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Enabling Delta Life

Adaptive Water Management for Delta Regions: Towards GREEN Water Defense in East Asia

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Summary
This report is about integrated water resources planning and management for delta regions with a focus on flood risk management under a changing climate in East Asia. GREEN Water Defense is based on the 'Green Growth' concept, as promoted by the World Bank, UNEP and others, as an innovation to traditional ways of flood protection. It addresses flood protection in a more holistic and natural way. Instead of depending mostly on building a dyke or concrete wall against a flood hazard, it uses a balanced structural and non-structural approach including maximum use of the ecosystem services to mitigate the flood hazard. In addition, it uses participatory spatial planning wherever possible or necessary: providing room for rivers, green corridors and urban space. The report describes best practices from the Netherlands, the USA and other OECD countries. These experiences show that GREEN Water Defense is feasible and effective, can be cheaper than traditional solutions, and is often more cost-efficient because it serves multiple purposes. The report also identified good opportunities for novel approaches in East and Southeast Asian countries, with special reference to the Mekong Delta, Vietnam and the Jakarta metropolitan area, Indonesia.

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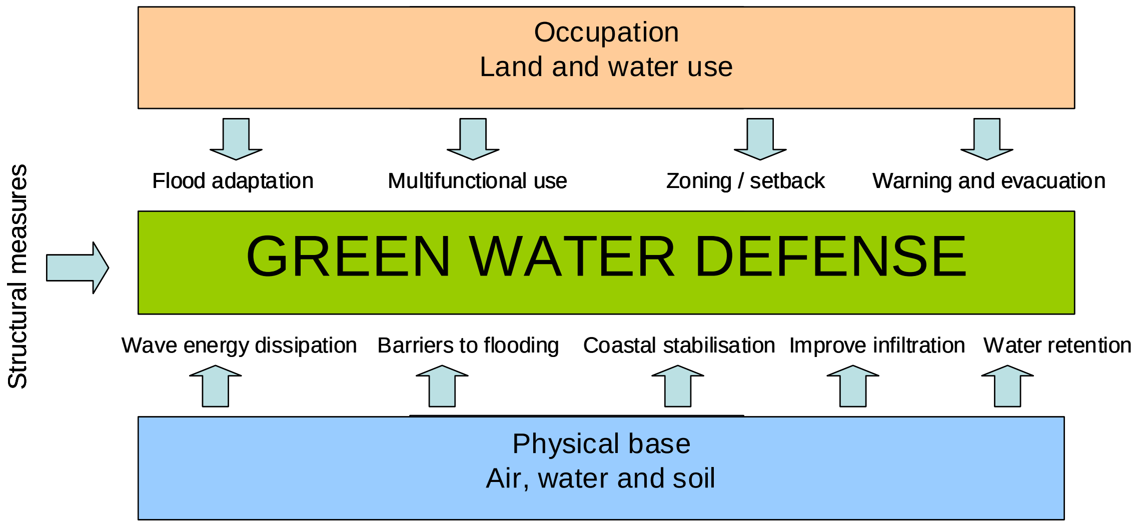
Executive Summary

This report is about integrated water resources planning and management for delta regions with a focus on flood risk management under a changing climate in East Asia. The countries in East and Southeast Asia face huge flood problems. The combined impact of increasing urbanization, population growth, socio-economic development and climate change in coastal regions that are already prone to multiple natural hazards is vast. This will lead to an increase in public infrastructure investments. The challenge is to ensure that these investments will be sustainable, climate proof and cost effective. GREEN Water Defense is an approach through which this challenge can be turned into success, if applied properly. The reason being that GREEN Water Defense does not focus exclusively on one type of solution, but addresses flood protection in an more holistic and ecosystem-based way: instead of focusing only on traditional infrastructural solutions, it emphasizes the interactions between those who occupy the deltas (the so called *Occupation Layer*), their infrastructure (the *Network Layer*) and the natural delta conditions (the *Base Layer*).

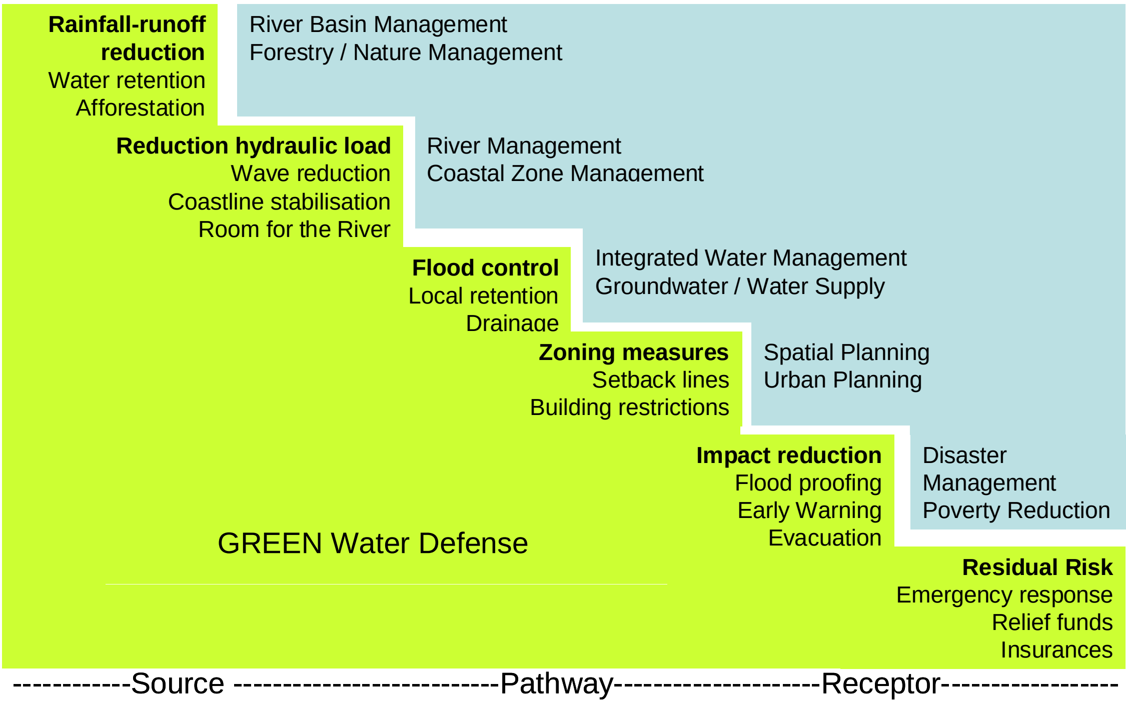
GREEN Water Defense has been based on the 'Green Growth' concept, as promoted by the World Bank, UNEP and others, as an innovation to traditional ways of flood protection. Basically it addresses flood protection in a more holistic and natural way: instead of keeping the three spatial layers separated from each other, GREEN Water Defense emphasizes the interactions between these three layers. Instead of depending mostly on building a dyke or concrete wall against a flood hazard, it uses a balanced structural and non-structural approach including maximum use of the ecosystem services from the base layer to mitigate the flood hazard. In addition, it uses participatory spatial planning wherever possible or necessary: providing room for rivers, green corridors and urban space (see figure below):



The GREEN Water Defense concept is by no means purely theoretical or academic. Indeed, it has manifested itself already in a wide range of examples and projects. Some of the best practices described in this report have started already in the early 90s of the past century. And from these practices we have drawn lessons that can be used for implementation in other countries and situations. The report describes best practices from the Netherlands, the USA and other OECD countries. These experiences show that GREEN Water Defense is feasible and effective, can be cheaper than traditional solutions, and is often more cost-efficient because it serves multiple purposes. The report also analyzed the opportunities for novel approaches in East and Southeast Asian countries, with special reference to the Mekong Delta, Vietnam and the Jakarta metropolitan area, Indonesia.

To facilitate the implementation of GREEN Water Defense measures a menu type list has been prepared, based on i) flood type; ii) defense mechanism and iii) spatial layer. Three flood types are distinguished: Coastal, Fluvial and Pluvial floods. Defense mechanisms include wave energy dissipation, coastline stabilization, infiltration, (upstream) water retention and room for the river as well as more traditional systems, such as flood defenses, early warning and evacuation.

The Source-Pathway-Receptor approach provides a cascade of risk reduction measures: starting from rainfall in the upper catchment all the way down to the individual or household that is impacted. The cascade can be used – in a generic way – as guidance for priority setting: obviously, it is best to remove the source of the flood altogether, but this is not always completely possible. So going down the cascade, we find reduction of the hydraulic load, flood control, zoning measures, impact reduction and finally measures to compensate the residual risk.



The cascade also visualizes that for each step in the GREEN Water Defense strategy there is always a corresponding policy and management field and sometimes more than one that is relevant (in blue color). Since flood risk management cannot be implemented independently, it is crucial to make linkages and agreements with these other policy domains.

Setting up a successful GREEN Water Defense project requires good cooperation between government agencies, local inhabitants / stakeholders and knowledge providers. This requires good preparations in terms of stakeholder participation, good governance and sound project management. In addition to these preparations, we identified 6 key issues indispensable for GREEN Water Defense:

1. Raise awareness for integrated flood risk management among all relevant actors and stakeholders: it is not only an issue for engineers of public works departments.
2. Share knowledge between all relevant actors and stakeholders. Combine scientific knowledge with local environmental knowledge. Use easily accessible methods and models and ensure that all have trust in this knowledge.
3. Develop a shared vision that integrates flood risk with economic development and environmental sustainability.
4. Translate the vision into concrete, accountable targets (SMART objectives) for flood risk management. Make upfront financial arrangements, using the ‘who benefits should pay’ principle and make these benefits as explicit as possible, including ecosystem services.
5. Do not prescribe a blueprint for local solutions, but use the genius of the place.
6. Prepare a monitoring program and build in evaluation procedures.

Preface

This study is part of efforts towards development of ‘Green Growth’ knowledge base by the World Bank. It has been executed by Deltares in collaboration with key experts from Vietnam and Indonesia. The study took a ‘case approach’ in order to identify the key elements of best practices and successes to promote climate change adaptation of water resources management in low lying coasts and deltas. The report describes best practices from the Netherlands, the USA and other OECD countries and analyzed the opportunities for novel approaches in East and Southeast Asian countries, with special reference to the Mekong Delta, Vietnam and the Jakarta metropolitan area, Indonesia.

This report is written for a broad audience of water professionals, decision makers, Bank staff working in water and related sectors, as well as the general audience who is interested in climate change adaptation in water management.

The authors wish to thank Dr. Xiaokai Li of the World Bank for his inspirational support and advice, Dr. Frank van der Meulen for reviewing the report and Mieke Ketelaars, Tim van der Staaij and Laurence Koetsier for their assistance.

The views expressed in this report are those of the authors only and do not necessarily coincide with those of the World Bank.

Contents

1 Time for a change

1.1 Deltas in times of climate change

Most developing countries spend 2 to 6 percent GDP on infrastructure development. For Asia alone, public funding of infrastructure by 2020 will total US$400 billion (Robichaud, 2010). It has been estimated by the Organization for Economic Co-operation and Development (OECD) that some 40 % of all these development investments are at risk due to climate change (OECD, 2005). Water infrastructure seems especially vulnerable to climate change, as the hydrological cycle responds to even small shifts in climate in often unpredictable ways (IPCC, 2008). This has prompted the UN World Water Assessment Programme to state that, for humans, climate change is water change (UNESCO and Earthscan, 2009).

For the highly populated deltas in the world this is very much the case, being wedged in between the sea and rivers. The rivers flowing through the deltas are an important source of fresh water and nutrients critical for sustaining life. At the same time these rivers carry polluted water originating from upstream waste discharges and may cause serious pollution problems. The mixing of salt and fresh water in their estuarine part creates environmental conditions for a unique flora and fauna. Delta ecosystems are therefore valuable and among the most productive ecosystems on earth. But, being low-lying areas, deltas are also vulnerable to flooding and have to cope with stagnating drainage. That is why living in deltas has always required human intervention. Land reclamation, irrigation, soil drainage and embankments have made many a delta a safe place to live and work.

This report is about integrated water resources planning and management for delta regions with a focus on flood risk management under a changing climate. Flood risks are part of a wider problem in which local and regional changes in land use interact with regional and global environmental changes, such as subsidence, sea level rise and climate change. Climate change as such is not the main immediate threat, but in combination with all other human induced changes, such as population growth, economic development and urban migration poses a great challenge on the medium to long term. This is not something that happens to us. Indeed, as actors ourselves we can act now to help reduce vulnerability against floods. Flood risk management should therefore be considered in the wider framework of adaptive, integrated water resources management, in which rainfall patterns, spatial planning and land use, environmental conservation (e.g. wetlands), urban drainage etc. all play an important role. This warrants a renewed attention to the role of natural processes and how they can be used to our benefit. Creation (or restoration) of room for natural processes to take place could lead to a significant reduction of flood risks, while at the same time provides other ecosystem services as well. Traditional civil engineering and ecological engineering can complement each other as ingredients of the recipe. Experts need not only work together, but also with stakeholders and government policy makers alike to contribute to an integrated adaptive water management for delta areas.

1.2 Flooding, coastal development and climate change

Here we describe the potential increase in flood risk due to major changes in the coastal and delta environments due to physical, socioeconomic and demographic drivers. We will use a general assessment framework, based on the spatial layers model for deltas.

In order to understand how drivers lead to changes in the flood risk of a delta, a multitude of relations between human activities, physical and ecological delta conditions need to be accounted for. To provide insight in this complex system, we use a simplified structure of a delta in the form of a *Layer model*. This Layer model recognizes three physical planning layers (Figure 1.1): the Base layer (water and soil), the Network layer (infrastructure) and the Occupation layer (zoning of land use functions), each with different but interrelated temporal dynamics and public-private involvement (VROM, 2001). The model indicates a physical hierarchy in the sense that the Base layer influences the other layers through both enabling and constraining factors. For instance, the soil type determines largely the type of agriculture that can be performed in the occupation layer. Unfavorable conditions (constraints) posed by the Base layer can to a certain extent be mitigated through adaptations in the Network layer or occupation layer. For example, farmers can use agrochemicals to improve soil conditions. And dykes can be constructed to protect low lying land from flooding. But these adaptations to the original physical geography of an area require investments and need to be managed.

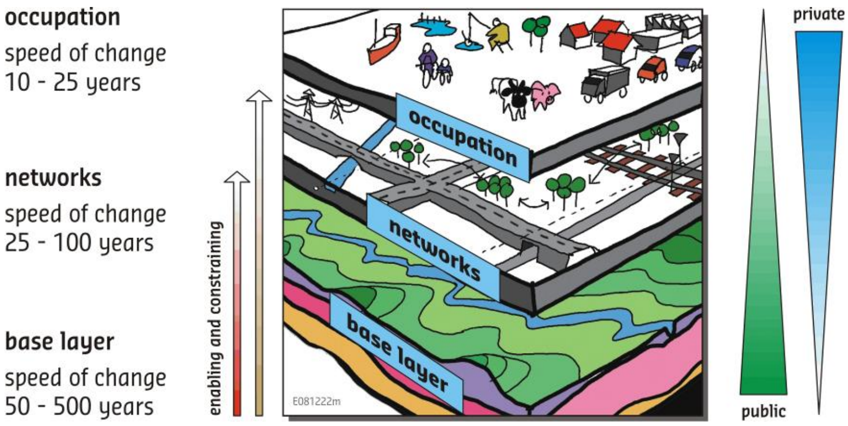


Figure 1.1 The Layer Model for Deltas

Applying this model to flood risks, we can nicely fit the elements of hazard, protection and vulnerability in the Base, Network and Occupation Layers, respectively (Figure 1.2). Floods have their origin in the physical base of the delta itself and of the geophysical relations the delta has with upstream (the river basin) and with marine / ocean environments. In other words, to understand the hazard we have to describe the processes occurring in the Base Layer and the drivers that impact on it, such as climate change and soil subsidence. The impact of a high water event can be mitigated through flood protection measures, such as dams, dikes and drainage systems that are part of the Network Layer. Technical innovations are major drivers of change for this Layer. An eventual impact due to failure of the protection system on society is determined by its vulnerability and can be described by occupation patterns and human activities in the Occupation Layer. Major drivers that influence this layer are population growth and economic development.

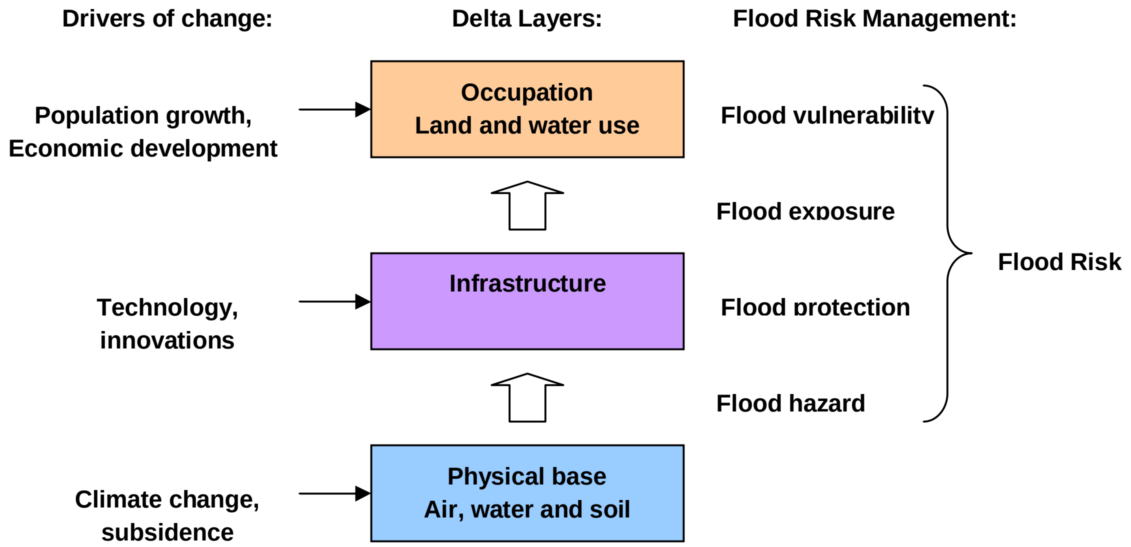


Figure 1.2 Spatial Layer Model applied to flood risks in deltas

This framework shows three important messages:

1. Flood risk is a combination of the hazard, vulnerability and protection measures. Hazard reduction, improved protection and increased resilience leading to reduced vulnerability can reduce the over-all flood risk. Its management should therefore address these three components together. We will see later (in Section 1.4) that the GREEN Water Defense concept uses these three components and therefore addresses the opportunities for improvements in each of the three layers in an integrated way.
2. Future changes in flood risk are a combination of different drivers of change, most importantly these are climate change and variability, subsidence, population growth and economic development.
3. Flood protection or flood defense measures can be improved through technological and institutional improvements and innovations, but also with ecological engineering techniques to reduce the hazard and/or exposure.

1.3 Current flood vulnerability and outlook for the East Asia Region[1]

In the past decades, the coastal zones in East and Southeast Asia showed a drastic urban development. In fact, 14 of the world's 17 largest cities are located along coasts. Eleven of these cities, including Bangkok, Jakarta, Singapore, Manila and Shanghai, are in Asia (Creel, 2003). Many of these cities are located in deltas or low coastal areas, which means that they are vulnerable to flooding from three sources: heavy local rainfall, river floods and storm surges. Additionally, many coastal regions in Asia are exposed to a tsunami risk (Figure 1.3). Two recent major tsunamis, the 2004 South Asia tsunami and the 2011 Japan tsunami has once again showed the immense force of nature and the intense damages and sufferings they can generate. Besides the actual deaths, many millions of people were exposed to the impact of the tsunamis. It has been estimated that the 2004 tsunami affected between 10 and 20 million people who lived within 1 to 2 km of the coastline (Balk et al., 2005).

[1] We include the following countries: Brunei Darussalam, Cambodia, China, East Timor, Indonesia, Japan, Laos. Malaysia, Myanmar, North Korea, Papua New Guinea, Philippines, Singapore, South Korea, Taiwan, Thailand, and Vietnam.

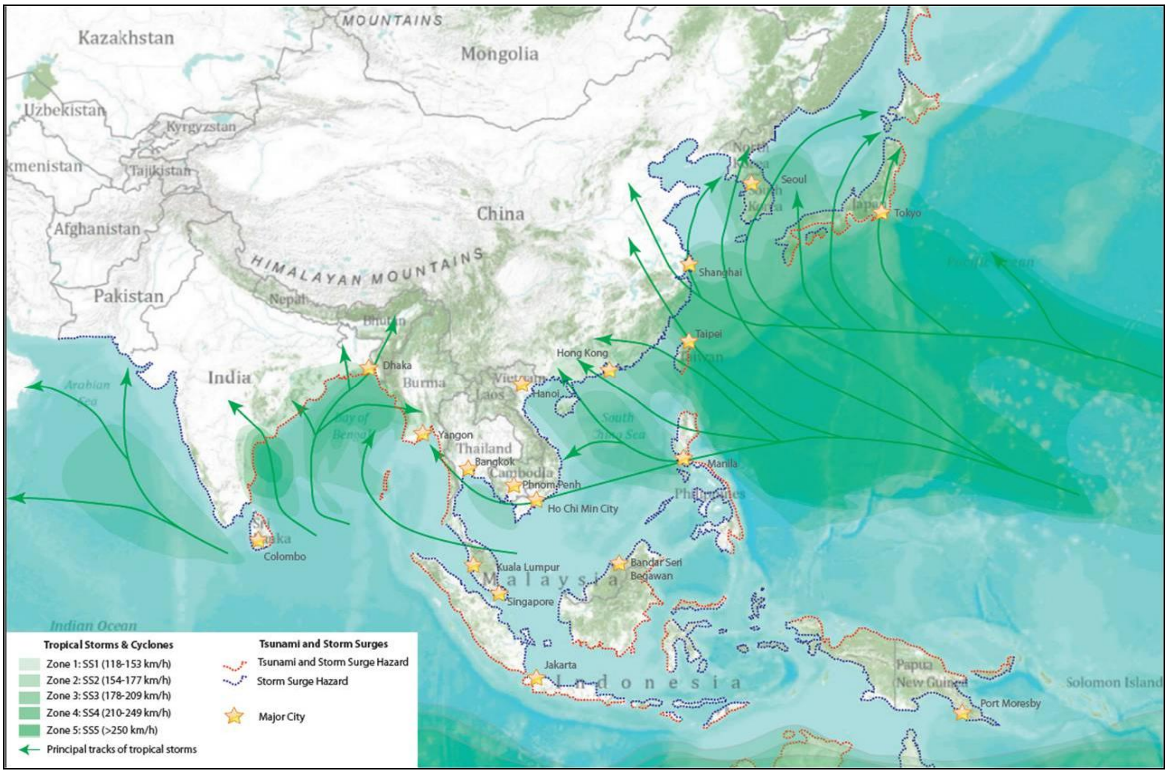


Figure 1.3 Natural flood hazards in East Asia (adapted from ISDR World Map of Natural Hazards)

Table 1.1 shows a list of recent major water related disasters in Asia. These disasters alone caused the death of many more than 300,000 people and a damage of well over 300 billion US$. Interesting is the often large difference in losses and the number of casualties between these disasters. For instance, tsunamis by far caused major number of casualties as well as damage. But also tropical cyclone Nargis resulted in huge human losses in Myanmar. Floods from rivers tend to cause fewer casualties but may also be devastating in economic damage. It shows that the actual human and economic losses from a water related disaster depends on a combination of factors: the type of exposure, the population density of the location and its socio-economic condition, the level of preparedness etc. In general, one can state that better early warnings and preparedness result in less casualties, and increased economic wealth results in higher damages. Therefore, reducing vulnerability to floods and storms requires a broader set of measures than is usually taken into account by disaster management, such as flood protection and early warning. Also measures that reduce the sensitivity and increase the resilience of households and societies are needed if we want to reduce the impact of water related disasters (Marchand, 2009).

Flooding is not only caused by the external hazard, such as excessive rainfall or a storm surge, but also by ongoing subsidence (e.g. Bangkok 2 – 5 cm/y; Jakarta up to 20 cm/y) and insufficient drainage systems. In addition, the vulnerability increases because of higher population densities in low lying areas, and vital economic infrastructure that is easily disrupted by inundation (e.g. subways, (nuclear) power plants).

Table 1.1 Major water related disasters in Asia in the past decade

Year	type of flood	City / country	Number of casualties	Damage ($)	source
[2]2011	Floods	Thailand	270	2 billion	The Assosiated Press, 2011
2011	Tsunami	Japan	25.000	309 billion	National Police Agency of Japan, 2011
2010	Typhoon Fanapi	Taiwan, China	105	115 million	Taipei Times, 2010
2010	Floods	China	3.185	51 billion	Xinhaunet, 2010
2010	Floods	Thailand	250	1,6 billion	Bangkok Post, 2010
2010	Floods	Philippines	110	48 million	NDRRMC, 2011
2009	Typhoon Ketsana	Manila	464	237 million	NDRRMC, 2009
2008	Cyclone Nargis	Myanmar	138.000	4 billion	Swiss Re, 2008
2007	Floods	Jakarta	54	879 million	Rukmana, 2009
2007	Cyclone Sidr	Bangladesh	4.000	1,7 billion	KNMI, 2007
2004	Tsunami	Banda Aceh	160.000	5 billion	Asian Development Bank, 2005

The outlook on flood vulnerability depends on a number of factors, of which their trend can be estimated with broad bands of uncertainty. First there is the growth of cities, and that has the least uncertainty. This growth will most probably continue for a number of decades. This directly influences the vulnerability, because more people and assets will become exposed to flood hazards.

Then there is the climate change and associated sea level rise. Expected sea level rise on a global scale is between 18 and 60 cm for the next century. However, there can be substantial regional differentiation in sea level rise, due to a combination of factors. Increases in storm intensities are likely, but no trend has been discovered in storm frequencies (IPCC, 2007).

In many cases, subsidence of deltas due to compaction and extraction of groundwater or fossil fuels will continue over the next decade or two, unless countermeasures are fast and effectively implemented, which proved to be rather difficult.

When sea level rise is combined with the lack of sediment inflow and ongoing subsidence in most deltas, we see a rather disturbing picture. Many of the Asian deltas are considered as ‘in peril’ or ‘in greater peril’, because aggradation rates are far too low to compensate for the sea level rise (see Table 1.2). With currently already more than 200 million people living in these coastal or delta areas, the number of vulnerable people in the next decades is certainly going to rise sharply, if no additional measures are taken.

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[2] At the time of writing

Table 1.2 Overview of flood issues in major deltas and cities in coastal East Asia

Country	Delta and / or City	Population estimate * (10^6)	Flood hazards	SLR Risk level**
Myanmar	Irrawaddy delta, Rangoon & Pathein	10	Typhoon / Storm surge / Tsunami	4
Thailand	Chao Phraya, Bangkok	14	Tidal surge, River flood	5
Malaysia	Kuala Lumpur	1.5	Flash floods	
Singapore	Singapore	5	Pluvial, flash floods	
Vietnam	Mekong Delta, Ho Chi Minh city	17[3]	River flood / storm surge	4
	Red River Delta, Hanoi & Haiphong	19[3]	Typhoon / storm surge	
China	Yangtze Delta, Shanghai & Ningbo	20-85[1]	Flash flood / floods / landslides / typhoon	5
	Yellow River Delta	5,2[4]	River flood	5
	Pearl River Delta	20[5]	Typhoon	5
Indonesia	Ciliwung Delta	23[1]	River, Pluvial, Tidal, Tsunami, flash floods	
	Mahakam Delta	0,02[5]		1
Papua New Guinea	Fly Delta	0,005[6]	Tsunami	
East Timor	Dili	0.2	Tsunami	
Brunei Darussalam	Bandar Seri Begawan	0.2	Pluvial, tidal	
Philippines	Manila	1.6	Typhoon	
Japan	Tone, Chiba Tokio	31	Typhoon / Tsunami	5
Taiwan	Taipei	2.6	Typhoon / Tsunami	
North Korea	Pyongyang	3.2		
South Korea	Seoul (Han river)	10.5	Typhoon / flash flood	
TOTAL		184 - 249		

* Total number of population depends on the definition of the delta

** The Sea Level Rise risk level of deltas is defined as follows (following Syvitski et al., 2009):

1: Deltas not at risk: aggradation rates unchanged, minimal anthropogenic subsidence

2: Deltas at risk: reduction in aggradation, but rates still exceed relative sea-level rise

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[3] *Bucx et al. (2010)*

[4] *China today (2011)*

[5] *Bookshelf (2011)*

[6] *Overeem & Syvitski (2009)*

3: Deltas at greater risk: reduction in aggradation where rates no longer exceed relative sea level rise
4: Deltas in peril: reduction in aggradation plus accelerated compaction overwhelming rates of global sea level rise
5: Deltas in greater peril: virtually no aggradation and/or very high accelerated compaction

1.4 GREEN Water Defense: a promising new approach

Floods and storms are an integral part of ecosystem dynamics and have both positive and negative effects on human well-being. Floods interact directly with the ecosystems of a floodplain while a storm interacts with coastal and estuarine ecosystems. Public perception and response to floods and storms are largely driven by the short-term and negative impact of these disasters. Therefore, the responses have been historically focused on interventions to modify and control natural flood regimes through structural means (for example dams, embankments and drainage canals). But although these structures (if properly designed) protect communities and infrastructure, they also often create irreparable damage to ecosystems and ecosystem dynamics.

GREEN Water Defense is based on the 'Green Growth' concept, as promoted by the World Bank, UNEP and others, as an innovation to traditional ways of flood protection. Basically it addresses flood protection in a more holistic and natural way: instead of keeping the three spatial layers separated from each other, GREEN Water Defense emphasizes the interactions between these three layers. Instead of depending mostly on building a dyke or concrete wall against a flood hazard, it uses a balanced structural and non-structural approach including maximum use of the ecosystem services from the base layer to mitigate the flood hazard. And it uses participatory spatial planning wherever possible or necessary: providing room for rivers, green corridors and urban space (Figure 1.4):

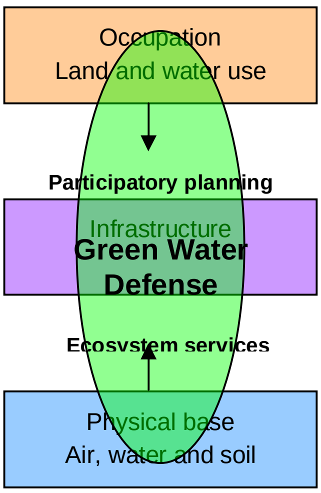


Figure 1.4 GREEN Water Defense integrating the three layers of a delta

In the next picture, this interaction between the layers is further detailed. We see that from the top layer several contributions can be made towards GREEN Water Defense: such as functions that are adapted to flooding (e.g. floodproofing of houses), multifunctional use of structural flood measures such as dikes, zoning regulations, setback lines for coastal development and early warning plus evacuation procedures.

Ecosystem services that are most relevant for flood risk management are also mentioned in the figure (such as wave energy dissipation and water retention). The next chapter gives a more extensive description of these services.

In addition, the structural infrastructure measures such as dikes, dams and sewage systems are of course also important. These are pictured by the arrow at the left.

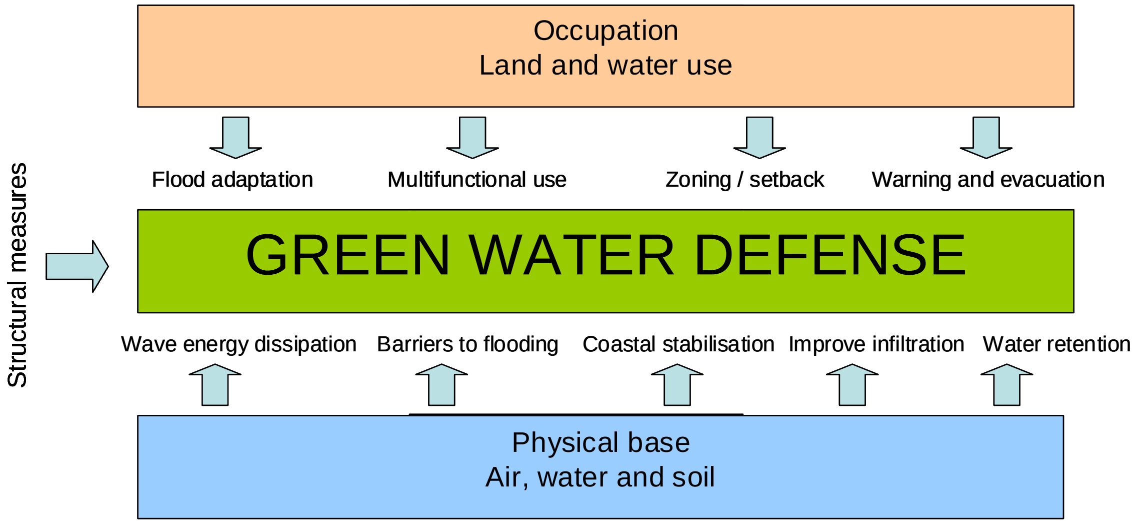


Figure 1.5 Main components of GREEN water defense

GREEN Water Defense is therefore an expression of truly integrated flood risk management: it combines elements of flood vulnerability, the hazard and the infrastructure into an optimal mix. Examples of approaches and innovations that can be grouped under GREEN Water Defense include:

- The concept '***Building with Nature'***. This method was first coined by J.N. Svašek in 1979. It is based on morphological theories and uses 'soft' solutions for coastal defense, with a focus on using the materials and forces present in nature. Waterman (2010) defines the essence of the concept as: 'Flexible integration of land-in-sea and water-in-the-new-land, using the materials, forces and interactions present in nature, where existing and potential nature values are included, as well the biogeomorphology and geo-hydrology of the coast and seafloor.' This concept therefore focuses mainly on coastal defense.
- 'Ecological engineering' or '***Eco-engineering'*** was designed by Howard T. Odum in 1962. The concept was then defined as 'the cases in with the input delivered by humans is small in comparison to natural sources, but enough to produce big effects in the eventual patterns and processes.' (Odum, 1971, 1989). Mitsch & Jørgensen broadened this original definition in 2003 to 'the design of sustainable ecosystems that integrate human society with its natural environmental to promote both'. The self-organizing principle of nature is essential in this concept.
- '***Green adaptation'*** is an application of eco-engineering and aims specifically at adaptation to the negative effects of climate change. This is done by making use of ecosystem services, which naturally adapt to environmental changes. The approach has a strong connection to moderating risks of climate change on local people and their livelihoods.
- ***Integrated Water Resources and River Basin Management***. Already several decades this concept advocates approaching the management of water resources in a truly integrated way, thereby combining issues of water scarcity, water quality and flood problems. It takes the entire hydrological cycle into account, viz. rainfall, runoff, rivers,

groundwater, surface waters and coastal waters. Relatively recent is the attention given to the linkage between rivers and coast: the Integrated River Basin and Coastal Management (ICARM) programme of UNEP-GPA.

- ***More crop per drop***. Freshwater scarcity worldwide leads to the need to save water and to use it more efficiently. This is also the case in delta areas, although here the problem is not or not only the amount of freshwater that is limited but also its quality, which is under stress from both pollution and salinity intrusion. Technical solutions in the field of irrigation are not always sufficient to solve this problem. Therefore also alternative cropping practices are developed, such as cropping of salt tolerant species or varieties and mixed farming practices. This is a typical example of adaptations in land and water use (the top layer in the delta model) to changes in the base lager.

An interesting example of how GREEN Water Defense crosses the traditional borders of policies and management domains is the relation between flood control, water scarcity and hydropower generation. Manifold are the situations in which a flood could not be prevented because the upstream storage reservoirs were full at the time of heavy rainfall. They were full because these reservoirs were built for only a single purpose, e.g. hydropower generation or water storage for irrigation. Such situations could have been avoided if a true integrated approach for river basin management was adopted.

2 What is GREEN Water Defense?

2.1 A working definition

There is no generally used definition of GREEN Water Defense yet. In this study we will use the following working definition:

> *GREEN Water Defense is a balanced and adaptive philosophy and management approach which seeks to integrate natural forces and artificial interventions, and to balance incentive-based and supply-driven measures, with low footprints and externalities in sustainably managing water services and related climate risks.*

It can be represented conceptually by four building blocks:
- *Cleaner water and greener environment*: Integrated water resources planning and management under changing climate
- *Balanced water defense*: building of 'soft' defense and green infrastructure for adaptation to climate variability
- *Produce more with less*: conserving water for higher agricultural water productivity and less undesirable externalities
- Provide *high quality water supply and sanitation services* efficiently at low social costs.

In this report we will focus on a balanced water defense. We will first present a typology of measures – or building blocks – that are available to develop an integrated water defense for cities and deltas. We use the Layer model introduced in the previous chapter and describe measures from each of these layers. After having produced a list of the measures we will discuss the scale levels on which these measures can be applied and finally link them to other relevant policy and management fields.

2.2 A typology for GREEN Water Defense examples and practices

Because GREEN Water Defense is still a loosely defined concept it is important to make clear what we are talking about. From practices that are already implemented as well as from examples that range from visionary ideas to concrete plans it becomes evident that the concept has many manifestations. Therefore, we first describe three different characteristics related to the concept: i) types of flood hazard; ii) the ecosystem processes and services we can make use of; and iii) the measures typically related to the spatial occupation layer.

2.2.1 Type of flood hazards

Coastal floods

Coastal floods are caused by storm surge (from a depression or hurricane), a tidal action or tsunami. Storm surges are waves originating from coastal storms. Coastal storms can be divided into two main categories. The first type is the extra-tropical storm, which is characterized by (intense) momentum transfer from the atmosphere to the ocean. The second type is the tropical storm, which can extract energy from the warm ocean water to sustain itself and to grow in strength. Tropical storms are known under different names: cyclones (Indian subcontinent), typhoons (Southeast Asia) or hurricanes (Americas), but their physical characteristics are essentially the same. Both the storm induced surge and wind waves cause hazards for navigation and port operations. They can cause severe damage to coastal defenses. Examples are dune erosion, dike collapse as a result of saturation due to sustained wave overtopping and or pressure on the dike due to surge and wave forces (Jonkman et al., 2012)

Tsunamis have a very different origin. It is a wave cause by a sudden rising or lowering of the ocean floor or by large masses of earth falling or sliding into the water and propagates as consecutive, very long period ocean waves over long distances. Tsunamis are mostly (around 90% triggered by strong earthquakes below the ocean floor. A typical characteristic is that on high seas, even large tsunamis with amplitudes of mostly only a few decimeters are not registered due to the enormous wavelengths of several 100 km. They therefore cause no risk to ships on high seas. It is only in the shallow waters of the coastal areas that the dangerous water fronts build up to several 10 m (Bormann, 2006).

Coastal floods are capable of causing large numbers of fatalities, as they are often characterized by severe flood effects (large depths, flow velocities and waves). In addition, coastal storms have often occurred unexpectedly, i.e. without substantial warning. This allowed little or no time for warning and preventive evacuation and resulted in large exposed populations.

Fluvial floods
Fluvial or riverine flooding originates from a river discharge that exceeds the capacity of the main river channel, leading to spill over onto the floodplain. Flash floods are a special case of fluvial flooding. Flash floods can occur within a few minutes or hours of excessive rainfall, thunderstorms and heavy rains from hurricanes and tropical storms; they can occur from a dam or levee failure, or from a sudden release of water held by an ice jam. Although flash flooding occurs often along mountain streams, it is also common in urban areas where much of the ground is covered by impervious surfaces (Mirza *et al*., 2005) or where drainage systems are blocked by (solid) waste disposal.

Pluvial floods
Pluvial or rainfall floods are a form of localized flooding due to intense rainfall occurring over a sustained period of time and the consequent drainage congestion (Mirza et al., 2005). Pluvial flooding occurs when the local drainage system is not capable of collecting and conveying surface runoff. This may be caused by i) the lack of a properly designed and built storm drainage and sewer system, ii) heavy rainfall in excess of the ‘design storm’, iii) catchment conditions worse than those assumed when the drainage system was designed, iv) partial or complete blockage of inlets and/or sewers pipes due to bad maintenance or v) failure of pumping stations, collapse of trunk sewers etc.(Zevenbergen et al., 2011).

2.2.2 Ecosystem services for flood and storm control (‘Base Layer’)
Ecosystem services are the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulation services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits (Millennium Ecosystem Assessment, 2005). Ecosystems play an important role in modifying and regulating hydrological and meteorological processes, and thereby affect the positive as well as the negative consequences of floods and storms. The functions of ecosystems range from the regulation of surface and sub-surface flow to the modification of wave dynamics in coastal and near-shore areas. Normal as well as flood flow regimes are affected by vegetation and its characteristics; hence, one important ecosystem service is to control floods and storms (Mirza *et al.*, 2005). In this respect we distinguish between the following services:
1. Wave energy dissipation (through coral reefs, vegetation and geomorphology)
2. Barrier to flooding (through natural terrain elevation, dunes etc.)
3. Coastal stabilization / erosion control / sediment retention
4. Reduction of waterlogging / improving infiltration and drainage
5. Lowering of flood levels / room for the river / flood water retention

Before describing these individual services, it must be stressed that most ecosystems are capable of providing more than one of these services and simultaneously provide other services beyond those related to storm and flood control. For instance, a mangrove forest provides wave energy dissipation, sediment retention, nutrient cycling, nursery area for fish and shellfish, habitats for birds etc. etc. Furthermore, in undisturbed environments individual ecosystems such as mangroves and coral reefs are often bordering each other, which would result in waves being dampened by a shellfish reef first, then by the seagrass bed behind the reef and finally by the adjacent salt marsh. These so-called ‘service cascades’ may even be more efficient than the sum of their individual services (Hulsman *et al*., 2011).

Another important aspect to consider is the non-linearity in ecosystem services. Since natural processes tend to vary over time and space, the ecosystem services these processes provide are therefore also highly variable. For instance the wave attenuation of coastal vegetation is highly determined by the vegetation structure and biomass, which in temperate regions often varies over the seasons. Clearly, protection will be diminished if storms occur when plant biomass and/or densities are low. In tropical areas, biomass tend to be less variable over time, and therefore provides more predictable coastal protection throughout the year (Koch *et al*., 2009).

1. *Wave energy dissipation*

Reduction of high waves is especially important along coastal environments, where storm surges and tsunamis are among the most destructive forces of nature. Also in inland lakes and riverine environments wave reduction can be important, but to a lesser extent. Coastal ecosystems such as mangroves, coral reefs, seagrass beds and saltmarshes constitute elements that can physically exert an effect on waves. They cause a hydraulic resistance that can break the waves and reduce their velocity, thereby reducing the energy of the waves. Especially mangroves are able to significantly reduce the energy of huge waves such as storm surges that accompany cyclonic depressions (see Box 1 and 2). It is one of the main reasons for substantial mangrove rehabilitation efforts all over the world. Over the years these efforts show mixed results. It is therefore crucial to learn from these experiences in order to increase the success rate of mangrove restoration (more details are provided in Chapter 4).

Box 1: Mangroves protect sea dykes in Vietnam

To protect sea dykes, people of Thai Thuy and Tien Hai (Thai Binh province) and Xuan Thuy (Ha Nam province) have planted stretches of pure *Kandelia candel* forests outside the sea dykes. These have provided protection for dykes and soil for the last several decades. The planting of *Kandelia candel* also helps in the natural regeneration of some species such as *Aegiceras corniculatum* and *Acanthus ilicifolius.* (Hong & San 1993)

2. *Barrier to flooding and elevated areas*

Geomorphological features such as dunes and river levees are natural flood protection systems by providing barriers to flooding and higher areas to keep dry feet. Typically, dunes are formed at the interface between the coastline and the sea and can have an elevation which is significantly higher than that of the land behind it. In some places this land can even be below sea level, especially in delta areas (for instance in the Netherlands). Although the naturally formed dunes are usually characterized by small inlets and wash-overs, man often has closed these sea intrusions and thus formed a continuous high dune area that effectively protects the hinterland from flooding.

Historically, man has started settling first of all on the higher, more sandier natural levees along the rivers and old beach ridges along the coast. An often encountered pattern of development is that towns and cities expand along these natural features, but later also settled in newly reclaimed land, that previously consisted of marsh or peat. Extreme flood events are likely to cause greatest damage and casualties in these low lying parts of the city (e.g. New Orleans).

3. Coastal stabilization, erosion control and sediment retention for deltas

Coastal erosion is the process of wearing away material from a coastal profile due to imbalance in the supply and export of material from the coast. It takes place mainly during strong winds, high waves and high tides and storm surge conditions. During calmer periods some of the sediment may return to the coast through natural coastal wave and wind processes. Many coasts, including delta coasts, show a dynamic behaviour of accretion and retreat over both short and long time scales. This is an interplay between natural forcing factors, such as tides, storms and sea level changes, ecosystem responses and human interferences. Coastal vegetation plays a significant role in mitigating coastal erosion and promoting sediment deposition. Especially mangroves and saltmarshes are typical examples of 'ecosystem engineers', in that they modify their local hydrodynamic and sedimentary surrounding (see Box 2). This make these ecosystems capable to adapting to rising sea levels provided the tidal movement is not restricted by human interference.

Natural sediment dynamics play an important role in delta formation and sustainability. Evidently, deltas are relatively young landforms shaped by the interplay of coastal and riverine processes. For example, the entire Yellow River Delta was formed in a period of slightly more than a century. Since 1855, when the Yellow River shifted its course from debouching in the Yellow Sea towards flowing into the Bohai Sea, each year up to several thousands of hectares of new land was formed (Liu & Drost, 1996). This rapid expansion of the delta is thanks to the enormous quantities of sediment transported by the Yellow River from the extensive Loss plateaux and from which the river has received its name. Although the Yellow River is quite exceptional in its sediment load, all other deltas have formed by the sediments brought in by their respective river and shaped by the interplay of tides, waves and currents.

Many of the deltas presently suffer from a sediment deficit, as has been evidenced by the research of Syvitsky and colleagues (Syvitski et al., 2005; Milliman & Syvitski, 1992; Syvitski & Milliman, 2007; Overeem & Syvitski, 2009; Syvitski et al., 2009). Partly this is the result of sediment starvation due to upstream developments (e.g. storage dams), but partly this is also the result of flood control measures. By preventing regular flooding of the delta, the river is not able to deposit sediments any longer. By protecting people from floods, also the benefits of flooding are lost, which, in combination with ongoing delta subsidence, leads to the problems many deltas now face (see also Table 1.2).

Box 2: Mangroves as coastal protection forest

Mangroves are tidal forests commonly observed along the sheltered shorelines of most tropical and few subtropical countries. Situated between land and sea, the mangrove forest is host to some 69 species of plants called mangroves. More landward the mangrove tree species mix with freshwater-adapted species, which in truly freshwater or terrestrial environments outcompete the mangroves.

The protective function of mangrove forests can be split up into three components:
- wave attenuation, mitigation of the hydraulic forces of storm surges and tsunamis;
- storm protection through windbreak;
- shoreline stabilization, sediment retention and erosion control.

Wave reduction by mangrove forests can be considerable. Especially in delta and coastal areas where a large natural belt of healthy mangrove exists, a significant protection against storms is possible. Both experimental tests and field observations have proven the dampening impact of waves by mangrove vegetation through hydraulic roughness (Gedan et al., 2011). With regard to the much more powerful waves of a tsunami, the mitigating effect of mangrove forests is less than that for a storm surge. Quantitative data on the mitigating effect is still limited. Coastal forests generally collapse by a tsunami of over 4m height. However, in case of lower tsunami waves, a healthy mangrove forest of 200 m wide can reduce the tsunami inundation depth to 50-60% and flow velocity to 40-60% (Nippon Koei, 2005).

Mangrove trees may reduce wind speeds up to an distance about 20 to 30 times their height of the trees. Hence, with mangrove trees up to around 10m height their impact on wind velocity is considered to a distance of about 0.25 km (Mohapatra & Bech, 2001).

Mangroves are capable of reducing coastal erosion due to their positive effect on local sedimentation An important precondition for the sustenance of this feature is that the tidal movement of water in and out of the mangrove forest is not disturbed (e.g. by detached breakwaters) (Winterwerp et al., 2005). In this way they can trap up to 1000 tons of sediment per km^2 (Ellison, 2000).

4. Reduction of waterlogging, improving infiltration and drainage

Vegetation can have a mitigating effect on the impact of heavy rains in catchments and urban areas. Foliage act as an umbrella that reduces raindrop impacts on the soils, thereby decreasing the risk of erosion and landslides. Roots strengthen the soil and improves soil texture, which increases the retention (sponge) capacity. Organic matter from roots and leaves improves soil structure and increases both infiltration rates and water-holding capacity that is, the ability of the soil to retain water against gravity (Mirza *et al.*, 2005).

Changed vegetation cover affects the hydrological behavior of a catchment. The influence of deforestation on the deterioration of flood disasters has been recently analyzed using data collected from 1990 to 2000 from 56 developing countries (Bradshaw *et al*., 2007). The researchers found that flood frequency is negatively correlated with the amount of remaining natural forest and positively correlated with natural forest area loss (after controlling for rainfall, slope and degraded landscape area). Although not uncontested (see for instance Van Dijk *et al.,* 2009), these findings could lead to the conclusion that unabated loss of forests may therefore increase or exacerbate the number of flood-related disasters.

There has been a huge increase in attention given over the past decade on reducing waterlogging and flood problems in urban areas. Hydrological processes in the urban fabric are complex and relate both to water quantity and quality (see box 3). One of the most conspicuous differences with a natural or agricultural area is the high percentage of impervious surface, that can cover up to 75 to 100 % of the urban area. This can lead to more than half of the precipitation flowing down as run-off, compared to 10% under natural conditions (Zevenbergen *et al.*, 2011). Permeable paving for roads and parking lots, urban wadis and more green space can lead to an increase of infiltration capacity, thereby reducing the flood hazard. Green areas such as parks and waterbodies also act as (temporary) retention areas. To reduce peak flows from surface runoff, process stormwater infiltration facilities and other best management practices, also called sustainable urban drainage systems (SUDS) have, since the late 90’s been increasingly implemented (Zevenbergen et al., 2011).

Green roofs are also rapidly growing in popularity (Box 4). Green roofs do not only provide a habitat for insects and birds in a highly urbanized area, but also have a capacity of annually immobilizing up to 200 g of dust and harmful air particles, purify nitrates and other pollutants in the water and are capable of fifty to ninety percent of rainfall retention (Reinberger, 2009).

Box 3: The urban hydrological cycle

In urban areas five interrelated types of water can be distinguished: groundwater, surface water, stormwater, drinking water and wastewater. Wastewater from households and industry is transported to a treatment facility by a sewer system, after which it is discharged into surface water outside the city. Often this is done by a combined sewer system that conveys both wastewater and stormwater runoff. However, during heavy rainstorms the capacity of the combined sewer systems could be exceeded, leading to combined sewer overflows taking place. This leads to the emission of diluted wastewater and sewage sludge to the urban surface water. It is now generally accepted that relatively clean stormwater should not be mixed with wastewater flows. Therefore, separate sewer systems that drain stormwater to the urban surface water and wastewater to the treatment plant are more or less standard in contemporary urban drainage systems (Zevenbergen et al., 2011).

5. Lowering of flood levels / room for the river / flood water retention

River floodplains and wetlands act as a natural buffer during high river discharges by enabling horizontal expansion of water mass, thereby reducing the maximum high water levels. But in many countries the area available for the rivers has decreased continually during the past centuries. Lowland and delta rivers nowadays are often embanked in order to protect agricultural fields and urban areas from flooding. For instance, as a response to the disastrous Mississippi River flooding in 1927, the U.S. Army Corps of Engineers built the longest system of levees in the world and minimized flooding and improved navigability. However, during the 1993 flood, 40 of these 229 federal levees and 1,043 of 1,347 non-Federal levees were overtopped or damaged (NOAA 1994). In the Netherlands, river canalization and embankment strengthening started centuries ago, but a wake up call was received in 1993 too, and another in 1995. This was the start of a renewed thinking called Room for the River (see section 3.1)

There are many examples around the world of constructed or restored wetlands that act as a buffer and also have the advantage of natural water treatment, improving the quality of the outflowing water (see box 5).

2.2.3 Planning and adaptation measures (‘Occupation Layer’)

When considering what can be done in the Occupation Layer, we in fact are reducing the vulnerability of the human society to floods. Often these measures are also named as non-structural, although this is not completely right. Sometimes a lot of engineering is involved, such as flood proofing of buildings. But what is important that these are measures that require active involvement of actors, modification of land use, and other adaptations of society. We consider four groups of measures:

1. Flood adaptation
2. Zoning and coastal setback lines
3. Multifunctional use of infrastructure
4. Warning and evacuation

Flood adaptation

Flood adaptation is a very broad category of measures that are taken to reduce the impact of a flood. It consists of structural measures and coping mechanisms by which people have adapted their way of living and livelihood to regular or incidental flooding. One can think of building houses on raised land or on poles, growing flood resistant crops, diversifying livelihood, etc.

Zoning and coastal setback lines

Traditionally people used to choose areas to live that were relatively safe for flooding. But because of growing population pressure, urbanization and marginalization, nowadays many people tend to live at most hazardous places. Zoning regulations can try to keep most hazardous places uninhabited, although this is often quite difficult. A setback line is defined as the landward limit of a buffer zone along the coastline where building restrictions or prohibitions are applied. It allows room for coastline dynamics.

Box 4: Encouraging Green Infrastructure through IPA (Germany)

In many northern European countries, urbanization and climate change are two interlinked problems. The population density increases the spatial pressure and leaves little room for green and water. Many cities are looking for possibilities to use space in a multifunctional manner. This means that practicality meets nature, storm water management and environmental quality improvement. The use of these so called green technology is referred to as green infrastructure.

There are already many technological concepts for multiple use of space and infrastructure, but almost in all cases the construction costs are higher, while the savings on maintenance are uncertain. Thus, it is often unclear who has the most benefit and who should invests the most. Also in Germany this is not an unheard problem. That's why the government decided to leave the initiative with the property owners and users.

How does one get private parties to invest in a common good, like flood safety and climate adaptation? German law states that any development on previously undeveloped land, should be paired with compensation for lost ecological value. The use of green infrastructure can provide a solution. Besides the practical uses of green infrastructures, like green roofs and storm water reuse, it increases the esthetic value of the landscape, and in the case of businesses, it can be beneficial for the reputation of a company.

Since the 1970's most German households are charged for storm water services based on an estimate of storm water burden generated from their properties. This approach of individual parcel assessment (IPA) differs from most other countries, where a collective rate is charged for a certain area, uninfluenced by any measures that may be taken to decrease the pressure on storm water management infrastructure. Since individual parcel assessments in Germany are used to assess fees that relate directly to conditions present on specific parcels, and because land-use decisions (like paving a driveway or installing a green roof) have major impacts on the amount of storm water leaving a property, this approach creates incentives for individuals to incorporate green infrastructure on their properties (Buehler et al., 2011).

Box 5: Sengkang Floating Wetland (Singapore)

In the northeastern part of Singapore lies the Punngol Reservoir and Sengkang Floating Wetland. The pond and constructed wetland are part of the Sengkang Riverside Park. It is used for recreational purposes such as water sports and taking a walk in a scenic environment. The water reservoir also acts as a buffer during heavy rainfall. Excessive rainfall collected in the pond will be released by special outlets in two or three days. The floating wetland has been artificially created. It's the largest man-made floating wetland in Singapore. It has a surface of approximately 2500 m^2.

The constructed wetland treats storm water runoff and natural sewage. First, the coarse particles in the water are filtered in two sedimentation basins. If the volume of water flowing in is larger than the basins capacity, the water will be redirected through a bypass into the pond, without being filtered through the macrophyte plants. This is necessary to prevent damage to the wetland. After the sedimentation process, water flows slowly into the macrophyte zone. Macrophytes are plants that thrive in marshlands, like reed, cattails and, through photosynthesis, absorb nutrients and release oxygen.

The constructed wetland also provides a new habitat for fish and birds. It strengthens the local ecosystem and increases biodiversity. The roots of the plants cleanse the water and absorb pollutants from the reservoir, improving the water quality in the Punggol reservoir. The wetland is home to approximately 18 species of plants. The plants are selected by both their cleansing and esthetic properties.

The Sengkang Floating Wetland has more assets than just ecological development and water quality improvement. The wetland can be reached with a boardwalk, connecting Anchorvale Community Club to the Sengkang Riverside park. Also local schools have adopted parts of the wetland and are responsible for maintaining their own piece of wetland. This way the authorities hope to connect the community with nature and water.

Multifunctional use of infrastructure

A most evident example of multifunctionality in flood management is the use of a dike for transport purposes. Dikes and roads are almost the perfect symbiosis in infrastructure. But there are many more opportunities for combinations, many of which have only recently being explored. For example using parking garages or sporting fields for temporary water storage.

Warning and evacuation

Early warning systems are being developed and used on an increasing scale. One of the main reasons is the improved ability of predicting floods through a combination of real time data collection and model application. And it is expected that this will significantly reduce the number of casualties, on the condition that the warnings are channeled up to the local level and that people know how to act accordingly. Evacuation plans and refuge areas are therefore of equal importance as the warning systems.

2.2.4 List of measures

Based on these descriptions of ecosystem services and planning/adaptation measures a long list of measures and interventions has been prepared (Table 2.1). The list is alphabetically ordered and a short explanation is provided. Also traditional measures are included in the list, such as dikes and barriers. This finds its rationality in the fact that in practice often a combination of engineering works and more ecosystem-based flood protection is required. Many traditional designs can be enhanced by making use of ecosystem services. For instance a combination of a dike with a willow forest in front of it reduces wave attack and therefore is a more robust flood defense than a dike alone.

In the list we also find a number of measures that mitigate the impact of a flood rather than prevent it. For instance mounds on which people live or can find refuge are not defense systems, but make the inhabitants less vulnerable when a flood occurs. Also flood proofing measures for buildings and houses fall under this category.

Table 2.1 Long list of measures for GREEN Water Defense.

Measure / ecosystem	**Explanation**
Buffer zone / setback line in coastal areas	A setback line is defined as the landward limit of a buffer zone along the coastline where building restrictions or prohibitions are applied. It allows room for coastline dynamics.
Bypass / green river	Bypasses are artificially created waterways, which will redirect excessive (river)discharge.
Detached breakwater	Parallel to and at a certain distance from the shore, used to change the transport capacities both along and perpendicular to the coast.
Dike / embankment	A dike or embankment is constructed to keep water out and may consist of sand, clay or peat soil. It is usually protected from erosion by a grass, stone, rubble or concrete layer. High growing vegetation, such as trees are normally not allowed to grow on a dike because of safety reasons. Grass / shrub vegetation often provides good erosion protection.
Dunes	Natural elevations consisting of sand, fixed by vegetation. Act as natural flood defense.
Early Warning	A non-structural measure to warn people for an imminent flood danger
Evacuation	A temporary moving out of an area that (probably) gets flooded
Flood adaptation	A range of measures and approaches by which people have adapted their way of living and livelihood to regular or incidental flooding.
Flood retention areas	Sacrificing designated areas to retain water, by inundation (in emergency situations)
Flood proofing	Buildings that are flood proof will resist floods and dissipate wave energy, as well as decreasing current velocity.
Green roofs	Vegetated roofs can retain rainwater, reduce heat stress, improve air quality and increase insulation of buildings.
Green space / parks in urban areas	Green areas such as parks and water bodies act as (temporary) retention areas and also improves the infiltration capacity
Groynes	Groynes are typically found in river systems to maintain a certain navigational depth. Also applied along the coast, where they reduce the longshore sediment transport capacity and thus the coastal erosion.
Infiltration constructions	Constructions, such as infiltration crates, which are placed under a paved surface to retain and infiltrate rainwater. Another example is a permeable paving for roads and parking lots.
Lakes, ponds, lagoons	See wetlands.
Lowering of floodplains	By lowering floodplains flooding will occur more often, creating a larger wet surface and lowers the water levels, thus preventing floods elsewhere along the river. The higher flood frequency results in more sedimentation and stabilization of the dikes.
Lowering of groynes	By lowering of groynes the hydraulic resistance in the river is reduced, leading to a reduction of high water levels.
River dredging / Lowering riverbed	By lowering the riverbed, the river can discharge more water and flood water levels are reduced.
Managed realignment / dike relocation	Used along the coast: reconstruction of dike or seawall inland in order to create a buffer zone (coastal wetland, saltmarsh). Along rivers the relocation of a dike is a measure to provide more room for the river.
Mangrove	Mangroves grow in the supratidal and intertidal zone of (sub-)tropical coasts. Mangroves have a multiple function for coastal protection. They can increase sedimentation, reduce erosion, reduce the energy of high waves and reduce wind speed.

Mound, refuge area	Elevated area in an area liable to flooding.
Natural or artificial reef	Has the same effect as a Detached breakwater.
Removal of obstacles	Removing obstacles along the river or in the floodplain reduces the hydraulic resistance.
River levees	Natural elevations along rivers, mostly consisting of sandy soils. May act as natural flood defense.
Room for the River	A strategy to reduce water levels by decreasing the hydraulic resistance in the river bed and its floodplain. It includes a variety of measures, such as floodplain lowering and widening of the floodplain by realigning embankments.
Saltmarshes	Saltmarshes grow in the supratidal zone of temperate climate zones. Saltmarshes have a multiple function for coastal protection. They can increase sedimentation, reduce erosion and reduce the energy of waves.
Sand nourishment	Mechanical placement of sand in the coastal zone to advance the shoreline or to maintain the volume of sand in the littoral system.
Seagrass beds	Seagrasses are able to reduce erosion of subtidal areas and promote sedimentation.
Seawall	Often concrete or stone wall along the coast.
Separate sewerage system	The rainwater will not be drained in mixed sewerage (rainwater and waste water) but separately and directly on open water bodies.
Shellfish reef / bed	Shellfish (bivalves such as oyster and mussels) are able to reduce erosion of intertidal areas and promote sedimentation.
Storm surge barrier	Storm surge barriers are constructions which are only activated during a flood. Examples are the Oosterschelde barrier in Southwestern Delta and Maeslant Barrier in Rotterdam harbour (remains open for navigational purposes).
Submersible dike	Dike that can withstand water overflowing without breaching.
Sustainable urban drainage systems (SUDS)	An approach to reduce urban flooding due to stormwater and to improve water quality. Contains many different measures, such as green roofs, infiltration swales, revegetation etc.
Superlevee, superdike	High and wide levee or dike combining flood protection with use functions (such as roads, buildings and parks)
Temporary water storage in buildings	Storage of water in underground garages, cellars etc.
Urban wadis	A depression in the surface, which is not paved, to retain water and infiltration possibilities. In dry spells the wadi will not be retaining water.
Waterplaza	A paved square, which can be flooded in stages. In dry spells the square is dry and in heavy percipitation it can retain water, untill the drainage capacity is restored.
Wetlands	Generic term for areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static of flowing, fresh, brackish or salt, including areas or marine water the depth of which at low timed does not exceed six metres (Ramsar Convention). Wetlands may function as buffer zones between upstream and downstream regions, which may reduce peak-flood levels and increase low-flow levels.

2.2.5 Scale levels

The understanding of flood risks is greatly influenced by the multi-scale nature of biophysical and human systems and the interactions between them across scales. Normally, disasters occur at the local level, for instance at low coastal deltas or floodplains. But in order to understand the hazard level at a specific location, one needs to know the larger geographic context: for instance the rainfall characteristics for an entire watershed determines a flash flood risk for a village. Within the flood hazard, a source, pathway and receptor framework can be used (Samuels et al., 2009). The risk sources include the hydrological or hydraulic boundary conditions that may provoke a flood. The pathways are the ways through which the flood waters flow, including breaching processes of man-made and natural protection systems. And the receptors include the people and their assets that may be impacted by the flood. This model provides a basis from which to understand and manage the flood risk in a holistic way. To understand and to reduce the source of the flood risk usually requires the largest scale level of a river basin or catchment or regional sea. The pathway requires a smaller scale level of for instance a lowland river or delta. The actual receptors are local villages, urban areas and coastal zones. For urban flood risk management also more detailed scale levels may be used, such as neighborhood and building level.

In order to address appropriate measures for reducing flood risk the processes and ecosystems at each of these scale levels need to be taken into account. Failure to do so often results in underperformance of measures. For instance, a study by Kalman et al (2000) demonstrates the economic limits of uncoordinated institutional management at the local or individual level and attests to the value of coordinated basin-wide management. Many GREEN Water Defense measures are localized and should work best when applied over the entire river basin or coast. They modify the environment within the capillaries of the water system and, although their impact may be small on that level, exert a significant influence on the whole hydrological cycle. An example is the green roof concept, which is a small scale measure which works best when implemented for as many houses as possible.

2.3 A menu type list of GREEN Water Defense measures

From the description of measures above it becomes clear that not all measures are applicable everywhere under all conditions. Indeed, much depends on the type of flood hazard as well as on the scale of operation and the type of process[7]. In order to categorise the measures a menu has been prepared, based on i) flood type, ii) mechanism and iii) spatial layer. With this list an easy selection of an appropriate measure can be found based on the type of problem and environmental characteristics at hand (Figure 2.1). From this menu it becomes evident that for a measure to be effective for flood management, good knowledge is needed for which process the measure should be used. For instance, making room for water is an effective means of lowering high waters in river systems, but of far less use in coastal and estuarine environments. In the latter situation, the amount of water that is pushed up from the sea is almost infinite, any extra room for water is rapidly filled and then water levels continue to rise. Hence, all kinds of buffer areas between coast and land do not function in the same way as those between river and land. Instead, such areas along the coast are beneficial in another way, i.e. in reducing the wave energy and in contributing to sedimentation leading to coastline stabilization.

[7] Also the socio-cultural context is important in selecting measures, since people may have different perceptions to floods and respond differently (Hoekstra, 1988). This is not included in this menu.

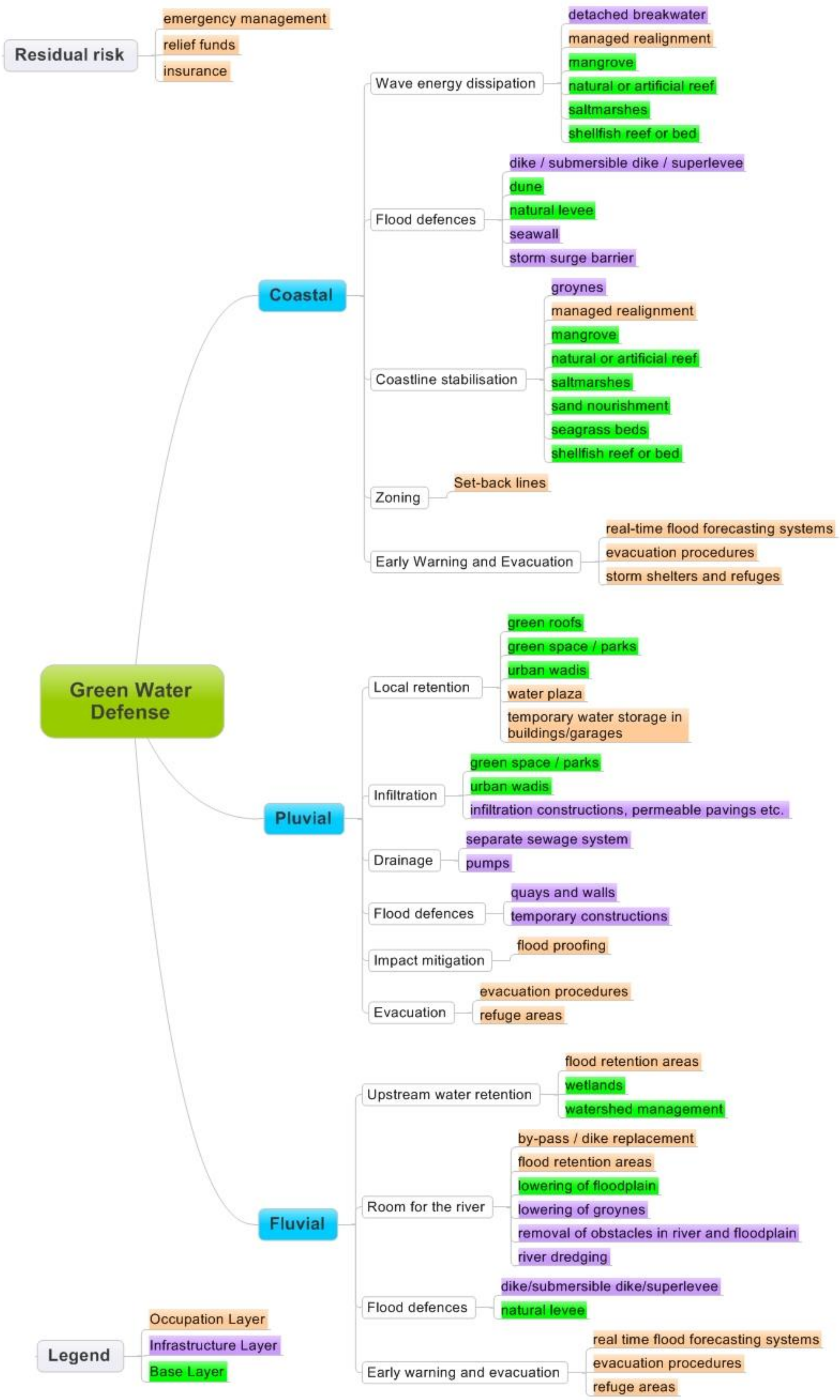


Figure 2.1 Menu of measures based on flood type and process. Colors refer to the spatial layer.

3 Does it work? Best practices from the Netherlands and USA

In the Dutch water management a significant change occurred from an *optimization* paradigm to an *adaptation* paradigm over a time period between the 1970s to around the year 2000. The belief in the human ability to control the water system has been replaced during this period by a paradigm of adaptation and anticipation. In this latter paradigm, the world is perceived as dynamic, complex and inherently uncertain and consequently water managers have to continuously adapt the water system and anticipate the future. Water is understood as an integral part of a social-ecological system. The most important water related value is still safety, but the ecological quality is deemed much more important than during the technocratic regime (Van der Brugge, 2009). One of the driving forces behind the greening of water management in the Netherlands was Henk Saeijs, who once worked for the Dutch Rijkswaterstaat at the time of the building of the Eastern Scheldt storm surge barrier. Instead of technology-driven solutions Saeijs advocates the power and flexibility of Mother Nature, because after all *'she has over 3 billion years of experience'* . In fact, he was one of the first to promote depoldering as a means to provide more room to natural processes (Saeijs, 2008).

In this chapter examples of GREEN Water Defense will be presented. Each example will be described in words and with figures and the key factors of success will be identified.

Box 6: Green Water Defense makes Dutch flood defense millions of Euros cheaper

A recent inventory for the Dutch Delta Programme revealed that flood defenses could lead to substantial savings in the order of tens of millions of Euros (Fiselier et al., 2011). Natural solutions use ‘soft’ materials like soil, sand, clay and vegetation to reduce the load on the defense system. Furthermore, with the areas under consideration, the main issue is the deployment of foreshore elements such as (salt) marshes, sand flats, sand bars and tidal areas. An important aspect of these natural solutions is the use of natural processes and sedimentation, as well as the development of vegetation. These are deployed when and where possible in various project phases – construction, management and maintenance. There are clear advantages of this “building with nature” concept. Moreover, natural sea defenses are better able to cope with changes in the system, such as rising sea levels.

3.1 Room for the River (NL)

3.1.1 General description of the programme

Climate change could lead to a 30% increase in flood discharges in the Rhine River. Instead of raising the levees it was decided to give more room to the river. This would substantially lower flood levels and sustain a more attractive environment, both urban and natural. Room for rivers was officially adopted by the Netherlands government to achieve the required safety level for the river systems. It became the guiding principle for climate change adaptation along the major rivers.

The Room for the River program consists of 39 different projects, located along all the main branches of the river Rhine. The first machines started digging in 2007 and the whole program will be finished in 2015. The map below highlights all the project locations of the program.

Figure 3.1 Map showing the project locations of the Room for the River program

3.1.2 The challenge, objectives and measures

Objectives

The delta of the river Rhine is the biggest economic region in the Netherlands, and also the most densely populated area. To protect its people and their assets, the Dutch have put an enormous effort in building embankments and dikes along the rivers, using a safety standard of 1/1250 per year. That dike maintenance and vigilance remains crucial was clearly demonstrated in two near floodings: in 1993 and 1995 the government received a wake up call from Mother Nature, as water levels reached dangerously high levels and two hundred fifty thousand people were evacuated as a precautionary measure.

Figure 3.2 Emergency repair at a river dike in 1995

These incidents, combined with worries about higher peak levels that can be expected due to climate change made the government aware of the need for new safety measures. But instead of the traditional way – building stronger and higher dikes – in this program a new wind blows. The Dutch government is making a change in its approach to flood control. This new way of water defense combines building with nature with safety against flooding.

The overarching idea is to give the rivers back the space that was taken during the past centuries. Floodplains became occupied by industries and residential areas. At many locations along the rivers cities expanded and reduced the floodplain area. Bottlenecks were thus created and resulted in increasing water levels during high river discharges. A good example is the development of the city of Arnhem (Figure 3.3).

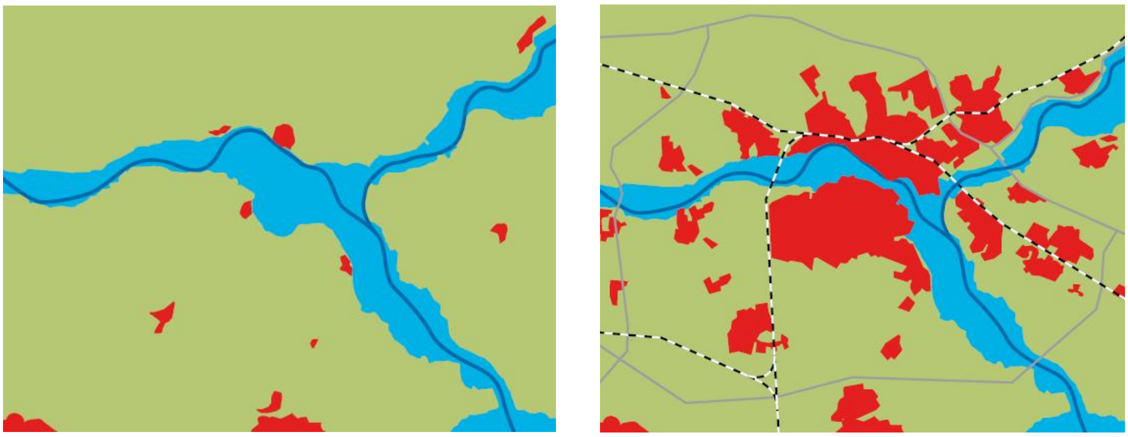


Figure 3.3 Historic development of cities along the Rhine river: the case of Arnhem. Left: 1830, right: 2000 (Source: Programme Directorate Room for the River)

The main goal is to maintain the safety of the land against flooding from the river for higher river discharges that are expected in the near future. Currently, the river embankments are able to withstand flood waters up to 15,000 m3/s, a condition which occurs roughly once in 1250 years. This normative design discharge of the Rhine is expected to increase to 16.000 m^3/s in the year 2100. Without additional measures this would imply higher water levels. The Room for the River program consists of a range of innovative measures that will result in lower water levels in order to maintain the current flood protection level (1/1250 per year).

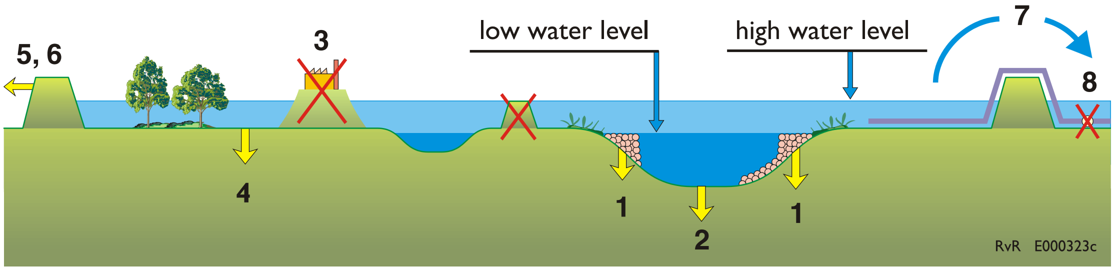
Besides the main goal of flood protection, the program also focuses on the spatial quality, amenity and nature values of the river landscape. Especially, the program focuses on:

- Increasing the landscape diversity between river branches,
- Strengthening the openness of the river with its characteristic waterfronts,
- Conserving and developing the scenic, ecological, geological, cultural and historic values,
- Improving the environmental quality, and
- Promoting the use of the main navigable waterways.

Types of measures

The Room for the River program consists of 8 basic types of measures to reduce the water levels in the floodplain (see Figure 3.4):

1. *Lowering groynes*: At high water levels groynes can hinder the river flow. By lowering the groynes the flow capacity increases.
2. *Deepening low flow channel*: Excavating the surface layer of the river bed increases the wetted area within the river channel, thereby increasing its flow capacity.
3. *Removing obstacles*: Modifying or removing obstacles in the river floodplain creates more room and thus reduces the hydraulic resistance.
4. *Lowering floodplains*: excavating the floodplain lowers the water level during high river discharges.
5. *Dike relocation*: Displacing the dike landwards, increasing the width of the floodplain.
6. *Setting back dikes on a large scale (depoldering)*: By relocating the riverside dike, a previously reclaimed floodplain area can be restored so water can flood the area during high tides.
7. *Detention reservoir*: Additional place for temporary water storage in exceptional times.
8. *Reduction of lateral inflow*: by preventing local water runoff, water levels are reduced.
9. *High-water channel*: a bypass is created to discharge water using a different route.
10. *Strengthening dikes*: Where creating additional room for the river is not an option, e.g. due to urban areas, the dikes are strengthened.

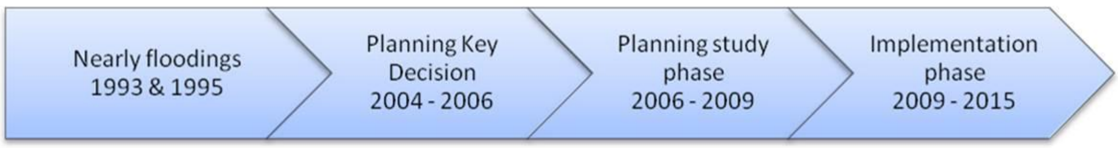


1 - lowering of groynes
2 - deepening low flow channel
3 - removing hydraulic obstacles
4 - lowering flood plains
5 - locally setting back dikes
6 - setting back dikes on a large scale
7 - detention reservoir
8 - reduction lateral inflow

Figure 3.4 Cross section of river floodplain showing types of measures of the Room for the River program

3.1.3 Implementation and stakeholder participation

Not surprisingly it took several years of studies, planning and deliberations before these measures were actually implemented. It first started with a number of studies and research activities, which concluded that the traditional way of flood protection (larger dikes) would take up much space and would affect the beautiful river landscape, that the urban squeeze would require more fundamental solutions and that due to climate change the rivers will have to convey more and more river discharge. Studies pointed out several locations where extra room can be created and in the year 2007 the Dutch government approved the Room for the River program that included 39 locations were measures would be taken.



Since such a large scale program has a national interest, it was the central government that decided on the policy to give more room to the rivers. A Planning Key Decision (PKB) was formulated, that outlined the locations and types of measures. However, for its overall implementation of each of the 39 projects local governments (municipalities) en stakeholders had to become involved as well. Many parties have interests because they own land along the river, have a house there or use the floodplain as recreational area. These people live in the area every day, so it is important that they are content with the new situation. Therefore, much attention was given to information and consultation meetings with local administration and stakeholders, which was a relatively unique and new approach.

Figure 3.5 Local inhabitants discussing a Room for the River project

The local government worked closely with the inhabitants of each project location. All the stakeholders tried to find a solution for the main question: “how do you want to achieve the required reduction of the water level?” From the beginning it was clear for everyone that the general objective of the program, i.e. reducing water levels at high discharges, was not negotiable. But the type of measures, their exact location and implementation was open for discussion. In this participative planning process solutions were found where all parties were satisfied with.

During this process the role of information and knowledge is crucial. Both national and regional authorities, municipalities and individual citizens proposed around 700 local measures that could help reducing the water levels. Each of these measures would have secondary impacts and different costs. A *Planning Kit* was especially developed to handle such a huge amount of information and proved to be successful in supporting joint planning with stakeholders. Underlying the tool are advanced scientific, cause-effect models. These remain hidden to the users of the tool. Users can add measures to the existing situation of a river area in an intuitive manner, directly relating to their normal perception. They can for instance lower a dam or remove an obstacle. The tool visualizes the results of such interventions, again, in an intuitive way, e.g. showing the effects on natural quality and water levels. In this way, stakeholders – ranging from authorities to citizens – can jointly evaluate different strategies for adaptation in a river area, without being burdened with interpreting the results of the underlying models.

In total 17 different governmental agencies are involved in the program: two ministries, one central executing agency (Rijkswaterstaat), four provinces, six waterboards and four municipalities. A Programme Directorate “Room for the River” was established which is responsible for the implementation of the program and acts as the link between the central government and the region. The Program Directorate verifies that the plans are compatible with the Room for the River policy, monitors the cohesion between the measures being taken, facilitates the process and promotes exchanges of expertise and experience among the 39 projects.

3.1.4 Does it work?

Because of the large size of the program and the many different projects and measures, a complete description would be out of place here. Instead, we zoom in on two projects that illustrate how the innovative, GREEN Water Defense type of measures work out in practice.

Water innovation in the Noordwaard polder

To avoid extreme high water levels at the city of Gorinchem, downstream in the Rhine Delta, it was decided to set back the dike of the Noordwaard polder to create more room for the river. This so-called depoldering of the Noordwaard would allow water to flow freely over 468 hectares of floodplain again. As a side-effect the renewed tidal influence will reshape the area in a more natural condition.

Although some residents initially opposed the plan and produced an alternative solution, the majority united in the 'Bandijk society' was in favour, provided that a fast implementation and good damage compensation was guaranteed. The alternative solution was rejected by the decision-maker, in view of the fact that this alternative would not provide sufficient safety on the long term, which would require a second major intervention in due course.

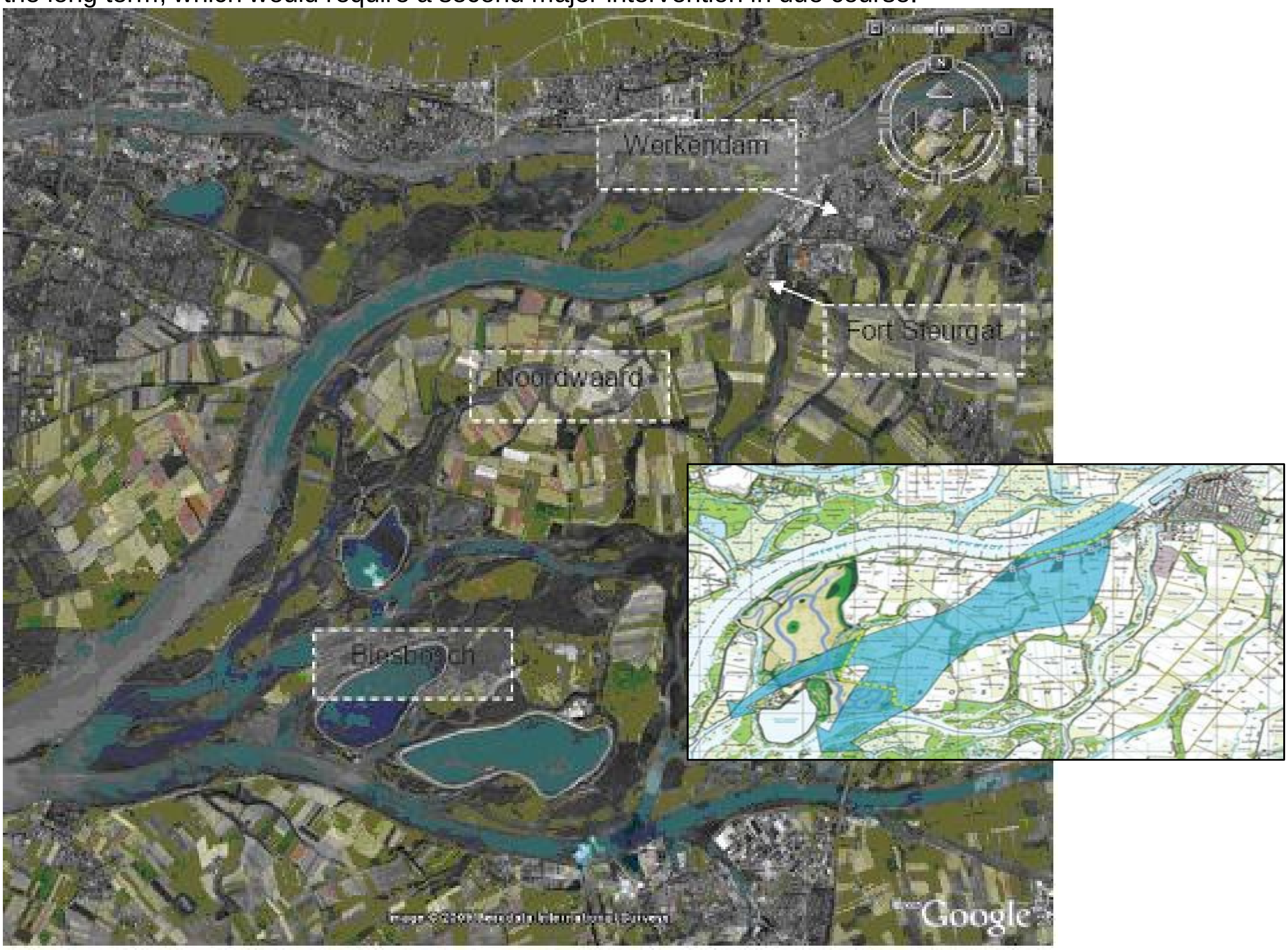


Figure 3.6 Map of the Noordwaard polder and overflow area (inset)

Within the Noordwaard a small area with houses and a historic building ("Fort Steurgat") will have to be protected from floodwater. Instead of a traditional dike, a lower dike with wave reducing willow-plantations in front was chosen in mutual agreement with the stakeholders.

The strip of willow trees will be 2 km long and 100 meter wide and will effectuate a wave reduction of 80% (Figure 3.7). In this way the dike can be lower and the environmental quality is increased at the same time. And it has been calculated that, despite the higher maintenance costs, this alternative is much cheaper. The willow-plantation would cost around 318 euro per m dikelength, whereas raising and armouring the dike would cost around 1800 euro per m of dike (De Bel et al., 2011)

Figure 3.7 Artist impression of the willow forest in front of the dike

Mounds in the Overdiepse Polder

In times of high water levels, one of the branches of the river Rhine (Bergsche Maas) threatens the cities and villages along the river. Lowering the old dike will reduce this flood risk by allowing the Overdiepse Polder to store redundant water. This will lower the high water level by approximately 27 cm. It is expected that once in every 25 years the Overdiepse Polder will be flooded. A new dike is necessary to protect the hinterland.

Figure 3.8 Location of the Overdiepse Polder

Initially, the residents of the Overdiepse polder strongly rejected the plans, because they would loose their farmhouses. The local government understood this problem and together they came with a new plan. By constructing their farmhouses on dwelling mounds ('terpen'), the residents can live safely, harvest their crops and let their cattle graze. The project also has many benefits for nature. Along the river nature-friendly zones will be developed. Another benefit is the Westplas, a pond in the making. These unique nature-friendly areas will attract new plants and animals.

This project is a perfect example of collaboration between the different stakeholders and the synergy between the different parties. It shows how the users of the area have worked out a plan from the central government in detail. The new way of protecting the Dutch against water thus focuses not only on designing with nature but also on designing with people.

Figure 3.9 Artist impression of the Overdiepse Polder with farms on mounds during low (left) and high (right) water

3.1.5 Financial aspects

The total budget for the program is estimated at about 2.3 billion euro (Table 3.1) and is financed by the Dutch Government. The table below shows the distribution of the costs over the different program phases. This budget is reserved for projects that are necessary for ensuring safety. Should local interests, such as municipalities choose to combine the measures with existing plans that lead to extra costs, the extra budget should be found elsewhere. In the budget no allocation for annual maintenance (such as regular trimming of vegetation to reduce hydraulic resistance) is included.

Table 3.1 Financial data of the Room for the River Project

Phase	Euros (million)
Planning Key Decision Phase	39,2
Planning Study Phase	72,2
Implementation Phase	2.120,7
Program Management	109,9
Total Project Budget	**2.342,0**

At the start of the project a Cost-effectiveness analysis (CEA) was performed by the national economic planning bureau (Ebregt et al., 2005). In this CEA a method was developed for evaluating measures and packages with more than one effect at the same time. Increase in safety, growth of the number of hectares with desired nature, and value judgements on spatial and recreational quality were used as objectives in this CEA. For each objective separate unit costs were defined. By adding up these unit costs for a specific project and comparing this with the actual total project costs, insight was gained on the cost effectiveness of the project. If the project costs were lower than the sum of the unit costs, the project was considered 'cheap'. It was concluded that combining increase in safety with the development of nature in one measure in most instances does not reduce costs. There are two explanations to this conclusion: first, natural vegetation in the river floodplain increased the hydraulic roughness, which means that for safety reasons the nature areas need recurrent maintenance (which costs money). In the second place, time pressure to reach the required safety increases the land price and thus the cost of land conversion into nature.

Interestingly, the Noordwaard project (see previous section) scores 'cheap' in the CEA and is considered a cost-effective measure with both significant effects on safety and on compensating loss of nature elsewhere.

The CEA report has been an important source of information for the formulation of the decision to implement the Room for the River project, but it was acknowledged that the financial aspects were not decisive. In her letter to the Parliament, minister Schultz van Haegen wrote: 'A robust design was chosen for in which sustainable safety, spatial measures and quality as well as regional support were the decisive factors. This fulfils the paradigm shift 'more room for water', which was announced earlier in the cabinet standpoint […]' (Schultz van Haegen, 2006).

3.1.6 Lessons learned

From this successful programme a number of lessons can be learned for similar programmes and projects. We will do this by formulating a number of factors that have greatly contributed to the success of the programme. Of course every new project is different and lessons cannot be simply transferred to other situations or countries. This should always done with care and with respect for local circumstances.

Agreement on programme objectives and sense of urgency

Active support from all stakeholders starts with agreement on the overall programme objectives. In the case of the Room for the River programme a sense of urgency was created by nature itself through the 'near miss' of flooding in two almost subsequent years (1993 and 1995). Hence a clear need for measures was felt, not in the least because of the future prospect of more frequent high river discharges.

A second important factor that contributed to the support was the dual objective approach of the government: equal to safety against flooding a second objective was formulated, namely the improvement of the local environment (landscape amenity, ecology, recreational values). Safety was no longer the only argument for measures and interventions. New and unconventional measures became negotiable as long as safety was improved as well.

Good governance and stakeholder participation

Participation in planning, design and implementation has been (and still is) a strong point of the programme. Important factors that contributes to this success are trust, early involvement, and a special Planning Bureau. Participation started with a secured public involvement in the Planning Key Decision phase for the entire programme and is continuing up till this moment during the implementation of all the projects.

The programme combines clear central programme management with a large degree of freedom for the local participants to design their project within the boundaries and objectives set by this management. The availability of the tool box (Planning Kit) with which stakeholders could design and evaluate their plans was also very helpful in this participatory process (see below).

Good communication

Communication is one of the key factors for the success of a program such as Room for the River. Between the governance and the different stakeholders, the communication is essential to execute the different projects. Miscommunication between these parties can lead to complete failure of a project, due to lack of support, execution of the wrong plans, no solution for unexpected problems, etc. The Room for the River programme has invested much in providing information to the public, through brochures, public hearings, a web-site and other media tools.

Sound and undisputable knowledge

The Planning Kit proved extremely important in facilitating the public discussion - as well as among professionals - in the planning, design and decision making phases for the Room for the River. Some three thousand copies of the Planning Kit have been distributed in the Netherlands. With this computer programme measures can be selected according to various criteria, such as cost-effectiveness, enhancing nature areas, inside or outside the floodplain, etc. Once measures are selected, their impact on flood level reduction is calculated using a hydraulic model that is part of the software. In this way participants were able to select the most appropriate solution that leads to the required reduction of flood level, prescribed by the overall safety objective of the programme. The embedded knowledge of the river system was not disputed by participants which greatly contributed to the success of the programme.

The other main objective, improvement of the local environment, is more difficult to measure as it contains several intangible criteria, such as ‘landscape amenity’. Therefore, a special Q-team has been installed, consisting of landscape architects, geographers and other experts, that provides advice on all the different projects.

Sufficient budget and clear financial arrangements

For the Room for the River programme a substantial budget of around 2.3 billion Euro has been reserved by the central government. This budget is meant for all projects that are necessary for securing the safety objective. Additional regional ambitions that are not necessary for the safety, such as a nice waterfront, new residential areas and infrastructural improvements, should in principle be paid for by the region or municipality that benefits from these improvements. By combining such projects, savings can be substantial. For instance, soil excavation to lower the floodplain can be used for raising nearby areas for new housing development.

The Cost-Effectiveness Analysis done for the programme learns us that providing room for the river not necessarily leads to the cheapest solution for multiple objectives. Much depends on local situations and conditions, which leads to a package that contains both traditional dike reinforcements as well as innovative measures. It also learns us that cost-effectiveness is not the only and decisive factor for decisions. A robust climate proof solution may be initially more costly but can prove to be a wiser solution on the longer term.

Box 7: International Waterfront Center Award 2011 for Room for the River Waal project

The Dutch ‘Room for the River Waal’ programme received the Excellence on the Waterfront Honor Award 2011 presented every year by the Waterfront Center.

Valued at EUR 350 million, the prestigious 'Room for the River Waal' at Nijmegen is one of the most significant projects in the Room for the River program. A side-channel is being added to the River Waal at Nijmegen, and an elongated island formed just opposite the historic city centre. The side-channel and island both offer unique opportunities for nature conservation, recreation and living. 50 homes and businesses have to give way to the project.

The jury praised the way residents are involved, the innovative balance between flood protection and local development, and the sharing of knowledge with riverside towns in neighbouring countries.

3.2 Sand nourishment and the Sand Engine (NL)

3.2.1 General description of the project

Since 1990 a new Dutch policy on coastline management has been implemented, called 'Dynamic Preservation' which is based on sand nourishments as the preferred method for protection. Only when this measure is not possible the alternative of hard engineering structures, such as groynes, breakwaters and sea walls is opted for. This policy has resulted in a safe, environmentally sound, sustainable and natural coastal defense system, consisting of dunes and beaches along the majority of the Dutch coastline.

Sand nourishment is the mechanical placement of sand in the coastal zone to advance the shoreline or to maintain the volume of sand in the littoral system. It is a soft protective and remedial measure that leaves the coast in a more natural state than hard structures and preserves its recreational value. The method is relatively cheap if the borrow area is not too far away (<10 km) and the sediment is placed at the seaward flank of the outer bar where the navigational depth is sufficient for hopper dredgers. Three types of nourishments are distinguished: beach, shore face and dune nourishments (Figure 3.10).

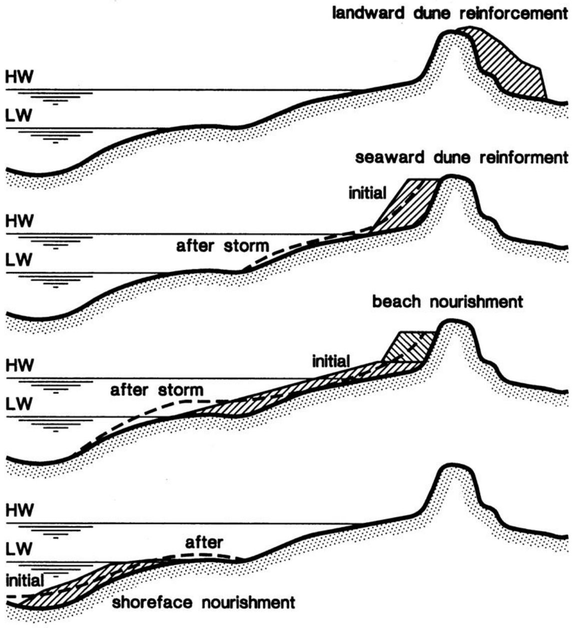


Figure 3.10 Types of sand nourishments (source: Van Rijn, 2010)

Recently, a new innovation has been introduced that further builds on the traditional sand nourishments: the Sand Engine. Instead of many small nourishments, this intervention consists of depositing a large volume of sand in the foreshore, thus creating a temporal peninsula from which adjacent coastal stretches are fed by sediments through the natural processes of waves and currents.

3.2.2 The challenge, objectives and measures

The majority of the Dutch coastline consists of sandy beaches and dunes, which are subject to erosion and accretion. When there is too much erosion, the coast will retreat and may even result in flooding of the land behind the dunes. In fact, the dunes form a natural flood protection for large areas that lie even below sea level. Fortunately, at most places the dunes are sufficiently high and wide to withstand an attack during a storm. And the system is quite resilient in the sense that it can (partly) replenish the sand lost. During a subsequent calmer period after a storm part of the sediment may return to the coast through onshore directed wave- and wind-driven transport, usually resulting in accretion in the beach zone (Figure 3.11). However, longshore currents may also move the sediment further away from the original location.

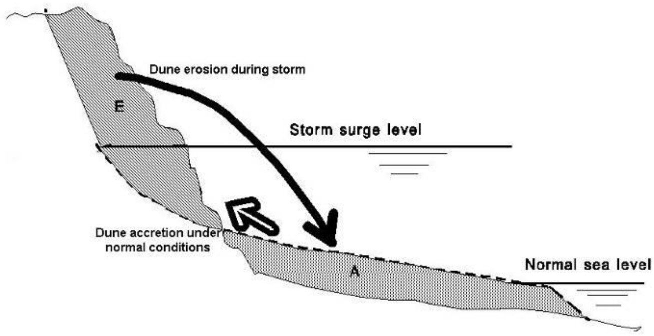


Figure 3.11. Basic process of coastal erosion and accretion (source: Marchand, 2010)

The idea of sand nourishments is basically to enhance the natural resilience of the sandy coast, by adding sand in the system where too much sediment has been eroded due to longshore transports. After careful scientific studies and monitoring, the Dutch government decided in 1990 to maintain the coastline position and not allow structural retreat anymore and that the main measure would be through sand nourishment. Every year up to 12 million cubic metres of sand is used for this purpose. Figure 3.12 illustrates the cumulative sand nourishment efforts of the past decade.

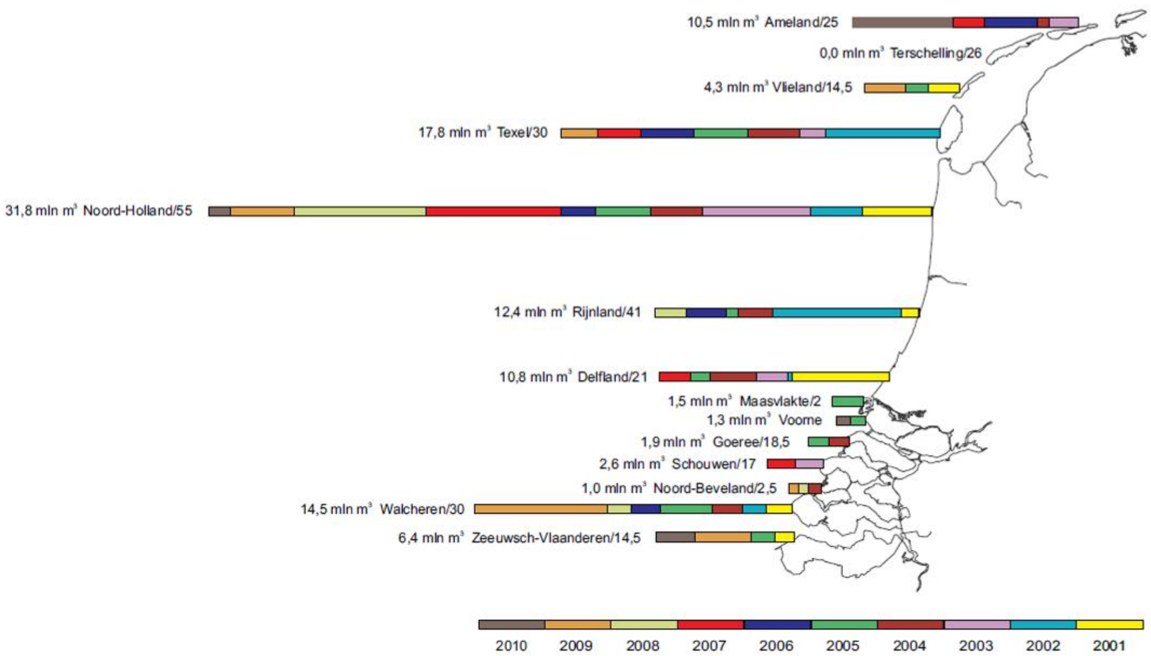


Figure 3.12. Map showing the Dutch coastline and the volume of sand used in the past decade for nourishment (source: Rijkswaterstaat)

Using the coastline position of 1990 (the 'basal coastline' BCL) as benchmark, every year the government agency Rijkswaterstaat (RWS) evaluates whether the actual coastline meets the standards and, if not, decides on a nourishment. If a beach does not meet the standard, RWS will issue a tender for contractors. The work is mostly executed between April and November in view of the sea and weather conditions.

Considering that morphological developments at larger scales (e.g. sand losses at larger depths and long term developments such as sea level rise) were neglected, the Dutch Government decided in 1995 on an extended large-scale approach: additional compensation of sand losses at deeper water. Therefore, the policy defined the preservation and improvement of the Coastal Foundation: the area between dunes and the –20 m depth contour.

With this additional objective the Dutch coastal policy now includes management objectives at three different scales (see also Figure 3.13):
- Guarantee **residual dune strength**
- Maintain coastline position of 1990 (**basal coast line**)
- Preserve and improve **coastal foundation**

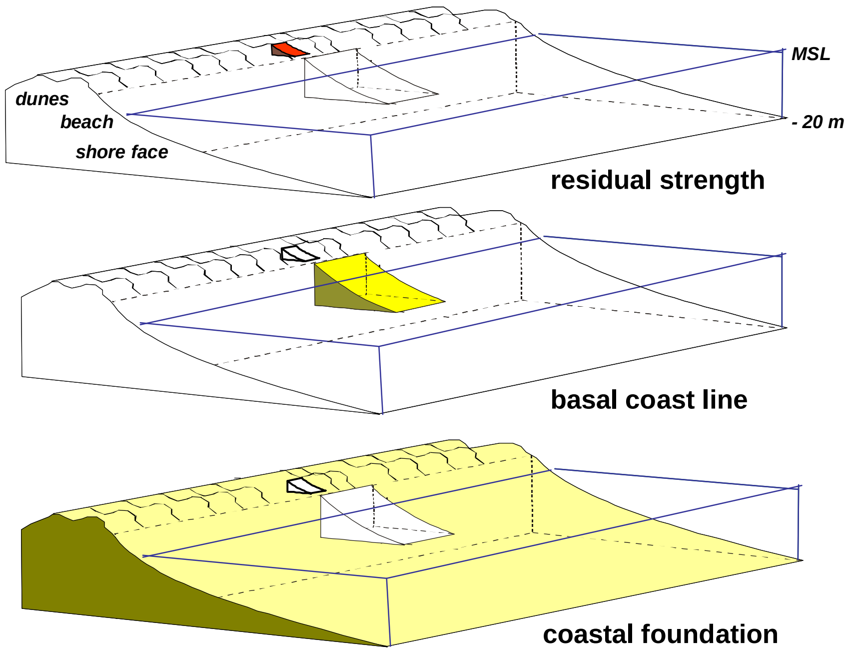


Figure 3.13 Definition sketch of three different management objectives: dune residual strength (days – metres); Basal Coast Line (years – kilometres) and Coastal foundation (decades to centuries – 10s to 100s of kilometres) (source: Mulder et al., 2011)

The basic idea behind the distinction into different management scales is that the large scale provides boundary conditions for the smaller scales. The minimum requirement of the dune strength creates boundary conditions for safety against flooding in any place at any time. The maintenance of the Basal Coast Line (BCL) creates boundary conditions for the assurance of the dune rest strength over a period of (10) years and alongshore distances of kilometres. The preservation of the Coastal Foundation in turn creates boundary conditions for maintenance of the BCL over decades to centuries and over alongshore distances of 10s to 100s of kilometres.

Thus the sand nourishments support multiple functions: flood protection, maintenance of the coastline position (no structural erosion), a wide beach and adaptation to sea level rise. This results in a cost effective, efficient and sustainable coastal zone with plenty of opportunities for a healthy ecosystem as well as for recreation and tourism.

3.2.3 Implementation and stakeholder participation

Safety against flooding from the sea is a responsibility of the national government. As an executive branch of the Ministry of Infrastructure and Environment (MI&E), Rijkswaterstaat is responsible for the maintenance and observation of the entire coastline. However, the execution of the monitoring and maintenance efforts are sometimes performed by local agencies, such as the water boards and provinces, if this proves to be more efficient. In these cases RWS and the local governmental bodies communicate and agree on the tasks of each party, but RWS remains ultimately responsible. The decision to perform a nourishment lies with the Minister of I&E who is advised by RWS. Other parties, such as the provinces, municipalities and water boards participate through RWS. Also NGOs, such as nature conservation groups and water companies are consulted in the sand nourishment decision model (see Figure 3.14). When RWS plans to perform a nearshore nourishment activity it will consult the other stakeholders. If for instance a municipality prefers a more expensive beach nourishment, because it will increase the width of the beach and therefore enhances recreational opportunities, it can advise RWS to do so. In that case the municipality will have to invest in the nourishment too.

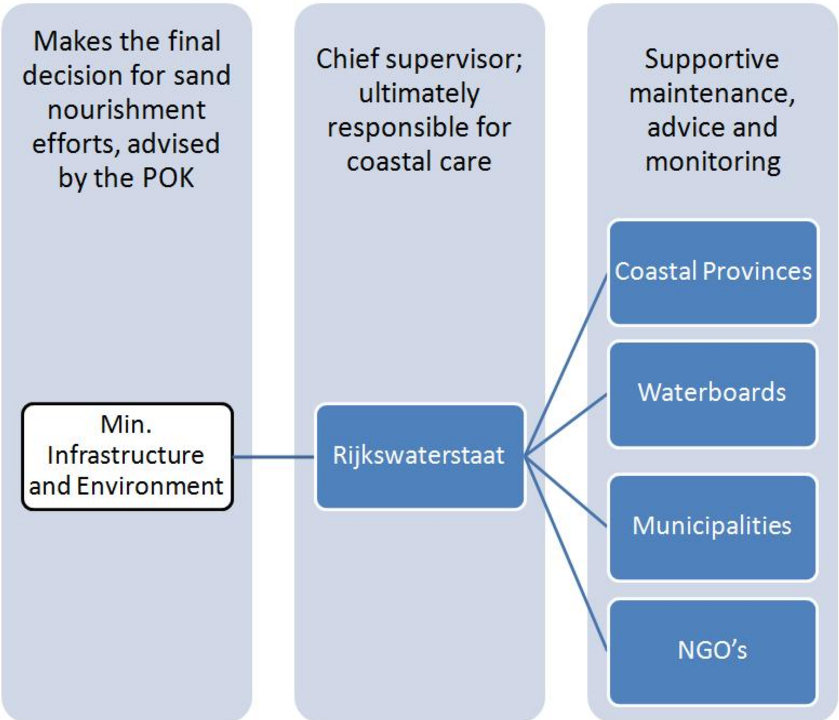


Figure 3.14. Decision model for sand nourishment. Rijkswaterstaat is the executive branch of the Ministry of Infrastructure and Environment. The provinces, waterboards, municipalities, NGOs and companies have an advisory role.

The decision on the sand nourishment policy has passed with relative ease. Contrasting to 'hard' measures (seawalls, breakwaters, etc.), sand nourishment maintains the historical landscape of the coastline. This improves the recreational value of the beach and dunes. It also keeps natural gradients (wet-dry, salt-fresh, shallow-deep) intact which is beneficial for the coastal ecosystem. These conditions favored support for the strategy both from nature conservation organizations and the wider public.

3.2.4 Does it work?

Successive evaluations of the policy in 1995 and 2000, pointed out that the BCL was successfully being maintained (Hillen & Roelse, 1995; Roelse 2002). Thus the structural erosion of the Dutch coast was controlled and the position of the coastline was maintained since 1990. However, considering that morphological developments at larger scales, e.g. sand losses at larger depths and the impacts of sea level rise were neglected by the BCL-approach, it was concluded that the long term sustainability of the method was questionable. As a result, the Dutch Government decided on an extended large-scale approach: additional compensation of sand losses at deeper water. This resulted in an additional large-scale objective being defined: the preservation and improvement of the coastal foundation. The coastal foundation consists of the area between dunes and the -20 m depth contour (see Figure 3.13).

Another important conclusion from the latest policy evaluation (Lubbers et al., 2007) is that the objective to sustainably preserve not only safety, but also boundary conditions for all other functions in the coastal system, is only partly achieved. It appears there is a societal need – expressed by provinces, municipalities and private parties – to explicitly execute sand nourishments for other coastal functions than coastal safety alone. In practice, however, nourishment claims for these other user functions (e.g. in coastal towns) often imply relatively expensive beach nourishments, whereas safety issues can be served by cheaper shoreface nourishment. This shows that at present, functional integration in Dutch coastal management still is limited (Mulder et al., 2011).

Sand nourishment is a safety strategy with many advantages. Compared to the lifespan of a 'hard' water defense structure, sand nourishment doesn't necessarily cost more. And besides protection from high water levels, it potentially provides recreational and natural value. By enlarging the transition area between dry and wet, deep and shallow, sea and land a high biodiversity can be ensured. This contributes to the conservation of the natural coastal landscape of the Netherlands. This in turn will attract more tourists and recreationists, boosting the local economy. Furthermore, it is a robust strategy, because future accelerated sea level rise can easily be coped with by increasing the nourishment volume.

3.2.5 Financial aspects

The costs of a sand nourishment largely depends on the availability of sediment relatively close to the project area and the type of nourishment. Beach and dune nourishments are considerably more expensive than nearshore nourishments. Unit prices of sand typically range between 3 and 5 Euro per m^3, but sometimes can be as high as 10 Euro.

Sand nourishment as a coastal defense strategy is not necessarily cheaper than hard structures, but it yields more benefits for other purposes than flood risk alone. The ecological development and flood safety are public benefits with intangible values. And there are indirect benefits, such as increase in land value near the sea, additional income for local businesses and jobs.

Furthermore, it requires regular investments, because nourishments have a typical lifetime of 4 to 5 years. The maintenance interval depends on the rate of erosion of the shore and distance to the burrowing area, making a fixed budget impractical. Continuation and commitment is crucial for the effectiveness of sand nourishment efforts on the long term. The government budget for coastal care in 2009 amounted to €65 million.

3.2.6 The next step: the Sand Engine

Although the current sand nourishments are successful and effective for local coastline maintenance, the government and involved partners decided to research more sustainable ways of replenishing the Dutch coast. The idea is to apply an extra amount of sand that will be redistributed by nature itself, thus stimulating natural dynamics of the coast, increasing a buffer zone for future sea level rise and enlarging the coastal intertidal zone with benefits for nature and recreation. Such a super-nourishment could prove to be more efficient by serving more functions than safety alone.

Figure 3.15 Artist impression of the Sand Engine

Between March and October 2011, Rijkswaterstaat and the Province of South Holland have created the Sand Engine, a hook-shaped peninsula. It extends 1 km into the sea and is 2 km wide where it joins the shore. Dredgers picked up the sand ten kilometers off the coast and took it to the designated area. There will also be two offshore replenishment locations alongside the peninsula. These are expected to be completed in March 2012. The total costs are €70 million of which the national government contributes €58 million and the Province of South Holland provides €12 million.

The challenge
The Sand Engine is expected to relieve replenishment efforts for the coming 20 years. However, an artificial peninsula of that magnitude will inevitably influence the coastal currents to a certain extend. By building the Sand Engine a new opportunity arises to research the possibility of utilizing natural processes to replenish the beaches. The influence on the coastal currents has been studied with computer models and scale testing. But only the actual construction of the peninsula will show whether the test results have been correct. The Sand Engine is in fact a large scale pilot.

Researchers agree that the Sand Engine will erode and saturate the sea water with sand, but the exact behavior of the currents remain uncertain. Nature is a capricious business partner. Yet the benefits such as added recreational value, nature development and knowledge acquired by executing this project outweigh the uncertainties.

Figure 3.16 Construction of the Sand Engine

Building with Nature
The Sand Engine is a unique example of building with nature. By depositing a vast volume of sand in a single operation, repeated disruption of the vulnerable seabed can be avoided. The traditional nourishment of the coastline has a significant impact on the local ecosystems. Both the dredging at the sand extraction zones and the beach nourishments disrupt the ecosystem every 5 years approximately. By depositing a large amount of sand and increasing the disturbance interval from 5 to 20 years, the ecosystem gets the opportunity to recover in a longer time period. The Sand Engine on this scale is one-of-a-kind. With this project the Netherlands continues to set the standard in water management. The emphasis lies on working *with* nature.

Space, peacefulness and quietness
The Sand Engine will be open for recreational purposes after construction. The peninsula has been opened to visitors in the latter half of 2011. Visitors are able to dwell over the enormous sand shoal or go up the watchtower to savor the views. Seals have already found their way to the Sand Engine. Of course, nature needs time to develop. After a few years, visitors will be able to explore the new nature, which will be allowed to develop freely on the Sand Engine. The Sand Engine provides a new option for anybody looking for space, peacefulness and quietness, as a refuge from the hectic life in the cities of the western Netherlands (Zandmotor 2011).

Figure 3.17 the Sand Engine is nearing completion (source Joop van Houdt, 2011)

3.2.7 Lessons learned

Sediment management represents the core of the Dutch coastal erosion policy and – management. As such the approach totally complies with the first key recommendation on erosion management as issued by the EU in 2004: “Restore the sediment balance and provide space for coastal processes” (European Commission, 2004). From the Dutch experiences we can draw a number of lessons and identify key success factors.

Sufficient (scientific) knowledge

Management plans for coastal erosion should be based on the principle of working with natural processes. In order to do so we therefore need to have a good understanding of these natural processes. Coastal sediment dynamics evolve in an interplay of many different physical forces, such as currents, winds, waves, tides and salinity gradients. Over the past decades a substantial body of scientific knowledge has built up on coastal morphology. This groundwork provides a firm basis for developing a management plan. Yet a crucial next step is to used this knowledge in a policy relevant way. An important unifying concept which bridges the scientific knowledge with application in a management context is the coastal sediment cell. By using this concept at three spatial scales, the Dutch policy of dynamic preservation was successfully worked out. The basic idea between the distinction into different management scales is that the larger scale provides boundary conditions for the smaller scales.

The general lesson learned is: a sustainable solution to coastal erosion problems should be based on an understanding of the sediment dynamics, framed in a policy context with explicit objectives.

Good monitoring system in place

Because of the dynamics of the coastal morphology, accurate, reliable and up to date information is needed on the condition or state of the coast. Fortunately, the Dutch coast has been monitored each year for over hundred years now. This database is of great value for improving our knowledge, for validating numerical models and for informing the coastal manager when to apply a nourishment.

Clear responsibilities for who is doing what.

Because sand nourishment is a strategy that requires close monitoring of the state of the coast and recurrent interventions, it requires a clear institutional setting. Arrangements with respect to who is doing what, budget rules and public information need to be set up between government agencies at central, regional and local level.

Enough sand available at close distance
Last but not least, a nourishment policy can only succeed if its cost can compete with other solutions. The distance to the nearest sediment reservoir is one of the major factors that determine the price per cubic metre of sand. Therefore, it is advisable to identify strategic sediment reservoirs of appropriate characteristics, that are available for replenishment of the coastal zone, either temporarily (to compensate for losses due to storms) or in the long term. They can be identified offshore, in the coastal zone itself and on land (Marchand, 2010).

3.3 Waterplan 2 Rotterdam (NL)

3.3.1 General description and history of the project[8]

'*Waterplan 2 Rotterdam'* is an ambitious on-going programme to better cope with present and future water risks. It is a unique cooperation between the municipality of Rotterdam and three waterboards to integrate urban developments and spatial planning with a better water management. Besides the need to accommodate more water in the future, the Waterplan 2 also takes account of water quality and other functions of the urban water system. In fact the idea is that these components can actually reinforce each other, by using the synergies between land, water and environmental management.

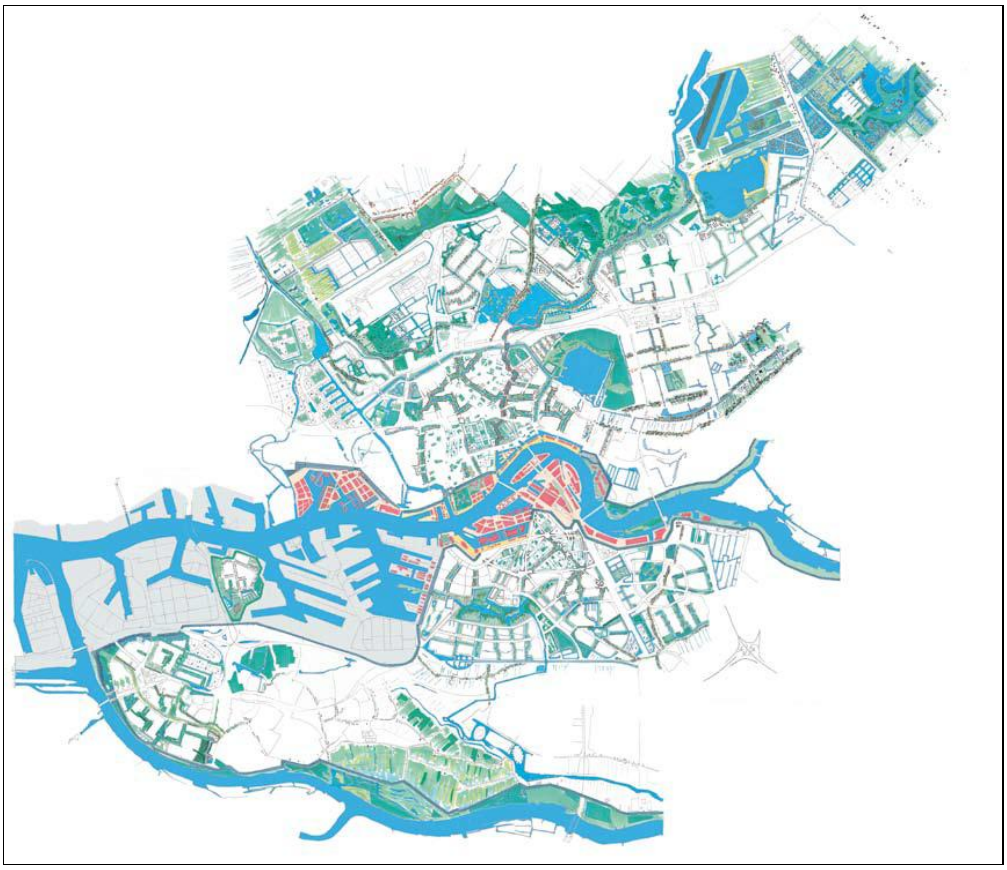


Figure 3.18. Vision of Rotterdam Water City 2030

[8] *Based on http://www.rotterdam.nl/waterplan_2_en_deelgemeentelijke_waterplannen and personal communication Mr. J. Pieneman program coordinator Waterplan 2.*

The history of Waterplan Rotterdam dates back to 2005 when the city hosted the International Architecture Biennale Rotterdam. During this event a Masterclass was held which resulted in 'Rotterdam Water City 2035', a visionary future in which the water challenge is not seen as a threat but as an opportunity. Based on this vision the Waterplan Rotterdam was drafted, incorporating the legal frameworks of the EU-Water Framework Directive and the national agreement on water (Nationaal Bestuursakkoord Water). Later this plan was updated and Waterplan 2 is currently being implemented.

3.3.2 The challenge, objectives and measures

The harbor city of Rotterdam (600,000 inhabitants) is part of the economic heart of The Netherlands. Situated in the Rhine river delta it has to cope with many water problems. Water threatens this city from at least three different directions: from the river Rhine, from the North Sea and by precipitation from above (see Figure 3.19).

Figure 3.19: Water threats for Rotterdam, The Netherlands

Although Rotterdam has much, if not all, of its prosperity gained through its excellent strategic position along the river, it is realized that water can also threaten its existence. After constructing the Maesland Barrier (in 1997) much of the water safety problem from the sea has been solved. But being situated in a low lying delta, the problems associated with heavy rainfall are still lingering. At this moment the city is insufficiently prepared for the drainage of water during a heavy downpour. It has been calculated that for effectively coping with a one in hundred year rainfall event, the city needs an extra storage capacity of 500,000 to 600,000 m^3. This is the equivalent of 50 to 60 hectares of land with 1 m water level. In such a high density urban area this space is simply not available, so alternative solutions need to be found to ensure that this 'water task' can be met. And in view of future climate change, this task could even grow to as much as 750, 000 m^3, although precise numbers are of course difficult to provide. The numbers are based on model calculations and extrapolations, and it could well turn out that the actual need for extra storage capacity is less. Indeed, recent more detailed studies revealed that these figures need significant adjustments. Nevertheless, both Rotterdam municipality and the three water boards of Hollandse Delta, Delfland, Schieland & Krimpenerwaard have joined hands to start working on this challenge together.

The Waterplan consists of three types of projects: projects to improve safety, projects to cope with the quantity (thus storage) of water and to improve the quality of the water. In this section examples of executed projects are described. At this moment a number of innovative urban water management projects have been realized:

- Open water storage: extra storage in open water areas, such as parks and canals (25,000 m^3);
- Subsurface storage e.g. in parking garages (12,400 m^3);
- Water plazas;
- Separated sewerage – drainage systems;
- Green roofs.

Parking garage Museumpark

A perfect example of a multifunctional use solution is the underground water storage at the Museumpark, where a parking garage can be used to store 10,000 m^3 of water. Thanks to the special design, the water can be stored during heavy long term precipitation, and at the same time the garage can still be used for car parking. When the worst rain is over, the stored water can be discharged into the drainage system of the city. The garage has a total number of 1150 parking spaces and the construction was finished in 2010.

Figure 3.20 Water storage in parking garage

Redevelopment Junction Kleinpolderplein

Driving from the north-west to Rotterdam over the highway, one enters the city at Kleinpolder, which used to be a typical Dutch polder landscape with ditches and cows. But since the late 1960s a junction between highway A13 and A20 has been constructed and the entrance of the city has become one big spaghetti of concrete mass. Now that also this part of the city (the district of Overschie) has to take its part in contributing to the water task of the municipality, a new plan has been designed to create extra water storage under the junction. It is included in a total upgrade of the waterways. During the construction of the traffic junction many waterways in the district were filled with soil and the remaining canal system has resulted in a poor flow, a monotone ecosystem and poor water quality.

The new plan consists of the construction of a water pool with natural banks *under* the junction. The pool will have a surface of 6,000 m^2 and creates an extra storage capacity of 2,520 m^3. Adjacent to the central pond a water plaza will be constructed. It will generate an extra storage capacity of 960 m^3 and will be decorated with sculptures to increase the attractiveness of the entrance to the city. The redevelopment has started in 2010 and is expected to be completed in 2013. The costs have been estimated at around 1.5 million Euro, of which the waterboard covers fifty percent.

Figure 3.21 Design of Kleinpolderplein reconstruction (A. Diekman, Landschapsarchitecten)

Green roofs
Since 2008 around 50,000 m^2 of green roofs have been created in Rotterdam, of which around 35,000 m^2 were realized with a subsidy of 30 Euro/m^2 from the municipality and waterboard. From 2011 the Waterplan 2 sets a target of realizing 40,000 m^2 of green roofs per year. The municipality and waterboards will do their share by greening the roofs of their offices and private house owners will be stimulated to do the same through a subsidy and other modes of support. Interestingly, green roofs cannot help in the water task of the waterboard, because it does not count officially as a storage measure, because it only retards run-off and delays the peak flow.

Separated sewerage system
Sewage pipes last roughly about fifty years. This means that for some older parts of the city the sewerage system needs upgrading. By doing so a new, separated sewerage system is installed when technically and financially possible. One system is for the waste water coming from the residents, the other system is for the precipitation water coming from the roofs and the streets. (Figure 3.22). By separating these two systems the risk of a spill-over during high intensity precipitation of untreated sewage water into the surface water is greatly reduced. However, it does not add to meeting the water storage requirement of the city.

Figure 3.22: Old sewerage system (left) and separated sewerage system (right)

3.3.3 Implementation and stakeholder participation

The vision and goals of the Waterplan have been broadly formulated by the municipality of Rotterdam and the Waterboards. It is up to the city districts to formulate and work out in detail the different projects on local scale and to execute these plans. Usually a consultant is commissioned to do a study and prepare a detailed project design. In order to create uniformity between the districts a standard format has been formulated by the municipality and the waterboards. In this format the districts fill in their own plans and objectives.

The organization of the local projects consists of a project board and a steering board. Based on the emphasis and type of project, this organization can be extended with a sounding board to preserve local interests and to create public support. This board includes stakeholders such as housing corporations, Rijkswaterstaat as manager of the national waters, the province of South-Holland, the Environmental Department of the Municipality, the Harbor company of Rotterdam, nature and other interest associations and resident associations. Also an expert team is seconded to the project team to advise on technical subjects and to answer detailed questions.

Citizen participation in Waterpan 2 consists in the consultation of designs and plans of the district government, after which these can be adjusted or redesigned. Together with the waterboards the municipality has installed a ‘Waterportal’ where information can be obtained.

3.3.4 Does it work?

In total about 37,000 m^3 of extra water storage has been realized, which shows that progress is being made, albeit too slow to have the entire water storage target fulfilled in 2015. It must be realized in this respect that some of the municipal districts have had their water plans approved only quite recently. In order to speed up the project development and implementation in the coming years, new partners will be approached next to the existing ones, such as real estate developers and housing corporations.

By performing more detailed analyses with better baseline data at district or ward level the water storage target has been calculated again, leading to a significant reduction of the target. Besides better data also a change in area classification from ‘high value’ to ‘low value’ can greatly reduce the need for extra water storage (these are classes used for determining the threshold for accepting flood inconveniences).

3.3.5 Financial aspects

The total investments for the Waterplan between the year 2007-2012 amounts to about 82 million Euro. More than half of this budget is provided by the waterboards, with the remaining coming from the Municipality of Rotterdam. The idea behind the division in costs is called ‘the task holder pays’, which means that the waterboards are responsible for the measures that contribute to the water quality and water quantity goals and the municipality pays for the measures dealing with sewerage, open space, recreational facilities etc. It was also agreed that the municipality would provide land, if required, free of charge.

A unit price for seven different types of water storage measures has been defined, which enables to calculate total costs of a project attributable to the water task. The cheapest solution is the creation of extra water storage in rural areas (€ 50,=/m^3). For water redevelopment areas in open public space (gardens, parks or squares) this averages around €350,=/m^3, whereas construction of underground water storage peaks around €1000,=/m^3. These figures are excluding the acquisition of land, if needed.

3.3.6 Lessons learned

Rotterdam has embarked on an ambitious development, which started with several initiatives some years ago: Rotterdam Climate Initiative, Rotterdam Climate Proof, Waterplan, etc. The city wants to become a world leader in climate mitigation and adaptation. This has resulted in a range of projects and programmes, that combine urban/harbour renovation and development with climate mitigation and adaptation. Some noticeable lessons can be drawn from its success.

Joint vision, collaboration and local initiatives

In order to get maximum support from all parties a clear vision is necessary, which needs to be formulated together by all these parties (says Molenaar, program manager Rotterdam Climate Proof). Clearly, Rotterdam Water City 2035 provided this vision. It was the first time that water was not seen as a threat but as an opportunity. It was also the first time that waterboards, the water management and the spatial development departments of the municipality started cooperation on a structural rather than ad hoc basis.

The Waterplan has explicit, quantitative goals, at the level of the city as a whole and also for each district. For instance, the extra water storage has been translated up till the local (district) level in quantifiable objectives. Local initiatives are stimulated by providing freedom in implementing solutions.

Dual objectives, multifunctional use and visible change

The Waterplan has an explicit dual objective: both improving water management and improving the spatial quality of the city. By combining functions and promoting multifunctional use of space in a densely populated city, the water management measures are more easy to finance and to get support for. When users see the actual change on a short term, for instance when water quality or amenity improves, the local support among the residents and other users of the city grows substantially.

Solid financing structure

Also crucial for the success were the agreements *upfront* of who is going to pay what. Unit costs were agreed for every type of measure, so that allocation of costs are relatively straightforward. A favorable economic climate at the start of the programme facilitated the provision of a generous budget, which eased implementation of the first projects. Currently, with declining government resources, projects are scrutinized one by one in terms of their necessity and cost effectiveness.

3.4 Wetland Restoration Louisiana (USA)

3.4.1 General description and history of the project

In November 1990, Congress passed Public Law 101-646, the *Coastal Wetlands Planning, Protect and Restoration Act (CWPPRA)*. CWPPRA was the first federally mandated restoration effort to take place along Louisiana’s coast and the first program to provide a stable source of federal funds dedicated specifically to coastal restoration. The Act directed that a task force consisting of five federal agencies and the state of Louisiana develop a "comprehensive approach to restore and prevent the loss of coastal wetlands." CWPPRA has been the State of Louisiana's primary tool for responding to coastal wetland losses. CWPPRA emphasizes intergovernmental cooperation. As of June 2010, there are 180 active CWPPRA projects, 85 have been constructed, 12 are under construction, and 26 have been de-authorized or transferred to another program. The remaining projects are in various stages of planning and design.

3.4.2 The challenge, objectives and measures

Louisiana boasts more than 4 million acres of wetlands, representing 40% of the nation's total. These wetlands are among the world's most diverse and productive ecosystems. The wetlands:

- support and protect a multi-billion dollar oil and gas industry.
- provide nursery grounds for fish and shellfish for much of the nation's seafood.
- protect over 400 million tons of waterborne commerce annually.
- provide winter habitat for about one-half of the Mississippi Flyway waterfowl population.
- serve as a buffer from hurricanes and storms.

The wetlands of Louisiana are disappearing at a high rate. Every 38 minutes, a football field sized parcel of Louisiana's wetlands is taken over by water. The U.S. Geological Survey estimates that if present trends continue, the state will have lost 2,400 square miles of land between 1932 and 2050. That's an area about 25 times the size of Washington, D.C. Across the region, communities are being threatened, jobs are being lost, and habitats are vanishing. The loss of Louisiana's coastal wetlands is one of the most serious environmental problems facing the country today. The causes of Louisiana's wetland loss have been extensively researched and are well-documented as being the result of cumulative natural and human-induced effects, which include hydrological alteration due to levees; oil and gas developments and canals; subsidence; salt water intrusion; and storms (Steyer & Llewellyn, 2000).

In an effort to offset land loss, several initiatives have been taken over the past decades. Since 1991 most projects have been supported by federal funds and matching state funds through the Coastal Wetlands, Planning, Protection, and Restoration Act, commonly referred to as 'The Breaux Act'. This act mandates the implementation of a comprehensive approach to restore and prevent the continued loss of coastal wetlands in Louisiana through 1) the development of an organizational structure facilitated by an interagency Task Force; 2) intensive planning for the development of restoration strategies; 3) annual development and implementation of restoration projects and 4) development and implementation of a comprehensive monitoring program to evaluate the effectiveness of wetland restoration projects (Steyer & Llewellyn, 2000).

Projects are selected in the context of the region-specific restoration objectives to which they contribute. The projects fall within the following restoration techniques: freshwater or sediment diversions, outfall management, barrier island restoration, marsh creation through the use of dredged material, hydrologic restoration, marsh management, vegetative plantings, sediment and nutrient trapping, shoreline protection, or combinations of these types (Steyer & Llewellyn, 2000). An example is the restoration technique known as the beneficial use of dredged material: CWPPRA Project BA-39 Mississippi River Sediment Delivery – Bayou Dupont. Sediment is used from the Mississippi River to rebuild wetlands in a new location. A dredger near the levee pumps sediment to the fragile wetlands. The sediment is then used to rebuild marsh that had turned to open water, creating new wetlands (Figure 3.23).

Figure 3.23 Bayou-Dupont. The red boat near the levee is pumping sediment to wetlands in the top left of the image. (Source: www.lacoast.gov)

Another example is sediment diversion, which redirects sediment to nearby wetlands to promote natural land-building processes. A gap, called a crevasse (see Figure 3.24) is cut into a river levee, allowing river water, nutrients and sediments to flow into a marshland. As of June 2007, federal agencies and Louisiana were designing and engineering seven projects and had completed five projects to divert sediment to nearby wetlands (GAO, 2007).

3.4.3 Implementation and stakeholder participation

CWPPRA has been the primary mechanism for implementing coastal wetland protection and restoration projects in Louisiana as a result of the consistent long-term funding stream authorized by Congress. The CWPPRA has proven to be very effective and efficient in designing and implementing medium to large-scale projects. This was accomplished by using a bottom-up and collaborative multiagency approach that closely engages the public, local governments and other important stakeholders (CWPPRA, 2010).

A Task Force was established that consists of representatives of five federal agencies and the state of Louisiana to implement the Act. This Task Force is supported by a Technical Committee and a range of workgroups on environment, engineering, monitoring etc. Also a Citizen Participation Group was established, which represents local officials, landowners, sportsmen, commercial fishermen, oil and gas developers, navigation interests and conservation organizations, to provide general input from the diverse interests across Louisiana's coastal zone (Steyer & Llewellyn, 2000).

Figure 3.24 A crevasse in a sediment diversion project (source: GAO, 2007)

But the CWPPRA is not the only organization dealing with wetland conservation and restoration. There are many NGO’s active in the region and there is the Coastal Protection and Restoration Authority (CPRA). This Authority was established in December 2005 after the devastation of Hurricanes Katrina and Rita. Prior to the hurricanes, safeguarding Louisiana's coast meant separate planning for hurricane protection and coastal restoration. CPRA considers both "hurricane protection and the protection, conservation, restoration and enhancement of coastal wetlands and barrier shorelines or reefs". May 2006 the CPRA completed the first annual coastal protection plan for the state that integrates both hurricane protection and coastal restoration projects.

3.4.4 Financial aspects

Federal funding for the engineering, design, construction, operation, maintenance, and monitoring of CWPPRA projects has averaged approximately $50 million each year, ranging from about $28 million per year in the early 1990s to $71 million in 2007. Up to 2007 an estimated US$ 1.78 billion was spent on projects(GAO, 2007).

The cost of projects can vary considerably from about $9,000 per acre to plant marsh plants to almost $54,000 per acre to restore barrier islands. Projects also require a continuous source of funding to maintain them over their expected life spans, which in most cases are about 20 years—yet like naturally occurring wetlands, most restored wetlands are also subject to continuous erosion and subsidence over time (GAO, 2007).

Overall figures from the CPRA shows an increase in the number of projects and budget. From 2000 to 2007 37 projects were scheduled worth US$381 million, from 2008 to 2010 this was 49 projects with a value of US$438 million. Scheduled for 2011-2012 are 90 projects with a total value of US$810 million (Graham, 2011).

3.4.5 Does it work?

Over the last 17 years under CWPPRA, federal agencies and Louisiana have designed and/or constructed 147 projects to restore and protect over 120,000 acres of coastal wetlands—about 3 percent of the Louisiana coast.

In a report of the US Government Accountability Office (GAO, 2007) a review of the CWPPRA program was presented. It concluded:

‘Previous and ongoing efforts to restore and protect Louisiana’s coastal wetlands offer important lessons to guide future restoration plans and strategies. Of particular importance is maintaining the collaborative process used by the CWPPRA program agencies, under which scientists, engineers, and others with a range of experience and expertise work together to plan and design restoration projects that are feasible and achievable. In addition, a number of other issues will need to be addressed as larger and more complex restoration efforts are undertaken in the future. Specifically,

- Increasing project costs can delay individual projects, as well as the overall program—currently 10 CWPPRA projects are on hold waiting for funds because estimated construction costs exceed funds available.
- Without an integrated monitoring system, officials cannot determine whether goals and objectives are being met—even after 4 years such a system is not fully implemented for CWPPRA.
- Identifying and addressing private landowner issues is critical in the project design phase—in some instances, these issues have led to costly project modifications or construction delays for some CWPPRA projects.
- Some projects simply fail to perform as designed due to landscape, structural, or other causes beyond the designers’ control—some CWPPRA projects were terminated because such problems were not anticipated or could not be resolved.
- Storms and hurricanes can result in significant setbacks to projects—large areas of both naturally occurring and restored wetlands can be destroyed in just a few days if hit by a powerful storm.

A well-developed implementation strategy that has mechanisms to address these types of uncertainties, when they arise, is more likely to be successful.’ (GAO, 2007)

4 Guidance for GREEN Water Defense

4.1 The GREEN Water Defense cascade

Now that we have seen how several programs used elements of GREEN Water Defense it is time to draw lessons on these Best Practices. First we start with an overview of approaches and measures in a structured way. We do this by using the Source-Pathway-Receptor approach, which to a large extent also follows scale levels (Section 2.2.5). We thus get a cascade of risk reduction measures: starting from rainfall in the upper catchment all the way down to the individual or household that is impacted (Figure 4.1).

The cascade can be used – in a generic way – as guidance for a priority setting: obviously it is best to remove the source of the flood altogether. Hence, for flash and river floods the reduction in rainfall-runoff would prevent high discharges downstream and subsequent high flood risks. Of course this is not possible in the case of coastal storm surges or tsunamis: a depression or earthquake cannot be prevented. In that case the reduction of the hydraulic load (in terms of wave energy and water height) is the starting point. Making Room for the River is a good example of lowering the high water levels, thereby reducing the chance of levee overtopping or a dike breach.

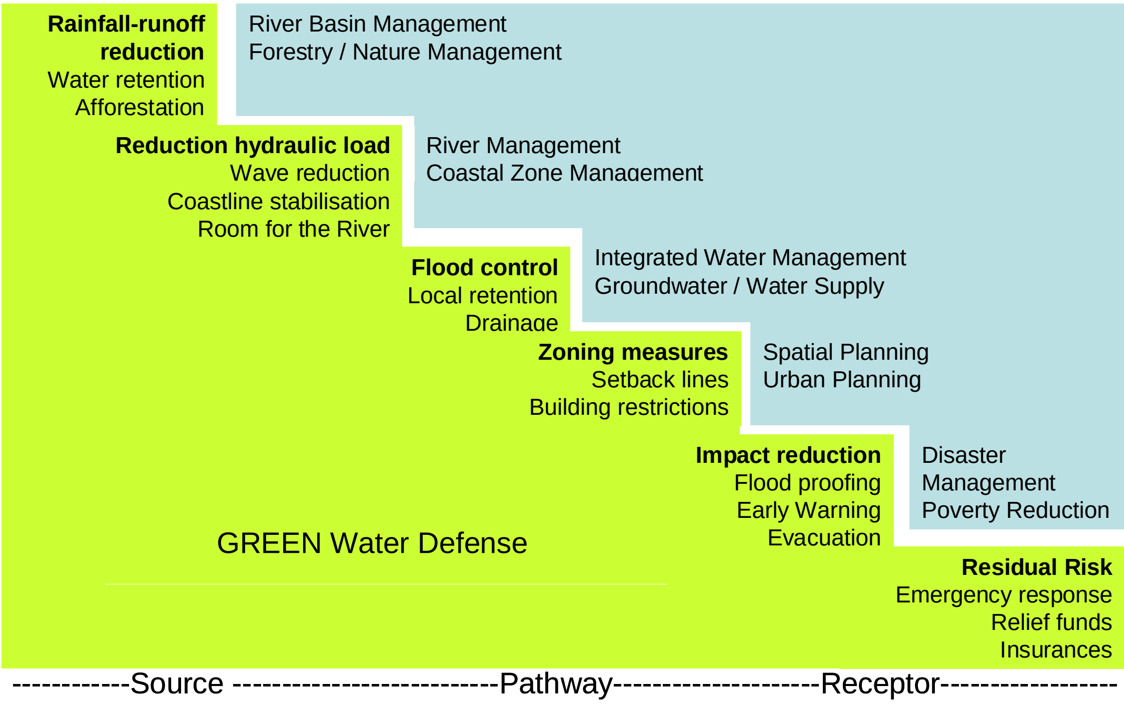


Figure 4.1 A cascade of GREEN Water Defense measures

More or less traditional flood control measures, such as dikes, and drainage systems are found at the next step. Zoning measures help reducing the potential impact should a flood nevertheless occur. Further down the steps we find more impact reduction measures, such as flood proofing of houses, early warning and evacuation. Characteristically, these measures prevent damage or casualties even when flooding cannot be avoided. And finally there is the residual risk when all previous measures were not sufficient to prevent damages. When the damages are done all that remains is helping people out and to assist them with relief and recovery.

The cascade also visualizes that for each step in the GREEN Water Defense strategy there is always a corresponding policy and management field and sometimes more than one that is relevant (in blue color). Since flood risk management cannot be implemented independently, it is crucial to make linkages and agreements with these other policy domains.

4.2 Guidelines and steps

GREEN Water Defense is a broad term that encompasses many different approaches, many of which already have their own rules and guidelines. The following concepts and practices are good examples that can be used to implement GREEN Water Defense:
- Eco Dynamic Design (EDD)
- Sustainable Urban Drainage Systems (SUDS)
- Adaptive delta management
- Mangrove restoration

Eco Dynamic Design (EDD)

With Eco Dynamic Design the dynamics of the natural system is used in the design of water related infrastructure, such as flood control systems. By making use of natural resources, ecosystem services and technologies additional value is created that serves multiple functions, is more sustainable and often with lower societal costs. As part of the Building with Nature Program in the Netherlands a stepwise process has been designed for the implementation of EDD. These steps are:

Step 1: Understand the system

Acquire a better understanding of the system in which an infrastructural development is planned. In depth knowledge of the biotic and a-biotic system, the socio-economic system, as well as the governance context, is crucial to identify potential win-win solutions. Multidisciplinary information about the system and its historical evolution can be derived from various sources: from science and from local society.

Step 2: Identify realistic alternatives

Identify realistic alternatives that provide true win-win solutions delivering services beyond mitigation and compensation, by bringing together academic experts, field practitioners, community members, business owners, decision makers and other stakeholders to formulate these alternatives. Involve relevant other disciplines in the design process as soon as possible. Answer the following questions:
- Utilizing services provided by the ecosystem: How can better use be made of locally active (natural) resources and dynamics: tide, waves, gradients, sediment availability, flora, fauna, economy, cultural values, etc? Can system dynamics be used as a positive rather than a negative aspect?
- How can we strengthen the functioning of the receiving system - ecology, recreation, landscape?
- How can a project deliver benefits to the overall system in which it resides or how can the project at least be more ecologically friendly and increase nature value?
- Can available resources (e.g. sediments) be utilized to reduce construction and maintenance costs (more flexible solutions), reducing the use of energy or materials and lower the carbon footprint?

Step 3: Valuate the qualities of alternatives, pre-select an integral solution

Assess inherent qualities of alternatives and combine them into one optimal integral solution. Valuate the green alternatives against a traditional water defense or infrastructure design; perform a cost benefit analysis, take into consideration construction costs and maintenance costs as well as social, economical and nature benefits. Actively involve the community in this; evaluate and communicate benefits in terms of supporting livelihoods, and make communities co responsible for the success of a solution.

Step 4: Embed the solution in a project approach
Embed the integral solution in a project context considering practical restrictions and governance context, so that it may actually be constructed. To enable implementation of solutions, networks and connections need to be established between all organizations involved; and stakeholders need to be effectively involved in the design and realization process. Knowledge sharing is essential; this requires an open atmosphere of trust.

Step 5: Translate the solution into a technical design
- Handle the practical bottlenecks to get the solution included in the next phase of the project realization: inclusion in request for proposals, inclusion in the detailed design, inclusion in the project delivery, inclusion in the maintenance and monitoring scheme.
- Involve stakeholders in the search for additional funding if required, and identify as soon as possible potential bottlenecks in terms of permitting. It is essential to prepare risk analysis.
- Ecosystems are dynamic by definition. Make sure the project takes this aspect into consideration (adaptive execution, adaptive management and maintenance).

Sustainable Urban Drainage Systems
Over the last decades there is a growing number of floods in urban areas. Climate change and rapid urbanization will exacerbate this trend. Flooding incidents in urbanized catchments areas can lead to great public concern and anxiety and the economic impacts are severe. New integrated approaches are being developed and implemented. One of such approaches is the sustainable urban drainage system (SUDS).

SUDS approaches are operational in various countries and in the UK and Germany design procedures are defined within a number of standards (e.g. in Germany in DWA-A138 and in the UK in CIRIA, 2008)(Zevenbergen *et al*., 2010).

Adaptive Delta Management for flood risk and climate change
Making deltas climate-proof requires new adaptation strategies which are timely, technically sound, economically feasible and socially acceptable. However, both climate change and socio-economic developments come with large uncertainties. In order to develop adaptation strategies for climate proof deltas, fundamental questions need to be answered, such as:
- What are the requirements which the key economic sectors (e.g. agriculture, transport, energy, tourism, industry) and nature put on water management and spatial planning in deltas?
- Under what circumstances do current strategies for water management and spatial planning fail to meet those requirements (when, where, how often)?
- What are the adaptation options that will allow us to keep on living and working in the deltas?
- How much time is available to implement these adaptation options?

To answer such questions the formulation of adaptation paths for water management can be used. One of the key elements in such method is the so-called adaptation tipping point. An adaptation tipping point is a level where natural (physical) boundary conditions exceed technical, spatial or societal acceptable limits. An adaptation tipping point identifies the point where a policy on water management or spatial planning needs to be revised and where a new strategy needs to be implemented. For instance, an agricultural cropping strategy can become impossible when a certain salinity level of the surface water is exceeded, which would trigger the need for an alternative cropping pattern (e.g. more salt tolerant crops or a shift to aquaculture).

GREEN Water Defense measures are often flexible and therefore capable of postponing a tipping point. For instance, sand nourishment for coastline maintenance can be easily adapted to rising sea levels: should the sea level rise accelerate, simply more sand is nourished. Also mangroves are a good example of a robust measure for coastal management: they can easily adapt to changing environmental conditions due to climate change.

As a general rule, the adaptation to current urgent problems in water management is the best way to become climate proof, as long as measures are designed with both short and long term impacts accounted for.

Mangrove restoration
Mangrove restoration is an activity that fits very well in concepts such as EDD and Building with Nature. Because of its potential in tropical and subtropical coastal environments, it is highly illustrative and useful to learn from experiences over the past decades.

Figure 4.2 Mangrove restoration project in Banda Aceh, Indonesia after the Asian tsunami

In Bangladesh 120,000 ha of mangroves have been planted since 1966 (Saenger & Siddiqi, 1993, cited in Field, 1998). Nowhere else have mangroves been planted on such a large scale. In this case the mangroves were planted on newly accreted land. According to Field, the planting of mangroves has been highly successful in protecting and stabilizing coastal areas and in providing substantial timber production (Field 1998). However, Lewis (2005) states that ‘in spite of the success in Bangladesh, most attempts to restore mangroves often fail completely, or fail to achieve the state goals’ (Lewis, 2005, page 404). Failures in mangrove restoration have been reported in literature (Primavera & Esteban 2008; Suwannodom et al. 1998; Erftemeijer & Lewis III 1999; Seto & Fragkias 2007; Samson & Rollon 2008). The single most important factor in designing a successful mangrove restoration project, according to Lewis (2005) is determining the normal hydrology (depth, duration and frequency, and of tidal flooding) of existing natural mangrove plant communities (as a reference site) in the area in which one wish to do restoration.

Five critical steps are necessary to achieve successful mangrove restoration (Brown & Lewis, 2006):

1. Understand the autecology (individual species ecology) of the mangrove species at the site; in particular the patterns of reproduction, propagule distribution, and successful seedling establishment.
2. Understand the normal hydrologic patterns that control the distribution and successful establishment and growth of targeted mangrove species.
3. Assess modifications of the original mangrove environment that currently prevent natural secondary succession (recovery after damage).
4. Design the restoration program to restore appropriate hydrology and, if possible, utilize natural volunteer mangrove propagule recruitment for plant establishment.
5. Only utilize actual planting of propagules, collected seedlings, or cultivated seedlings after determining (through steps 1-4) that natural recruitment will not provide the quantity of successfully established seedlings, rate of stabilization, or rate of growth of saplings established as objectives for the restoration project.

4.3 Lessons learned, bottlenecks and solutions

Based on the Best Practices described in Chapter 3, a number of lessons can be drawn that make the implementation of GREEN Water Defense successful. The picture below shows these steps by starting from the spatial layer approach and ending with a mosaic of concrete applications, where the three layers are optimally integrated. It shows that for a shared vision the people who normally are bounded in their own layer need to share their information, knowledge and ideas. From this shared vision, which is often still a bit vague and idealistic, very concrete obtainable objectives need to be drawn. Once these have been decided upon, concrete designs and implementation can start, using elements from all three layers according to the local needs and circumstances (Figure 4.3).

Raise awareness (sense of urgency)

A well known problem with flood risk management is that immediately after a flood disaster people are well aware of the problems, but that this often wanes rather quickly when life returns to normalcy. Especially when floods do not occur frequently the problem disappears fast from the political agenda. One way of tackling this problem is to mainstream flood risk management with the more broader concept of integrated water management. Because IWRM deals with day-to-day issues such as providing sufficient freshwater to the users and building and maintaining sewerage systems, the trick is to add flood risk considerations to the design and implementation of these water management measures.

Another solution is to formulate a specific flood risk policy on a national scale and to work this policy out in specific regulations, safety standards and legal requirements. The implementation of the policy should be thus formalized, monitored and evaluated.

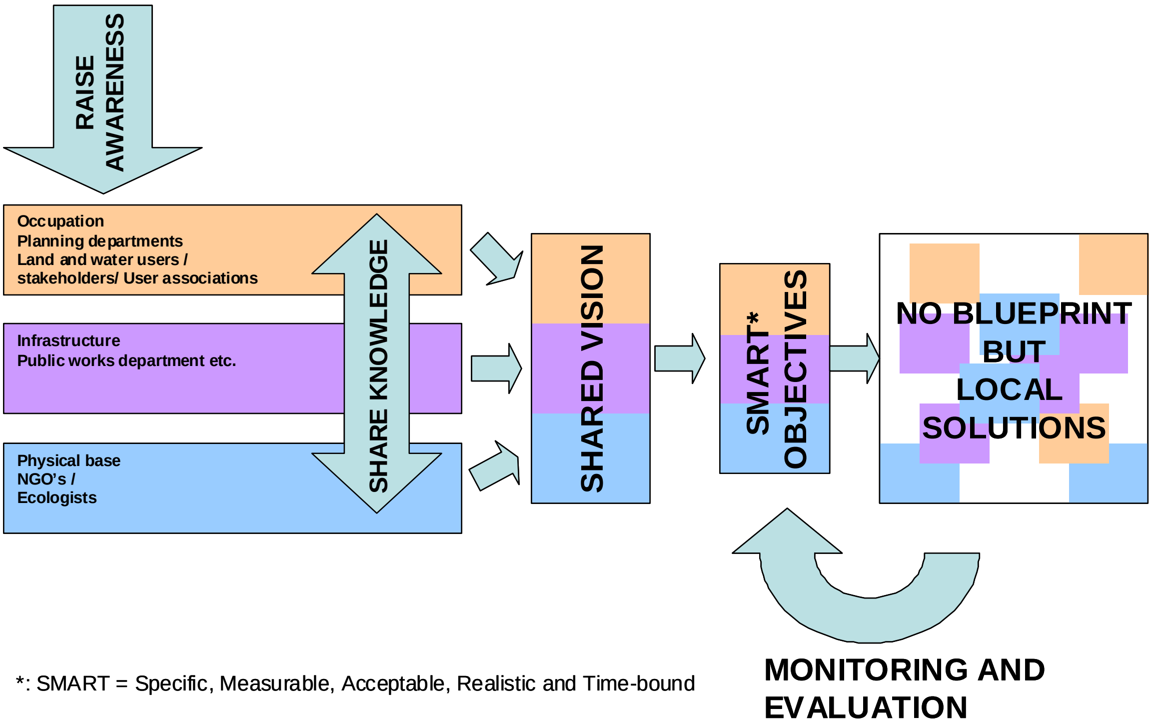


Figure 4.3 Major steps in GREEN Water Defense solutions

Share knowledge

Making use of innovative solutions, ecosystem services and other non-traditional technologies can make people wary of the effectiveness. A major pitfall in participative planning in water management is lack of trust. This can easily happen when people are not used to new ideas, even when scientific evidence is provided. Ways to overcome this problem include a variety of tools (e.g. the Planning Kit of Room for the River), starting pilot projects to show effectiveness and working closely together with local citizens who have often more local knowledge than the engineer who comes from elsewhere.

Shared vision

A successful program should have a shared vision to start with. This vision should integrate water and sustainable development goals through using water as an opportunity rather than a threat or inconvenience. Ideally all stakeholders should embrace the vision, which could start with a design workshop, a contest or any other type of meeting. Brainstorming and open mindedness are crucial in this first phase.

SMART objectives

A programme can only be successful if the overall objectives are explicit and SMART: Specific, Measureable, Acceptable, Realistic and Time-bound. The objectives should therefore be formulated up to the level of concreteness that people exactly know what their task is. Good examples are the quantified objectives of Room for the River ('safe discharge of 16,000 m^3/s') and of the Waterplan 2 ('creating 600,000 m^3 of water storage in the city'). These targets set the boundary condition in which individual projects can find a GREEN Water Defense solution, based on the unique environment in a polder, district or other locality.

No Blueprint but local solutions

The concept of GREEN Water Defense relies heavily on what can be called the ‘Genius of the Place’: general ideas such as building with nature and green infrastructure need to be worked out in specific circumstances, making use of the opportunities and possibilities the social and natural environment provides. It is therefore not wise to use a rigid form that dictates which solutions should be used.

Sufficient budget and clear financial arrangements

Another problem which is related to the absence of a detailed blueprint when starting an innovative GREEN Water Defense programme (since designs are very much dependent on local situations) is estimating the financial budget that is required. Flexibility and adaptation in time is necessary, together with a clear schedule of who is paying what. Typical of GREEN Water Defense projects is that different government agencies have to work together, not only at national (ministerial) level, but also between the national, regional and local (municipal) levels. This often initially results in vagueness and ambiguity, or even distrust, regarding financial arrangements. A principle such as ‘who benefits should pay’ may help to clear things up, but requires that before decisions are made all parties agree on what the benefits are. Also the use of a unit price for certain measures (e.g. in m^3 extra water storage or in cm water level reduction) can greatly help in drafting a realistic and transparent financial budget plan.

Monitoring and evaluation

Because of the relative recent implementation of best practices there is a general shortage of empirical knowledge. It is therefore very important for the success to prepare and implement a monitoring and evaluation program as part of the project. We have seen in the sand nourishment example that frequent monitoring of the coastline is a precondition for a successful implementation. And in the Rotterdam WaterPlan a monitoring program has started to monitor the effectiveness of the green roofs in the city.

4.4 Effectiveness, cost efficiency and other benefits for society

One of the most limiting resources on this planet is space. This is most conspicuous in urban environments, but also in deltas, which can be considered as the most densely populated areas in the world. Therefore, it is not surprising that many of the best practice examples of GREEN Water Defense try to combine various functions on the same area. For instance, creating storm water storage in parking garages or combining room for the river with nature and recreation facilities. Clearly, alternative solutions for flood protection, using natural ecosystems such as mangroves or wetlands often take up more space than a dike, in order to be equally effective. In economic terms this can be offset by taking into account the multi-functionality of the solution, leading to added benefits for society. The difficulty here is that such benefits are not always translated into monetary terms. Economic valuation of such (ecosystem) services is however possible and methods are available (McNeely, 1988, Barbier, 1994; Turner et al., 2000).

Maintaining and enhancing delta ecosystems could greatly contribute to the economy of a country. For instance, estuaries have the highest economic value of 23,000 US$ per hectare per year of all world ecosystems (Costanza et al., 1997). And in a recent study it has been calculated that coastal wetlands in the US are providing USD 23.2 billion per year in storm protection services (Constanza et al., 2008).

From the best practices described in Chapter 3 we learn that alternative, green, solutions for flood risk management can be as effective as the traditional ones. Especially in a country such as the Netherlands, which has one of the highest flood protection standards in the world, the government would not allow for any solution that does not meet these standards. We also saw that such alternatives can be cheaper, even if the often higher maintenance efforts are taken into account. And sometimes they require more investments, but that this has not excluded their use. This is because the added, societal benefits were considered sufficiently high to offset the difference.

4.5 Governance issues for GREEN Water Defense

Governance plays a most important role for successful GREEN Water Defense. Issues here are quite similar to those that appear in the practice of integrated water management and participatory planning. Therefore, reference can be made to the literature on this aspect (Rogers & Hall, 2003).

Of special relevance, which clearly stands out in the example of Room for the River is the importance of true local participation – not only consultation – in designing projects. This requires: trust, explicit tasks, freedom for local solutions, a good financial framework and sufficient technical support.

In general, five different phases can be discerned in this process:

- At first most inhabitants are still unaware of the program and many may not see the urgency of the problem. Some even will reject the idea that their safety is in danger and protest against the interventions.
- In the second phase – in which all the stakeholders have to be made aware of the problem and have to accept the necessity for change – it is important for the government to gain sufficient trust from the inhabitants. Without any trust, there will be no fruitful collaboration.
- The third phase is a kind of brainstorm phase. All the stakeholders try to find a solution that contributes to the general target or objective (e.g. reducing the maximum water level). Of course with different stakeholders come different desires.
- Eventually a compromise in which all stakeholders feel comfortable is necessary. This is the fourth phase in the process. This phase creates a win-win situation included with all the interests of the different stakeholders.
- After finding this solution, there is one more phase to go through. The last phase is all about which stakeholders pays his/her share of the pie. In other words, who is responsible for the costs?

5 Applications in East Asia

East Asia has extensive coastlines and many densely populated and enormously productive deltas such as Mekong Delta, Jakarta, Manila and Pearl River Delta, which are highly susceptible to river flooding, storm surge and sea level rise. Much progress has been achieved in the past decades in East Asia towards improving the management of water-related risks. However, a great deal more needs to be done to bridge the gaps in sustainable water resource development and management to ensure lower impacts and damages from extreme weather hazards. Also the growing populations, a deteriorating environment and a changing climate call for new strategies and approaches.

It is encouraging to note that some of the GREEN Water Defense concepts are already being used in this region. Some of them still nascent (see Box 8), but others, such as mangrove rehabilitation, already with quite a long standing experience. In this chapter, we will describe two quite different case studies: the Mekong Delta in Vietnam and Jakarta City in Indonesia. The former being still a largely rural area, while the latter is an example of a very highly urbanized metropolitan area.

Box 8: Bali Beach Conservation Project.
Sanur and Nusa Dua Beach are two of the most famous tourist destinations in Bali. Severe beach erosion caused the loss of their white sandy beaches. Started back in 1997, the Government of Indonesia together with Japan entered a bilateral cooperation to rehabilitate these beaches. The project design used sand nourishment combined with engineering constructions, walkways and public facilities in order to conserve the natural beach ecosystem, beach utilization and local social and cultural values. By the end of the project along 14 km of shoreline the wide white sandy beaches have been restored. Monitoring results showed that the number of visitors at Sanur and Nusa Dua Beach increased 2.5 times and total hotel guests increased up to 1.8 times compared to the situation before the project (Wijaya, 2009).

5.1 Practical application of GWD approach in proposed Flood Risk Management for Mekong Delta, Vietnam

Floods play an important role in the life of people living in the Mekong Delta. Each year floodwaters inundate 1.9 million ha and affect the lives of more than 2 million people. Normally, these floods are essential to food security and biodiversity and people have a tradition in living with the floods. However, extreme mainstream flood events can be destructive and cause enormous damages.

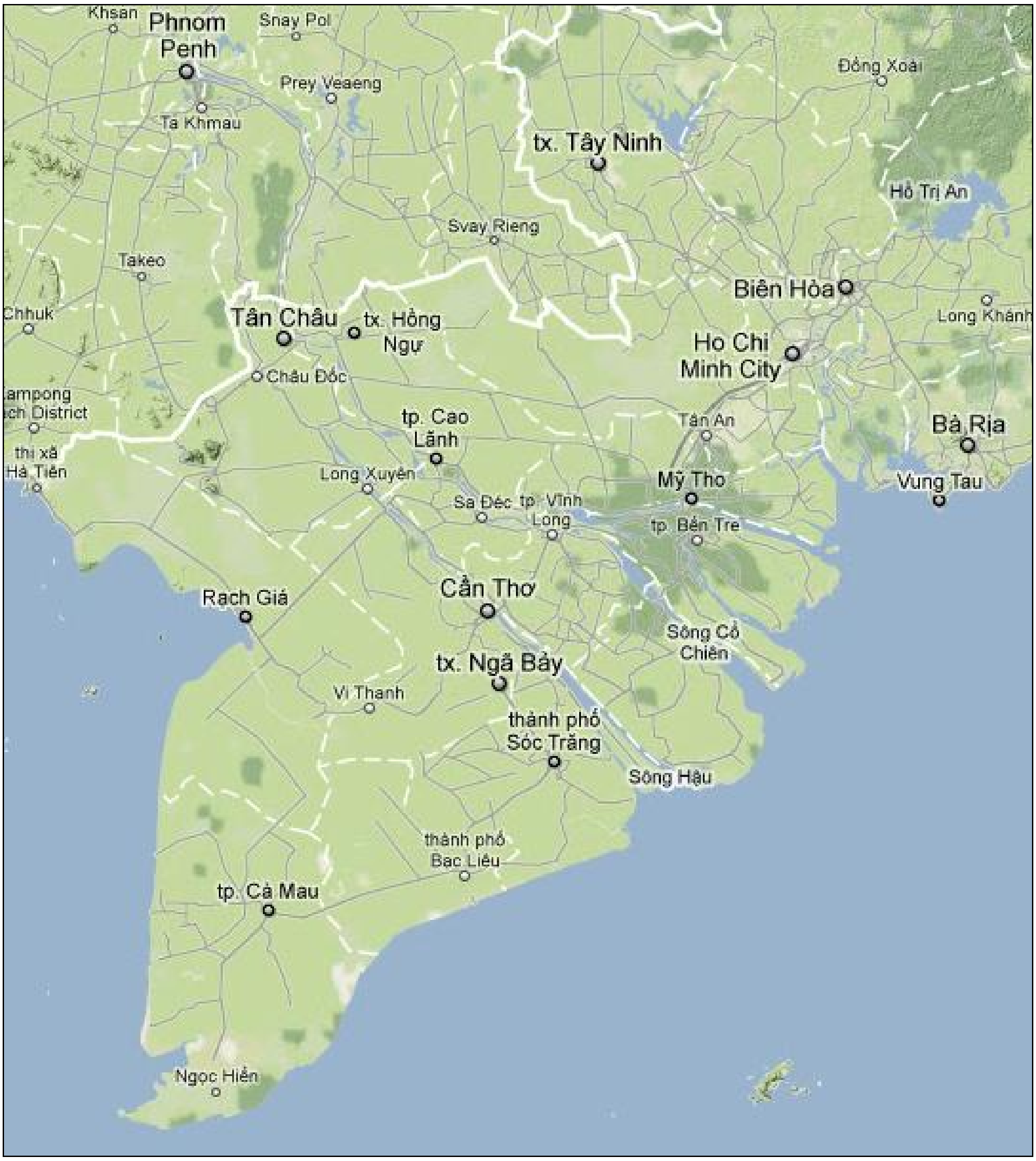


Figure 5.1 Map of the Mekong Delta (Google Maps)

Sea level rise is expected to result in large areas of permanent and more frequently inundated coastal plains. Furthermore, a rise in sea level will increase salinity levels in the Delta rivers and its water network. Agricultural production will be affected through more frequent and longer periods of flooding as well as because of salinity intrusion.

The projection of population size for the year 2050 is from the present 17 million up to around 30 million. This will fuel the urbanization trend, taking more land out of agricultural production. At the same time more people need to be provided with food and fresh water. Ongoing industrialization will also take up more space and increase the demand for water as well as the production of wastewater. Both trends will increase the need for proper spatial planning, efficient water supply, investments in water treatment and stringent enforcement of environmental legislation.

The water management system currently implemented still uses the 1994 Mekong Delta Master Plan as a reference. An update is presently under discussion in order to include environmental and socioeconomic developments as well as recent innovations and modern approaches.

The integrated concept of GWD can be very useful in combination with the traditional (structural) measures for flood control. And in fact, several good practices of the concept have already been applied in the Mekong Delta. Adaptation through Living with Floods has been practices for centuries already. Furthermore, several GWD concepts can be found in Government decisions and design guidelines for infrastructure and land use.

Opportunities for GWD can be grouped in the following measures according to the GWD cascade:

a. ***Rainfall-runoff reduction***: most part of the Mekong River Basin lies in upstream countries, therefore continued international cooperation and coordination through the Mekong River Secretariat is of high importance.

b. ***Reduction hydraulic load***: canals and rivers need to be annually dredged in order to keep their current conveyance at design level. The deposition of dredged materials on the land could at least locally compensate for this loss and make the delta less vulnerable to sea level rise.

c. ***Flood control***: early flood control (‘August system’) as practiced can be optimized. There is significant scope for protection of sea dikes by mangroves, especially on 28,000 ha of newly accreted land in the southern provinces. The potential of using Vetiver grass (*Vetiveria zizanioides*) to protect rural infrastructure against erosion is quite high. During recent decades Vetiver grass has been used to stabilize highways, railroad dikes and embankments. Certain areas require improvements in drainage capacity to reduce flood duration.

d. ***Zoning measures:*** increased urbanization and industrialization will require different flood safety standards across the delta.

e. ***Impact reduction:*** Integrated rice-shrimp aquaculture is an adaptation to salinity intrusion. Melaleuca forests can improve deteriorated (acid sulphate) soils.

f. ***Residual risk***: continued efforts in poverty alleviation and improvements in housing, water supply and sanitation will reduce the vulnerability of the communities and households.

Public awareness and participation of the community should be a basic principle in the flood mitigation program.

5.2 Practical application of GWD approach in proposed Flood Risk Management for Jakarta, Indonesia

Jakarta is a city with more than 9.6 million inhabitants (2010) and is prone to flooding due to the combined effects of high river discharges of its rivers and close proximity to the sea. Large parts of the city are below sea level (about 60% of the area) and the soil is subsiding at a high rate (about 10 cm per year on average), due to compaction and water abstraction. Inundations from heavy rainfall are frequent and cause severe disruptions of city life due to traffic jams. Every now and then high river flows coincide with spring tide, causing more severe flooding, the latest of which was experienced in 2007, which cost 57 lives, displaced more than 400,000 people and caused an estimated damage of USD 695 million. The combined effect of sea level rise with soil subsidence will in the future increase the frequency of such extreme floods if no additional measures are taken.

Figure 5.2 Map of Jakarta (Google Maps)

The Indonesian government is well aware of this problem, of which the causes are complex and solutions should be found in an integrated manner: combining flood risk management with spatial planning, water supply, environmental quality, waste management and traffic planning. Besides the need to take a whole range of urgent, no-regret measures – such as reducing groundwater abstraction, cleaning up drains and rivers, larger pumps, raising embankments and constructing seawalls, watershed management and creating more retention areas – it is clear that in the longer term these actions do not suffice. The main reasons are that i) the process of subsidence cannot be stopped immediately; ii) sea level is rising; and iii) space continues to be one of the most critical and limiting factors in Jakarta. This has recently opened up the discussion how to combine land reclamation with a flood defense strategy: various options are now explored that could protect Jakarta from coastal flooding and at the same time provide sufficient storage capacity for storm water runoff.

The basic notions of GWD can already be found in many plans and measures for flood risk management in Jakarta. Opportunities for GWD are in line with the guidelines of the spatial plan DKI Jakarta 2011-2030 and can be grouped in the following measures according to the GWD cascade:

a. ***Rainfall-runoff reduction***: upstream water should be retained by vegetation in the high lands of the south (Puncak). New development should not increase peak discharge. Use innovative methods, such as on-site stormwater detention (OSD) and biopori.
b. ***Reduction hydraulic load***: more room for water and vegetation, provide more green space and blue space. Use innovative methods such as percolation wells. Reduce soil subsidence by discouraging the use of groundwater.
c. ***Flood control***: implementation of polder system in North Jakarta. Enlarging drainage capacity by constructing new infrastructure and improvements in existing drainage systems, better maintenance (waste management). Land reclamation in combination with coastal defense, using ecodynamic design principles.
d. ***Zoning measures:*** enforcement of spatial planning regulations, esp. along waterways, natural rivers and reservoirs.
e. ***Impact reduction:*** early warning, reservoir safety inspections and building codes for flood proofing,. Capacity building and strengthening of BPBD (citywide agency for disaster risk management); implementation of community disaster management plans.
f. ***Residual risk***: continued efforts for provision of housing for the poor and middle-income classes and poverty alleviation programs will reduce the vulnerability of the communities and households.

Public awareness and participation of the community should be a basic principle in the flood mitigation program.

6 Conclusions and recommendations

6.1 Conclusions

The countries in East and Southeast Asia face huge flood problems. The combined impact of increasing urbanization, population growth, socio-economic development and climate change in coastal regions that are already prone to multiple natural hazards is vast. This will lead to an increase in public infrastructure investments. The challenge is to ensure that these investments will be sustainable, climate proof and cost effective. GREEN Water Defense is an approach through which this challenge can be turned into success, if applied properly. The reason being that GREEN Water Defense does not focus exclusively on one type of solution, but addresses flood protection in an more holistic and natural way: instead of focusing only on traditional infrastructural solutions, it emphasizes the interactions between those who occupy the deltas, their infrastructure and the natural delta conditions. Additionally, it integrates flood risk management with other objectives, such as water quality and drought management.

The link between the urgent need for better flood risk management and climate change which will manifest itself on the longer-term, if not already happening, is that adaptation to current urgent problems is the best way to become climate proof, as long as measures are designed with both short term and long term impacts accounted for. Ageing infrastructure and need for urban (re-)development requires investments on the short term. This should be seen as an opportunity to introduce the GREEN Water Defense concept.

The concept is by no means purely theoretical or academic. Indeed, it has manifested itself already in a wide range of examples and projects. Some of the best practices described in this report have started already in the early 90s of the past century. And from these practices we have drawn lessons that can be used for implementation in other countries and situations. Before doing that, we have to remind that one of the principles of GREEN Water Defense is to make use of the local natural and socioeconomic conditions and that therefore solutions in one country do not necessarily lead to success in other countries if applied unconditionally.

In short, we can state that GREEN Water Defense:

b. is a paradigm shift (soft versus traditional hard engineering), requires flexibility in thought
c. is more adaptive, but has also more uncertainty in end result (non-linearity in ecosystem services)
d. can be cheaper than traditional solutions, since it can save substantially in investment costs, even taking higher maintenance costs into account
e. serves multiple purposes and is therefore often more cost-efficient
f. is no solution for everything: soft when possible, hard when required
g. makes use of the genius of the place: best practices are not easily transplanted, requires tailor made approach
h. is rooted in tradition, but still in its infancy
i. needs pilot projects to learn from and build up a body of knowledge

Setting up a successful GREEN Water Defense project requires good cooperation between government agencies, local inhabitants / stakeholders and knowledge providers. This requires good preparations in terms of stakeholder participation, good governance and sound project management. In addition to these preparations, we identified 6 key issues indispensable for GREEN Water Defense:

1. Raise awareness for integrated flood risk management among all relevant actors and stakeholders: it is not only an issue for engineers of public works departments.
2. Share knowledge between all relevant actors and stakeholders. Combine scientific knowledge with local environmental knowledge. Use easily accessible methods and models and ensure that all have trust in this knowledge.
3. Develop a shared vision that integrates flood risk with economic development and ecological sustainability.
4. Translate the vision into concrete, accountable targets (SMART objectives) for flood risk management. Make upfront financial arrangements, using the ‘who benefits should pay’ principle and make these benefits as explicit as possible, including ecosystem services.
5. Do not prescribe a blueprint for local solutions, but use the genius of the place.
6. Prepare a monitoring program and build in evaluation procedures.

6.2 Recommendations

6.2.1 For the World Bank and governments

The concept of GREEN Water Defense is a promising vehicle for promoting the Green Growth principle embraced by the World Bank. As shown in this report it provides guidance to mainstream flood risk management in other major policy domains, such as river basin planning, urban planning and poverty alleviation programs. The GREEN Water Defense Cascade (Figure 4.1) can be used to identify the strong relations and dependencies between GREEN Water Defense and these other policy and management domains. This should result in a dialogue between people working in these fields. The World Bank and national governments are recommended to actively promote this dialogue.

Furthermore, it is recommended to promote a dialogue between actors working often too separated in each of the three spatial layers: planning departments, land and water users in the occupation layer, public works and other infrastructure departments in the network layer and environmental departments, ecologists and NGO’s active in the base layer. People need to be made aware that they are dependent from each other for developing a more sustainable and integrated flood risk management. Based on this awareness a free flow of information, data and knowledge needs to be established, resulting in a shared knowledge of the problems and the opportunities for a truly integrated solution. The World Bank and national governments are recommended to actively promote this knowledge sharing.

6.2.2 For the scientists, practitioners and managers

GREEN Water Defense encompasses a huge range of interventions and measures, the effectiveness of which highly depends on the geographic location, environmental characteristics and social context. It is therefore advised that a knowledge base and communities of practice are built, both internationally and locally, to promote a better flow of knowledge. Guiding principles should be further developed, education and training promoted and design workshops organised. Needless to say that these activities should be set up in an interdisciplinary way, including participation by engineers, ecologists, sociologists and so forth. Pilot projects can act as experiment sites to gain further knowledge and to learn from the field.

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