Colophon

Text
Team Urban Water Management, Deltares
(team-uwm@deltares.nl)

With contributions from
Frans van de Ven, Hans Gehrels, Hans van Meerten,
Bas van de Pas, Erik Ruijgh, Deepak Vatvani,
Niels van Oostrom and Thomas van der Linden

Deltares

PO Box 85467
3508 AL Utrecht
PO Box 177
2600 MH Delft
The Netherlands
T +31 (0)88 335 82 73
info@deltares.nl
www.deltares.nl

Deltares

Land & water management in the urban environment

Deltares
Enabling Delta Life

Land & water management in the urban environment

Land & water management in the urban environment

Deltares
Urban water management
December 2009

Contents

Objective

This statement sets out the Deltares view of how to manage urban land & water in a robust and sustainable way. What do we see as the future of cities worldwide? And how do we contribute to that future? What are our aims and objectives, the values that merit protection and that we work to support? The role of Deltares is to help governments, profit and non-profit organisations and consultants with our expertise. We disseminate scientific developments and knowledge about urban land & water systems to society as a whole, developing new concepts, innovative solutions and new technologies in an integrated, interdisciplinary approach.

This document is addressed to our clients. It clarifies what Deltares stands for and what we can do when they call on our knowledge and expertise. It sets out our views in the light of our goals and it also supplies background information, because what we say and see depends on advances in our understanding.

The vision in this document provides a context for the questions of our partners and clients. It serves as a compass for the Deltares experts, allowing them to steer their research and consultancy work and to evaluate its quality. We describe our approaches to problems and opportunities. Creating a pleasant urban living environment that engenders wide support is not only a matter of integrating all the relevant issues and disciplines. It also means combining the various approaches to solving problems and to designing and maintaining top-quality urban environments, with a well-balanced and successful decision-making process as the outcome.

We hope this document will challenge and inspire you. We look forward to your feedback so that we can join forces in working towards our shared ultimate goal: *Enabling better life in delta cities.*

Deltares, Team Urban Water Management
team-uwm@deltares.nl

1 Introduction

Introduction

Our ambition

The number of people living in cities nowadays exceeds the size of the rural population. Urbanisation is proceeding rapidly throughout the world. And this urbanisation predominantly occurs in deltas, lowlands and riverine flood plains, even though physical conditions in these regions are often less favourable. Adaptation is required to create good conditions for living there. Deltares mission is to ***Enable Delta Life.*** The ambition of the organization is therefore to make a strong contribution to enabling better life in delta cities, this **by working towards a more sustainable, more climate-robust, adaptable, healthy and pleasant living and working environment for all residents of urban areas in deltas and in floodplains.** We contribute to the realization of these ambitions by developing knowledge and innovations in delta technology and in related aspects, such as land & water management, creative design, governance and institutional development. Deltares is continuously establishing partnerships to work on these challenges in a learning community.

Our vision

To be effective in our mission, Deltares needs to share our understanding of what we mean by "a better life in delta cities" with our partners and clients. We must engage in the joint development of a vision for the future of cities in deltas, with a particular focus on land and water management. This document is a first step towards opening up a dialogue about specific requirements. Our achievements depend on a shared understanding of the vision, ambitions and context, an understanding that will encourage and guide our advisory activities, our network development, innovations and research investments.

Water underlies the delta city

Our primary aim in this document is to respond to the enormous problems faced by society in its attempts to develop conditions for sustainable urban life. However, we want to do more than just solve existing problems. Looking at the long term, we also want to improve the urban living and working environment by exploiting the available opportunities in ways that work in different circumstances around the world. The dialogue we hope for is the first step in tailoring our work for the conditions and ambitions of different regions.

Water underlies the delta city, both metaphorically and literally. To create a more sustainable, more climate-robust, healthy and pleasant living and working environment, water management should be improved in concert with soil, subsoil and land use. That is why Deltares focuses on the Water City and the ways we can contribute to the creation of this city.

The next chapter provides an overview of the Water City concept. Chapter 3 contains an overview of new approaches that we consider necessary in the transition to a Water City.

The concept of the Water City builds on a number of challenges, and on theoretical and conceptual developments over the past ten years. This background is described in Chapters 4 – 6.

2 The Water City

The Water City

In response to the ambition to create a more sustainable, more climate-robust, adaptable, healthy and pleasant urban living environment, the Water City concept places water at the heart of the city. In order to make these cities more sustainable we first of all have to make them less parasitic, i.e. less dependent on external resources and less waste-producing. We have to reduce the egological footprint of the urban area. For example, we have to reduce inputs and outputs by:

- Reducing inputs of water, food and energy
- Reducing imports of sand, ground and building material
- Recycling water

The Water City places water at the heart of the city

Major adaptations in the urban water system are moreover required to get closer to this self-sustaining 'closed city':

- Making water more multifunctional
- Surface water providing space
- Water as an energy source
- Water for food production
- Water supporting the soil

For making the city more climate-robust and adaptable we have to develop ways for:

- Climate-robust building
- Adaptable building

And for making a more healthy and pleasant urban living environment:

- Enabling water quality
- Water supporting the quality of the urban landscape

These are the features of the Water City that we strive for. The available water – surface water, groundwater, stormwater, drinking water and wastewater – is used intensively as a resource; and the vulnerability of this city to flooding, drought, extreme heat and land subsidence is reduced through water-wise design, operation and management. This can only be achieved if all stakeholders, including residents, work together, not only during the design and construction phases but throughout the entire life cycle of the system.

The features mentioned above are not the only ones that are characteristic for a sustainable, climate robust, adaptable, healthy and pleasant city. They are, however, the ones to be strengthened. Moreover, they are partly overlapping. Let us briefly elaborate on each of these features, to get a clearer picture of their meaning and consequences.

2.1 For a more sustainable city

Reducing inputs of water, food and energy

The need to reduce the input of water, food and energy derives from the highly parasitic behaviour of cities, as is shown in Chapter 4. Input and output of large quantities make it possible to pass on problems. This throughput also requires transport networks, sufficient transport capacity and energy, all of which are, to a greater or lesser extent, scarce commodities. All this makes the modern city highly dependent on external sources and vulnerable, and so transport networks are of strategic importance; their failure paralyses society, as is demonstrated by failures in the water supply and/or sanitation system.

Reducing consumption is often seen as a valid way of reducing throughput. However, this is not the only answer, as illustrated by the cradle-to-cradle concept[3]. Recycling and, in particular, upcycling represent valid solutions. Using internal sources alongside external sources widens the diversity of resources, reducing the vulnerability of urban areas.

Reducing imports of sand, ground and building material

A particular building material import is sand and ground for filling construction sites. A closed ground balance is an ambition for many new city development areas. However, in practice, differences in the quantity and the quality of the

ground and slow consolidation make this difficult to achieve. So many new urban areas end up with a ground surplus and elevated street and park levels, hampering the runoff of stormwater to green spaces where it could infiltrate into the ground.

Integral and partial filling, or backfilling under roads, are common practices during the development of urban areas. Building lots are filled, sometimes one by one, or integral filling takes place on larger projects. But the demand for building sand is huge, and the sustainability of this practice is at least questionable. However, abandoning this practice requires a new approach to urban development and building, and this is not an easy obstacle to surmount, even though such a new approach would save millions of cubic metres of sand and ground.

Recycling water

Local surface water, groundwater, stormwater, and sometimes even wastewater and effluent can be used for numerous purposes, certainly after "upcycling" to the appropriate water quality. Water can often be re-used after serving domestic and industrial purposes. Grey wastewater can be used again for several "low-grade" operations. Water demand in the city will rise in the future as demand for irrigation water increases. Examples are water for irrigating green roofs and for cooling heat peaks. In Tokyo, for example, wastewater treatment effluent is already being used to cool road surfaces. So we must cherish the city's internal water sources.

Multifunctional use acts as a safeguard for sustainable water management

Recycling water amounts to a multifunctional water use, but over time rather than in parallel. If people are aware that water is to be used again for other purposes later, they will be more careful about wasting or spoiling water.

Making water multifunctional

Water plays an important role in our urban environment by supporting the quality of the living environment. People are barely aware of the five types of water that are available in urban areas or of the functions they serve. Groundwater, surface water, drinking water, stormwater and wastewater are present and can be used for numerous purposes. The functions served by these sources depend not only on the volume (m^3), area (m^2), depths (m^1) and distances of water resources, but also on their quality.

The multifunctional use of water resources acts as a safeguard for sustainable water management. It requires the involvement of multiple interests and stakeholders. Balancing these interests determines the quantity and quality of water. Overexploitation and "overpollution" become unlikely when water is used multifunctionally since, in these circumstances, they threaten numerous interests, if not immediately then certainly in the long term. A prerequisite is that all stakeholders must have the power to influence water management policy: single-issue management is likely to result in unsustainable situations.

Surface water providing space

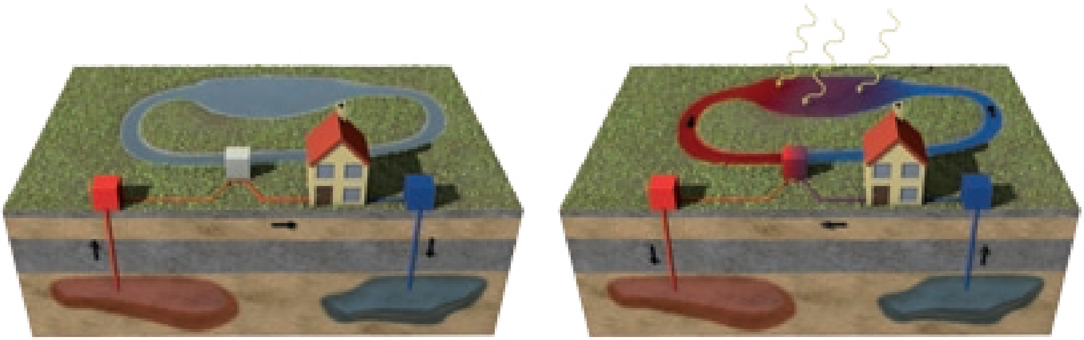
Buildings can be built in, on and above surface water. And the water surface can also be used for other valuable purposes such as recreation, solar heat collection, cooling and so on. Surface water is generally considered to be

part of the public urban space, but water surfaces are also sold or leased as areas to build on, or as locations for floating homes. This can make water surfaces very expensive on the land market. In traditional economic analyses of urban development plans, water surfaces are generally considered to be cost components, but the moment we start selling or leasing water surfaces for building in, on or above, the same area can be converted into a source of revenue – and sometimes even a cash cow.

Water as an energy source

Aquifer thermal energy storage (ATES) is a technique that is increasingly common as a way of supplying houses and offices with heat during winter and cold during the summer[1]. Shallow and middle-deep groundwater is used to store heat and cold as a seasonal buffer.

To balance a heat or cold deficit, ATES can be combined with a surface-water energy system; surface water can be used as a solar collector or as a cold-harvesting device[2]. Systems like these can reduce fossil energy consumption and related CO_2 production for heating and cooling by more than 50%. In addition, surface-water cooling during hot periods in summer enhances water quality. Lower water temperatures impair algae growth and pathogen survival. And, last but not least, the lower surface water temperature exerts a cooling influence on the urban heat island.



ATES providing heating in winter (left) and cooling in summer (right).

Water for food production

Food production has more or less disappeared from the modern city. In a sense, this is a strange development, since there is large demand for food in every city and large amounts of nutrients are present. Reintroducing food production to urban areas would somehow seem logical in the longer term; this is an idea that McDonough has also advocated in his design for a city in China[3]. Green roofs and floating gardens provide an effective starting point for growing or coproducing food. The next step could be the combination of buildings with greenhouses on top for growing crops, harvesting heat and condensing pure water for re-use and for use in basement ponds for fish hatcheries.

Water supporting the soil

The subsoils in delta areas are soft and sedimentary. Clays and peat layers are very sensitive to changes in pressure; extra weight means land subsidence. Land subsidence is a slow process and residents have to cope for many years with consequences that are sometimes dramatic, particularly if the subsidence is unevenly distributed. Broken pipes and cables, elevated entrances, damaged buildings, low and wet gardens, uneven roads with raised sewer manholes… Maintenance costs can be extremely high.

Extra weight may result from land filling but instability can also be caused by falling groundwater levels, permanent or temporary, during dry spells or due to groundwater extraction. Heavy traffic can aggravate the problem.
Keeping groundwater levels high throughout the year reduces land subsidence and the related damage. Although groundwater drainage depth has been reduced in recent years[4], the problem of residual subsidence is not under control yet.

There can be serious land subsidence problems in peaty soils. Peat oxidises and "evaporates" as CO_2 if exposed to the air. This process can only be stopped by keeping the peat completely wet all the time. However, wet conditions cannot be combined with, for example, agriculture or playgrounds. And gardening is only possible with the appropriate species of plants. Moreover, the load-bearing capacity of peaty soil is very limited. That is why peaty areas are often filled with large amounts of sand, and this approach also results in a subsidence problem. More sustainable solutions can be found in floating structures (houses, roads, etc.) combined with wet urban landscaping.

Another way to manipulate groundwater flow and land subsidence is by using Smart Soils. Deltares has developed techniques to petrify and to seal sedimentary deposits *in situ* in order to prevent land subsidence and groundwater leakages, for example into building pits.

2.2 For a more climate-robust and adaptable city

Climate-robust building

Urban areas should be designed to handle extreme weather conditions. Ongoing urbanisation already leads, in itself, to significant changes in the local meteorological conditions. The effects of climate change come on top of that; more frequent and more heavy rainfall is to be expected, droughts will last longer and temperatures will increase further. Building design, urban landscapes, infrastructure and water management have to be adapted to cope with these more extreme circumstances if we are to prevent serious damage to public health and the economy. Climate-robust cities are both water-robust and heat-robust. Numerous structural and non-structural measures can be taken to make the urban environment climate-robust. Their effectiveness however, depends on the local circumstances. A solid strategy is required to select an appropriate set of measures in each specific case, involving all the relevant stakeholders. The costs and benefits should match the interests of the parties. This can be done relatively easy for greenfield developments by comparison with brownfield developments or retrofitting. Climate-robust building not only refers to housing. Climate-robust infrastructure is as important as climate robust houses, offices and industrial buildings.

Water is the cooling fluid of the city. Evapotranspiration reduces ambient temperatures, but requires water. Extremely high temperatures and droughts are therefore interrelated phenomena. Heat affects demand for irrigation water in dry periods.

Climate-robust building changes all the components of the urban skin: surface water, pavement colours, shading strategies, urban green design and maintenance, water storage and supply, and so on. Climate-robust building therefore starts in the earliest phase of urban planning, with the selection of a suitable urban development site, and continues even in the phase of urban maintenance, keeping facilities and non-structural measures operational.

Adaptable building

Climate change is not the only change affecting urban areas. Economic changes, demographic developments and changing demands from society will also have their impact. And all these factors are extremely unpredictable, particularly in the long run. This requires adaptability and flexibility in housing areas and industrial zones, and also in local water management and water supply and land use planning.

Urban regeneration, the replacement of existing infrastructural facilities and the reconstruction of existing houses, offices, industrial buildings, roads, canals and so on, has proven to be very difficult and cost-intensive, even though it is obvious that improvement is required. The result is that many urban regeneration projects take many years and much more budget to complete, while the mismatch persists between the actual and the desired situation. Another approach to the construction of the urban water system, including a different approach to managing water, can help to make cities more adaptable to new circumstances that we cannot yet foresee.



From left to right: the original canal (past), turned into a highway (present) and back into a canal (near future).

2.3 For a more healthy and pleasant city

Enabling water quality

The multifunctional use of water requires adequate water quality, both for surface water and for groundwater. Three factors mean that cities are in a relatively good position to manipulate the quality of surface water and groundwater: most urban waters are controlled, artificial / man-made or semi-natural; many pollution sources in urban areas can be controlled by appropriate design, construction, operation and maintenance; and natural purification processes can be boosted by smart design, constructions and operation. To maintain multiple functions, now and in the future, we can use ecological engineering technologies to minimise pollution of the water system and maximise natural retention and purification capacity.

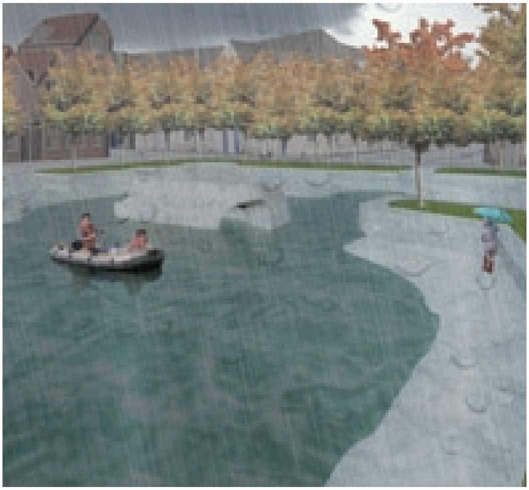
Public health is a major concern in the management of the quality of the surface water and groundwater. The precautionary principle requires actions and measures to ensure that users are protected against waterborne diseases. And groundwater pollution must be prevented to safeguard the broad use and cleanliness of subsurface drainage discharge.

Furthermore, good water quality allows ecosystems to be biodiverse and stable. Ecological monitoring and evaluation provide valuable information about the quality of the water system.

Water improves the quality of the urban landscape

The quality of an environment or landscape is improved by introducing visible water. A pond, a fountain, a canal, a brook or a lake: all this visible water creates a positive mood for the residents – unless it is visibly polluted. Now that we are able to control the quality of urban water better, we can use this positive psychological influence to design higher-quality urban landscapes. Even though the old and the new Dutch water cities are highly rated abroad – examples being Almere, Amsterdam, Delft, Nijmegen and Rotterdam – there is still considerable potential for raising the quality of the urban landscape.

Delta urbanism is developing rapidly. The question how to integrate surface water in designs for new urban areas and in urban regeneration projects is a joint challenge for urban designers and urban water managers working in close cooperation. Cultural values and sometimes even religious values are part of the total value of water in the urban environment. They have to be respected and reflected in the design as much as sound engineering and water management.



A clever design of a playground provides water storage in rainy periods.

3 New approaches to planning and design

New approaches to planning and design

Creation of the Water City requires a specific approach. Sectoral solutions are no longer sufficient; an integrated approach is needed based on cooperation between the water sector and other disciplines and organisations to find solutions with widespread support. This integrated approach requires different procedures, different ways of organising the work, different competences and skills from experts, and different activities. However, an integrated approach is not enough to achieve implementation of a plan. Stakeholders are to be receptive to the plan. Receptivity is therefore an important requirement to get a good plan realised.

Receptivity is required to get a good plan realised

Modelling of salinity in Marina Reservoir, Singapore.

As much of the features of the Water City require a shift of roles, tasks and activities of one or more involved parties, transition management is an important tool to achieve the desired change. Transition management theory can help us organise niche formation for innovative developments and can help mainstreaming promising new technologies and processes.

Approaches to planning and design are developing rapidly, based on the worldwide research in governance, process management and allied fields of science. So, we are still learning how to do better. However, we are already in a position to emphasise the importance of the following process issues.

3.1 Integrated approach

Three-track approach

The planning, design and realization of urban water systems is always a combination of three "problems": it is an optimisation problem, a design problem and a negotiation problem at the same time. Sustainable solutions can be found only by addressing the three problems simultaneously in a three-track approach. Creating a more sustainable, more climate-robust, healthy and pleasant living and working environment requires not only the "best technical resources" or best management practices, but also a nice, equilibrated design, and agreement between all stakeholders about construction, maintenance, financing and so on. Proper planning and design is of course rooted in a profound knowledge of the biophysical, social and economic systems and on the processes that influence the numerous factors, including residents with their cultural heritage and emotional values.

The multi-functional, multi-stakeholder nature of urban land and water management issues leads, quite logically, to situations in which full consensus is seldom reached about the definition and the priority of the problems and/or the best response to those problems. These complex, non-structured, wicked problems can only be solved by negotiating, designing and exploring options in parallel. It is the interaction between the three tracks – optimisation, design and negotiation – that helps to produce the best solution under the given circumstances.

Only parts of the complex problem can be solved by optimising selected components and processes within the total system or by trying to find new innovative solutions.

The role of experts in the process

In the optimisation process, experts search for the best solutions, applying tools such as multi-criteria analysis to assess and compare various alternative solutions. In the negotiation process, experts assist stakeholders in their search for convincing arguments in a negotiation strategy. Stakeholder and power field analysis and gaming tools accompany the technical system analysis. And experts help to resolve design issues by collaborating with designers in their creation of aesthetically pleasing solutions. Using collaborative system analysis, they help to select specific features and characteristics that are useful for the design. Enquiry by design and concurrent engineering help designers and experts to co-create widely appreciated and accepted solutions.

3.2 Creating receptivity

Any change and, in particular, new and innovative solutions like the Water City tend to encounter resistance. Collaborative design helps to create support among stakeholders and citizens during the design phase. This support can, however, be developed much more systematically by working on the receptivity[14] of all the parties involved. Receptivity to new solutions requires the application of four capabilities:

- Awareness – the capability to identify problems and opportunities and to search for new solutions and new applicable knowledge;

- Association – recognition of the potential benefit of this knowledge by associating it with our own needs, capabilities and capacities;
- Acquisition - the ability to acquire technologies or learn new methods and ways of working which support exploitation of the new knowledge;
- Application – the ability to actually apply this new knowledge to achieve a benefit.

To achieve change, planners, policy developers and project developers generally tend to focus their efforts on creating awareness and applicability. However, association and acquisition must be encouraged as well in order to come to a smooth realization of a plan. That is why we develop relevant communication strategies and packages of activities together with our partners and clients.

Drawings of children's views on water: an example of creating receptivity by involvement of the youngest generation of users.

Receptivity is also influenced by the perceived risk involved in the implementation of new solutions. Decision-makers hardly ever take a positive decision if the risks are not covered properly. That is why project risks must be addressed and thoroughly analysed. Deltares has already developed Geocheck procedures to evaluate the technological risk of plans in a systematic way, building on experience from the past, and also identifying financial, social and institutional/political risks. Even more importantly, we will assist in developing ways to reduce, eliminate or allocate these risks in acceptable ways.

3.3 Transition management

Transition management addresses change processes in complex problems. Changes in urban water management often require adaptations in policy, regulations, building and construction praxis, monitoring and evaluation and organization. Experience with new methods and technologies is collected in pilot projects, driven by niches of stakeholders. And mainstreaming such a new method or technology starts only if first experiences are positive. This mainstreaming process, however, requires a more programmed approach than the explorative pilot phase. Two components of transition management are highlighted here.

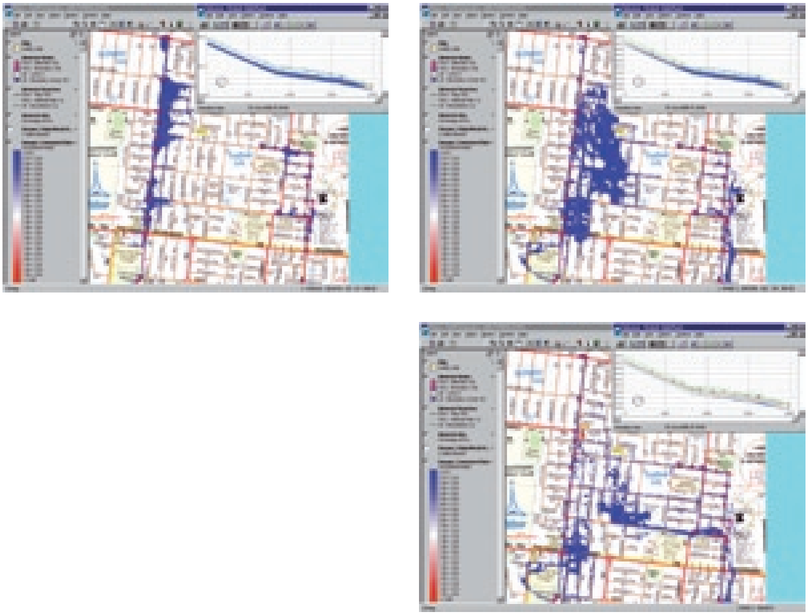
Monitoring and evaluation

Monitoring and evaluation are essential for good planning and design. Learning by doing and social learning processes depend on them. However, there seems to be a reluctance to invest in monitoring and evaluation in practice, even though society calls for transparency and accountability. Monitoring allows us to keep track of the biophysical, social and economic dimensions of changing systems. It helps us to understand what is going on and how effective steering actions are. Good monitoring covers all hard and soft areas – biophysical, social and economic – and is therefore extensive and, in one sense, expensive. However, making mistakes is much more expensive and requires much more time and energy to correct.

Dynamic programming

In an optimal system, failures can also propagate optimally. In dynamic systems, diversity, redundancy and adaptability to new circumstances reduce the risk of system failures; these are effective ways of dealing with uncertainties in the long term. Planning and design should therefore include these components in order to strengthen adaptive capacity and therefore reduce vulnerability. Strengthening this capacity may move solutions away from their minimal cost price now but future benefits are expected to compensate for the extra investment costs.

There are many uncertainties in a transition process. Flexibility in the way to go, in the ambitions and objectives and in the deliverables are preconditions for a successful process. This requires dynamic programming rather than optimal programming.



Simulation of flooding of the sewer and at street level in Melbourne, Australia.

4 Background on the Water City

Background on the Water City

Challenges

Urbanisation is proceeding rapidly throughout the world. For the first time in history, the proportion of people living in cities matches the world's rural population[5]. The percentage of the global population living in cities is expected to increase further to 60% in 2030. Urbanisation is predominantly a feature of deltas, lowlands and riverine flood plains. In 2030, some 50% of the world's population is expected to be living within 100 kilometres of the coast[6] .

Urban areas have a number of significant side-effects, particular in the face of ongoing major developments such as urbanisation, climate change, changes in the economic regime, increasing prosperity, and so on. Major effects include:

Parasitic behaviour

All urban areas are highly parasitic. Cities, with their residents and economic life, can only survive if water, food, construction materials and energy are imported in massive amounts and if the city is able to release its waste, nutrients, wastewater and heat. An illustration of the throughput is found in the illustration.

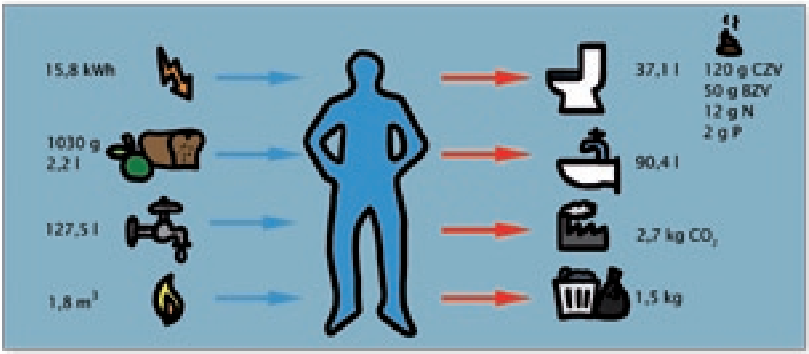


Figure 1. Resident-related imports and exports of water, food, and energy[7].

Vulnerability to climate change

Most areas of the world are affected by climate change in some way. More heavy rainfall and more severe droughts are expected in many places, while land and water management for urban areas is not designed for these more extreme conditions. Water supplies and flood protection are under particular pressure.

Urban Heat Island

The structure of the urban area and the reduced levels of evapotranspiration there mean that temperatures exceed those in the country side. If city residents are not sufficiently protected against heat, mortality rates could increase substantially. And protection means more air conditioning, boosting energy demand and heat production.

Urban infrastructure facilities wearing out

Major investments have been made in urban areas over the past century, not only in buildings but also in infrastructure such as roads, sewers, power lines and water supply systems. As these facilities reach the end of their lifetimes, they have to be replaced. Overhauling the highly centralised systems in place is a costly process, particularly in the case of the large-scale public – or privatised – systems. However, postponing replacements makes the systems more vulnerable.

Moreover, the specific conditions in deltas and flood plains result in some problems that are typical for lowland urbanisation. We now turn to those problems.

Flooding and ponding

First of all, there is the low surface gradient, which reduces the flow velocity of surface water and groundwater. Backwater effects are common; storage is an important component of all water management. Water ponding on surfaces is common and shallow flooding of streets and parks may result. Residence times tend to be long, leading, if not properly addressed, to an increased risk of algae blooms, mosquito breeding and other public health risks.
Urban areas below or slightly above mean sea level are facing rising sea levels and therefore an increasing risk of flooding. Millions, if not billions, of people are living in such flood-prone areas.

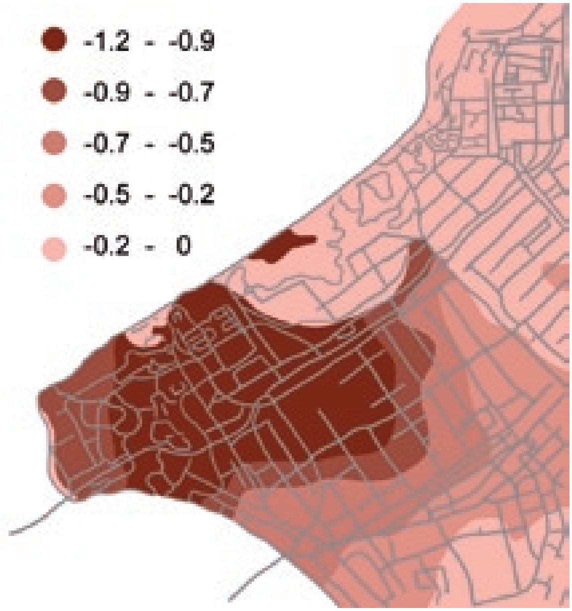


Figure 2. ***Land subsidence***
Many urban areas suffer from substantial residual subsidence, as illustrated by the case of the city of Almere (subsidence in meters over a period of 30 years).

Land subsidence

Sedimentary, and often soft, soils such as sand, clays and peat are common in the soil and subsoil of delta areas and floodplains. Urban areas can be sensitive to land subsidence, depending on the material characteristics, the loads imposed, the local water and drought conditions, groundwater abstraction and the design and management of urban functions.

Lack of land

In most urban areas, land is scarce and expensive. As a result, building and population densities are high. Multifunctional land use is common, and this also applies to water surfaces, as shown in Table 1. Nevertheless, urban sprawl continues. Even with active spatial planning, urban areas continue to extend. The density of the existing urban area and the amount of paved surface is rising continuously. Areas for water retention come under pressure and are reduced, and groundwater recharge can be affected.

Multifunctional water use

Surface water, groundwater and drinking water are each used for a wide variety of functions, as Table 1 shows. Storm water and waste water can be used mulitfunctionally as well. The challenge for urban water managers is to fit these functions into the same space or volume of water without significant conflict, while taking water quality into account.

Surface water	Groundwater	Drinking water
• Discharge water surplus	• Discharge water surplus	• Human water supply
• Store water (peak and seasonal)	• Store water (peak and seasonal)	• Household water supply
• Supply water (irrigation, flushing, cleaning, household)	• Supply water to vegetation	• Public health vector
• Control of water level	• Provide water (industry, households)	• Industrial water supply
• Transport pollutants	• Retain pollution	• Cleaning / flushing water supply
• Groundwater level control	• Transport pollution	• Irrigation water supply
• Degrade pollution	• Degrade pollution	• Fire-fighting
• Transport and/or retain pollution	• Support terrestrial ecosystem	• Feeding groundwater (leak)
• Support aquatic ecosystem	• Store thermal energy (heat & cold)	• Cleaning / flushing water supply
• Support terrestrial ecosystem	• Maintain anaerobic underground	• Irrigation water supply
• Water-related recreation e.g.	• Reduce weight (effective stress)	• Fire-fighting
- Boating	• Reduce subsidence	• Feeding groundwater (leak)
- Fishing	• Reduce oxidation (e.g. of peat)	
- Swimming	• Fire-fighting	
- Strolling		
• Collect solar thermal power; provide cooling		
• Fire-fighting		
• Strengthen quality urban landscape		
• Separate (functions, areas)		
• Cultural identity		
• Housing (living boats, floating houses, houses on poles)		

Table 1. Various functions of surface water, groundwater and drinking water in urban areas.

Socio-economic capital

There is a high level of awareness of vulnerability to flooding and the importance of adequate drainage and flood protective measures. Living in a delta or flood plain means cooperation is needed in areas like flood protection and drainage. The relation between water and public health has been recognised for centuries. Investments in water supplies and sanitation have prevented billions of premature deaths. This awareness is not only the basis of our Dutch water boards, but also the driver behind huge and ongoing investment programmes in flood protection, water supplies and sanitation.

Mono-disciplinary or integrated solutions

The traditional disciplines associated with urban land & water management, such as hydrology, hydraulics, geology, geohydrology, geography, morphology, hydrochemistry, ecology, economy, sociology and governance are of crucial importance for an understanding of natural and societal systems, their components and their interactions. Traditionally, this understanding is used for policy analysis and system optimisation. The challenges to urban water management mentioned above and the worldwide need for sustainable urban development have engendered discussions about better ways to respond. Novel solutions are now being developed and implemented: not only high-tech ones for developed countries, but also low-budget ones.

In the field of urban drainage, solutions have developed in the form of numerous best management practices or sustainable urban drainage systems. A few examples:

- in-line and end-of-pipe stormwater infiltration facilities to reduce peak discharges and to reduce pollution loads from combined sewer overflows;
- pollution prevention through regulations for building materials, cars, pesticide applications and so on;
- stormwater infiltration and biofiltration as methods for source control.

Water supply systems have improved significantly in terms of water quantity, water quality and, in particular, the reduction of the failure risk. Reservoir management has improved, as has source protection. New treatment technologies have been installed to remove harmful substances from the water. And water has been extracted from other sources, if necessary even from saline ones. On the wastewater side, treatment technology has improved and treatment plant effluent is now used as source of water for domestic use or even as a source of water for drinking water production. Over the course of recent decades, these innovations have certainly mitigated the problems relating to urban land and water.

However, these innovations tended to be mono-disciplinary, aiming at optimizing or strengthening specific areas. These innovations often lack the creativity and the beauty of good design. "Optimal" and "beautiful" are very different things; and a good solution needs both. Moreover, the management of urban land and water is a multi-stakeholder problem, resulting in a complex and non-structured problem. Table 2 shows the solution strategy for non-structured problems of this kind.

		Problems & objectives	
		Known or agreement about	Unknown or no agreement about
Measures to be taken	Known	Optimise	Negotiate
	Unknown	Innovate	Design

Table 2. Solution strategies for various complex problems[8, 9].

To create a Water City and to find better responses to the challenges above, we have to include design and negotiation to our way of working, alongside our "classic" search for improvements and innovations. To do this effectively, we have to strengthen our knowledge and capabilities in the disciplines of urban landscape design, urban planning and in sciences such as psychology and communication. We need a three-track approach to find genuinely integrated solutions to water management problems, solutions that are appropriate for all the stakeholders and interests, their challenges and their opportunities.

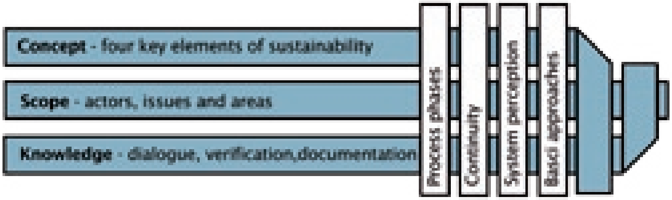


Figure 3. Crucial components of the planning and design process[10].

In order to synchronise the three tracks of our approach in each phase of the process, we have to ensure that the concept, the scope and the knowledge are harmonised at all times. See Figure 3.

The *concept* includes a permanent dialogue on the meaning of sustainability. This includes the way that our ambitions and principles are translated and elaborated in our plans and designs. The *scope* refers to the permanent dialogue about the scope of our problem. This scope includes the actors and the way they are – or could/should be – involved, the planning area, the problem area and the issues to be addressed. This is shown in Figure 4. And *knowledge* refers to the way knowledge and information are dealt with by the stakeholders during the process. Verification of knowledge and an open dialogue are required to produce "negotiated knowledge"; a lack of verification can result in "negotiated nonsense" that will affect the process. The way this knowledge and information are stored and how they are made accessible to the actors in the process are particularly important for the efficiency of the process. Is all information easily accessible to a newcomer in the playing field? Or will the project collapse if the project manager falls ill? Creating an open repository of all negotiated knowledge, decisions and negotiations is important for the efficiency and the quality of decision-making.

The three-track approach to complex urban water management problems shows optimisation, design and negotiation in parallel, all working with the same actors on the same issues in the same area. Feeding the results of each track to the other two in a more or less permanent process improves the quality of single-track solutions[11] for the creation of Water Cities.

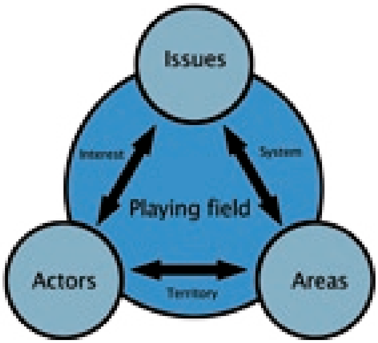


Figure 4. The playing field with its actors, areas and issues[11].

Managing transitions

A three-track approach to policy development, planning, design and implementation is, however, no guarantee for a successful implementation of measures, in particular if these are innovative in character. It is hard to implement innovative plans or to mainstream new solutions. To achieve a real breakthrough, a large number of conditions have to be fulfilled. An example can be found in innovations in urban water management in Melbourne, Australia[12]. See Figure 5.

Key Transition Factors

Group of champions | **The Enabling Context**

Group of champions:

1. Vision for Waterway Health
2. Multi-Sectoral Network
3. Environmental Values
4. Good Public Attitude
5. Best Practice Ideology
6. Learning by Doing
7. Opportunistic
8. Innovative & Adaptive

The Enabling Context:

1. Socio-Political Capital
2. Bridging Organisations
3. Trusted & Reliable Science
4. Binding Targets
5. Accountability
6. Strategic Funding Points
7. Demonstration Projects & Training
8. Market Receptivity

Figure 5. Key factors for a successful transition [12].

This same research group concluded[13] that, in addition to champion behaviour and the presence of an enabling context, it is often the lack of a receptivity continuum[14] that prevents the breakthrough of innovative solutions. Jeffrey and Seaton state that this continuum consists of four essential components to achieve change:

- Awareness – the capability to search and scan for knowledge which is new;
- Association – recognition of the potential benefit of this knowledge by associating it with needs and capabilities;
- Acquisition - the ability to acquire technologies or learn new models of behaviour which support exploitation of the new knowledge;
- Application – the ability to actually apply this new knowledge to achieve a benefit as judged by the recipients.

People generally tend to focus their efforts on creating awareness and applicability. To achieve a transition, we also have to encourage association and acquisition.

5 Defining a Water City

Defining a Water City

What does 'sustainable', 'climate-proof' and 'healthy' mean to us?

To achieve a more sustainable, more climate-robust, healthy and pleasant Water City, we are searching for new ways to:

- minimise the ecological footprint of urban areas by minimising the input of water, food, energy and building material and minimising the output of waste, wastewater, heat, and so on;
- minimise transport of all these goods to and from all residents by large transport systems requiring a lot of energy;
- make sustainable use of the land in terms of land subsidence and soil quality;
- use natural processes to clean up polluted environments;
- provide equity in the supply and use of natural sources of water goods.

Before turning to a description of the latest views about this "utopia", however, we should first analyse our ambitions in greater depth. What does "sustainability" mean to us, what does "climate-robust" mean and what exactly is meant by "healthy and pleasant urban areas"?

Sustainability

The meaning of the term sustainability in everyday practice depends very much on personal preference. Rijsberman et al.[15, 16] managed to split a large group of scientific articles and papers into four categories, depending on the language they use to express themselves. The four categories classify people into a group with more human-oriented objectives of sustainability, as opposed to a group with more eco- or nature-oriented objectives. There is a similar breakdown between people who prefer a normative, SMART approach to sustainability and a group that prefers a more abstract, value-oriented way of dealing with sustainability. The four groups are:

Four approaches to sustainability [17].

1. Ratio. People in this group prefer a rational approach to the problem, quantifying assessments and judgments to find the best solutions for us and for our descendants.
2. Capacity. The carrying capacity of our environment is the central point. Environmental technology is used to avoid over-stretching. Setting and maintaining standards is a way of regulating a sustainable future.
3. Socio. Protecting and if possible enhancing the value of land and water for future generations is essential. We should never pass on problems to future generations.
4. Eco. If we are able to create conditions to keep our natural systems healthy and strong, sustainability will be safeguarded. Investing in these conditions is a no-regret strategy.

Each person has his own preferred approach to sustainability. And many dialogues about projects are confusing only because of differences in this perceived meaning of sustainability. As there is no valid preference for any of the four interpretations, we have to take all four into account when formulating ways to improve our living environment.

Vulnerability

To make our cities more climate-robust we need a more profound understanding of what is meant by concepts such as resilience, robustness and vulnerability. First of all, we prefer the term "robust" to "resilient" since urban systems will never return to their original state after being exposed to significant stress, as resilience would suggest. A robust system is able to handle the shock; it is changed by its impact but is capable of handling the consequences. It is the antonym of "vulnerable"; a vulnerable system is changed by a shock and is not able to cope adequately with the consequences, with considerable damage as a result. Vulnerability and robustness are not normative concepts. We can understand that one system will be more robust than another one in certain conditions. However, making robustness and vulnerability SMART is difficult.

Flooded streets in Cologne, Germany.

Four types of system capacity may reduce vulnerability[17] and therefore enhance robustness:

Threshold capacity,	to prevent damage by taking measures;
Coping capacity,	to reduce damage by coping with the problem better;
Recovery capacity,	to reduce sequellae by repairing the damage quickly;
Adaptive capacity,	to adapt flexibly in the longer term.

In land and water management, we focus particularly on enhancing threshold capacity, for example by building higher dikes and installing larger pumps in order to reduce the probability of a catastrophic event. Measures to enhance coping capacity include wet-proofing houses and buildings, and effective and efficient evacuation schemes. Recovery capacity requires sufficient stocks of critical supplies and the effective transportation of machines and materials. And adaptive capacity includes the need for diversity and redundancy in, for example, supply sources and protection mechanisms. Flexibility in the long term also means flexibility in real estate, rather than real estate that is built to stay in place for centuries.

Climate robustness is often limited to coping with increased risks of flooding resulting from longer and more intensive rainfall. In many cities, climate change will result in more droughts and higher temperatures. These effects – which are problematic in themselves – also exacerbate the risk of fire, particularly in the urban fringe. The capacity to deal with these consequences must be enhanced as well as the capacity to deal with the increased risk of flooding.

Health and well-being

Almost two centuries ago, people started to improve the water supply system and the wastewater drainage system because they realised this was crucial to public health. Sources of water supply gradually disappeared from urban areas, and water treatment processes improved to produce the finest drinking water quality. Wastewater was first collected in combined sewer systems and later in separate systems to make sure that all of the most heavily polluted wastewater is transported to a treatment plant. And wastewater treatment plants became more and more efficient in removing pollutants; technology is available to polish plant effluent up to drinking water quality, but high costs and limited environmental benefits mean that not all technology is applied in every treatment plant. Decent water supplies and sanitation are still considered to be one of the greatest achievements of the past; and the fact that so many

people in countries in need lack these facilities is rightly considered to be a major global problem.

Public health concerns were, until the 1970s, limited to improving water supplies and sanitation by extending and strengthening central supply and drainage systems. Increased environmental awareness triggered a pollution prevention and source control approach that has been in place since then in order to prevent health damage resulting from environmental pollution. Cleaner cars, cleaner building materials, less harmful pesticides and a whole set of other measures were introduced to reduce water pollution levels from point and non-point sources.

At the turn of the century, eco-engineering was added to the pallet of environmental quality management. "Building with nature" is used to strengthen the robustness of natural water and groundwater systems to the inevitable pollution entering them in urban areas. Enhancing natural purification processes and strengthening diversity and ecological stability are new goals for urban water management with the aim of creating healthy water systems. And healthy water systems are at the basis of a healthy urban society.

Healthy water systems provide water that can be used for a whole spectrum of functions, ranging from ecological to various recreational functions and even to water supply. Healthy water systems are productive in terms of providing not only water but also food and energy. To achieve this goal the chemical, bacteriological and ecological quality of the water must be beyond reproach.

Pleasant living environment

The perceived quality of the living environment is highly dependent on the visibility of water. This has been found in numerous sociological studies using questionnaires as well as psychological experiments[18]. Eleven different values of water can be discerned[19]: biotic, sensitive, analytical, formative, lingual, social, economic, aesthetic, juridical, ethical and pistic. Anthropological studies[20] show that people assign profound values to water that must not be neglected in any plan to change water management. Nowadays, we can identify and quantify these values but we have to improve our ability to include these values in the design of urban water systems using a three-track approach (see paragraph 3.1, page 25).

6 Emerging paradigms and concepts

Emerging paradigms and concepts

To establish a firm basis for new approaches to managing urban land and water, attempts are being made to formulate new supporting principles. We now turn to three examples that are relevant for the development of the Water City: one from the city of Almere, the Netherlands and two interrelated ones from Australia.

Almere principles

Working with the cradle-to-cradle philosophy[3], the city of Almere formulated seven principles for an economically, socially and ecologically sustainable future, "as an inspiring guide for everyone involved in the decades to come in the design of Almere as a sustainable city"[21].

Almere, a city built in the 1970's on new land in the lake IJsselmeer, The Netherlands.

1. Cherish diversity, to enrich the city with diversity:
   - Ecological; extend biodiversity;
   - Social; correct the unilateral middle-class population; attract upcoming elite;
   - Economic; let the local economy flourish.
2. Connect places to context to strengthen own identity:
   - Identity; peculiarities as a new town, in particular its relation with water and nature as the genius loci;
   - All directions; at the fringe of the Randstad and farmland, the city needs an orientation in all directions;
   - Accessibility; infrastructure for public and private transport urgently needs improvement.
3. Combine city and nature in order to enhance awareness of the human link with nature:
   - Preserve the unique network of nature. Time will make the existing green structure of the city more mature;
   - Use nature as an artery, at every scale level, from large city forest to green roof, from wetland survival tours to energy production;
   - Combine, since nature raises the level of urban functions, and vice-versa.
4. Anticipate changes by creating flexibility in planning and programming:
   - Create enduring spatial redundancy to create flexibility for this generation and for future generations;
   - Try to make reversible developments now that the limits of urban extension are getting closer;
   - Create mental redundancy in rules, regulations, standards and financial arrangements. Dare to plan in innovative ways.
5. Make continuous innovations to processes, technologies and infrastructure, and provide support for experiments and knowledge transfer:
   - Innovation and sustainability in urban development. Experiments and pilot project generate national and international status;

- Concentrate and accumulate knowledge. Make Almere a centre of capacity and market activity in the field of sustainability;
- Make institutional innovations since a mental, instrumental and governmental transition is required. Make Almere an example for others.

6. Design healthy systems; apply “cradle-to-cradle” solutions in the awareness that ecological, social and economic health are interdependent:
   - Mentality. Urban systems are non-linear and highly complex design problems, be aware of the need to contribute to the mitigation of climate change;
   - Hardware. These changes in mentality become visible in the hardware of the city, its water management system, its systems for the supply of water and energy, its traffic system and its waste disposal system. Clean technologies and more high-grade water, waste and resource cycles will be developed;
   - Continuity in goals and objectives, so be prepared and have the power to keep on this course for a long time.
7. People make the city, so support their ambition to realise unique opportunities, with soul and dignity:
   - Planning has to be powerful in its outlines but provide room for private initiatives and co-creatorship;
   - Self-organisation is the social base for sustainability. And sustainability is an inspiring theme for the creation of social organisation;
   - Knowledge and care. Good education and good care provide residents with the knowledge to steer their lives independently without fears about the future.

These powerful ambitions are the basis for the city’s urban water management and urban design. Spatial and urban design problems are complex, as is the search for better solutions. Improving land and water management is part of that complex problem. The principles, however, devote only limited attention to urban development as a multi-stakeholder negotiation problem.

Water-Sensitive Urban Design

Water-Sensitive Urban Design[23] (WSUD) was developed in Western Australia as a new paradigm for developing urban drainage and water supply, urban infrastructure and its maintenance from the very beginning of the planning process. The objectives of WSUD include:

- Reduction of drinking water consumption by water saving, using rainwater and grey water;
- Minimising wastewater production and treating wastewater to a quality level that allows for reuse and/or unproblematic discharge of the effluent into receiving water systems;
- Treat stormwater runoff up to a quality level that allows for reuse and/or unproblematic discharge of the effluent into receiving water systems;
- Preserve the river basin's natural hydrological regime.

WSUD is based on six main principles:[24, 25]

1. Protect natural water systems and the ecosystems that depend on these water systems, as these are truly valuable assets;
2. Integrate stormwater treatment facilities in the landscape and use the aesthetic and recreational possibilities the water offers; make use of the natural topography of the terrain;
3. Protect water quality and treat polluted water close to its source of pollution, so that no damage will be done to natural water courses;
4. Reduce peak discharges from urban areas by introducing a large number of small storage facilities; large storage facilities are not necessary if small ones are installed;
5. Reduce the costs of development and drainage. Cost reductions downstream and more natural drainage raise the value of the urban area;
6. Reduce drinking water consumption; use rainwater instead and reuse water for non-potable functions.

Fundamental water-sensitive urban design practices are based on these principles. This leads to designs characterised by features such as:

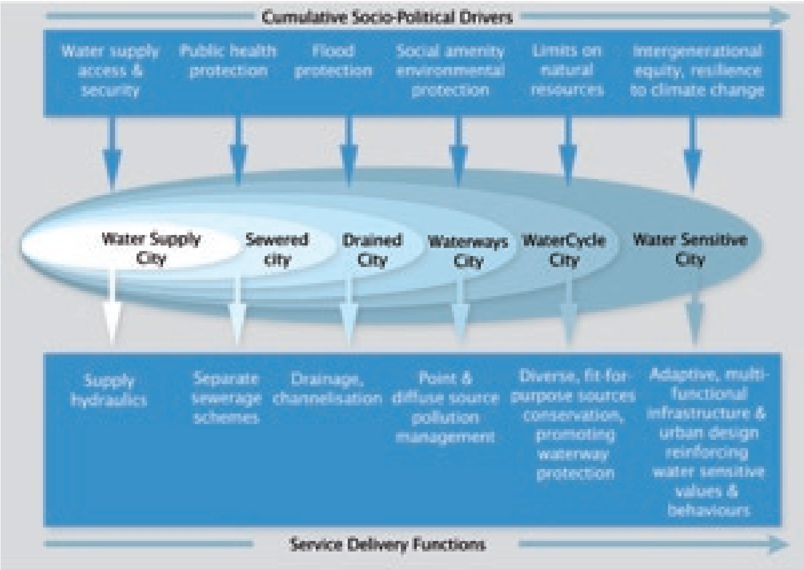
- retain and store rainwater runoff instead of draining it;
- collect and use rainwater runoff as an alternative to the use of drinking water;
- use vegetation to filter and to purify water;
- water saving gardening and landscaping;
- protect water-related cultural, recreational and environmental values;
- de-central and close-to-source collection of water for various purposes;
- de-central and close-to-source treatment of wastewater.

Facilities are integrated in the urban landscape, while adapting the landscape to allow for the natural processes that are to be encouraged.

Water-Sensitive City

Using an historical analysis of its socio-political drivers, Brown and others[26] developed a heuristic to show the development of urban drainage and water supply and the services it delivered, including a view of the future.

Western cities now tend to be Waterways Cities; some are still in the Drained Cities phase and some are working their way up to become Water Cycle Cities. The European Water Framework Directive and national policy and regulation stimulate the protection of the aquatic environment by reducing point and non-point sources of pollution, reducing pollution loads from combined sewer overflows and stormwater in order to create healthy waterways.



Urban Water Management Transitions Framework[26].

The first signs of a Water Cycle City can be observed in cities with constraints on natural water sources. They are starting water-saving programmes, they recycle rainwater and grey water for irrigation and toilet flushing. They are starting to diversify their natural water sources and to invest in people's awareness of the interrelations between their behaviour, consumption and waterway health, the exploitation/over-exploitation of groundwater resources and land subsidence. In the Netherlands, this phase is known as a "Closed City". The next and ultimate phase is the Water-Sensitive City, in which the water management of the city is governed by the principle of intergenerational equity and interwoven with spatial planning and design. Water use is multiple and multifunctional, minimising the ecological and aquatic footprint of the city while maintaining the quality of the living environment.

Natural water systems are valuable assets

In order to encourage Melbourne to become a more Water-Sensitive City, the Australian National Urban Water Governance Program formulated nine key principles for water policy-making and water management in the Water-Sensitive City, building on the principles of Water-sensitive Urban Design (WSUD):

1. Intergenerational equity – Communities understand and agree that current development should not compromise the ability of future generations to enjoy secure water supplies and healthy natural water environments;
2. The value of water and water services is measured in social, environmental and economic terms rather than financial "costs"; (cf. Almere principles);
3. Integrated approach: Water supply, sewerage and stormwater services are managed as part of the total water cycle. Water is also part of the nutrient and energy cycle and is managed taking into account interrelations with other components of the urban infrastructure in a way that contributes to waterway and ecological health and to communities' well-being;
4. Diversity of water sources provided by a range of centralised and decentralised infrastructure. Providing a "portfolio" of water sources to cities creates opportunities to reduce the impact of water supply on the environment and the economy of both the city and its rural surroundings;
5. View the city as a catchment with stormwater and treated wastewater as internal water sources. Minimise imports of water and the export of wastewater. Instead, optimise the use of water resources within the city on fit-for-purpose lines;
6. Ecosystem services – Healthy ecosystems and waterways provide valuable ecosystem services that contribute to the quality of the living environment and that mitigate the impact of the city on the aquatic systems within the city and downstream of the city; healthy waterways contribute to the food webs supporting recreational and commercial fishing and to the processing and assimilation of pollutants;
7. Resilience to climate change, including flood, drought and heat resilience. WSUD will also provide micro-climate benefits and act as heat sinks;

8. Communities are actively engaged in decision-making and will respond to signals relating to responsible water use. This social capital will extend to professionals and practitioners in the water sector. Technology, infrastructure institutions and urban form are designed in ways that back up sustainable practices and social capital;
9. Business case - Governments and the private sector will have the institutional and economic incentives to invest in sustainable solutions.

The Water-sensitive City, Water-sensitive Urban Design and the Almere Principles create the basics for the utopia (en-topia: good city) of the Water City Deltares is working on.

References and annexes

References

1 Bakema, G., V. van Hoegaerden, N. van Oostrom, et al., 2007, Bodem onder energie. Toestand en trends in bodemenergie. Augustus 2007, Stichting Kennisontwikkeling en Kennisoverdracht Bodem, Gouda.

2 De Graaf, R.E., B. van Ee, L. van de Winckel et al., 2007, Verkenning technische en financiële haalbaarheid watersysteem als energieleverancier "De Draai", Heerhugowaard. Rapport P1002.2006.5 Leven met Water / TU Delft Faculteit Civiele techniek en Geowetenschappen, afd. Watermanagement.

3 Braungart, M. and W. McDonough, 2007, Cradle to Cradle – afval = voedsel. 2002, Cradle to Cradle – remaking the way we make things), Sciptum, ISBN 978 90 5594 577 1.

4 Biron, D.J., 2004, Beter bouw- en woonrijp maken: een verkennend onderzoek naar het bouw- en woonrijp maken in de Nederlandse Praktijk en de problematiek rondom wateroverlast op de bouwplaats. Stichting Bouw research, TU Delft, Faculteit Civiele techniek en Geowetenschappen, Afd. Watermanagement.

5 UNFPA, 2007, State of World Population 2007, New York, USA.

6 Adger W.N., Hughes T.P., Folke C., Carpenter S.R., Rockstrom J., 2005. Social-Ecological Resilience to Coastal Disasters, Science 309, 1036-1039.

7 Brauw, H. de, 2009, Duurzaam Almere-Oost; ontwerp van een waterhuishoudkundig systeem. MSc thesis Water Management, TU Delft/ Deltares.

8 Ven, F.H.M. van de, 2007, Urban water Management, Lecture notes. Delft University of Technology.

9 Thompson J.D. and A. Tuden,1964, Strategies, structures and processes of organizational decision. In: Leavitt H.J., and R. Pondy (eds.), Readings in managerial psychology, University of Chicago Press, Chicago.

10 Rijsberman, M.A., F.H.M. van De Ven, 2003, Urban water planning: Working with subjectivity, Progress in Water Resources, 8, pp. 13-25.

11 Ven, F.H.M. van de, S.P. Tjallingii, P. Baan,P.J. van Eijk and M. Rijsberman, 2005, Water in Drievoud; benaderingen voor stedelijke waterplannen. Eburon, Delft, ISBN 90-5972—096-2.
12 Brown, R.R., and Clarke, J.M., 2007, Transition to Water Sensitive Urban Design: The Story of Melbourne, Australia, Report No. 07/1, Facility for Advancing Water Biofiltration, Monash University ISBN 978-0-9803428-0-2.
13 Brown, R.R. and N.A. Keath, 2008, Drawing on social theory for transitioning to sustainable urban water management: Turning the institutional super-tanker. Australian Journal of Water Resources, Vol.12, Nr 2.
14 Jeffrey, P. and Seaton, R. A. F., 2004, 'A Conceptual Model of 'Receptivity' Applied to the Design and Deployment of Water Policy Mechanisms', Environmental Sciences, 1:3, 277 — 300.
15 Rijsberman, M.A., 1999, Wat is duurzaamheid; concepten en benaderingen van duurzaamheid in het waterbeheer. Mededeling nr. 81 TU Delft, Fac Civiele techniek en Geowetenschappen, afd Watermanagement.
16 M.A. Rijsberman and F.H.M. van de Ven, 2000, Different approaches to assessment of design and management of sustainable urban water systems. Environmental Impact Assessment Review (20), pp. 333-245.
17 Graaf, R.E., F.H.M. van de Ven , N.C. van de Giesen, 2007, Alternative water management options to reduce vulnerability for climate change in the Netherlands. Natural Hazards, DOI 10.1007/s11069-007-9184-4.
18 Berg, A. van den, M. Bloemen, T. de Boer and J. Roos-Klein Lankhorst, 2002, De beleving van watertypen: Literatuuroverzicht en validatie van de indicator "water" uit het belevingsGIS. DLO Natuurplanbureauonderzoek. Werkdocument 2002/xx, Alterra, Wageningen.
19 Lems, P., 2008, The values of water. In: Proceedings 11th International Conference on Urban Drainage, Edinburgh, Scotland, UK.
20 Strang, V., 2004, The meaning of water. Berg, ISBN, 1 85973 748 X.
21 Gemeente Almere, 2008, De Almere Principles voor een ecologisch, sociaal en economisch duurzame toekomst van Almere 2030. Gemeente Almere.

22 Graaf, R.E. de, 2008, Urban Water Sustainability CaseStudies; lessons from Australia and the Netherlands. Final Report Leven met Water Project 4086, April 2008. Delft University of Technology.
23 Graaf, R.E. de, 2008, Urban Water Sustainability CaseStudies; lessons from Australia and the Netherlands. Final Report Leven met Water Project 4086, April 2008. Delft University of Technology.
24 Lloyd S.D. et al. 2002, Water Sensitive Urban Design- a stormwater management perspective, Catchment Hydrology.
25 Anonymous, 2003, Water Sensitive Planning Guide for the Sydney Region, Sydney: Upper Parramatta River Catchment Trust.
26 Brown, R., N. Keath and T. Wong, 2008, Transitioning to Water Sensitive Cities: Historical, Current and Future Transition States. In: Proceedings 11th International Conference on Urban Drainage, Edinburgh, Scotland.

Annex I
R&D focus on the Water City

The role of Deltares – see text box – includes furthering knowledge about how to make cities more sustainable for their residents, more robust in extreme conditions and more adaptable to long-term changes. However, this means not only research and development in new tools and technologies. It emphatically includes the requirement of collaborating with other partners in order to strengthen their knowledge and expertise as well. Deltares organises much of its work as a joint learning process with allied institutions, companies, contractors and clients. And that is why the demands of these partners have a strong influence on the Deltares R&D agenda, year after year.

Deltares is a leading research institute for water and subsurface issues with its base in the Netherlands. Throughout the world, our advanced expertise enables safe, clean and sustainable living in deltas, coastal areas and river basins. With this goal in mind, we develop knowledge, innovative products and services, pool our knowledge with others, and make the results available. We advise governments and the private sector, and use our expertise to make sound and independent assessments of the physical condition of deltas, coastal areas and river basins. This range of roles can be seen in our work throughout the world. We extend our knowledge base in government research programmes and contract research, teaming up with universities and other research institutions along the way. In the process, we encourage innovations, and speed up the pathway making new advances available for application in practice.

To live and work comfortably and safely in the narrow confines of coastal areas and river basins, local residents need smart approaches to the subsurface and the water systems. Deltares supplies answers to social issues by combining technical expertise with an understanding of political, administrative and economic processes. This interdisciplinary approach and our independent position mean we can get pro-actively involved in public debate, implementing our strategic principle: ‘Enabling Delta Life’.

In the light of our vision of the Water City and after consulting the partners in our network, Deltares decided to focus its R&D in the area of urban land & water management in the near future on six topics:

1. Improving the quality of the living environment
2. Climate-robust cities
3. Cities without subsidence
4. Water as a solar energy collector and cooler
5. City/river basin interactions
6. Water City design

Each of these topics has technical, ecological, process, institutional, social and economic dimensions.

1. Improving the quality of the living environment

Water is instrumental in improving the quality of the living environment, not only because of its role in improving the design of urban landscapes, but also because it provides better chemical and ecological quality and reduces the public health risks associated with pathogenic organisms and waterborne diseases. More effective use of urban surface water for recreation and as a source of water for irrigation and domestic purposes results in a stronger focus on the quality and the availability of the water. One of our goals is to boost natural purification processes through smarter design. Adverse effects on public health associated with groundwater can be avoided by controlling groundwater levels more effectively with subsurface drainage. If the quality of the water permits, this drainage water and the local groundwater can be used as a significant water resource.

2. Creating climate-robust cities

Climate-robust cities are capable of handling heavier rainfall, more severe droughts and more extreme maximum temperatures without excessive damage. The vulnerability of urban areas to climate change, rising sea levels and ongoing urbanisation is being analysed and strategies to evaluate and select structural and non-structural measures are being developed. Creating climate-robust cities implies not only large-scale measures like flood protection techniques but also measures such as green roofs or surface water cooling. Deltares is developing and testing the full range of these techniques and concepts, starting with flood hazard mapping and flood early warning systems up to prediction of land subsidence and water allocation problems.

3. Cities without subsidence

Expected subsidence is studied on the basis of soil and subsoil properties. Smart strategies are being developed to control subsidence with groundwater level management, light filling materials and light structures, as are ways to strengthen the soil matrix. Subsidence control strategies are being looked at in conjunction with urban planning. GeoChecks are conducted to reduce risks associated with construction works.

4. Water as a solar energy collector and cooler

Reducing the energy input and heat output of cities is an increasingly important objective; cities' internal sources of energy should be used better. And water can play a major role here because of its high specific heat and its transportability. Surface water is an effective solar collector; groundwater is a massive store for heat and cold – if properly managed the combination could provide plentiful energy for heating and for cooling.

5. City/river basin interactions

Cities are parts of drainage basins for surface water and for groundwater. And even though we would like to reduce the input and output of water and related substances, the city will never become completely sealed off from the rest of the world. Urban areas can even help resolve the water management problems of the basin. It is, for example, easier to create space for water storage in an urban area than in rural areas: the water space in urban areas can be used for many urban functions but farmers cannot use water to grow crops on.

Urban flooding is often the result of water intruding into the city from its surroundings or of impaired or blocked drainage from the city to its surroundings. The prevention of flood damage is a top priority.

6. Water City design

The quality of the urban living environment is improved by creating visible water; flowing water adds an extra dimension to that quality. We have to improve our understanding of (1) the way people value the water in their living environment and (2) the way we can include or re-introduce these water elements in urban environments. "Research by design" helps us to improve the quality of the urban landscapes we create. Delta urban planning makes us understand how these water elements can be included in delta cities so that they contribute to emotional, cultural, economic and ecological quality. Urban design is meant to create and make use of opportunities, not just to solve problems with water. The question is how this can be achieved in practice.

Permanently ongoing changes in the climate, demographics, economic conditions and public demands require a more flexible and adaptable city; this imposes new demands on the design of the Water City and on the management of land & water in the urban setting.

Annex II
Capacity-Building

The challenge of change

Making changes in urban water management always affects many people and interests. It means changing policies and practice, legislation, regulations and institutional arrangements and maintenance & operation. All the parties involved have to learn how to deal with the new situation. All have to develop the capacity – in other words, the knowledge and the skills – to do well in their new role. That is why Deltares considers it a significant part of its role to do capacity building. As well as delivering top-level expertise and providing our partners and clients with trusted and reliable science[12], we also have to create a collaborative learning process with them in order to transfer our knowledge in an effective way.

Transition management

As a capacity-building organisation, we try to apply the latest findings about social learning and transition management for the purpose of the successful implementation of concepts, plans and measures that we develop together with our clients and partners. We advise on, and help with, the creation of enabling conditions and planning strategic interventions by leaders. We assist with communication planning, including the planning of when and how scientific information is introduced during the process.

Annex III
Managing land & water in the urban environment: the Deltares vision

To implement and develop further the Deltares vision of urban land and water management, we work with many stakeholders. Not only for national, provincial and municipal government authorities, the European Commission or water boards, but also for consultants, project developers, building companies, housing corporations, banks, architects and landscape planners in the Netherlands and abroad.

Our work draws on our:

- thorough knowledge of urban water systems, water supply and sanitation, groundwater, surface water, rivers and catchments;
- solid expertise in the areas of soils, subsoil, geohydrology and geo-engineering, land subsidence, monitoring and surveying technology;
- wide-ranging expertise in optimising solutions, in creative design and in negotiations; and
- extensive networking and communicating capacity.

A lot of our biophysical knowledge is reflected in our modelling suites for hydraulic, hydrological, geohydrological, hydrochemical, hydrobiological, ecological, thermal, soil mechanical and economic simulations, our hydro-informatics data systems and the ways these models and databases contribute to risk reduction, scenario analyses, virtual reality training tools, and design & dialogue support systems. We combine the hard system information with the soft information from social and economic surveys and from governance processes to produce integral and sound advice for our partners and clients or to produce second opinions during the checks, audits and evaluations that we conduct for designs and ongoing projects.

Colophon

Land & water management in the urban environment

Text
Team Urban Water Management, Deltares

Editing
Pete Thomas

Graphical design
DRUKKERS DIE MEEDENKEN.NL

Printing
Drukkerij JB&A van Driel

Images and photography
All images by Deltares with the exception of cover (Angelique van der Voort), page 20 (Gemeente Utrecht – POS, Het Utrechts Archief, The Netherlands), page 22 (VHP stedebouwkundigen + architekten + landschapsarchitekten, the Netherlands), page 23 (Dura Vermeer Groep NV)