UNEMBANKED AREAS

A risk assessment approach | Michiel Wolthuis

Master Thesis

Unembanked areas

A risk assessment Approach

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Preface

Risk has a direct impact upon our life. It is not just only an interesting academic subject, people die, suffer or can experience serious losses because they have misjudged or ignored risks. It is also a very multidisciplinary science dealing with statistics, engineering, social, economic and legal sciences. This interdisciplinary character made me choosing this subject. Balancing benefits and costs of investments for flood management measures is pre-eminently for unembanked areas an interesting subject as the costs of measures have to be paid by the initiators of the project. The policy, compensation instruments, responsibilities and liability of damage are not so straight-forward for unembanked areas as expected which gave this research an extra dimension.

This thesis is the result of my graduation research for the Master Watermanagement at the faculty of Civil Engineering and Geosciences of Delft University of Technology. The research has been done at the unit land and water of DHV; a consultancy and engineering firm.

I would like to express my appreciation and thankfulness to my graduation committee Prof. dr. ir. Nick van de Giesen, Prof. dr. ing. Sybe Schaap, Dr. ir. Olivier Hoes and Ir. Steven de Boer for their guidance and support during my research.

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Michiel Wolthuis,

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SUMMARY

Areas outside the primary flood defenses, here called unembanked areas have a special status in the Dutch water safety policy. Whereas, primary flood defenses have to fulfill to legal standards and a functional manager is appointed for construction, maintenance and management of water defenses. For unembanked areas this situation is different; some provinces have water safety policy and adopted flood probability standards and there is no functional manager who controls these areas. According to the national water plan residents and users are responsible for taking consequence reducing measures of floods. For the development of new areas decisions have to be made about the desired level of safety and how this is achieved. This leads to the issue of optimal adaptation strategies. What is the best level of safety so that unnecessary high risk levels and overinvestment in safety related infrastructure can be circumvented? This study presents a framework for municipalities and property developers how to deal with flood risk in unembanked areas.

952 developments are planned in unembanked areas of which 183 comprise urban dwelling projects. This thesis especially focuses on these urban dwelling projects where flood events can be regarded as a local, regional and direct tangible risk. The following research question is answered:

How can we deal with the uncertainties of flood risk in investment decisions in the development of unembanked areas?

1. What is the current policy of building in unembanked areas and what are the responsibilities of the government?
2. Which strategies can be formulated to create the desired level of safety and how should they be compared?
3. How can a multi-layer safety approach contribute to the safety of the project area?
4. How do area specific characteristics influence the cost effectiveness of the measure?
5. How to deal with the residual risk?

The national government advocates a multi-layer safety approach; this approach assumes three layers in flood control:

1. Prevention: characterized by structural measures which influence the boundary conditions of the project area. Surface level heightening and the construction of an embankment are discussed.
2. Spatial planning, characterized by structural measures which influence the exposure and vulnerability. Wet proofing, dry proofing and an elevated configuration are discussed.
3. Disaster control, characterized by non-structural measures which influence the exposure and vulnerability. Organizational aspects and financial compensation are discussed.

It was founded that the urban dwelling density of a project area determines the profitability between individual consequence reducing measures (layer 2 of the MLS approach) and collective probability reducing measures (layer 1). The profitability of collective measures grows linear with the dwelling density and transcends individual measures at 24 dwellings/hectare. An elevated configuration is preferred above wet and dry proofing. Considering the construction of an embankment it was founded that the profitability grows according to a power function and transcends surface level heightening at 35 ha. All proposed urban dwelling plans in unembanked areas are analyzed on these criteria and it was founded that for 23% of the plans individual measures are preferred above

collective measures. 62% of these plans are located in areas where the province has no flood probability standards and therefore consequence reducing measures have a good chance. The other 38% of the plans are located in provinces with flood profitability standards and the profitability of extra consequence reducing measures is dependent on the level of this standard. For the remaining 77% of the areas a probability reducing approach is preferred; of which for 6% the construction of an embankment is preferred and for the other a surface level heightening strategy is preferred.

This framework is used for an urban redevelopment project of 180 dwellings called Heijplaat where a decision about the desired water safety level has to be taken. Due to the urban dwelling density of 33,5 dwellings/ha, surface level heightening is the most cost-efficient strategy. According to the principle of Van Dantzig it advised to raise the surface level with 0,15 m.

It is demonstrated that an economical efficient investment in flood management results in a residual risk. The acceptance of this risk is a social and political discussion. At this moment flood damage originating from fresh water can be compensated by the central government according the Calamities and Compensation act. The physical operation of this law is an ex-post political decision which will only take place in the case the flood results in a considerable disruption of public safety and requires a coordinated effort of organization and civil services. Private flood insurance is unavailable in the Netherlands, mainly due to the specific characteristics of the Netherlands; large flood prone areas but high safety levels compared to other countries leading to high impact, low probability events which make insurability difficult. All criteria of insurability (grouped in actuarial, market-determined and societal) are analyzed for a flood damage insurance for unembanked areas. Due to the physical aspects and policy of unembanked areas the formulated criteria of insurability score better for unembanked areas. The actual realization will depend on the market determined criteria.

TABLE OF CONTENTS

ABBREVIATIONS

Abbreviation	English	Dutch
B/C	Benefit Cost ratio	Kosten-batenverhouding
CBA	Cost-Benefit Analysis	Kosten-baten analyse
DEM	Digital Elevation Model	Digitaal hoogtemodel
GBKN	Large-Scale Base Map of the Netherlands	Grootschalige BasisKaart Nederland
GDP	Gross Domestic Product	Bruto Binnenlands Product (BBP)
GFA	Gross Floor Area	Bruto Vloer Oppervlak (BVO)
GIS	Geographic Information System	Geographisch Informatie Systeem
LTO	Dutch Federation of Agriculture and Horticulture	Land- en Tuinbouw Organisatie Nederland
MAD	Mean Annual Damage	Verwachtingswaarde jaarlijkse schade
MLS	Multi-layer safety	Meerlaagsveiligheid
NAP	Amsterdam Ordnance Datum	Normaal Amsterdams Peil
NBW	National Administrative agreement Water	Nationaal Bestuursakkoord Water
Nirov	Netherlands Institute of Housing and Planning	Nederlands Instituut voor Ruimtelijke Ordening en Volkshuisvesting
NPV	Net Present Value	Netto Contante Waarde
PBL	Netherlands Environmental Assessment Agency	Planbureau voor de leefomgeving
PV	Present Value	Contante waarde
SN	Statistics Netherlands	Centraal Bureau voor de Statistiek
TOP10	Vector map file of the Netherlands	Landsdekkend vectorkaartbestand
VINEX	Policy briefing note about large outer city areas for massive new housing development	Vierde Nota Ruimtelijke Ordening Extra: uitgangspunten voor de bouw van nieuwe woningbouwlocaties
VON	market value of a dwelling including conveyance tax, VAT, notarial charges and estate agent charges	Vrij op Naam: gebruikelijke verkoopprijs van nieuwbouwwoning waarbij alle bijkomende kosten inbegrepen zitten in de prijs
WTS	Calamities and Compensation act	Wet tegemoetkoming schade bij rampen en zware ongevallen

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

1.1 PROBLEM DESCRIPTION

Areas outside the primary flood defenses, here called unembanked areas have a special status in the Dutch water safety policy. Whereas, primary flood defenses have to fulfill to legal standards, for unembanked areas this situation is different and according the Dutch National Waterplan (2009-2015) residents and users are responsible for taking consequence reducing measures of floods. For the development of new areas decisions have to be made about the desired level of safety and how this is achieved.

Flood damage is a consequence of an extreme natural disaster, but also a consequence of conscious handling of government, private parties and acting of the public (Kok, Mogelijkheden voor het verzekeren van waterrisico's, 2000). By choosing the building site, the height of a dike, the floor level, the construction method and by the perspective of action of the public the probability and consequences of a flood event can be influenced. Reducing the probability of a flood event has a long time history in the water safety policy of the Netherlands, but there is growing interest in consequence reducing measures (Most, Wit, Broekhans, & Roos, 2010). The central Dutch government follows this approach, as mentioned in the National Water Plan, according to the multi-layer safety principle. A multi-layer safety approach focuses on prevention (layer 1), spatial planning (layer 2) and disaster control (layer 3).

Flood risks imply big challenges for the public and private sector. A lot of different government layers and institutions deal with the layer of prevention. Safety norms are set and waterboards have to adapt their water defenses to these norms. Within the field of spatial planning, municipalities play a big role by the creation of zoning plans. But reduction in the costs of flooding can also be found in adjustment of designs of dwellings to reduce the costs associated with flooding. Here project developers, home owners, construction firms, municipalities and architects play a role. The water safety policy in unembanked areas gives opportunities to assess measures in terms of risk and compare different strategies based on cost and benefits.

This leads to the issue of optimal adaptation strategies. What is the best level of safety so that unnecessary high risk levels and overinvestment in safety related infrastructure can be circumvented? This study presents a framework for municipalities and property developers how to deal with flood risk in unembanked areas.

952 developments are planned in unembanked areas of which 183 comprise urban dwelling projects. This thesis especially focuses on these urban dwelling projects where flood events can be regarded as a local, regional and direct tangible risk.

1.2 STUDY OBJECTIVE

This study aims at constructing a framework for the development of unembanked areas; a risk-based approach to deal with flood risks in the design and development of unembanked areas. Risk is here quantified as the probability of an event occurring, that is viewed as undesirable, times the expected harm of the event. General criteria are formulated to deal with flood risks for unembanked areas and recommendations are formulated for the planned urban dwelling projects in unembanked areas. This is put into practice with a case study in the city harbor of Rotterdam, Heijplaat.

1.3 Research questions

How can we deal with the uncertainties of flood risk in investment decisions in the development of unembanked areas?

1. What is the current policy of building in unembanked areas and what are the responsibilities of the government?
2. Which strategies can be formulated to create the desired level of safety and how should they be compared?
3. How can a multi-layer safety approach contribute to the safety of the project area?
4. How do area specific characteristics influence the cost effectiveness of the measure?
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1.4 Report outline

Chapter 2 describes the water safety policy of the Netherlands and addresses the flood damage compensation instruments. Chapter 3 comprises the constructed framework; the different measures are described and the methodology is explained. Chapter 4 deals with cost optimal investment decisions for flood management measures in unembanked areas. Chapter 5 puts the framework into practice with a case study about Heijplaat, a redevelopment project in Rotterdam. The thesis ends with the conclusions and recommendations in Chapter 6. In this chapter the main research question is answered by answering the five sub questions.

2. Water safety

This chapter deals with the water safety policy of the Dutch government; trends, responsibilities and the approach are discussed. The actual water safety situation can be divided into different 'systems'. This thesis addresses the topic of coastal and fluvial floods of surface water. Due to responsibilities and the way water safety standards are derived, different systems can be distinguished. Chapter 2.2 deals with the primary flood defenses, 2.3 with the regional flood defenses, 2.4 with unembanked areas, 2.5 with the multi-layer safety approach which aims to control flood risks by different layers, 2.6 with the compensation of flood damage and 2.7 with the conclusions which will be used for the constructed framework.

2.1 Introduction

The Netherlands has a long time tradition in flood control and water management. As 59% of the land surface is vulnerable to flooding and 26% is situated below NAP[1] level the society protected themselves by big structural works, dike enforcements and reclaiming of land (PBL, 2007). These activities required the need of institutions for construction, maintenance, collection of taxes and so on. The government is doing this mainly via governance control; the government serves the public interest by radical regulations (Warner, Meijerink, & Needham, 2007).

The institutional hierarchy is drawn in Figure 1. The ministry of Infrastructure and Environment is responsible for water safety at the national level. Rijkswaterstaat is the executive organization that manages and develops the main national infrastructure. It is the functional manager of main water systems (e.g. Lake Ijssel, the major rivers and sea). The Netherlands has 12 provinces which construct water safety standards for regional systems and construct a provincial structure vision for spatial planning. The main actor for spatial planning is the municipality which determines zoning plans. They are only allowed to issue a building permit if it is not in conflict with the zoning plan. The waterboard, which is a functional decentralized government which is exclusively in charge with the management of regional water systems, also plays a role in spatial planning with the 'watertoets'. This is exclusively meant to take water management objectives into consideration in the process of spatial planning (Havekes, 2009).

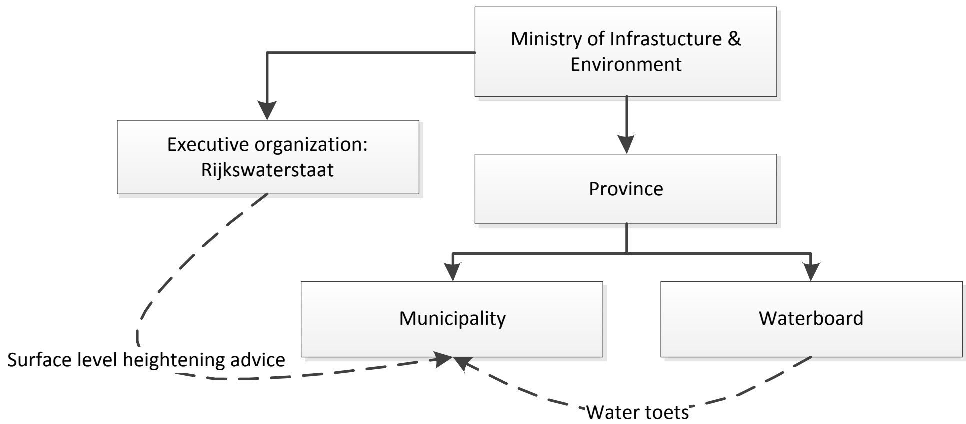

FIGURE 1: ACTOR HIERARCHY

[1] Normaal Amsterdams peil or Amsterdam Ordnance Datum: reference level more or less equal to mean sea level

2.2 PRIMARY FLOOD DEFENSE SYSTEM

The primary flood defense system of the Netherlands consists of 53 dike ring areas. These dike ring areas are protected by structures, dikes, dunes and high grounds against flooding. The water safety standard for these areas is set by law (current: Water act of 2009), as the average annual overtopping probability per year of the highest high-water level which the primary defense structure should withstand. The structures protect the dike ring area against high storm surges and high water levels of the rivers, Lake Ijssel and Lake Marker or a combination thereof (Klopstra & Kok, 2009) (Ministry of Transport, Public Works and Water Management, 2010).

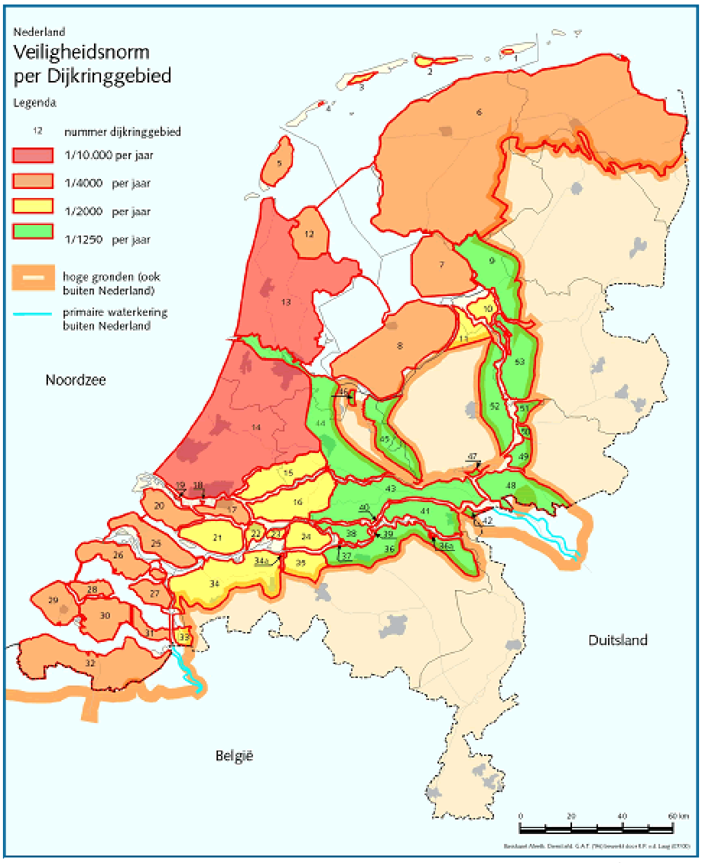

FIGURE 2: SAFETY STANDARD PER DIKE RING AREA (SOURCE: RIJKSWATERSTAAT DWW)

These safety standards are developed by the first Delta commission after the disastrous flood event of 1953 and mainly developed for coastal flooding. These protection levels were based on a risk analyses for the central part of the Netherlands. The standards vary for thinly populated dike ring areas and areas with a lesser economic value to be protected. For the dike rings along the non-tidal part of the Meuse River normative water levels with an exceedance frequency of 1/250 per year apply, in the upper rivers region 1/1250 per year, in the transition area 1/2000 per year, for the dike rings along the coast (apart from North and South Holland) 1/4000 and for North and South Holland, the densely populated western conurbation known as the 'Randstad' and the economic heart of the Netherlands, 1/10,000 per year, see Figure 2 (Ministerie van Verkeer en Waterstaat, 2005).

The Minister of Infrastructure and the Environment issues guidelines which lay down the standards which the structural design must meet. These contain that the crest level of the dike must be at least half a meter higher than the normative water level, specifications about the strength of the dikes and guidelines for the design and strengthening. The Water act stipulates that every five years the Ministry of Infrastructure and the Environment must test whether the normative water levels have changed, e.g. due to climate change, or due to extra storage and discharge capacity of the river (Room for the River project). On this basis the Directorate-General of Infrastructure and the environment sets the hydraulic boundary conditions that the water defenses must meet in the next five years. The dike managers then assess whether each section of the dike meets these boundary conditions and reports the results to the Minister. Some remarks by this approach are:

- In the current statutory standards only exceeding the normative water levels is expressed as a probability (failure mechanism of overflow and wave overtopping). The occurrence of other failure mechanisms is not expressed in probabilities. The statutory standard is not the total exceedance probability for the entire dike ring, but for a section of dike of several hundreds or thousands of meters long. For these reasons, the present exceedance standard does not match the probability of flooding of a dike ring.

- The results from the last test of 2006 showed that only 44% of the dikes and only 29% of the structural works comply with the legal standard. There is a lot of information missing so dike managers are not able to make a judgment (Inspectie Verkeer en Waterstaat, 2006).

- The legal safety standards are designed for the economic situation of the 60's, the Gross Domestic Product (GDP) is nowadays 5 times as large, and the population grew with 44% (Bouwer & Vellinga, 2007).

- The legal standards only apply to the prevention layer of the multi-layer safety approach. Legal standards for the layers of spatial planning (2) and disaster control (3) do not exist. For these layers it is not known how much they contribute to water safety (Kolen, Maaskant, & Hoss, 2010).

2.3 Regional flood defense system

For regional situations, two situations can be distinguished: floods from regional surface water and flood or failure of secondary dikes.

2.3.1 Floods from regional surface water

The scale of this type of flood is small; the cause is an extreme rainfall event by which the water system (ditches and creeks) experiences an overload. Consequently the water flows over the surface level and can damage properties and land (Klopstra & Kok, 2009). The National Administrative agreement Water[2], an agreement of the central government, provinces, municipalities and waterboards, states down the principles of the 'working standards'. These standards are formulated for different types of land use: ranging from a flood probability of 1/10 per year for grass land and 1/100 for urbanized area (Stowa, 2004). The further elaboration of these standards is worked out by waterboards, municipalities and provinces (Mostert, Water law and organization, 2009).

2.3.2 Flood or failure of secondary dike

The difference of flood standards of the regional system compared to the primary flood system is that of a different responsibility in setting the standards. In case of the regional system; the province is charged to determine by provincial order flood standards with the objective to secure a certain safety level against floods of the regional water system, which are mainly polder canals. The basis of the standard is a damage calculation of the polder, this is further translated to a dike category. Five dike categories are determined with a corresponding overtopping probability ranging from 1/10 until 1/1000 per year. The flood probability is assumed to be 0,2 times the overtopping probability (Stowa, 2004).

[2] In Dutch: Nationaal Bestuursakkoord Water (NBW) 2009-2015

2.4 Unembanked areas

Unembanked areas count for 3% of the surface area of the Netherlands. The foreland areas of the Meuse count for 1% (PBL, 2007), see Figure 3. These areas can be divided into three areas (Bergh & Pas, 2008)

- Raised areas for industry and activities which need the river.
- Exterior polders protected by foreland defenses
- Not protected, nor raised areas for nature or extensive agricultural use.

FIGURE 3: UNEMBANKED AREAS IN THE NETHERLANDS (IN RED)

The national policy about water safety and unembanked areas is formulated as follows in the National Administrative agreement Water:

On the contrary to primary dike ring areas there are no legal standards for flood protection in unembanked areas. The basic principle is that homeowners are for themselves responsible for taking consequence reducing measures and they bear the risk themselves. The role of the central government is facilitating to inform and warn about flood risks. Rijkswaterstaat is doing this and gives advice about flood probabilities of the project area to the municipality; this is no obligatory advice because this could give obscurity about responsibilities (personal communication with Rijkswaterstaat). The assessment about the actual safety situation, communication and balancing the benefits and need of additional protective matter is a task of regional and local governments (NBW, 2009). According to the policy line big rivers of 1997 the national government is only concerned about the effect of developing unembanked areas on the primary flood defense and the discharge and storage capacity of the rivers. According to this policy line a permit is requirement for the areas defined in this policy (Ministerie van Verkeer en Waterstaat, 2006).

The fact that these areas do not have any national arranged flood probability standards does not automatically mean they are faced with a higher flood risk. The majority are raised areas due to sedimentation of the rivers. As can be seen from Figure 4 a flood in unembanked areas will cause a small layer of water unlike floods in primary flood defenses from where the protection is heavily bases on dike systems.

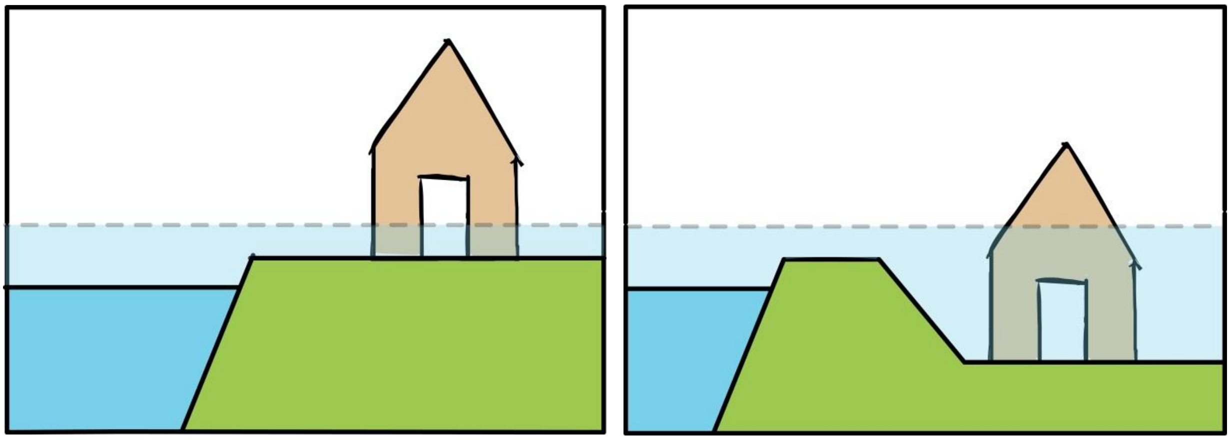

FIGURE 4: UNEMBANKED AREAS VERSUS PRIMARY FLOOD DEFENSES

This means that regional and local governments have to deal with the actual safety situation. The liability for potential damage for province, waterboard and municipality cannot really be foreseen. As the municipality is the main stakeholder in spatial planning and issuing building permits they have to make well considered choices in their communication and approach to deal with flood risk. Also the policy of the province affects the liability of the province. By setting legal standards the province are owed to fulfill to these standards. In the case they are not able to do this they could be liable for the occurred damage. The same situation is likely to appear for municipalities, the degree of liability, is dependent on the way the municipality communicates about the risks. Two examples will be given how municipalities deal with this:

- The municipality of Dordrecht communicates to all citizens living in unembanked areas with a yearly letter about the flood risk. They send a map together with the surface levels and possible actions of handling of the municipality and public in the case of a hazard (Gemeente Dordrecht, 2008).
- The municipality of Rotterdam or the borough of Charlois does not communicate; inhabitants of Heijplaat probably do not know they are living in unembanked areas and are not aware of the risks they face (personal communication with housing corporation and municipality).

Within spatial developments in unembanked areas, three tracks can be divided: a water safety and hydraulic approach, urban development aspects via zoning plans and building permits and risk and crisis communication via disaster control. All tasks and responsibilities are summarized in Table 1.

Province	National	Provinces	Municipality
Groningen		Surface level heightening or consequence reducing measures is responsibility for initiator	
Friesland		Own risk, province and waterboard will give information about responsibilities	
Drenthe			
Overijssel	• Constitution • Water act • Policy line big rivers • National Water plan • Own risk • Basis safety • Disaster control • Calamities and • Compensation Act (WTS)	Provincial Living Environment Vision, discharge and storage capacity for the Vecht	• Spatial planning act • Zoning plan • Crisis plan • Safety zone act
Flevoland		Water plan, water defenses around unembanked areas are seen as regional defenses, for new areas standards are set.	
Gelderland		Water plan, own risk	
Utrecht		Water plan, safety standards	
Noord-Holland		Coast: central government. Lakes: safety standard	
Zuid-Holland		Risk analyses: casualty and public disruption	
Zeeland		Own risk, assessment	
Noord-Brabant		Grant exemption	
Limburg		Policy line big rivers, WTS	

TABLE 1: RESPONSIBILITIES GOVERNMENT (HOITINGA, 2010) (BERGH & PAS, 2008)

Only the provinces Flevoland, Noord-Holland and Utrecht use flood probability standards.

Flevoland: has adopted flood probability standards for their unembanked areas (25) ranging from 1/10 year to 1/1000 year based on land use and the overtopping frequency at the moment they issued the standards. The management of the actual water safety situation and water defenses is now the responsibility of the waterboard.

Noord-Holland: applies a ‘working’ standard of 1/4000 year for new to develop and redevelopment areas at Lake Ijssel and Lake Marker. For existing areas they aim to enter an agreement with municipalities and waterboard. For areas at the North Sea coast the National Government guarantees the safety levels of 1998.

Utrecht: For new developments the province is using a standard of 1/1250 year. The floor level should additionally incorporate a water level rise of Lake Marker of 0,30 m because of a plan of different water level operation between the seasons. For existing areas the province aims to make an agreement with the municipality (Provincie Utrecht, 2010).

The vision of most provinces is that users in existing areas live in unembanked areas at their own risk. They should take themselves mitigating measures. The province of South-Holland is making new policy and running a special testing year. They have the most sophisticated policy and examine projects on the criteria casualties and social disruption. This policy enables municipalities to take measures in all layers of the multi-layer-safety approach. Their ambition is that municipalities use the constructed methodology in their zoning plan procedure; the province aims to require this to include this policy in their spatial planning structure vision.

An important distinction between flood management measures in unembanked areas compared to the other systems is the allocation of the associated costs. In general, flood management is seen as a public good; a good that is non-rival and non-excludable. Especially for dike based systems this is the case because the consumption of the good does not reduce the availability for others and no one can be effectively excluded. To overcome the market failure of this public good; inhabitants can benefit from water defenses without contributing, involuntary provision from the government is arranged via waterboards which collect taxes from their inhabitants. Inhabitants from unembanked areas do not benefit from all flood management measures and the associated costs of flood management measures for the project area are for the initiators of the project. These costs will form part of the land and estate development budget.

2.5 Towards multi-layer safety

It can be concluded from chapter 2.2 and 2.3 that water safety in these systems is arranged with flood probability standards. Also for unembanked areas this is the case for some provinces. Nevertheless, the national government puts its effort towards a multi-layer safety approach; this approach is first introduced in the national waterplan in 2009. The idea behind this approach originates from the debate about possible additional measures to the layer of prevention to control flood risks. A multi-layer safety approach assumes three layers in flood control: 1.) prevention, 2.) spatial planning and 3.) disaster control. The preventive layer stays the main pillar of the flood control. The layers spatial planning and disaster control deal with the reduction of the consequences of a flood, both economically as well as casualties. Measures in the three layers comprise:

1.) Prevention which can be defined as minimization of the probability that areas inundate due to overtopping or failure of flood defenses by influencing the boundary conditions of the project area. Examples of preventive measures are: building flood defenses (construction, maintenance and reinforcement), raising the surface level and prevent higher discharges (e.g. room for the river project, retain and store water upstream).
2.) Spatial planning solutions are characterized by consequence reducing measures by influencing the exposure and vulnerability of the project area by taking water safety explicitly into account in the procedure of location choice and design and construction of new developments. Examples of spatial solutions are: flood adapted buildings, building at less flood prone areas, compartmentalize and elevated infrastructure.
3.) Disaster control measures are characterized by all non-structural measures which influence the exposure and vulnerability of the project area. Examples are disaster plans, risk maps, early-warning systems, evacuation, temporary physical measures such as sand bags, financial compensation and medical help.

In the discussion about multi-layer safety cost efficiency in combination to the spatial scale plays an important role. It is argued that it is not cost efficient to introduce additional measures to a system mainly based on dikes. On the other hand, a portfolio of measures can enhance diversification to reduce uncertainty of future developments (Aerts, Botzen, Veen, Krywkow, & Werners, 2008). Different layers of safety also create a higher safety perception. Although, flood safety systems have to be seen as strong as the strongest link, measures in layer two and three can reduce the impact of a flood in the perspective of 'there is always a probability of flooding'. The potential of a multi-layer safety approach lies in areas where the risk of flooding is concentrated and not homogeneous spread in the project area or in situations where measures in layer 2 and 3 can form an alternative because measures in layer 1 are limited or cost inefficient (Hoss, 2010).

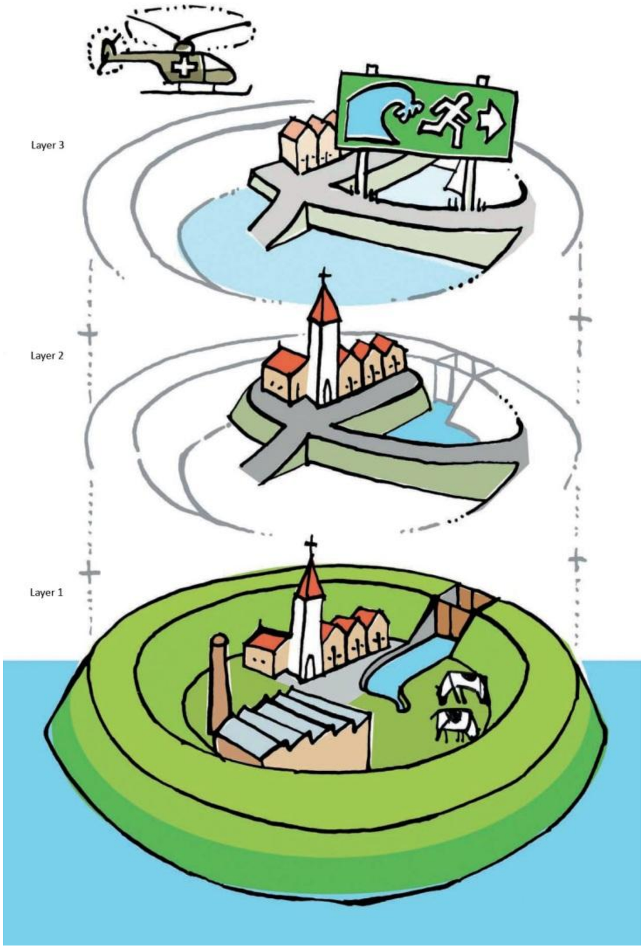

FIGURE 5: MULTI-LAYER SAFETY (MINISTERIE VAN VERKEER EN WATERSTAAT; VOLKSHUISVESTING, RUIMTELIJKE ORDENING EN MILIEUBEHEER; LANDBOUW, NATUUR EN VOEDSELKWALITEIT , 2009)

In practice, the realization of the multi-layer safety principle in Dutch flood management is limited because only for layer 1 tangible standards apply. By law the water manager is required to fulfill to these standards. For layer 2 and 3 only 'process' standards apply, for example the waterboard which has to be involved in the planning phase of new developments according to the 'watertoets', the necessity of having a disaster plan and doing trainings (Kolen, Maaskant, & Hoss, 2010).

The current flood probability standards do not give any flexibility to apply measures in layer 2 and 3. Except for unembanked areas for which no policy exists, or for example the policy of the province of Zuid-Holland which applies a risk assessment based on the criteria casualties and public disruption. To give the multi-layer safety principle a real chance, it can be concluded that it is necessary to:

- Move responsibilities, as flood probabilities are arranged by the national government and spatial planning procedures mainly by the municipality. Strong control by regional parties seems inevitable.
- Moving in financing constructions seems necessary; as different actors deal with the different layers.
- Safety standards which take measures in layer 2 and 3 into account by for example using risk instead of probabilities.

2.6 COMPENSATION

From 1998, government compensation for floods is arranged by the Calamities and Compensation act (WTS)[3]. Damage relief was already provided on ad-hoc basis for the floods of 1993 and 1995, but this law gave damage compensation a more structural character. The physical operation of the law is a political decision, and cannot be guaranteed. The WTS only provides compensation if a flood originating from fresh water results in a considerable disruption of public safety and requires a coordinated effort of organization and civil services. Floods originating from storm surges are excluded because the expected damage will be too high, like the storm surge of 1953 which had a direct damage of €0,7 billion (Botzen W. , 2010).

The WTS has big solidarity; all citizens pay for the occurred flood damage. It is only possible to lay a claim on the WTS if the damage is not possible to insure privately. Extreme rainfall events of 1998 have laid a big claim on the budget of the Dutch government. This is why the central government wanted to extend the private insurance constructions for extreme weather circumstances. Together with the Dutch Association of Insurers and the Dutch Federation of Agriculture and Horticulture[4] this has led to a crop damage insurance for farmers. Also the coverage against building and content damage is extended with damage as a consequence of extreme rainfall events in the Netherlands. This clause provides coverage for damage by rainfall falling in the area of the risk address. Exceptions are made for damage by groundwater, damage by failing water defenses and damage by badly maintenance or open windows or doors (Wateroverlast in Nederland, 2000) (Wateroverlast in Nederland, 2001).

Although the WTS is mainly issued because of floods in the foreland areas of the Meuse, it is argued that people in unembanked areas are not able to lay any claim on the WTS because a flood in unembanked area will not cause a calamity or social disruption (Woning, 2009) (Kok, Mogelijkheden voor het verzekeren van waterrisico's, 2000). Generally, unembanked areas are elevated, either by sedimentation or artificial surface leveling, so flood depths will not be as high as a dike breach and will rather cause inconvenience and economic damage than casualties. Also the NBW emphasizes that people living in unembanked areas have to face flood risk for their own. It can be concluded that the working of the WTS remains an ex-post political decision, and the circumstances are dependent on the political climate at that moment.

[3] In Dutch: Wet Tegemoetkoming Schade
[4] In Dutch: Land- en Tuinbouw Organisatie (LTO) Nederland

It cannot be stated that every flood in an unembanked area will not lead to a calamity and social disruption. An example is the province of South-Holland where 65.000 people live in unembanked areas and also public utilities are located which can even give disruption outside the flooded areas

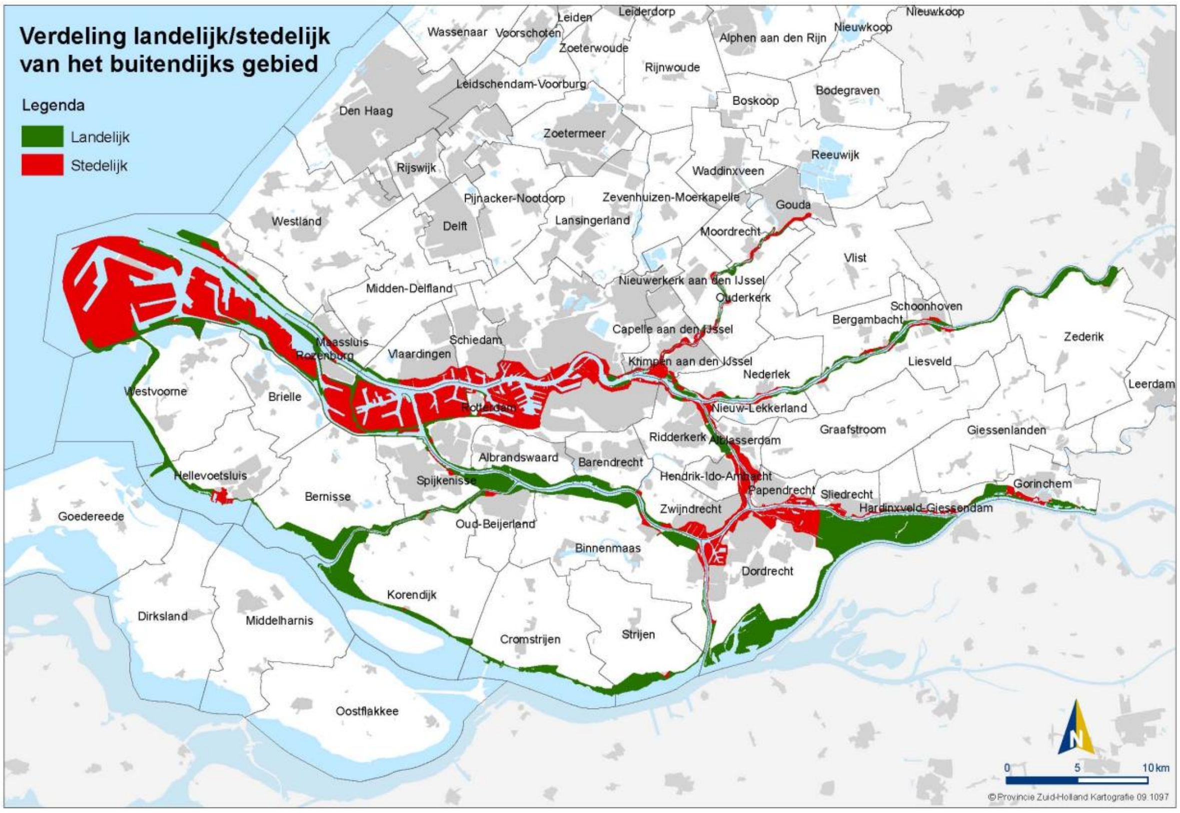

FIGURE 6: UNEMBANKED AREAS IN SOUTH-HOLLAND

An important issue in this matter is also the duty of the water manager to provide the water safety standard according to the law. In case the water manager is not taking the appropriate measures to provide or maintain the standards according to the law they could be liable for the occurred damage. These measures are not explicitly mentioned in the water act but should be seen according to the relevant jurisprudence. An example is the dike failure of the secondary dike in Wilnis in 2003. This dike collapsed due to a severe drought, which the peat couldn't cope with; a failure mechanism which was at that time unknown. This event caused a damage of 16 Million euro to inhabitants, municipality and the waterboard. Until now this case is being tried in court between municipality and waterboard about the liability to compensate the damage. The Supreme Court is now taking a new decision after several court sessions (Rechtennieuws, 2010). The WTS is also put into practice which covered two third of the damage. From this case can be concluded that the duty to provide and maintain is not as straightforward as it seems, as the actual determination of who can be hold responsible already takes seven years.

Private flood insurance for other situations as described in this paragraph is not available in the Netherlands and remains a topic of debate between engineers, financial specialists and policy makers. After the flood event of 1953 the Dutch Association of Insurers has prohibited its members to include flood damage in their policies because of the big losses. Although this agreement was withdrawn because of the EU competition law in 1998, flood insurance is still unavailable (Jongejan &

Barrieu, 2008). A (private) insurance construction is aiming to spread the risk of an unforeseen financial occurrence of individuals over time and place. The policyholder pays a yearly premium and thereby the insurance company is obliged to compensate the occurred damage during the agreement. Although it is possible to insure yourself, and you're property to almost every hazard; flood insurance stays uninsurable in the Netherlands. According to Swiss Re, a big reinsurance company which purchases insurance policies from insurance companies as a means of risk management: risks that are insurable are measurable, bounded and well behaved. The premium rates must be acceptable to both insurers and insured's (Swiss Reinsurance Company, 2005).

	Category	Criteria	Characteristic
1.	Actuarial	Risk	Measurable
2		Losses occurrences	Independent
3.		Maximum loss	Manageable
4.		Average loss	Moderate
5.		Loss frequency	High
6.		Moral hazard, adverse selection	Not excessive
7.	Market-determined	Insurance premium	Adequate, affordable
8.		Insurance cover limits	Acceptable
9.		Industry capacity	Sufficient
10.	Societal	Public policy	Consistent with cover
11.		Legal system	Permits the cover
13.		Risk perception	High

TABLE 2: CRITERIA OF INSURABILITY (TO (SWISS REINSURANCE COMPANY, 2005))

The actuarial criteria of insurability, see Table 2, number 1 until 6, are those criteria of concern of the insurance company to be able to assess a risk based fair premium. A risk should be measurable in the sense that the probability of occurrence should be known as well as the expected losses (average and maximum). The occurrences should not be overly correlated with each other within the portfolio. Because the insurance company is only able to compensate the damage if the sum of the premium rates and his assets are amply sufficient to compensate the insured it is necessary that the probability that all insured are faced with damage is sufficiently low ($\approx p^N$). The risk profile should have sufficiently events with low severity and high frequency in order to fulfill the Law of Large Numbers so the damage compensation behaves stable ($\approx pN$) (Vrijling, 2008).

These mentioned criteria affect the insurability of flood damage; inherent to floods is the big concentration of damage: low frequency, high severity and highly correlated. Regionally operating insurers will not be able to devise a sufficiently balanced portfolio; as a consequence reinsurance capacity will be necessary. These transactions do not take place at the moment: reinsurance quantities are low and prices high. Reasons for this can be found by both demand as supply side, as well as by handling of third parties. Froot (2001) mentions 8 reasons for this market failure:

i. insufficient capital in reinsurance,
ii. reinsurers have market power,
iii. the corporate form for reinsurance is inefficient,
iv. the frictional costs of reinsurance are high,
v. markets are degraded by moral hazard and adverse selection,
vi. ex-post intervention by third-parties substitutes for insurance,
vii. agency issues distort insurance managers decisions and

viii. behavioral factors dampen demand (Froot, 2001)

Moral hazard and adverse selection refers to information asymmetries between insurers and the insured because high-risked individuals are more likely to demand insurance coverage than low-risked individuals. The consequence will be that insurance premiums will have to go up and the insurance will be less attractive to people with a low risk profile. Consequently, insurance companies might end up with portfolios of only high risk policies. The question arises if this information asymmetry is a real problem in the Netherlands since information on flood risks is rather a public matter, especially since the European Union asked his member states to undertake a flood risk assessment and prepare flood risk maps and flood risk management maps (Mostert & Junier, The European flood risk directive: challenges for research, 2009). In practice, insurance companies are able to monitor individuals in the flood risk they face and adjust the premium. Another question is whether individuals have superior knowledge about flood risks since the perception of individuals towards flood risks seems to be low (Botzen & Bergh, 2008), (Terpstra, 2009). Moral hazard concerns the issue of insured behaving less carefully because they obtained insurance coverage. This problem of moral hazard is mainly on the side of the government, as flood protection is publicly provided. As is already mentioned in paragraph 2.2 standards are set by law, but meanwhile these standards are not met. For unembanked areas, insurers could apply underwriting clauses in the sense of consequence reducing measures and constructional requirements (e.g. a tile floor instead of wood and requiring installations on the second floor). It can be concluded that excessive adverse selection for the Netherlands cannot be blamed for the uninsurability of flood damage. Moral hazard on the side of individuals can be overcome by the design of the insurance policy but by the side of the government cannot really be overseen.

The market determined criteria (number 7 until 9) reflect the state of the insurance market. Premium rates should be affordable to insured's as well as sufficient for the insurers to compensate damage. They should be able to set cover limits to limit the maximum compensation. Finally, industry capacity must suffice to cover the risk. For the Netherlands, there are no private sector initiatives; a common reason is that regional operating insurance companies do not have sufficient capacity to include flood damage. Cooperation within a public-private partnership to have sufficient assets could be a solution.

The societal criteria (number 10 until 13) concern the societal and administrative background. The covering must be consistent with societal values and be legal. The risk perception of individuals plays a role because the risk perception seems to be low; they believe probabilities to be negligible and people are not likely to buy insurance against low probability, high impact events. Kunreuther (1976) states 'Only if a person is aware of the hazard is he likely to investigate protective actions such as purchasing insurance'. Terpstra (2009) argues that citizens regard flood damage as a government responsibility and will hold negative attitudes towards the introduction of a flood insurance program (Terpstra, 2009).

2.7 Conclusion

The conclusion of this part will form input for the constructed framework.

- It can be derived that for unembanked areas two acts can be distinguished as most relevant: the water act and the spatial planning act.
- The national government is only involved in the development or restructuring of unembanked areas in the case this influences the primary flood defenses or the storage and discharge capacity of the rivers. There are no water safety standards set by law.
- Only a few provinces have constructed policy about water safety in unembanked areas, in contrary to water safety standards for secondary dikes because provinces are legally bounded by the water act to lay these down by provincial order.
- Issuing standards can affect the liability of the province and could lead to inequality between existing areas and new to develop areas. Issuing standards for existing areas may lead to huge investments.
- The municipality is a big stakeholder in the development of unembanked areas. By spatial zoning plan procedures and building permits they can require measures to provide water safety.
- Risk communication by the municipality plays an important role for the liability of damage of the municipality. It can also create awareness and lead to individual measures and preparations of citizens.
- Water safety norms like flood probabilities lead to traditional measures like surface level heightening or protection by a dike. New building methods which aim to reduce the consequences of a flood and measures in layer two and three of the multi-layer safety approach cannot be evaluated.
- The province of South-Holland constructed a methodology to assess the flood risk in unembanked areas by the criteria casualties and social disruption. These calculated values have to be compared to the prevailing 'orientation norms'. This approach gives the opportunity to take measures in all layers of the multi-layer safety approach.
- Compensation for flood damage is arranged via the Calamities and Compensation act, the actual operation of the act is uncertain; it is argued that a flood in unembanked areas will not lead to a disruption of public safety and therefore citizens in unembanked areas cannot make a claim for compensation. These arguments are questionable for the areas in South-Holland where a lot of people and utilities are located resulting in a large indirect damage.
- Private flood insurance is unavailable in the Netherlands, mainly due to the specific characteristics of the Netherlands; large flood prone areas but high safety levels compared to other countries leading to high impact, low probability events which make insurability difficult. Experts do also twist about the necessity of this insurance; mainly because the associated costs are expected to be too high and the public character of water safety. For unembanked areas this is seen different because the government is not offering formal protection by law.

3. Framework

This chapter will describe a framework how municipalities and project developers should deal with flood risk in their investment decisions.

3.1 Introduction

As risk is in engineering calculated as the probability times the consequences, see Figure 7, you can prevent the risk of occurring by reducing the probability; by for example building at a surface level so a flood will have no impact. Either you can take mitigating measures by for example making dwellings flood proof or by not using you're ground floor cost intensive. By spreading risks in time or/and in place home owners will not be faced with a big loss at once and the economic costs of a disaster will be spread between the policy holders.

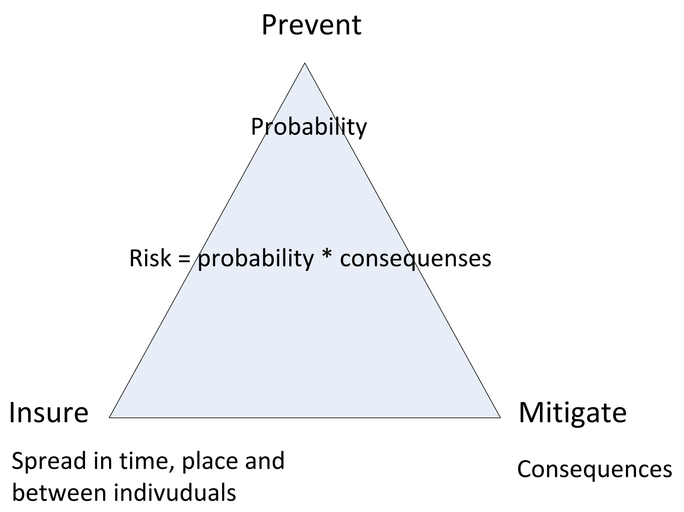

FIGURE 7: RISK APPRACH

3.2 Situation analyses

Before a risk assessment framework is constructed the situation of the proposed project needs to be analyzed. Answers to the following questions are needed:

- What are the general areas of concern, or themes, that the project will focus on?
- What is the spatial level of the project?
- What is the project aiming to achieve?
- What political, socio-economic, technological and biophysical environment will the project operate within?
- Who are the major stakeholders? What are their interests and what tools do they have to influence the process?

A distinctive analysis at forehand will be helpful to generate scenarios and give insight into the perspective and interests of the different stakeholders. Because land and estate development deals with a lot of different stakeholders, as well in the public as in the private sector, and the associated costs for flood management measures are for the initiators every stakeholder will have a different perspective about the desired safety level and how this will be accomplished.

3.3 Vulnerability

The vulnerability framework is formulated as a combination of the following components: threshold capacity, coping capacity, recovery capacity and adapting capacity. Vulnerability can be considered as the ability to build a threshold against disturbances or the ability to cope with disturbances as a determining factor of vulnerability. In this mentioned framework also the capacity to recover from disturbances are taken into account and future elements are included in the approach toward vulnerability. The objective of building threshold capacity is prevention of damage. Developing coping capacity is meant for the reduction of damage. The third component, recovery capacity, has its objective to quickly and effectively respond after a disaster. The objective of developing adaptive capacity is to anticipate on future developments and impacts by constructing a robust living and working environment. The components within this framework are highly interrelated; increasing one component typically leads to the decrease of one or more other elements (Graaf, Giesen, & Ven, 2009).

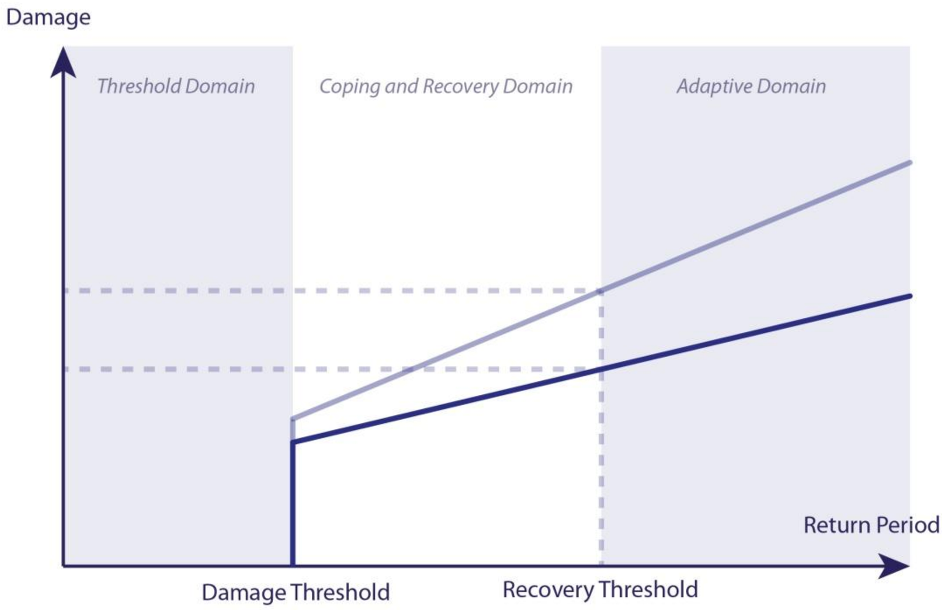

FIGURE 8: THE FOUR COMPONENTS AND THREE DOMAINS OF THE VULNERABILITY FRAMEWORK ILLUSTRATED BY A DAMAGE RETURN PERIOD GRAPH. THE DARKER LINE SHOWS LESS DAMAGE BECAUSE OF DAMAGE MITIGATED MEASURES AND A FASTER RECOVERY.

3.4 Measures

All taken measures can be grouped into probability and damage reducing interventions and placed into the vulnerability framework. Probability reducing measures are measures in the threshold domain and include surface level heightening, dike heightening and for example the construction of extra storage and discharge capacity to reduce peak flows. Consequence reducing measures are measures in the coping domain and include flood adapted buildings, the construction of a safe evacuation route or for example compartmentalize of a flood prone area so the affected area will be reduced. All these measures are structural measures; they reduce or avoid possible impacts of hazards with a physical construction. Non-structural measures do not involve physical constructions but use knowledge, practice or agreement to reduce risks and impacts. Examples are land use planning, laws, public awareness, evacuation plans and insurance (Freitag, Bolton, Westerlund, & Clark, 2009).

	Structural	Non-structural
Threshold capacity	Dikes, surface level heightening, extra storage and discharge capacity	Safety standards
Coping capacity	Flood adapted buildings, safe evacuation route, compartmentalize flood prone areas	Effective emergency and evacuation plans, communication plan, clear organization and responsibilities for disaster management
Recovery capacity	Flood adapted buildings	Financial compensation, responsibilities

TABLE 3: FLOOD RISK MANAGEMENT MEASURES

3.4.1 Surface level heightening

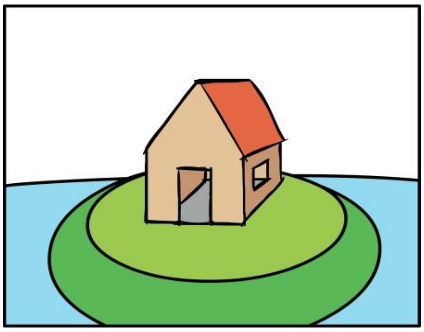

FIGURE 9: SURFACE LEVEL HEIGHTENING

A long tradition for coping with flood risks is to raise the surface level. Already from 300 B.C. people built on mounds to protect themselves against high waters. A common practice for unembanked areas at this time is to raise the surface level to an acceptable height, for example to a corresponding water level with a return period of 10.000 years.

Objective: *prevent the entrance of flood water into dwellings (and open spaces) to decrease the probability of a flood and increase the threshold capacity*

Choices can be made regarding a complete or partial surface level heightening strategy. A conceivable strategy is to create a lower level for public areas like streets, parking lots and parks.

Activities: Applying a layer of sand is usually done by truck, but is also possible by rainbowing.

Remarks:

- As unembanked areas are located at the waterfront, the transport of sand can take place by barge, a cheap way of transport.
- By raising the surface level integrally the issuing of building grounds has to take place at once, gradually issuing is difficult due to geotechnical stability.
- By raising the surface level, setting will take place. The amount of setting depends on the way of raising, the amount, composition of the soil and material used for raising (Baron, 2004).

- The possibilities to increase the water safety after construction are limited, so anticipation on future developments as climate change needs consideration in the planning stage. The adaptive capacity of this single measure is small.

3.4.2 Flood adapted buildings

These measures deal at building level with the reduction of the impact of a flood. Two strategies can be distinguished in this approach. They comprise individual flood proofing of buildings and adapting the building activities to the risk. Flood proofing involves dry proofing the buildings, wet proofing the buildings, an elevated configuration and floating or amphibious solutions. Dry proofing involves activities which aim at keeping the flood water outside the building by sealing external walls or by shielding with water barriers. Wet proofing is based on the acceptance that some water will enter the building (until a certain height) but by the use of materials that are more water resistant the impact on fabric and structures will be minimized. An elevated configuration is accomplished by elevating the whole structure by building on walls and using a concrete staircase to reach the surface level. Floating and amphibious structures are not considered in this study; the possibilities for floating structures are small as unembanked areas are generally elevated areas due to sedimentation this will require excavating sand or constructing in the waterway. Large water level fluctuations and the velocity of the water may influence the construction and thereby the building costs. Compared to regular dwellings the investment costs are expected to be too big.

By adapting the building activities the flood risk is explicitly taken into account in the design of the buildings. An example is that endangered floors are not used cost intensively, like non-habitable ground floors for parking, storage or public spaces. This strategy can have adverse consequences for the appearance of the streetscape and perceptions of public safety and security.

This section will deal with individual flood proofing techniques by wet and dry proofing and elevated configurations.

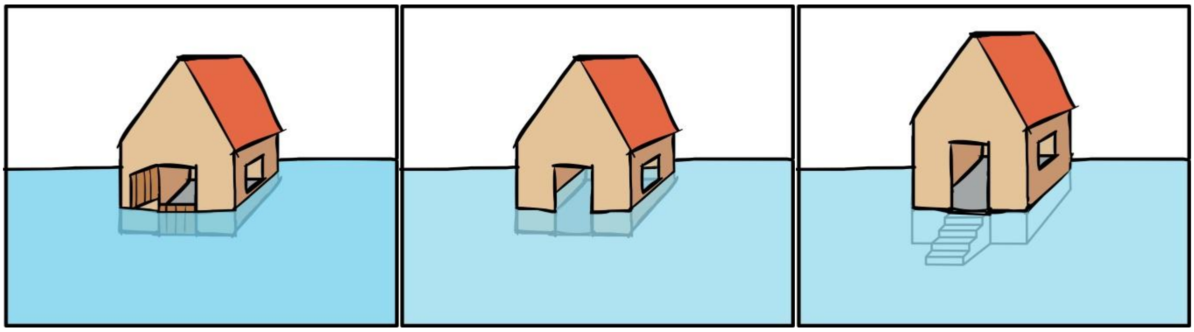

FIGURE 10: DRY PROOF, WET PROOF AND ELEVATED DWELLING

Objective: *reduce the consequences of a flood (economic damage) and increase the coping capacity.*

Activities:

- Constructional dry proof measures: Sprayed on cement, flood resistant external doors, non-return valves in waste pipes and outlets, airbrick covers, pump and sump, drainage line around perimeter of house.

- Constructional wet proofing measures: Solid concrete slabs, plastic flooring, closed cell insulation, composite internal walls, flood resilient kitchen, flood resilient doors, windows and frames (Gersonius, Zevenbergen, Puyan, & Billah, 2008).
- Constructional measures elevated dwelling: Concrete walls, concrete staircase and extra cables.

Remarks:

- It is expected that flood adapted buildings not only increase the coping capacity but also the recovery capacity because the repair work to dwellings after a flood is limited.
- Flood adapted buildings can contribute to the social and spatial context of the project; in practice they are rarely adopted due to risk aversion of policy makers (Nijburg, Pol, Duijn, & Groen, 2010).
- Dry proofing technique is only effective for a flood depth until 0,9 m; above this depth the damage will be equivalent to a regular dwelling. Wet proofing is designed for flood levels until 1,2 m; above this level the damage will have the same rate of growth as regular dwellings.

3.4.3 Embankment

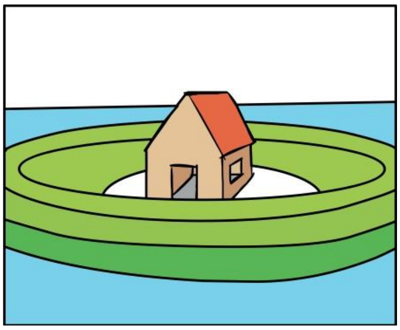

FIGURE 11: EMBANKMENT

By constructing a dike around an unembanked area, the probability of a flood will be reduced. The province is able to appoint the dike as a secondary water defense whereby this dike has to fulfill to the corresponding water safety standards. In that case the waterboard is responsible for management and maintenance. They have to examine the embankments regularly and prepare plans for management and maintenance. They have to lay down how the embankment looks like, who is responsible and which building activities are allowed around the embankments.

Objective: *prevent the entrance of flood water entering the project area to decrease the probability of a flood and increase the threshold capacity.*

Activities: A dike consists of a body of sand covered with a layer of clay and a cover of grass or if necessary another coverage. Clay is used because of the limited permeability, the dimensional stability and the erosion durability.

Remarks:

- Responsibility, management and maintenance needs to be coordinated. Besides these costs, construction costs and reduced profit of the development or acquisition cost for the space of the defense needs to be accounted.
- An embankment requires space and needs to be fitted in the project area. Especially for foreland areas in the rivers they should not decrease the storage and discharge capacity.

3.4.4 Accept damage

Taking measures to cope with flood risks should be regarded to the without-project situation. This situation of course depends on the initial situation of the project area. In the case of a restructuring project this can be the existing situation. In the case of building in a floodplain this purely depends on the height of the surface level.

3.5 Discussion

It is important to realize who pays and who benefits from flood management measures. In the Netherlands waterboards are established to take care of flood management and collect tax to pay for their investments. Inhabitants of unembanked areas do not profit from this tax payment but are nevertheless obliged to pay according to the principle of living, working and recreation; although their dwelling will not be protected, it is argued they profit because they can work and recreate in the protected areas (Mostert, Water law and organization, 2009).

Municipalities and project developers measure the profitability of a new urban dwelling project on the residual ground value. The residual ground value can be deduced by subtracting the building and construction and design costs of the area from the market value[5] of the land. The costs of using floodplain land are influenced on two ways.

Floods do not only cause damage to the contents and structure of dwellings but also influence the market value of the land. Floods of the Meuse River in the Netherlands in 1993 and 1995 had negative effects on the prices of the houses that were affected; a permanent decrease of 9% was observed (Daniel, Florax, & Rietveld, 2009).

On the other hand flood management measures increase the building costs of the dwellings and will reduce the residual ground value. Individual flood proofing measures directly increase the building cost of the dwelling and collective measures increase the construction and design costs of the area; which will both lead to a smaller residual ground value.

If the real estate market would work perfectly, the market value of the land would include the expected flood damage; the market value would rise equally after taking a flood management measure with the capitalized decrease of flood risk. Since there even is uncertainty about the possible liability of flood damage in unembanked areas and the low risk perception of inhabitants it is very unlikely that this situation can be expected. The increase of the market value will be smaller than the decrease of the damage (Foster, 1976).

It can be concluded that project initiators have to pay for flood management measures and the inhabitants will benefit with a smaller amount than the decrease of damage.

3.6 Cost-benefit

Reduction of the flood risk is the main issue in decision making about flood management measures. But against which cost are measures profitable? And how should measures be compared?

[5] In this case the market value includes conveyance tax, VAT, notarial charges and estate agent charges. In Dutch: VON (Vrij op Naam).

In order to be able to compare different structural measures, it is vital to know if the benefit of a measure is worth the cost. To do this it is necessary to construct a cost-benefit analysis (CBA) to get insight into the cost effectiveness of different alternatives. To use CBA quantitatively for the guidance of a decision there are a few steps in every case (Snell, 1997):

a) Define the decision, normally between a possible course of action and its alternative
b) Fix, at least tentatively, the decision criteria
c) Estimate the cost of taking that course of action
d) Estimate the benefits it would bring
e) Weigh up the costs and benefits by means of some quantitative indicator
f) Consider uncertainty and the range of possible outcomes
g) Apply the criteria, consider the CBA alongside other relevant decision guides like environmental aspects and make the decision.

The CBA can be used to guide an investment type decision whether or not a single project or course of action will be undertaken.

3.6.1 Cost

For every measure the investment costs have to be determined. These include for example the labor, the amount of material, engineering costs and maintenance costs.

3.6.2 Benefits

The benefits in a CBA are equal to the reduction of the expected annual flood damage. The steps which have to be taken to assess them are as follows, see also Figure 12:

- Probability functions of flood levels
  These can be derived from statistics of water levels or from a combined rainfall and hydraulic model (SOBEK) to simulate flood levels.
- Determination of the inundation areas
  SOBEK-2D is able to calculate overland flow and thereby construct flood extend maps. This is done with the use of a Digital Elevation Model[6] (DEM), where all surface area of the Netherlands is stored in respect to NAP. In case such a model is not available flood extend maps should be created manually from water level statistics and DEM. GIS[7] is a powerful tool to analyze and present this data.
- Exploration of the vulnerability
  The GBKN[8] map is a topographic map covering the whole Netherlands having a big detail; usable from a scale from 1:500 until 1:5000. By using this map it is possible to assess the vulnerability for every dwelling. A transformation has to be made, because the map doesn't contain closed polygons but is using lines instead. The TOP10 map is an object oriented information map consisting of geo-objects with their characteristics. This collection is using polygons. The disadvantage of this map it that it displays housing surfaces instead of individual dwellings. For every object the inundation has to be determined.
- Assessment of the expected damage

[6] In Dutch: Algemeen Hoogtebestand Nederland (AHN)
[7] Geographic Information System
[8] Large-Scale Base Map of the Netherlands, in Dutch: Grootschalige BasisKaart Nederland

The damage corresponding to a certain water level is obtained from the flood-damage curve. Integration is applied to calculate them for a range of flood-exceedance probabilities.

- To assess the risk of flooding the expected damage is multiplied with the exceedance probability corresponding to that event. The Mean Annual Damage (MAD), which can be described as the average contribution of each damage level per year, can be calculated by:

$$MAD = \int_{P_0}^{P_{max}} D(p)dp = \sum_{i=1}^{I} \frac{d_{i-1} + d_i}{2} \Delta p_i$$

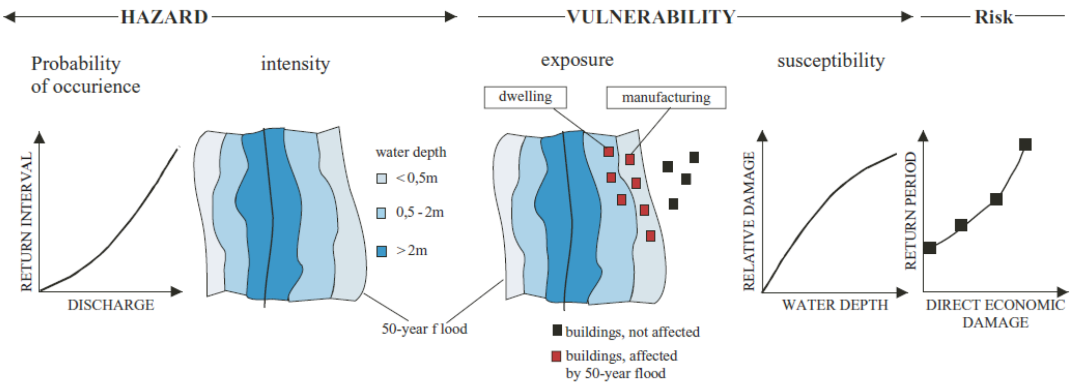

FIGURE 12: FLOOD RISK AS INTERACTION OF HAZARD (EXCEEDANCE PROBABILITY AND INTENSITY) AND VULNERABILITY (EXPOSURE AND SUSCEPTIBILITY) (MERZ, THIEKEN, & GOCHT, 2007).

Type of Damage

Flood damage can be divided into direct damage, which occurs as a direct consequence to movable and immovable property as a result of direct contact with water and indirect damage caused to customers and suppliers outside the flooded area by the loss of turnover and as a result of the increase in traveling time through blocked supply routes. Tangible damage is the cost that can be appraised at an approximate economic value. As only monetary values can be compared by cost-benefit analysis, the intangible damage have to be taken alongside the CBA.

	Tangible	Intangible
Direct	Houses Infrastructure Home contents Cleaning costs Vehicles Capital goods Agriculture and livestock Company fall out Costs repair water defense structures Costs evacuation and aid	Casualties Diseases Inconvenience and moral cut Infrastructure cut Fall out public utilities and communication Cultural-historical objects Landscape, nature and environment
Indirect	Damage to suppliers and buyers Substitution production Temporary housing of evacuees	Societal disruption Psychological traumas Undermined trust in public authorities

TABLE 4: DAMAGE CATEGORIES (EVENHUIS, MORSELT, BERNARDINI, & JONKMAN, 2007), (JONKMAN, BOČKARJOVA, KOK, & BERNARDINI, 2008)

Stage-damage functions are essential components of flood damage estimation models. They relate flood damage to flood inundation parameters for different classes of objects. The flood inundation parameters considered for stage-damage functions are flood depth, duration, fresh or salt water and velocity, which govern the damage characteristics. The stage-damage functions are usually derived two ways: one way is based on damage data of past floods, another way is from hypothetical analysis based on land cover and land use patterns, type of objects, information of questionnaire survey, etc. known as synthetic stage-damage functions (Dutta, Herath, & Musiake, 2003).

For this study, empirical stage-damage curves are used, see Appendix B: Flood damage curves. To evaluate the damages, replacement, residual, repair or relocation values can be used. For this study replacement and residual values have been used. Replacement costs represent the potential expenses for replacement of the dwelling, content, infrastructure, etc. at the price it can be bought at the capital market. Residual values count for depreciation (Hoes, 2006).

The actual return is the prevented damage of the individual measures. These damages have to be discounted every year due to time preference; one euro today is valued more than one euro next year. That's why cost and benefits have to be converted to comparable amounts; present value (PV). The PV represents the current worth of a future cash flow. It can be derived by multiplying the formula below with the cash flow in the corresponding year.

$$PV_{(year\ n)=\frac{1}{(1+r)^n}} \quad For\ n \to \infty: PV = \frac{1}{r}$$

With this formula the present value at year n can be calculated using an annual time preference rate r. In the Netherlands an annual time preference rate of 2,5% is used, which is a risk free discount rate. This rate is adopted by the minister of Finance. This implies that a flood now weighs two times as much as a flood in 28 years' time. These present values are summarized for all years of the analysis period. For the analysis period, it is common to use the technical or economical period of the project. For flood management measures sometimes an infinite period is used, for projects in urban areas it is common to use a period of 50 years mainly to compensate uncertainties (Eijgenraam, Koopmans, Tang, & Verster, 2000) (Snell, 1997).

In order to compare different projects it is most common to calculate two indicators; the net present value (NPV) and the benefit-cost ratio (B/C). The NPV can be calculated by subtracting the present value of the costs from the present value of the benefits. The B/C ratio divides these values. As so, the NPV gives an estimate of the absolute size of the net social benefits. The B/C ratio summarizes the relative size of the benefits and cost of a project.

The decision rule when using the NPV is:

- Accept a policy or project only if NPV > 0.
- In deciding between policies or projects select the one with the highest NPV.

When using the B/C ration:

- Accept a policy or project only if the B/C ratio > 0.
- In deciding between policies select the one with the highest B/C ratio.

The B/C ratio is preferred in situations where capital projects are funded from a limited pool of funds. In this case, where flood management measures have to be paid from the dwelling exploitation of the project developer the B/C ratio criterion is preferred.

3.7 Residual risk

The remaining risk after taking mitigated measures is defined as the residual risk. An important issue is the acceptance of this residual risk by the involved stakeholders. An insurance construction for unembanked areas for the structure and content of the dwelling does not exist at the moment. As insurers are unknown with insuring flood risks in the Netherlands they are not known with flood risk assessments.

A risk based premium may influence the acceptance of the residual risk. Especially for unembanked areas the mentioned criteria of insurability of paragraph 2.6 will be mentioned here, see Table 5. Regarding the actuarial criteria of insurability, flood risks in unembanked areas are measurable risks which can be assessed by a risk assessment. The losses occurrences can be characterized by high discharges from rivers Rhine, Meuse and Ijssel, high water levels from Lake Marker and Ijssel and storm surges at sea or a combination thereof. This implies that the loss occurrences will not be independent. The maximum loss for flood damage in unembanked area is estimated at one billion euro which seems in contrary to a failure of the primary flood defense with a maximum loss of €500,- billion euro more manageable (Pols, Kronberger, Pieterse, & Tennekes, 2007). Due to the fact that most areas are elevated the average loss is expected to be small and the loss frequency larger than for dike ring areas. Moral hazard is in the case of unembanked areas not at the side of the government but at the side of the individual and initiator of the project as the government is not responsible for taking flood management measures in unembanked areas.

Three important societal differences can be distinguished considering flood insurance for unembanked areas:

- On one hand there is no duty of the water manager, so no obscurity about responsibilities will occur in contrary to a dike breach of the primary or secondary system like the case of Wilnis. On the other hand the flood risk inhabitants face need to be communicated beforehand to assure liability at the side of the owner.
- The national government emphasizes that people live on their own risk in unembanked areas and have to take mitigating measures themselves. A risk-based premium based on the actual exposure and vulnerability of the dwelling may enhance mitigating measures of home owners.
- A flood in unembanked areas will less soon be regarded as considerable disruption of public safety, which gives less chance for compensation of the WTS.

	Category	Criteria	Characteristic
1.	Actuarial	Risk	Measurable
2		Losses occurrences	Independent
3.		Maximum loss	Manageable
4.		Average loss	Moderate
5.		Loss frequency	High
6.		Moral hazard, adverse selection	Not excessive
7.	Market-determined	Insurance premium	Adequate, affordable
8.		Insurance cover limits	Acceptable
9.		Industry capacity	Sufficient
10.	Societal	Public policy	Consistent with cover
11.		Legal system	Permits the cover
13.		Risk perception	High

TABLE 5 CRITERIA OF INSURABILITY

This leaves the actual realization of a flood insurance to the market; insurers and reinsurers should underwrite capacity and individuals should be willing to buy insurance. It is still questionable if the market size is big enough to fulfill the law of the Large Numbers as the people who live in unembanked areas is limited.

4. INVESTMENT DECISIONS

This chapter deals with the cost efficiency of flood management measures for unembanked areas. Based on general characteristics of unembanked areas statements are formulated for optimal investments for flood management measures.

4.1 INTRODUCTION

According to the presented framework described in chapter 0 an assessment will be made which structural measures described in paragraph 3.4 are cost efficient for which areas. This method is valid for urban dwelling projects where direct tangible damage has the mayor contribution to the risk.

The following external criteria affect the cost efficiency of flood management measures:

- Water level statistics
- Building costs of dwelling, contents, infrastructure and cars.
- Stage-damage curve
- Cost of measure

And the following area specific criteria affect the cost efficiency:

- Amount of dwellings
- Initial safety level
- Surface area (A)
- Housing density (ρ)
- Circumference (C)

For this analysis an analysis period of 60 years is used for the CBA and a risk free time preference rate of 2,5%. For the associated cost of measures and potential damage, see Appendix C: Costs.

4.2 3D-VISUALISATION

In the constructed flood risk model; the project area is modeled by a square, so the circumference can be defined as $4\sqrt{A}$. The housing density can be deduced by dividing the surface area from the amount of dwellings. This analyses is calculated with a public infrastructure percentage of 18%, a car ownership of 0,83[9] cars per house and with an inundation depth of 0,06 m for a return period of 10 years and 0,92 m for a return period of 20.000 years. It was founded that two independent factors say much about the profitability of different measures; amount of dwellings and the surface area. For the collective measures this relationship is visualized in a 3D-graph as this is for the individual measures just a linear relationship. It can be concluded that especially the number of houses i.e. the amount of protected value determine the profitability of collective measures.

[9] According to Statistics Netherlands there are 376 cars per 1000 inhabitants and the average household size is 2,22 people.

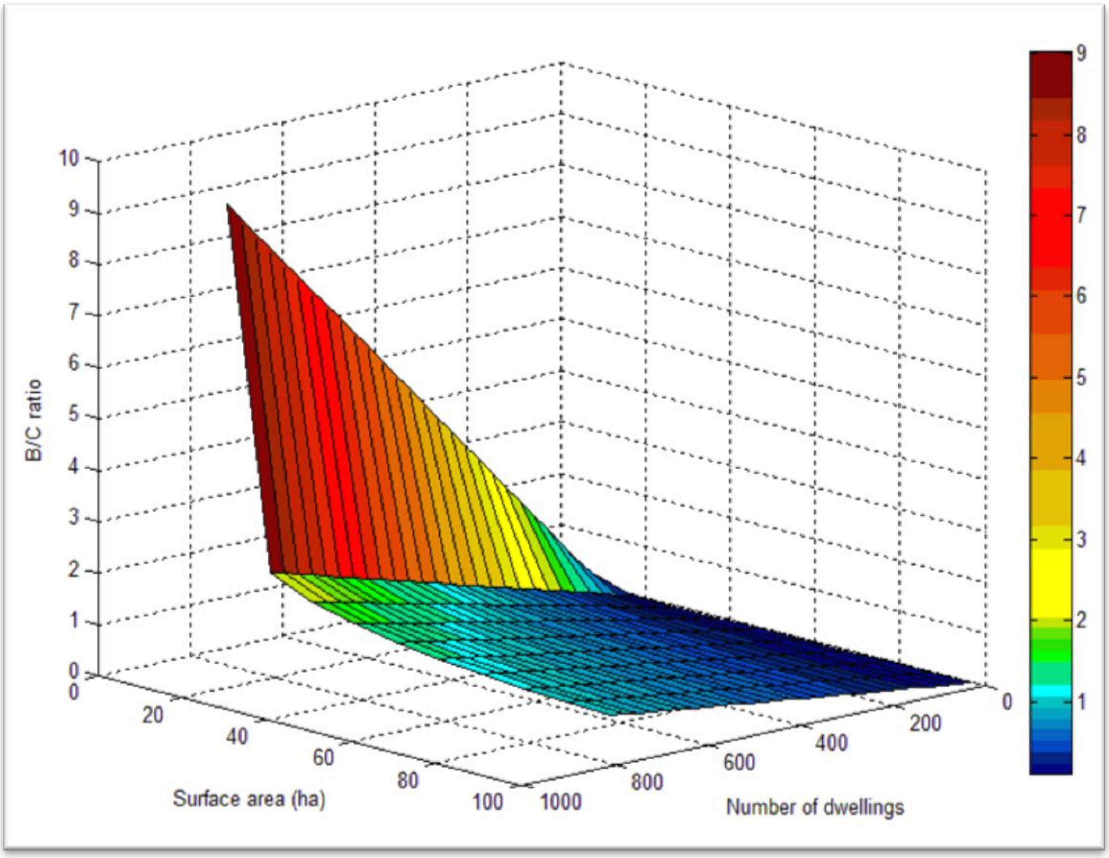

FIGURE 13: B/C RATIO OF EMBANKMENT AS A FUNCTION OF THE SURFACE AREA AND THE AMOUNT OF DWELLINGS

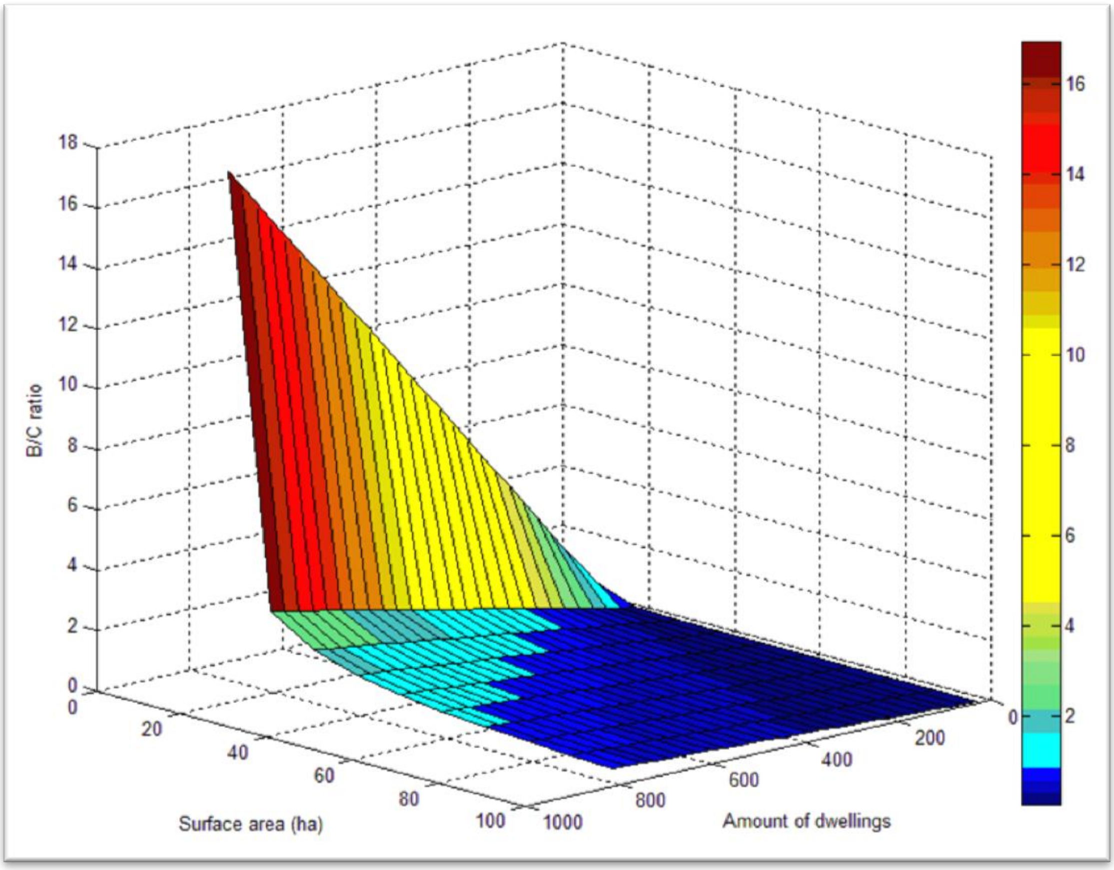

FIGURE 14: B/C RATIO OF SURFACE LEVEL HEIGHTENING AS A FUNCTION OF THE SURFACE AREA AND THE AMOUNT OF DWELLINGS

4.3 Housing density

The main criterion for choosing between a collective measure and an individual measure is the housing density of the project area. Considering Vinex[10] locations the following values are attached to the housing density (Lörzing, Klemm, Leeuwen, & Soekimin, 2006):

- Low: < 15 dwellings/ha
- Medium-high: 15-35 dwellings/ha
- High: >35 dwellings/ha

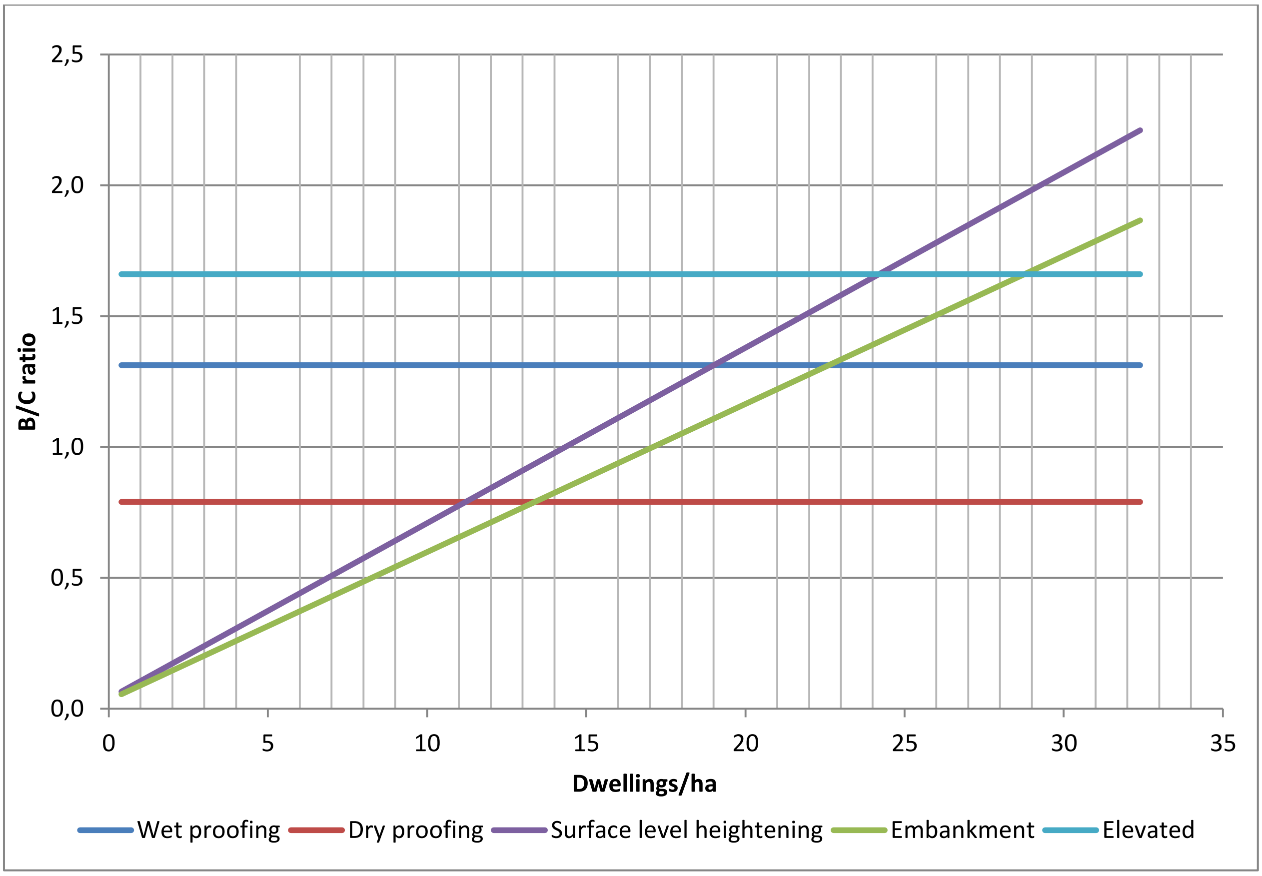

FIGURE 15: B/C RATIO AS FUNCTION OF HOUSING DENSITY

From Figure 15 can be deduced that the collective measures grow linear with the dwelling density and transcend the individual measures at 24 dwellings/ha. The individual measures do not grow because the benefits and cost grow with same rate. It was founded that this intersection does not significantly change in respect to the initial surface level. Although the preference position of the different measures can differ in relation to the initial surface level, see D1: Model parameters. It can also be concluded that an elevated configuration scores is valued the best from the individual measures.

[10] Large outer city areas pointed out for the policy for massive new housing development. In Dutch: **Vi**erde **N**ota Ruimtelijke Ordening **Ex**tra.

4.4 Surface area

The criterion to choose between surface level heightening and construction of an embankment is the surface area of the project; when the surface area increases with 10%, the circumference for building an embankment increases only with the square root of this amount. As the mean housing density of new dwelling projects (Vinex projects) is around 30 dwellings/ha this value was used.

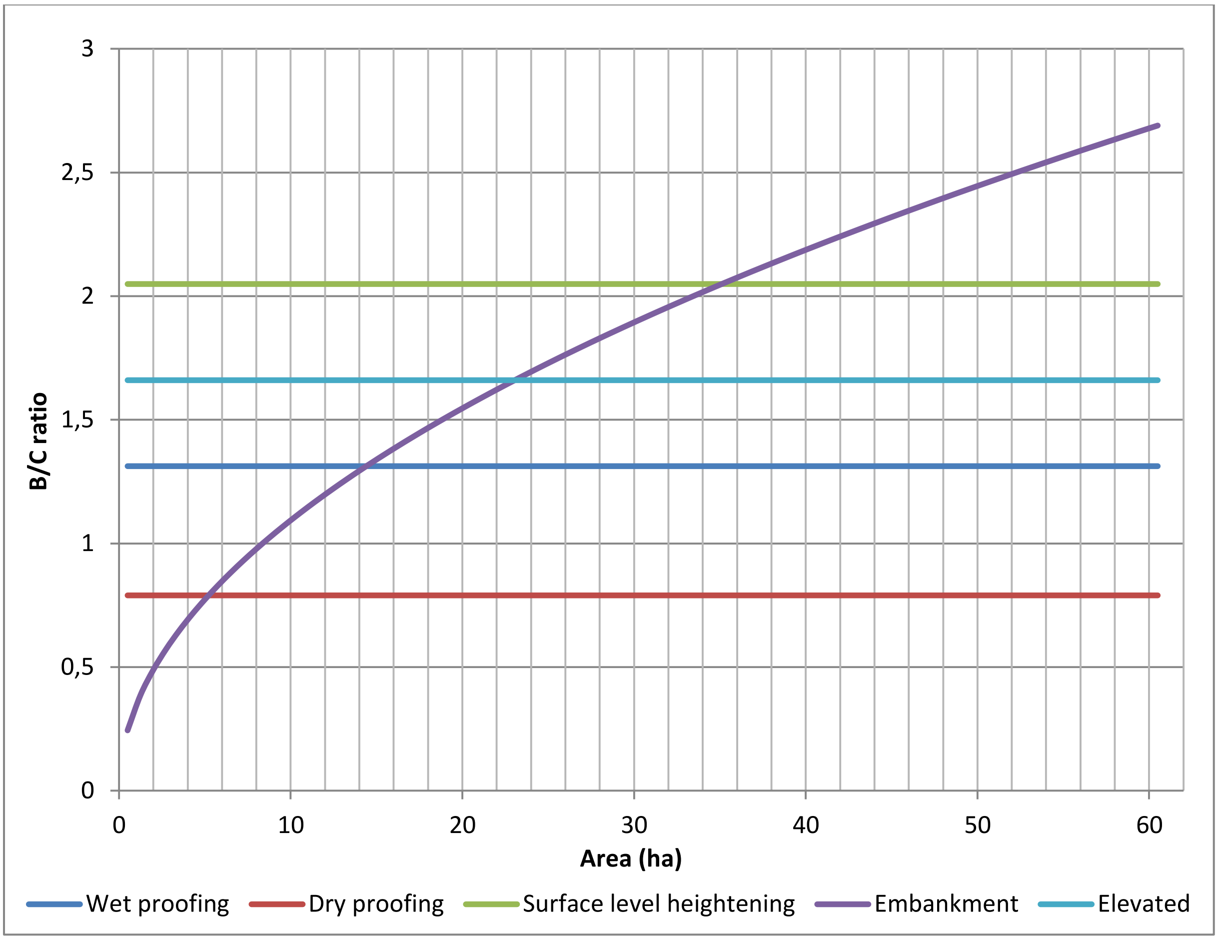

FIGURE 16: B/C RATIO AS A FUNCTION OF THE SURFACE AREA

As a larger surface area also involves more dwellings, the B/C ratio of all measures exept the contstruction of an embankment stays the same. For these measures, the benefits and costs rise lineair for bigger areas. As the ciccumference does not rise linear but according to a power function with exponent 0,5, the rise of costs of an embankment are determined by this rate of growth.

It was founded that this optimum is very sensitive to a low initial safety level. As the embankment, elevated strategy and the creation of an embankment are modeled to an increase of 0,9 m; water overtopping the embankment will cause much more damage than the other strategies. From 2,7 meter onwards the optimum stays the same around 35ha.

4.5 CONCLUSION

It was founded that the housing density is the main criterion for private flood management measures. For choosing between an embankment and a surface level heightening strategy the surface area is the main criterion.

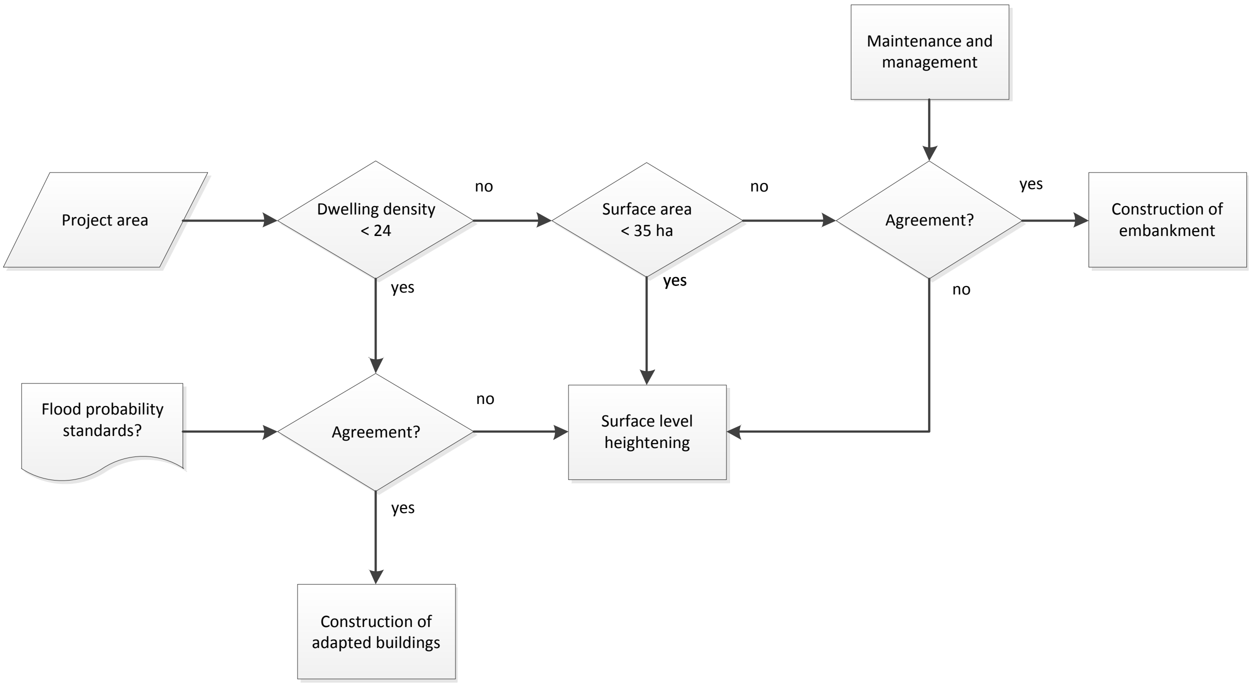

FIGURE 17: DECISION TREE FLOOD MANAGEMENT MEASURES

Figure 17 reflects a simplification of the decision tree of flood management measures for unembanked areas. According to paragraph 2.4 it was founded that three provinces adopted flood probability standards. The profitability of extra measures depends on the level of these standards. Another issue is the policy of the municipality as usually their only policy instrument is an issuing level policy; this instrument leaves little scope for discussion about flood adapted buildings. To assess these measures the consequences of a flood should be included in the standard.

Regarding the construction of an embankment, agreements have to be made about maintenance and management. A possibility is that the province appoints the embankment as a regional flood defense; as a consequence, the waterboard will be the functional manager. A register has to be made where the administrator is obliged to put down the location, shape, dimension and construction of the embankment. The administrator is allowed to locate protection zones around the embankment.

After analysis of the New Map of the Netherlands of the Netherlands Institute of Housing and Planning (Nirov) all urban planning projects in unembanked areas were screened on these two criteria. The New Map of the Netherlands is a geographic information system where all intended spatial developments are collected which are put down in spatial plans.

As can be seen from Figure 18 it is recommended that 132 of the 183 new projects are raised with a layer of sand, 9 projects with an embankment and 42 with flood adapted buildings. Especially for 26 of these areas consequence reducing measures will have a good chance because the provinces of these areas did not adopt flood probability standards. The other 16 plans are located in provinces with flood profitability standards and the profitability of extra consequence reducing measures is dependent on the level of this standard.

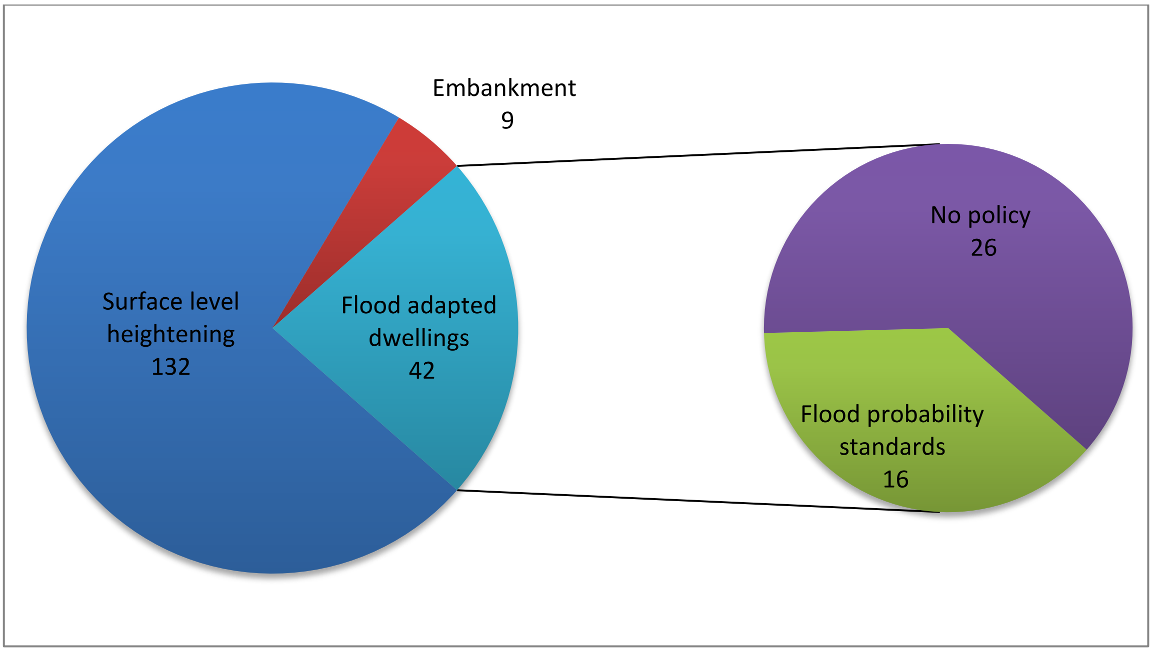

FIGURE 18: OPTIMAL FLOOD MANAGEMENT MEASURES

5. Case study

5.1 Introduction

The project area Heijplaat is situated at the island of IJsselmonde in the municipal borough of Charlois in the city of Rotterdam, see Figure 19. It is part of the project ‘Stadshavens’ Rotterdam of the municipality and harbor of Rotterdam, a redevelopment project of 1600 ha for the coming 30 years to create a new working and living environment for the old harbor areas of Merwe-Vierhavens, Rijn-Maashaven, Waal-Eemhaven and RDM-Heijplaat; all situated outside the primary water defenses.

This case study will focus on the redevelopment of the ‘new village’of Heijplaat where housing estates are surrounded by industrial harbors, as they were initially constructed for workers of a shipyard, the Rotterdamse Droogdok Maatschappij (RDM). The construction started in 1914 and finished in the early 20’s with a community of churches, homes, shops and schools. In the 80’s the RDM went bankrupt and the livability of Heijplaat went down. At this time there were plans to demolish the whole neighborhood but after big protests of inhabitants these plans changed.

The current situation is that a small area the ‘new village’ will be redeveloped, 288 properties will be demolished to create 180 – 200 new dwellings. The municipality of Rotterdam is aiming to take water safety for this project area into consideration in the plan phase as well as in the implementation phase.

The policy of the municipality for water safety in unembanked areas is only an issuing level policy for new development projects. The municipality has no policy for water safety and damage compensation for existing areas. As a consequence, the steering parameters for the design of project areas are very small.

FIGURE 19: HEIJPLAAT (IN ORANGE, THE REDEVELOPMENT ASSIGNEMENT)

5.2 SITUATION

The redevelopment of the new village of Heijplaat has known a lot of delay. Initially, the municipality of Rotterdam advocated to follow the surface heightening advice of Rijkswaterstaat and the surface level needed to rise to 3,90 m, corresponding to a return period of 10.000 year in the middle climate scenario of 2100. As the developers believed this was too expensive the project came to a standstill. At this moment, the municipality has departed from its position because the thought on this matter is that flood adapted building is more cost efficient than surface level heightening. All stakeholders and their interests will be mentioned here:

Municipality of Rotterdam

The municipality has no policy for water safety and flood damage for existing areas. For new to develop projects they only have an issuing level policy. Considering other measures they do not have an appraisal instrument. The municipality is not playing an active role in communication about flood risks in unembanked areas.

Project office Stadshavens Rotterdam

The Rotterdam port authority works together with the municipality of Rotterdam within the project office Stadshavens. The ambition of this organization is to transform 1600 ha of the old harbor part of Rotterdam to an attractive destination for living, staying and working in a sustainable way in relation to climate, environment, socially and economy.

Woonbron

The current owner of the dwellings is housing association Woonbron. They aim to sell the new dwellings at the private market. Water management measures have to be taken by the initiator 'Woonbron' and cost optimum measures will maximize their profit.

Province Zuid-Holland

The province has constructed policy about water safety in unembanked areas to bring water safety and spatial planning together. The policy is more constructed to give insight into flood risks of unembanked areas to municipalities than to lay down safety standards. Only when casualties and social disruption can occur, the province plays a role. As velocity and rate of rise of the water is expected to be small and no public utilities are situated in the project area the province is not concerned.

Rijkswaterstaat (Ministry of Infrastructure and the Environment)

Rijkswaterstaat is the manager of the big rivers and accordance with the policy line big rivers they determine if building in unembanked areas is allowed. In areas situated in the part of the river contributing to the discharge building is not allowed. In the designated 'Wbr-2a' areas, not essentially contributing to the discharge capacity of the river but to the storage capacity it is allowed under the following conditions: securing the safety of the flood defense, no obstruction to an increase of the discharge capacity and a minimal influence on the storage capacity. As the project area is situated in this area it is exempted of a permit. Thereby the only role of Rijkswaterstaat within this project is to give advice about the expected water levels.

Waterboard Hollandse Delta

Part of the spatial planning procedure is the 'watertoets'; the waterboard gives advice to the project initiators. The waterboard is the functional manager of the water defenses, as the project is not situated close to the water defenses and new developments will have no influence to the management of the water defenses the role of the waterboard will probably be limited.

5.3 Cost-Benefit

5.3.1 Procedure

The masterplan of the new village of Heijplaat has been obtained from Woonbron Development Company, which reflects the boundary of the project area and the individual buildings. After some GIS operations this plan is used as layer above the elevation map which has been obtained from the waterboard Hollandse Delta. For the roads, use has been made of the TOP10 vector map. With use of the water level data of Appendix A: Water level Heijplaat flood extend maps can be created, an example is Figure 20 which shows the inundation depth for a return period of 10.000 years in the current scenario.

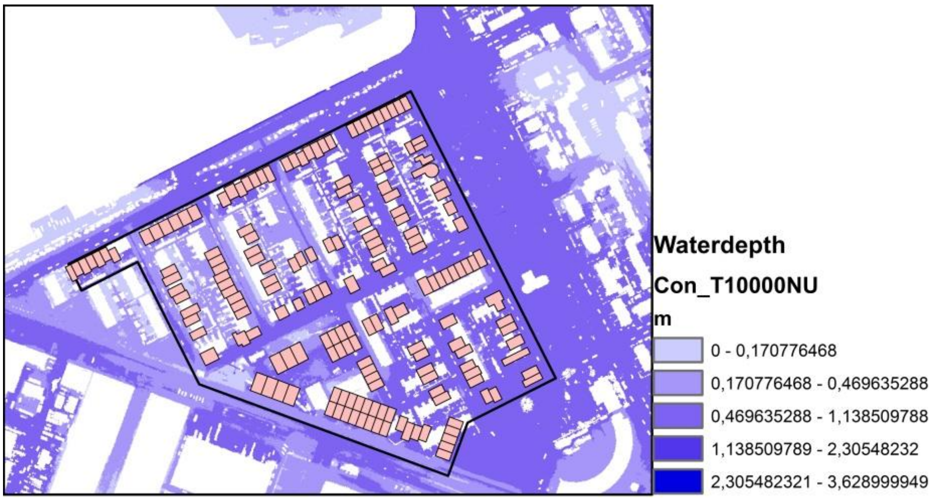

FIGURE 20: FLOOD EXTEND MAP CURRENT SCNEARIO WITH RETURN PERIOD OF 10.000 YEARS

For the assessment of damage, the stage damage curves of Appendix B: Flood damage curves have been applied. The maximum damages are shown in Table 12 of Appendix C: Costs.

5.3.2 Surface level heightening

The costs for surface level heightening are estimated at 12,5 €/m^3 sand, see Table 13 in Appendix C: Costs. In this price, the key variables are the market price of sand and the delivery mode, as the project area is situated at the river; it is possible to deliver the sand by barge. The costs for surface level heightening are purely the extra cost to make the project area ready for building. Sand, as compensation of setting is already part of the ready for building activities and thereby not part of the surface level heightening strategy to cope with flood risks.

The surface area of the project area is 53.722 m^2 and the mean surface level is 3,07 m. This makes the associated costs of surface level heightening to 3,90 m 559.971 €, see Figure 21 for the investment costs associated to surface level heightening to the desired return period.

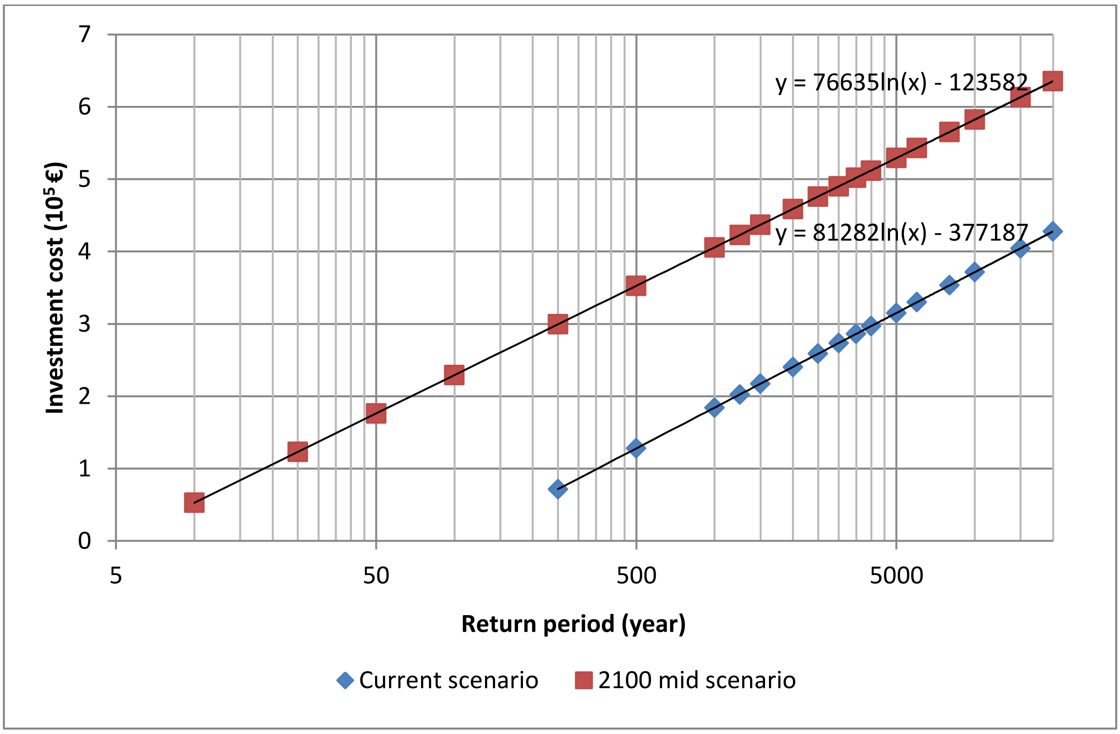

FIGURE 21: INVESTMENT COSTS RELATED TO THE DESIRED RETURN PERIOD

5.3.3 Flood adapted buildings

The total cost for dry proof dwellings are estimated at €1.647.360,- and €267.696,- for wet proof dwellings. The total cost of elevated dwellings with a flood design level to 3,90 m are estimated at €746.220,-, see Appendix C: Costs for a specification.

5.3.4 Embankment

For the construction of an embankment in the project area, a slope is assumed of 1:2 and a crest width equal to the height. The total investment for the construction of an embankment to a height of 3,90 m is calculated at €691.892,-. This investment includes the reduced profit for the dwelling exploitation on the place of the embankment. The surface area of the embankment equals 13,9 dwelling plots.

5.3.5 Comparison

The project without taking any flood protection measures i.e. building regular dwellings at the current surface level will result in the damage-probability curve of Figure 22. The MAD of the total area; the surface area under the graph is €7425,-.

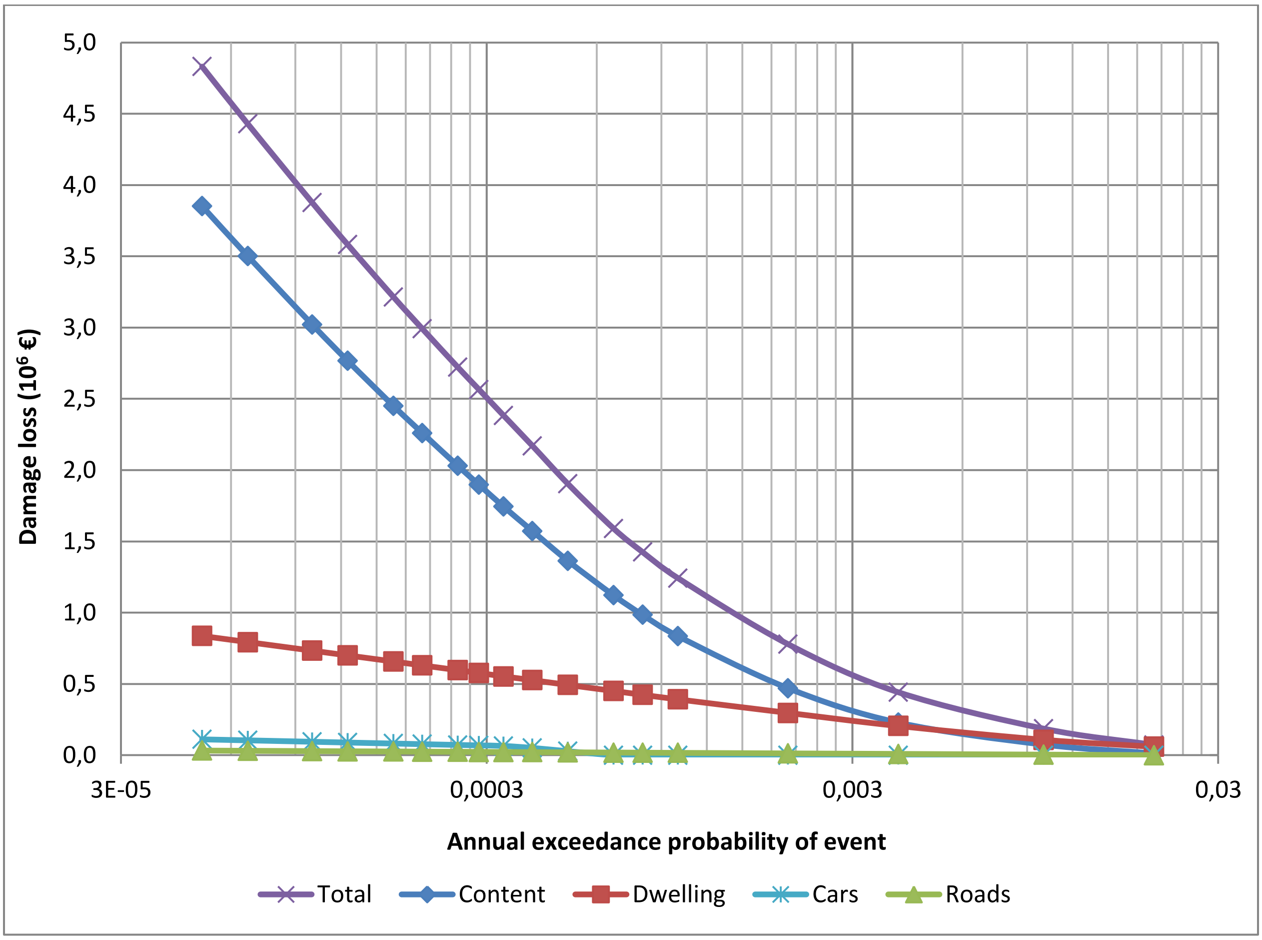

FIGURE 22: DAMAGE-PROBABILITY CURVE BASE SCENERIO UNDER CURRENT WATER LEVEL

To account for climate change in the cost-benefit analyses, the water level for the last year of the period of the cost-benefit has been calculated using linear interpolation between the current scenario and the middle scenario for 2100. The corresponding damage for this scenario can be obtained from Figure 23. The MAD for this scenario is €51.578,-, an increase in risk of 680%. In the intervening years the increase of damage is assumed to be linear.

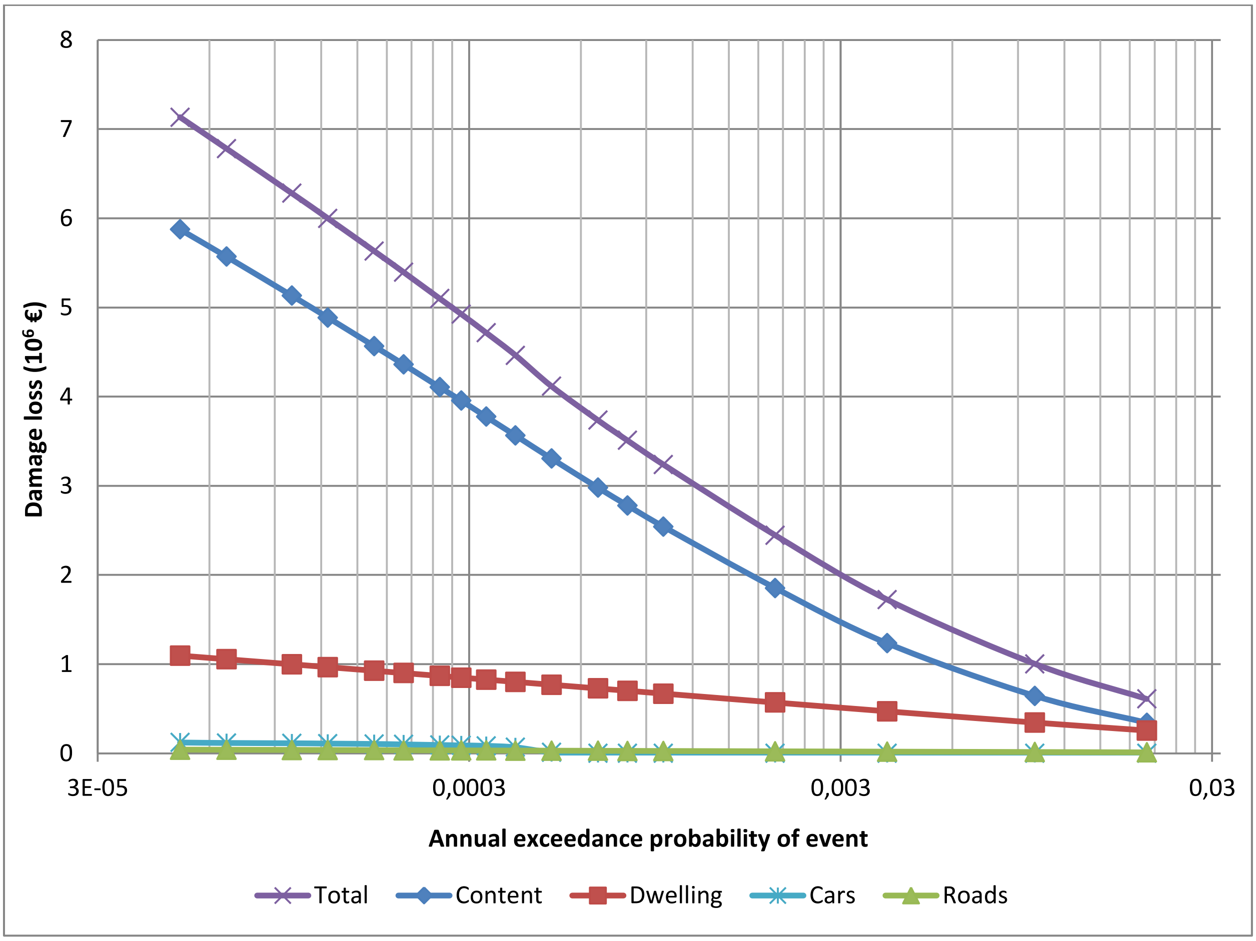

FIGURE 23: DAMAGE-PROBABILITY CURVE SCENARIO 2072

When the present values of the cost and benefits are compared, the results from Table 6 can be obtained. As the housing density of the project area is 33,5 dwellings/ha and the surface area is 5,4 ha; according to the results of chapter 4, the only profitable measure is surface level heightening.

Measure	B/C ratio	NPV
Surface level heightening	1,33	186525
Elevated dwellings	0,98	-12266
Embankment	0,45	-897535
Wet proof	0,56	-118820
Dry proof	0,44	-928710

TABLE 6: COST EFFICIENY OF FLOOD MANAGEMENT MEASURES

5.3.6 Optimal surface level

Decisions about optimal investments in flood management measures are optimization problems. According to Van Dantzig the total cost of the system have to be minimalized; the investment in safety measures and the present value of the MAD (Jonkman, Brinkhuis-Jak, & Kok, 2004). This is elaborated for the measure surface level heightening, as this is the only profitable measure for this project area.

The optimal surface level is the level where the sum of the present value of the flood risk and the investment costs are the lowest. The present value of the flood risk is calculated by assessing the

MAD for every surface height for the current water level as well as for the scenario in 2072. These have been interpolated through the years and discounted. As can be deducted from Figure 24, the optimal surface level would be around a (current) return period of 370 years, which corresponds to a surface level of 3,22 m + NAP (which is on average + 0,15).

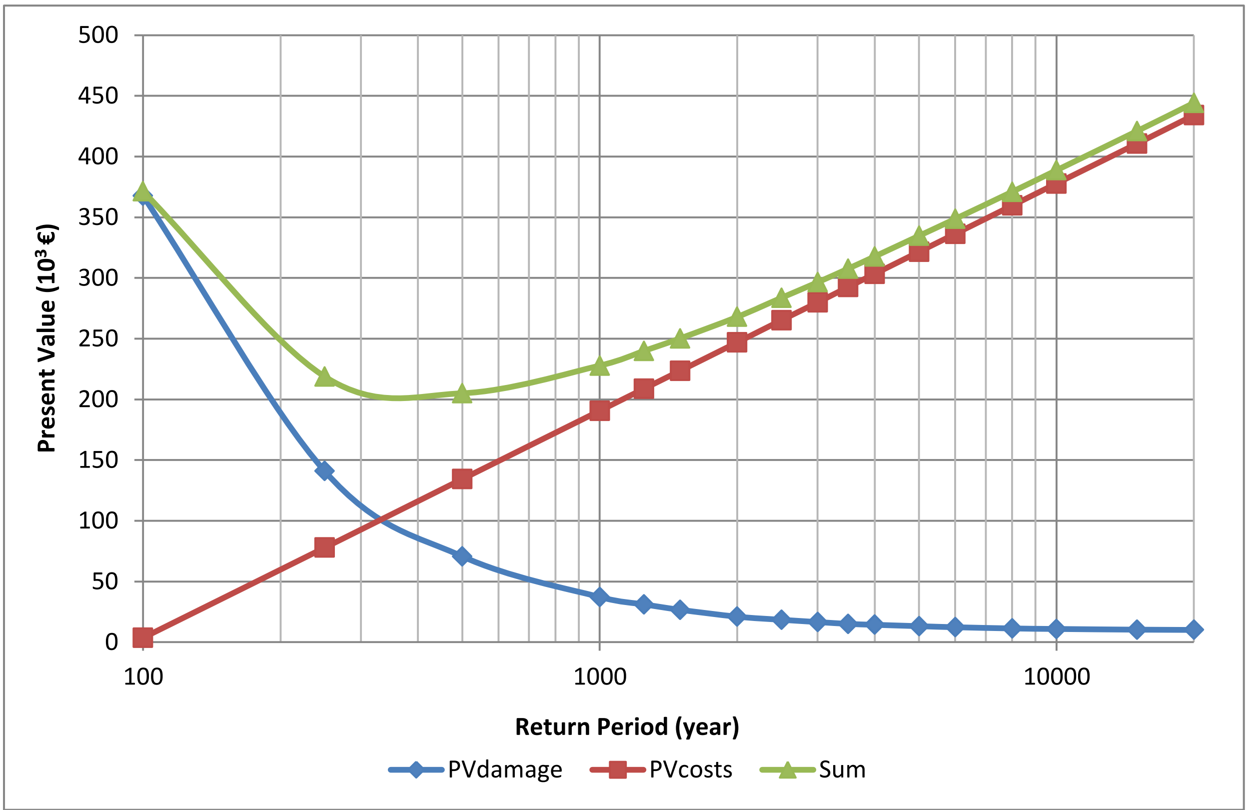

FIGURE 24: TOTAL COSTS FOR SURFACE LEVEL HEIGHTENING

5.3.7 Residual risk

At this surface level of 3,22 m, still a residual risk is present, which can be deduced from Table 7.

	Mean Damage [year^{-1}]	Expected increase due to climate change [-/year]	Max damage [€]	Expected increase due to climate change [-/year]
Content [€/dwelling]	1,2	4,1%	11.986,7	1,2%
Dwelling [€/dwelling]	2,9	3,4%	3.609,3	0,6%
Roads [€]	33,3	2,1%	25.209,1	0,3%
Cars [€/car]	0,038	1,76%	528,7	0,5%

TABLE 7: RESIDUAL RISK AND DAMAGE AT OPTIMAL SURFACE LEVEL

It can be noticed that the maximum damage, the total replacement of the dwelling will not occur. This makes capital for reinsurance easier as they look more than insurers to the accumulation of risk and the total exposure (Lengkeek, 2010). Also the expected increase of the maximum damage is much less than the increase of the mean damage. The MAD for the structure and the content of the dwelling is just €4,1-/year; a very small amount. The premium insurers should ask to policyholders is based on the following three components:

$$Premium = MAD + Risk\ load + Expense\ load$$

The risk load is here defined as the uncertainty surrounding the MAD and reflects the insurer's concern with the survival constraint and the need for surplus capital. A usual way of deriving the risk load is by using the standard deviation of the loss for which the portfolio composition is needed. The expense load is represented by the administrative cost involved in insurance contracts (Kuzak & Larsen, 2005). Vrijling argues that this risk and expense load can be 2 until 10 times the MAD, then the premium would after adding up arrive between €12,30- and €44,20- (Vrijling, 2008). Experience from Germany show that if the pool of risks is big enough the risk and expense load will be around €50,-, which would arrive at a premium of €54,1- (personal communication with Achmea). Compared to a current insurance premium of a home and content insurance which insures against fire, burglary and storm which costs on average €131,- per year per house this seems a reasonable premium (Centrum voor Onderzoek van de Economie van de Lagere Overheden , 2011).

5.4 Discussion & Conclusion

- The only profitable flood management measure for the 'new village' of Heijplaat is surface level heightening. Depending on the acceptance of the residual risk it is advised to raise the surface level integrally to 3,22 m.
- Although it is difficult to estimate an insurance premium for a single case, as this should consist of a large and diversified portfolio, it can be concluded that an insurance premium for the 'new village' of Heijplaat can be estimated at a reasonable insurance premium.
- It is recommended to the municipality of Rotterdam to make a risk assessment instead of using the issuing level policy of raising the surface level to the water level of 1/10000 year^{-1} in 2100 as this will make it possible to assess every flood management measure.
- It is recommended to the municipality of Rotterdam to communicate about flood risks in unembanked areas. Give inhabitants perspective of handling, e.g. where to get sandbags? This will also influence the final responsibility for damage.
- It is recommended to investigate the profitability of flood management measures for the whole area of Heijplaat, as the 'old village' also faces flood risks and a bigger surface area increases the profitability of collective measures.

6. Conclusions & Recommendations

This thesis demonstrated that by addressing flood risk in the design and development phase it is possible to overcome too big investments or too high risk levels. The research question will be answered by answering the sub questions.

How can we deal with the uncertainties of flood risk in investment decisions in the development of unembanked areas?

1. What is the current policy of building in unembanked areas and what are the responsibilities of the government?

- It can be derived that for unembanked areas two acts can be distinguished as most relevant: the water act and the spatial planning act.
- The national government is only involved in the development or restructuring of unembanked areas in the case this influences the primary flood defenses or the storage and discharge capacity of the rivers. There are no water safety standards set by law.
- Only Flevoland, Noord-Holland, Utrecht and Zuid-Holland have constructed policy about water safety in unembanked areas. In contrary to water safety standards for secondary dikes because provinces are legally bounded by the water act to lay these down by provincial order. Flevoland, Noord-Holland and Utrecht have laid down flood probability standards and Zuid-Holland uses a risk approach.
- Issuing standards can affect the liability of the province and could lead to inequality between existing areas and new to develop areas. Issuing standards for existing areas may lead to huge investments.
- The municipality is a big stakeholder in the development of unembanked areas. By spatial zoning plan procedures and building permits they can require measures to provide water safety.
- Risk communication by the municipality plays an important role for the liability of damage of the municipality. It can also create awareness and lead to individual measures and preparations of citizens.

2. Which strategies can be formulated to create the desired level of safety and how should they be compared?

- In this thesis surface level heightening, flood adapted buildings (wet, dry, and elevated configuration) and an embankment are discussed. By means of addressing the flood risk which comprises of the probability of an event occurring and the economic consequences these measures can be compared by a cost-benefit analysis.
- The benefits in a cost-benefit analysis of flood management measures consist of the expected yearly prevented damage which can be calculated by the use of water level statistics, elevation data, topographical data, stage damage curves and replacement or residual values.

3. How can a multi-layer safety approach contribute to the safety of the project area?

- A multi-layer safety approach assumes taking flood management measures of at least two of the three layers consisting of prevention (layer 1), spatial planning (layer 2) and disaster control (layer 3).
- Preventive measures are defined as probability reducing measures which influence the boundary conditions of the project area: surface level heightening and the construction of an embankment are discussed. For 77% of the plans of urban dwelling projects in unembanked areas these measures are founded to be most cost efficient.
- Spatial planning measures are defined as consequence reducing measures which influence the exposure and vulnerability of the project area: wet, dry and an elevated configuration are discussed. For 23% of the plans of urban dwelling projects in unembanked areas these measures are founded to be most cost efficient. As most municipalities only have a surface level heightening policy it is required to have municipal policy to assess the risk of these measures.
- Disaster control measures are defined as all non-structural consequence reducing measures which influence the exposure and vulnerability of the project area: financial compensation and organizational aspects are discussed.
- It can be concluded from paragraph 5.3.6 that according to Van Dantzig cost optimal flood management measures leave a residual risk (optimal investments equal the minimum of the sum of the investment and the present value of the MAD). The existence of a residual risk requires measures of layer 3; adequate policy considering liability and clearness about financial compensation.

4. How do area specific characteristics influence the cost effectiveness of the measure?

- It was founded that the housing density is the dominant criterion for choosing between individual consequence reducing measures and collective probability reducing measures. The surface area is the dominant criterion for choosing between the construction of an embankment and surface level heightening.

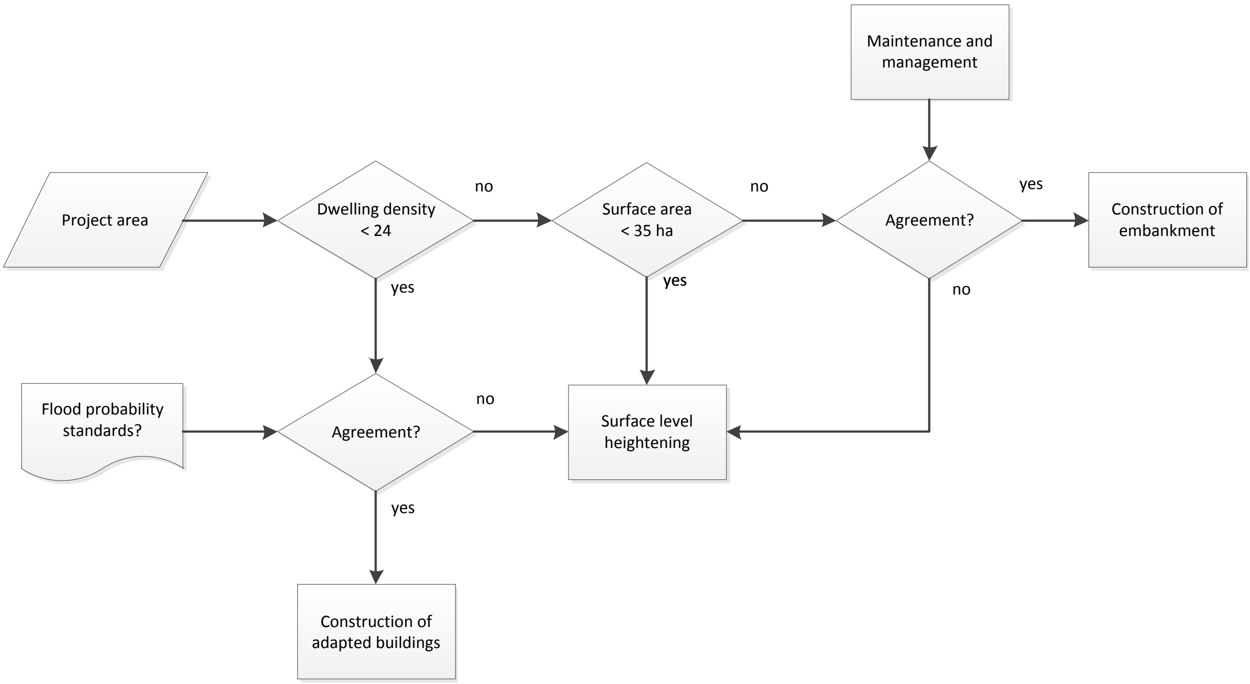

FIGURE 25: DECISION TREE FLOOD MANAGEMENT MEASURES

- Provincial legislation and municipal policy may influence the actual implementation as flood probability standards only aim to reduce the probability of a flood event. With this approach the consequences are not assessed. Municipalities need policy to facilitate flood adapted buildings as a surface level heightening policy does not fulfill to create flood adapted buildings. For the construction of an embankment agreements have to be made about maintenance and management.

5 How to deal with the residual risk?

- It is demonstrated that an economical efficient investment in flood management results in a residual risk. The acceptance of this risk is a social and political discussion.
- At this moment flood damage originating from fresh water can be compensated by the central government according to the Calamities and Compensation act. The physical operation of this law is an ex-post political decision which will only take place in the case a flood results in a considerable disruption of public safety and requires a coordinated effort of organization and civil services.
- Private flood insurance is unavailable in the Netherlands, mainly due to the specific characteristics of the Netherlands; large flood prone areas but high safety levels compared to other countries leading to high impact, low probability events which make insurability difficult. For unembanked areas this situation is different as these are mainly raised areas with a limited exposure (maximum loss). It is argued that due to the physical aspects and policy of unembanked areas the formulated criteria of insurability score better for unembanked areas. The actual realization will depend on the market determined criteria.

7. LITERATURE

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APPENDIX A: WATER LEVEL HEIJPLAAT

River discharges have to be transformed to hydraulic parameters like water levels and consequently to inundation depths. The water level statistics and their corresponding return periods are derived from the software module Hydra-BT. In particular with respect to residual risks model parameters should also be valid for extreme events (Oberle & Merkel, 2007).

The Hydra software is constructed for examining the primary flood defenses for compatibility with the appointed standard. This process requires modeling of many different load combinations. The water levels in a tidal river are calculated by combinations of sea water levels and storm surges at sea, discharges of the rivers Rhine and Meuse, the local wind (speed and direction), the control of structural works and the prediction of the sea water level near Hoek van Holland. Every combination has a certain probability of occurrence. This is not just a simple multiplication, because the values are correlated. Every combination leads to a certain maximum water level near Heijplaat. The combinations which lead to the same water level, we call state variable Z. The sum of all probabilities of all combinations which lead to a higher water level, we call the exceeding frequency of Z (Beckers, 2008).

The combinations used for this exercise are from the TMR2006 boundary conditions for the tidal river; at the moment the most up to date (Rijkswaterstaat, 2007).

The project area is protected for storm surges by two movable storm surge barriers; the Maeslant and Hartel storm surge barrier. These barriers close at an expected sea water level of 3,0 m + NAP. The probability of failure of both barriers (dependent failure at the same time) is assumed to be 1/100 per closing operation. This probability is changed in the Hydra software because in the design of the Maeslant storm surge barrier the criterion was applied that the probability of failure per closure should be no more than 1/1000. From further analysis appeared that this requirement could not be met, and would be around 1/100 (Inspectie Verkeer en Waterstaat, 2006) (Alkyon, 2008).

The used water level predictions for climate change scenarios are derived from bigger discharges in the rivers Rhine and Meuse and sea water level rise. The scenarios are described in Table 8 to Table 10.

Year	Minimum (m^3/s)	Middle (m^3/s)	Maximum (m^3/s)
Current	16000	16000	16000
2100	16800	17600	19200

TABLE 8: DISCHARGE OF THE RINE AT LOBITH AT RETURN PERIOD 1250 YEAR

Year	Minimum (m^3/s)	Middle (m^3/s)	Maximum (m^3/s)
Current	3550	3650	3650
2100	4200	4550	5300

TABLE 9: DISCHARGE OF THE MEUSE AT LITH AT RETURN PERIOD 1250 YEAR

Year	Minimum (m)	Middle (m)	Maximum (m)
2100	0,20 m	0,60 m	1,10 (m)

TABLE 10: SEA WATER LEVEL RISE

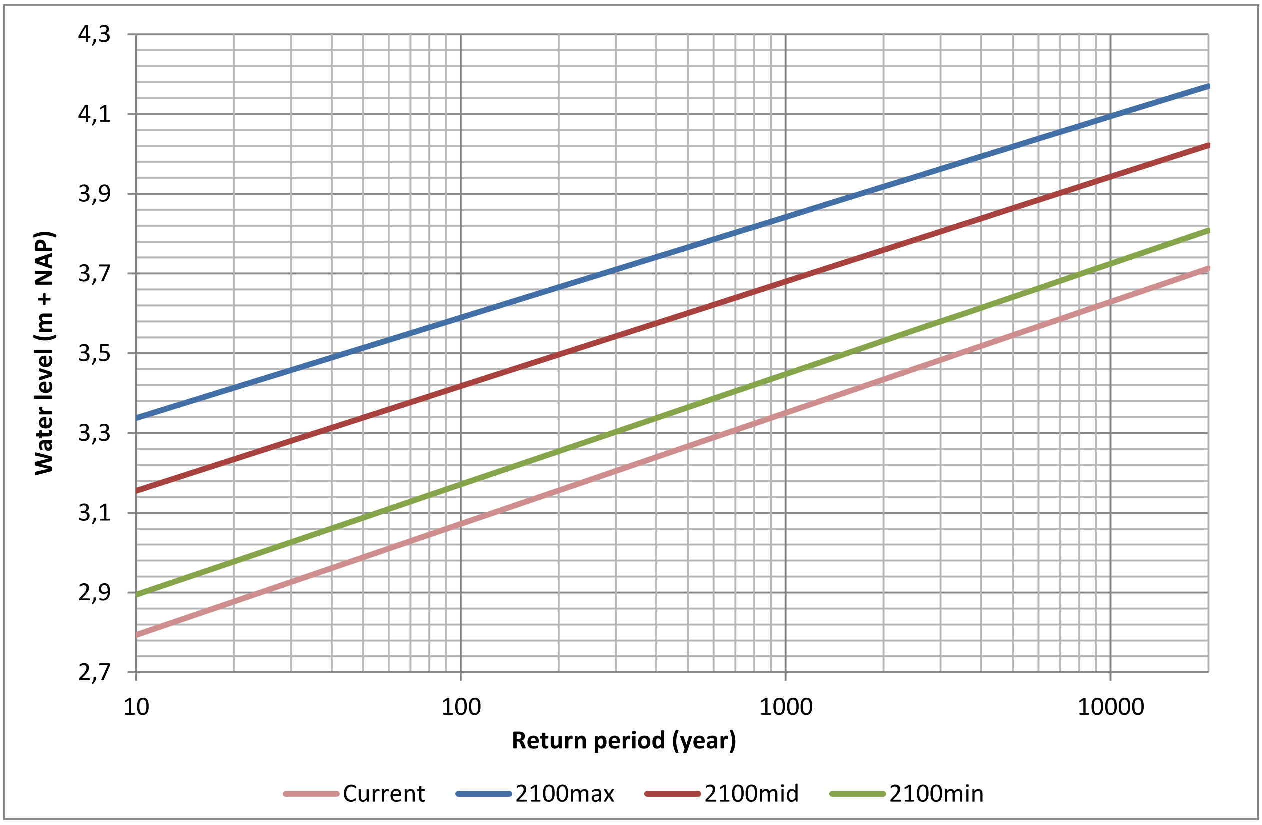

FIGURE 26: WATER LEVEL-FREQUENCY RELATIONSHIP

The water levels are calculated for 20 return periods ranging from 10 year to 20000 year. In Figure 26 the average water level of four calculation points is plotted for the current situation and different climate scenarios.

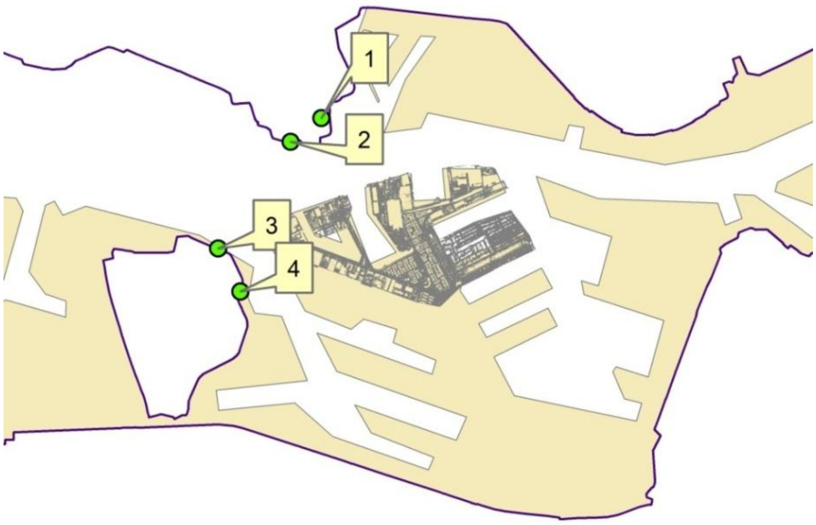

FIGURE 27: CALCULATION POINTS

As the hydra software is constructed for examination of the primary flood defenses, no information is available for unembanked areas. For this reason 4 calculation points surrounding the project area are used. For further analysis, the average water levels of these points are used.

Calculation point	Description	X-coordinate	Y-coordinate
1	Dike ring 14, Location 16	87565 m	435554 m
2	Dike ring 14, Location 22	87272 m	435330 m
3	Dike ring 18, Location 3	86578 m	434310 m
4	Dike ring 18, Location 8	86791 m	433901 m

TABLE 11: CALCULATION POINTS

Appendix B: Flood damage curves

For the evaluation of direct economic damage of a flood event, it is common to use stage-damage curves, describing the relation between the flood level and the amount of damage. The flood level is generally the most important and most frequently used inundation parameter in damage evaluation. The amount of damage can be described relative as part of the total assets or absolute. Another distinction is the way these curves are constructed. They can be empirical; constructed from flood damage evaluation of the past or synthetic; using hypothetical data such as repair costs for the fabric (Middelmann-Fernandes, 2010).

The availability of empirical up to date stage-damage curves for the Netherlands is small; due to the small statistical information of flood data in the Netherlands. Especially for small water depths, the precision of this method is limited; differences between buildings and their contents are neglected. The specific building methods in different countries make comparison between countries difficult, that's why for this assessment functions are used from the standard method 2004 constructed by Rijkswaterstaat; they comprise empirical flood damage data from the past such as the catastrophic flood in 1953 in the Netherlands and later events, like local flooding caused by high discharges in the river Meuse in 1993, combined with existing literature and expert judgment (Kok, Huizinga, Vrouwenvelder, & Barendregt, 2005) (Jonkman, Bočkarjova, Kok, & Bernardini, 2008). Considering wet and dry proof dwellings synthetic stage damage curves are estimated according to the available literature as there is no experience with flood damage with these dwellings in the Netherlands.

The critical flow rate for brickwork dwellings within this method is assumed to be 2 m/s, above this velocity the dwelling will collapse.

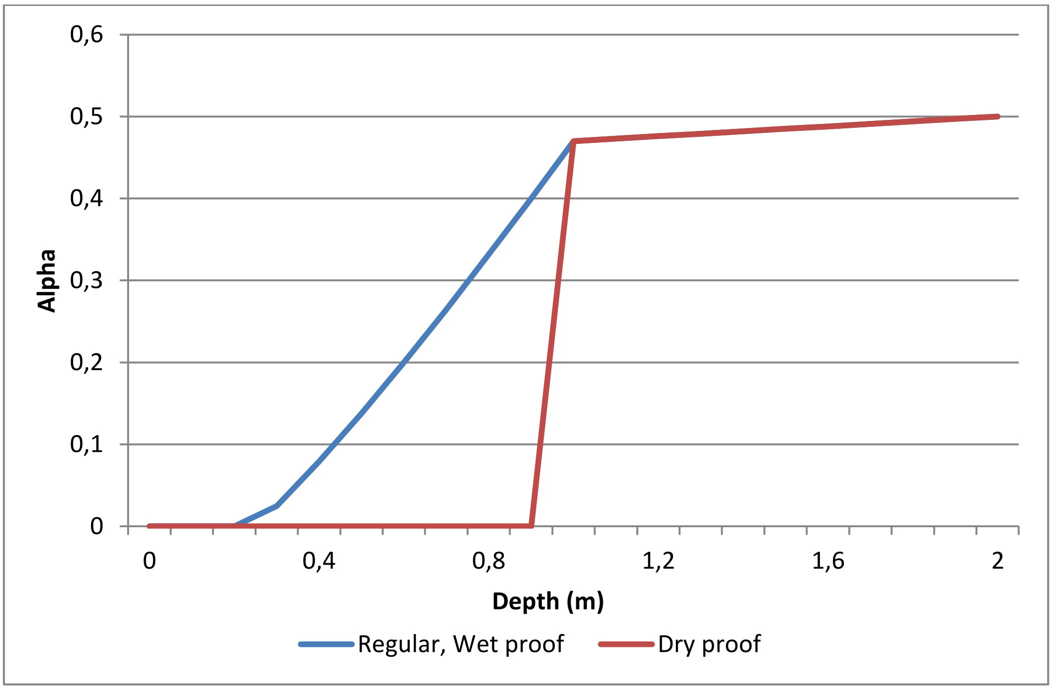

FIGURE 28: SUSCEPTIBILITY TO CONTENT OF DWELLING

$$If\ d\ \leq 0{,}9\ Then\ a\ = 0 \text{ \{dry proof dwellings\}}$$

$$If\ d\ \leq 1\ Then\ a\ = -0{,}47 * \sqrt{d} + 0{,}94 * d$$

$$Else: If\ d\ \leq 2\ Then\ a\ = 0{,}03 * d + 0{,}44$$

$$\propto = \max(0; \max(a; 0))$$

Dry proof dwellings are designed to keep the flood water out until 0,9 meter and thereby no damage will occur to the contents until 0,9 m. It has to be noted that damage to contents is highly correlated with risk communication. In the case of high discharge peaks from the river Rhine and Meuse these can be predicted around five days ahead for the river Rhine and around one or two days for the river Meuse. Storm surges can relatively accurate predicted two days ahead. In the case these peaks are good communicated residents are able to move their contents to higher floors.

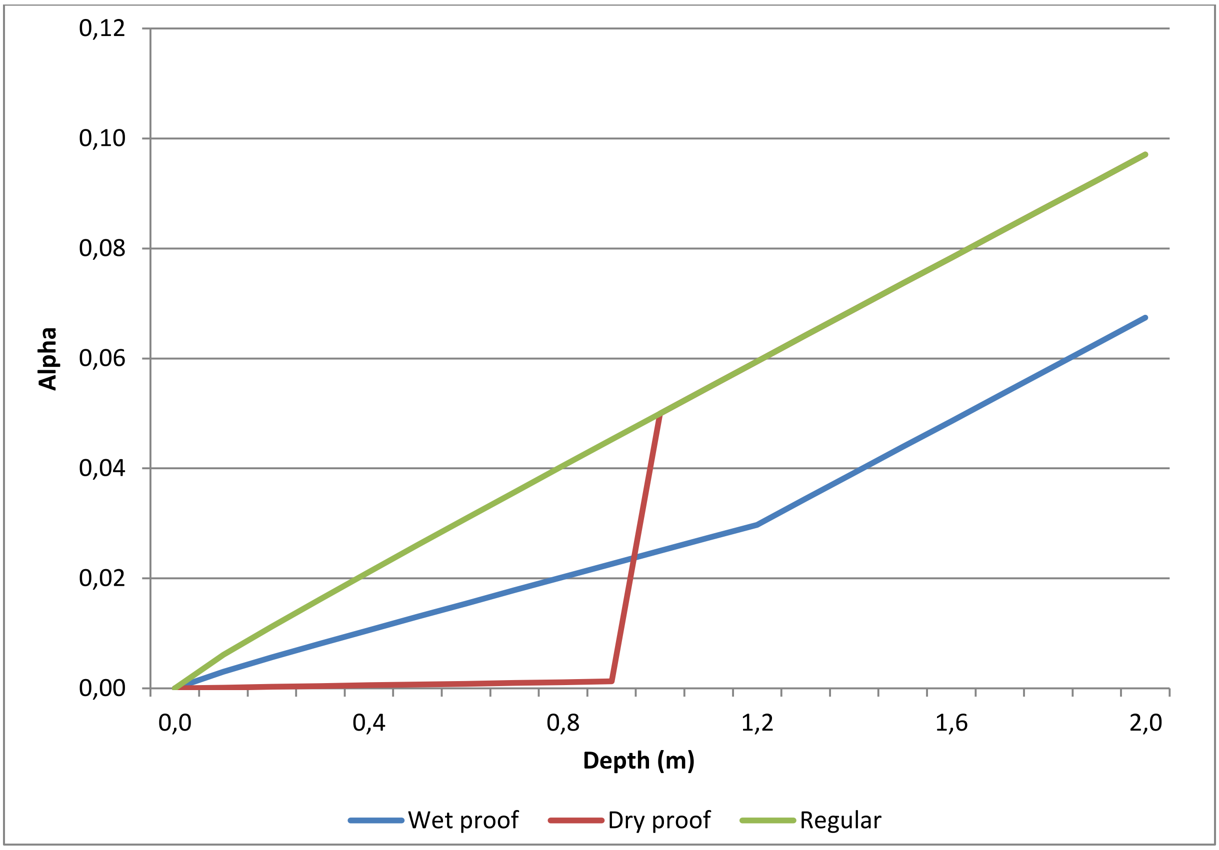

FIGURE 29: SUSCEPTIBILITY TO STRUCTURE OF DWELLING

$$If\ d\ \leq 2\ Then \propto = 0{,}005 * \sqrt{d} + 0{,}045 * d \text{ \{regular dwellings\}}$$

$$If\ d\ \leq 0{,}9\ Then\ \propto = 0{,}0014 * d \text{ \{dry proof dwellings\}}$$

$$Else: If\ d \leq 2\ Then \propto = 0{,}005 * \sqrt{d} * 0{,}045 * d$$

$$If\ d\ \leq 1{,}2\ Then\ \alpha\ = 0{,}0025 * \sqrt{d} + 0{,}0225 * d \text{ \{wet proof dwellings\}}$$

$$Else: If\ d\ \leq 2\ Then\ \alpha = 0{,}047 * d - 0{,}0266$$

Dry proof dwellings are assumed to keep the water outside until 0.9 meter, cleaning costs are assumed until this depth at €4,- /m^2, 50 € start up, and a mean circumference of a dwelling of 35 meter. Above this inundation depth the dry proofing technique has no effect and the damage will occur as a regular dwelling.

After Analyzes of the stage damage curves of Gersonius et al. (2008) and a study of Kreibich et al. (2005) of the 2002 Elbe flood it was assumed that wet proofing a dwelling will result in 50% damage reduction until 1,2 m and above this depth will have the same angle as a regular dwelling. It was founded from the Elbe flood that flood adapted interior fitting resulted in 53% damage reduction; and was founded mainly effective for frequent small floods (Kreibich, Thieken, Petrow, Müller, & Merz, 2005)

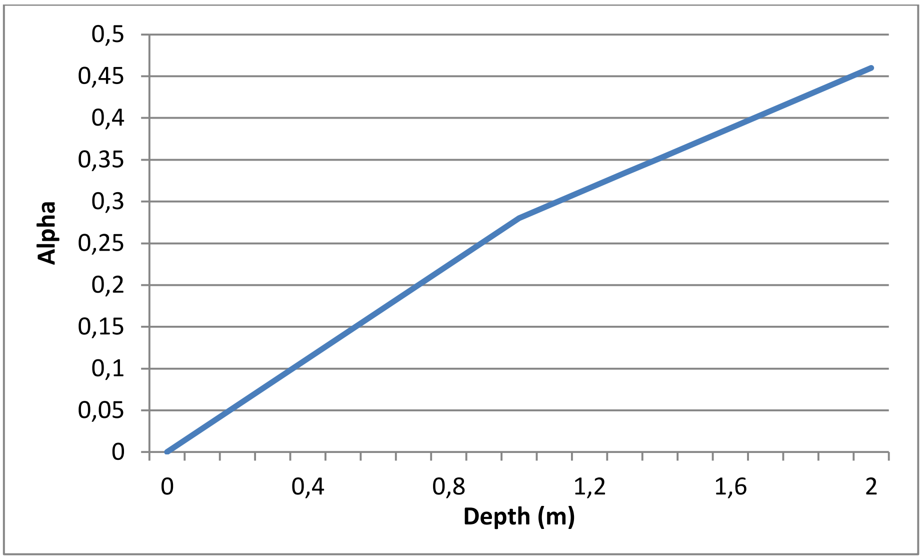

FIGURE 30: SUSCEPTIBILITY TO ROADS

$$\propto = \min(0{,}28 * d; 0{,}18 * d + 0{,}1; 1)$$

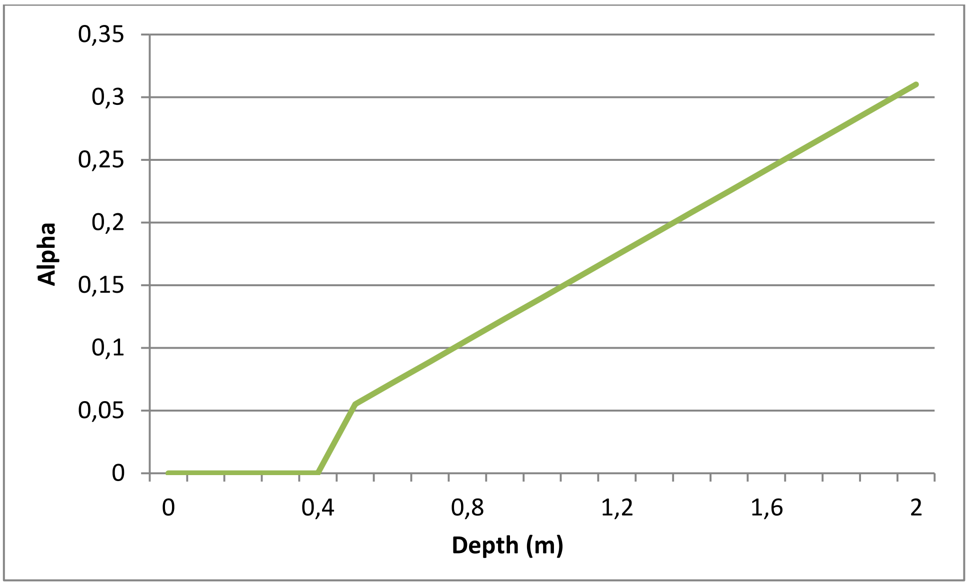

FIGURE 31: SUSCEPTIBILITY TO CARS

$$\propto = \max(0; \max(\min(0{,}17 * d - 0{,}03; 0{,}72 * d - 0{,}3; 0{,}31 * d + 0{,}1; 1);\ 0)$$

APPENDIX C: COSTS

Damage

The flood damage is assessed with the following formula:

$$S = \sum_{i=1}^{n} \alpha_i S_{max,i}$$

Where S is the total damage, alpha the relation with the water level for a category i, n are the number of categories and S_{max} is the maximum damage for a category i.

Cost estimations have been made using experts, papers and construction costs websites. Table 12 shows maximum damages (S) for each category.

Type	Costs	Source
Content	91.728[11] €/dwelling	(Kok, Huizinga, Vrouwenvelder, & Barendregt, 2005)
Dwelling	775 €/m^2 GFA[12]	Woonbron Development Company
Paving brick	15,42 €/m^2	www.bouwkostenonline.nl
Car	10.500 €/car	ARN, BOVAG, SN[13]

TABLE 12: MAXIMUM DAMAGES

The content and car values constitute residual values and the dwelling and paving brick constitute replacement values.

Investment costs

The investment costs of surface level heightening consists of:

Action	Costs (€/m^3)
Buying	7
Extraction	0,5
Transport (30 – 40 km)	3
Unload	0,5
Intern transport	1
process	0,5
Total	12,5

TABLE 13: COST ESTIMATION SURFACE HEIGHTENING (EXPERT JUDGEMENT DHV)

Flood adapted buildings

Zevenbergen et al. (2007) estimates the cost of flood adapted buildings as €8000 for dry proofing dwellings and €1300 for wet proofing dwellings. These costs are translated to the current price level.

[11] Adjusted to price level 2011 according to price index figures of dwelling contents of Dutch Association of Insurers

[12] Gross Floor Area: Floor area inside the building envelope: includes external walls

[13] According to the Dutch center of expertise for recycling in the mobility sector (ARN) the average age of their incoming vehicles is 16,4 year; no value is assumed at this age. The average age of a car is 8,6 year according to Statistics Netherlands and the average replacement value is 22.075 €. A linear relation was assumed.

	Dry proofing	Wet proofing
Investment costs	€9152,-	€1487,-

TABLE 14: COSTST ESTIMATION FLOOD ADAPTED BUILDINGS[14] (ZEVENBERGEN, GERSONIUS, PUYAN, & HERK, 2007)

The investment costs of elevated dwellings by building on walls are shown in Figure 32 (Gersonius, Zevenbergen, Puyan, & Billah, 2008).

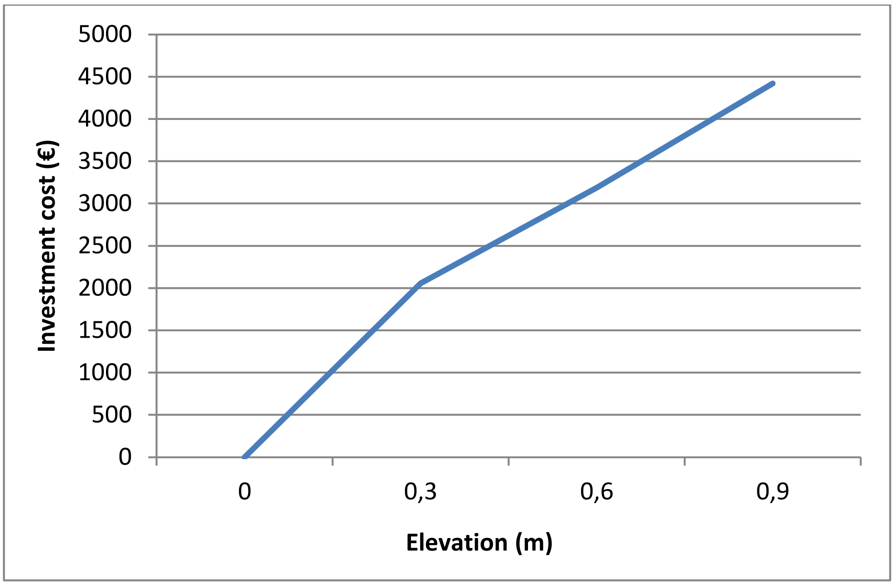

FIGURE 32: INVESTMENT COSTS ELEVATED DWELLING BY BUILDING ON WALLS

Embankment

For the construction of an embankment, the core of the dike is assumed to be from clay, covered with grass. This is a usual method for river embankments. Because the embankment occupies ground surface area which could otherwise be used for dwelling exploitation, this is included by the reduced profit of the dwelling exploitation.

Clay	17,50 €/m^3 (Expert judgment DHV)
Apply grass	0,0971 €/m^2 (www.bouwkostenonline.nl)
Reduced profit dwelling exploitation	360 €/m^2 (Woonbron ontwikkel company)

TABLE 15: COST ESTIMATION EMBANKMENT

[14] Prices adjusted to January 2011 price level according to price-index figure construction costs of new dwellings of Statistics Netherlands

Appendix D: Sensitivity analysis

D1: Model parameters

To be acquainted how model output changes when model parameters are changed a sensitivity analysis has been performed. The objective is to know whether the preference of alternatives change with different model parameters and stage damage curves. To do this an individual parameter variation study has been performed; individual parameters are altered to analyze the effect of this change on the B/C ratio of the different measures.

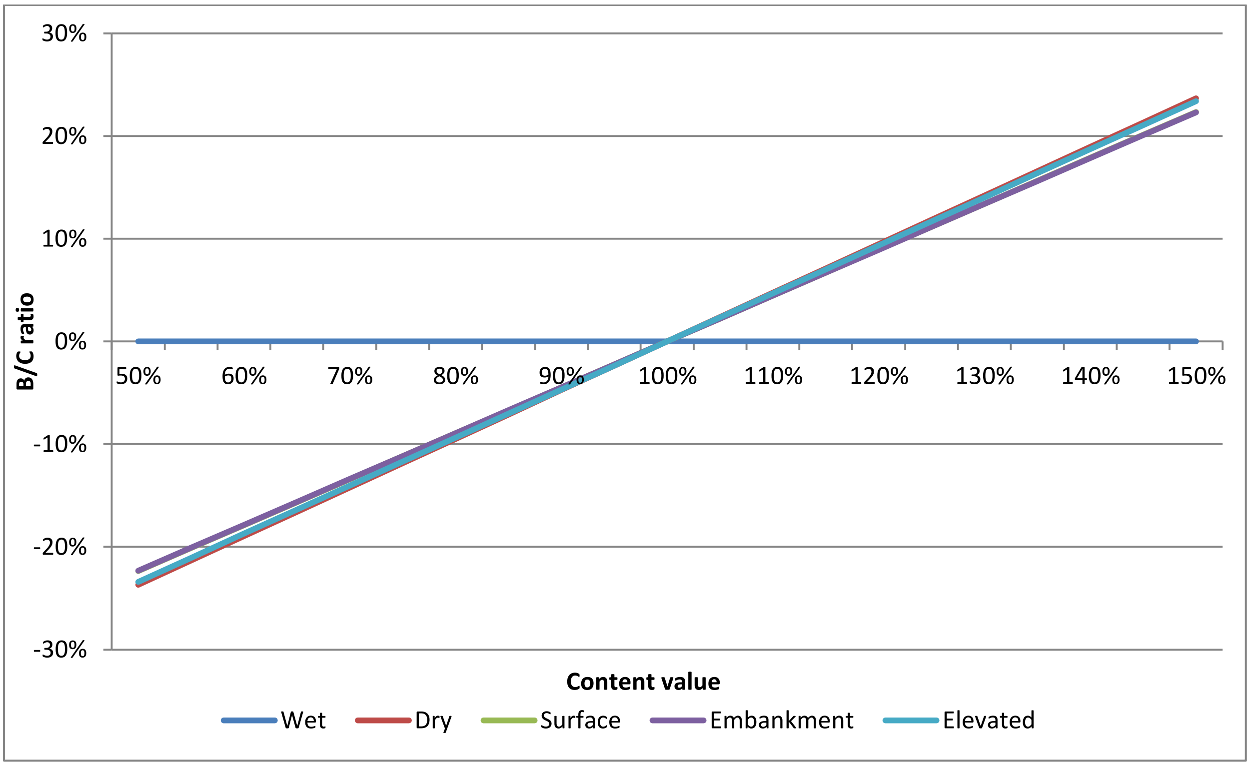

FIGURE 33: CHANGE OF B/C RATIO AS A FUNCTION OF CHANGE OF CONTENT VALUE

As can be seen from Figure 33 the B/C ratio of wet proof buildings does not change due to an alteration of the content value because this measure does not protect the contents of the dwelling. The benefit i.e. the prevented damage compared to a regular dwelling stays the same. For the other measures the prevented damage is higher with a higher content value resulting in a higher B/C ratio.

Figure 34 shows that wet proof dwellings are much more sensitive (1:1) to changes of the replacement costs of dwellings than other measures. This is mainly wet proof dwellings are not sensitive to the value of the content of the dwelling. This strong sensitivity changes the preference of the different measures; when the replacement costs are 2,4 times higher, a wet proof dwelling is preferred above constructing an embankment.

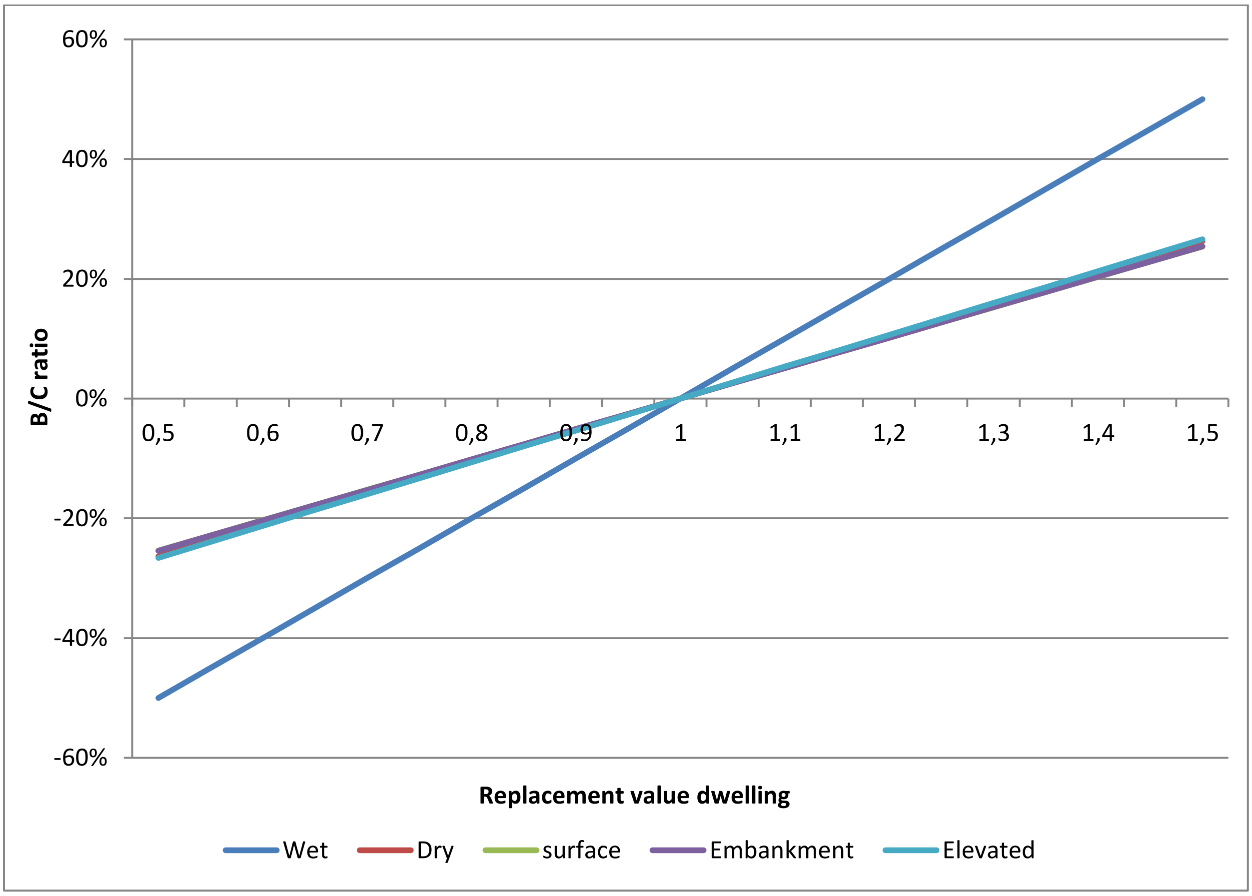

FIGURE 34: CHANGE OF B/C RATIO AS A FUNCTION OF CHANGE OF REPLACEMENT VALUE DWELLING

Figure 35 shows the B/C ratio as a function of the initial surface level. The initial surface level has a big influence on the profitability of different measures. Between wet and dry proofing and elevated dwellings and the construction of an embankment also a preference difference can be noticed

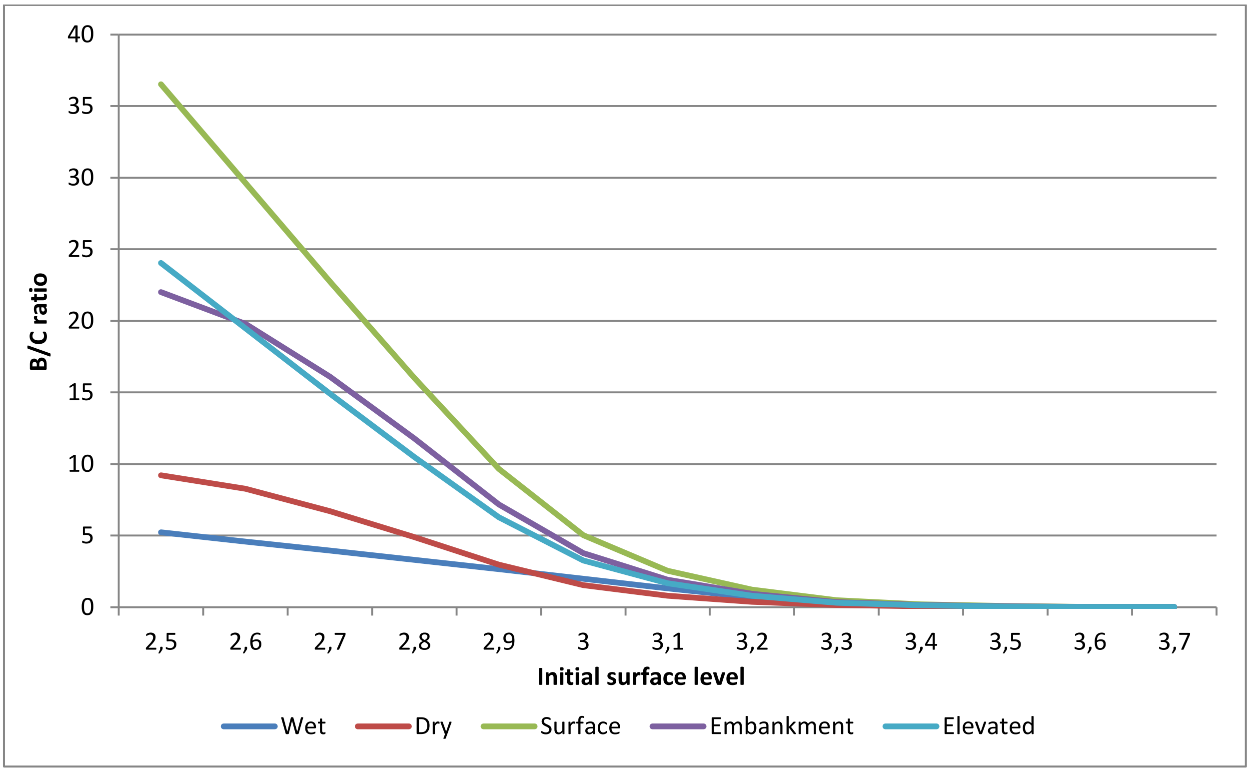

FIGURE 35: CHANGE OF B/C RATIO AS A FUNCTION OF INITIAL SURFACE LEVEL

D2: STAGE DAMAGE CURVES

For this analysis all parameters of the stage damage curves are altered. As 'Alpha' is multiplied with the maximum damage and thus entails the damage and thereby affects the benefits of the benefit cost analysis the benefits cost ratio for a bigger alpha increases.

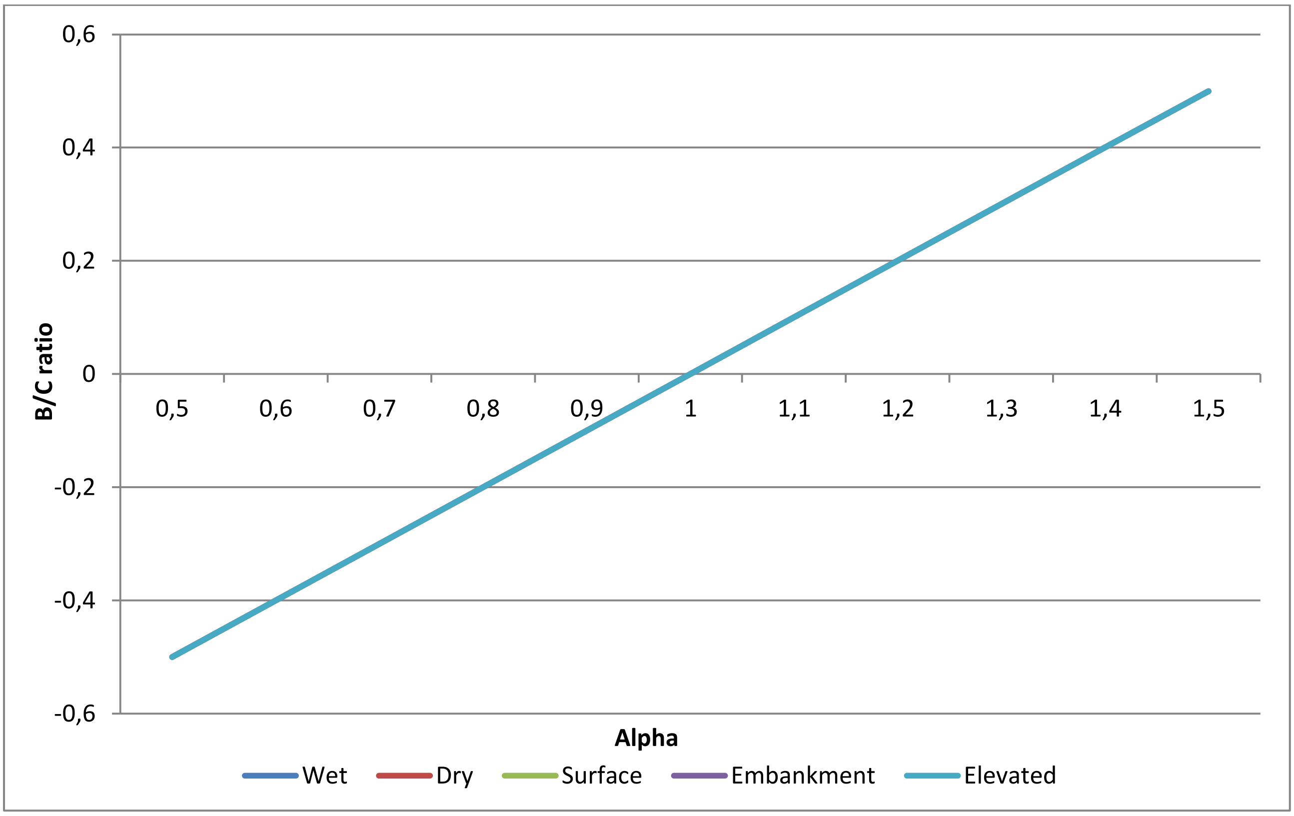

FIGURE 36: CHANGE OF B/C RATIO AS A FUNCTION OF THE STAGE DAMAGE CURVE