Delta Cities – Water Cities

Villes des deltas – Villes d'eau

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RÉSUMÉ

Ce document prospectif esquisse un futur durable pour les villes des deltas. L'empreinte écologique des villes est beaucoup plus grande que l'espace qu'elles occupent. Ainsi, à l'extérieur comme à l'intérieur des zones urbaines, les problèmes écologiques s'accumulent, et doivent être résolus pour créer des villes durables. En particulier, faire évoluer la gestion de l'eau à un autre niveau peut contribuer grandement à trouver les solutions nécessaires pour créer une ville plus durable. Mais, la gestion de l'eau urbaine ne doit pas seulement tenir compte des aspects techniques ; la gestion repose également sur une optimisation, une conception et un processus de négociation. Ceci nécessite une approche intégrée pour pouvoir suivre chacune des trois voies parallèles. De nouveaux concepts et outils sont développés pour soutenir cette approche intégrée. Une des principales conditions est de créer et maintenir la réceptivité de tous les acteurs nécessaires. Le résultat d'une approche bien équilibrée serait une ville d'eau. Cette ville aurait un comportement moins parasite (minimisant le gaspillage des ressources de qualité et réduisant ses déchets), elle pourrait s'adapter aux changements et bénéficier d'une bonne qualité de l'eau. Les recherches futures devraient contribuer à suivre l'approche intégrée. Si la ville d'eau devenait la norme, les villes s'inscriraient plus dans une démarche durable.

ABSTRACT

This prospective paper sketches a sustainable future for delta cities. The ecological footprint of cities is much larger than the space they occupy. Inside and outside of the city environmental problems are raised and should be solved in order to achieve sustainable cities. Shifting water management to another level can contribute largely to solutions for a more sustainable city. Urban water management has to deal with more than technical issues; it is an optimization, design and negotiation problem in one. This requires a more integrated approach to follow all three tracks parallel. New concepts and tools are being developed to support the integrated approach. One major prerequisite is to create and maintain receptivity by all needed actors. The result of a well balanced approach may be the Water city. This city has a less parasitic behavior (wasting high quality resources and dumping waste products), is adaptable to changing conditions and benefits of a good water quality. Further research should be contributing to the integrated approach. If the Water city becomes the standard, we will have cities which are worth living in.

KEYWORDS

Adaptive planning and design, sustainable development, urban land and water management, water city

1 INTRODUCTION

On a global scale, the proportion of people living in cities now exceeds the rural population (UNFPA, 2007). Urbanisation predominantly takes place in delta areas, coastal and river plains that are exposed to flooding risks. In 2030, some 50% of the world's population is expected to be living within 100 kilometres of the coast (Adger et al., 2005). All these urban areas and the ongoing urbanization have a number of significant side-effects in the field of urban land & water management. Major effects in delta cities 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. As a result, urban water quality is poor and the ecological footprint of urban areas is extensive, as well as its dependency on external resources and transport facilities.

- Vulnerability to extreme weather

Heavy rainfall and severe droughts occur every now and than, while land and water management for urban areas is not designed for handling these extreme conditions. Water supply and flood protection are under particular pressure.

- Urban Heat Island

The texture of the urban area and the reduced levels of evapotranspiration there lead to temperatures that exceed those in surrounding rural areas. If city residents are insufficiently protected against heat, mortality rates will increase substantially. And protection requires more air conditioning, boosting energy demand and heat production.

- Flooding and ponding

Due to the low surface gradient, water ponding on urban 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.

- Land subsidence

Sedimentary, soft soils and subsoils are common in delta areas and floodplains. Urban areas are sensitive to land subsidence, depending on the soil material characteristics, the loads imposed, the local water and drought conditions and on groundwater abstraction.

- 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 multiple land use also applies to water surfaces; surface waters provide numerous functionalities, including space for recreation and housing. 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 is affected.

- Multifunctional water use

Five types of water are found in urban areas: surface water, groundwater, storm water, drinking water and wastewater. They are each used for a wide variety of functions and disposed of after application. The challenge for urban water managers is to fit all these functions into the same space or in the same volume of water without significant conflict.

Tackling these problems and challenges requires that water is put at the very heart of urban development. Water underlies the delta city, both metaphorically and literally. That is why planning and design of these cities start with planning and designing the water system. Objective of this paper is to outline how to achieve this position and how this position of water influences the technical research agenda of urban hydrology and urban water management.

2 WATER, KEY TO IMPROVEMENT

Traditionally, these above mentioned problems were solved in an mono- or oligo-disciplinary way by policy analysis and system optimisation. Today's challenges to urban water management however engendered discussions about better ways to respond. Using an historical analysis of its socio-political drivers, Brown and others developed a heuristic to show the development of urban drainage, from control over water flows and water quality in the past to fair multifunctional use in what they call a water sensitive city of the future (Brown et al., 2008). See Figure 1. This water sensitive city is based on water sensitive urban design principles, aiming at reducing the ecological footprint of urban areas (Lloyd et al., 2002; Upper Parramatta River Catchment Trust, 2003).

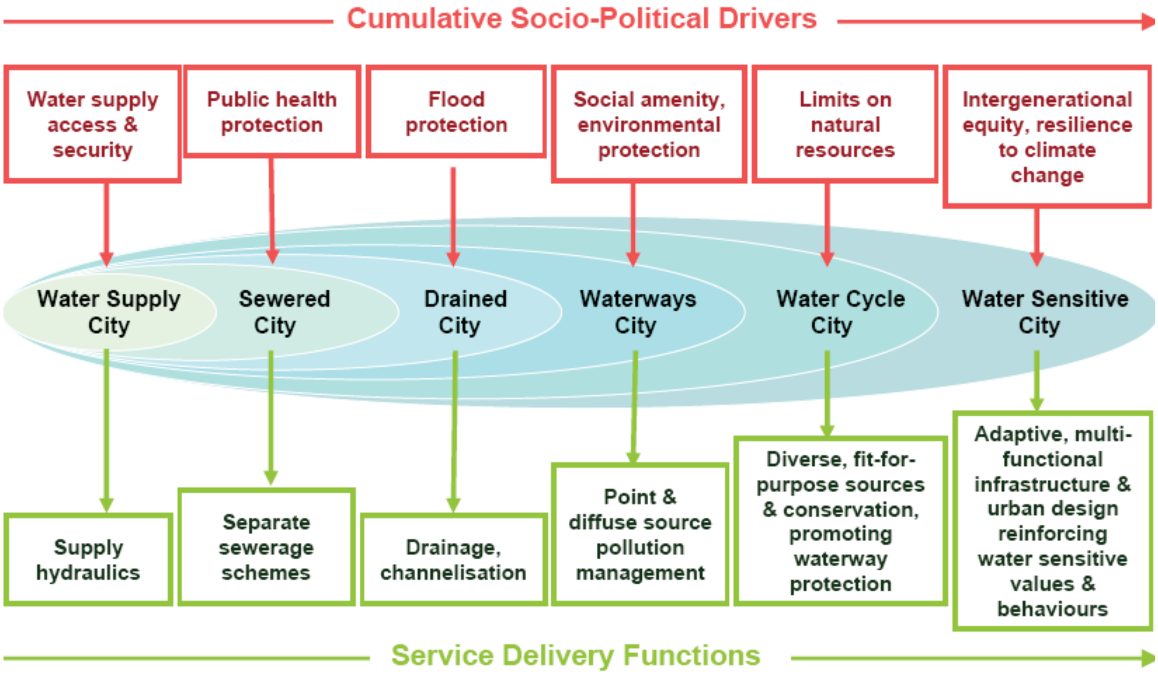

Figure 1. Urban Water Management Transitions Framework (Brown et al., 2008)

2.1 Sustainability

For obtaining designs of more sustainable cities other principles were developed as well. Baumgart and McDonough developed their cradle-to-cradle philosophy and applied these principles in urban design (Braungart and McDonough, 2007). Almere, a rapidly growing new town in the Netherlands, 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" (Gemeente Almere, 2008).

Sustainability is a rather multi-interpretable demand. Rijsberman et al. showed four fundamentally different understandings of the meaning, by classifying views into a group with more human-oriented objectives of sustainability, as opposed to a group with more eco- or nature-oriented objectives and by making a similar breakdown between authors who prefer a normative, SMART approach to sustainability and a group that prefers a more abstract, value-oriented way of dealing with sustainability (Rijsberman, 1999; Rijsberman and Van de Ven, 2000). This results in a Ratio, a Capacity, an Ecological and a Social approach to sustainability.

Sustainability alone is however an insufficient requirement to provide a high quality living and working environment for the residents of the city, now and on the long run. Long term changes such as climate change, demographic and economic developments ask for adaptability and flexibility on the long run, as well as for climate robustness. And residents prefer a healthy, pleasant and nice-looking urban environment. These requirements add interesting dimensions to the programme of demands of urban developments and reconstruction projects.

2.2 Climate robustness

Creating adaptability is only part of creating climate robustness. Four system capacities need to be strengthened in order to reduce the vulnerability of the urban environment to flooding, drought and heat problems (De Graaf et al., 2007). These are:

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

In land and water management, we tend to focus particularly on strengthening threshold capacity, for example by building higher dikes and installing larger pumps. Measures to enhance coping capacity can include wet-proofing buildings, and effective evacuation schemes. Recovery capacity requires e.g. sufficient stocks of critical supplies. And adaptive capacity includes the need for redundancy. Adaptability also means flexibility in real estate, rather than real estate that is built to stay in place for centuries.

2.3 Public and ecological health

Public health concerns were, until the 1970s, limited to improving water supply and sanitation systems. Increased environmental awareness triggered a pollution prevention and source control approach that has been in place since then in order to protect the ecosystems and biodiversity. Non-point sources became a concern. 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. And nowadays we study options for eco-services, services that contribute to our personal and economical well-being, with public health as one of the beneficiaries.

2.4 Quality of the urban environment

The perceived quality of the living environment is highly dependent on the visibility of water. This has been found in numerous sociological studies (Van de Berg et al., 2002). Lems sees eleven different values of urban water: biotic, sensitive, analytical, formative, lingual, social, economic, aesthetic, juridical, ethical and pistic (Lems, 2008). Strang's anthropological study shows that people assign profound values to water, values that should not be neglected in any plan to change water management (Strang, 2004). Urban landscape designers now learn how to use these values of water in urban design. This resulted in a new Dutch water city (Hooimeijer et al., 2005).

2.5 Water management

The management of the urban surface water, groundwater, storm water, drinking water, and wastewater plays a crucial role in realizing these objectives. Organizing the urban water system is therefore the first and essential step in creating a sustainable, climate robust, healthy and nice urban environment. This however requires that the water system design is made concurrently with the urban design, in an integrated approach. This integrated approach not only asks for new working methods and procedures but also for new skills and capacities of the urban water management engineers.

3 TRULY INTEGRATED APPROACH

3.1 Optimization, design and negotiation

Urban water management is a triple problem: it is an optimization problem, a design problem and a negotiation problem in one (Van de Ven et al., 2005). To achieve sustainable solutions these three problems are to be solved simultaneously, in a three track approach. It is. In order to synchronise the three tracks in each phase of the process, we have to ensure that the concept, the scope and the knowledge are harmonised at all. (Rijsberman and van de Ven, 2003). For harmonizing the *concept* a permanent dialogue is required with all stakeholders on the meaning of sustainability, vulnerability / robustness, adaptability and quality. This dialogue includes the way that ambitions and principles are translated and elaborated in plans and designs. The *scope* refers to the permanent dialogue about the scope of our problem. This scope includes the group of stakeholders and the way they are – or could/should be – involved, the planning area, the problem area and the issues to be addressed.. 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 disturb the process on the long run. 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 the moment the project manager falls seriously ill? Creating an open repository of all negotiated knowledge, decisions and negotiations is important for the efficiency and the quality of planning and decision-making.

Integrating an optimization process and a design process is being practiced in design workshops, using methods such as collaborative design, concurrent engineering and enquiry by design. Engineers, urban planners and urban landscape designers co-operated successfully in many new urban developments in the Netherlands. And technical support tools for this concurrent design process gradually become available. Examples are the interactive design table and Urban Strategy. Integrating negotiations in this planning process is the hardest part. Every design decision interferes with the interests of stakeholders. Serious games are now being tested to contribute to well-balanced planning.

3.2 Receptivity

Objective of the negotiations is to reach agreement on the plan. And to that end we have to improve the receptivity of stakeholders for certain choices. Receptivity to any new choice requires fulfilling four conditions (Jeffrey and Seaton, 2004):

- 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 consensus, planners, policy developers and project developers generally tend to focus their efforts on creating awareness and applicability. However, association and acquisition must also be encouraged as well in order to come to agreement.

Receptivity is 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, to allow for a positive association.

3.3 Transition management

The failure risk of experimental applications of new methods and technologies is larger than application of proven technologies. Application of innovative solutions often requires adaptations in policy, regulations, building and construction praxis, monitoring and evaluation and organization. The role, tasks and capacities of the own organization changes if such a new method or technology is applied. It therefore takes courage and endurance to become launching customer. However, mainstreaming new methods or technologies starts with successful pilot applications. To achieve a breakthrough, a large number of conditions have to be fulfilled, as shown by Brown and Clarke for innovations in urban water management in Melbourne, Australia (Brown and Clarke, 2007). Two components of successful transition management are mentioned 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, even though society calls for transparency and accountability. Monitoring helps us to understand what is going on and how effective steering actions are.

- Dynamic programming

In an optimal system, failures also propagate optimally. In dynamic systems, diversity, redundancy and adaptability to new circumstances reduce the risk of system failures. Planning and design should therefore include these components in order to reduce vulnerability. Strengthening robustness may move solutions away from their minimal cost price now but future benefits are expected to compensate for the extra investment costs. Flexibility in the way to go, in ambitions, objectives and in deliverables requires a dynamic approach.

4 THE WATER CITY

Based on the abovementioned considerations and development we formulated a utopia (eu-topia, good city) for delta cities. This utopia is called the Water City, as it builds on the water city developed by the urban designers (Hooimeijer et al., 2005).

In order to become more sustainable, we first of all have to make urban areas less parasitic, i.e. less dependent on external resources and less waste-producing. We can reduce its ecological footprint by:

- Reducing inputs of water, food and energy
- Reducing imports of sand, ground and building material
- Recycling water
- Making water more multifunctional / making better use of all available water
- Surface water providing space for urban development
- Using water as an energy source
- Using the available water for food production
- Using water for 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:

- Providing an enabling water quality
- Using water to support the quality of the urban landscape

These are features of the Water City. They are to be strengthened. The available water – surface water, groundwater, storm water, drinking water and wastewater – is utilized intensively as a resource, rather than managed and controlled; and the vulnerability of this city to flooding, drought, extreme heat and land subsidence is reduced through water-wise design, operation and management.

This Water city can only be achieved in a co-operative effort of all stakeholders, including residents, not only during the design and construction phases but throughout the entire life cycle of the system. This means that planning, design, construction and maintenance process needs another, more integrated approach.

4.1 Three track approach

The multi-functional, multi-stakeholder nature of urban land and water management issues leads to situations in which full consensus is seldom reached. Such complex problems can only be solved by negotiating, designing and exploring better options in parallel. It is the interaction between the three tracks of the planning and design process – optimisation, design and negotiation – that helps to produce the “best” solution under the given circumstances.

The role of the expert is different in each track, and so are the research questions and the information demand. 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 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 designer. Enquiry by design and concurrent engineering helps designers and experts to co-create widely appreciated and accepted solutions. The information demand for planning and design does not only include land and water data, but also data on economical, ecological and social aspects of the urban (re)development at hand.

Process and transition management are used to steer the development process, in addition to project management. Innovative solutions in particular require transition management, as they often require adaptations in policy, regulations, building and construction praxis, monitoring, maintenance and organization. Creating receptivity is one of the most challenging tasks in this process; and the engineers play an important role there, as they are the ones to provide factual evidence as a basis for negotiated knowledge.

5 RESEARCH AGENDA FOR THE WATER CITY

Based on this idea of the Water City we are now able to restructure the research agenda for urban water management, to re-establish research priorities and to put ongoing research in new context.

- Improving the quality of the living environment

Water is instrumental in improving the quality of the living environment and to reducing the ecological footprint of urban areas. Processes in surface and groundwater improve their chemical and ecological water quality. And clean water reduces the public health risks associated with pathogenic organisms and waterborne diseases. Intensified use of urban surface water for recreation and as a source of water for irrigation and for domestic purposes results in a stronger focus of society on the quality and the availability of the water. One of our goals is to boost natural purification processes through smarter design. If the quality of the groundwater permits, this subsurface drainage water and the local groundwater can be used as a significant water resource, along with treated storm water runoff.

- 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 is to be analysed and strategies to evaluate and select structural and non-structural measures are to be developed. Creating climate-robust cities implies not only large-scale measures to prevent urban flooding, but also small scale measures such as green roofs, drought control and heat control such as surface water cooling.

- Cities without subsidence

Expected subsidence effects are studied on the basis of soil and subsoil properties. Smart strategies are being developed to control subsidence with groundwater 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.

- 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 can be used better. Surface water is an effective solar collector; groundwater a massive store for heat and cold – if properly managed the combination could provide plentiful energy for heating and for cooling.

- 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 tend to divert its waste to the surrounding drainage area, polluting resources downstream. This negative impact is to be stopped. Urban areas could even help resolve the water management problems of the basin.

- 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. The way people value water in their living environment and the way we can include or re-introduce water elements in urban environments is however poorly understood. "Research by design" helps us to improve the quality of the urban landscapes we create. Delta urbanism makes us understand how these water elements can be included in delta cities so that they contribute to emotional, cultural, economic and ecological quality.

6 IN CONCLUSION

Urban water management in delta cities like those in the Netherlands is entering a next phase of development. This new phase could be called *water adaptive* as we build on our experience in controlling the five types of urban water – groundwater, surface water, storm water runoff, wastewater and drinking water – to a situation where we adapt ourselves to the water and where we adapt the water to our demands. Only by such a context driven approach to water management we can achieve sustainable, climate-robust, adaptable, healthy and nice urban environment. This water adaptive phase is characterized by an integral approach to urban water management problems, in which the optimization problem, the design problem and the negotiation problem is solved in parallel, in the context of the urban development planning, to allow for interference between the urban planning and the water planning. Only this way we can realize the ideals of the Water City.

Water adaptive planning and design sets a new research agenda on top of the existing one. Profound urban water system knowledge is insufficient to support solving the design and the negotiation problem. Our water system information is to be brought and presented in the context of the urban development ambitions, as elaborated above for the Water City.

The Water City first of all aims at reducing its ecological footprint – for water, food, energy, building materials. Delta cities moreover have to become more climate robust; more water is needed for controlling flooding drought and heat. And in view of the uncertainties to the future they better develop in a more flexible way, to allow for corrective measures on the long run. Water quality is a major concern of the water city, as many stakeholders use the water and depend on its quality. And, last but not least, water makes a magnificent contribution to the quality of the urban landscape. That makes a Water City worth living in!

LIST OF REFERENCES

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

Upper Parramatta River Catchment Trust (2003). *Water Sensitive Planning Guide for the Sydney Region*, Sydney, Upper Parramatta River Catchment Trust.

Braungart, M. and McDonough, W. (2007). *Cradle to Cradle – afval = voedsel. (2002, Cradle to Cradle - remaking the way we make things),* Sciptum, ISBN 9789055945771.

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 Adv. Water Biofiltration, Monash University ISBN 9780980342802.

Brown, R., Keath, N. and Wong, T. (2008). *Transitioning to Water Sensitive Cities: Historical, Current and Future Transition States*. In: Proceedings 11th International Conference on Urban Drainage, Edinburgh, Scotland.

De Graaf, R.E., Van de Ven, F.H.M. and Van de Giesen, N.C. (2007). *Alternative water management options to reduce vulnerability for climate change in the Netherlands*. Natural Hazards, DOI 10.1007/s1106900791844.

Gemeente Almere (Municipality of Almere) (2008). *De Almere Principles voor een ecologisch, sociaal en economisch duurzame toekomst van Almere 2030*, Gemeente Almere.

Hooimeijer, F, H. Meyer and A. Nienhuis (2005). *Atlas of Dutch Water Cities*. SUN Publishers, ISBN 9058751848

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.

Lems, P., (2008). *The values of water*. In: Proceedings 11th International Conference on Urban Drainage, Edinburgh, Scotland, UK.

Lloyd, S.D., Wong, T.H.F. and Chesterfield, C.J. (2002). *Water Sensitive Urban Design- a stormwater management perspective*, Catchment Hydrology.

Rijsberman, M.A., (1999). *Wat is duurzaamheid; concepten en benaderingen van duurzaamheid in het waterbeheer.* Mededeling nr. 81 TU Delft, Fac Civiele Techniek, afd Watermanagement.

Rijsberman, M.A. and Van de Ven, F.H.M. (2000). *Different approaches to assessment of design and management of sustainable urban water systems*. Environmental Impact Assessment Review (20), pp. 333-245.

Rijsberman, M.A. and Van De Ven, F.H.M. (2003). *Urban water planning: Working with subjectivity.* Progress in Water Resources, 8, pp. 13-25.

Strang, V. (2004). *The meaning of water*. Berg, ISBN, 185973748X.

UNFPA (2007). *State of World Population 2007*, ISBN 9780897148078, United Nations Population Fund, New York, USA.

Van de Ven, F.H.M., Tjallingii, S.P., Baan, P., Van Eijk, P.J. and Rijsberman, M. (2005). *Water in Drievoud; benaderingen voor stedelijke waterplannen*. Eburon, Delft, ISBN 9059720962.

Van den Berg, A., Bloemen, M., De Boer, T. and Roos-Klein Lankhorst, J. (2002). *De beleving van watertypen: Literatuuroverzicht en validatie van de indicator "water" uit het belevingsGIS*. DLO Natuurplanbureauonderzoek. Werkdocument 2002/xx, Alterra, Wageningen,