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Adaptive strategies for the Rotterdam unembanked area

Synthesis report



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Adaptive strategies for the Rotterdam unembanked area

Synthesis report

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1 Summary

A significant part of the Rotterdam urban area is not protected by the primary levee system. Due to climate change and urbanization of the former port areas the vulnerability of this area to flooding is increasing. The question is whether small-scale adaptive measures in public space or water-proof architecture can contribute to reducing the vulnerability of these flood prone areas. The aim of this research is to develop more knowledge on and evaluate adaptive strategies and measures for existing and newly developed residential areas located outside the primary water defences in the Rijnmond –Drechtsteden region.

This research focuses on two cases in the unembanked area of Rotterdam, Noordereiland and Feijenoord. In the first part of the research a detailed analysis of local floods and an assessment of the effects and impacts has been conducted. Based on a policy framework and a tipping point (ATP) analysis the moments are defined when and at what water levels a flood event is regarded not acceptable. These tipping points provide input for the design research.

The ATP method also proved to be an effective method to investigate which combinations of adaptive measures are able to deal with different possible climate scenarios and to define the moments when it is wise to switch to a different measure. This has given much insight into the long-term feasibility of an adaptive flood risk strategy.



2 Uitgebreide Nederlandse samenvatting

De regio Rotterdam wordt beschermd door een netwerk van hoofdwaterkeringen, die niet alleen het stedelijk gebied beschermen, maar ook de laaggelegen polders van de Randstad. De regio heeft een uitgebreid buitendijks gebied dat buiten de bescherming van de primaire waterkeringen ligt. Dit buitendijkse gebied is kwetsbaar voor overstromingen (Veerbeek, et al 2010, Veelen, et al 2010). Een groot deel van dit gebied is in de loop der tijd opgehoogd tot ca. 3 – 3,5 meter boven NAP. Slechts enkele, overwegend historische havengebieden, hebben te maken met een hoger risico op schade door overstromen (Veerbeek et al, 2010). In de komende periode zal het overstromingsrisico toenemen door het gecombineerde effect van stijgende waterniveaus door klimaatverandering en het doorgaande proces van verstedelijking van de voormalige haven- en industriële gebieden. De vraag is hoe deze bestaande en nog te ontwikkelen gebieden kunnen worden beschermd. Het doel van dit onderzoek is om meer kennis te ontwikkelen over adaptieve strategieën en maatregelen voor bestaande en nieuw te ontwikkelen woon- en werkgebieden in het buitendijkse gebied van de regio Rijnmond-Drechtsteden.

Er zijn ruwweg twee strategieën waarmee op het toegenomen risico kan worden gereageerd: een regionaal-preventieve strategie en een lokaal-adaptieve strategie. De regionaal-preventieve strategie richt zich op het verminderen van de kans op rivier- en kustoverstromingen door passieve en robuuste oplossingen zoals waterkeringen en grootschalige ingrepen in de delta (Zevenbergen, et. al., 2008). Een lokaal-adaptieve strategie richt zich op adaptatie op lokaal schaalniveau door het integreren van waterveiligheid met stedelijke functies, waarbij gebruik wordt gemaakt van de dynamiek van stedelijke ontwikkelprocessen. Deze benadering richt zich op het verminderen van de gevolgen van een overstroming door het inzetten van water robuuste architectuur en lokale adaptieve maatregelen in de overstromingsgevoelige gebieden.

Om deze lokale adaptatie in te kunnen zetten is het nodig om nieuwe planningsmethoden te ontwikkelen die beter in staat zijn om om te gaan met lange lange termijn onzekerheid. Een planningsconcept dat past bij deze benadering staat bekend als een *managed-adaptive strategy* (Gersonius, 2012). Met deze methode is het mogelijk om met stapsgewijze aanpassingen toekomstige, maar onzekere opgaven het hoofd te bieden door mogelijkheden open te houden en het herkennen van doodlopende richtingen in een vroeg stadium. Met behulp van deze methode is het mogelijk om verschillende strategieën of adaptatiepaden te ontwikkelen, die alle leiden naar hetzelfde einddoel.

De *managed-adaptive strategy* start met het afwegen van alternatieve oplossingen. Een bruikbare methode om alternatieve oplossingen af te wegen of te vergelijken is de Adaptatie Knikpunten Methode (Adaptation Tipping Points). Een Adaptatie knikpunt wordt gedefinieerd als het moment of de gebeurtenis waarbij klimaatverandering een dusdanige situatie bereikt, dat eerder vastgestelde beleidsdoelen niet meer haalbaar blijken te zijn en het nodig is om van strategie te veranderen (te Linde, 2011). In lijn met deze methode staat de me-



thode van Adaptatiepaden (*Adaptation Pathways*). Adaptatiepaden beschrijven een reeks van watermanagement maatregelen, waardoor beleidsmakers inzicht krijgen in de robuustheid of flexibiliteit van strategieën om veranderende condities, zoals klimaatverandering, het hoofd te bieden. Beide methoden zijn toegepast in dit onderzoek.

Als eerste stap (werkpakket 1) is gedetailleerd onderzoek gedaan naar het overstromingsgedrag en de mogelijke effecten van een overstroming, zoals fysieke schade aan bebouwing of problemen door het uitvallen van nutsvoorzieningen. Daarbij is ook rekening gehouden met het lange termijn effect van zeespiegelstijging door klimaatverandering. Het buitendijkse gebied van Feijenoord bestaat voornamelijk uit oude havengebieden die in de loop van de 20^e eeuw geleidelijk zijn getransformeerd naar woongebieden. Daarnaast zijn er belangrijke publieke voorzieningen als de spoorverbinding van de hogesnelheidstrein, een metrohalte en grote industriële bedrijven, zoals Unilever te vinden in gebieden die getroffen kunnen worden door een overstroming. Samen met studenten van de hogeschool Rotterdam zijn alle panden in de overstromingsgevoelige gebieden onderzocht en beoordeeld op mate van kwetsbaarheid voor hoogwater. Een belangrijke conclusie uit dit veldwerk is dat een groot deel van de bestaande bebouwing door opgehoogde entrees en natuurstenen plinten minder kwetsbaar is voor overstromingen dan eerder aangenomen. Daarnaast werd echter ook duidelijk dat nutsvoorzieningen, als elektriciteit en riool gevoelig zijn voor overstrooming omdat het herstel langdurig en kostenintensief kan zijn. Het ontbreken van goede risicocommunicatie en duidelijkheid over de rolverdeling bij de verschillende overheidsdiensten versterkt de gevoeligheid van het gebied voor een calamiteit. Om knikpunten te kunnen bepalen bleek het nodig te zijn om beleidsnormen voor overstromingsrisico en schade te kiezen, waarmee grenswaarden konden worden bepaald. Aan de hand van deze beleidsnormen zijn de studiegebieden geanalyseerd en bepaald in welke gebieden en bij welke waterstanden de grenswaarden worden overschreden.

In het tweede deel van het onderzoek (werkpakket 2) zijn mogelijke adaptieve maatregelen onderzocht. Door middel van een gedetailleerd ontwerpend onderzoek in twee cases (Noordereiland en Kop van Feijenoord) zijn de meest kansrijke adaptieve maatregelen om de kwetsbaarheid te verminderen geïdentificeerd. Deze maatregelen zijn beoordeeld op technische en juridische haalbaarheid en de ruimtelijke inpassing is bekeken. Alle denkbare maatregelen zijn verzameld in een 'toolbox' van hoogwater-adaptieve maatregelen. De toolbox is een hulpmiddel om een keuze te kunnen maken welke maatregelen het meest geschikt zijn voor een gebied. Bovendien is onderzocht hoe deze maatregelen zo veel mogelijk gekoppeld konden worden aan gebiedsontwikkelingsprojecten.

Daarnaast is onderzocht wat het draagvlak is bij bewoners en andere stakeholders voor deze maatregelen en is onderzocht of deze maatregelen te borgen zijn in huidige planvormen en bouwregels. Dit heeft geresulteerd in een selectie van de meest haalbare en kansrijke maatregelen voor de twee cases.

Een vervolgvraag is of deze maatregelen ook op de lange termijn, bij een verder stijgende zeespiegel en stijgende rivierwaterstanden, voldoende veiligheid en schadereductie bieden. Om hierop een antwoord te kunnen geven is per maatregel in beeld gebracht tot welke maximale waterstand de maatregel naar verwachting nog effectief is. Deze maximale waterstand is bepaald door technische randvoorwaarden te analyseren, maar ook door te onderzoeken tot welke mate maatregelen ruimtelijk nog in te passen zijn. Door dit onderzoek is het mogelijk om de maatregelen te koppelen aan klimaatscenario's en daarmee inzicht te krijgen in de maximale en minimale tijdsperiode waarbij de maatregelen nog effectief zijn. Daarmee wordt ook duidelijk met welke combinaties van maatregelen de kwetsbaarheid van het gebied kan worden vermindert en wanneer in de tijd het verstandig is om over te stappen van de ene maatregel op een andere.

Als laatste deel van het onderzoek is onderzocht aan de hand van een GIS analyse welke mogelijkheden de gebiedsontwikkeling biedt voor kansen om mee te koppelen. Dit onderzoek naar de verwachte renovatie en vernieuwing van gebouwen, buitenruimte en infrastructuur geeft inzicht in de zogenaamde adaptieve capaciteit van het gebied.

De belangrijkste conclusie van het onderzoek is dat de kwetsbaarheid van de Rotterdamse buitendijkse gebieden, als we kijken naar schades, slachtoffers en de uitval van vitale infrastructuren, momenteel beperkt is. Er is echter nog maar weinig bekend van de direct en indirecte impacts van mogelijke sneeuwbal effecten bij de uitval van bijvoorbeeld elektrische netwerken. Hoewel er dus op de korte termijn geen urgente reden is om te handelen, is de lange-termijn kwetsbaarheid van het gebied door zeespiegelstijging een reden tot zorg. Het is daarom noodzakelijk om een adaptatie-strategie te ontwikkelen om risico, hoge kosten en ongewenste ruimtelijke situaties te voorkomen, op de lange termijn.

Voor het gebied Kop van Feijenoord blijkt het voor de hand te liggen om de laaggelegen Nassaukade of de gebieden direct achter de kade op te hogen, waardoor het laaggelegen gebied van de Oranjeboomstraat veel beter beschermd is voor hoogwater. Bij het ophogen of aanleggen van de kade kan gebruik worden gemaakt van reeds geplande ontwikkelingen in het gebied. Twee oplossingsrichtingen zijn het meest interessant: het maaiveld van de geplande nieuwbouwwijk langs de Nassaukade en Oranjeboomstraat kan zodanig worden opgehoogd dat de achterliggende wijk beschermd wordt tegen regelmatige overstroming, waardoor in een klap een groot deel van het gebied beschermd is tegen hoogwater. Aanpassingen aan bestaande gebouwen zijn dan niet nodig. Een tweede mogelijkheid is om de herstructurering van de Nassaukade en de plannen voor een nieuwe brug naar het Noordereiland te benutten voor de constructie van een parkachtig opgehoogd boulevard die als een 'minidijk' het gebied beschermt tegen hoogwater.

Een lokale en integrale waterveiligheidsstrategie, gebaseerd op een gedetailleerde kwetsbaarheidsanalyse, is in veel gevallen een kosten-effectieve oplossing omdat investeringen voor waterveiligheid beter kunnen worden gepriori-



teerd en gekoppeld aan investeringen in gebiedsontwikkeling. Dit onderzoek heeft echter niet kunnen aantonen dat deze benadering ook op de lange termijn bijdraagt aan een kosten-effectieve en een meer flexibele aanpak van waterveiligheid. Om dit aan te kunnen tonen is een uitgebreide kosten-batenanalyse nodig.

Een belangrijke voorwaarde voor de inbedding van adaptieve maatregelen in ruimtelijke ontwikkelingsprocessen is het creëren van draagvlak en ondersteuning bij stakeholders, waaronder bewoners, omdat dit de legitimiteit van het besluitvormingsproces versterkt en mogelijkheden creëert voor meervoudige adaptieve oplossingen. Dit betekent dat het belangrijk wordt om nieuwe adaptieve *governance* methoden en innovatieve financiële, wettelijke en organisatorische arrangementen te ontwikkelen om een lokale adaptieve waterveiligheidsstrategie te kunnen faciliteren. Een belangrijke aanbeveling die uit dit onderzoek kan worden gehaald is dat het noodzakelijk is om duidelijkheid te verschaffen over de publieke en private verantwoordelijkheidsverdeling en het ontwikkelen van meer kennis over adaptieve governance arrangementen.

De knikpuntenmethode en het werken met adaptatiepaden bleek een effectieve methode om systematisch de effectiviteit van combinaties van maatregelen te onderzoeken. Het werken met adaptatiepaden is een effectief middel om in een context van onzekerheid inzicht te krijgen in lange termijn effecten van strategieën en deze door te vertalen naar korte termijn keuzes. De knikpuntenmethode en adaptatiepaden methode zijn echter op de lokale schaal alleen effectief als er gedetailleerde informatie over bijvoorbeeld overstromingsrisico, schades en maatregelen voorhanden is. Dit zorgt ervoor dat de methode minder geschikt is voor concrete planvorming, maar eerder een hulpmiddel bij de ontwikkeling van strategie en lange termijn besluitvorming (Stone, 2012).



3 Extended summary

A network of primary flood defences protects the city of Rotterdam and the deeply subsided polders of the Randstad conurbation. The region also has a large and highly developed urban area, which lies outside of the protection of this primary defence system. These unembanked areas are already vulnerable for flooding (Veerbeek, et al 2010, Veelen, et al 2010). The largest part of the area has been gradually raised to 3 to 3,5 meters above average sea level and only a few, mostly historic port areas run a high risk of sustaining flood damage (Veerbeek et al, 2010). In the next decades the risk of flooding is increasing due to the combined process of rising water levels due to climate change and the ongoing process of urbanization of the former port and industrial areas. The question is how to protect these existing and yet-to-be-built residential areas. The aim of this research is to develop more knowledge on and evaluate adaptive strategies and measures for existing and newly developed residential and industrial areas located outside the primary water defences in the Rijnmond – Drechtsteden region.

There are roughly two strategies with which we can respond to the increased flood risk: a regional-preventive and a local-adaptive strategy. The regional-preventive strategy focuses on reducing the probability of urban fluvial and coastal flood risk by passive, robust solutions, such as urban water defences and major interventions in the Dutch delta (Zevenbergen, et. al., 2008). A local-adaptive strategy focuses on adaptation at a local scale by integrating flood risk management measures with urban functions, using the dynamics of urban development processes. This approach aims to reduce the consequences of an inundation by promoting flood resilience architecture and local adaptive measures in the flood-prone areas.

To do so it is necessary to develop new concepts and planning methods for applying local adaptation. A planning concept that is in line with this approach is a managed/adaptive strategy. This type of strategy allows for easier adaptation in the future via incremental adjustments by keeping options open or recognize at an early stage future lock-in situations. Based on this approach it is possible to develop multiple strategies or pathways that lead to the same objectives. A useful framework to assess current policies or to compare and weigh alternative solutions is the Adaptation Tipping Point (ATP) method. An Adaptation Tipping Point is defined as the moment or event, when climate change effects reach such an extent that given policy objectives can not be met anymore and an alternative strategy is needed (te Linde, 2011). A promising method to deal with uncertainty is the Adaptation Pathway method. *Adaptation pathways* (AP's) describe a sequence of water management policies (or measures), enabling policy makers to explore options for adapting to changing environmental and societal conditions in time. Both methods are applied and tested in this research.



As a first step in developing possible flood risk management strategies for the Rotterdam unembanked area a detailed analysis of the vulnerability of the current system was performed. By systematically analysing the possible flood risk and impacts of the flood on housing, vulnerable functions and vital infrastructures, the vulnerability of the Rotterdam-Rijnmond unembanked area for the current flood conditions and two climate change scenarios is identified. As a second step it proved to be necessary to develop a clear set of policy objectives and to convert these objectives to a set of critical boundary conditions or thresholds (work package 1). Based on this research a norm-based performance assessment of individual areas was applied using the ATP method.

The second phase of the research consist of elaborating possible adaptive measures, which are able to solve or postpone the tipping points. Through a detailed research-by-design in two study areas (Noordereiland and Kop van Feijenoord) the most promising adaptive measures to reduce the flood risk were identified. These measures were assessed on legal, spatial, economical and technical feasibility in several expert sessions. Furthermore, an in-depth analysis of the acceptability of these measures among stakeholders (governance aspects of measures) and an assessment of legal aspects has been executed, resulting in a selection of most preferred measures for the two cases (work package 2).

Using an ATP analysis the sustainability of the current policy as well as the proposed flood risk reducing measures has been evaluated. This research delivered input for analysing different options and adaptive pathways in time to build up an adaptive strategy. Finally, the adaptive capacity of the urban area and opportunities to mainstream with urban development processes was analysed, resulting in components of a local flood risk policy for the case study area Feijenoord and Noordereiland (work package 3).

The overall conclusion of this research is that the vulnerability of the Rotterdam unembanked area to flooding, in terms of damages, casualties and loss of vital infrastructures is limited. There is still, however, little known of the sensitivity of vital infrastructures to flood situations and indirect impacts of possible multiplier effects that might affect large part of the city. Although there is no urgent need for flood impact reduction of the Rotterdam unembanked areas on the short-term, the unembanked area is vulnerable for sea level rise on the long run. It is, therefore necessary to develop an adaptation strategy to avoid risk, high costs and unwanted spatial situations in the long run.

For the Noordereiland it is shown that dry-proofing measures are highly effective in reducing the flood risk. Flood defence measures are slightly less effective but will still provide sufficient flood risk reduction for at least a period of 35 years. For the Kop van Feijenoord dry-proofing measures are not sufficient to reduce flood risks due to the large encountered water depths. For this area the flood defence measures show the highest effectiveness. Both cases show that determination of the most appropriate solutions largely depends on the local physical and socio-economic conditions.



An integrated local flood risk strategy, based on a detailed vulnerability assessment, is in many cases on the short term cost-effective because investments in flood risk reduction can be more focused and mainstreamed with spatial development processes. This research has, however, not proved that this approach in the long term also contributes to a more cost-effective and more flexible approach. An important prerequisite for the implementation of adaptive measures in spatial development is developing support from stakeholders, including residents, because this increases the legitimacy of the decision-making process and creates opportunities for mutually approved integrated measures. This means that developing adaptive governance methods and innovative financial, legal and organizational arrangements to facilitate a local adaptive flood risk strategy is extremely important. The main recommendation that can be derived from this research is that it is necessary to come to a debate on public and private responsibilities regarding flood risk and develop knowledge on adaptive governance arrangements.

The tipping point approach has proved to be a useful instrument to systematically assess and elaborate the adaptive measures. It is however a time-consuming technique, that relies on very detailed analysis of vulnerabilities and effectiveness of measures and a consensus among policy-makers and stakeholders on objectives and thresholds. In situations where these detailed information or a common consensus of objectives and thresholds is lacking the ATP and AAP method is less useful as a decision support method, but should be used as a test and research method to explore the limits and directions of a strategy or policy. It is recommended to test and further develop the ATP and AAP method in other small-scale cases, in other long-term decision-making processes and under different conditions.



4 Introduction

Local adaptation as a future flood risk strategy

The region of Rotterdam is vulnerable for both tidal and pluvial floods. The majority of this urbanized region is protected by a network of primary flood defences that not only protect the city, but also a large part of the Randstad conurbation and the urbanized part of the island IJsselmonde. The region also has a large and highly developed urban area, which lies outside of the protection of this primary defence system. In the Rotterdam-Dordrecht floodplain about 65.000 people (distributed over 46 municipalities) live in these unprotected areas (Veerbeek, et al 2010). Also the Rotterdam port industrial complex, which is vitally important for the Dutch economy and that of the neighbouring countries, is located outside of the levee system.

These unembanked areas are already vulnerable for flooding (Veerbeek, et al 2010, Veelen, et al 2010). The largest part of the area has been gradually raised to 3 to 3,5 metres above average sea levels. Only a few areas, like the Noorderiland and Heijplaat, run a high risk of sustaining flood damage (Veerbeek et al, 2010). In the next decades the city will face two important developments. While climate change increases the risk of flooding, the land use in the city centre and the former port areas outside the primary water defences is intensifying. This aggravates both the risk of future disasters, while at the same time the increased economic value and activities could cause the possible consequences of flooding to become more severe.

On this moment, there is no legal standardization or an integrated flood risk policy for flood protection in the unembanked areas. The municipality of Rotterdam holds an obligation for new developments to raise the ground level to about 4 meters above average sea levels, which offers a reasonable protection to storm surge flood events with a probability of 1/10.000. For existing urban areas there are no additional policies or building regulations to minimize the effects of a potential flood (Veelen, et al 2010). Homeowners are held responsible for possible damages caused by a flood and to take precautionary measures, though they are on this moment not properly informed about the local flood risks. The lack of an integrated flood risk policy and a clear division of responsibilities between levels of government, contributes to an increased vulnerability of the area.

The question, how to protect the existing and yet-to-be-built residential and industrial areas outside the dikes from flooding, is therefor urgent. There are roughly two strategies with which we can respond to the increased flood risk (Veelen, et al 2010). The first, and current flood management strategies in the Meuse-Rhine Delta, focuses on reducing the probability of urban fluvial and



coastal flood risk by passive, robust solutions, such as urban water defences and major interventions in the Dutch delta (Zevenbergen, et. al., 2008). This strategy is almost exclusively the domain of civil engineering and is almost entirely publicly funded. Facing the increasing uncertainty of the effects of climate change and the highly urbanized context, continuing this strategy can become inflexible and cost-expensive. In times of limited public investment resources, the call for a new approach is becoming relevant. An alternative strategy focuses on adaptation at a local scale by integration flood risk management measures with urban functions, using the dynamics of urban development processes. This approach aims to reduce the consequences of an inundation by promoting flood resilience architecture and local adaptive measures in the flood-prone areas.

There are several reasons why there is a growing need to reflect on the approach of local adaptation, as an alternative on the dominant approach of resistance of flood risk. First of all the growing awareness of the vulnerability of the urban area for the (residual) risk for flooding, promoted by devastating floods in New Orleans and Japan. These events have opened the eyes that, despite the high degree of water safety in the Netherlands, a flood can never be totally excluded (Adviescommissie water, 2012). A second reason for a changing attitude is the consideration that reducing the probability of floods by constructing stronger and more barriers in the delta depends very much on a clear understanding of the effects of climate change on the rising of the sea level. The local effects of climate change on sea level rise and river discharges are however highly uncertain. This means that designing appropriate large-scale constructions is difficult and requires a strong and centrally managed realization process and sufficient budget. In a period where the central government is more and more focusing on central tasks and with a shortage of public funds, this scenario is not very obvious.

Another concept in this perspective, which has been announced in the National Waterplan and recently has been advocated by the Delta commissioner (Adviescommissie Water 2012), is a flood risk approach by applying multi-layer security (meerlaagsveilig). In this approach the risks are, in addition to prevention, reduced by adapting spatial planning and urban design and by introducing disaster management. Depending on the local condition and the specific nature and probability of a flood, the focus will be on finding a balance between preventive measures, adaptive measures and disaster management measures. This also means that flood risk management becomes much more an integral part of area development processes.

To do so it is necessary to develop new concepts and planning methods for applying local adaptation that are able to deal with the dynamics and uncertainty at the long term, but that are also able to seize possibilities, by aligning with urban development processes in the short term. A planning concept that is in line with this approach is a managed/adaptive strategy. This type of strategy allows for easier adaptation in the future via incremental adjustments. A managed/adaptive strategy, therefore, confers the ability derived from keeping op-



tions open (i.e. in-built flexibility), to adjust to future uncertainties as they unfold (Gersonius, 2012).

Objectives of this research

The aim of this research is to develop more knowledge on and evaluate adaptive strategies and measures for existing and newly developed residential and industrial areas located outside the primary water defences in the Rijnmond – Drechtsteden region.

This research continues on the research projects “HSRR02 Flood risk of unembanked areas” and the definition study “HSRR09 Adaptive strategies for the Rotterdam flood plain”, both carried out in 2009 in the framework of the first tranche projects of the Knowledge for Climate research programme. The research HSRR02 on flood risk of the unembanked areas has delivered important new insights on flood extent and water depths and the characteristics of direct damage resulting from flooding. The outcomes of this research, however, are mainly suitable for flood risk assessment on the regional scale and still lack detailed analysis to provide a solid framework for choosing possible responses at the local scale.

The research HSRR09 has had the character of an exploratory study, with the aim to provide an overview of main topics, issues and challenges around adaptive building strategies and to define key research questions. This definition phase has shown that there is a lack of knowledge on three main themes:

- Detailed risk analysis and adaptive capacity
- In-depth exploration of adaptive measures
- Development of tools to support policy and strategy development

Central research question: Which adaptive measures and strategies for the unembanked area of Rotterdam are promising in terms of implementation, financial feasibility, climate resilience and contribute to more spatial quality?

Sub questions:

- What is the vulnerability of the Rotterdam unembanked areas for flooding, as we look at flood damages, failure of critical functions and risk of loss of life;
- How can we develop and apply a norm-based performance assessment of individual areas, using a climate change scenario by applying the ATP method?
- What is the adaptive capacity (adaptability to changing contexts) of some sample locations and how can this inventory be scaled up to an exploration of the adaptive capacity on the regional scale?
- What adaptive measures can be taken to reduce vulnerability of a building, a block or a district?



- What spatial, financial and temporal tipping points can be identified, where adaptive measures are not able to meet set policy objectives
- What are the consequences to policy instruments when an adaptive strategy is implemented?
- Is there sufficient support for a local adaptive approach among key stakeholders?
- What instruments are needed to implement an adaptive flood risk management policy in local area development strategies?

Boundary conditions

As an amendment on the project proposal the project group decided to limit the focus of the research on the existing urban areas and areas that are subject to urban renewal processes. The main argument for this limitation is that the existing urban areas turn out to be the most vulnerable for flooding (Veerbeek, 2010) and the lack of knowledge on adaptive measures, tools and policies to reduce vulnerability, by mainstreaming with urban renewal processes. Adaptation tools and strategies have been adequately studied within projects as urban flood management Dordrecht.

A second limitation is that this research will focus only on one case study location in the Rotterdam unembanked area, unlike the earlier intended focus on three cases at the regional scale (Rijnmond-Drechtsteden). The reason for this decision has to do with limited research capacity and the wish to perform in-depth research on location. Besides that, it appeared that both the VU Amsterdam as the Deltaprogramma Rijnmond-Drechtsteden, intended to do research on adaptation on the regional scale. Lessons of the Rotterdam case are however also applicable for Dordrecht cases and are valuable for the assessment of regional strategies that are prepared at the Rijnmond-Drechtsteden programme.

A final limitation is that this research only takes into account physical and spatial adaptive measures and coping strategies. Measures and strategies to promote recovery are not included in the research, but are regarded interesting alternatives in the case physical adaptation proves to be impossible or undesirable. This limitation to adaptive and coping measures proved to be necessary because of the lack of knowledge and data on the effectiveness of flood-recovery measures in the Dutch context.

In this research is chosen to work with a moderate climate change (CC-) scenario for 2050 G+ hoog (60 cm sea level rise) and a severe CC-scenario for 2100 (Veerman), following the nationwide used Delta scenarios. Based on these scenario's water levels of a 35 cm, 60 cm and 85 cm sea level rise have been deduced.



5 Approach and methodologies

Adaptation tipping point approach

Jaap Kwadijk and others (Kwadijk et al, 2010) distinguished two main approaches to support climate adaptation policy on a regional and local scale: a predictive top-down approach and a more bottom-up resilience approach. In the top-down approach, which is the common approach, climate change scenarios are used to analyse impacts and prepare adaptation strategies. A downside of this approach is that it depends largely on detailed information on climate change effects, which are subject to change when new information comes available. This makes that underlying assumptions of the previously defined strategy are changing, making continuously adaptation of the strategy necessary (Te Linde, 2011). A bottom-up approach focuses on the vulnerability assessment of functions and systems for effects of climate change, like a gradually rising sea level. This approach is more independent of climate change scenarios, because it focuses on understanding the magnitude of the change that a system is able to deal with and analysing under what conditions it is necessary to move to other strategies (Te Linde, 2011).

The moment or event, when climate change effects reach such an extent that given policy objectives cannot be met anymore and an alternative strategy is needed, is called an adaptation tipping point. An adaptation tipping point (ATP), in this context, does not necessarily coincide with a radical change in the physical system but can also refer to a situation where previously stated policy objectives prove not to be achievable or are even violated, under pressure from changing conditions. The period of time at which an ATP will occur depends on the bandwidth of considered climate change scenarios, in this case rising water levels, and defines the moment when alternative adaptation measures are needed. (Kwadijk, 2010). The ATP method can be applied to either assess current policy or to compare and weigh alternative solutions (te Linde, 2011). Within the context of the vulnerability analysis, the tipping point method is applied to assess the vulnerability of the pilot areas in time and thus gain an indication of the urgency for adaptation.

This ATP works well when there is a reasonable consensus on the direction and range of the change, as is the case for rising sea level. Working with ATP proves to be an appropriate instrument to develop adaptation strategies and is therefore a useful framework for this research.

An important step in the research is to link the ATP, with possible adaptive measures and uncertainty of future climate change. A promising method to deal with uncertainty is the Adaptation Pathway method (AAP). *Adaptation pathways* describe a sequence of water management policies (or measures),



enabling policy makers to explore options for adapting to changing environmental and societal conditions in time. Pathways can be assembled by exploring all possible routes with all available policy options. (Haasnoot et al, 2012a). By developing several AP's, decision-makers are provided insight into the effectiveness of different flood risk management approaches over time, possible lock-in situations, path dependencies or the availability to switch to other options in the future.

The ATP and AP method are partly based on an environmental assessment project that has been done in the Thames Estuary 2100 plan (TE2100). In this project, strategic options for long-term flood risk management for the London and Thames estuary are appraised, taking into account future climate change impacts. As one of the first steps of this research Early Conceptual Options (ECO) were evaluated on different aspects, like effect on reducing flood risk, spatial impact and so on. Subsequently, this information was used to build consensus on different steps of an Adaptation Route Map.

Although the ATP and AP methods are currently applied in strategic decision-making processes on the regional scale (TE 2100) and Deltaprogramma Rijnmond-Drechtsteden), the methods have not yet been applied in a concrete case study at a detailed scale. This research will also contribute to the further development and enrichment of the method.

Structure of the research

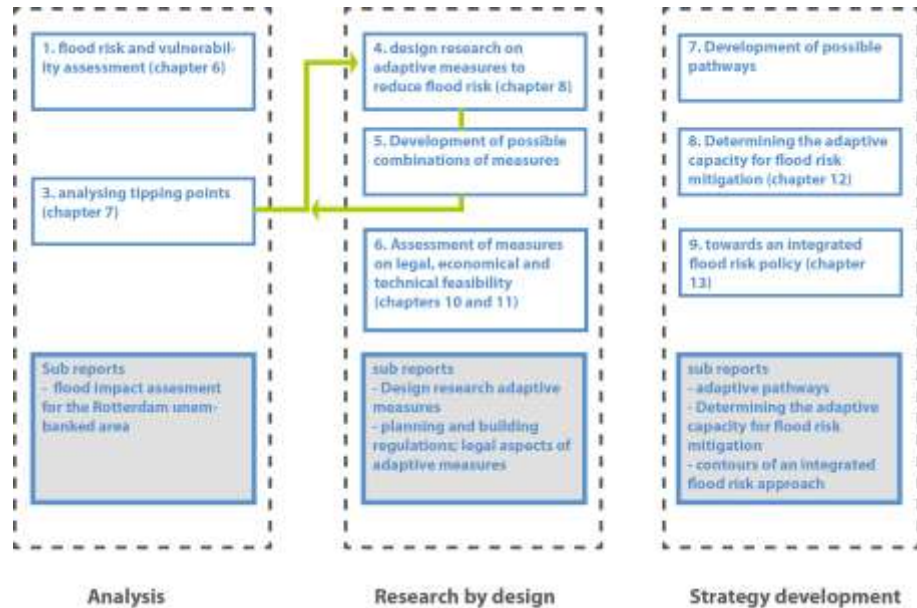
As a first step in developing possible flood risk management strategies for the Rotterdam unembanked area a detailed analysis of the vulnerability of the current system was performed. By systematically analysing the possible flood risk and impacts of the flood on housing, vulnerable functions and vital infrastructures, the vulnerability of the Rotterdam-Rijnmond unembanked area for the current flood conditions and two climate change scenarios is identified. As a second step it proved to be necessary to develop a clear set of policy objectives and to convert these objectives to a set of critical boundary conditions or thresholds (work package 1). Based on this research a norm-based performance assessment of individual areas was applied using the ATP method.

The second phase of the research consist of elaborating possible adaptive measures, which are able to solve or delay the tipping points. Through research by design in two study areas (Noordereiland and Kop van Feijenoord) the most promising adaptive measures to reduce the flood risk were identified. These measures were assessed on legal, spatial, economical and technical feasibility in several expert sessions. Furthermore, an in-depth analysis of the acceptability of these measures among stakeholders (governance aspects of measures) and an assessment of legal aspects has been executed, resulting in a selection of most preferred measures for the two cases (work package 2).



Using a tipping point analysis the sustainability of the current policy as well as the proposed flood risk reducing measures has been evaluated. This research delivered input for analysing different options and adaptive pathways in time to build up an adaptive strategy. Finally, the adaptive capacity of the urban area and opportunities to mainstream with urban development processes was analysed, resulting in components of a local flood risk policy for the case study area Feijenoord and Noordereiland (work package 3).

Figure 1: structure of the research and relationship between the various stages of the research and the sub reports.



Outline of this report

This synthesis report summarizes and connects the outcomes of several sub-reports. Fig. 1 shows the relationship between the various stages of the research and the sub-reports. This report follows the structure of the research and the different chapters are as much as possible linked to the sub-reports:

- Risk and impact assessment (chapter 6)
- Working with tipping points (chapter 7)
- Overview and assessment of adaptive measures (chapter 8)
- Adaptive pathways (chapter 9)
- Governance aspects of measures (chapter 10)
- Legal feasibility of measures (chapter 11)
- Determining the adaptive capacity (chapter 12)
- Towards an local flood risk policy (chapter 13)
- Conclusions and recommendations (chapter 14)
- Dissemination of Knowledge (chapter 15)

6 Vulnerability assessment of unembanked area

Introduction

A basic requirement of a local adaptation strategy is a comprehensive vulnerability assessment that covers both tangible and intangible flood impacts. Although recently, significant progress has been made in estimating the potential impacts of (climate change induced) floods on the unembanked areas of Rotterdam (Veerbeek, et al, 2010), much remains unknown. The outcomes still lack breadth and depth to provide a solid framework for choosing possible responses. Yet, in order to upgrade or adapt these areas to a possibly increased flood risk, a detailed assessment is needed of the expected impacts.

This chapter aims at identifying and quantifying the vulnerability of the Rotterdam-Rijnmond unembanked area for the current conditions and two climate change scenarios (G+ and Veerman). The outcomes should provide a deep insight into the flood vulnerability of the Rotterdam-Rijnmond unembanked area on a high level of detail using state-of-the-art assessment methodologies.

Vulnerability can be defined as the combination of flood risk, the flood impacts and the vulnerability to this impact of critical functions. This chapter therefore first focuses on a detailed analysis of flood risk and flood impact of the unembanked area of Rotterdam and in more detail on two case study areas Noorderiland and Kop van Feijenoord (section 7.3). Secondly, a damage assessment is executed by evaluating the flood sensitivity of individual assets and extending the damage assessment methodology that has been developed for the HSRRO2 project (section 7.4). Finally, flood prone critical functions in the area (e.g. utility lifelines, kindergartens, etc.) are identified and evaluated on their sensitivity to flood situations (section 7.5).

This chapter is based on the sub-report: “Flood impact assessment for the Rotterdam unembanked areas” (Veerbeek 2012a)

Approach and methodology

This chapter aims at extending the initial flood damage estimations made in the previous Knowledge for Climate HSRRO2 project (Veerbeek et al, 2010) both in depth and in breadth focussing on the Rotterdam-Rijnmond area. This includes the implementation of the doorstep heights of individual buildings in the inundation depth calculations. Although this seems a trivial aspect, the outcomes might be significant since the expected inundation depths in the area are limited. Furthermore, the flood impact assessment is extended by a comprehen-



sive analysis of the affected critical infrastructure and functions (e.g. schools, elderly homes).

Flood risk

6.1.1 Flood characteristics

The most common flood situations in this part of the delta are quite moderate. Floods of the unembanked area are in general characterized by moderate water depths of 0,1 meter to a maximum of 1 meter. Also, the expected flood velocities are estimated to be relatively low: in the order of 0.1 to 0.25m/s during flooding (Veerbeek, 2010). Due to the tidal influences floods are of a short duration. A general assumption is that the flood duration in the unembanked area never last longer than 35 hours (Veerbeek, 2012). Because of these specific conditions and the relative high predictability of a high water situation, flood risk is limited to risk of damage and social disruption and to a lesser extend the risk of fatalities (Veerbeek et al, 2010).

Despite the relatively moderate flood conditions, flooding properties on the local scale depends largely on local characteristics like ground level, micro watersheds, small elevations and embankments. To develop effective measures it is therefore necessary to analyse in further detail the local flood situations (fig 2).

Figure 2: flood extent associated with the predicted return periods for the current conditions in the Rotterdam unembanked area.



A large part of the unembanked areas has been raised following the gradual process of urbanization. The new port areas and some residential areas are raised to 3 to 3,5 metres above average sea levels. Only a few areas, mostly the nineteen-century historical port areas, like the Noordereiland, some parts of

Feijenoord, Heijplaat en Scheepvaartkwartier, are considerably lower and run a higher risk of flooding. These areas are already partly flooded during a 10y – 100y flood event, though, especially for lower return periods, the estimated inundation depths for these area are still limited.

Based on flood characteristics, like duration and depth of a flood, three flood prone areas can be distinguished (Kronberger, 2012):

- **Low islands** are low-lying, mound-shaped islands or peninsulas that has to deal with high flood frequencies. In these areas a flood situation might lead to considerable water levels, but due to the mound-shape the area is in general easily accessible. Also flood duration are limited to tidal fluctuations, since flood water is drained directly back in the river. An example is the Noordereiland
- **Deep basins** are bath-tub-shaped, low-lying areas that are flooded only at low frequencies. These floods are less easy to predict and occur more suddenly, with a relatively large vertical velocity and water depth. These floods generally last longer, because water has to be pumped out. An example is Feijenoord
- **High lands** are elevated, flat areas that are only flooded at a very low frequencies. These floods are highly predictable and only lead to a shallow flooding of the public area. Flood duration is limited to the duration of the high water peak. An example is the Wilhelminapier.

An analysis of the unembanked area based on the previous classification shows that the historical parts (i.g. the former merchant port areas) like the Noordereiland and Scheepvaartkwartier show comparable flood characteristics as the *low island*, whereas the modern parts of the redeveloped port areas, like the Wilhelminapier and Katendrecht take the shape of *high lands*. Also a considerably large part of the area hosts micro-watersheds in which the floodwater will reside even after the critical water stages have receded (Veerbeek, 2012a). These areas are in many cases historically low-lying port or urban areas that are enclosed by new developments along the waterfront, creating a 'bath-tub'-shape. These areas include not only the green natural areas like de Esch and het Park, but also residential areas like Heijplaat, Feijenoord and parts of Katendrecht and industrial areas like Sluisjesdijk and the south part of the Waalhaven (Veerbeek, 2012a, Kronberger, 2012).

6.1.2 Effect of climate change on flooding

The flood situation is changing due to the rising sea levels. When the current design water levels at different frequencies are compared with the design water levels at different scenarios for sea level rise (Fig 3) it is clear that even in



moderate scenarios flood frequency will increase considerably. This means that the already vulnerable areas will have to deal with much higher frequency of flooding, compared with higher water depths. But also the elevated and considered safe areas like the Wilhelminapier (designed to a water level of +3,60 m.) must prepare for a change in flood frequency that range from a RP=4000y to a RP=500y.

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Figure 3: corresponding water levels at the current situation and sea level rise for river section KM 999, Rotterdam

Sea level rise (cm)	0	35	60	85	130
Corresponding climate scenario's	Current situation	KNMI W/W+ 2050 KNMI G/G+ 2100 lower limit	KNMI G+ 2100 upper limit	KNMI W/W+ 2100	Veerman 2100
Frequency (1.X years)					
10	264	299	312	319	336
25	296	308	320	326	345
50	304	314	326	331	355
100	311	320	331	337	369
250	319	327	339	348	389
500	325	333	347	360	405
750	328	337	353	370	414
1000	330	339	359	377	421
1250	332	342	364	382	426
2000	336	348	375	394	437
2500	338	352	380	399	442
4000	344	362	391	410	453
5000	346	368	396	415	458
7500	353	378	406	425	468
10000	359	385	413	432	475
20000	377	403	431	449	492
50000	402	427	455	472	514

Impacts and vulnerability

6.1.3 Introduction

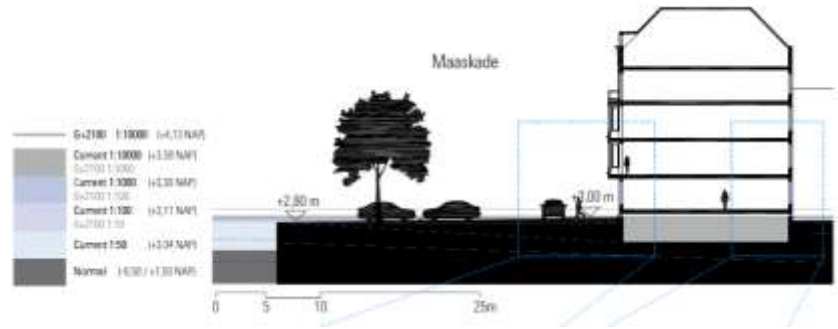
To establish a perspective on local adaptation measures, potential flood impacts have to be assessed on the level of neighbourhoods, blocks and individual assets. Flood impacts assessments are usually divided in assessment of flood damages, inventory and assessment of the vulnerability of critical functions and vital infrastructures and an assessment of risk of loss of life. As shown before the flood risk in this part of the delta is limited to risk of damage and social disruption and to a lesser extend the risk of fatalities (Veerbeek et al, 2010). The assessment of casualties is left outside the scope of this research.

6.1.4 Damage assessment

Since the flood depths in the Rotterdam-Rijnmond unembanked area are relatively small, a detailed analysis of the flood entry points of individual housing units is a determining factor by assessing flood damages. Since practically none of the buildings in Rotterdam is flood proofed, the location of the level of the ground floor defines the main threshold level for which floodwater can enter a building. To address this issue an on-sight inventory of the individual housing

has been performed, were not only the height of the doorsteps, but also other characteristics like ground floor bounded functions, ventilations slots and basements were identified (fig 4).

Figure 4: typical street profile in the Noorderiland area: inventory of door steps heights of individual buildings.



These adjusted elevation levels were added to the GIS database as additional attributes, indicating the minimal flood entry level. This detailed analysis cause significant damage reductions, which add up to an average of about 42%. For higher return periods associated to larger inundation levels, the reduction significantly drops.

Due to the in many cases high elevation levels combined with the location of the housing blocks and infrastructure, the exposed number of assets to flood inundation is relatively limited. The expected aggregate mean annual damage for housing and infrastructure though is considerable, and estimated at €77k. Application of the G+ and Veerman CC-scenarios increases this level to €222k and €615k respectively. To put this number in perspective, this currently amounts to only €4.07 per housing unit per year (including the infrastructure damage).

When breaking down the assessment to the individual neighbourhoods, the expected flood damage distributions show significant differences. In absolute terms, the expected annual flood damage in Feijenoord exceeds the damage for all other investigated neighbourhoods combined. Application of the CC-scenarios changes this ranking; the Heijplaat and Kop van Zuid-Entrepot areas are especially sensitive to increasing water stages and their consequent damages.

Damages to infrastructure are a significant contributor to the aggregate damages; these account for almost half of the expected flood damages. Due to their proximity to the perimeter of the areas, the damage contribution is largest during frequent flooding (RP = 10Y). Application of the CC-scenarios doesn't reduce this relative contribution; also here about half of the expected flood damages stem from the road network.

When comparing the average expected annual damage per ha, the neighbourhoods can be divided into two groups: The Feijenoord, Heijplaat and Noor-



dereiland areas all show significant damage levels, while for Katendrecht, Kop van Zuid, Kop van Zuid-Entrepot (and to a lesser extent the Afrikaanderwijk) the relative expected annual damages are minimal. Especially for the lower ranked neighbourhoods, the flood damages for infrastructure often exceed those for housing; due to the location of the residential areas, the expected damages to housing occur only during extreme events.

6.1.5 Critical functions and infrastructures

Critical functions

Flood prone critical functions include on the one hand functions that host communities especially vulnerable for flooding (e.g. elderly and children) and on the other hand functions that play a crucial role in the functioning of the neighbourhood city or region (e.g. utility lifeline, infrastructures, etc). Based on literature review and information that is used to develop the provincial risk assessment method, critical functions have been identified. These functions have been analysed by a combination of GIS-based analysis and verification using Google Streetview.

Vulnerable communities

The area hosts a significant amount of critical infrastructure and functions that host social groups that are especially sensitive to flooding. The unembanked area hosts 37 schools of which 4 are located in frequently flooded areas (RP = 50Y or less). From these 4 schools, 3 are located in low-rise buildings, mainly on the Noordereiland. The area hosts also several childcare facilities, but these are located in areas only exposed to extreme floods. There are no major hospitals or large nursing homes located in flood prone areas.

Accessibility and road network

In relation to potential evacuation and disaster management a good functioning road infrastructure is of vital importance. In order to identify the sensitivity of the infrastructural network, isolated areas have been identified during a 4000y flood. Based on this research it can be concluded that only small portions of the unembanked area get isolated. The majority of these 'islands' are located in port areas and no residential areas will be isolated. An area of concern, however, is the potential isolation and relatively long distance to the embanked area (5 km) of the RDM-Heijplaat area. For this area, which accommodates schools, companies and innovative industries and a small residential area, improving the accessibility and evacuation routes can be an effective adaptation strategy to reduce vulnerability.

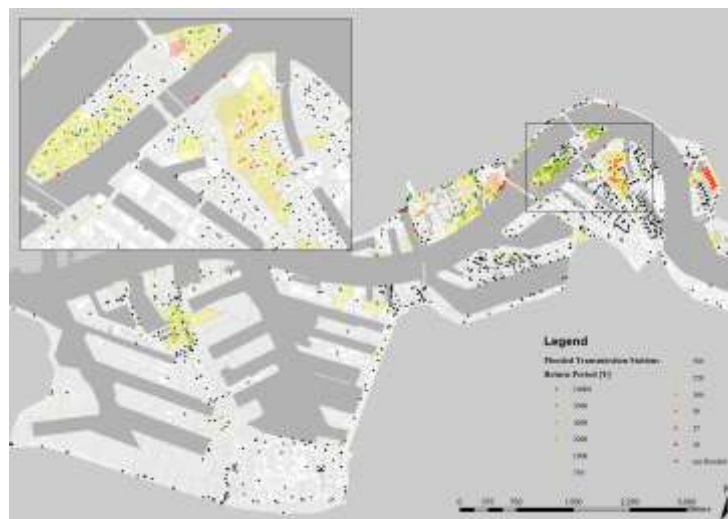
The unembanked area of Rotterdam host several tunnels and entrances of metro stations. Most of these tunnel entrances and stations are on this moment located outside of the flood plains and are not vulnerable to flooding. The

unembanked area is however crossed by a major railroad line, which connects the Randstad by regular and high-speed trains to Antwerpen and Brussels. This track is located inside the 1000y flood plains and is not protected by flood proof walls. Currently this entrance is expected to be flooded only during extreme events. Application of the CC-scenarios might shift this event to more frequent occurrences with RPs of 100Y and 10Y for the G+ and Veerman scenario respectively. The tunnel however can be closed by floodwalls during a flood to prevent water entering the tunnel, or prevent flooding of the embanked area, in case of collapse of the tunnel.

Electricity network

The majority of the large electricity transmission stations, that are responsible for distributing electricity to districts, is located outside of the major flood hazard zones. Only under the extreme climate scenarios these stations suffer from regularly flooding with return periods of 50 y or less. It is therefore not expected that a flood will lead to an electricity power cut that affects the city or regional level. The local electricity network, however, is vulnerable to flooding. Around 300 of these local transmissions stations are located in areas were they are exposed to a critical 30 cm flood level, during an extreme event (i.e. RP=10,000y). Although the effect of a failure of a local transmission station is limited, in many cases they serve only a single block, the majority of the vulnerable transmission stations are located in parts of Feijenoord, Noordereiland, Scheepvaartkwartier and Heijplaat (fig 5). This means that it is expected that at a moderate flood event (RP=50y – 1000y) a series of these devices will fall out. The indirect effects of a combined failure of multiple devices are unclear, but could cause a multiplier effect that affects large parts of the city.

Figure 5: Exposed local transmission stations for the current flood probability distribution



Sewer system



In the older (densely built) parts of the city a mixed urban sewer system is still in use. This means that rain water drainage is combined with the sewer system of individual houses. During flood situations, floodwater might enter buildings by overflowing of the sewer. This will lead to locally flood damages and flooded basements, and possibly a temporarily outfall of the sewer system of a building block or district. Especially in Feijenoord area, where floodwater is expected to stay for a couple of days due to its 'bath-tub' shape, this could lead to a severe sanitation problem.

Gas distribution

The vulnerability of gas lines is limited to casted iron pipes that have been used until the 70's, which break easily under mechanical pressure. A critical inundation for these pipes is set to a 30 cm flood. On this moment parts of Feijenoord, and Scheepvaartkwartier show a higher vulnerability for gas leaks and explosions due to a flood, although it is not clear whether parts of the gas distribution network in these areas already has been renewed or renovated.

Telecommunications

Although, the area host a network of local telecom hubs, that usually serve up to about a hundred customers, actual data on exact locations and sensitivity of these hubs to flooding, was not available. It is therefore not possible to draw conclusions on the vulnerability of the area due to an outfall of communication services. Local survey has, however, showed that the local cable distribution installations that provide internet and cable services are sensitive for inundation above 30 cm. Especially since television and internet is a major source of information, failure of these infrastructures comprises the coping capacity of the area during floods (Veerbeek, 2012, De Kort, 2012)

Conclusions

Although the area hosts a significant amount of critical functions, these are not located in the flood prone areas. Some schools in Noordereiland, however, need special attention, since they are low-rise buildings, located in the current 50y flood extent. The most flood prone critical piece of infrastructure in the area seems to be the train tunnel for which the entrance on the southern side of Rotterdam is located within the floodplains. An area of concern is also the accessibility of the RDM-Heijplaat area that is isolated from the embanked area and main infrastructure during a 4000y flood.

Apart from the road and train network, the area also hosts various telecommunications, energy and water related infrastructure including 1 power station. The actual flood hazard for these installations differs since they are distributed over the complete area at different elevation levels. Local transmission installations serving individual housing blocks are found throughout the region but only result in local power failure in 10s of building units.

All in all, the vulnerability of the Rotterdam unembanked area to flooding is limited. In terms of vulnerable functions, only during extreme events with high return periods the infrastructural capacity as well as sensitive social functions (e.g. education) is exposed to floods. The expected flood damages in the area are significant, but moderate. There is still, however, little known of the sensitivity of vital infrastructures to flood situations.

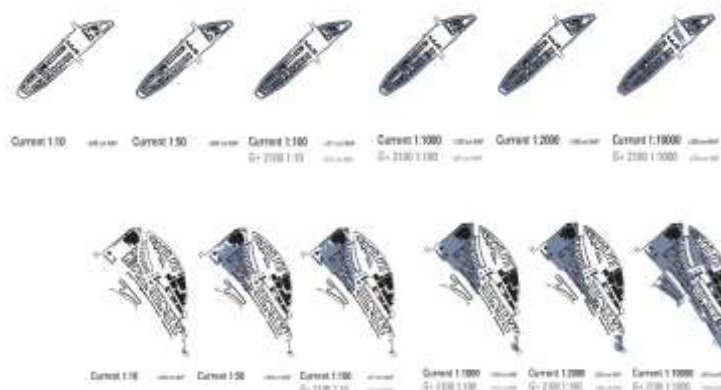
flood risk and vulnerability assessment of casus Feijenoord and Noordereiland

6.1.6 Flood characteristics of Feijenoord and Noordereiland

Although the Noordereiland and Kop van Feijenoord are both low-lying flood prone areas, they differ when it comes to flood characteristics such as flood frequency, water depth and flood duration [Veerbeek et al., 2012].

The Noordereiland is a low-lying mound shaped island that has to deal with high flood frequencies (fig 6). The quays of the island are flooded at a yearly or 10 year flood event. At a 50-year flood event (3,04m+NAP) water can enter the basements and ground floors of buildings that are situated at the southern and northern end of the island. By the mound shape of the island the duration of a flood event is expected to be short. The higher part of the island also forms a relatively safe 'backbone' that can serve as an evacuation route when the low-lying areas along the quays are flooded.

Figure 6: flood characteristics at different return periods and climate change scenarios for Noordereiland and Feijenoord



The Kop van Feijenoord is a deep basin with high flood frequencies (Kronberger, 2012). In contrast to Noordereiland, the area can be compared to a 'pool' that retains flood water after a flood event. At a 50-year flood event (3,04m+NAP) water flows over the Nassaukade in the low-lying area between Oranjeboomstraat, Nassauhaven and Damstraat. Half of the case study area is flooded with a water depth of 50cm. Water enters the ground floors of more than half of the buildings in this area. At more extreme flood events the



flooded area hardly changes, but the water depths may rise to 80 – 100 cm and serious damage to the façade and the interior of buildings can be expected. By the pool like shape of the area, the floodwater cannot run-off or drain to the river. It is expected that a flood in this area will last for a couple of days.

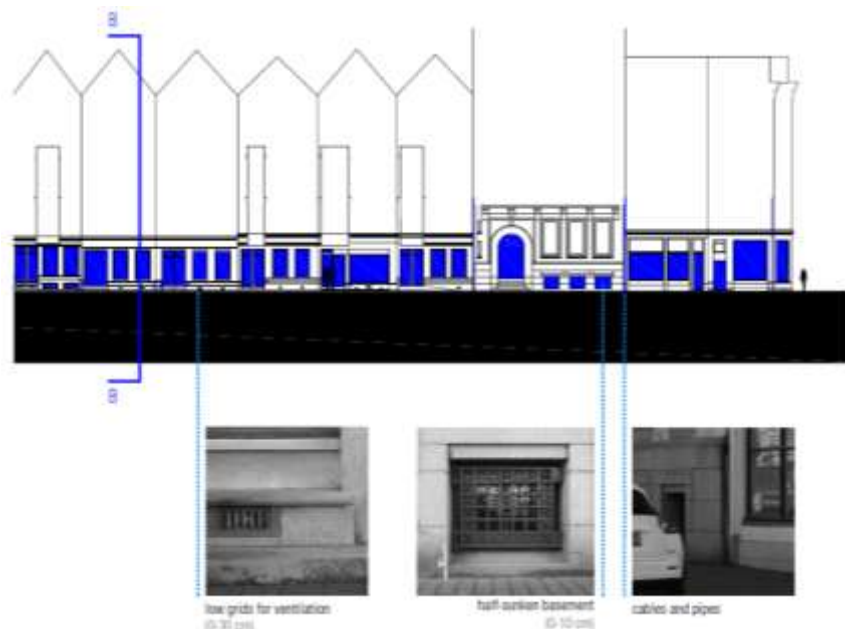
6.1.7 Vulnerability assessment of two building blocks

To get a better understanding of the impact of a flood and vulnerability of the housing stock of both case studies a detailed analysis of the specific physical attributes of two building blocks has been performed.

On Noordereiland, many nineteenth-century buildings have elevated doorsteps, which lower the chance of flooding for dwellings or other ground floor functions [Veerbeek et al., 2012]. These buildings are vulnerable for flooding by small openings in the plinth zone, like basement windows, door openings, power boxes, pipes and ventilation grids. Also the analysis of the building block (Figure 7.) illustrates that basements of buildings are particularly vulnerable to flooding, especially when they are part of dwellings (Half-sunken basements or Sous-terrain dwellings). The vulnerability of these basements is likely to increase because these basements, which initially were meant for storage, are more and more renovated and integrated in the building.

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Figure 7: analysis of a building block in Noordereiland. Inventory of vulnerable elements: basements, windows and ventilation slots.



The housing stock in the Feijenoord area consist of a combination of nineteenth century buildings, urban renewal projects from the 80's and small scale additions and renovations in the nineties. A typical situation in Feijenoord is the combinations of a nineteenth-century building block at street level adjacent to

the new social housing blocks that were built elevated. The difference between street level and doorstep level is sometimes more than 1 metre.

The buildings of Feijenoord are typical nineteenth-century working class buildings that in contrast with the monumental architecture of the townhouses of the Noordereiland have low entrances and windows. By the gradually raising of the street levels, the door openings are in many cases even lower than street level. These buildings are extremely vulnerable for flooding, especially because many of these buildings are divided in single apartments, making horizontal evacuation impossible.

Conclusions

The overall conclusion of these outcomes is that the vulnerability of the unembanked urbanized areas in the Rotterdam-Rijnmond region is limited. Only during extreme flood events infrastructure and critical functions are affected. Also the estimated damages are relatively moderate and only during extreme events they are considerable significant. Yet, the applied CC-scenarios do cause some concern since the frequency of these extreme events shifts into more regular events.

Nevertheless the local effects of a flooding can be severe. The Noordereiland and Heijplaat are the most vulnerable areas to flooding. Significant changes in impacts caused by climate change and associated flood events are most likely to occur in Heijplaat and the Kop van Zuid-Entrepot neighbourhoods.



7 Working with tipping points: bridging the gap between vulnerability assessment and adaptation measures.

Introduction

To be able to assess the climate ‘proofness’ of an area and the performance of measures under current and future climate conditions, it is required to define clear objectives as well as threshold values for these objectives.

The current flood risk policy of Rotterdam only provides limited clues to develop a set of clear objectives. Currently, only for newly developed areas a flood risk policy is in effect. For these areas the municipality holds an obligation to raise the grounds to a ground level that is equal to the current 1:10.000 water level, supplemented with an addition for sea level rise (in most cases this level is set to 3,90 + NAP). For the existing urban and port areas there are no specific flood risk regulations set.

The province of South Holland is currently developing a methodology to assess flood risk for new urban development projects in the unembanked areas, based on a maximum limit value for two aspects, namely individual risk of loss of life and social disruption, due to outfall or damage of vital infrastructures. Based on the limit values that have been developed in the framework of this provincial flood risk methodology, it proved possible to deduce a combination of objectives and threshold values. In addition to the provincial methodology, objectives and threshold values for damage to buildings and infrastructures were based on widely used maximum flood damages frequencies of storm surge flood situations.

This chapter provides an overview of the chosen objectives and threshold values on three aspects: risk of loss of life, social disruption and direct damages (8.2). Then it is examined what these new set of objectives and threshold values imply for the case study locations Feijenoord and Noordereiland and when in time these policy objectives can not be met anymore. These tipping points are important input for the design research section (Chapter 9).

This chapter is based on the chapters 1-4 of the sub report “ Exploring adaptation pathways” (Stone, 2012).

Defining policy objectives for the unembanked area

Objectives for social disruption

Social disruption is not easy to define. According to the province social disruption is the extent to which people experience physical, social and emotional nuisance due to a flood situation. Based on the methodology of the province and other experiences with flooding in other areas (Huizinga et al, 2011) a common used threshold value for social disruption is 10 affected days per year per hectare. Functions that are highly vulnerable (see section 6.6) to flooding are public utilities, infrastructures, medical and health care, hotel and catering and industrial areas.

In fact, it is possible to define a unique threshold value for each of these functions. This would, however, be totally ineffective in practical situations, as for every function a new threshold has to be met. As a guideline for this project, the functions have been grouped into three categories, which define the acceptance of disruption due to flooding:

- 'Hardly ever' (probability < 1:10.000 years);
- 'Sometimes' (probability < 1:100 years) and
- 'Often' (probability < once a year).

Objectives for Risk of loss of life

Consistent with the provincial risk assessment method, individual risk of loss of life (IR) is set on a limit value of a change of 10^{-6} for 95% of the area. Using the risk assessment tool of the province, the areas are defined that meet this objective.

Direct damages

For existing buildings and public space no damages is tolerated for flood events with a frequency of 1:100. For newly built and renovated buildings this threshold is set to a 1:1000 event. This threshold equals the threshold that is commonly used in urban areas to define the acceptability of urban flooding due to overflowing of canals and smaller watercourses.



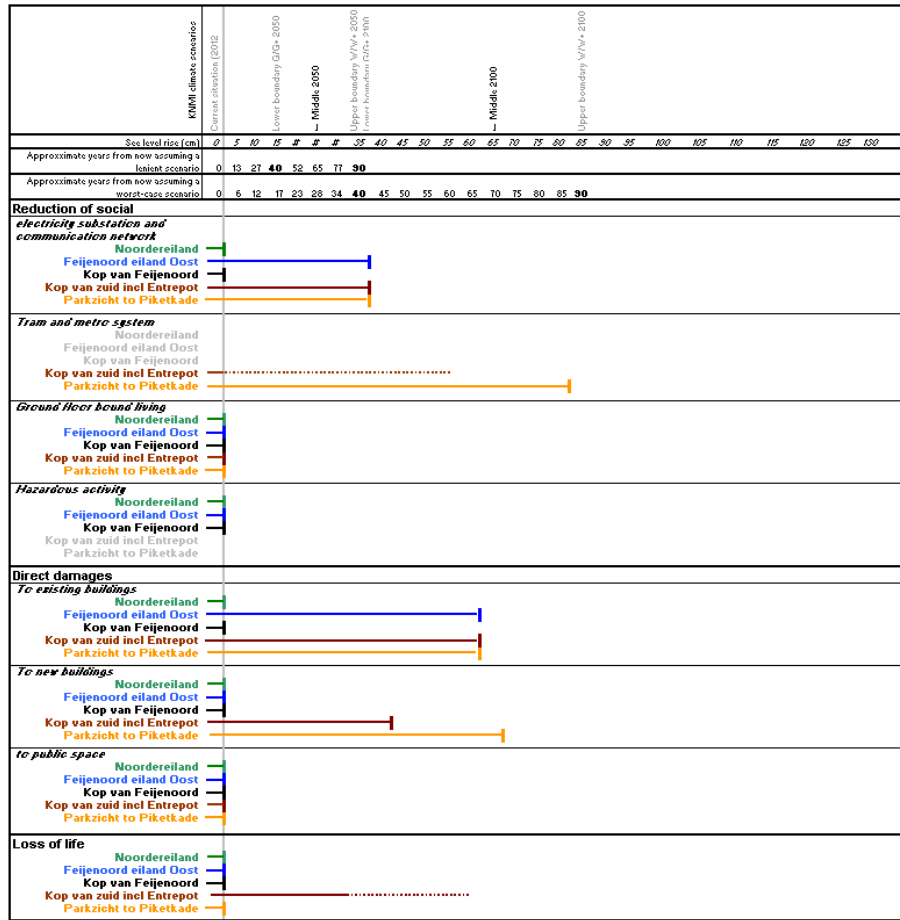
Tipping points analysis of Feijenoord and Noordereiland

When applied to the Feijenoord and Noordereiland case (fig 8) we can derive the following conclusions:

- A vulnerable critical function is the railway track and tunnel entrance of the high-speed train. The track and tunnel entrance are prone to flooding at frequencies that exceeds the set threshold value, already at current water levels.
- All areas exceed the objective to reach an individual risk of equal or smaller than 10^{-6} for 95% of the area at a 35 cm sea level rise. Areas that exceed the norm to a large extent are the western and eastern part of the Noordereiland, Feijenoord-Oranjeboomstraat and part of the Afrikaanderwijk. The Wilhelminapier exceeds the threshold at a 10 cm sea level rise situation.
- When it comes to flood damages there is a striking difference between the low-lying areas as Noordereiland and Feijenoord-Oranjeboomstraat and the relatively higher parts of the area. Damages due to a flood of existing buildings already exceed the limit threshold of 1:100 a year for the areas Noordereiland, Feijenoord-Oranjeboomstraat. The other parts of the area, Kop van Zuid and Feijenoord-oost only exceed the threshold at a 60 cm sea level rise situation.

Working with tipping points: bridging the gap between vulnerability assessment and adaptation measures.

Figure 8: Overview of tipping points analysis results for different policy objectives applied to the cases Feijenoord and Noordereiland.





8 Flood adaptive measures

Introduction on adaptive strategies

Both the vulnerability and resilience of a system to flood events can be defined by the combination of different capacities: *threshold* capacity, *coping* capacity, *recovery* capacity and the capacity to adapt. *Threshold* capacity, in this context, is defined as the ability of a society to built-up a threshold against variation of the water system in order to prevent damage. In the Dutch flood risk approach thresholds are the common components to design and assess flood risk measures. *Coping* capacity is the capacity of a society to deal with an event that exceeds the damage threshold. In many cases, this capacity is determined by the availability of effective emergency and evacuation plans and damage reducing measures. *Recovery* capacity is the capacity of a society to return to the same or an equivalent of the previous system, by a quickly and effective respond after a disaster. *Adaptive* capacity is the capacity of a society to cope with or react on uncertain future developments, like climate change (Graaf, 2010, cited in Kronberger, 2012). Adaptive capacity in this definition is related to the general ability to plan and react on long-term uncertainty, rather than an ability to respond directly to flood risk events.

The general emphasis of this research is on increasing the adaptive capacities of local flood prone areas and communities. Measures that increase the threshold and coping capacities, such as a local embankment or wet proofing existing buildings will be included in this chapter on adaptive measures. The recovery capacity – such as a calamity fund or the organization of a respond team - are not included in this research.

This chapter is based on the sub report: "Design research adaptive strategies in the unembanked area of Rotterdam" (Nabielek, 2012).

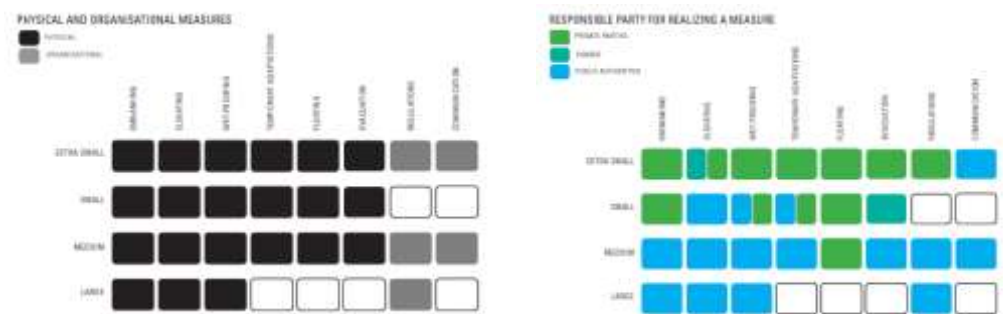
Classification of adaptive measures

Current local measures to prevent flooding on Feijenoord are restricted to the elevation of ground or buildings. However, there is a much broader spectrum of flood adaptive measures, ranging from purely organizational measures such as risk communication to physical measures such as embankments. A long-list of 33 measures is summarized in a so-called 'toolbox of flood adaptive measures'. These measures are grouped in different categories, based on the study *Overstromingsrisico als ruimtelijke opgave* (Pols et al, 2007), see also figure 9.

To provide a link between flood adaptive measures and urban planning and design, measures of each category are subdivided into different scales.

Based on this scheme, it is concluded that in many cases private parties as project developers, social housing associations and property-owners are responsible for most of the small-scale measures in the public realm whereas public authorities are in general in charge of measures on a neighbourhood and district-scale. Furthermore, most measures are likely to be implemented in a period of urban renewal (new building of neighbourhoods) or redevelopment (new construction of public space) as they often involve major structural adaptations. The choice of measures that can be applied on existing buildings at any time is limited.

Figure 9: classification of adaptive measures on nature of measures and actor responsibility



During a workshop with external experts and stakeholders on 29th September 2011, the measures were evaluated on aspects as the juridical, financial, technical feasibility and spatial quality. From this expert workshop it appears that large-scale infrastructural flood protection such as dykes are deemed undesirable on Feijenoord. Elevation of buildings and public space, floating constructions and temporary adaptations are desirable on all scales, and evacuation and regulation measures preferably on the smaller scale. The evaluation of the wet-proofing measures is contradictory (wet-proofing on a large scale is desirable, but on the small scale opinions differ). The categories 'regulations' and 'communication' were only partly judged. The judgement of experts and stakeholders forms the basis for the selection of measures on the two case study areas Kop van Feijenoord and Noordereiland, which is described in the following chapter in greater detail.

Promising measures for casus Feijenoord and Noordereiland

If we take a look at the local level of the case study areas of Feijenoord and Noordereiland, the palette of measures is naturally limited by their specific spatial conditions. Based on the flood risk profile (chapter 6.1) and the



analysis of spatial characteristics of the build up area (section 6.2) a range of measures has been pre-selected, which were theoretically applicable. In a second workshop with local stakeholders and experts of different departments of the municipality these measures were classified from a qualitative point of view in 'desirable' and 'undesirable', thus creating a short list of most 'promising' flood-adaptive measures.

On Noordereiland a selection of 13 measures of the categories embankment, wet- or dry proofing¹, temporary adaptation, evacuation, regulation and communication proved to be promising. There are many restrictions for the application of flood adaptive measures with regard to spatial quality. The island is already a densely built-up area with houses of historical value that are protected by law. In the quay area, a temporary flood defence that is raised by hand (aqua barrier) or a low retaining wall with openings that are only temporarily protected are most desirable. Another possibility is to adapt the closely standing riverside facades of building blocks to a flood defence and combine them with temporary fillings of street openings.

Compared to Noordereiland, the building stock and public space of the area Kop van Feijenoord is more varied. Consequently, this variety of buildings, public and private spaces and functions leads to the wider range of 19 possible flood-adaptive measures of all categories except in the category 'floating'. Especially on the building scale there is more choice as the development areas offer the possibility of flood-adaptive new building and large-scale ground elevation. The most promising intervention in the quay area is a multifunctional dike along the Nassaukade that could be shaped as an urban landscape. Another possibility is to allow water in the area and equip existing buildings and vulnerable functions with various flood-adaptive measures. Major renovation works however, can only achieve this. New buildings could be built on mounds or on stilts or be equipped with dry-proof plinths. To secure the accessibility of the area in the event of an emergency, an elevated escape route leading to flood-safe areas could complement measures on the building scale.

Robustness and effectiveness of packages of measures

The next step was to find the 'natural' spatial and technical limits of each measure in 'guideline values' that could be directly compared with flood levels. These guiding values determine the maximum water level to which a measure still offer sufficient flood protection, and in the same time complies with the

¹ dry floodproofing is defined as measures that prevent the entry of flood waters into a building. Wet floodproofing allows flood waters to enter specific flood proof areas of a building (e.g. the hall or first floor)



of this POM is to meet the *minimum* requirements (e.g. the threshold values based on current water levels and return periods). The second objective is to illustrate in how far the proposed POM can adapt to rising sea level. Therefore, each POMs also has a corresponding *maximum* level of protection.

Conclusions

Based on this research-by-design it is clear that by applying small-scale adaptation measures the previously set policy objectives on maximum accepted flood damage and social disruption can be met. Specifically, for the case study Feijenoord the realization of a super dike along the Nassaukade meets all the previously stated policy goals and appears to be a robust solution, when it comes to adapting to climate change. Wet- or dry proofing the existing building blocks seems to be a less favourable strategy because of the considerable high water levels and physical limitations. For the Noordereiland the outcomes are less clear. Both a temporary flood defence and the combination of dry-proof plinths or a low retaining wall combined with closing of street openings, prove to be acceptable measures to reduce flood risk and adapt to climate change. Both cases show that determination of the most appropriate solutions largely depends on the local physical and socio-economic conditions.

9 Adaptive pathways; time dimensions on adaptation strategies for flooding

Introduction

The selection of an appropriate local flood risk strategy is often based on the assessment of the current flood risk situations, as well a projection of the future flood risk due to climate change. The problem with this approach though, is that predicting the future flood risk is highly uncertain, due to uncertainties in the current climate models and specifically uncertainty about the local impacts of climate change. Rather than trying to identify a singular (optimal) strategy that requires judgement on which of the various and constantly changing scenarios may be most likely, planners could select an adaptive strategy (Defra, 2006, cit. Gersonius, 2012). An adaptive strategy introduces the factor time by defining the moments *when* a specific situation is likely to take place and what combinations of measures in time could meet the required flood risk reduction.

To do so, a tipping point analysis has been performed to evaluate how long a certain measure appears to be able to comply with the limit values (thresholds or tipping points) that have been identified in the previous sections (8.4). This gives more information on when a flood risk strategy may fail and new strategies are needed. Based on this analysis, it has been investigated what different combinations of measures could be applied in time to meet flood risk objectives. These sequences of measures in time, which are implemented, to deal with flood risk under changing climate conditions are known as adaptation pathways (AP's). Adaptation pathways provide insight into options, lock-in possibilities and path dependencies (Haasnoot, 2012b). By using these pathways it is possible to identify opportunities, threats, timing and sequence of policy options, which can be used by policy makers to develop water management road maps for the future (Haasnoot, 2012a).

To develop AP's, use is made of the knowledge on the effectiveness of measures from the design by research exercise (section 9.4), the analysis of different water levels and flood impact at different climate scenarios (chapter 7) and the analysis of tipping points based on the set combination of policy objectives on social disruption and damage (section 8.4) were used. The adaption pathways that are defined in this section provide the basis for developing an adaptive policy (chapter 13).

This chapter is based on chapter 5-7 of the sub report "Exploring adaptation pathways" (Stone, 2012).



The AP's were developed through a workshop following a simplified version of the process as described in Roosjen (2012). This method distinguishes the next steps:

- determine the possible measures and switch possibilities between measures
- Select a policy approach (PA) as a starting point.
- Determine the pathways, combination of measures in time that match the approach and earlier set policy objectives.
- Determine risks (internal and external), lock-inns, advantages or considering other factors like costs and spatial quality of some preferred pathways.

By following this method the participants were stimulated to an adaptive way of thinking by included elements such as the diversity of future perspectives and the possibility to switch to other measures or AP's (Roosjen, 2012).

Defining possible strategies through adaptation pathways

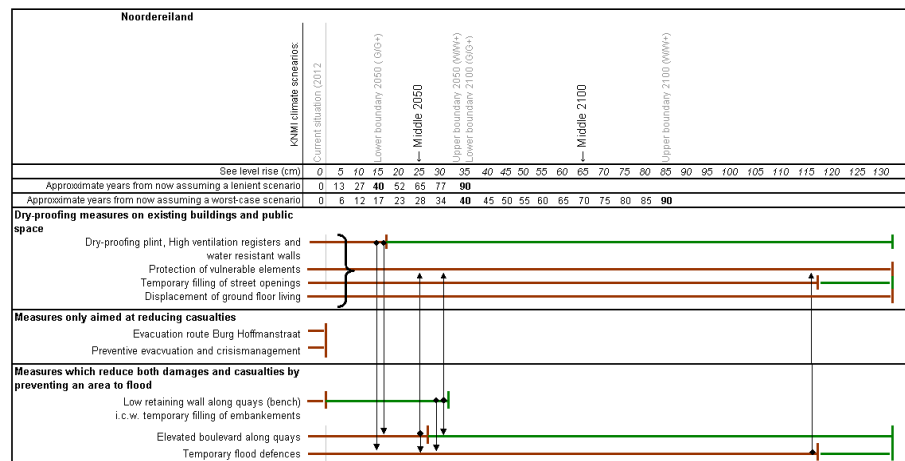
Based on the research on robustness and effectiveness of the possible measures that have been identified in a design research exercise (section 9.4), an overview of the effectiveness of measures at different climate change scenarios has been developed for the case study areas Kop van Feijenoord and Noorderiland (fig 12 and 13). In this overview the effectiveness of measures is illustrated for social disruption and damage. The effectiveness of measures in reducing individual risk could not be evaluated, since the provincial assessment model is not able to assess the effectiveness of measures on district level, such as a local floodwall.

This overview can be used in two ways. First it is possible to identify at what sea level rise events (5, 10 or 15 cm, etc.) a certain adaptive measure is not able to meet the previous set policy objectives and to identify which switches to other measures are possible and desirable. In the overview these possible switches are indicated with vertical arrow lines. Secondly, the scheme can be used to examine the time bandwidth available for a preferred measure to deploy and within what time period it is desirable to switch to a different measure.

A sustainable adaptation pathway describes a set of measures which is sufficiently robust to cope with different future scenario's but also adjustable to be able to adapt to unforeseen future situations (Roosjen, 2012). Often several AP's can be identified depending on the strategy one wants to follow, depending on the local situation, political preferences and actual costs of measures. Basically there are two directions that can be applied: dealing with an uncertain future can be done either by developing a so-called *robust* flood risk management strategy where measures are chosen that are able to deal with a large range of flood situations over a long period of time, or a more *adaptive* strategy where measures are implemented that are able to addressing the urgent issues in the short term, but are to be followed by measures that are able to deal with higher flood situations in the future. And thus offer a higher rate of flexibility.

figure 12 Effectiveness of flood risk reducing measures for the case study area "Noordereiland" on risk of social disruption (red lines), damages to new buildings(orange lines) and damages to existing building (green lines). The vertical arrows indicate possible switches to other measures.

Adaptation pathways Noordereiland and Kop van Feijenoord



For the case study areas Noordereiland and Kop van Feijenoord different possible AP's have been identified, based on differences in policy approaches. These policy approaches are constructed based on the option of a public responsibility or a more shared responsibility and the option of a preventive strategy or a strategy where partly flooding is accepted. This has resulted in the following conclusions:

Noordereiland

A policy approach that is deployed on preventing the area from flooding through preventive measures like a local retaining wall, embankment or a temporary flood defence, could provide an acceptable situation for at least the coming 30-65 years. By expanding the embankment with a small retaining wall or a temporary flood defence, basically a future proof solution can be realized. This solution is attractive because the embankment could easily be combined



with a new design of the public space and be designed in a way that can be anticipated on changing conditions. One concern however is the relatively high costs of the construction, which are not matching the avoided damages during a design flood event. Possibly the costs can be reduced by mainstreaming investments with the cycle of investments of public space and infrastructure.

An adaptive strategy is to accept a partial flooding of the public quays of the area, but prevent water entering the area by dry-proofing the existing buildings and closing of the street openings by temporary flood defences. This strategy meets the previously set standards only for a period of 20 - 40 years, because the closing-off of the façade openings is only effective to a limited extent (see section 9.2.3). After this period a switch can be made to other preventive options like a retaining wall or a temporary flood defence. The main discussion, here is whether it is a responsible course of action to ask residents and businesses to invest in dry-proofing measures, for only a limited period of time.

An alternative to this strategy is that the public authorities take preparatory measures for or start the construction of a flood prevention measure, up to a certain predefined water level. After an X number of years an evaluation can be made to identify to what extent building owners managed to dry-proof their buildings. At this point the decision can be made to either precede the dry-proofing strategy or to continue the preventive strategy, by adjusting the construction or adding a temporary flood defence. A major drawback of this strategy is that the incentive to invest in dry proofing of existing buildings is weakened, because homeowners are offered a basic water safety level for at least 10-20 years.

Finally, a policy approach has been analysed that is based on the doctrine that the responsibility of the municipality is limited to reduce the risk of casualties and the continuation of the functioning of vital infrastructure. Homeowners and businesses are responsible for damage-reduction. This means that the municipality will invest in measures, which prevent damages to the public space and vital infrastructure and invest in risk-communication, preventive evacuation and crisis management. Homeowners are stimulated to invest in dry proofing or wet-proofing their buildings. This strategy provides a water safe situation from the perspective of accepted damage for 20-40 years, as there is a limitation to the effectiveness of dry proofing. Possibly, flood insurance could extend this period, but this option is still not available at this moment.

Adaptive pathways; time dimensions on adaptation strategies for flooding

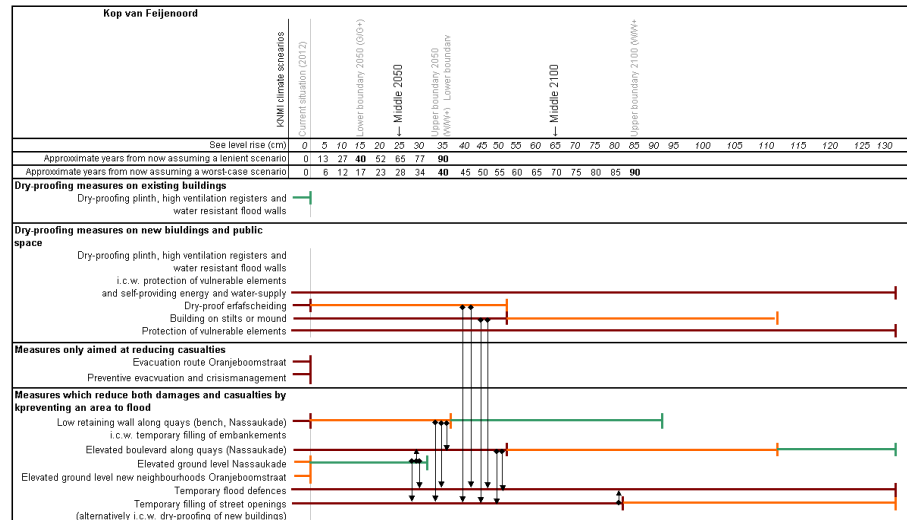


figure 13 Effectiveness of flood risk reducing measures for the case study area “Kop van Feijenoord on risk of social disruption (red lines), damages to new orange lines) and damages to existing building (green lines). The vertical arrows indicate possible switches to other measures.

Feijenoord

The first Policy Approach that has been explored assumes a full responsibility to prevent damage to buildings by the building owners. The municipality will need to take responsibility for prevention of damage to public space and provide sufficient safety measures. This is a challenging approach as substantial water depths can occur in this area. Adaptive measures on existing buildings (e.g dry proofing) are therefore not effective, but dry-proofing measures as well as (or in combination with) elevation building sites for new developments is an effective strategy up to at least 50 years from now. This strategy however, does not meet the set standards, as long there is no acceptable solution for the existing buildings. If we assume a large-scale redevelopment strategy of the Kop van Feijenoord wherein the old buildings will be rebuilt or redeveloped, it will be possible to accept a temporary exceeding of the accepted damage levels for existing buildings, during the upgrade period. This is actually the current policy approach.

A fallback option is to develop a small-scale flood defence. This would, however, imply loss of the initial costs for dry proofing the existing buildings and elevation on new developments, unless this flood defence will be constructed further in time (at least 50 years from now) or act as a double layer protection to protect from overtopping water at a moderate flood situation. It will be, however, hard to persuade developers and homeowners of the necessity of additional measures.

A second policy option is to develop a flood prevention approach, as the area faces substantial water depths due to its ‘ bath tub’-shape. As seen in the flood risk and spatial analysis (chapter 6), a large part of river front areas, which have been redeveloped in the 80’s are raised to safe levels. Only two sections of the



riverfront are still at a lower original ground level. A flood prevention approach would encompass measures that close off these fallow sections. This can be done by developing an elevated boulevard or by applying a grow model, where a low retaining wall, when changing conditions require so, is extended to an elevated boulevard or provided with a temporary flood defence.

Because mainstreaming with current developments is possible, this solution could be quite cost-effective, also because a large area benefits from the protection of a relatively small flood defence section. The approach does, however, imply full responsibility for execution, maintaining and inspection by the municipality.

An addition to this approach is to integrate the flood preventive measures in the new developments along the Nassaukade. By elevating the ground level or creating a flood retaining section in the façade of the new apartments, the cost-effectiveness of this preventive strategy can be increased and may create a higher development potential of the area. This approach, however, implies a shared responsibility on realization and maintaining of the flood defence with different stakeholders.

Conclusions

General conclusions

The results show that the higher areas within the study area only require immediate attention when it comes to ground floor bound living and the presence of hazardous activities in floodable areas. On the other hand, the urgency to tackle the encountered flood risk for the lower lying areas 'Kop van Feijenoord' and 'Noordereiland' is high.

For the Noordereiland it is shown that dry-proofing measures are highly effective in reducing the flood risk. Flood defence measures are slightly less effective but will still provide sufficient flood risk reduction for at least a period of 35 years. For the Kop van Feijenoord dry-proofing measures are not sufficient to reduce flood risks due to the large encountered water depths. For this area the flood defence measures show the highest effectiveness. The actual choice depends on the policy one wants to follow as is illustrated through the AP's.

The research focused mainly on the areas where the flood risks were highest. For the area where large flood depths are expected, the emphasis is on solutions aimed at flood prevention such as floodwalls and temporary barriers. Solutions where water can flow controlled within the urban area are less effective in these areas, but these measures could be interesting in areas, which will flood with shallower water depths.

Conclusions on the adaptation pathway method

The adaptation pathway method supports policy makers in making a choice for a certain long-term flood risk management approach. The method results in an insight into the urgency to adapt to climate change, insight into the effectiveness over time of the possible measures and visualizes the link between long term policy approaches and the possible measures.

The method proved to be an added value to the design research process as it adds an extra dimension through the insight into the effectiveness of solutions on the longer term. By connecting the technical solutions, different policy approaches and information on the physical boundary conditions such as the flood risk and climate change, a bridge towards developing long-term policy was created. In addition it links the urban planning and flood risk management. Like the research design exercise, the method also brings different expertise together and from the experience it was also learned that the *process* of developing the AP's is as important as the actual end-result.

From the experience it was also learned though that the concept of AP's is not easily understood. The used models and diagrams are quite technical and difficult to understand for non-professionals. This makes the method somewhat less useful for stakeholder session. It is therefore recommended to develop more easily readable diagrams and models and develop explanatory notes to introduce the method.

It was also seen that the effectiveness of measures and strategies depends strongly on the choice of the objectives. In this research the objective on social disruption was set quite strict and for the current urban design already none of the assessed areas comply with the set objectives. Less strict objectives will result in lower flood risk and more robust measures. It is therefore of great importance to choose a set of objectives which is sufficiently supported by the stakeholders. The exercise also showed that some of the objectives could not be assessed thoroughly due to a lack of information. It is therefore recommended to define objectives which can be assessed in accordance to the data availability or invest in gaining more and detailed data.



10 Governance of a local adaptation strategy

Introduction

Inner city area redevelopment may provide opportunities to integrate flood management measures in planning processes. The basic assumption is that by mainstreaming flood management measures with urban development processes the adaptive capacity to cope with the effects of climate change might increase. The aim of this chapter is to reveal the barriers and opportunities for stakeholders' support of effective adaptation measures and strategies. And to develop generic lessons and recommendations for the implementation of these strategies in local policies and urban development processes.

In order to investigate the support of stakeholders for risk-reducing adaptive measures an in-depth interview has been conducted with key stakeholders from the study area. Interviews have been taken from public officials of the municipality of Rotterdam and the Feijenoord borough, managers of real estate development companies, a housing association, a large company, and active residents in the neighbourhoods. Each interview was recorded and transcribed in full. This chapter is based on the sub-report: "Increasing the adaptive capacity in the unembanked areas: an exploration of stakeholders support"(Kokx, 2012)

Responsibility distribution

Actor-satisfaction about the division of responsibility and the process

Actors stated to perceive a shared responsibility with respect to climate adaptation in the unembanked inner-city area development. Therefore, we may expect a policy network that integrates climate adaptation measures with the policy aims of inner-city area development in our case study. Besides, stakeholders would depend on each other and through the exchange of resources (money, knowledge, information) might reach their aims. This requires a shared vision on both the area development and the most effective climate adaptation measures.

However, in practice we found traditional hierarchical government steering with respect to water safety policies, namely elevation of the land as an instrument to increase the water safety in the neighbourhood. An explanation for this hierarchical government steering can be found in the path-dependency of former Dutch sectoral water management. Within this hierarchical but also

neoliberal governance arrangement, the government sets the standards, and market parties are responsible for climate adaptation implementation in the neighbourhood.

Market parties are dissatisfied with this division of responsibility, because only they have to pay for the costs of water safety in the neighbourhood. Besides, this hierarchical steering restricts innovation in climate adaptation, whereas the market has a self-steering capacity to be innovative. Therefore, opportunities to increase the adaptive capacity are not taken seriously. Furthermore, uncertainty about future climate change is not taken into account.

This hierarchical steering also makes cooperation difficult, because no attention is paid to the specific context in the area and the actors' interests. Recently, though, the municipality has taken the first steps in adaptive management by bringing stakeholders together in expert meetings and by sharing information and knowledge. However until now, residents are excluded from these meetings, whereas water safety policies are directed towards their neighbourhood. This may decrease the adaptive capacity in the neighbourhood.

Support for climate adaptive measures

Firstly, we conclude that the sectoral adaptive measure of elevation of the land generates important negative effects on other policy aims for the area, such as improving the spatial quality and the (social) quality of the living environment. Furthermore, it leads to a diversion with respect to water safety in the neighbourhood, because only new building locations will be elevated. From a social justice perspective, this approach can be questioned with respect to the division of risks: residents in social housing with fewer resources are excluded from water safety policies, whereas more affluent households in the new dwellings are included.

In sum, there is not much stakeholders' support for this adaptive measure. This also reveals the relation between dissatisfaction about the process and policy. However until now, market parties' financial considerations have been decisive to choose this adaptation measure for a development location. This could have been different with a combination of adaptive measures and by linking other investments in the area, or in other words by an integral approach in urban planning.

Secondly, our research reveals that the support for specific adaptation measures (quay, dry proof and wet proof buildings) is very physical context-dependent. For example, it depends on the spatial design in the neighbourhood, the possible level of high water in the area, and decisions about the existing housing stock (demolishing or not/ renovation or not). Probably, a combination of adaptive measures could also have increased the feasibility of these



alternatives, in which specific disadvantages of an adaptive measure can be compensated by opportunities for realizing other local objectives. Therefore, stakeholders support the importance of the development of an integral adaptive strategy for the neighbourhood.

Conclusions

The main conclusion is that the most important barriers for integrating climate adaptation measures into that neighbourhood are policy fragmentation of water safety policy (elevation of rebuilding locations) and the hierarchical governance arrangement in water management. This type of fragmentation, leads on its turn to fragmentation of other policy goals for the neighbourhood. It also leads to fragmentation between different areas in the same neighbourhood that received political attention and those, which are excluded, from water safety policy. The divergence as an effect of policy-making in water safety questions this approach, in a sense of social justice. Another important side effect is that this governance arrangement also restricts innovation towards climate adaptation.

Therefore, an important lesson learned is that integrating water safety policies in urban planning (in its capacity as a more integrative and spatial comprehensive approach) should be considered the best option to increase the adaptive capacity in delta cities. Not only, the negative effects in terms of policy fragmentation can be dealt with effectively, but also spatial fragmentation can be tackled.

11 Legal aspects of adaptive measures

Introduction

Locally implemented adaptive measures, such as wet-proofing of existing buildings and the construction of a local flood defence, are largely dependent on the legal feasibility. The aim of this chapter is to evaluate the feasibility of adaptive measures from a legislative perspective. Moreover, this chapter will focus on the effect of policies, laws and regulations on the potential of reducing flood damages through spatial planning measures, flood zoning and building codes.

The research starts with a literature review of policies, laws and regulations, which formed the basis for a series of interviews with legal and zoning specialist of the municipality of Rotterdam. Two workshops were held, which also included discussions on the legal feasibility. This chapter is based on the sub-report “Planning and building regulations: legal aspects of adaptive measures” (Vliet, 2012).

Key policies, laws and regulations

Policies and laws

After a number of severe floods in Europe, the European Union developed the *European Flood Directive* (2007), which offers a framework for assessing flood risks and decreasing the negative consequences of floods. The new Dutch Water Act of 2009 incorporates the EU Flood Directive in the Dutch legislation. The Water Act provides legal protection for main watercourses and primary levees.

In the Water Act also the distribution of responsibilities of flood risk management of unembanked areas is established. The act makes clear that the assessment of the local flood risk situation, risk communication and weighing whether and under what conditions it is acceptable to build in unembanked areas lies within the regional and local authorities (ministry of transport, public works and waterways, 2009). However, until now this local responsibility has been barely translated into local action plans or regulations by local communities.

The water boards have no formal responsibility for flood risk management of areas outside the protection of the primary water defence system, although in some cases the river foreland is considered to be part of the protection system. The provinces are allowed to develop their own spatial and water policies, re-



sulting in different approaches on flood management in the unembanked areas. The provinces not only develop policy documents on the desired spatial planning, but also enforce the most important aspects via spatial planning regulation.

The province of South-Holland has no specific rules for flood risk management in unembanked areas, but has recently developed a new instrument to assess flood risk of new developments of the unembanked areas, which takes a flood risk instead of a flood probability approach. This GIS-based tool is, however, not intended as a basis for strict regulation, but is meant to operate as an information and communication tool. Moreover, a discussion is going on whether the flood risk policy of the province should confine only to risk of loss of life and leave the assessment of vulnerability and damages to the local communities.

The Major Rivers policy states: New activities in the unembanked areas may not impede the rivers' discharge, as that would increase flood risks of the embanked areas. Most of the unembanked areas of Rotterdam are however excluded of this rule. Municipalities that are located more upstream of the main rivers are however subject to this rule and are only under strict regulation allowed to raise or change river fore grounds.

The current flood risk management policy of the municipality of Rotterdam is to gradually elevate the ground level of the unembanked areas, by enforcing a higher building level in the case of new developments and a flood risk action plan for existing areas. By an indication in the water section of the local zoning plan (*waterparagraaf*) landowners and residents are informed about the flood risk situation and that they are responsible in the event of any damage as a result of high water. The municipality of Rotterdam has no policy for risk communication and uses no special planning regulations for water safe building.

Local regulations and legal instruments

Building level (Uitgiftepeil)

The policy of the municipality of Rotterdam to gradually elevate the ground levels consists of a recommendation of a safe construction level, to which the outdoor space is elevated. Although this building level is a recommendation and could be set aside, the municipality may define a construction level as a binding pre-condition in the urban development contracts (*anterieure overeenkomst*). These urban development contracts are only granted in case of public land sale or mutual financial obligations between public and developing parties. This means that in case of small redevelopment projects a construction level cannot be enforced.

land use zoning

The Major Rivers policy is enforced via the Dutch spatial planning regulations and Water Act. The spatial planning act states that municipalities should develop land use zoning plans (*'Bestemmingsplan'*) every 10 years. In these plans they have to incorporate legal rules from higher government layers. In order to demonstrate a good spatial planning, it can be necessary to demand for extra measures to be taken. The zoning plan can only describe spatially relevant rules and obligations. This means that for the assurance of external risks, as flood risk, usually a spatial translation must be found, for example specific rules for the use or the building level of the ground floor.

In special cases, non-spatial measures can be enforced, provided that spatial planning is at stake. Such, in the zoning plan included conditions or obligations, offer opportunities for defining adaptive measures. Jurisprudence shows at least one case in which a plan was expunged in which flood risks in unembanked areas were not taken into account, for instance by elevating ground level.

Waterboards have the right through a special section in the spatial zoning plans, the so called *waterparagraaf* to ensure that all water related aspects are well recorded in the spatial zoning plans. Although the *Watertoets* on this moment is not currently used to capture flood risk management aspects, the *Watertoets* would however be an appropriate instrument to ensure long term flood risk strategies (Pieterse, 2009, cited in Vliet, 2012))

Building codes and local regulations.

The national building codes contain norms for buildings, like escape routes, strength of walls, day lighting, etc. This national building code has a pre-emptive effect; local governments cannot enforce norms that are stricter than the building codes' norms. In the current code is no regulation on flood proof constructions. Matters not covered by the National building codes, may be arranged by local municipalities by contract or otherwise (Groen, 2012, cited in Vliet 2012). Possible tools that local municipalities could develop to stimulate or enforce adaptive measures are planning pre-conditions (stedenbouwkundige randvoorwaarden) or local building regulations.

Under the new Spatial Planning and Environmental Act (*omgevingswet*) the current land use zoning plans will probably be incorporated into the environmental regulation (*omgevingsverordening*). The expectation is that the local building regulations will be included to the land use zoning plans. The question is whether there are under the new spatial planning and environmental act, sufficient opportunities to include local building regulations.



Legal enforcement of adaptive measures

Although there are only few policy restrictions on building in unembanked areas of Rotterdam, the legal enforcement of local adaptive measures proves to be difficult or even not feasible.

Measures, which directly affect the design and materialisation of existing and new buildings, like wet-proofing and dry-proofing, are very difficult to legally enforce. These measures require detailed local building regulations that go beyond the national building codes. As long as the national building codes do not pay attention to building in the flood plain, municipalities lack the tools for these measures to subscribe. Possibly, wet-proofing might be regulated, through an appeal on good planning in the zoning plan, although this still needs to be clarified. Wet-proofing and dry-proofing can only be promoted by non-legal measures like cooperation, subsidies, training and risk-communication.

The development of a local embankment or other preventive measures poses no legal problems, especially if the embankment is build on public owned space and the works are carried out and financed by public authorities. The embankment can be legally defined in the local zoning plan and even be appointed as a secondary levee by the Province or water board. This situation is however more complex, when the embankment should be enforced at a private development. Although a specific area could be appointed as local embankment in the zoning plan, the actual construction of the embankment only can be enforced, when part of a development contract.

The regulation of flood-prone functions and land use can be provided through the zoning plan. Although flood zoning in the Netherlands, when compared to the UK or US, is an unknown phenomenon, flood zoning could be applied relatively easy in newly developed areas. It is, however not possible to enforce a certain land use, for example restricted use of the ground level of buildings, unless the public authorities are willing to provide compensation.

Horizontal evacuation strategies (leaving the area) are difficult to control through planning, unless rules are explicitly needed from a 'good planning' perspective. Evacuation routes can be destined in the zoning plan and combined with infrastructure. Vertical evacuation (inside the building) is more difficult to enforce by the limitations of the building code. The building code does have rules for escape routes, but they are mainly focussed on fire, leaving the building, and not on flood situations.

An important area of concern is still what public or private partner takes responsibility for maintenance and daily management of a local embankment or inspection of adaptive measures. Water boards are at first sight the appropriate partners, because they could provide the knowledge, legal means and infrastructure to ensure the long-term water safety of the area. The Water boards have however, as stated before, no legal responsibility for water safety of the unembanked areas. The local authorities could fill the gap, but here is

the problem that the interest of short-term area development could conflict with the long-term water safety. Especially the small municipalities lack the knowledge and time to fulfil this role. Obtaining clarity on this point is one of the main challenges for realization of a local adaptation strategy.

Conclusions

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- In the Netherlands, there is relatively little need for adaptive measures, as the embanked areas have a very high safety level and most inhabited unembanked areas have been elevated in the past. Furthermore, water and flood management issues only play a moderate role in spatial planning. Inhabitants have little or no experience with flooding, which otherwise functions as a pressure for more adaptive measures.
- As there is relatively little experience with adaptive measures, the laws and regulations are often not clear on the use and impact of them. Currently flood risk management is no element in a zoning plan, and is only on voluntary basis mentioned to inform stakeholders. Adaptive measures and building regulations are until now not included in the national building act (bouwbesluit) and are not included in local building codes (integrale bouwverordening)
- Flood zoning as instrument in new areas will not prove to be problematic, but is much harder in existing areas as land use zoning plans cannot change current functions.
- Several of the adaptive measures, like dry-proofing and flood zoning are difficult to decree by local or national regulations, especially in existing urban areas, as building permits application can only be denied when they do not meet the land use zoning plans or the national building codes. Given the way spatial planning is organised in the Netherlands, it will be more feasible to decree these measures for new urban developments.
- Because of the integrated nature of adaptive flood management the possibilities are influenced by other factors than flood risk policies and laws alone. Aspects like spatial quality and social safety will also play a role in spatial planning. For a more adaptive flood management a paradigm shift is needed among spatial planners, water managers and policy makers on the different government levels involved, as well as among the major stakeholders.



12 Determining the adaptive capacity for flood risk mitigation

Introduction

In the previous sections we have seen that urban adaptation to cope with (increasing) flood risk includes retrofitting of different types of assets within the built environment. This includes flood proofing of buildings, infrastructure and the utility lines. Although desirable, this upgrade is most of the times not performed in a single increment but in gradual steps over time. Even so, adapting the existing city to new standards often proves to be expensive and difficult especially in cases where no significant flooding has occurred in recent history. Yet during major renewal/maintenance cycles, retrofitting schemes can be mainstreamed into the planning of new constructions or major refurbishing. Depending on the end of lifecycle of the existing asset stock and the local flood characteristics, this so called ‘opportunistic adaptation’ can potentially facilitate flood mitigation measures without the need for large-scale interventions. Furthermore, due to the gradual upgrading, new knowledge about climate change and subsequent river stages can be integrated over time. This chapter is based on “Determining the Adaptive Capacity for flood risk mitigation: a temporal approach” (Veerbeek, 2012b)

End of Life Cycle (EOLC) methodology

In order to study the potential of such an approach, it is vital to gain insight into the urban dynamics of asset replacement (i.e. the expected lifecycles of groups of assets). This chapter introduces a first attempt at developing and applying a methodology that estimates the end of lifecycle of buildings, infrastructure, public space and utility lines in the Rotterdam unembanked area. Based on the construction year and expected lifespan, the individual asset’s end of lifecycle is determined (fig 14). Except when performing critical functions, it is unfeasible that individual assets are replaced. Therefore a hierarchic system of inheritance has been developed where dominating assets pass their end of lifecycle on to dependent assets. For instance, only when a street is upgraded the sub-surface utility system (i.e. pipe network) will be replaced. Furthermore, within asset classes, the replacement of groups often prevails over the replacement of individual assets; if possible, complete housing blocks are replaced instead of individual units. The outcomes of this study are based on this approach. Furthermore, since the lifespan of assets (especially buildings) is dependent on a large set of endogenous and exogenous factors, a stochastic approximation has been developed in which the uncertainties stemming from ownership and other factors is expressed. This provides the outcomes with ranges instead of fixed future moments in time in which (sets of) assets reach the end of their lifecycle.

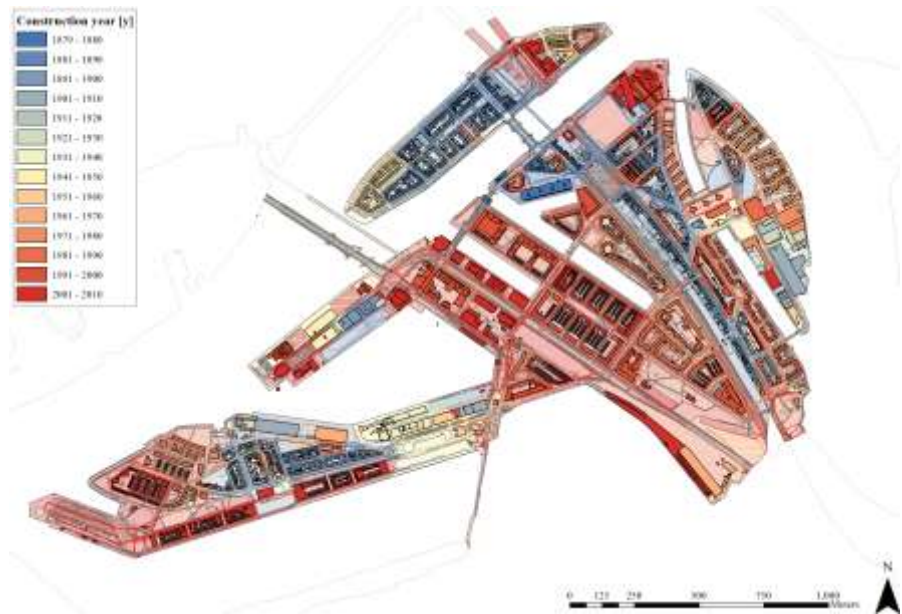


Figure 14: Estimated construction year of assets within the study including inherited construction years for infrastructure, public space and utilities.

The final aim is to gain some insight in the potential adaptation rate (i.e. the adaptive capacity) when flood adaptation is exclusively performed through proactive retrofitting of new constructions.

Conclusion

One of the most important observations of this study is that mainstreaming adaptation with the urban renewal cycles on street, block or neighbourhood level (i.e. cluster level) significantly delays the upgrading of flood protection standards.

Although the mainstreaming of adaptation and subsequent pro-active retrofitting with urban renewal might lead to an embedding of an adaptation strategy within urban development, the question remains if the study area, or more generally, the Rotterdam metropolitan area can afford to wait. This is to some extent depended on then identified flood risk in the areas; areas with only limited flood risk might not need urgent action to upgrade protection standards. Furthermore, increased knowledge about the trend changes in sea level rise and river levels might favour a strategy that is not only flexible in its protection level, but also in time (e.g. Gersonius, 2012). Probably, it is safe to conclude that a mixed-strategy is needed in which the protection standard for the most vulnerable areas is upgraded to a sufficient level (either by limiting hazard, exposure or sensitivity). Future adaptation can then proceed incrementally and be synchronized with the identified renewal cycles.



The estimation of the EOLC of various asset classes in the project area provides strategic information that could provide a guideline for opportunistic adaptation (i.e. adaptation integrated in urban renewal). Especially on a larger scale level, it could provide opportunities for long term regional and national adaptation strategies.

13 Towards an integrated flood risk policy

Introduction

As we have seen in the section on legal feasibility of local adaptation (section 12.2) the current policy frameworks on European, national and provincial level delegates responsibility for the assessment of the local flood risk situation and the development of a local flood risk policy to the local authorities. However, most of the municipalities in the region Rotterdam and Drechtsteden have not yet developed policies for flood protection for the built-up unembanked areas. As flood risk is increasing, due to rising sea levels and on-going urbanization of the river front areas, developing an integrated flood risk policy on the local scale is becoming more urgent.

Together with municipalities in the greater Rotterdam-Drechtsteden area a working session is held to exchange experiences on flood risk policies and practices on the development of river front areas. This session revealed that there are two key questions when determining a future local flood risk policy:

- Is local flood risk protection a shared responsibility between government and other stakeholders or will it remain an exclusively public task?
- Are we continuing a prescriptive approach, based on norms and rules that can be applied to the entire unembanked area or are we moving towards an impact-oriented approach, based on differences in local conditions?

This chapter examines the contours of a local integrated flood risk policy, based on the results of the research on the legal aspects and governance aspects (chapter 11 and 12) and an overview of different policy approaches of other delta cities in the Netherlands and abroad. Finally the contours and building blocks of a local flood risk policy are presented. This chapter is based on the sub-report: "Contours of a local flood risk policy in Rotterdam" (Siepman, 2012)

Overview of flood risk policies of other delta cities

The comparative study of different flood risk policies of delta cities in the region shows that most cities have guidelines and building regulations for new development in flood prone areas and has developed procedures to manage and respond to a high water situation, especially in the low-lying historical parts of the cities. The city of Dordrecht has, for example, developed a detailed



emergency action plan, that contains not only procedures for placing temporal flood walls, but also a risk communication plan. Annually is practiced with placing the flood protection and the distribution of sandbags, to be prepared for flood events. Cities with urbanized zones with a high risk of flooding, as Dordrecht, Vlaardingen and Maassluis, apply an early warning system that informs residents and companies in the flood prone areas of a high water situation. More general risk communication is not widely applied. Experience and research (de Boer, 2011 cited in Siepman, 2012) show that especially in areas with a moderate flood risk, awareness among residents and businesses is very low.

Although most cities in flood prone areas do have guidelines and flood management procedures, these guidelines are not integrated in an integrated flood risk policy. This means that, depending on local conditions and advices of the Department of waterways and public works on local maximum flood levels flood mitigating measures are chosen. In almost all cases the municipalities demand to raise the ground level of the area to acceptable flood levels, when the area is developed. An exception is the city of Vlaardingen. The city has challenged the developing parties to come up with alternatives for local flood protection, as part of the overall development strategy of the riverfront of the old harbour of Vlaardingen. The role of the municipality is facilitative and limited to provide objectives, based on national and regional legislation.

The conclusion is that, although there is no standardized flood risk policy, the following principles can be identified:

- Flood risk of existing flood prone urban areas is regarded as a responsibility of homeowners and companies. The public task is limited to reduce the impact of a flood situation by informing and training stakeholders, developing an emergency action plan, a risk communication plan to inform stakeholders and to invest in reducing the vulnerability of vital infrastructures;
- For newly developed areas the strategy is focussed on developing a robust solution, where the role of the municipality is limited to set targets and objectives, but the development of a flood reduction strategy and implementation is left to developing parties and other stakeholders.

Some considerations of a local flood risk strategy

If water safety is regarded as a joint responsibility of the municipality and residents, companies, developers and other stakeholders, one of the main challenges is to develop new financial arrangements to finance and distribute costs and benefits between the different stakeholders. A local flood risk tax could be a way to jointly invest in long-term flood safety. In Hamburg, already is experi-

mented with a so-called *Poldergemeenschap* with which the costs and maintenance of local flood reducing measures are brought together and managed directly by the stakeholders.

The question on financing also depends on the question which party is able to make a proper balance between the interests of area development and long-term water safety. The water board has the knowledge and the proper legal instruments, but currently has no responsibility for managing flood risk in the floodplains. The municipality would be able to take this role, but there is the risk of a conflict of interest, when the municipality is stakeholder in area development.

Finally, it is necessary to develop new legal and spatial planning instruments to ensure that flood risk strategies are also on the long-term integral part of area development. The current zoning plan is not suitable, because it is a descriptive instrument, with a limited time horizon.

Conclusions

Based on the results of the research and the session with neighbouring communities in the delta, an area-oriented approach seems to be the best opportunity to develop a cost-effective and flexible flood risk approach. An area oriented or local flood risk approach allows for customized solutions, taking into account the spatial and demographic characteristics of an area and the spatial developments that take place in the area.

A prerequisite of an area approach and local customization is the development of clear objectives and limit values and to invest in detailed knowledge on the flood risk and impact of a flood. The limit values that are currently developed by the Province South Holland, could be helpful to set up a clear framework.

Secondly, the implementation of a flood risk strategy could be a shared responsibility of municipality and local stakeholders, where the government is concerned with providing frame works, target levels, knowledge, information and communication and has the responsibility to reduce the vulnerability of vital infrastructures and objects, the local stakeholders are responsible for implementing and maintaining measures to prevent damages.



14 Conclusions and recommendations

General conclusions

- The vulnerability of the Rotterdam unembanked area to flooding, in terms of damages, casualties and loss of vital infrastructures is limited. There is still, however, little known of the sensitivity of vital infrastructures to flood situations and indirect impacts of possible multiplier effects that might affect large part of the city.
- Although there is no urgent need for flood impact reduction of the Rotterdam unembanked areas on the short-term, the unembanked area is vulnerable for sea level rise. It is, therefore necessary to develop an adaptation strategy to avoid risk, high costs and unwanted spatial situations in the long run;
- For the Noordereiland it is shown that dry-proofing measures are highly effective in reducing the flood risk. Flood defence measures are slightly less effective but will still provide sufficient flood risk reduction for at least a period of 35 years. For the Kop van Feijenoord dry-proofing measures are not sufficient to reduce flood risks due to the large encountered water depths. For this area the flood defence measures show the highest effectiveness. Both cases show that determination of the most appropriate solutions largely depends on the local physical and socio-economic conditions.
- An integrated local flood risk strategy, based on a detailed vulnerability assessment, is in many cases on the short term cost-effective because investments in flood risk reduction can be more focused and mainstreamed with spatial development processes. This research has, however, not proved that this approach in the long term also contributes to a more cost-effective and more flexible approach.
- Developing support from stakeholders, including residents, is extremely important for the implementation of adaptive measures in spatial development, because this increases the legitimacy of the decision-making process and creates opportunities for mutually approved integrated measures.
- Working with different policy objectives for social disruption, damages and individual risk proved to be complicated. Although this classifica-

tion reflects the complexity and multiple aspects of flood risk, it turned out to be time-consuming and rather subjective to reach consensus on thresholds for vulnerable functions. Working with a 1-100 return period norm for flood damage turned out to be a useful policy objective. It is necessary to convert these objectives and thresholds to more generic and more workable and better communicable targets.

- The ATP approach has proved to be a useful instrument to systematically assess and elaborate the adaptive measures. It is however a time-consuming technique, that relies on very detailed analysis of vulnerabilities and effectiveness of measures and a consensus among policy-makers and stakeholders on objectives and thresholds. In situations where these detailed information or a common consensus of objectives and thresholds is lacking the ATP method is less useful as a decision support method, but should be used as a test and research method to explore the limits and directions of a strategy or policy.
- A point of attention, considering the ATP method is defining tipping point for 'soft' adaptation measures, like evacuation or an early warning system. These organizational measures normally have little spatial impact and for this group of measures it is difficult to use spatial tipping points, as thresholds are not clearly determined.

Recommendations:

- Develop an impact and area-oriented flood risk approach, based on a clear understanding of vulnerabilities. Develop, together with key stakeholders in specific area development packages of adaptive measures that are able to reduce vulnerability to floods. These agreements can be defined in a local flood management strategy. This new approach, where water safety is a shared responsibility of several actors, also implies that new knowledge is needed about financial, legislative and organizational arrangements and partnerships. It is recommended to do further research on this topic.
- A major challenge for a local adaptive flood risk strategy is to come to an agreement of a mutually acceptable distribution of costs and benefits on the short and long term and to develop workable arrangements to secure responsibilities, risks and investments on the long term. An important condition for a local adaptive flood risk strategy is a clear responsibility distribution for the long-term flood risk strategy. Which public or private party could take responsibility for maintenance and daily management and the long-term implementation of the local flood risk strategy? It is necessary to come to a debate on public and private responsibilities regarding flood risk.



- The detailed level of the two case studies resulted in very specific and concrete measures. Decision-making on a local adaptation strategy, however, also depends on decisions that are taken on the larger scale of the regional water system. For the Rotterdam case, a partly closing of the main branches of the rivers as a future flood management strategy, can greatly affect local decision on adaptation. It is recommended that further research into the relationship between scales and temporal aspects of adaptation will be conducted.
- It is recommended to develop legal instruments to facilitate adaptive architecture and construction. One option is to include adaptive building regulations in the National Building Code or allow municipalities to include local building regulations in the zoning plan.
- To bridge the gap between strategy- and policy development and implementation of adaptive measures, it is necessary to do additional research to engineering aspects of dry-proofing and wet-proofing.
- Current doorstep heights, elevation of critical functions and information on building materials and constructions are not integrated in the municipal datasets for individual buildings. To extend the damage assessment for large areas it is recommended to record and integrate these data into the datasets of new buildings.

15 Dissemination

Local and regional flood risk policies

This research has laid the knowledge foundation for the reassessment of the current flood risk strategy for the unembanked areas in Rotterdam. The current flood risk policy of the municipality of Rotterdam consists of an obligation for new developments to raise the ground level or first floor to about 4 meters above average sea levels. This policy has proven to be an effective tool in large-scale waterfront developments of former port areas, but it is increasingly regarded as less effective in small-scale and incremental redevelopment projects. Due to the current weak market situation these incremental transformation processes are becoming the mainstream. The proposed flood risk strategy focuses on adaptation at a local scale by integration of flood risk management measures with urban functions, making use of the dynamism of urban development processes. This approach aims to reduce the consequences of an inundation by promoting flood resilient architecture and adaptive measures. Together with key stakeholders in specific area development, agreements will be made on a package of measures aimed at reducing vulnerability to floods. These agreements will be defined in a local flood management strategy. This new comprehensive approach will be applied at two pilot areas, Heijplaat and Feijenoord.

Together with two social housing associations (Woonbron and Woonstad), both responsible for managing and developing the majority of build-up property in the flood plain areas, a Policy Framework on flood resilient architecture and public space will be developed. This framework will consist of preconditions for developing in flood prone areas and building codes and regulations to facilitate flood-resilient area development.

Furthermore, the results of this research and in particular the method of Adaptation Tipping Points and Adaptive Pathways, will be used as input for the development of a regional strategy on flood risk management of the unembanked areas of the metropolitan region Rijnmond-Drechtsteden.

Follow-up research

For various flood prone areas (Heijplaat and Feijenoord), the developing parties and stakeholders (including AM developers, social housing corporation Woonstad and local district representatives) have indicated that they wish to contribute to the development of a local flood management strategy. However, lack of knowledge of financial, legal and organizational tools to support a sustainable long term integration of water safety with spatial development processes makes it extremely difficult to come to decisions that are supported by all local



parties in the short term. To deal with these questions a research group of Deltares and Erasmus University, together with experts, both from municipalities and local government agencies and universities, will start a research project to develop knowledge about other forms of partnerships and arrangements (legal, financial and organizational) that can facilitate an integrated strategy for a local flood strategy at the district Feijenoord. First results of this research are expected summer 2013.

Towards implementation

In the borough Heijplaat, the social housing association is developing a new residential area of approximately 250 single-family houses. The results of the research on vulnerability and damage assessment have been used to develop a local flood risk strategy. The preferred flood risk strategy consists of a partial elevation of a quay, to protect the new development and an existing village, combined with flood proof design of the buildings blocks.

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