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A National Guideline for Climate Adaptation Planning; the Climate Stress Test for Urban Areas

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Abstract
To make urban environments in the Netherlands climate-proof and water-robust the Delta Programme launched guidelines and tools for climate adaptation planning, including a climate stress test. This test builds on new principles and concepts, making spatial adaptation a key element of building climate resilience. The test starts with a quick-scan of the climate vulnerability of an urban area and focuses on adaptation planning for the 'hot spots' in the next phase. Collaborative spatial planning to retrofit attractive solutions and system analysis of the vulnerabilities and of the effectiveness of adaptation measures are intertwined in both phases of the test. Vulnerability analysis is focused on the risks due to existing and future climate related hazards as well as on the adaptability of the urban environment and on the opportunities that come with adaptation; Special attention is paid to critical infrastructure, objects and the protection of vulnerable population groups. A vulnerability analysis of the governance system can also be part of this vulnerability scan. Tools are made available for both the vulnerability analysis and for supporting the collaborative planning process. The stress test and other guidelines on www.spatialadaptation.com , though not compulsory, are used by municipalities, water authorities and their consultants, but adapted to the local conditions in each city or village. Moreover, spatial adaptation is an essential part of the multi-level water safety policy and will become a key element of the National Adaptation Strategy of the Netherlands

Keywords
climate stress test, urban areas, planning principles, vulnerability, receptivity, climate adaptation

INTRODUCTION

The Dutch national Delta Programme aims at protecting The Netherlands for flooding and at ensuring a sufficient supply of fresh water. One of the key elements of this programme is a 'delta-decision on spatial adaptation'. Core of this decision is the collective ambition of the central, provincial, municipal and water authorities to have a climate-proof and water-robust organization for the Netherlands by 2050. By 2020 at the latest, all authorities should have incorporated this approach in their policies and act accordingly. New developments, redevelopment, management and maintenance will entail as little incidental risk as is reasonably possible of damage or victims caused by expected increase in heat stress, heavy rainfall (pluvial flooding), drought and flooding from rivers and/or the sea. In order to achieve this goal the authorities have to complete three steps, if necessary in cooperation with social organisations and private parties: (1) 'Analysis, including an analysis of the vulnerability of the area, a so called 'climate stress test'; (2) 'Ambition, translating threats and opportunities found in the analysis into a supported ambition and adaptation strategy and (3) 'Action, indicating how the objectives impact its own policy, spatial plans, regulations, business cases, implementation, management and maintenance activities. (Delta-programma, 2014)

To support these policy goals a Guide to Spatial Adaptation was prepared by the Delta Programme and was made available to all regional and local authorities on the digital knowledge portal

www.ruimtelijkeadaptatie.nl, including a summary in English on www.spatialadaptation.com . The portal contains data and tools to assist all stakeholders with relevant information, tips and procedures to facilitate climate-resilient planning. New climate scenarios for the Netherlands for the reference years 2030 and 2050 were published earlier by the national meteorological office (KNMI, 2014). The guidelines are not obligatory, but are meant to give directions and to some extent harmonize the approach to creating a more water-robust and climate-resilient urban environment.

Objective of this paper is to present the national guidelines including the backgrounds and principles that underlie them. Some of these backgrounds and principles reflect a paradigm shift in thinking about ways to create resilience and to improve the liveability of our urban environment. The guidelines' focus is on retrofitting adaptation measures in existing urban areas in particular, as spatial adaptation is harder there than in new urban developments.

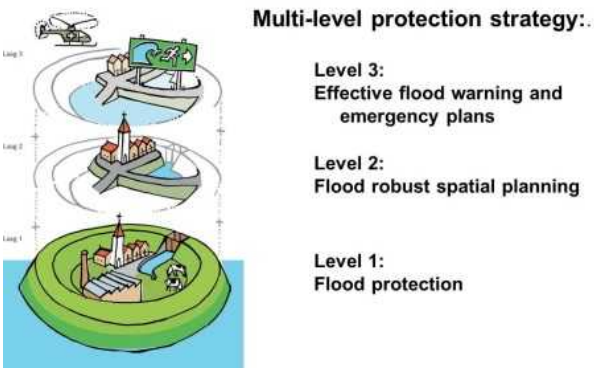
UNDERLYING CONCEPTS AND PRINCIPLES

The approach to planning and designing a climate resilient urban environment is based on a number of concepts and principles:

Water is key factor

Water is an essential part of a climate resilient urban environment. This is evident for all forms of flooding and drought, but is also valid for heat stress. Heat stress is for a significant part a result of water shortage for evapotranspiration. Urban areas are, as compared to vegetated rural areas, less able to 'sweat' and by consequence run hot. Also land subsidence – a process that aggravates flood risk – is largely a consequence of water management: Groundwater extraction, excessive drainage and/or low groundwater levels during periods of drought cause the land to subside.

Spatial planning: essential component of flood protection



Flood protection is not only realized by strong dikes/levees. Flood protection also requires a water robust spatial planning and effective flood warning systems and emergency plans. The Netherlands applies this multi-level flood protection strategy (Figure 1) to reduce flood vulnerability of the country. At the level of flood robust spatial planning many measures can be taken in the design, construction and maintenance of infrastructure, buildings, land levels and water system to reduce vulnerability for flooding.

Figure 1. Flood protection strategy of the Netherlands (Nationaal Waterplan, 2009)

Flooding, drought and heat stress risk reduction integrated

Risks related to flooding, drought and heat stress are not independent and neither are the adaptation measures. E.g. measures to protect the city from flooding could increase drought and heat stress problems. That is why climate adaptation planning has to address all climate hazards and adaptation strategies in an integrated way.

Most spatial adaptation plans are however not triggered by the need for climate adaptation but by the need for urban renewal and reconstruction. Though the reason for adaptation is different, such adaptation planning processes provide an excellent window of opportunity for retrofitting climate adaptation measures at relatively low costs.

Maximize added value of adaptation measures

Most structural adaptation measures have – or can have - multiple use functions. Many ecosystem

and economic services can be provided in addition to flood protection, drought mitigation and heat stress reduction; e.g a superlevee is used to build housing on, an urban wetland also purifies stormwater and serves ecological, recreational and landscaping functions. Multi-functionality also creates more direct stakeholders – shareholders - resulting in more pressure on decent maintenance. It is a true design challenge of climate adaptation planning to maximize functions, services and values of spatial adaptation.

Minimize damage of a failing protection system

Civil engineers design protection systems on a probability of failure standard. This return period of system failure is very high for the levees that protect the heart of Holland from fluvial and coastal flooding- or low for pluvial flooding of streets. Acceptable probabilities of failure for drought and heat stress are not formally regulated. But the message is that every protection system is designed to fail under some extreme condition. A new and additional design challenge (assignment) is to minimize the damage of such a system failure (Fratini *et al*., 2012). If we are able to keep critical infrastructure working and to protect the most valuable and vulnerable parts of our urban system we can shorten time to recover from disaster and minimize both economic and social damage.

Vital and vulnerable functions and people

Vital and vulnerable objects, networks and population groups need extra protection, as their failure would lead to supra-regional damage. Power supply, telecom connections, water supply, waste water collection and treatment facilities, health care facilities, pumping stations, road, railroad and subway systems, rescue teams and vulnerable people like the disabled and the elderly; all these facilities and groups are to be identified and to be given extra protection, both from an economic and from a social perspective.

Co-creation

Public authorities are generally unable to handle extreme weather conditions on their own and on public land only. Many adaptation measures are to be realised in the private realm, rather than in the public domain, to retain water in times of surplus and to provide water in times of drought and heat stress. And private stakeholders have an interest in taking additional protection measures, both to create protection against extreme weather conditions and to create development opportunities. That is why spatial planning of adaptation measures is not only a task for local and water authorities but should involve private stakeholders or their representatives. Co-creation of adaptation plans also helps maximize the willingness to invest in adaptation measures by private parties.

GUIDE TO SPATIAL ADAPTATION

The resulting stepwise approach to planning and design of a climate resilient urban environment is illustrated in Figure 2 (Deltaprogramma Nieuwbouw en Herstructurering, 2014). Characteristic of this *stress test* procedure is that adaptation problems are addressed as development opportunities. Climate adaptation plans are matched with adaptation plans that result from regular maintenance operation and/or the need for technical or socio-economic reconstruction. Therefore, the co-benefits of climate adaptation measures are as important as the climate resilience benefits.

A first phase focuses on the vulnerability of the urban system, including an outlook towards opportunities and potential solutions. Hotspots and windows of opportunity for implementing adaptation measures are identified, so that the next phase can be concentrated on areas and issues that require our attention most urgently. This first phase has a quick-scan character, to avoid spending too much effort on issues that are not a real and urgent problem. The next adaptation planning phase is meant to study problems and challenges more in depth and to develop concrete adaptation plans for the short, medium and long term. Both phases reach their climax in workshops that are meant to create agreement among the stakeholders on the problems, the opportunities, priorities and on an appropriate package of adaptation measures. The two phases can be separated strictly, but the adaptation planning phase can in principle start the moment vulnerabilities were

Figure 2. Stress test approach to climate-proof and water-robust spatial planning of urban areas (Deltaprogramma Nieuwbouw en Herstructurering, 2014)

identified. Some peculiarities of the two phases are elaborated in the next sections.

Decisions on the adaptation strategy – e.g. ratio green versus grey infrastructure, ratio investments in threshold capacity to avoid damage versus investments in coping capacity to reduce damage of a failing system – are to be taken by the local stakeholders, in line with the multi-level protection strategy.

Vulnerability scan

Although the vulnerability scan is primarily meant to identify the 'hot spots' requiring adaptation this phase also includes (1) a step that is focussing on the opportunities that are created by both climate change and adaptation and (2) a climate workshop that is focussing not only on a shared understanding of the challenges but also on identifying potential adaptation solutions. It is important to investigate which new opportunities will emerge from climate change as well as from adaptation and how adaptation measures contribute new added values to an urban area and can stimulate social and economic development, meanwhile reducing risks related to extreme weather conditions. Any problem without an attractive solution is preferably neglected by investors and decision makers and this is equally true for climate adaptation.

The vulnerability scan phase is also meant to create awareness for climate vulnerability and receptivity for adaptation. In line with receptivity theory (Jeffrey and Seaton, 2004) the stake-holders learn about new and better solutions, learn to associate the potential benefits of these solutions with their needs an capabilities, they will acquire the capacity to exploit such new measures and learn how to apply these in their area. The more in depth the vulnerability scan is executed, the less analysis work is to be done in the next phase of adaptation planning.

Important component of the start-up activities is to organize stakeholder engagement. There is no generic answer to the question who and how to involve stakeholders in the planning process. However, as climate resilience cannot be achieved by actions on public land only it is recommended to involve also private organizations and representatives of local companies and residents at this very early stage of planning, in order to create an open atmosphere for the exchange of knowledge

and ideas. The climate workshop often helps create commitment of stakeholders, as it is easier for many participants to 'think in solutions' than it is to think in terms of problem definition.

Commonly an important hurdle in this phase is the disclosure of all the relevant data. Many data are relevant for analyzing the vulnerability and for formulating potential solution pathways. Data on weather, subsurface, soil, groundwater, surface water, water quality, land level, utilities infrastructure, urban green, building foundations, ground floor levels, land and building ownership and so tend to be scattered in different organizations and in different parts of each organization. Bringing this data together is a substantial effort that requires 'willingness to share' and cooperation of many parties.

The vulnerability analysis of the physical urban system is composed of three components: (1) Analysis of future climate hazards and exposures to sea level rise, extreme rainfall and river floods, droughts and heat waves, These depend on the projected climate in e.g. 2050 and 2100, but also on the future state of the existing protection facilities under their regular maintenance and replacement scheme – a business as usual scenario- as well as projected urban developments. Localized projections of climate and sea level rise lie at the basis of this analysis. (2) Analysis of the damage sensitivity (susceptibility) of the project area, including the critical and vulnerable objects, networks and population groups. Risk is often seen as the product of probability of exposure and potential damage or damage sensitivity Damage sensitivity is therefor to be quantified. (3) Analysis of the adaptability of the urban system; if the system is easily adaptable to new environmental conditions it is less vulnerable. Adaptability is defined in many ways; Deurloo (2016) summarized physical adaptability of the urban environment as "the speeds and efforts in which adjustments are possible in social practice and processes or in the physical structures of the current system to projected or actual changes of climate" So, adaptability is seen as a combination of speeds and efforts; the speeds in which measures can be implemented and the efforts needed for this implementation. To map adaptability Deurloo used thirteen indicators, including percentage buildings, percentage green, planned works, availability of budgets and projected end of life cycle of building. The hazard maps and susceptibility maps for flooding, drought and heat stress as well as the adaptability maps are at the core of the vulnerability scan.

Adaptation planning

Once the climate vulnerability 'hot spots' in town are known we can start the more detailed planning of adaptation measures. To do this, we have to repeat the steps of the vulnerability scan, but now more detailed and precise, so that decisions on reconstruction investments can be made. In general, this means a more active involvement of more stakeholders, the use of more detailed data and the use of simulation models to quantify the effects and effectiveness of adaptation measures. Adaptation planning workshops are meant to collaboratively plan adaptation measures in a project area, up to a degree that adaptation targets are met. This spatial planning and design process is iterative in character. Design and negotiations between stakeholders go hand in hand until agreement is reached about a fair distribution of costs and benefits of the package of adaptation measures. Once the negotiations are close to consensus a final adaptation plan can be drafted and submitted for final decision making by the political authorities and private investors.

Planning support tools

The whole stress test procedure is supported by toolsets for data collection and analysis, for identification of critical and vulnerable objects, networks and groups, for governance analysis, hydraulic and (geo)hydrological modelling, for supporting collaborative planning & design during the workshops and for mainstreaming and smartly coordinating implementation of adaptation measures.

For stakeholder identification gross-lists were produced of potentially relevant actors. For each actor an indication can be made on the desired degree of involvement, ranging from informing to co-deciding. Another gross-list was produced of critical and vulnerable objects, infrastructural

networks and population groups that are to be considered and mapped. Municipal authorities can use this list to check whether such critical facilities and vulnerable groups are found in the project area and how they can get extra protection. For governance analysis the PRIMO chain approach (ARB 1997) is recommended. Adaptation plans that fit in existing Policies, Regulations, Implementation practices, Maintenance practices and Organizational structure are easier to implement. The PRIMO chain is as strong as its weakest link. Adaptation of the governance infrastructure often takes considerable time - but is unavoidable in some cases to provide sufficient protection against nature's extremes.

Many stakeholders are not at all familiar with the many adaptation options to make an urban area more climate resilient. To inform them about potential solutions a Climate Adaptation App was made. This app is available in the app-stores and on www.climateapp.org. The tool contains a long list of 120 adaptation measures and a set of filters to rank then in. Pictures under each tile and a brief description provide users an impression on what a solution can look like. This climateApp is available for free.

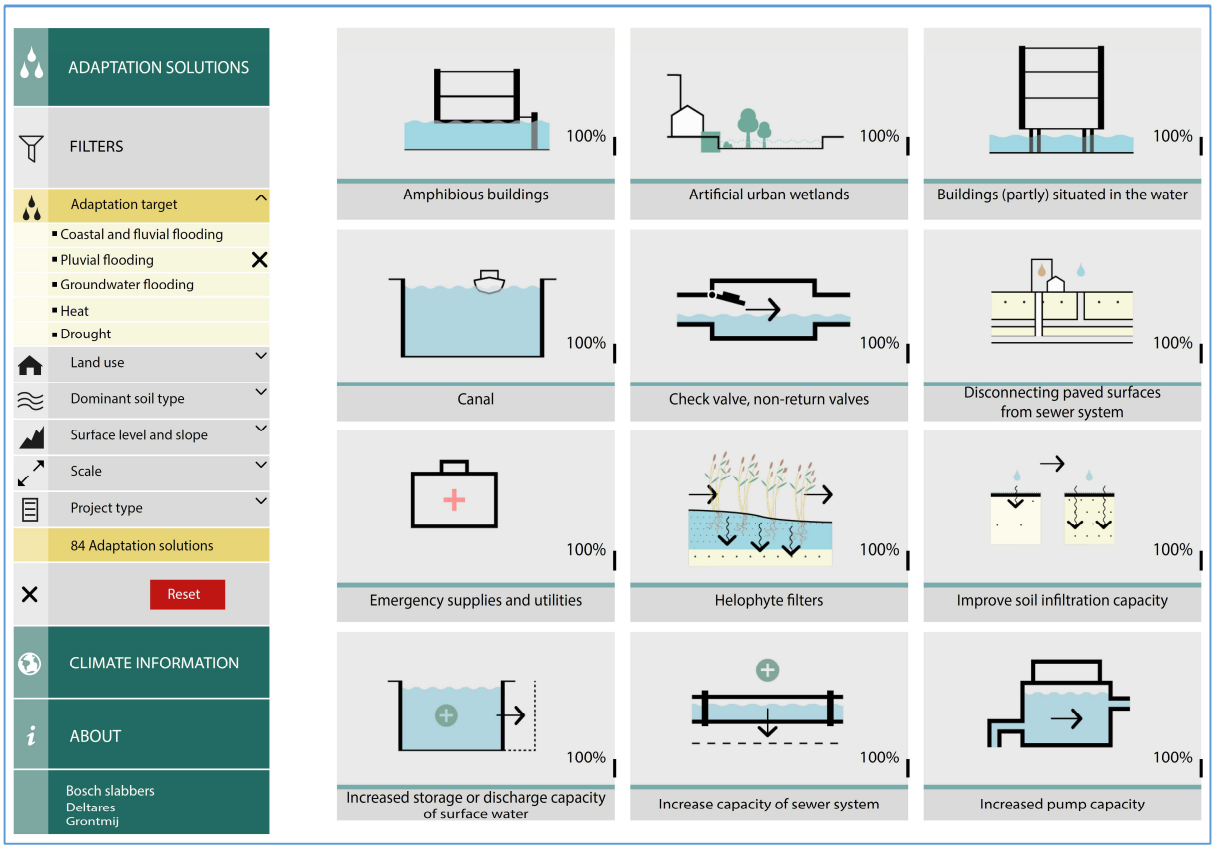


Figure 3 Screen of the Climate Adaptation App (www.climateapp.org). Adaptation measures are ranked by toggling filters on or off. More information on a measure is obtained by clicking the tile.

For supporting collaborative climate resilience planning in the first, conceptual phase of design, during climate workshops and adaptation workshops the Adaptation Support Tool was developed (Van de Ven *et al*. 2016) On a touch table, users can select green, blue and grey adaptation measures from a ranked list of measures, apply these measures in a project area and see what the estimated costs and climate resilience effectiveness are of each individual measure and of the package of measures in total. The tool generates estimates of the resilience effectiveness in terms of created water retention volume, peak flow reduction, water quality improvement and additional groundwater recharge and heat stress reduction. In addition to construction costs also an estimate is given of the maintenance costs of the facilities. During the climate and adaptation planning workshop participants can create a variety of alternative plans, discuss cost/benefit effectiveness of selected measures and check how far the selected package of measures meets adaptation targets

For the technical evaluation of final designs of adaptation measures a large variety of hydraulic and hydrological simulation models is available. Models like 3Di, Sobek, SWMM, et cetera can be used to simulate water flows and flooding during extreme rainfall conditions. For drought evaluation water balance models are used and local heat stress reduction effects can be estimated with rare models that estimate the spatial heat stress reduction effect of blue and green infrastructure. Standardized models for the Netherlands to quantify ecosystem services, social and economic effects of adaptation are not yet available. As a result, final evaluations of adaptation plans are made up case by case, each with own metrics and evaluation schemes.

APPLICATION

Although the stress test approach has no formal or legal status it is now being used, one way or another, by a growing number of Dutch municipalities and water authorities to study the vulnerability of their systems and to develop adaptation plans for a more resilient and water-robust urban environment. Consultants added their own 'flavour' for local clients and use the approach also abroad to structure urban planning for climate adaptation in cities (Tipping et al. 2015). The ministry of Infrastructure and Environment continues to support local climate workshops and stimulates regional and local authorities to develop pilots and showcases. They moreover support an independent foundation Climate Adaptation Services for maintenance of the knowledge portal www.ruimtelijkeadaptatie.nl, the Netherlands' climate atlas – a digital atlas showing a first estimate of the climate hazards in the country – and providing knowledge support to local initiatives.

Activities to implement the national spatial adaptation policy at local level show significant variability across the country. Front runners like Rotterdam and Amsterdam have already started implementing adaptation measures while the majority of the cities and villages made or are making a vulnerability scan, meanwhile taking adaptation measures in places that already suffer from frequent flooding or heat stress. Some tend to focus on flooding only; heat stress reduction is often not very high on the priority list, even though a significant increase in mortality is being reported during heat waves. Another remarkable consequence of the vulnerability scans is that land subsidence is recognized as a consequence of drought. The link between summer water demand of urban area, land subsidence control and heat stress reduction by evaporation is getting recognized.

Private participants in climate and adaptation planning workshops seem to focus first on the opportunities of climate adaptation, in particular on improvement of the liveability of the area through greening and blueing the urban landscape. Climate resilience comes as a co-benefit for them, rather than as a primary driver of investments. Water authorities combine climate adaptation planning with the opportunity to disconnect paves surfaces from the combined sewer systems and thus reduce frequency and volume of combined sewer overflows and reduce the hydraulic (rainwater) loading of wastewater treatment plants. And municipalities are looking for opportunities to link implementation of adaptation measures with other maintenance and reconstruction activities such as street, pavement and sewer renovation as this substantially saves implementation costs.

The Ministry of Infrastructure and Environment is now preparing a National Adaptation Strategy, The need for spatial adaptation to strengthen climate resilience will be a pivotal element in this strategy. Stress tests may be the basis for negotiating agreements with and between authorities. Those agreements should create a new innovative arena for both businesses and project developers. If this should prove to be insufficiently effective, the government could consider implementing legal robustness requirements, thus placing a governance focus on spatial development. (Ligtvoet et al., 2015). So, future progress evaluations will tell what the legal status of the climate stress test is going to be.

CONCLUSION

The Guide to Spatial Adaptation as part of the Dutch Delta Programme and accompanying toolsets provide an effective structure for climate-resilient urban planning. Water system thinking is key to

achieve a climate resilient environment. Paradigm shifts include: 1. Inclusion of drought and heat stress in one comprehensive planning approach, in addition to flood protection, urban reconstruction and greenfield project development; 2. Maximize benefits and co-benefits of adaptation measures; 3. Minimize damage of failing protection systems, 4. Extra protection for critical infrastructure, vital objects and vulnerable population groups and 5. Co-creation of adaptation plans together with and to the benefit of private stakeholders.

The approach to stress testing the climate resilience of an urban environment is characterised by two phases. The vulnerability scan is meant to identify both problematic 'hot spots' and opportunities of climate adaptation in a quick scan, while in the next phase of adaptation planning detailed adaptation plans are being made for selected areas. This procedure or an adapted version with a slightly different order of the steps, and the supporting tools are used by the local authorities and their consultants to assess the need for adaptation as well as to plan adaptation measures in consultation or co-creation with the other relevant stakeholders.

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