018530 - SWITCH

Sustainable Water Management in the City of the Future

Integrated Project
Global Change and Ecosystems

Water Sensitive Urban Design for a Sustainable Stormwater Management in the City of the Future – SWITCH Research Results

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presented at 5th SWITCH Scientific Conference, 13 – 16 October 2010

Due date: M 60
Actual submission date: M 60

Start date of project: 1 February 2006 Duration: 60 months

Organisation name of lead contractor for this deliverable:
HafenCity Universität, Hamburg, Germany

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including Commission Services)	
RE	Restricted to a group specified by the consortium (including Commission Services)	
CO	Confidential only for members of the consortium (including Commission Services)	

5th SWITCH Scientific Meeting
Lodz, Poland
13th – 15th October 2010

Water Sensitive Urban Design for a Sustainable Stormwater Management in the City of the Future – SWITCH Research Results

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Abstract
During the last years decentralized solutions for sustainable stormwater management have been developed all over the world and legislation has been advanced. However these systems are underutilized and public as well as professional reception is still quite low. One reason is that stormwater facilities have often been engineered without considering ecological, social, or aesthetic qualities.

In fact, ecological, social, and aesthetic qualities are important, because they influence public perception and acceptance. The main question that needs to be answered is: How can sustainable stormwater management be integrated into urban design in order to create livable, sustainable, and attractive cities? One approach that supports this intention is the idea of Water Sensitive Urban Design (WSUD).

WSUD, originally developed in Australia, strives to harmonize the urban built environment and the urban water cycle, combining the functionality of water management with principles of urban design. The approach embraces an interdisciplinary cooperation of water management, urban design, and landscape planning in order to reach WSUD goals as well as the integration of water management concerns into overall concepts and development plans.

Within the scope of SWITCH, HafenCity University of Hamburg researched in the field of WSUD. The main research questions have been:

- What is Water Sensitive Urban Design?
- What principles need to be considered when applying WSUD?
- What does WSUD look like (case studies)?

All results of the research will be included in a manual on WSUD that aims to inspire stakeholders involved in the planning, design, and maintenance of stormwater management in urban areas (such as civil engineers, planners, landscape designers, project managers, architects, administrative officers, and policymakers). Therefore the manual provides an overview of the WSUD approach, creates guidelines by setting principles for WSUD, and presents case studies demonstrating WSUD principles.

Keywords: sustainable stormwater management, integrated planning, sustainable urban development

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1 Introduction

Conventional water management in cities is based on pipes and sewer systems. The main intention of these systems is to rapidly collect and drain stormwater from cities. These highly efficient systems have gradually improved over time and most cities rely on them. Most of time, conventional stormwater systems work well. However, they can cause a number of problems:

1. **Conventional stormwater systems are not sustainable:** These systems drain stormwater rapidly from surfaces and therefore reduce infiltration and groundwater recharge rates. This has a negative impact on local climate (Heat Island Effect) and increases the risk of sewer system overflows causing local flooding and other flood disasters.

2. **Conventional stormwater systems are not flexible enough to be adapted to uncertain or changing conditions:** Rising rates of stormwater runoff as result of continued ground sealing and climate change effects cannot be managed and on-going adaptations of existing systems can be extremely expensive.

3. **Conventional stormwater systems keep stormwater invisible:** With conventional systems, stormwater is not visible to city inhabitants and therefore does not contribute to water awareness or developing of a much-needed sense of responsibility for the water as a resource.

With these problems in mind, decentralized solutions for stormwater management (e.g. infiltration trenches, bio swales or detentions ponds) have been developed all over the world and legislation has been advanced. However these systems are underutilized and public as well as professional reception is still quite low. One reason is that stormwater management systems have often been engineered without considering ecological, social or aesthetic qualities, and even manuals on sustainable stormwater management have been developed without consideration of these important points.

In fact, ecological, social and aesthetic qualities are important, because they influence the public perception and acceptance of the systems. As Richard Echols pointed out right, there are still too few sustainable stormwater management systems that have been applied in a manner that is appreciated by the public. In consequence, sustainable stormwater management is either seen as messy or unusual when it is not designed in a pleasing way or badly maintained, or in turn, people do not use sustainable stormwater management measures, because they do not see a clear added value for extra costs (Echols 2007, 2).

2 The Water Sensitive Urban Design Approach

Decentralized stormwater management can draw a significant contribution to the sustainable development of our cities in the future. To bring it more into practice, public and professional acceptance must be improved. The main question, that needs to be answered, is: How can sustainable water management be integrated into urban design in order to create liveable, sustainable, and attractive cities? Therefore an integrated approach linking urban design and water management must be formed. The idea of Water Sensitive Urban Design serves this intention.

Water Sensitive Urban Design (short: WSUD) is the interdisciplinary cooperation of water management, urban design, and landscape planning. It considers all parts of the urban water cycle and combines the functionality of water management with principles of urban design. WSUD develops

integrative strategies for ecological, economical, social, and cultural sustainability. In result, WSUD not only effectively resolves urban water management issues, but also contributes to the visual and recreational amenity of the city (fig.1).

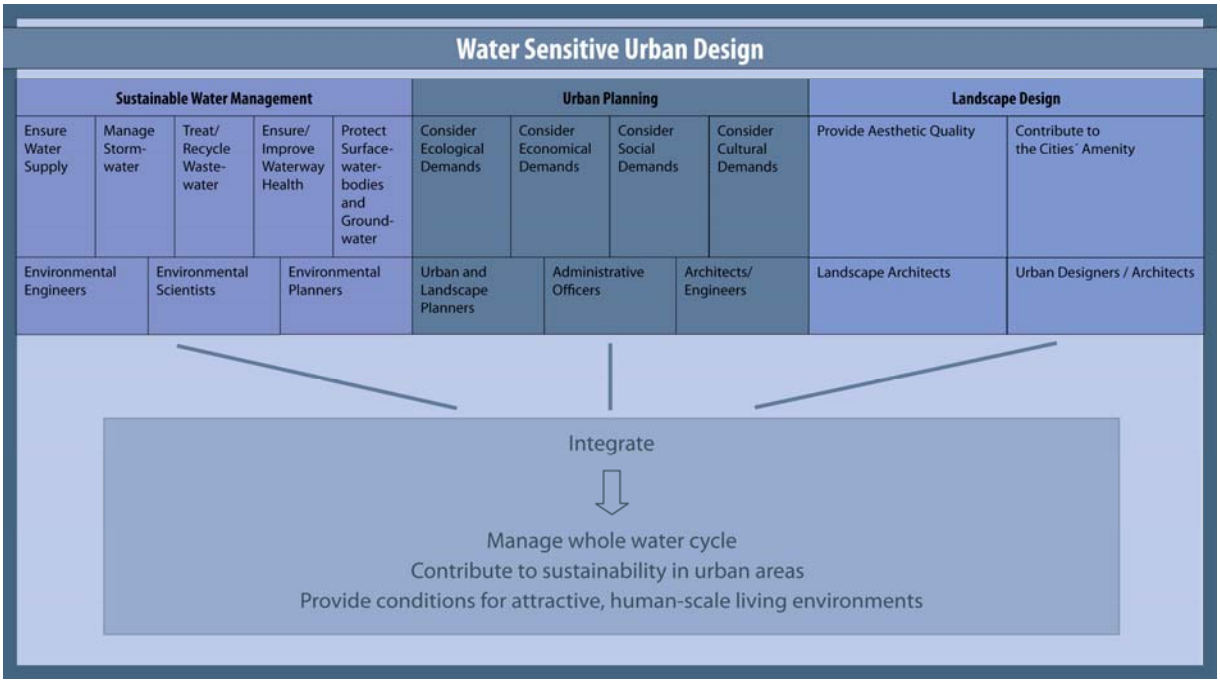

Fig. 1. Components of Water Sensitive Urban Design (© HCU Hamburg).

Originally, the term "Water Sensitive Urban Design" considered the management of entire water systems (drinking water, storm water run-off, waterway health, sewerage treatment and re-cycling). However, stormwater is a key element, both as a resource, and for the protection of receiving rivers (Melbourne Water 2005). For that reason the Water Sensitive Urban Design approach is predominantly used in its application on urban stormwater management that aims to recreate a natural-oriented water cycle while contributing to the amenity of the city.

According to the Urban Stormwater - Best Practice Environmental Management Guidelines of the Victorian Stormwater Committee (The Urban Stormwater Best Practice Environmental Management Guidelines 1999), the goals of WSUD from a stormwater management and planning perspective are:

- Protection of natural water systems within urban developments;
- Protection of the water quality by using filtration and retention techniques;
- Reduction of stormwater runoff and peak flows by using local detention and retention measures and minimizing impervious areas;
- Reduction of drainage infrastructure and the related development costs, whilst improving sustainability and amenity of urban areas;
- Integration of stormwater management into the landscape by incorporating multiple use corridors that contribute to the visual and recreational amenity of urban areas.

3 Research results

3.1 Principles for Water Sensitive Urban Design

Based on the goals developed by the Victorian Stormwater committee (compare chapter 2), HafenCity University developed principles that can be seen as recommendations for planners and practitioners in the sector of water management and urban design/planning.

For the success of decentralised stormwater management in combination with urban design (Water Sensitive Urban Design), it is important that the solutions are water sensitive (i.e. they bring stormwater management closer to the natural water cycle), functional, aesthetically pleasing, usable and accepted by local inhabitants. The five topics are defined:

- Water Sensitivity
- Aesthetics
- Functionality
- Usability
- Public perception and acceptance

According to these topics, WSUD-solutions……..

	Principle	Short form	Topic
1)	…… should use decentralised methods to bring urban water management closer to the natural water cycle.	Water sensitivity	WATER SENSITIVITY
2)	…… should be used to provide an aesthetic benefit where possible.	Aesthetic benefit	AESTHETICS
3)	…… should be adapted to the design of the surrounding area.	Integration in surrounding area	
4)	…… should be used in an appropriate way, adapted to the local basic conditions and the intended use.	Appropriate design	FUNCTIONALITY
5)	…… should consider the corresponding maintenance requirements	Appropriate maintenance	
6)	…… should consider possibilities for adaptation to uncertain and changing basic conditions.	Adaptatability	
7)	…… should be used to create places that are usable for recreation and/or nature conservation purposes.	Appropriate usability	USABILITY
8)	…… should consider the demands of all stakeholders and involve them in the planning process.	Public involvement	PUBLIC PERCEPTION & ACCEPTANCE
9)	…… costs should be comparable to the costs of conventional solutions.	Acceptable costs	

In order to meet the demands of all the different topics, it is necessary to integrate the principles listed above. Therefore WSUD solutions…..

Principle	Short form	Topic
10) …… should combine function, aesthetics and use.	Integration of demands	INTEGRATIVE PLANNING
11) …… should be planned in interdisciplinary co-operation of urban planning, urban design, landscape architecture and water management.	Interdisciplinary planning	
12) …… should be designed in an aesthetic, well-functioning and usable way in order to improve the public perception and acceptability of WSUD.	Impact on public perception	

3.2 Case studies

During SWITCH research it became apparent that the Water Sensitive Urban Design approach can be applied in different scales: on site level, on district level or as strategy for a whole city. For this reason, case studies showing the principles of WSUD also comprise these three levels: large scale (city), medium scale (district), and small scale (site). Three exemplary case studies are presented in this paper.

Large Scale: Waterplan 2 (Rotterdam, Netherlands)

Project	Water Sensitivity	Aesthetic Benefit	Integration in Surrounding Area	Appropriate Design	Appropriate Maintenance	Adaptability	Appropriate Usability	Public Involvement	Acceptable Costs	Integration of Demands	Interdisciplinary Planning	Impact on Public Perception
	1	2	3	4	5	6	7	8	9	10	11	12
Waterplan 2 Rotterdam	✓	✓	✓	✓	(✓)	✓	✓	✓	(✓)	✓	✓	✓

The city of Rotterdam is situated two meters below sea level. Up to now, water was seen as a threat. The city is surrounded by dykes and has a complex pumping system that bewares the city from flooding. Until 2007, Rotterdam's water management primarily focused on safety, quantity, and quality aspects of water. In 2007, it became increasingly clear that Rotterdam will be highly affected by climate change (higher water level due to the rise in the sea level; increased instances of flooding caused by increasing rainfall) (Municipality of Rotterdam et al. 2007) and the city changed its focus: Also effected by population decline, particularly among its working class, Rotterdam started to see water as an opportunity and developed its second water plan. Contrary to the first water plan, this second water plan developed concepts that focus on enhancing existing qualities, considering peoples'

needs and using synergies between water management and spatial development to make Rotterdam to the Rotterdam Watercity 2030.

The Rotterdam Waterplan 2 integrates water management planning with concern of urban development. Therefore innovative solutions for water management, such as green roofs, water squares, and water gardens will be implemented in coming year. They do not just serve the demands of sustainable stormwater management but also the demands of urban design, aiming at making Rotterdam to a city that is more attractive as a place to live, work, study and to spend leisure time.
Furthermore, Rotterdam significantly invested in doing research, developing pilot projects and investigating in unconventional solutions for urban stormwater management.

One of the most innovative solutions they developed is the water square. Invented by De Urbanisten and Studio Marco Vermeulen, this solution contributes to the quality of public space and uses technical engineering systems to manage stormwater. During dry periods the square is used as a public open space while during heavy rainfalls the square is used for temporary rainwater storage. A pilot type of the water square has been designed and will be implemented to detect problems and improve the concept. Construction is planned for 2011 (Boer 2010).

The efforts of Rotterdam have a significant influence on public perception. They make aware that cities have to deal with problems of flooding and that they can do this in alternative ways. With the Waterplan 2, Rotterdam draws connections between different types of planning and does not shy away from unproved solutions that can cause difficulties. The responsible stakeholders are working together, and planning takes place as cooperation that enables the city to use synergies. With this, the city wants to become known as a "showcase for water and climate adaption" (Gemeente Rotterdam n.d., 11), both nationally and internationally and to serve as a source of inspiration for other cities, particularly those in comparable situations.

Medium Scale: Trabrennbahn Farmsen (Hamburg, Germany)

Project	Water Sensitivity	Aesthetic Benefit	Integration in Surrounding Area	Appropriate Design	Appropriate Maintenance	Adaptability	Appropriate Usability	Public Involvement	Acceptable Costs	Integration of Demands	Interdisciplinary Planning	Impact on Public Perception
	1	2	3	4	5	6	7	8	9	10	11	12
Trabrennbahn Farmsen	✓	✓	✓	✓	✓	✓	✓		(✓)	✓	✓	✓

This residential multifamily housing district "Trabrennbahn Farmsen" was developed on the area of a former horse track in suburban Hamburg. It was the main intention for this new development to manage all stormwater on site: As infiltration was not possible due to the loam and clay underground conditions, planners decided for an open drainage system and they designed it in an attractive way as contribution to a pleasant living environment.

Owing to the sites' history as a horse track, the residential buildings as well as the stormwater management facilities were arranged in an oval manner. In its centre two large ponds serve for

stormwater retention. A system of two meters wide, artificially shaped drains collects all stormwater from the roofs and paved areas and leads it to the central ponds, from which the water is slowly discharged to a natural receiving water course called “Hopfengraben”.

Fig. 2. A system of drains and ponds serves the surface detention of stormwater at “Trabrennbahn Farmsen” (© M. Derneden).

The entire district is characterized by a contrary design that changes from hard, rectilinear concrete structures in public areas to naturally shaped ponds and ditches in the central part. The drains are used to separate public from private spaces, sharp and artificially shaped towards the public areas while soft and natural designed to the private gardens of the residents. In result, a different and appropriate design of stormwater facilities was found for each part of the area. When people walk around they can find different situations straddling from urban density to landscapes’ pleasantness. This serves to create an attractive and exciting environment.

There are many people working with drains and ditches for decentralized stormwater management and most people are even bored of these techniques. “Trabrennbahn Farmsen” shows that even drains can be used to create an inspiring and attractive atmosphere when using varieties in shape, width, depth and landscaping.

Small Scale: 10@Hoyt Apartments (Portland, Oregon, USA)

Project	Water Sensitivity	Aesthetic Benefit	Integration in Surrounding Area	Appropriate Design	Appropriate Maintenance	Adaptability	Appropriate Usability	Public Involvement	Acceptable Costs	Integration of Demands	Interdisciplinary Planning	Impact on Public Perception
	1	2	3	4	5	6	7	8	9	10	11	12
10@Hoyt Apartments	(✓)	✓	✓	✓	(✓)	(✓)	✓		(✓)	✓	✓	✓

10@Hoyt Apartments are located in the upcoming district Pearl Harbor in the heart of Portland, Oregon. As the city of Portland set a code which stated that a surface retention facility is required for all new and re-development projects with a minimum of 500 square feet (approx. 46 m²) of impervious surface (Portland Bureau of Environmental Services, cited in: Rodes 2007, 6), the developers of a new apartment complex took this up as an opportunity. They decided to do more than just meet this requirement: they aimed to display the rainwater and to use it in a unique way to create an elegant, urban space.

The courtyard of the apartment complex located at cross section of 10th and Hoyt Street is designed as a garden on the roof of the underground parking garage. A system of downspouts, channels and concrete cascades captures, conveys and creatively displays all rainwater from the roofs of the site to the courtyard, where it visibly flows over back lit and coloured glass dotted Cor-Ten steel weirs into rectangular river stone filled basins. From there water is leaded to a 4000 gallon cistern below grade and then circulated to Cor-Ten steel fountains that sprinkle water for up to 30 hours. In the cistern, particles are allowed to be settled. After the rain storm the water is slowly released to the public sewer system.

Fig. 4. A system of concrete cascades, river stone filled basins and Cor-Ten steel weirs manages all rainwater at 10th@Hoyt Street Apartments in Portland on site (© J. Hoyer).

The design of the stormwater facilities at 10th@Hoyt apartment courtyard significantly influences the quality of life in the apartment complex. It makes rainwater visible and enables visitors and residences to follow the water flow from the roof to the ground, even when it is not raining. Steve Koch from Koch Landscape Architecture said: "You can do a lot of things to mitigate the impacts of stormwater, but typical and mostly mechanical methods provide no cultural or aesthetic function; the function here is detention and human delight" (Steve Koch, cited in: Rodes 2007, 8).

The 10th@Hoyt courtyard is highly appreciated among professionals and citizens. It won four awards: Green Space Award, Merit Award, Green Roofs for Healthy Cities Award and the Green Rooftops for Sustainable Communities Award. Through a combination of natural and urban structures the 10th@Hoyt courtyard also facilitates multiple uses. Mainly planned for the relaxation of the residents, the courtyard provides space for nature (planters and shrubs planted in black pots), and serves the demands of rainwater management through giving space to and emphasizing the water running from the roof to the ground. Visitors and residencies are encouraged to explore what the water is doing and learn about its environmental importance. By integrating stormwater management with artful design the courtyard has become an oasis in the dense urban area of Pearl District.

4 Conclusions

Having the effects of climate change in mind, it is clear that a sustainable development and management of the urban water cycle must be found. Decentralised stormwater management can provide solutions for the sustainable development of cities when ecological, social and aesthetical concerns are considered, when planning is done in interdisciplinary cooperation of experts in the fields of water management, urban design and landscape planning, and when the planning is linked to overall spatial development concepts.

Summarised as the concept of Water Sensitive Urban Design (WSUD), this approach will be essential for further water management development in urban areas. One of the main advantages of WSUD towards conventional planning practices is that synergies between urban development and water management can be achieved. This means: Multifunctional spaces can be created and costs can be bundled. Moreover, by applying WSUD, cities can prepare for unpredictable changing conditions in water management (e.g. trough climate change effects or demographic and economic changes) while effectively investing in cities' attractiveness as a place to live, to work, and to spend leisure time.

A manual on WSUD, developed by the HafenCity University of Hamburg, comprises the research results presented in this paper. It provides an overview of the WSUD approach, creates guidelines by setting principles for WSUD, and presents case studies demonstrating WSUD principles. Through this manual, different professionals involved in urban planning as well as urban water management will get inspirations and recommendations on how the approach of WSUD can be applied to cities in different scales. The manual therefore will help to go a big step forward in urban water management planning.

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