 'spatial quality' and 'sustainable safety', in line with the European Commission's Recommendation for ICZM, see the document: "Towards an Integrated Coastal Zone Policy" (Ministry V&W, Min. LNV, Min. VROM, and Min. EZ- 2002).

Present principles of ICZM in the Netherlands

The principles of ICZM are included in two Dutch policy documents: the 2005 'National Spatial Strategy', encouraging integrated spatial planning, and the 2000 'Third Policy Document on Coastal Areas' aiming at more resilient water systems in coastal zones.
These policy documents contain four main principles of ICZM:

1. 'Decentralisation': Implementation of spatial policy "should be decentralised wherever possible and centralised only where necessary".
2. Flood protection: "Soft wherever possible, hard only where necessary".
3. Raising awareness: "Successful ICZM requires understanding by stakeholders, public support and the active involvement of NGOs (WWF, 1996)".
4. Exchanging information: All EU coastal states face similar problems when developing ICZM strategies (CCC I-1-1). Regular regional information exchange is valuable.

Spatial planning
In the Netherlands providing protection from flooding and erosion management are priority areas. Other issues such as economic development, nature conservation, and recreation play a secondary role. Integrated spatial planning is the key to creating sustainable adaptive management of the densely populated coastal zone and play an important role in identifying emergency flooding locations along rivers and in spreading the population away from flood risk areas.

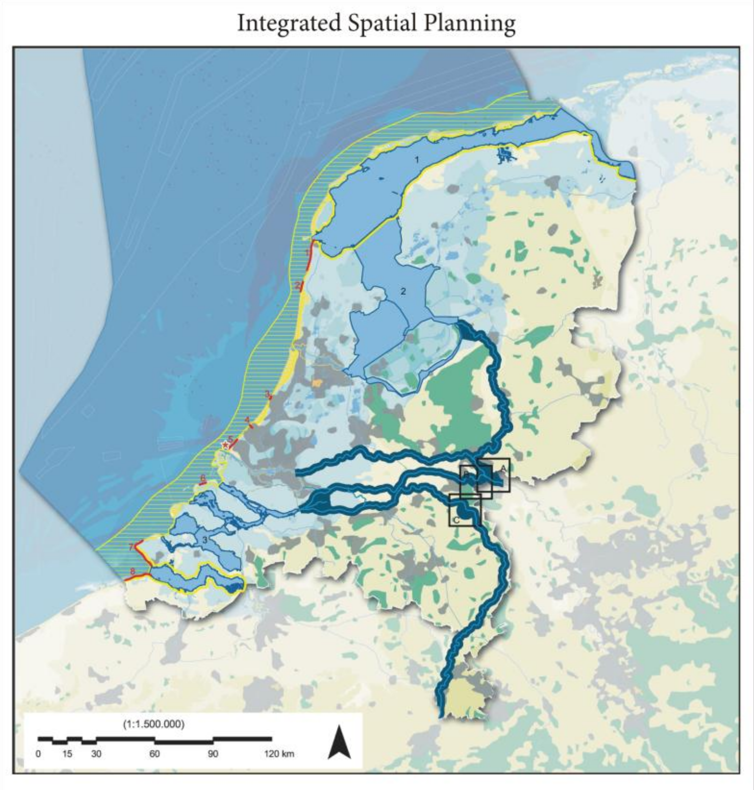

*Figure 8: **Water as guiding principle** in integrated spatial planning.*

<u>Legend:</u>
Blue rivers: "Room for Rivers projects" ;
Black open squares: non-effectuated emergency flooding polders, upriver ;
Dark Yellow: protected dune zone: flood safety is first priority;
Light Yellow: coastal foundation zone: area of nourishment: fore shore and deep water (unto 20 m below MSL) and reserve for sea ward extension;
Red areas in the coastal zone: weak links areas reinforcement is being executed;
Light Blue on land: area below sea level.

(source: 'Space for Development' –Gov. Document prepared by four Ministries and adopted by Parliament 2006 - Nota Ruimte)

The decentralisation of spatial policy has become clear in the last few years. For example, the annual planning of sand nourishment was delegated from the national to the provincial level. The national government continues to provide most of the financial resources for the primary water and coastal defence schemes. Together with this decentralisation, the national government is scaling down the size of the ministries (J. van Alphen & Q. Lodder, 2006). Both developments occur during a period when crucial long-term adaptive coastal management decisions and preparations for measures must be made.

6. Conclusions

Annual sand nourishment is an efficient means of coastal defence. It is flexible, cost effective and based on decades of monitoring and knowledge of coastal dynamics. This experience provides also a firm basis for creating new land in the sea to combat lack of space and adapting to the impacts of climate change.

Integrated spatial planning can play an important role in identifying and implementing adaptive resilient measures.
The Dutch experience has, over many centuries evolved into a coherent system of ICZM principles and practices, anchored in national legislation and national/regional planning. The Netherlands is willing to exchange its coastal and water management experience with other coastal countries.

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