trust
TRANSITIONS TO THE URBAN WATER SERVICES OF TOMORROW

IWW

IWA
the international water association

Proceedings

Cities of the Future Conference

Transitions to the Urban Water Services of Tomorrow (TRUST)

MÜLHEIM AN DER RUHR, GERMANY. 28 - 30 APRIL 2015

Programme, manuscripts and session summaries

Proceedings of the international conference – D73.2

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Review panel for conference contributions

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FOREWORD

Cities around the world are growing and are subject to a number of challenges such as demographic change, globalizing economies, social inequalities, technological innovation, growing resource-demand and environmental changes. The challenges are all expected to impose significant strains on urban water systems (UWS) over the coming decades.

Many cities across the world will experience increasingly frequent shortfalls in the supply / demand balance. More intense rainfall events will lead to local flooding of properties and transport systems and to pollution of receiving waters. Sustainable solutions to these challenges need to be sensitive to long-term investment needs, but also to increasing energy prices, demands for low carbon intensity solutions, and the need to reduce gas emissions from urban activities.

Water is vital for any human society, and therefore the urban water cycle services (particularly water supply and sanitation) are key factors for stable and healthy cities of the future. Within the context of a growing world population, continuing urbanization and the general pursuit of better living standards, there is an urgent need for really sustainable solutions for urban water services: solutions that meet the needs of the present without compromising the ability of future generations to meet their own needs.

The International Water Association IWA aims to catalyse the necessary actions and has set up a "Cities of the Future Programme" (CoF) to bring together brings together water professionals, urban planners, and social sciences to develop cities in an integrated way, and embrace water as a key contributor to healthy, liveable, risk-resilient, regenerative Cities.

The European TRUST (Transitions to the Urban Water Services of Tomorrow, funded by the European Union's Seventh Framework Programme, www.trust-i.net) has been working along the same line since 2011. With the IWA also being a project partner of TRUST, it was therefore a natural choice to join forces and to put the final event and presentation of TRUST results under the umbrella of the IWA Cities of the Future Conference Series, - thus combining the presentation of project results with a large number of additional presentations from leading international experts.

The conference "Cities of the Future – Transitions to the Urban Water Services of Tomorrow (TRUST)" thus provided an opportunity to present and discuss leading-edge developments in the area of urban water services with an international audience of water utility personnel, researchers, engineers, technology providers, city planners, consultants, regulators and policy makers. It focused on the techniques, technologies and management approaches aiming at enabling and supporting the transition towards more sustainable urban water futures, but also zoomed-in on the socio-economic requirements and aspects of this transition.

More than 120 participants from about 20 countries joined the three days event at Mülheim an der Ruhr (Germany) to enjoy and discuss more than 40 presentations and about 20 posters.

We are now happy to present and publish this volume with many manuscripts of the presentations given at the conference. We are confident that the promising results presented at the conference will resonate in the water sector and in the long term contribute to more sustainable water services in our Cities of the Future.

David Schwesig

IWW Water Centre, Coordinator of TRUST, on behalf of the Conference Commitees

REGISTER OF FULL MANUSCRIPTS

TRUST results

TITLE	MAIN AUTHOR
Decision Support System for the Long-Term City metabolism Planning Problem	M.S.Morley
Assessment of Urban Water System: A Case Study of Reggio Emilia, Italy	T.Lissera
Integrating Leakage, Pressure and Energy Management for Water Distribution Systems	M.S.Morley
A Roadmap for Transition Planning in Urban Water Cycles: The Demonstration Case at HAMBURG WASSER	H.J.Mälzer
Roadmap for reduced water consumption and leakages – case study Oslo	L.J.Hem
Sustainable Urban Drainage Systems (SUDS) as solution for reduction of Stormwater Overflow (CSO) discharge and urban flooding	S. Bandermann
Management Tools for Hydro Energy Interventions in Water Supply Systems	J.Frijns
Lessons learned in designing web-based support tools for urban water management	A. Gormley
Infrastructure asset management - the TRUST approach and professional tools	H. Alegre

Resource/Energy-efficient Urban Water Services

TITLE	MAIN AUTHOR
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Evaluating new processes and concepts for energy and resource recovery from municipal wastewater with Life Cycle Assessment	C.Remy
The HAMBURG WATER Cycle® concept as a future urban wastewater treatment & energy service and challenges of its implementation	M.Wuttke
SEMIZENTRAL (infrastructure solution for fast growing cities) - From scientific approach to implementation	J.Tolksdorf
Onsite Water Systems at Grove Library, Western Australia: Lessons Learnt for Decentralised Systems	M.Anda
Preserving the water resources by reducing the abstraction for urban uses	M. Lafforgue

Governing and Financing Urban Water Services

TITLE	MAIN AUTHOR
Water and Cities – Finance, Innovatioin and Governance to ensure Sustainable Futures - OECD – Environment Directorate	H.Leckie
New Challenges and Solutions for Financing Projects in the European Water Sector	M.Beros
City Blueprints: baseline assessment of the sustainability of UWCS in 30 cities	C.J.Van Leeuwen
Integrated settlement- and infrastructure modelling to support strategic planning of transition processes	G.Schiller
Manuel Krauß: Transition of water tariff models: impact on household costs and inner-city cash flow	M.Krauß
Governing Future Water Services: New Institutional Arrangements to Improve the Implementation of System Innovations	H.Kerber

Planning Future Urban Water Services - Strategies & Tools

TITLE	MAIN AUTHOR
The Future of Urban Water: Scenarios for Urban Water Utilities in 2040	D.Lambert
From Vision to Action: Roadmapping as a strategic method and tool to implement climate change adaptation: the Example of the roadmap "Water Sensitive Urban Design 2020"	J.U.Hasse
Future initiative "Water in the city of tomorrow"	E.Grün
The change towards more sustainable stormwater management practices: a contextual perspective	L.Goldkuhl
A Resilience Planning Framework for UK Water Companies: A Case Study Example and Consideration of 'Next Step' Issues and Challenges	P.J.Conroy
Thinking Catchments: a holistic approach to asset management in the water sector	C.Papacharalampou
The use of the Infrastructure Value Index to communicate and quantify the need for renovation of urban water systems	H. Alegre
Using cost-benefit considerations to evaluate infrastructure asset management data quality and availability	M.M. Rokstad

INIS: A German Research Cluster on Water Infrastructure

TITLE	MAIN AUTHOR
How can urban water infrastructures contribute to a sustainable urban metabolism?	E.Menger-Krug
Comprehensive scenario management of sustainable spatial planning and urban water services	S. Worreschk
Sustainability controlling for urban water systems	S.Geyler
Storm water balance for the cities of the future	M.Henrichs
Improving Urban Drainage in face of climate and demographic change: interim results of the joint research project KURAS	D.Nickel

Territorial & Urban Planning

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Rivers as social assets in urbanised areas: A cost-benefit analysis for bathing in the river Ruhr using contingent valuation method	M.Neskovic
Integrated water management in Reunion Island Ecocity	A.Daval
Water sensitive urban planning - Strategies for adaptation to climate change in the densely populated Ruhr area	M.Siekmann

Engineering Future Urban Water Services

TITLE	MAIN AUTHOR
High density urban environments: Mechanisms for delivery	M.F.O'Neill
Infrastructure solutions for fast growing cities – dimensions of adaptability requirements and urban resilience	S. Bieker
Rotterdam Innovative Nutrients, Energy and Watermanagement Local treatment of wastewater and reuse of nutrients, energy and water	S.A.T.van Eijk
Impact assessment of point and non-point sources of water pollution on a small urban stream	J.Nabelkova
Cost-benefit analysis of flood resilience strategies to cope with global change impacts. Application to the Barcelona case	M.Velasco
Innovative technologies for an optimal and safe closed water cycle in Mediterranean tourist facilities	J.Kisser

REGISTER OF POSTERS

TRUST Results

TITLE	MAIN AUTHOR
Quantitative Assessment of Future Sustainability Performance in Urban Water Services using WaterMet2	K.Behzadian
How to assess sustainability of urban water cycle systems (UWCS). Development of a metering methodology	S.Sægrov
Metabolism-modelling approaches support long-term sustainability assessment of urban water service. Scenario 2040 for Oslo as model city	S.Sægrov
Policy Guidance Material for the transition to sustainable urban water cycle services of tomorrow – A handbook for policy makers	D.Nottarp-Heim
Cost effective inline condition assessment of water pipelines	M.Poulton

Governing and Financing Urban Water Services

TITLE	MAIN AUTHOR
Scenario planning and long term investment planning for drinking water company for the year 2050	S.A.T.van Eijk
A tool to design efficient and fair water tariffs for Urban Water Services	S.Broekx

Planning Future Urban Water Services - Strategies & Tools

TITLE	MAIN AUTHOR
Smart Water Distribution System: The Etxebarri Case Study	C.Martin
Holistic Water Cycle Approach for Assessing and Monitoring Greenhouse Gas Emissions in Water and Wastewater Utilities - Thailand, Mexico and Peru	J.Grilo

INIS: A German Research Cluster on Water Infrastructure

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De-chlorination of drinking water by forced aeration	G.S.Hassan
NEW strategy: Should we recycle separated urine?	M.Došek
Dessin, demonstrate ecosystem services enabling innovation in the water sector	G.van den Berg

1 PROGRAMME OVERVIEW AND SPONSORS

TUE 28 APRIL	WED 29 APRIL	THUR 30 APRIL
Session 0 (not public) TRUST Project Meeting	Session 4 Governing and Financing	Session 8 Territorial & Urban Planning
Session 1 - Opening TRUST Results Part 1	Session 5 Planning Future Urban Water Services - Strategies & Tools 1	Session 9 Engineering Future Urban Water Services
Session 2 TRUST Results Part 2	Session 6 - INIS A German Research Cluster on Water Infrastructure	Technical Tour Emscher Conversion Visit selected sites of a huge river conversion project and the world's most modern wastewater system under construction. Pick-up & drop-off at venue. Registration required
Session 3 Resource/Energy Efficiency	Session 7 Planning Future Urban Water Services - Strategies & Tools 2	

In addition to funding by the European Commission for the TRUST project (under FP7 Grant Agreement No. 265122) the conference was supported by the following organisations (in alphabetical order).

aj BLOMESYSTEM	Exhibitor
DVGW energie | wasser-praxis	Media partner Layout of promotional material
EMSCHER GENOSSENSCHAFT EGLV.DE	Sponsor Technical Tour Member of Organising Committee
Endress+Hauser People for Process Automation	Exhibitor
European Investment Bank The EU bank	Sponsor coffee break Wednesday morning
Ruhrverband WISSEN, WERTE, WASSER	Delegate bag, note pad and pens Member of Organising Committee

This support and sponsoring is highly appreciated

2 DETAILED PROGRAMME

2.1 Day 1 - Tuesday 28 April

Session 0 (not public)

This session (09:00 - 10:30) is for TRUST project partners only.

Session 1 - Opening and TRUST Results Part A

Session Chair: David Schwesig, IWW Water Centre, Germany

TIME	PRESENTER	TITLE
11:00	David Schwesig (IWW) Corinne Trommsdorff (IWA)	Welcome and Overview: TRUST and the IWA Cities of the Future Vision and Program
11:30	Zoran Kapelan (University of Exeter)	Decision Support System for the Long-Term City Metabolism Planning Problem
11:45	Vittorio Di Federico (University of Bologna)	Metabolism-based Modelling for Sustainability Assessment of Urban Water Systems: A Case Study of Reggio Emilia, Italy
12:00	Mark Morley (University of Exeter)	Integrating Leakage, Pressure and Energy Management for Water Distribution Systems
12:15	Hans-Joachim Mälzer (IWW Water Centre)	A Roadmap for Transition Planning in Urban Water Cycles: The Demonstration Case at HAMBURG WASSER
12:30	Lunch Break and Exhibition (Exhibitors, Posters, TRUST Tool Stand)	

Session 2 - TRUST Results Part B

Session chair: Sveinung Saegrov, Norwegian University of Science and Technology

TIME	PRESENTER	TITLE
13:50	Lars Hem (Oslo VAV)	Roadmap for reduced water consumption and leakages: case study Oslo
14:05	Stephan Bandermann (IPS)	Sustainable Urban Drainage Systems (SUDS) as solution for reduction of stormwater overflow (CSO) discharge and urban flooding
14:20	Jos Frijns (KWR)	Management tools for hydro energy interventions in water supply systems
14:35	Aine Gormley (Cranfield University)	Lessons learned in designing web-based support tools for urban water management
14:50	Helena Alegre (LNEC)	Infrastructure asset management - the TRUST approach and professional tools
15:05	Panagiotis Balabanis (EC DG Research & Innovation)	Water research and innovation in the context of Horizon 2020
15:20	Coffee Break & Exhibition (Exhibitors, Posters, TRUST Tool Stand)	

Chair's Summary of Session 1 and 2

The session was opened by an introductory presentation jointly given by **David Schwesig** (local host IWW and Coordinator of TRUST) and **Corinne Trommsdorff** (IWA), outlining the main features of both the TRUST project and the IWA Cities of the Future Programme and how they are closely related.

Currently, cities all over the world are facing a number of challenges (e.g. rapid urbanization, increase of water-related risks, demographic and climate change), and urgent action is needed to assist cities in facing their water challenges. IWA aims to catalyse the necessary actions and has set up a "Cities of the Future Programme" (CoF) to bring together brings together water professionals, urban planners, and social sciences to develop cities in an integrated way, and embrace water as a key contributor to healthy, liveable, risk-resilient, regenerative Cities. The CoF programme aims to embrace five 'R-principles':

1. Reduce the amount of water being used
2. Reuse the water with different qualities for different usages
3. Recover the energy imbedded in water,
4. Re-cycle the nutrients in the wastewater, and
5. Replenish the surrounding environment so that the resources used are regenerated.

This will be achieved by addressing five focus areas which are needed as enablers to this agenda:

- Focus area 1: Vision and Leadership
- Focus area 2: Governance that enables Integration of Disciplines and Scales
- Focus Area 3: Capacity Building
- Focus Area 4: Tools for planning, decision making
- Focus Area 5: Tools for implementation

In order to achieve the ambitious goals of the CoF programme, more is needed than an endorsement of this agenda by policy and decision makers. A key factor to success would be to actually work on the ground on these subjects with key urban partners, and to assemble a portfolio of inspiring case studies that can help to share insights on what can be done by developing and applying cutting-edge solutions.

Another key requirement would be the development of an "Urban Water Framework", - a set of tools for Cities to assess, improve and monitor their water-related sustainability, including the synergies with other urban sectors.

The TRUST project has been working very much along the same line. The main ambition is to support city utilities in their transition to more sustainable urban water services of tomorrow. In a quick helicopter tour through the project, it was presented how the objectives and activities of TRUST were designed to achieve this ambitious goal.

- TRUST has started by developing a definition and assessment framework for sustainability of urban water services.

- It has delivered models, tools, guidelines for all stages of the transition process
- And it has demonstrated the feasibility of a range of innovative technology and management options.
- Most TRUST products and solutions have been co-produced with or demonstrated at ambitious European water utilities, to ensure their applicability and acceptability in the water sector.

Among the key products of TRUST are tools to enable a sound diagnosis (where are we now?), vision (where do we want to go?), analysis (what is needed to get there?), technology & management options (what can be done?), prediction (what happens if?), and decision support (which option is the best one?).

The following presentations from TRUST in session 1 and session 2 provided examples of TRUST tools to tackle these issues, and gave insights into experiences gained in their practical application at selected examples from the ten TRUST city utilities.

Zoran Kapelan (University of Exeter) tarted by presenting the TRUST Decision Support System for the long-term city metabolism planning problem, which builds on and integrates results from a so-called "Metabolism model" that had also been developed within TRUST. The Metabolism model (quantifies a number of urban water system flows/fluxes (e.g. water, energy, chemicals and greenhouse gases) which can be used to derive sustainability-based performance metrics based on the metabolism analogy. **Vittorio di Federico** (University of Bologna) resented the application of the above metabolism concept with the aim to evaluate and improve the level of sustainability in the water supply system of Reggio Emilia, Italy. This was complemented by a presentation by **Mark Morley** (University of Exeter) from the same Italian case study, how another TRUST tool, the Pump and Valve Logic Optimal Scheduling (PaVLOS) tool can reduce energy consumption and total cost of a network and minimize leakage whilst maintaining the required network performance level.

Hans-Joachim Mälzer (IWW) presented the application of a more conceptual tool: the TRUST roadmap methodology and guideline, and how it was applied at Hamburg Wasser, to develop a vision and a long term strategy for the realisation of changes in this utility. The case study focused on analysing the utilities' options to change strategies with regard to water metering and tariffing.

Session two continued by presenting selected highlights from the TRUST project and demonstrated the variety of the project activities. It also demonstrated the strong link between end users (water companies, cities) and the scientific partners of TRUST. The session started with a travel to severals city participants by three presentations.

Lars Hem (Oslo municipality) explained how the road mapping methodology had been useful for working out a long-term plan for reduction of water leakages. **Stephan Bandermann** (Sieker Gmbh), explained a methodology for planning separation of combined wastewater systems, applied in Oslo.

Jos Frijns (KWR) and **Christos Makropoulos** (Athens University) presented a planning framework for optimisation of energy consumption in urban water cycle systems, with examples from Portugal, Spain, Italy and in particular Greece.

Governance of urban water resources has been an important part of TRUST. Out of a variety of work, **Aine Gormley** (Cranfield University) presented two web-based tools designed to support urban water management, e.g. Adaptive Potential Self-Assessment and Financial Sustainability Rating Tool. She also gave some results from test applications and strategies on how to stimulate users to fulfil the training on the application of the tools.

Helena Alegre (LNEC) gave a comprehensive summary of the development of Integrated asset management in TRUST and explained how this build on previos projects including EU projects of Research Framework 5,6 and 7 (from 2001 until now). She clearly demonstrated how important the outcome from TRUST may be for the water companies and utilities

Finally, **Panagiotis Balabanis** (EC, DG Research & Innovation) gave the audience an overview of main thinking in EU Commission on current and future urban water related research within Horizon 2020. The EU funded programs will in future to a larger extent be seen as co-funding to larger project that involves collaboration between national authorities , such as JPI Water, other national activities and strategic support for industrial and infrastructure development. Projects are expected to be rather large and contain several links in the research value chain, from basic research to practice.

The session demonstrated the quality of TRUST and the potential the project has left for significant improvements in urban water cycle management throughout Europe and beyond.

Session 3 - Resource/Energy-efficient Urban Water Services

Session Chair: Corinne Trommsdorff, International Water Association

TIME	PRESENTER	TITLE
16:00	Willy Verstraete (University Ghent)	Keynote: The paradigm shifts and resource recovery from water
16:30	Christian Remy (Berlin Centre of Competence for Water)	Evaluating new processes and concepts for energy and resource recovery from municipal wastewater with Life Cycle Assessment
16:45	Maika Wuttke (Hamburg Wasser)	The HAMBURG WATER Cycle® concept as a future urban wastewater treatment & energy service and challenges of its implementation
17:00	Johanna Tolksdorf (TU Darmstadt)	SEMIZENTRAL (infrastructure solution for fast growing cities) - From scientific approach to implementation
17:15	Discussion	
17:30	Break & Exhibition (Exhibitors, Posters, TRUST Tool Stand)	

Chair's Summary of Session 3

Willy Verstraete (University of Ghent) invited us through an inspiring journey towards circular economy. We no longer want to talk about wastewater, but about "used water", no longer about wastewater treatment plants, but about biorefineries. Used water contains energy and materials that ought to be recovered, rather than "dissipated". After a rather futuristic talk from Willy, **Christian Remy** (KWB) showed how the use of Life Cycle Assessment tools can be instrumental in guiding our decision making on technology choice. In particular, when thinking about applying innovative technologies, which embrace the circular economy approach, LCA can be a powerful tool to show the benefits in terms of energy and carbon footprint.

Two case studies illustrated how this paradigm shift of valuing used water rather that waste or "dissipate" it can be applied in practice:

- The Hamburg Watercycle project (presented by **Maika Wuttke**) shows how greywater, blackwater and rainwater can all be valorized and energy recovered in a new development being currently constructed in an infill area of the City. The regulatory stakeholder engagement and coordination challenges outweighted by far the technical challenges. The first inhabitants are anticipated to move in by 2016.
- The Semizentral approach applied to the City of Qingdao, China (presented by **Johanna Tolksdorf**), demonstrates how this modular, flexible approach can provide a resilient wastewater and food waste treatment with energy recovery, and service water production. This modular approach is particularly adapted to fast growing cities, with high levels of urban planning uncertainties. The reduced operating costs, thanks to the energy recovery and water production, are anticipated to outweigh the higher capital investments.

2.2 Day 2 - Wednesday 29 April

Session 4 - Governing and Financing Urban Water Services

Session chair: Paul Jeffrey, Cranfield University, United Kingdom

TIME	PRESENTER	TITLE
09:00	Hannah Leckie (OECD)	Keynote: Water and Cities – Finance, Innovation and Governance to ensure Sustainable Futures
09:30	Marco Beros (EIB)	New Challenges and Solutions for Financing Projects in the European Water Sector
09:50	Kees van Leeuwen (KWR)	City Blueprints: baseline assessment of the sustainability of UWCS in 30 cities
10:10	Georg Schiller (IOER)	Integrated Settlement- and Infrastructure Modelling to support strategic planning of transition processes
10:30	Manuel Krauß (University Stuttgart)	Transition of water tariff models: impact on household costs and inner-city cash flow
10:50	Coffee break & Exhibition (Exhibitors, Posters, TRUST Tool Stand)	

Chair's Summary of Session 4

The session on 'Governing and Financing' was kicked off by **Hannah Leckie** from the OECD who provided an engaging and sharp keynote on the role of finance, innovation and governance to ensure sustainable water futures in cities. Drawing on recent OECD work in this area Hannah laid out a convincing critique of the challenges to water sustainability and spelled out how financial and governance interventions can catalyse innovation and change behaviours.

The second presentation was provided by **Sebastian Hyzyk** from the European Investment Bank who spoke on new challenges and solutions for financing projects in the European water sector. Having a speaker from this organisation greatly enhanced the practical focus of the session; investment and financing policy having a significant effect on urban water service quality and reliability.

Combining work conducted through the TRUST project and the EIP Water, **Kees van Leeuwen** from KWR Water Cycle Research showed how a comparative assessment of baseline assessments of the sustainability of Urban Water Cycle Services across 30 cities offers insight into city preparedness to meet these challenges. With worryingly little work having previously been conducted on this topic at this scale and extent the analysis has widespread value in shaping planning and capacity development agendas across Europe.

Georg Schiller from IOER Dresden then spoke stimulatingly about integrated settlement and infrastructure modelling, making the point that coupling these two aspects of urban development is crucial if planners and utilities are to collaboratively deliver resilient cities.

The final presentation came from **Manuel Krauß** (University of Stuttgart) who presented a modelling study of the impact of changing water tariffs on household costs and inner-city cash flow. This talk brought a welcome focus on the affordability of urban water services and highlighted the winners and losers under different tariff structures.

Questions and discussion during this session focused primarily on the structure and relative magnitude of water service tariffs how these might be expected to influence demand amongst different customer groups. Though an obvious implication, there was, interestingly, no debate about the potential for full economic cost recovery; a topic for a future session perhaps.

Session 5 - Planning Future Urban Water Services - Strategies & Tools 1

Session chair: Helena Alegre, Laboratorio National de Engenharia Civil (LNEC), Portugal

TIME	PRESENTER	TITLE
11:30	Daniel Lambert (Arup)	The future of urban water: Scenarios for urban water utilities in 2040
11:50	Jens Hasse (FiW)	From Vision to Action: Roadmapping as a strategic method and tool to implement climate change adaptation
12:10	Ulrike Raasch (Emscher-genossenschaft)	Future Initiative – Water in the Cities of Tomorrow
12:30	Lena Goldkuhl (Lulea University of Technology)	The change towards more sustainable stormwater management practices: a contextual perspective
12:50	Lunch break & Exhibition (Exhibitors, Posters, TRUST Tool Stand)	

Chair's Summary of Session 5

This session was rather inspirational. It demonstrated that it is feasible to look into the future in a disruptive way, but keeping our feet on the ground. It also demonstrated the key role of good governance in planning and implementing future urban water services.

Daniel Lambert (Arup) provided a comprehensive and general approach to building future scenarios, anchored on his experience in Australasia. **Jens Hasse (FiW)** continued by sharing a very successful implementation of measures to deal with climate change, where all key stakeholders were involved. The other two presentations by **Ulrike Raasch** (Emschergenossenschaft) and **Lena Goldkuhl** (Luleå University) were directed to stormwater management, and showed through real case implementations what and how stormwater can be sustainably management in urban environments, transforming a burden (water that society wants to get rid of) into a great resource for the urban environment and society well-being. Once again, the role of governance was key in both cases reported.

Session 6 - INIS: A German Research Cluster on Water Infrastructure

Session chair: Darla Nickel, German Institute for Urban Affairs (difu)

TIME	PRESENTER	TITLE
14:30	Helmut Löwe (BMBF)	The INIS Cluster: Smart and Multifunctional Water Infrastructure Systems
14:45	Eve Menger-Krug (Fraunhofer ISI)	How can urban water infrastructures contribute to a sustainable urban metabolism?
15:00	Silja Worreschk (University Kaiserslautern)	Comprehensive scenario management of sustainable spatial planning and urban water services
15:15	Stefan Geyler (University of Leipzig)	Sustainability controlling for urban water systems
15:30	Malte Henrichs (Univ. of Appl. Sciences Münster)	Storm water balance for the cities of the future
15:45	Darla Nickel (Difu)	Improving Urban Drainage in face of climate and demographic change: interim results of the joint research project KURAS
16:00	Coffee Break & Exhibition (Exhibitors, Posters, TRUST Tool Stand)	

Chair's Summary of Session 6

In this session, preliminary findings were presented from 5 of 13 research projects from the ongoing funding measure "Smart and Multifunctional Infrastructural Systems for Sustainable Water Supply, Sanitation and Stormwater Management" (INIS) of the German Federal Ministry of Research and Education (BMBF). These projects explore the application of innovative technologies, management instruments and transition strategies in context of urban water services to overcome the considerable challenges that urban water infrastructure systems are faced with today as a result of change, demographic change and ever scarcer resources.

Following a short introduction to funding measure provided by **Reinhard Marth** from Project Management Julich, the first speaker (**Eve Menger-Krug**, Fraunhofer ISI) presented an integrated concept for water, energy and nutrient reuse aimed at improving the urban microclimate and system resilience. **Silja Worreschk** (University of Kaiserslautern) delineated a comprehensive software-based decision support model for optimizing the long-term transition of urban water infrastructures, while **Stefan Geyler** (University of Leipzig) introduced a control tool for urban water systems extended to include future risks to sustainable management.

Using water sensitive urban design (WSUD) to manage stormwater at the source stood in focus of the last two presentation by **Malte Henrichs** (University of Applied Sciences, Münster) and **Darla Nickel** (Difu), which focused on approaches to modelling and including stakeholders in the decision-making process, respectively.

A recurrent theme in all presentations was the need to address and overcome a broad combination of technical, legal, organizational, economic and social barriers along the path of transition.

Session 7 - Planning Future Urban Water Services - Strategies & Tools 2

Session chair: Paul Conroy (CH2M Hill)

TIME	PRESENTER	TITLE
16:45	Paul Conroy (CH2M Hill)	A resilience planning framework for UK water companies
17:05	Chrysoula Papacharalampou (University of Bath)	Thinking Catchments: a holistic approach to asset management in the water sector
17:25	Helena Alegre (LNEC)	The use of the Infrastructure Value Index (IVI) to communicate and quantify the need for renovation of urban water systems
17:45	Marius M. Rokstad (NTNU)	Using cost-benefit considerations to evaluate infrastructure asset management data quality and availability

Chair's Summary of Session 7

This session was diverse and fascinating. It highlighted that risk based asset management and systems thinking is fundamental to many planning strategies; the scope covered water and sewer networks, data quality and cost, holistic catchment planning and an all hazards approach to reliance planning.

Paul Conroy (CH2M Hill) summarized the development of the resilience planning approach in the UK water utility sector, including the role played by Ofwat and the response from the water companies.

Helena Alegre (LNEC) described a pragmatic infrastructure value index based on consideration of asset fair value and replacement cost to inform strategic rehabilitation needs.

Chrysoula Papacharalampou (University of Bath) introduced the need for a goal orientated, holistic, systems-thing approach to asset management and finally, **Marius Rokstad** (SINTEF) highlighted issues and a methodology for appraising the cost and benefit of CCTV inspection data relative to the precision and uncertainty.

2.3 Day 3 - Thursday 30 April

Session 8 - Territorial & Urban Planning

Session chair: Theo van den Hoven, KWR Watercycle Research Institute, The Netherlands

TIME	PRESENTER	TITLE
09:00	Justin Abbott (Arup)	Keynote: Improving the Liveability and Resilience of our cities through a "Design with Water" approach
09:30	Katia Perini (University of Genoa)	Green Infrastructure in New York City: The case of the Bronx River
09:50	Marina Neskovic (IWW)	Rivers as social assets in urbanised areas: A cost-benefit analysis for bathing in the river Ruhr using contingent valuation method
10:10	Antoine Daval (Artelia Group)	Integrated water management in Reunion island Ecocity
10:30	Thorsten Pacha (Stadt Bochum)	Water-sensitive urban planning - strategies for adaptation to climate change in the densely populated Ruhr area
10:50	Coffee Break & Exhibition (Exhibitors, Posters, TRUST Tool Stand)	

Chair's Summary of Session 8

Session 8 led the audience to the world of designers, urban planners and project managers.

In his keynote **Justin Abbott** (Arup) painted the evolution of urban water design practices. Past practices understandably focused on hard infrastructure to deliver services and to protect society against natural hazards. Current challenges linked to climate change, urbanization and the need for ecosystem protection call for more adaptive and integrated and more 'working with nature' water management solutions. Through varies case studies Justin showed the benefits of these frameworks in terms of resilience, wellbeing and biodiversity of cities.

Follow up presentations on case studies very much supported the benefits of adaptive and integrated design frameworks. **Katia Perini** (University of Genoa) showed how the implementation of green infrastructure in the Bronx river area in New York did improve the environmental quality and livability. A willingness-to-pay study for bathing options in the river Ruhr (**Marina Neskovitch**, IWW) led to the foundation of an interest group which will work on the implementation of the preferred option. A flexible 10 years agreement enabled an integrative and participatory design and implementation of an Ecocity on the Reunion Island (**Antoine Daval**, Artelia Group). **Thorsten Pacha** (City of Bochum) showed how a water sensitive urban planning (including multifunctional land use) is able to cope with future challenges of urban floods.

All presentations underlined the importance of cooperation with local communities and across sectors and disciplines.

Session 9 - Engineering Future Urban Water Services

Session chair: Thomas Wintgens, University of Applied Science NW-Switzerland

TIME	PRESENTER	TITLE
11:30	Michael O'Neill (Arup)	Green infrastructure retrofitting in high-density urban environments: mechanisms for delivery
11:50	Susanne Bieker (TU Darmstadt)	SEMIZENTRAL: Infrastructure solutions for fast growing cities: dimensions of adaptability requirements and urban resilience
12:10	Sebastiaan van Eijk (Evides)	Local treatment of wastewater and reuse of nutrients, energy and water
12:30	Jana Nabelkova (CTU Prague)	Impact assessment of point and non-point sources of water pollution on a small urban stream
12:50	Marc Velasco (CETaqua)	Cost-benefit analysis of flood resilience strategies to cope with global change impacts. Application to the Barcelona case
13:10	Lunch Break & Exhibition (Exhibitors, Posters, TRUST Tool Stand)	

Chair's Summary of Session 9

The session concluded the conference and focused on technical infrastructure related solutions can find their way into integrated urban water management. **Michael O'Neill** (Arup) illustrated the broader perspective of greening urban infrastructure and how water related improvement can be achieved through combining different important aspects such as vision, collaboration, management and funding. He gave impressive examples e.g. on sustainable urban drainage projects in Melbourne, New York and Wales.

In the second presentation **Susanne Bieker** (Technical University Darmstadt) explained the SEMIZENTRAL approach which includes an "infracstructure on demand" concept which is particularly applicable to fast growing urban centres in Asia. Diversity, flexibility and modularity are main features of such an approach.

Sebastiaan van Eijk (EVIDES) presented the innovative RINEW project to be implemented in the Rotterdam harbor area. It includes a new type of wastewater treatment which puts emphasis on resource recovery, e.g. through nanofiltration of pre-screened wastewater and subsequent anaerobic digestion of both screenings and concentrate.

Jana Nabelkova (CTU Prague) described a comprehensive study on a peri-urban to urban catchment in the Prague area and how the different inputs influence the water quality.

Finally, **Marc Velasco** (CETaqua) presented a cost-benefit analysis study comparing different flooding mitigation actions in Barcelona. The options considered ranged from soft protection measures through SUDS application and major structural changes of the draining infrastructure and considered event of different intensity as well as their respective impacts under the different adaptation scenarios.

Technical Tour "Emscher Conversion" (Registration required)

13:45 Pick-up by coach in front of the Stadthalle building.

17:30 (approx) Drop-off at Stadthalle

The technical tour was sponsored by:

3 FULL MANUSCRIPTS

3.1 TRUST Results

Decision Support System for the Long-Term City metabolism Planning Problem

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Abstract

A Decision Support System (DSS) tool for the assessment of intervention strategies (Alternatives) in an Urban Water System (UWS) with an integral simulation model called “WaterMet2” is presented. The DSS permits the user to identify one or more optimal Alternatives over a fixed long-term planning horizon using performance metrics mapped to the TRUST sustainability criteria (Alegre et al., 2012). The DSS exposes lists of in-built intervention options and system performance metrics for the user to compose new Alternatives. The quantitative metrics are calculated by the WaterMet2 model and further qualitative or user-defined metrics may be specified by the user or by external tools feeding into the DSS. A Multi-Criteria Decision Analysis (MCDA) approach is employed within the DSS to compare the defined Alternatives and to rank them with respect to a pre-specified weighting scheme for different Scenarios. Two rich, interactive Graphical User Interfaces, one desktop and one web-based, are employed to assist with guiding the end user through the stages of defining the problem, evaluating and ranking Alternatives. This mechanism provides a useful tool for decision makers to compare different strategies for the planning of UWS with respect to multiple Scenarios. The efficacy of the DSS is demonstrated on a northern European case study inspired by a real-life urban water system for a mixture of quantitative and qualitative criteria. The results demonstrate how the DSS, integrated with an UWS modelling approach, can be used to assist planners in meeting their long-term, strategic level sustainability objectives.

Assessment of Urban Water System: A Case Study of Reggio Emilia, Italy

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Abstract

A new class of conceptual simulation tools, as a complement to physically based models, is becoming available to simulate the whole water cycle in urban areas for strategic planning often involving the allocation of great amount of financial resources. These simulation tools are required to estimate the impact of the today decisions on the system performance over the next decades and to compare and rank different intervention strategies. For this purpose, the recently developed WaterMet2 model quantifies a number of urban water system flows/fluxes (e.g. water, energy, chemicals and greenhouse gases) which can be used to derive sustainability-based performance metrics based on the metabolism analogy. This paper presents the application of the above metabolism concept with the aim to evaluate the level of sustainability in the water supply system of Reggio Emilia, Italy, which is one of the demonstration case studies in the EU TRUST project. Based on the strains imposed by pressing challenges (here population growth) two intervention strategies were analyzed. The results obtained show that the built and calibrated WaterMet2 model allows a broader understanding of the impacts of alternative intervention strategies taking into account multidimensional aspects of the sustainability beside conventional service performance.

Keywords: Urban water systems, TRUST, WaterMet2, Intervention strategy, Sustainability.

Integrating Leakage, Pressure and Energy Management for Water Distribution Systems

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Keywords: Energy, optimization, pressure management, pump-scheduling, water distribution networks.

Extended Abstract

This paper presents the development and application of a new methodology for leakage reduction via integrated energy and pressure management in Water Distribution Systems (WDS) with the aim of saving both water and energy. This new methodology approaches the management problem by means of a single, integrated multi-objective optimization task, rather than two separate problems (as is currently done) by considering the simultaneous use of flow/time modulated and/or fixed-setting pressure reducing valves (PRV)/throttle valves on one hand and improved pump and source water scheduling on the other.

The optimization seeks to minimize the total costs of network operation and minimizing leakage whilst ensuring that minimum network performance constraints continue to be met. Constituent costs that can be considered include those of energy consumption in

pumping and pump and valve actuation costs. The minimization of valve and pump state changes can also be specified as a secondary objective with a view to an associated reduction in maintenance costs

This new methodology has been implemented as a stand-alone software application, the Pump and Valve Logic Optimal Scheduling (PaVLOS) software, which employs a pressure-driven WDS hydraulic model. The methodology is demonstrated on a real-life case study of Langhirano WDS in Reggio Emilia, Italy for which three different optimization scenarios have been modelled:

1. **PUMP only** optimization in which the operation of the pumps can be changed at hourly control intervals. The decision variables of this scenario are defined by the status of each pump (1 - working, 0 - not working) at each interval of the scheduling horizon. In addition, prior to the optimization, each pump may have its status fixed to "Always on", "Always off" or to respect the existing pump control as defined in the hydraulic model. In this scenario, the PRV settings are fixed and tank levels are fixed. The initial tank levels are the same as the baseline condition.

2. **PUMP and PRV** optimization in which the operation of the pumps and the setting of the PRVs can be changed at hourly control intervals. Similar to the PUMP only optimization, the operation of the pumps and PRV settings can be fixed *a priori* preventing the optimization from considering changes to individual pumps or valves, or changed at each interval of the scheduling horizon. In addition, if desired, selected PUMPs and PRVs can be entirely disabled prior to optimization thus effectively removing them from the system. In this optimization scenario, the initial level of tanks is the same as the baseline condition.

3. **PUMP, PRV and Levels** optimization in which the operation of the pumps, the setting of the PRVs can be changed at hourly control intervals and the initial tanks levels specified. The decision variables in this scenario are defined by the operation of pumps, PRV settings and the addition of the initial level for each tank.

In each of above scenarios, a population of 200 individuals has been considered for the optimization, with 200 generation run (overall 40,000 to the hydraulic model). The dimension of an individual of the population (equal to the number of the decision variable) is 264, 408 and 414 for the three scenarios, respectively. The best solution for each of the three optimization scenarios has been compared to each other, and to the baseline condition that represents the actual operation of the Langhirano WDS. The optimization process has been applied to a re-sampled version of the calibrated model that considers 1hr timestep from the original 5 minute timestep. Figure 1 shows the Pareto optimal fronts (i.e. trade-offs) obtained for each of the optimization scenarios using PaVLOS.

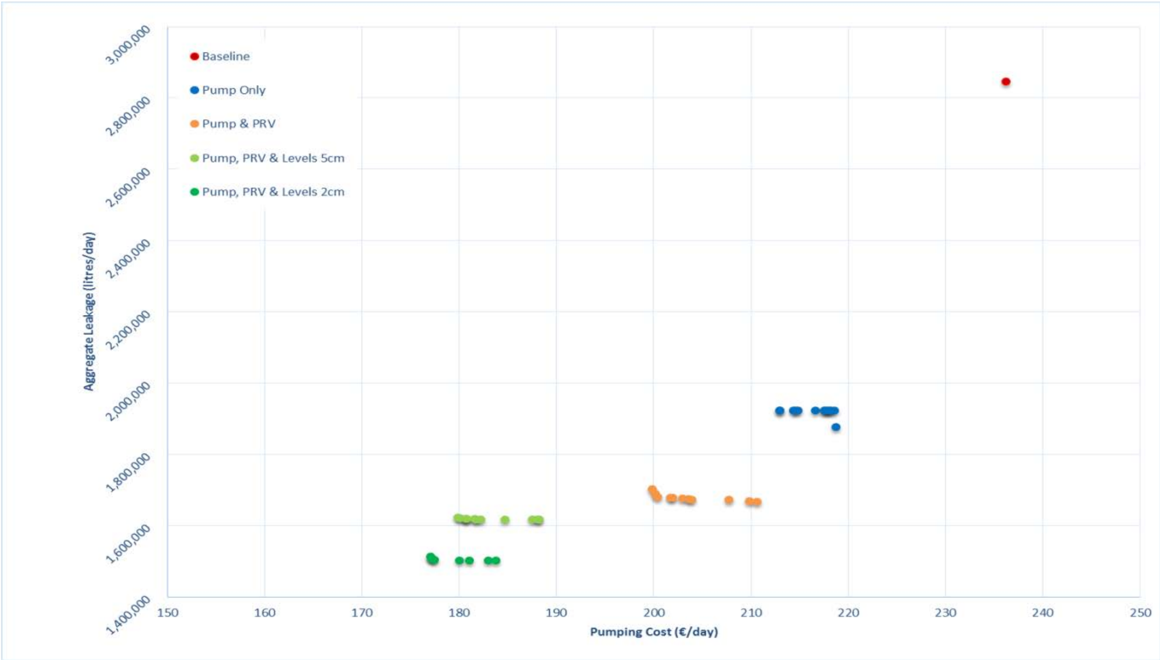

Figure 1 Best solutions found for PUMP only; PUMP and PRV; and PUMP, PRV and Levels optimisation scenarios compared with the baseline condition.

The new methodology and the accompanying software tool can deliver substantial savings to water utilities. Both pressure and energy management, i.e. the scheduling of pumps and valves can lead to a substantial reduction in system leakage and the associated costs. To obtain the optimal trade-off between the two, an optimization problem should be formulated and solved. Integrated pressure and energy management has a synergistic effect, is more beneficial than each of these on their own. Pump scheduling leads primarily to the reduction of energy costs (by taking into account different tariffs) whilst the PRV scheduling leads primarily to leakage reduction (via reduced system pressures) which then, in turn, leads to reduced energy costs (due to reduced volume of water pumped).

A Roadmap for Transition Planning in Urban Water Cycles: The Demonstration Case at HAMBURG WASSER

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Abstract

In the European research project "TRUST – Transitions to the Urban Water Services of Tomorrow", the classical roadmap approach was adapted to the needs of urban water cycle systems (UWCS) and a roadmap guideline was developed. The roadmap approach comprises four phases: Scoping, Visioning, Backcasting and Transfer. It enables decision makers dealing with UWCS to identify individual pathways for more sustainable water cycle services in the future. Roadmapping is a common strategic planning process. It links strategy to future needs and actions and explicitly incorporates a plan for necessary adaptation measures to be available at the right time. This paper refers to the application of the roadmap guideline to the TRUST demonstration case at the utility HAMBURG WASSER, which provides drinking water supply and sanitation for the city of Hamburg, Germany. The HAMBURG WASSER case study shows, that the TRUST roadmap guideline proved to be an adequate strategic planning tool to develop a vision and a long term strategy for the realisation of changes in a utility.

Keywords: Drinking water, Metering, Roadmap, Strategic Planning, Tariffing, Urban water cycle

Introduction

One of the main objectives of the European research project TRUST (Transitions to the Urban Water Services of Tomorrow) is to support water authorities and utilities in Europe in formulating and implementing appropriate urban water policies in order to enhance urban water cycle systems (UWCS). TRUST's aim is to deliver knowledge to support UWCS towards a sustainable water future without jeopardizing service quality. The idea is to achieve this through research-driven innovations in governance, modeling concepts, technologies, decision support tools, and novel approaches to integrated water, energy, and infrastructure asset management. There is no unique or general pathway for the adoption of sustainable practices for water utilities, cities, or any other organization involved in UWCS. A roadmap enables decision makers to plan and implement a pathway to achieve desired objectives. At the same time it serves as an excellent communication tool. A roadmap guideline and the appended templates have been developed in TRUST (Hein et al., 2012). It provides a description of how transition planning efforts in Urban Water Cycle Systems can be organised by a roadmap approach, and offers templates to support the working process. The roadmap guideline illustrates diverse aspects in water supply and waste water management in terms of sustainability, following the five sustainability dimensions identified by TRUST as relevant for UWCSs: the social, environment, economic, governance and assets dimensions (Brattebø et al., 2012). The TRUST project also demonstrates the roadmap approach in different city clusters: "Water Scarcity Cities", "Green Cities" and "Urban/peri-urban Cities". Participating city utilities in the TRUST project provide the link between science and practice. The roadmapping process in each city utility is guided by the roadmap guideline and tools, explicitly designed in and for TRUST, which form a key result of the TRUST project (Hein et al., 2012). The guideline is the first manual developed for practitioners, taking into account the roadmap methodology and it provides a generic understanding of the roadmapping process and structure. In the following, the method of the roadmapping and the demonstration within the green citiy cluster at the utility HAMBURG WASSER are illustrated. Key results of the roadmap demonstration and conclusions are also presented.

Methods

During the demonstration case at HAMBURG WASSER the methods of roadmapping and sustainability assessment have been applied, which are explained in the following chapters.

TRUST roadmapping

The transformation of UWCS in regards to future needs is a creative process and an interdisciplinary planning procedure that affords a lot of expert discussions – the level of discussion needed will depend on the overall objective of each planning process. A roadmap enables the planning and implementation of the path to achieve desired objectives, while serving as an excellent communication tool. Roadmapping also enables the development of strategies for future actions and explicitly incorporates a plan for needed capabilities and technologies to be in place at the right time. The applied roadmap procedure considers the classical stages of the roadmapping process: scoping, forecasting, backcasting and transfer

(Hasse et al., 2012). For developing a roadmap, a roadmap core team must be installed as well as a working group. The roadmap core team should consist of three to six members, including the relevant actors in the transformation process. The roadmap core team should be managed by a project leader, who acts as roadmap manager (figure 1). The roadmap core team has the task of conducting the roadmap process in very close collaboration with the involved actors and stakeholders. The goal is to implement the roadmap results in the urban water system's planning and policies in a collaborative way that includes intensive communication between the relevant actors and stakeholders. Concerning the roadmap working group design, it is suggested that different educational and professional backgrounds (engineers, economists etc.) should be included into the roadmap working group. Various perspectives (e.g. from managers and engineers) will ensure a good balance for a strategic urban water cycle perspective. This will ensure that the actors will be part of the whole planning process in order to concentrate their efforts on an overall target.

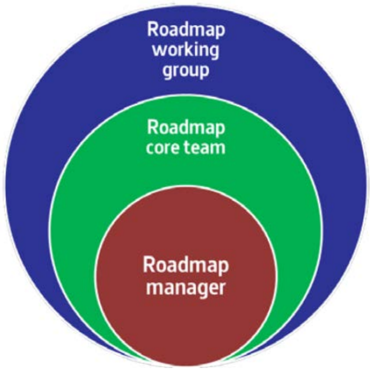

Figure 1: Roadmap manager, roadmap core team and roadmap working group (Hein et al., 2012).

Figure 2 illustrates the stages of the roadmap approach. Scoping is the first main stage of the roadmapping process and defines the scope of analysis in terms of system descriptions and definition of boundaries. It provides a baseline understanding of today's UWCS and delineates the system boundaries. In this stage, relevant actors are identified as well as asset structures, today's status and the impact of existing drivers, pressures and trends on the UWCS of the city as a reference point against which future developments will be addressed. Furthermore, scoping focuses on collecting information and gathering knowledge about the objectives. This stage has to ensure that all relevant parameters and information related to the objectives are available to the roadmap core team, in order to draw a realistic picture of today's UWCS. Forecasting, the second stage, creates a vision of the sustainable UWCS of the future. In the TRUST project the future is defined by the reference year of 2040. It furthermore projects future scenario(s) for the development of the external system and boundary conditions and their potential impact on the UWCS. For this broad analysis, using the DESTEP method is recommended, which considers the development of demographic, economic, social, technological, ecological (environmental) and political factors (Leemann, 2010). Collecting and processing this information is an ambitious task and can probably best be accomplished by using a mix of in-house research of the utility and expert consultation

(Hein et al., 2012). The rationale of forecasting is to project current trends into the future, to anticipate potential barriers and to obtain a perspective for a future scenario of the year 2040. Forecasting is a very creative working step. By a mere projection of the trends into the future, no reliable change in potential can be developed. To achieve sustainable results, it is therefore necessary to apply various methods (like moderated workshops, Delphi survey and scenario analysis) (Rowe et al., 1991). The choice of the optimal method depends on each individual case and the data availability and its degree of detail, but a mix of different techniques is common. Backcasting, the third roadmapping stage, looks iteratively back from the envisioned future state of the UWCS in 2040 and works backwards via (at least one) intermediate state(s) to the presence. The overall purpose of this stage is to characterise how an UWCS might shift from its present state to the desired end point. Backcasting identifies the needs for a multi-step transition to achieve the future desired state (vision 2040). For the TRUST roadmap, one of these intermediate states for UWCSs should be centered on a year (e.g. 2025) or a time period (e.g. midway between 2010 and 2040). Whether or not additional intermediate states are useful can be left to the discretion of the roadmap core team. Transfer is the last stage of the roadmapping process in which the results of the Backcasting are evaluated and transferred into an action program. This includes the definition of the needed activities and their chronological order, which are necessary to transform the system from the present state via the intermediate states to the future. For each activity, details concerning involved actors and stakeholders, responsibilities, methods to be applied and available financial resources must be specified.

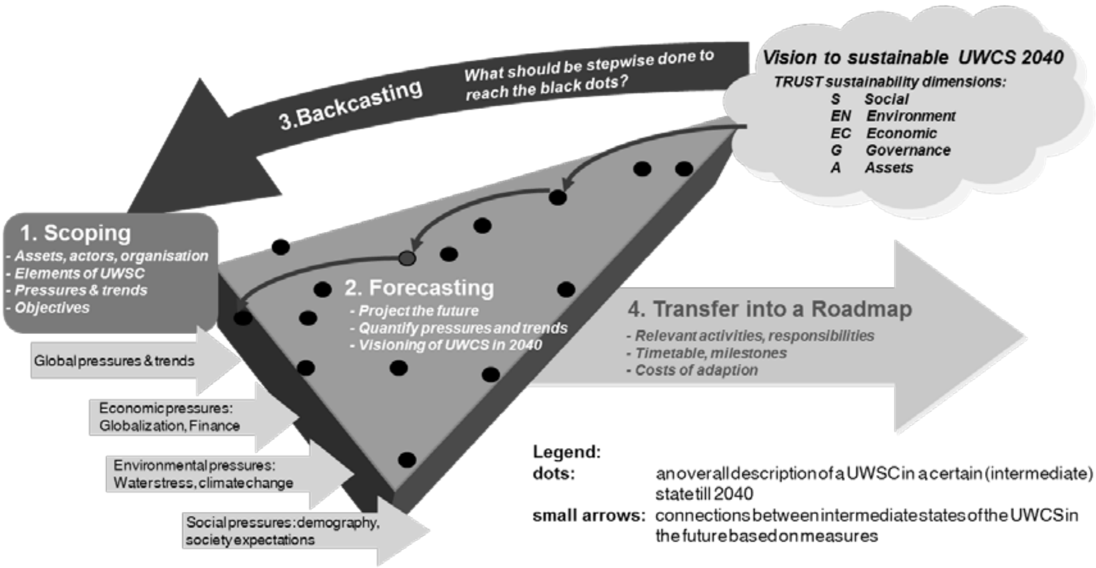

Figure 2: Stages of the roadmap process for UWCS transition (Hein et al., 2012).

Finally, creating a roadmap means development and transfer of identified actions and measures into prioritized recommendations for responsible people or institutions. An adaptive roadmap results in listings of relevant actions, identified measures, indications of prioritization, time scales, milestones, progress monitoring aspects and an illustration of possible or expected prospects and risks, including possible stumbling blocks. All relevant information will be documented in the final document called “roadmap”. This comprises all relevant data and results, outcomes of the individual working stages and involved experts and partners, because the roadmap itself represents a collective result.

TRUST sustainability assessment

To assess the effect of the transformation of UWCS from the present to the future, an additional method is needed. Generally, this can be done by using performance indicators. A selection of suitable IWA performance indicators for drinking water and wastewater (Alegre et al., 2006; Matos et al., 2003) is available in the TRUST roadmap approach. Furthermore, these indicators incorporate the TRUST sustainability approach, which is based on the so-called triple-bottom-line approach considering the social, economic and environmental dimensions as the skeleton of sustainability assessment, but additionally considers two further criteria as supporting dimensions: assets and governance (Alegre et al., 2012). The rationale for considering the supporting dimensions of assets and governance is to explicitly take into consideration two important dimensions for complex infrastructure-based systems like UWCS. Assets are associated with the system of physical infrastructure, namely their durability, reliability, flexibility and adaptability, but also soft infrastructure, meaning human capital as well as information and knowledge management. Governance relates to the political, social, economic and administrative processes, which affect the development, delivery or management of water resources and services. Key governance considerations are transparency, broad participation in decision making, the effectiveness and efficiency of measures taken, the quality of the accountability and adjustment mechanisms, and also the existence and alignment of city planning with UWCS. The TRUST approach to sustainability assessment is shown in figure 3. Table 1 presents the sustainability dimensions with detailed objectives and criteria for the assessment of UWCS sustainability.

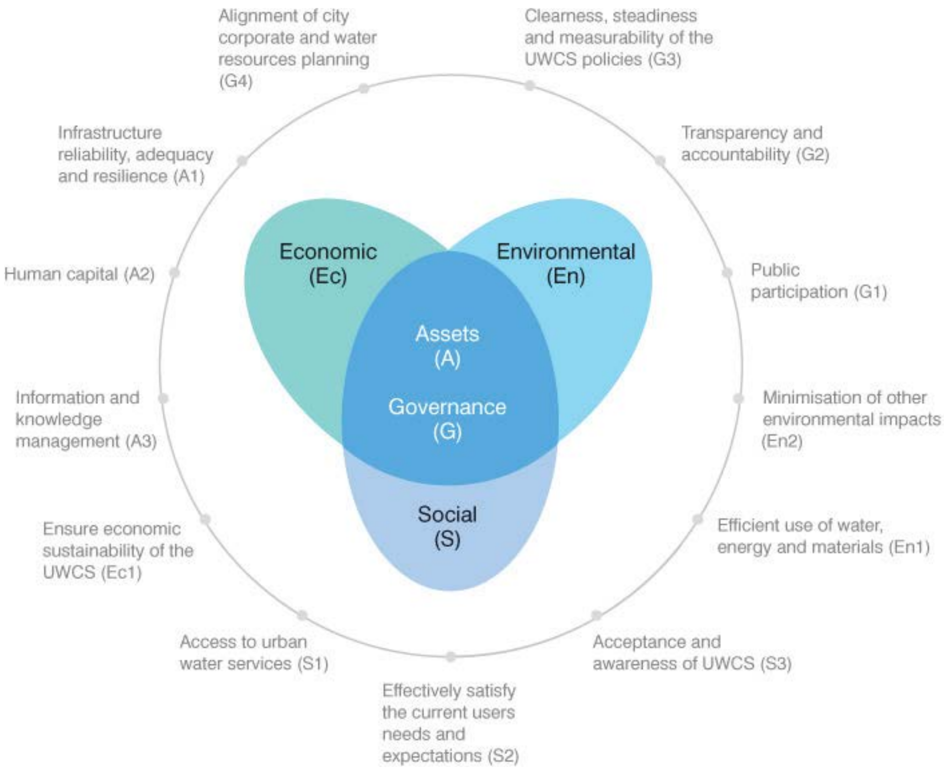

Figure 3: TRUST approach to sustainability assessment (Alegre et al., 2012).

Table 1: TRUST sustainability dimensions, objectives and assessment criteria (Alegre et al., 2012).

DIMENSION	OBJECTIVES FOR 2040	ASSESSMENT CRITERIA
Social	S1) Access to urban water services	S11) Service coverage
	S2) Effectively satisfy the current users' needs and expectations	S21) Quality of service
		S22) Safety and health
	S3) Acceptance and awareness of UWCS	S31) Affordability
Environmental	En1) Efficient use of water, energy and materials	En11) Efficiency in the use of water (including final uses)
		En12) Efficiency in the use of energy
		En13) Efficiency in the use of materials
	En2) Minimisation of other environmental impacts	En21) Environmental efficiency (resource exploitation and life cycle emissions to water, air and soil)
Economic	Ec1) Ensure economic sustainability of the UWCS	Ec11) Cost recovery and reinvestment in UWCS (incl. cost financing)
		Ec12) Economic efficiency
		Ec13) Leverage (degree of indebtedness)
		Ec14) Willingness to pay (accounts receivable)
Governance	G1) Public participation	G11) Participation initiatives
	G2) Transparency and accountability	G21) Availability of information and public disclosure
		G22) Availability of mechanisms of accountability
	G3) Clearness, steadiness and measurability of the UWCS policies	G31) Clearness, steadiness, ambitiousness and measurability of policies

DIMENSION	OBJECTIVES FOR 2040	ASSESSMENT CRITERIA
	G4) Alignment of city, corporate and water resources planning	G32) Degree of alignment of city, corporate and water resources planning
Assets	A1) Infrastructure reliability, adequacy and resilience	A11) Adequacy of the rehabilitation rate
		A12) Reliability and failures
		A13) Adequate infrastructural capacity
		A14) Adaptability to changes (e.g. climate change adaptation)
	A2) Human capital	A21) Adequacy of training, capacity building and knowledge transfer
	A3) Information and knowledge management	A31) Quality of the information and of the knowledge management system

Results and discussion

To apply the roadmap, a core team was established consisting of one member of HAMBURG WASSER and two members of IWW Rhenish-Westphalian Institute for Water Research as scientific partners (IWW). The roadmap working group consisted of decision makers from HAMBURG WASSER with different competences, decision making power and educational backgrounds. The roadmap management was carried out by a member of IWW. In the scoping stage, a data collection and analysis with the templates based on IWA performance indicators from the roadmap guideline were worked out. Existing drivers, pressures and trends affecting the urban water systems in the city of Hamburg were analysed. The range of the major trends in the Hamburg demonstration included e.g. demographic changes, water demand forecasts, structural changes in local economy, environmental drivers and change in attitude of customers. As the result of this analysis, the roadmap topics "water metering" and "tariffing" were identified to be adapted to the future development of HAMBURG WASSER. In Germany, water metering is required by law and different methods for the metering of water consumption exist, for example the metering of the water consumption in buildings or apartments. In Hamburg, water consumption is measured with water meters for each apartment. This procedure was introduced in 1994 and became part of building regulations with the aim to increase citizens' awareness of water consumption by making it more transparent and ultimately, to stimulate saving water. In case water is heated at a central place in the house and then distributed to the apartments, not only cold- , but also hot water meters are installed in each apartment. The water meters must be calibrated according to German law every six years for cold water and five years for warm water.

Therefore, water meters are exchanged every five years for calibration. In comparison, other European countries, such as Norway or Netherlands have longer intervals for exchange (8-10 years) or even no regulation for the exchange interval as is the case in France. HAMBURG WASSER manages the initial installation, exchange, calibration, maintenance and billing of approximately 870,000 water meters. Currently, about EUR 15 million per year are spent for exchange of water meters and approximately EUR 13 million per year for billing and customer service. Therefore, a need for future change of "water metering" was identified. German water tariffs presently comprise a basic price and a quantity price. On average, the basic price accounts for about 20% of the tariff and the quantity price accounts for about 80%. The quantity price leads to a persistent decline in sales and correspondent cost recovery margins. Steady price adjustments of the quantity price must be made or tariffs with a higher basic price can reduce this effect of a decline in water consumption and a correspondent cost recovery margins (Neskovic and Hein, 2012). This in turn may lead to consumer dissatisfaction. The ratio of basic and quantity price described above is also applied in Hamburg. To overcome expensive metering and inadequate tariffing, new concepts should be identified and made ready for implementation during the roadmap process so as to maintain a healthy financial-economic situation of the utility HAMBURG WASSER, while enabling the company to maintain high supply standards in the future. Therefore, the second focus of the TRUST roadmap approach was "water tariffing". In the second stage of the roadmap, the forecasting, the future development of the existing drivers, pressures and trends affecting the urban water systems in the city of Hamburg, which have been already investigated for the present state in the scoping stage, have been estimated for the years 2025 and 2040. Nevertheless, it wasn't possible to define one vison on how to adapt water metering and tariffing to the need of the years 2025 and 2040. Therefore, several (altogether seven) possible future scenarios have been defined, which may be suitable to meet the needs of metering and tariffing of HAMBURG WASSER in the future. The scenarios are shown in figure 4. Scenarios 1 to 3 focused on different possibilities how metering might be done in the future while scenarios 4 and 5 focused on future possibilities for tariffing. The individual scenarios will be not explained in detail in this paper for reasons of confidentiality of information.

To identify which of these scenarios will be the most suitable one for the future needs, it was tried to apply the performance indicators developed in the TRUST roadmap guideline, but it became clear that on the one hand the indicators are not specific enough and will not be suitable for the description of the topic of metering and tariffing, while on the other hand, valid numbers are missing for the future. In addition, it proved difficult to quantify the future developments for most of the drivers. Therefore, it was decided to perform the assessment in a semi-quantitative way under application of the five sustainability dimensions of the TRUST project (economy, environment, society, governance and assets), using scores between +2 und -2. A score of -2 means a significant deterioration and +2 a significant improvement, compared to the present state. In an intensive discussion process, the seven scenarios were assessed by the working group in this way. The sum of all scores gave the final result of the assessment of a scenario. It was decided in the working group, that no weighting scheme should be applied for the assessment process as all dimensions are of the same importance. The scenario with the highest score is supposed to be the most sustainable one and will be taken as basis for the development of the vision for the future. It proved to be difficult to describe the development of the drivers, pressures and trends in 2040 according to the TRUST project, because this stage was considered to be too far ahead, and the estimations too uncertain. Therefore, an additional intermediate stage for the year 2025 was introduced, conforming to the TRUST roadmap approach. Table 2 represents the results from the assessment of the scenarios of the year 2025 and 2040 for HAMBURG WASSER. In the column “Assessment” the sum is shown and the highest-rated scenarios are written in bold. The scenario 5 was not evaluated completely, because a flat rate model in the year 2025 is not very likely from today's perspective.

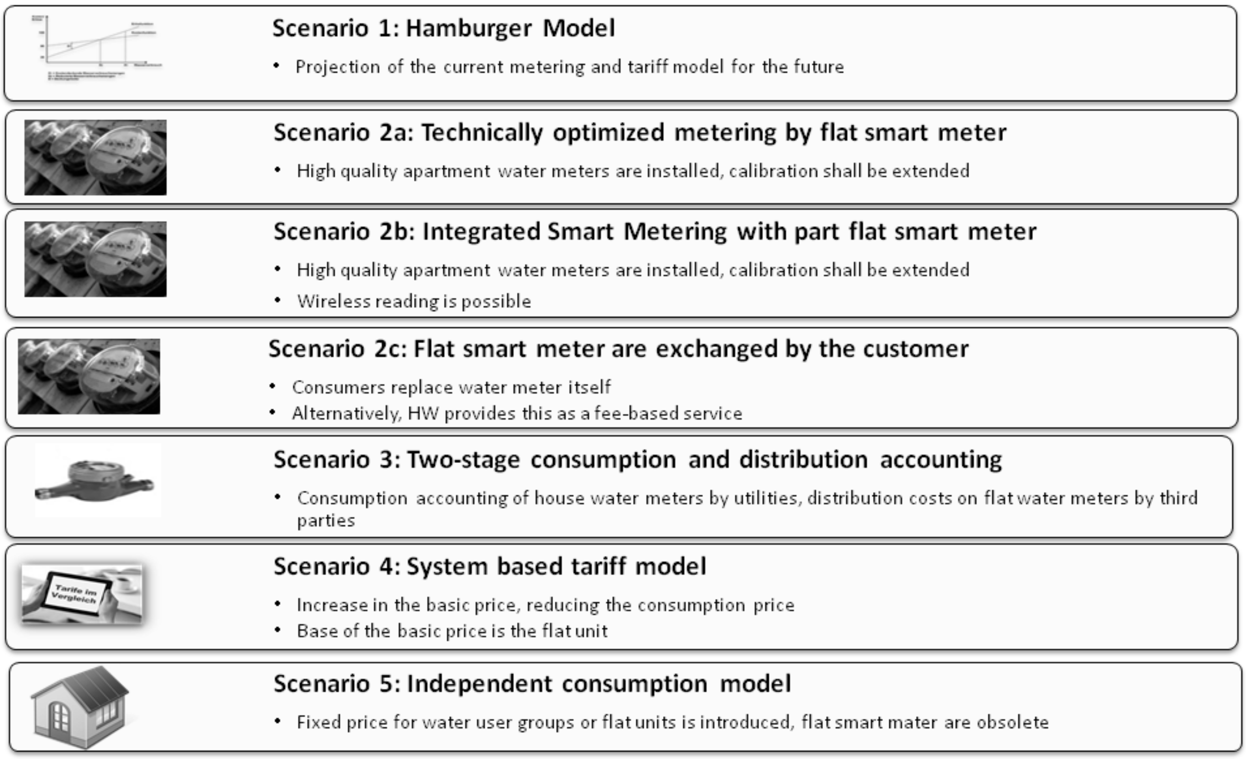

Figure 4: Possible future scenarios in 2040 for HAMBURG WASSER

Table 2: Specific assessment of the scenarios 2025 and 2040 for HAMBURG WASSER

SCENARIO	YEAR	SOCIAL	ENVIRON-MENTAL	ECO-NOMIC	GOVER-NANCE	ASSETS	ASSESS-MENT
Scenario 1: Hamburger Model	2025	0	0	0	0	-1	-1
	2040	0	0	1	0	1	2
Scenario 2a: Technically optimized metering by flat smart meter	2025	1	1	1	-1	-1	1
	2040	1	1	2	-1	1	4
Scenario 2b: Integrated smart metering with part flat smart meter	2025	1	2	1	-1	-1	2
	2040	1	2	2	-2	1	4
Scenario 2c: Flat smart meter are exchanged by the customers	2025	0	1	0	0	-2	-1
	2040	0	1	1	0	0	2
Scenario 3: Two-stage consumption and distribution accounting	2025	-1	1	0	-1	-1	-2
	2040	-1	1	1	0	1	2
Scenario 4: System based tariff model	2025	0	0	1	1	2	4
	2040	0	0	2	1	2	5
Scenario 5: Independent consumption model	2025						
	2040	-1	-1	2	-1	2	1

Based on this assessment, the vision for HAMBURG WASSER was discussed and then developed in a next step. The vision contains both topics "water metering" and "water tariffing" and takes into account the two future scenarios for the years 2025 and 2040. Concerning the water metering, the future desired state is the use of high-quality water meters or the options with and without smart metering. For the water tariffing, the vision to change from the present water tariff to a system-based model was built. Via backcasting, the third roadmap stage, the roadmap working group characterised two necessary intermediate states (the year 2015 and 2020) for HAMBURG WASSER to shift from its present state to the desired future. It was proposed that in the year 2015 studies on the economics, which are considering different options of "water metering" and the ratio of the basic price and quantity price in "water tariffing", are necessary to sharpen the visions and to develop more detailed specifications. In the transfer stage for both topics "water metering" and "water tariffing" the proposals for an action plan, covering needed measures, capabilities, technologies and studies, which are necessary to realise the visions, were worked out by the roadmap core team and communicated to the working group. After this the core team got feedback from the roadmap working group by the Delphi-style technique and finalized the action plan. Finally, the process of the roadmapping and all results have been documented in a report.

Scope of the planned studies at HAMBURG WASSER

As a result of the roadmap a prioritised action plan has been worked out to achieve the visions for "water tariffing" and "water metering". Among other things, the action plan involves studies, which are to be conducted in order to achieve the vision. As one of the key results of the roadmap process it was recognized, that the cost effectiveness of the business field metering is almost unknown at HAMBURG WASSER. It was defined in the roadmap that a study on the cost effectiveness of the present metering process has to be carried out as the first step for the realization of the vision. For the transition to a future state, additional cost will occur for the communication with customers and for organizing the change. Furthermore, the roadmapping process indicated that the strategy to invest in long-lasting water meters may be more cost-effective, even if the replacement of water meters needs high investments. In case of legal changes longer running times between calibrations will become possible, resulting in savings for the exchange and calibration of the water meters. These savings cannot be quantified yet and are also subject of the intended study. Similarly, to sharpen the vision of a financial sustainable water tariff by change of the tariffing from the present model to a system-based model, a study on the best relation between basic and volume water price was found to be necessary. In both cases, the conduction of the studies itself will be outside of the financial and temporal frame of TRUST and is supposed to start in the year 2015.

Conclusion

The roadmap guideline proved to be an adequate strategic planning tool to develop a vision or long term strategy for the water utility HAMBURG WASSER. Core elements for a successful roadmap exercise are communication and exchange between the partners. Participants in the roadmapping procedure should have an open interest in the transition and adaptation needs of "their" existing UWCS. The development of a roadmap supports communication between involved operators, stakeholders, administration and the public, which is necessary for establishing a mutual understanding of the needs of transition, and for supporting a collaborative planning process. A core element for a successful roadmap application is the role of communication and exchange between the partners. The roadmap guideline developed in TRUST showed to be generally suitable for application, but needed to be modified and adapted to the contexts and individual needs of the cities. Especially tools and methods for the development of the vision had to be selected and applied according to the individual problems. It proved to be important to pick up already open questions under discussion and to include already ongoing activities in the roadmapping process to avoid parallel developments and duplication of activities. Roadmapping is a very contextual process. The methodology, but not the results, will be transferable to other utilities. For the roadmap process a guided procedure through well prepared and target-oriented workshops with the actors showed to be successful to induce fruitful discussions. Finally, the achievement of meaningful results was also due to the excellent availability and quality of data and information. This shows the importance and effectiveness of current ratios, financial data and process descriptions for a utility. The results of the roadmap process are currently discussed at HAMBURG WASSER for strategic decision making.

Acknowledgement

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Roadmap for reduced water consumption and leakages – case study Oslo

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Abstract

Today's water utility is under pressure, squeezed by the rapidly changing socio-technical drivers and mandate to deliver high levels and reliability of service. Under pressure to transform, utility companies have to handle strategic matters and balance between strategic development and day-to-day operation. Oslo Water and Sewerage Works (Oslo VAV) is among the utilities that have an abundance of inexpensive, local water resources and low value of water loss. However, meeting the needs of a fast-growing population in the form of new water source and treatment plant as well as handling infrastructure renewal has created political pressure to revise the balance of supply and demand and management of its components. In order to explore the way for a transition from status quo to the long-term visions and goals, roadmap for reducing water demand and leakage has been developed with inputs from internal and external stakeholders. The roadmap provides a reliable guideline for integrating sustainable water consumption and leakage management into the post-2015 development plans.

Keywords: Water consumption, leakages, sustainability, roadmap

Introduction

Oslo Water and Sewerage Works (Oslo VAV) supplies drinking water to Oslo and Ski, a neighboring municipality. Oslo is a city in growth, with an estimated growth in population from 630,000 inhabitants in 2014 to between 700,000 and 860,000 in 2030. The Ski municipality has almost 30,000 inhabitants and is expected to grow to more than 35,000 in 2030. The population growth from 2000-2015 and further prognoses are shown in Figure 1.

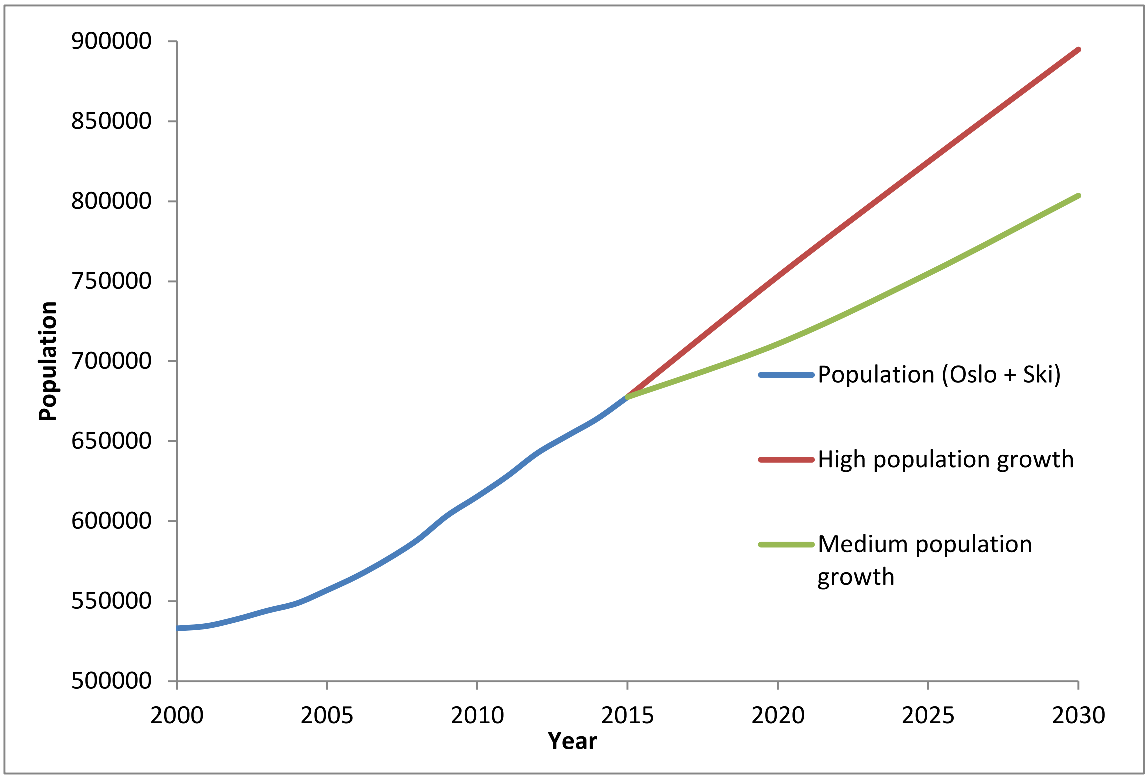

Figure 1 The population growth from 2000-2015 and further prognoses

Without any actions to reduce the specific water consumption per capita, an increased population will result in higher water demand. The present estimated water consumption of 160 L/pd and leakages of 30 % in the water distribution system in Oslo are higher than what is considered sustainable. Reductions in water consumption and leakages will therefore be an important part of the new master plan for water supply in Oslo that is prepared for the period 2016-2030. These reductions will not only give a more sustainable water supply, but also help improve financial feasibility of the necessary investments in the water infrastructure for a growing city like Oslo. The goal for the city of Oslo is to maintain the yearly water demand on the present level despite the population growth. In order to keep the demand on the present level for the entire master plan period planned actions need to bring results within the next few years, meaning that the timing of the actions will be important to promote the desired effects.

The total water production in Oslo from 1995 to 2015 and possible scenarios for the next 15 years is shown in Figure 2. Water production decreased from 1995 to 2000, partly because of an intensive leakage control, partly from reduced industrial consumption and partly because of less water consuming domestic appliances (showers, dishwashers etc.). From 2000 to 2015 the water production has been constant even though the population has increased by 27 %. For the period 2015-2030 three scenarios are shown, one where Oslo reaches the goal of a stable water demand and two where the leakages and the specific water consumption remain on the present level.

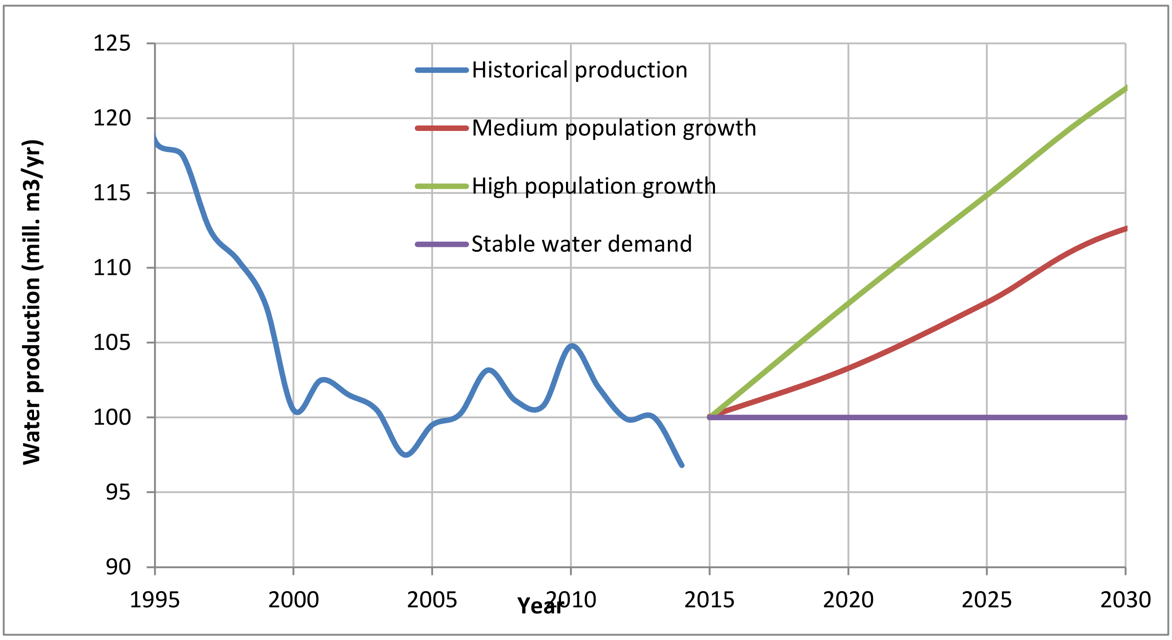

Figure 2 The water production from 1995-2015 and further prognoses

When joining EU TRUST project a roadmap for reduction in water consumption and leakages was chosen for a case study in the city of Oslo in order to establish a toolbox necessary to reach the goals for the total water demand in Oslo.

Roadmap's development process

The measures and their timetables that constitute the TRUST roadmap of Oslo VAV were created through group work done in the workshops as shown in Table 1. The kick-off meeting included defining stakeholders and goals, while the two workshops included Scoping/Forecasting and backcasting/transfer of the roadmap process.

Table 1 Roadmapping timeline for Oslo 2013 – 2014

ROADMAPPING ACTIVITIES	DESCRIPTION	ACTORS INVOLVED	DATE
Kick-off meeting	The roadmap started in Oslo VAV with a start-up meeting to introduce the roadmap process and gather all the stakeholders. Presentation of TRUST tools. Topics for the roadmap process was decided to be: a) reduction of water use; b) reducing leakages	Oslo VAV, SINTEF, NTNU, Food Authority Oslo	27th of May, 2013
Workshop # 1	Scoping and Forecasting of the roadmap process.	Oslo VAV, SINTEF,	1st of November, 2013
Workshop # 2	Backcasting and Transfer of the roadmap process.	Oslo VAV, SINTEF	28th of April, 2014

In the final workshop the participants were split into groups to discuss relevant measures to reduce water demand and water leakages. Based on this group work a list of measures with timelines for both topics was created.

Results and discussion

The measures are summarized in a roadmap for Oslo VAV (see Table 2 and 3). Table 2 is the roadmap for the topic of reduced water demand in Oslo. Each topic (reduced water demand and reduced leakages) has its own diagram. The measures were split into four categories; technical, information, attitude and framework, signifying the type of measure. Introduction of water metering for all customers is suggested. Table 3 is the roadmap for reduced leakages and includes implementation of new technology as well as physical measures in the network.

Table 2 The roadmap of Oslo VAV for reduced water demand (target < 130 L/pd within 2030)

ACTION	COMMENTS	STEP 1	STEP 2
TECHNICAL			
Water economizer in showers	Already exists, but the use should be extended	Pilot with information campaign	Full-scale rolling-out
Smart water meters at building or household level	Requires political decisions	Pilot within limited area	Full-scale rolling-out
Water saving toilets	Already exists, but the use should be extended	Pilot with information campaign	Full-scale rolling-out
Recycling at fountains	VAV has taken over operation, recycling are partly implemented		
Alternative water sources for sweeping and flushing roads			
BEHAVIOUR			
Best practice campaign for households	Environmental focus. Reduce water losses in watering gardens, running taps, leaking toilets		
Best practice campaign for public sector	Optimized frost prevention tapping, reduced watering of parks through proper selection of plants, alternative water sources for sweeping and flushing roads		
Control of consumption at public water taps (for ships etc)	Installation of water meters and locks to control the use		
INFORMATION			
General information campaign towards all consumers			
PUBLIC FRAMEWORK			
Collection of rain water for garden watering	Information, financial incitation	Feasibility study, pilot	Full-scale rolling-out
Differentiated water tax, higher taxes when the consumption exceeds for instance 130 L/pd	Requires political decisions, requires water metering		
Integrating water consumption in energy usage benchmarking			

Table 3 The roadmap of Oslo VAV for leakage control (target < 20 % within 2030)

ACTION	COMMENTS	STEP 1	STEP 2
TECHNICAL			
Taking over private service pipes	Totally or in public roads (including connections), requires political decisions	Review	
Implementing all new connections in man-holes	Ensures a better control for leakages in service pipes		
Online modelling of the network			
Enhanced renovation of the network	Present renovation is 1 % per year		
Active pressure control	Combined with smart water meters?	Pilot study in a limited area	Full-scale rolling-out where applicable
Improved leakage detection	Some leakages are not detected with existing methods		
INFORMATION			
Evaluating new technology whenever available			
Informative mission in the municipality	Review of technical regulations and guidelines		
Evaluation of financial incitation for the service pipes	Possible support for leakage detection and repair		

A roadmap does in general include the necessary time of implementation. For the actions summarized in Table 2 and 3 the question, regarding the targets for 2030, is rather how fast the actions can be evaluated and possibly implemented. To answer this question is now an important task for Oslo VAV.

The different actions identified in the roadmap are now being implemented in the new master plan, either as actions to be put into practice or actions to be further evaluated. Examples of ongoing or planned actions are:

- Water metering is planned for a part of Oslo as a pilot and based on the experiences gained a decision on water metering for all customers will be made.
- Pressure reduction is evaluated to identify benefits, risks and necessary investment in the network.
- A new information campaign for reduced water consumption was carried out in January 2015.

Other actions, such as innovative “off the shelf” solutions for controlled drilling of service connections, will take a longer time to implement. Whether Oslo VAV should take over the operation of service pipes will be a political issue.

The roadmapping process in Oslo was closely related to the development of a new master plan for water supply. This relation benefited the roadmapping process will help Oslo VAV to implement the results from the roadmapping in the operational work.

Few of the identified actions from the roadmapping process were new to Oslo VAV since the topic of reductions in specific water consumption and leakages has been an issue for some time. The benefits for the city of Oslo were therefore not primarily the suggestions for new actions, but the process of identifying known actions and systemize these. Further benefits were gained from identifying when the different actions should be finalized and when to start the different tasks in order to achieve this. There is a need for some actions to take effect within a few years, meaning that several actions will be in effect simultaneously in the coming years.

Conclusion

Roadmapping was a good tool for the identification and systemization of relevant actions to reduce specific water consumption and leakage in the city of Oslo. The process resulted in the creation of sets of measures which have been plugged into the master plan and prioritizes according to their effect on water consumption and leakage reduction in the coming years. As a power communication tool the roadmapping process helped to improve stakeholders’ understandings of their respective views and options, and strengthen cooperation between participants.

Sustainable Urban Drainage Systems (SUDS) as solution for reduction of Stormwater Overflow (CSO) discharge and urban flooding

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Abstract

In many municipalities combined sewer systems create problems in local water bodies. The drainage system fails more often due to an increase of urban area and thus increased run-off and combined sewer overflows (CSO). As a result, the water bodies are more and more polluted and inhabitants complain of bad smell. The mentioned problems occur in a suburb (Hoffsvela) of Oslo, capital of Norway. The drainage system of this suburb was a case study within the TRUST project (43.1: D43.1Results from overall exploration of potential for sustainability improvements). It was examined how to minimize the inflow to the drainage system by sustainable urban drainage systems (SUDS) instead of an increase of the infrastructure.

In order to get an overview of potentials for sustainable urban drainage systems (SUDS) within the catchment of Oslo Hoffsvela and Sandnes (city center), a GIS- (geographical information system) based method was applied to produce a “stormwater management map”. In the process of identifying impervious areas that can be disconnected (separated) from the sewer system and treated by SUDS in the most efficient and economical way, diverse criteria were considered.

The drainage systems of Oslo Hoffsvela were examined (set up) with a run-off model (STORM, Sieker). After calibrating the run-off models of Hoffsvela, a long-term series was conducted and the overflow frequencies of stormwater overflow structures and peak flows for a base and a "SUDS" scenario were determined and compared.

Keywords: Sustainable Urban Drainage System (SUDS), Combined Sewer Overflow (CSO), Urban flooding, stormwater management map

Introduction

Space in urban areas is limited. Thus stormwater in cities is often considered as a problem and has to be removed quickly. Normally it disappears after a rain event from the impervious area as run-off into pipes and is led to central measures, so called „end of pipe solutions". But stormwater in general is a precious resource which is more worth than to waste. Furthermore, existing urban drainage systems fail frequently, because new challenges, like fast growing cities and climate change, overload the drainage infrastructure. Therefore alternative solutions, especially sustainable urban drainage systems (SUDS), were proved for two catchments in Oslo Hoffsvela, Norway. SUDS were already often planned, but in general as single measure and not as a general alternative solution catchment wide.

The investigated drainage system is located in Oslo, Norway, the size of the catchment area is 9 km^2 (Figure 1). It is divided into two sub-catchments (HO10M: 543 ha and HO4HI: 348 ha). The total length of the considered sewer system is approximately 14 km. The catchments are dominated by forests in the northern and urban areas parts in the south. Mainly single-detached houses are spread within the two catchments. In some parts apartment buildings characterize the surroundings. The catchments are naturally drained by creeks.

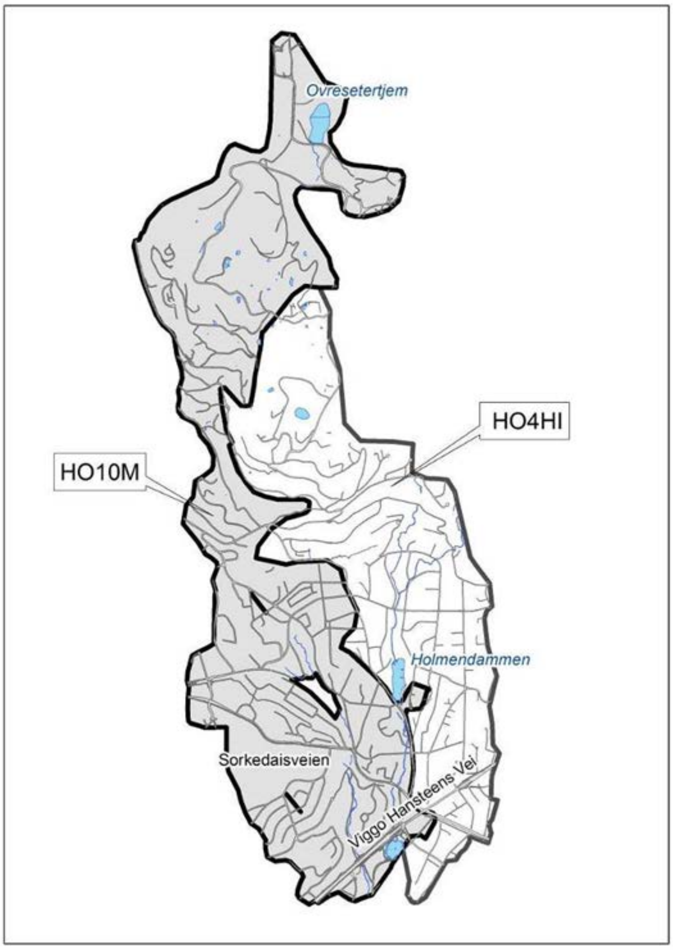


Figure 1: Overview of investigated sewer catchments

Methods

In the process of identifying impervious areas, which can be disconnected (separated) from the sewer system in the most efficient and economical way, many different criteria have to be considered.

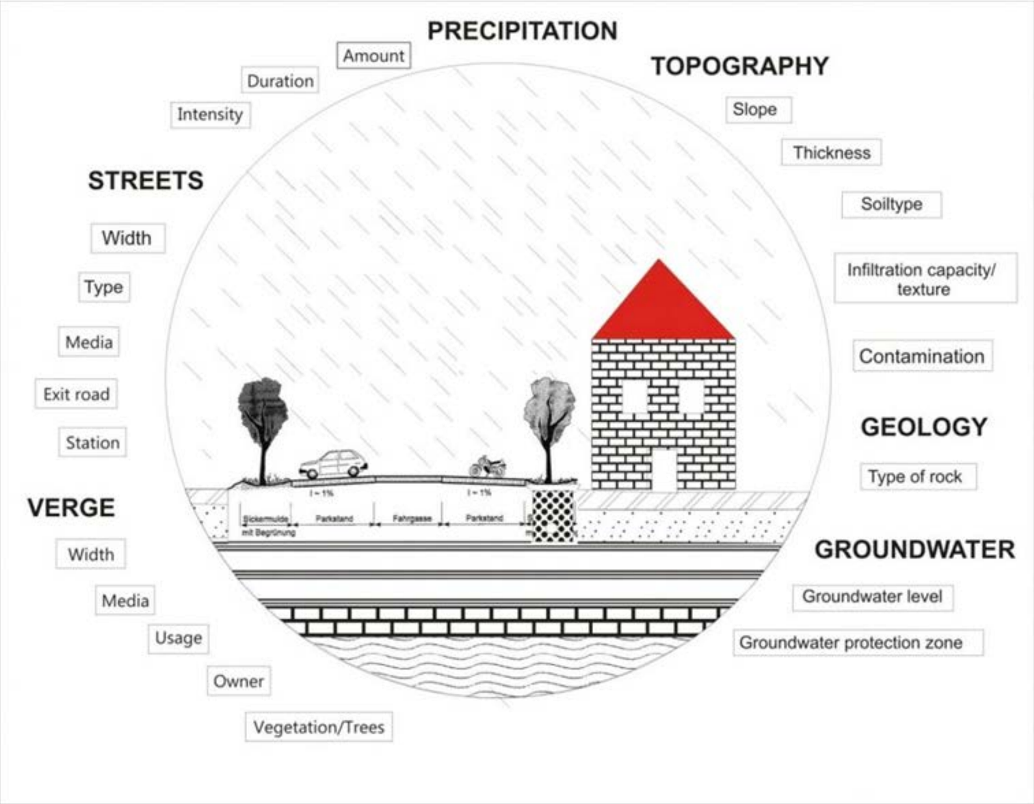


Figure 2: Influencing criteria on planning SUDS

Mainly the criteria shown in Fig. 2 influence the application of SUDS. SUDS cannot be implemented everywhere with the same technique. Especially natural factors (geology, soil, and slope) affect the application of SUDS technique. Other criteria, which are related to build-environment, influence the selection of possible location for SUDS (disconnection/separation potential).

The approach of creating maps of SUDS by using GIS is mainly based on the idea published at the 8th ICUD conference (Vol.4, p.1671). It describes the identification of disconnection potential for buildings and impervious areas of private property.

Due to the characteristics of the Hoffsvela catchment, where most of the run-off originates from streets and runs into the sewer system, the method had to be adapted to the disconnection of run-off from streets.

1. "Map of SUDS technique". This map shows the spatial distribution of the best applicable SUDS technique, taking into account different influencing, natural criteria.
2. "Disconnection potential" maps. These maps estimate the amount of impervious areas, which can be isolated from the sewer system and treated by SUDS.

Methodology of creating Map of SUDS technique

The methodology of creating the map of SUDS technique is depicted in Figure 3. The spatial distributions of the important criteria were collected and then classified according to their effects on SUDS. Thereafter all parameters were intersected or overlaid (depend on the criteria), to create the “Map of SUDS technique”, which describes the suitable SUDS in a spatial distribution of the catchment.

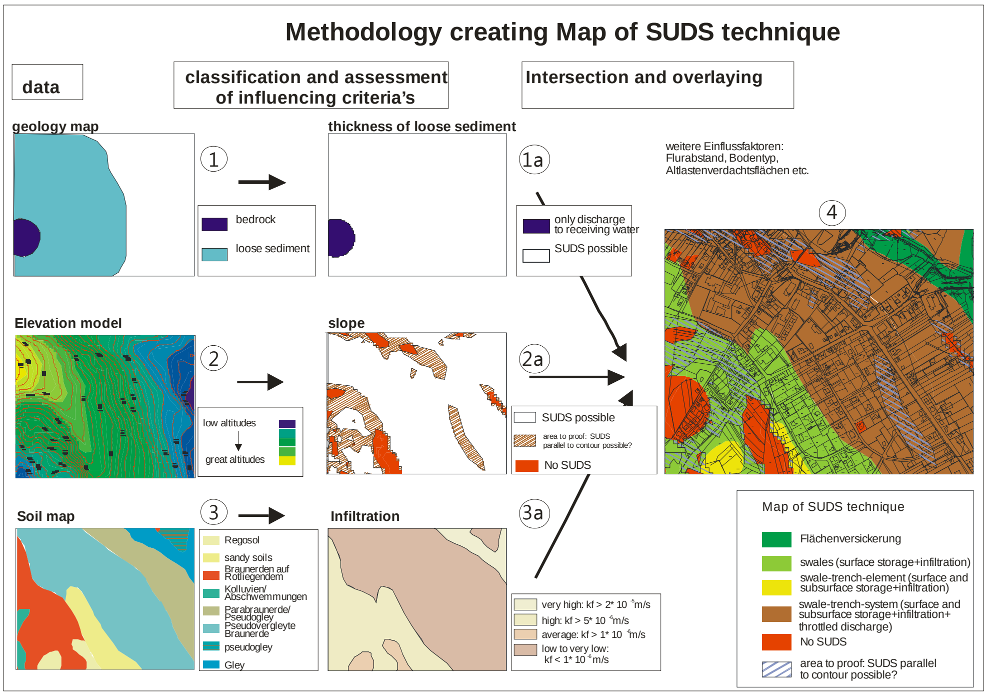


Figure 3: General methodology of creating maps of SUDS technique

A closer look to one of many criteria (infiltration capacity) shows the details of the applied method:

The soil map of the investigated catchments was evaluated to get the values of the infiltration capacity. The effects on SUDS of the criteria “infiltration capacity” are shown in Figure 4. The lower the infiltration rate, the higher the demanding storage volume. The technical requirements rise with decreasing infiltration rate. This scheme was applied for other criteria like soil thickness, soil type, groundwater distance.

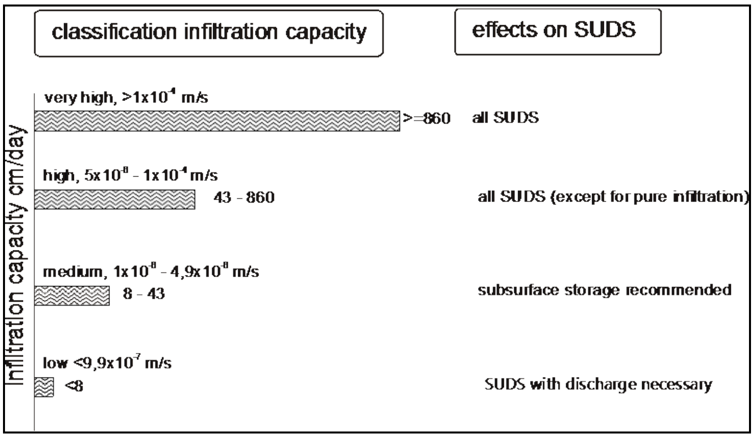


Figure 4: Infiltration capacity and its influence on SUDS

Within the catchments only average to low infiltration capacities are explored. Due to low infiltration capacity, SUDS are mainly recommended which combine the effects of purification, infiltration, storage and throttled discharge (Figure 5). In the northern parts of the catchments different SUDS are required. The bedrock close to the surface doesn't allow any underground storage. Therefore, surface storages and discharge into nearby creeks and rivers are favorable techniques for SUDS. After overlaying all influencing criteria, the result map of applicable SUDS technique is shown in Figure 6.

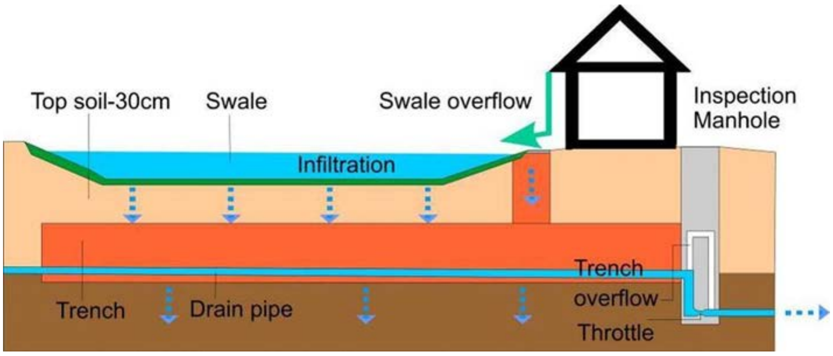


Figure 5: A recommended SUDS by many for some areas in Hoffsvela: Swale-Trench System

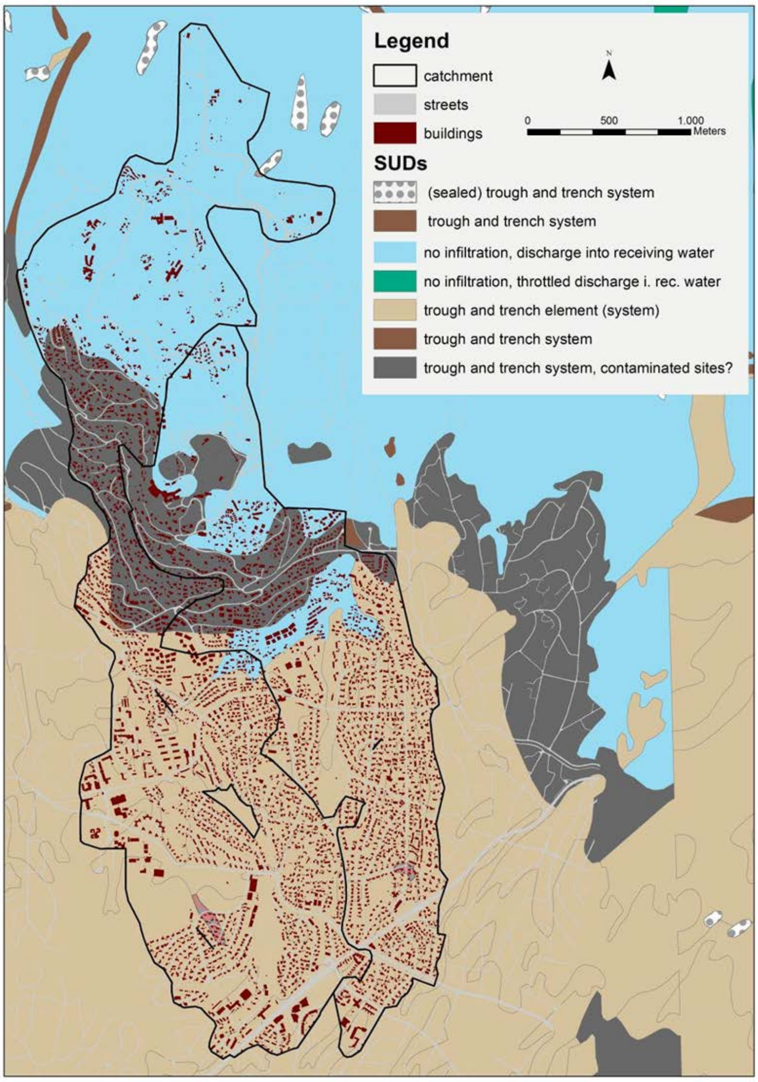


Figure6: Map of SUDS technique for Oslo Hoffsvela

Methodology of creating Disconnection Potential Map

The sewer system in Oslo mainly transports stormwater run-off from streets. Thus the investigation of possible location in Oslo Hoffsvela deals with SUDS located nearby or next to streets. Due to this fact a new methodology was developed, which creates a “Map of disconnection potential” especially for streets. A general overview of the demanding input data is depicted in Figure 7.

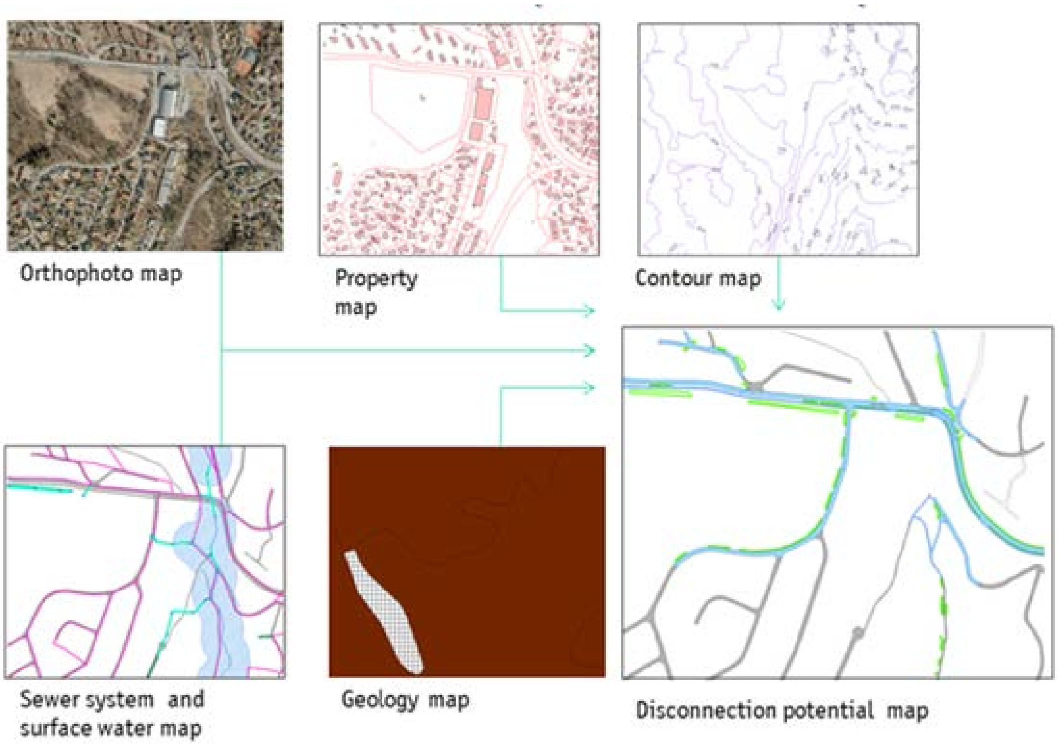


Figure 7: Process of creating map of disconnection potential map

As a result of the assessment of all maps a classification of different types of streets is given (Figure 8). These different types have different potentials of SUDS implementation (disconnection potential).

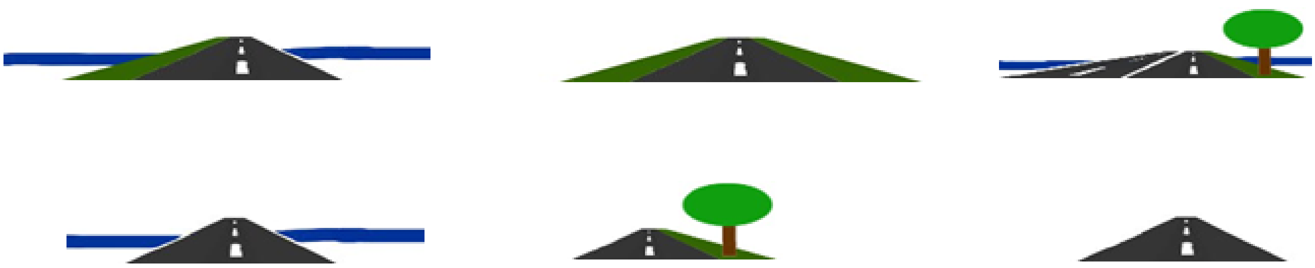
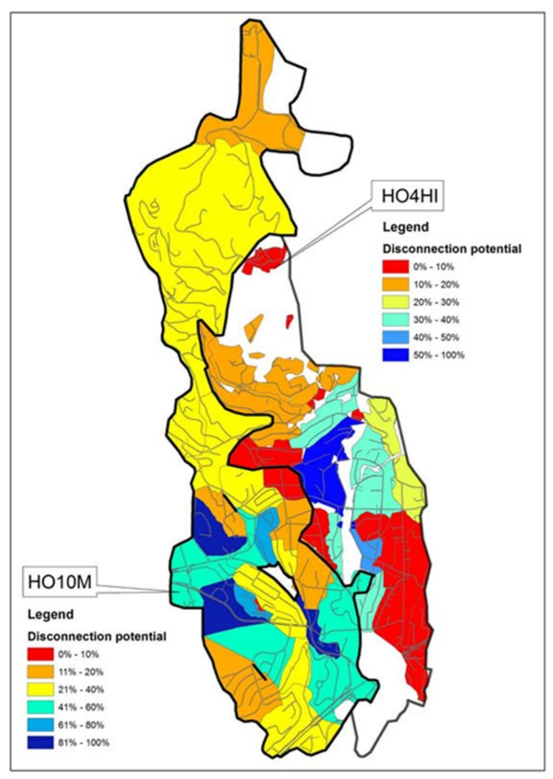


Figure 8: Identified types of streets with different effects on SUDS potential.

The results of the applied methodology show (Figure 9), that the explored potentials of SUDS vary in a wide range within the catchments. Depending on the local conditions the potential area for SUDS differs from less than 10% up to 90%. Sub catchments of very high and very low potentials may be located next to each other.

To obtain reliable results concerning on-site stormwater potentials, an accurate assessment of the criteria mentioned are essential. The average disconnection potential is 19%, however, both the considered catchments have very different potentials for stormwater management. In HO4HI only 12.3% are estimated as potential for SUDS, in HOM10M 25% (Figure 9).



Catchment	Total impervious area (connected to sewer system)	Disconnection potential ha
HO4HI	22.13	2.73
HOM10M	24.2	6.19
Total	**46.33**	**8.92**

Figure.9: Spatial distribution of disconnection potential for catchment HO4HI and HO10M with detail

Building and calibrating run-off model

STORM is a hydrological run-off model. All main components of the hydrological cycle are included. Urban water elements and natural areas can be defined. Thus STORM is able to set up run-off models for complete river catchments. The software is able to calculate both time series and design storm. Originally it was programmed for the design of SUDS. Therefore diverse typologies of SUDS are implemented (swale, green roof, cistern etc.). It is an ideal program to calculate the effects of SUDS to urban water hydrology (and river hydrology).

The STORM model was calibrated to an existing Mike Urban model of the catchment Hoffsvela by comparison of the peak and volume overflow hydrographs of the rainwater overflows for a 2 year design storm (+20%). The deviations were minimized as good as possible. For almost all main devices a good approach of the run-off overflow could be obtained (Figure 10).

In a next step the proposed SUDS had to be designed by the software STORM. The given time series of rain data from Oslo were used for the calculation of the necessary size of SUDS. After implementing the results of the disconnection potential maps into the STORM model, the SUDS scenario (long-term series and design storms; 2-year and 10-year events) were simulated.

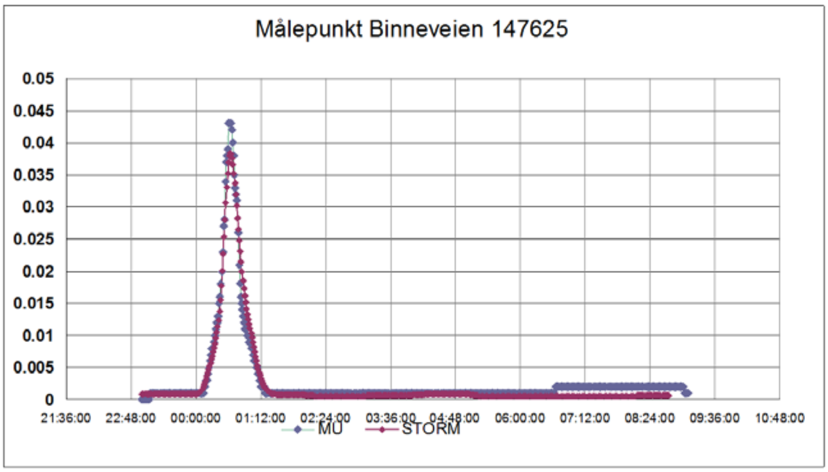


Figure 10: CSO Ho16Ma 2 year rain event (blue: Software Mike Urban, red: Software STORM)

Results and Discussion

The effects of SUDS on the behavior of each rain water overflow (CSO) were calculated. Depending on the location of the CSOs within the sewer system and the amount of disconnected impervious areas, the frequencies, volumes and peaks of the overflows were more or less reduced. The general result is as follows:

In a first comparison of the base- and SUDS scenarios a two-year rain event (design rain +20% due to climate change) was used for run-off calculation. The effects of SUDS are shown in Figure 11. In general, a distinct reduction of the peak overflow is obtained. Some devices don't even overflow in the base-scenario due to lack of characteristic curve (neither in Mouse model nor in STORM model).

The comparison in Figure 10 depicts an average reduction of the peak flow of 31% for all overflows in the SUDS scenario. The variety of reduction for the single overflows is great.

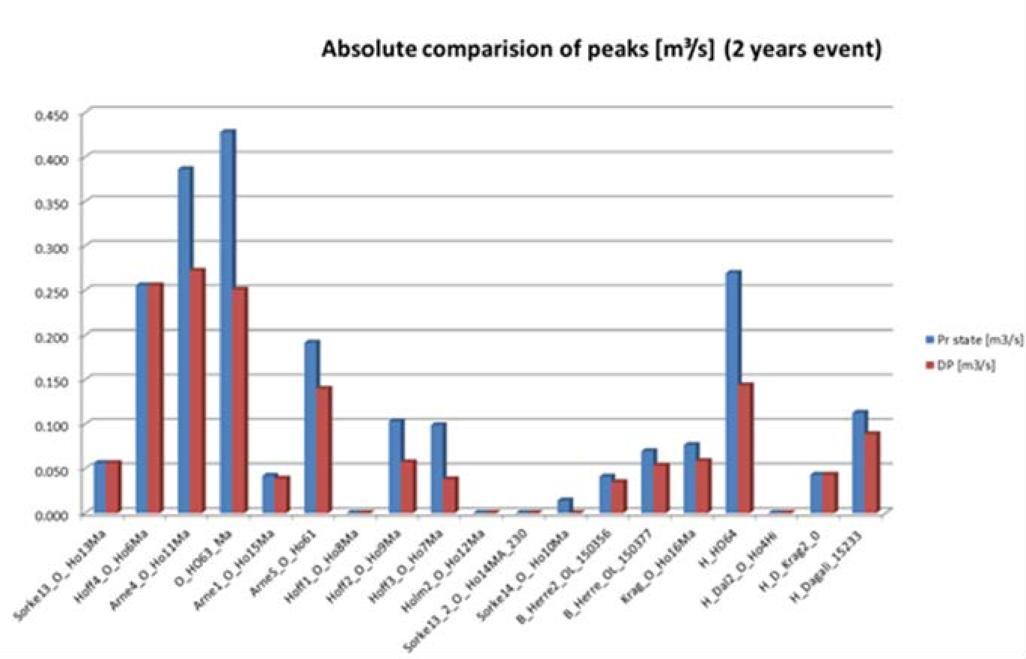


Figure 11: Comparison of peak overflows [m^3/s], 2 years event (blue base scenario; red: SUDS Scenario,)

In a second comparison of the base- and SUDS scenarios the frequencies of CSO overflows were considered. A a long-term series was made (43 years of local rain station).

The SUDS scenario counts 37% less overflows (4999) compared to the base scenario (7988), though the disconnection potential is only 19% (Figure 12). The CSO overflow frequency behaves in comparison to the disconnection potential disproportionately.

The big difference in overflow frequencies of both scenarios can be attributed to many small rain events (compared to rare extreme storm events), which produce overflow mainly in the base scenario, the SUDS scenario shows fewer overflows. During big storm events the CSO takes place in both scenarios, but the peak flows in "SUDS scenario" are distinctly reduced.

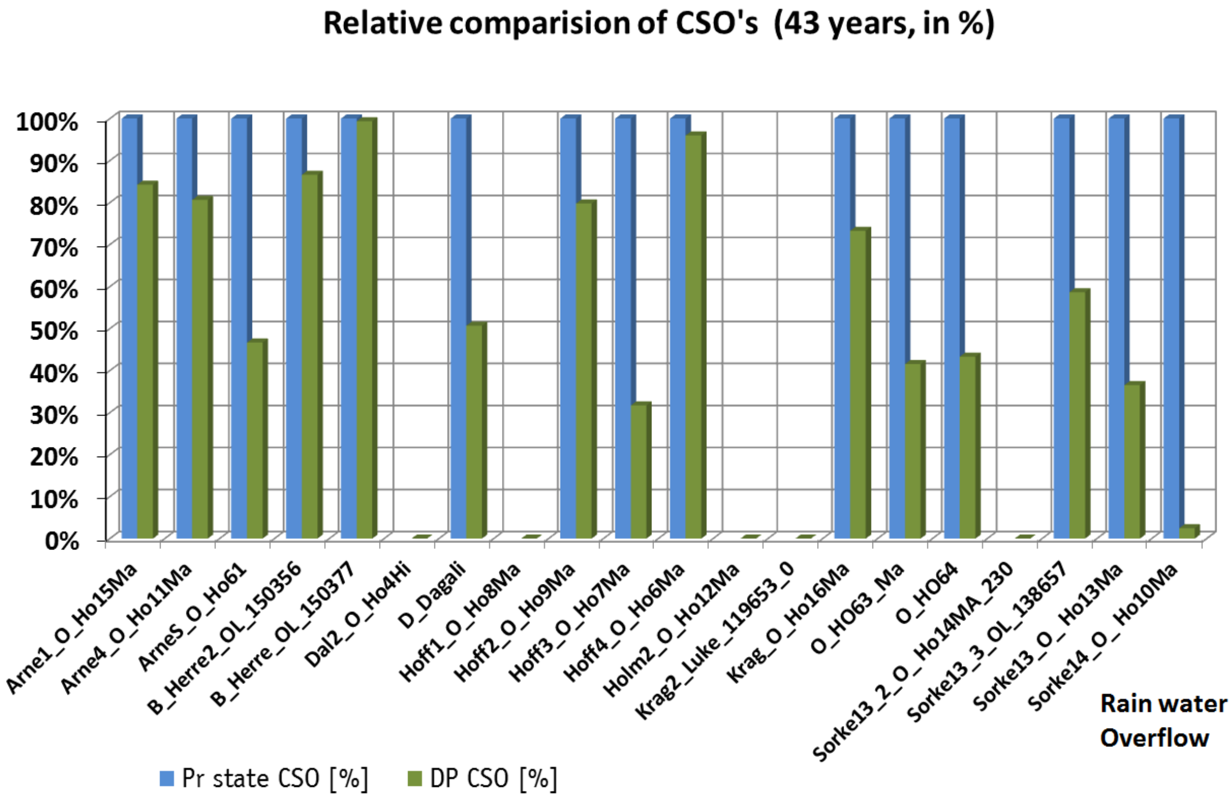


Figure 12: Relative comparison of CSO frequency for base (blue) and SUDS scenario (green)

Conclusion

The investigation of the Oslo Hoffsvela drainage catchment proved that SUDS are a serious alternative to conventional measures. It has been shown that SUDS can be implemented in many parts of the examined area. The two derived maps ("Map of SUDS technique" and "Disconnection potential map"), realized with the explained methods, show that citywide planning of SUDS is possible.

On the one hand side applicable techniques for SUDS for different hydrogeological conditions are available. On the other hand it could be shown there is enough area to disconnect (separate) rainwater from the sewer system and treated by SUDS.

In a long-term perspective it is worth examining the potential of SUDS in urban areas. The consistent application of SUDS leads to many benefits in urban hydrology:

- Run-off peaks, generated by impervious area, can be reduced significantly. Hydraulic stress (overflow frequency) is minimized.

- Run-off peaks in small rivers are clearly reduced
- Combined sewer overflows are disproportionately diminished – less hydraulic stress, less smell
- Urban water balance approaches clearly the natural water balance. Less run-off, more infiltration
- Costs for pipes and construction sites can be noticeably diminished.

The realization of SUDS in a countable number needs time. It is recommended to proof the realization of SUDS in combination with other infrastructure construction sites in the city (i.e. road construction, sewer rehabilitation etc.). Many synergy effects can be achieved.

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Management Tools for Hydro Energy Interventions in Water Supply Systems

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Abstract

There is significant potential for energy recovery through the use of micro-hydropower installations in water supply systems. To exploit the full potential of hydro energy in balance with the optimal hydraulic performance and water supply service, multi-objective management tools are needed. This paper presents the application of four management tools: 1) an energy audit to evaluate the potential hydro energy in the water pressurised systems of Alcoy; 2) multi-criteria decision making methods for the selection of the preferred energy efficient operation of a system with a pump-storage reservoir and hydro-turbines in the Algarve; 3) a numerical dynamic tool for optimal turbine operation in the water distribution of Langhirano; and 4) an urban water optioneering tool to estimate the hydropower potential of the external aqueduct network in Athens. These methods showed that through an integrated approach the water supply systems can be optimised for both hydraulic performance and hydro energy production.

Keywords: hydro energy, multi-objective management tools, water supply system

Lessons learned in designing web-based support tools for urban water management

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Abstract

Organisations have witnessed lately a proliferation of Web-based learning and training tools. These Web-based environments provide a convenient and economic way of overcoming spatial and temporal barriers for organisational learning. Their value and effectiveness, however, is uncertain. In this research, the authors present lessons learned in the development of two web-based tools designed to support urban water management: (1) the Adaptive Potential Self-Assessment (APSA) tool; and (2) the Financial Sustainability Rating Tool (FSRT) for urban water systems. The APSA tool has been developed specifically to help water sector organisations understand and improve their capacity to be adaptive. By doing so, an organisation can learn more from their experiences and adjust management practices as a result of what is learned. The FSRT offers water supply and/or wastewater removal companies an opportunity to rate the utility's financial sustainability. It gives the user an indication, which area from financial situation over asset management to business operation needs optimisation. Both tools were designed using distributed interactive environments. The results of an empirical study highlight the challenges faced in user recruitment and possible solutions for future tool design.

Infrastructure asset management - the TRUST approach and professional tools

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Abstract

Strategic asset management (AM) of urban water infrastructures faces the challenge of dealing with expensive and long lasting assets of very diverse nature, useful lives and costs. Typically, utility managers inherit an infrastructure with assets in assorted conditions and stages in their lifecycle. They are expected to manage their value in order to ensure a service of adequate quality, and make sure that what they pass on to their successors is capable of continuing to do so. Long-term vision is most definitely needed, and sound transition paths must be adopted in order to ensure that urban water services are sustainable, without jeopardizing the quality of the service provided during the transition. Focusing on the transition for more sustainable services, TRUST (www.trust-i.net) revisited the concept of sustainability, explored pressures and drivers, and developed and tested a roadmapping methodology to cope with the implementation of disruptive solutions. Leading-edge analysis and assessment methods and tools were developed, multiple technologies were tested, scientific and guidance publications were produced. All of this can be explored and integrated into a coherent management process. This paper describes the TRUST approach for infrastructure asset management, which addresses strategic, tactical and operational planning, supported by professional-grade software.

Keywords: Strategic planning, tactical planning, long-term, water infrastructures management, decision making.

3.2 Resource/Energy-efficient Urban Water Services

The paradigm shifts and resource recovery from water (Keynote)

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Some 40 years ago, the so-called 'Club of Rome' set out to predict the 'limits to growth' by means of a revolutionary set of computer based models. In those days, it was announced that around the current time period, we would experience major shifts in resource availability. Particularly water and food might become critical. Now 40 years later, we learn that not energy, but climate change and the supply of water and fertilizers for food (edible protein) production are of strategic importance in our thinking patterns. Clearly, we are up for a set of paradigm shifts, particularly in relation to the water cycle. We need to drastically redesign the conventional 'used' water treatment plant so that it becomes a 'biorefinery' in which by means of Good Manufacturing Practices the incoming resources are upgraded to products for which there is a genuine demand. In that respect we propose that treatment plants instead of dealing with 'dissipation' and 'destruction' of what enters, focus on upgrading by means of dedicated short-cycle technologies the inputs to valuable products such as reclaimed water at the one hand and edible feed/food products on the other hand. The IWA has set up a Cluster for Resource Recovery from Water which specifically deals with all aspects of recycling valuable commodities generated in the water business. It actually has participated by means of a White Paper at the World Water Forum in April 2015 in Korea. This Cluster will in the near future make available a Compendium of Best Practices. It will also organize a Resource Recovery Best Award. Moreover, there is 30 aug - 2 sept in Ghent the first IWA Conference on Resource Recovery. For more info, contact the IWA secretariat or check http://www.iwarr2015.org/ or http://bestresourcesfromwater.org

Evaluating new processes and concepts for energy and resource recovery from municipal wastewater with Life Cycle Assessment

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Abstract

Energy and resource recovery from municipal wastewater is a pre-requisite for an efficient and sustainable water management in cities of the future. However, a sound evaluation of available processes and pathways is required to identify opportunities and short-comings of the different options and reveal synergies and potentials for optimisation. For evaluating environmental impacts in a holistic view, the tool of Life Cycle Assessment (LCA, ISO 14040/44) is suitable to characterize and quantify the direct and indirect effects of new processes and concepts. This paper gives an overview of new processes and concepts for upgrading existing wastewater treatment plants towards energy positive and resource efficient wastewater treatment, based upon an evaluation with LCA using data from pilot and full-scale assessments of the considered processes.

Keywords: Wastewater treatment; energy recovery; phosphorus recovery; Life Cycle Assessment

The HAMBURG WATER Cycle® concept as a future urban wastewater treatment & energy service and challenges of its implementation

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Abstract

Within the past years factors such as urbanization, climate change and aging infrastructure facilities became critical parameters for future service provision. As a result, the need for higher energy and resource efficiency in service delivery becomes more and more urgent. The well-known way of replacing aged facilities might not be the right approach to cope with these challenges: a more resilient and adaptable system might become necessary [Hillenbrand & Hiessl 2006]. A promising solution to this problem is to decentralize infrastructure systems. In Hamburg, Germany, the water supply and wastewater utility company HAMBURG WASSER manages to implement the so called HAMBURG WATER Cycle®, a decentralized and integrated infrastructure concept, into the city's existing centralized system. In the new city quarter Jenfelder Au in the eastern part of Hamburg this source control based system is put into practice: rainwater, greywater and blackwater are collected and treated separately on-site and a synergy between wastewater management and energy production is established. With more than 600 connected households and about 2,000 inhabitants the Jenfelder Au currently is the largest demonstration of resource-oriented sanitation throughout Europe.

Keywords: HAMBURG WATER Cycle®; Jenfelder Au; source separation; blackwater digestion; energy generation; challenges; stakeholder

THE HAMBURG WATER Cycle® in the settlement Jenfelder AU

The settlement Jenfelder Au

In 2006 it was decided to transform a former military barracks area into a new housing district – the Jenfelder Au. The area is located in the district Wandsbek in the eastern part of Hamburg, Germany, and covers 35 ha. The urban development plan intends to renew the image of the city quarter Jenfeld from its formerly highly diverse socio-economic mix into a socially sustainable and attractive neighborhood. This is realized by building a combination of living and working spaces in an urban, yet green, context: water and green areas are incorporated into the public space (see fig.1). The concept of *West 8 Urban Design & Landscape Architecture* contains a range of various building types and multiple public spaces and is dominated by the three principles 'Partial Collectivity', 'Clear Individuality' and 'Sustainabilty'. As the area has been neglected by urban planning processes in the past, this emphasis on social sustainability is of major importance. In the Jenfelder Au buildings for living and working, small businesses, restaurants and cafés and retail centers are built to provide a good mix of cultural, social and public functions. The green areas are closely connected to the rainwater management: rainwater is collected in small ditches and led into a cascade that ends in the so-called Kuehnbachteich, a pond that is in fact a retention basin for rainwater with a retention volume of 5,000 m^3.

Figure 1: A part of the city quarter Jenfelder Au seen from above [West 8 Urban Design & Landscape Architecture]

In addition to these architectural and socio-ecological considerations, a new approach to urban wastewater management is implemented in Jenfelder Au: the HAMBURG WATER Cycle® (HWC). Working with source-separation of wastewater streams the HWC closes loops and provides a possibility to not only safe resources but also to generate energy.

The HAMBURG WATER Cycle®

The HAMBURG WATER Cycle® is an innovative and integrated concept for wastewater treatment and energy generation. Based on the different characteristics of wastewater, different treatment processes can be applied. The main differentiation can be made between blackwater (toilet wastewater that contains urine and faeces), greywater (the wastewater from kitchens and bathrooms) and rainwater [Schonlau et al. 2008].

The household wastewater flows are separated directly at their source. The concentrated blackwater is collected via negative pressure toilets and a tailor-made negative pressure pipe network and led to the work yard of HAMBURG WASSER, which is located in the new settlement, for further treatment. Together with additional biomass the blackwater is digested anaerobically to produce biogas that can be used for the generation of heat and electricity. As a result, a part of the settlement's energy demand can be covered using the energy produced from blackwater. Besides the positive effect of energy generation, the collection of blackwater by means of negative pressure technology is an efficient way of using valuable drinking water: a negative pressure toilet only needs about 1 liter per flush where a conventional one needs approximately 6 liters. This could be a crucial factor especially in regions where water resources are scarce.

The lighter polluted greywater, which is produced in larger volumes is being collected in a gravity sewer system and also led to the work yard of HAMBURG WASSER where it is treated. The rainwater is collected separately and used for landscape architecture and led back into the natural water circle afterwards (see fig.2).

In addition to these features other benefits of the HWC such as nutrient recovery and water recycling are going to be investigated within the associated research project KREIS – Kopplung von regenerativer Energeigewinnung mit innovativer Stadtentwässerung (linking renewable energy production with innovative urban wastewater drainage) but are not implemented in Jenfelder Au. KREIS receives funding from the German Federal Ministry of Education and Research. Furthermore the project is funded by the EU Life+ program and the Federal Ministry of Economics and Energy.

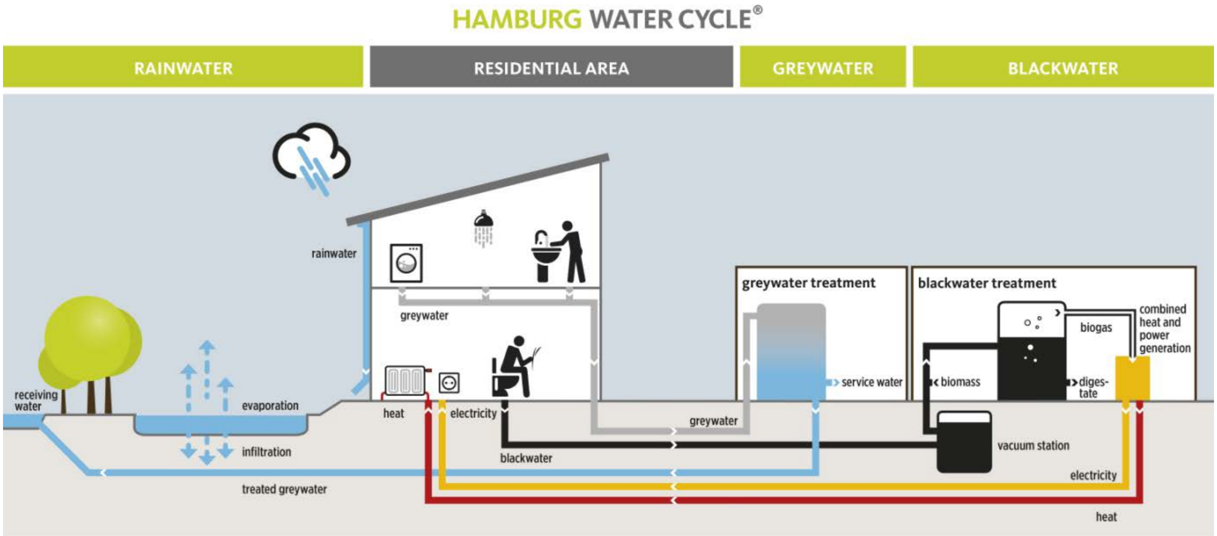

Figure 2: The concept of the HAMBURG WATER Cycle® [HAMBURG WASSER]

During the planning and the beginning construction process it could be found that a successful implementation of the project is dependent on several technical and non-technical factors such as the setting of the legal framework, finding the best layout for a reliable negative pressure system or the motivation of various stakeholders.

Optimization of the blackwater negative pressure network

So far HAMBURG WASSER has extensive experience and knowledge in the construction and operation of gravity sewers. The negative pressure system implemented in Jenfelder Au is an innovation within the company, thus HAMBURG WASSER was dependant on external knowledge and experiences as references for the planning and construction of the negative pressure pipe network meant to be used in Jenfelder Au. The ambition to build a customer-friendly, highly reliable large-scale blackwater negative pressure system led to a combination of the external references with several tailor-made in house innovations [Skambraks et. al. 2014]. The latter have been subject to extensive planning and testing.

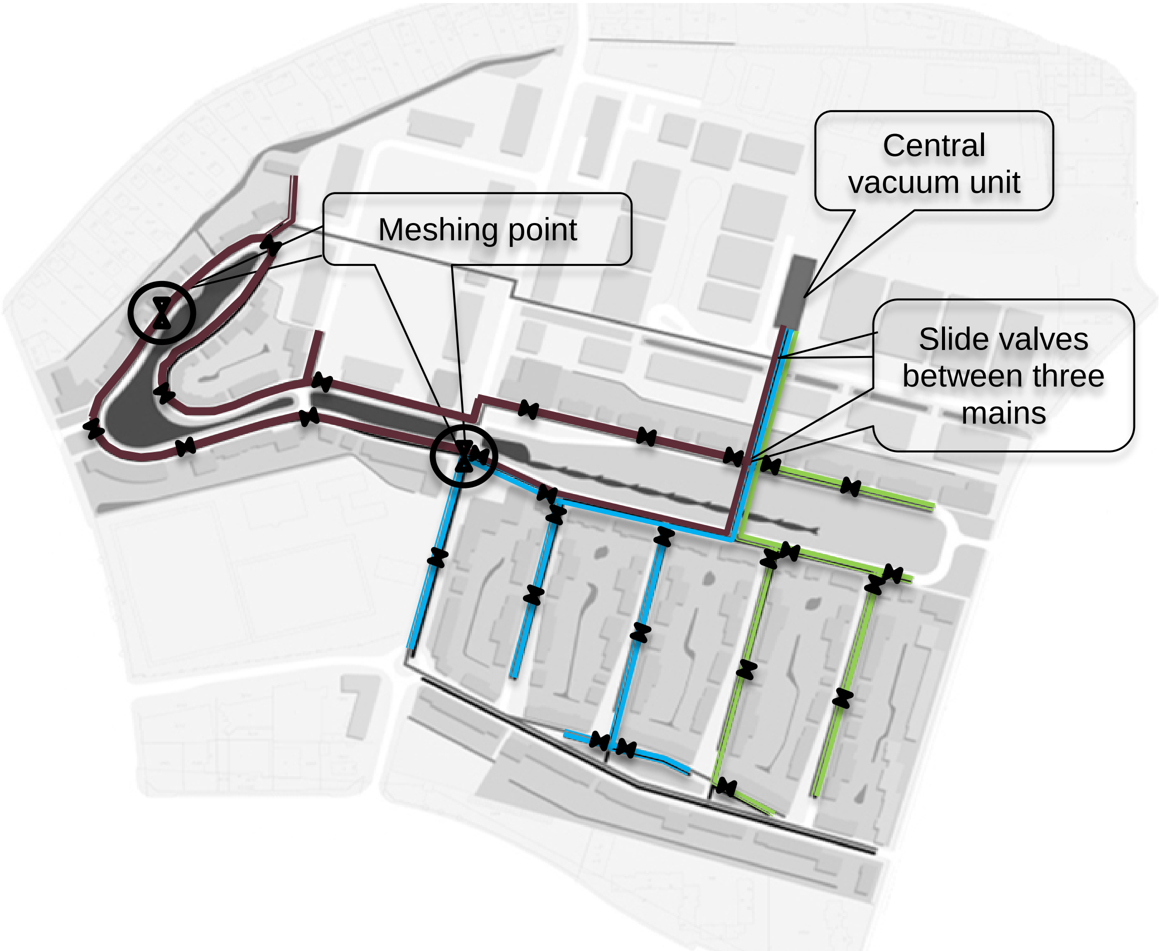

Figure 3: Network design of the blackwater negative pressure system in Jenfelder Au [HAMBURG WASSER]

To ensure a high reliability of the pipe network it is constructed in saw-tooth profile including slope and leaps [DWA 2008]. Furthermore, the main pipelines are constructed with a redundancy of 20 % and with gate valves approximately every 50 meters within the sewer system. In case of blockages in one of these pipelines it is possible to close the particular gate valves and to dewater the whole settlement via the remaining pipelines – even against the flow direction and the incline- by using the connections between the different sub networks. (see figure.3).

Besides the aim of the construction of a high reliable system it was a major aim to create a network with a high level of maintainability and flexibility in everyday operation. A solution to that is given by the implementation of revision chambers along the whole pipe network every 20 to 50 meters. Like this every part of the system can be accessed easily for maintenance or inspection purposes.

In addition to the features realised for the network construction, general provisions for a continuous generation of negative pressure will be made. That is why the negative pressure station – two negative pressure tanks each with three vacuum pumps – will be built with a redundancy of 100 % to ensure a smooth operation of the negative pressure network: at any point and time a low pressure of -0.3 bar is guaranteed within the whole settlement.

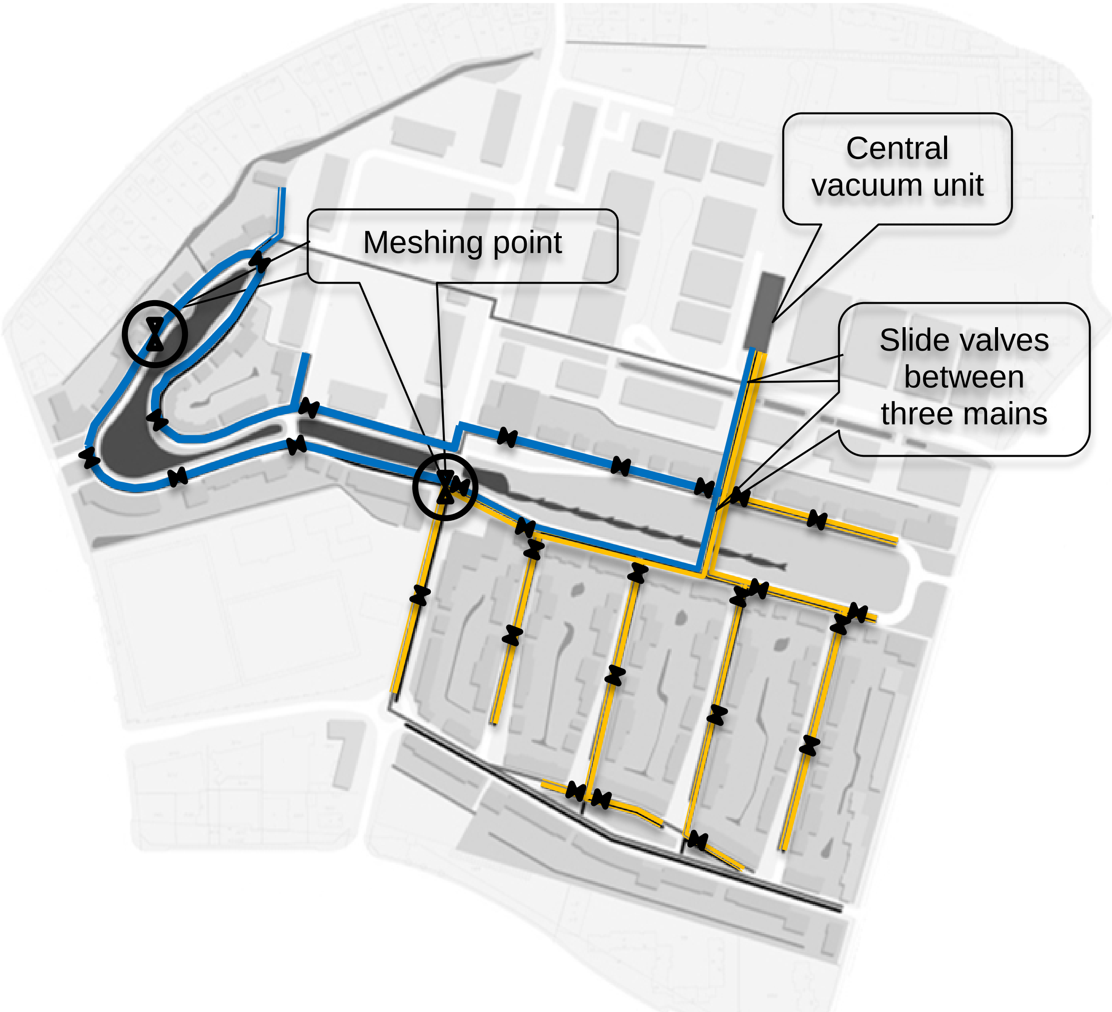

Figure 4: The two sub networks of the blackwater negative pressure system in Jenfelder Au [HAMBURG WASSER]

As the comparably small area of the settlement Jenfelder Au holds a strongly different altitude profile, the areas with different heights go along with different hydraulic pressure drops. To ensure a low pressure of -0.3 bar in the whole settlement the pressure generated by the negative pressure station would need to be -0.7 bar. This would result in comparably low pressures of about -0.6 bar in the areas of the settlement that are located higher than the deepest point [Giese et. al. 2014]. In addition the energy consumption of the system and the noise emissions in the various households would be higher. As a consequence the blackwater negative pressure network in Jenfelder Au will be operated with two different pressure zones (see fig.4), which ensures to achieve minimal hydraulic pressure drops within the different areas. On the one hand it will result in a reduction of the energy consumption of the vacuum station. On the other hand this kind of operation will reduce noise disturbances at the vacuum toilets and increases customer satisfaction.

Legal interfaces

Until now wastewater drainage within the Free and Hanseatic City of Hamburg was conducted using gravity sewers and pressure sewers. Both systems collect the wastewater and subsequently transport it to one central treatment plant. The legal framework for the operation of these two drainage types is set by the current wastewater bylaw of Hamburg (HmbAbwG). As the negative pressure drainage system in Jenfelder Au is an innovation, it was necessary to adapt the legal framework: the concept of the separate collection of greywater and blackwater directly at their sources within the households had to be introduced to the HmbAbwG. Because the process is still ongoing the HWC became as well a mandatory measure for all newly built houses in Jenfelder Au [Skambraks et. al. 2014]. This fact includes the existence of parts of the negative pressure system that are located on private ground and thus are not in the area of influence of HAMBURG WASSER (see fig.5). To cope with this dependency on components of the negative pressure system on private ground, a shut-off ball valve is installed at every house connection located in the public space. In case of a leakage within the network on private ground, the housing unit can be disconnected from the system until the leakage is closed again. The rest of the negative pressure system can be operated normally. To be able to conduct maintenance or cleaning processes an inspection chamber for the blackwater negative pressure pipe is installed on private ground. These features allow HAMBURG WASSER the operation of the negative pressure network with a certain independence from the private components.

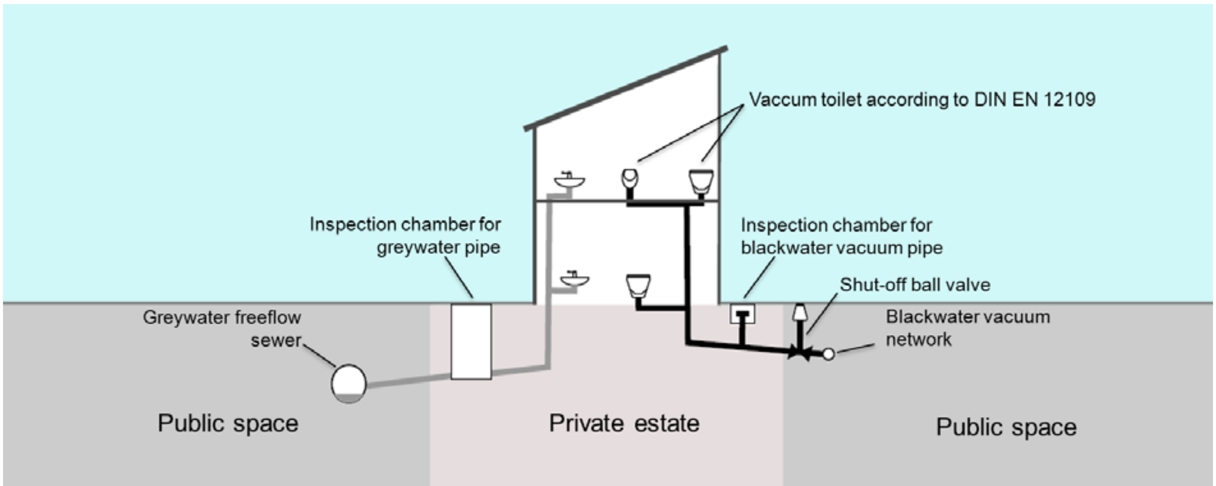

Figure 5: Private and public components of the drainage system in Jenfelder Au [HAMBURG WASSER]

Stakeholder interfaces

During the implementation of a new decentralized and integrated infrastructure concept into an already existing centralized system, various interfaces to several groups of stakeholders arise. Because it has been found that a disregard of stakeholders and a lack of communication can put a whole project at risk [Telkamp et. al. 2009], the success of a project is strongly dependant on the acceptance of the various stakeholders involved. Furthermore, the different opinions and expectations of the different stakeholders can result in a conflict of interest. It is therefore of major importance to publicise information about the innovative infrastructure concept as well as to integrate the communication with stakeholders and their participation into project implementation.

As the level of innovation of the HWC concept still results in scepticism among the stakeholders involved, HAMBURG WASSER focuses on stakeholder-tailored communication to keep the project on track until its operation begins. In order to understand the individual objectives of the involved parties a stakeholder analysis was conducted. Based on the results HAMBURG WASSER developed communication methods fitted to meet the needs of the various stakeholders.

In addition to project brochures, flyers, newsletters and a project website a permanent on-site exhibition have been brought to life to intensify the communication with the public and possible future inhabitants of Jenfelder Au. The decentralized and integrated infrastructure project HAMBURG WATER Cycle® in the Settlement Jenfelder Au was awarded with several prizes and external funding including the VKU Innovation Prize 2013 from the Association of municipally determined infrastructure undertakings and economic enterprises Germany and Landmark in the Land of Ideas (sponsored by Deutsche Bank). Furthermore it has been IBA REFERENCE Project by the International Building Exhibition IBA Hamburg in 2013. These awards help to procreate trust in the innovative project HAMBURG WATER Cycle® among stakeholders and the public in general.

Very important stakeholders during the implementation of the new infrastructure project are architects, technical planners for plumbing or building as well as services engineers. To create a reliable and trustworthy negative pressure sewer system, it is absolutely important to guarantee that all stakeholders, who are involved into the construction process, have the information needed. It is imperative that the technical planners appreciate the special features of the new sanitation system and the consequences it may have if something is not working the right way. Furthermore investors have to trust the negative pressure sewer system. Because of that a manual for negative pressure technology was prepared by HAMBURG WASSER and the Hochschule Ostwestfalen-Lippe supported by the above mentioned associated research project KREIS, containing recommendations for the planning and installation of high-quality negative pressure networks [Oldenburg et. al. 2015]. It substitutes the current requirements to look for technical information at various sources, such as DIN standard documents and individual installation guideline of the different vaccum network vendors. In addition technical counselling for architects, technical planners and engineers are offered in regard to the negative pressure technology and its special requirements on installation and noise insulation.

Conclusion

The innovative and decentralized wastewater and energy concept HAMBURG WATER Cycle® is based on source separation and efficient treatment of the different wastewater streams in households. By combining urban water and waste treatment with local energy production the HWC will contribute significantly to the sustainability of the new settlement Jenfelder Au. With more than 600 connected households for about 2000 inhabitants the HWC inside Jenfelder Au will be the largest resource-oriented sanitation project in Europe. This innovative concept is a lighthouse project and can be held up as an example for other projects in the water sector.

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SEMIZENTRAL (infrastructure solution for fast growing cities) - From scientific approach to implementation

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Abstract

The rapidity of urban growth, usually associated with regional water scarcity, represents a particular challenge for infrastructure planning. Intra-urban water reuse can contribute significantly to increasing local water availability. Water reuse protects valuable resources and reduces energy consumption, compared to alternative water sources, such as long-distance transportation or seawater desalination. SEMIZENTRAL is an approach to an energy- and resource-efficient solution for water supply and treatment systems in fast growing urban areas, enabling multiple water reuses. The approach has been realized, for the first time in full-scale, in Qingdao (P.R. China). Due to water reuse, the amount of water and, consequently, the load of pollutants discharged to the waterbody are reduced. The

comparison of calculated electric energy consumption and expected electricity production from biogas shows that energy self-sufficiency can be reached, depending on the amount of biomass treated and the applied technology and effluent standards.

Keywords: Water reuse; integrated infrastructure systems; energy efficiency

Introduction

Urbanization is one of the most important trends in the 21st century, resulting in challenges related to infrastructure development. According to the UN (2014), until the year 2050, the global urban population will rise to nine billion people. In industrialized countries, urban growth occurred over a longer period; therefore, it was possible to plan and adequately realize the (on pipes based) necessary infrastructure. Current urban growth is much faster than that of the industrialized countries; the population of Shanghai, for example, increases by 67 people per hour (UN, 2011). Assuming a specific water demand of 132 L/(C·d), the water demand increases by 200 m3 every day. Thus, every year, 77,000 m3/d water has to be supplied additionally and the resulting wastewater has to be treated. The strong dynamic of population growth produces new challenges for the planning and realization of (physical) infrastructure within short time frames. Furthermore, in fast growing urban areas, local water resources are currently not sufficient for the supply of the local population in highly densified urban areas. In Beijing, for example, the over use of ground water has led to an extreme drop of the ground water table by more than 10 m since 1986 (Sun et al., 2014). Widespread solutions, such as long-distance water transport or seawater desalination, are ecologically questionable and very energy intensive. Therefore, new infrastructure solutions are needed; water reuse as an energy saving alternative will be increasingly important, in the future, to ensure water supply. Moreover, systems must be flexible and adaptable to the fast development of cities.

In this context, the SEMIZENTRAL approach, a resource-efficient infrastructure solution, has been developed. SEMIZENTRAL integrates the sectors wastewater treatment, water supply, and waste treatment (e.g., Bieker et. al, 2010, Bieker et al. 2012). Depending on the technical realization, multiple water reuses, e.g., as service water for toilet flushing followed by reuse as intra-urban irrigation water, can be achieved. By integrating biowaste, energetically self-sufficient operation of the treatment plant, the so-called semicentralized Resource Recovery Center (RRC), is possible. The recommended size of semicentralized systems serves several 10,000 inhabitants and is, thus, much smaller than centralized but much larger than household-based decentralized systems. The size of such city-quarter-related, nodal, growth-adapted RRCs is defined by requirements of increased resource efficiency, flexibility, and adaptability, as well as by professional operation (Bieker et al., 2010). Water reuse fosters semicentralized structures, in which the used water is treated close to the user, thus saving energy for water conveyance and allowing heat recovery, e.g., from comparatively warm greywater. Because smaller systems are more flexible and can be realized according to the current demand, they reduce planning and investment risks resulting from the long time horizon for planning and realization. In addition, a professional operation of water supply and treatment systems is essential to ensure public health and environmental protection. Household-based decentralized systems cannot be operated by professionals, because professional operation requires a minimum size to be economically feasible.

Methods

The first full-scale Resource Recovery Center (RRC) was implemented in Qingdao (China), in 2014, within the framework of the World Horticultural Exposition (WHE). Based on data from Qingdao, the general concept SEMIZENTRAL was adapted for the actual location. SEMIZENTRAL is, fundamentally, an open-process approach: the choice of process technology depends on local conditions. Hereby, “fit for purpose” is the basic principle. In accordance with the German draft standard DWA-A 216, “Energy check and energy analysis – Instruments for energy optimization of wastewater treatment plants”, a plant-specific optimal value for energy consumption of the RRC in Qingdao has been calculated, based on physical principles and empirical values given in the standard. The standard does not provide information for the waste pre-treatment; thus, assumed nominal power and assumed operation times for the machines are used to calculate the energy demand. The basis for the calculation is the machinery list of the RRC in Qingdao ShiYuan. All the main electricity consumers were taken into account, whereas smaller consumers, such as the MSR technique or light, were neglected.

Results and discussion

Realization of the first Resource Recovery Center in Qingdao, PR China

The catchment area of the RRC consists of the ShiYuan-Village (3 hotels, guest houses, canteens, and office buildings) and two residential areas (Bijia A and Bijia C) that are located near the WHE exhibition area. Another residential area will be developed and connected to the RRC within the coming year. Greywater from showers, wash basins, and washing machines and blackwater from toilets and kitchen sinks of around 12,000 inhabitants within the catchment area is collected separately. Treated greywater will be used for toilet flushing within the ShiYuan-Village as well as in a future residential area. It was estimated that reuse water from greywater might be better accepted by the consumers, due to its lower fecal contamination. The treated blackwater will be used for irrigation purposes in the ShiYuan-Village. Thus, a multiple reuse, e.g., shower → toilet flushing → irrigation, was designed. Furthermore, collecting and treating biowaste from the households within the RRC catchment area was initially planned.

At present, the residential areas Bijia A and C are not being supplied with service water. The food waste from hotels and canteens from the ShiYuan-Village and nearby areas will be anaerobically co-treated within the RRC. The produced biogas will be used to generate heat and electricity, which will be used within the RRC. The integration of the biowaste treatment enables a calculatory self-sufficient operation of the RRC. Figure 1 illustrates the material flows within the semicentralized supply and treatment system in ShiYuan-Village of

Qingdao. To minimize possible nuisances, all treatment units are located indoors (see Figure 2) and an elaborated waste air treatment for immission control has been realized.

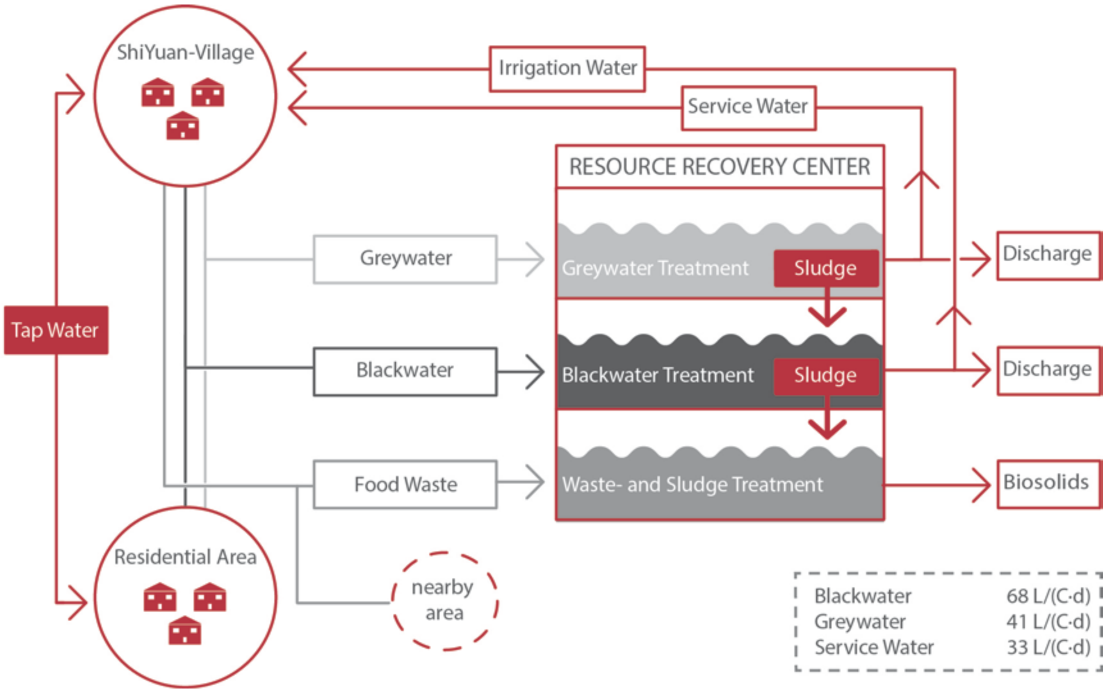

Figure 1 Material flows of the semicentalized supply and treatment system in Qingdao

Process design of the RRC in Qingdao

The RRC in Qingdao consists of four modules that are located in different parts of the building (see Figure 2).

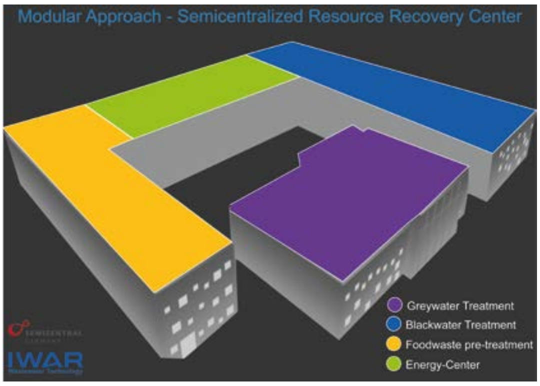

Figure 2 left: modular structure of the RRC in Qingdao (author's illustration), right: RRC in Qingdao (©Gehrmann)

Greywater Treatment: An inhabitant-specific greywater flow of 41 L/(C·d) was estimated by Bi (2004) For the hotels, the guest-specific wastewater amount is assumed to be 300 L/(C·d) for the 5-star hotel and 150 L/(C·d) for the 3-star hotel. Thus, the greywater treatment is designed for 17,500 population equivalents (PE) with respect to hydraulics, whereas 12,000 PE are assumed for the loads. Water reuse requires high hygienic standards and, depending on reuse purposes, a multi-barrier approach. Therefore, an MBR with downstream disinfection has been chosen. The mechanical pretreatment consists of a 1 mm sieve for the removal of fibrous substances, such as hair. To equalize the wastewater influent flow and load, and to balance the service water production and use, a pre-storage as well as a post-storage tank has been built. Because of the low nitrogen influent concentration, only carbon removal is required. Nevertheless, a sludge age of 25 d has been chosen to minimize membrane fouling. For both, greywater and blackwater treatment, Bio-Cel flat sheets modules from Microdyn-Nadir are used; the manufacturer recommends a sludge age between 15 and 25 d. According to the Chinese reuse standard (GB/T 18920-2002), chlorination of the service water is necessary. An option for heat recovery from greywater has not been realized in Qingdao ShiYuan.

Blackwater Treatment: The treated blackwater is partly reused for irrigation. Hence, high hygienic requirements for water reuse have to be fulfilled and an MBR system was also chosen. The process water from sludge dewatering is pretreated with the anammox process and then discharged into the blackwater influent pumping station. If there is a disturbance in the deammonification process, the total nitrogen load can be eliminated in the blackwater module by adding acetate for denitrification, because the C/N ratio is low, due to the separation of greywater from blackwater. The blackwater treatment consists of a pre-storage tank, followed by screen, grit chamber and pre-clarifier, and a 1 mm sieve as mechanical pretreatment. An advanced nutrient removal is necessary to reach the legal limits of 15 mg/L TN (GB/T 18918-2002). The blackwater is treated by pre-denitrification, followed by a post-denitrification step with acetate dosing, if necessary. The chosen sludge age is also 25 d. Phosphorus is removed by two-point-precipitation, to reach the limit of 0.5 mg/L for TP. In case the MBR effluent is colored, it can be filtrated by activated carbon, prior to disinfection with sodium hypochlorite. The post-storage tank is used to equalize demand and production of irrigation water as well as to ensure the availability of water for firefighting (for RRC).

Foodwaste pre-treatment and Energy Center: It was not possible to implement co-treatment of household biowaste in Qingdao. Instead, sludge is co-digested with food waste from hotels and canteens within the ShiYuan-Village as well as from nearby areas. The requirements for food waste pre-treatment differ from those for biowaste, e.g., in the method of disinfection. In China, there is currently no regulation for the disinfection of food waste; therefore, the planning was oriented to the European regulation (EC) No 1774/2002. According to this regulation, anaerobic thermophilic digestion (50°C) with a hydraulic residence time of 20 d is sufficient for hygienization of biowaste. Food waste, by contrast, has to be treated at 70°C for one hour. Accordingly, the pretreatment of food waste consists of an additional hygienization step, after the drum sieve and shredder. After the pre-treatment, food waste is mixed with sludge in the raw sludge storage tank. The co-digestion takes place in two parallel digesters. These have a rectangular base, to realize a small footprint. The digesters are mixed by recirculation pumps. The digested sludge is dewatered with a chamber filter press. The biosolids can potentially be used for landscaping or post-treated by composting.

Impacts of source separation

Due to the source separation (greywater/blackwater), the wastewater characteristics differ from those of conventional treatment plants. Infiltration water can be neglected, due to the short distance to the treatment plant and a large proportion of pressure pipes in the sewer system. This results in influent concentrations to the RRC given in Table 1; the assumed influent concentration to the blackwater module is considerably higher than the usually measured influent concentrations for wastewater treatment plants in China (see Qiu et al., 2010 in Table 1). However, the inhabitant specific loads are in the range of the loads given by the Chinese standard GB 50101-2005, which is the basic for the planning of wastewater treatment plants. According to the Chinese standard GB/T 50331-2002, the water consumption lies between 85 and 140 L/(C·d) in Shandong Province. For the year 2012, a water consumption of 110.6 L/(C·d) can be calculated (China Statistics Press, 2013). For the design of the RRC, 109 L/(C·d) are assumed, with 68 L/(C·d) for blackwater and 41 L/(C·d) (Bieker et al., 2010).

Table 1 Influent characteristics – comparison of basic data for RRC Qingdao and literature values for China

	ACCORDING TO GB 50101-2005	BASIC DATA RRC QINGDAO			MEAN VALUES IN CHINA (QIU ET AL., 2010)	BASIC DATA FOR RRC QINGDAO		
		total	greywater	blackwater		total	greywater	blackwater
	load g/(C·d)				concentration* mg/L			
COD	-	100	12.3	87.7	300-440	783	206	1290
BOD	25-50	50	4.9	45.1	-	391	82	663
SS	40-65	65	10.3	54.8	-	508	171	805
TN	5-11	11.3	0.3	11	34-40	88	5	162
TP	0.7-1.4	1.56	0.16	1.4	4-5.4	12	3	21

* greywater: calculated with 41 L/(C · d), hydraulic populati
blackwater: 68 L/(C · d)
total (greywater + blackwater): 68 L/(C · d) + 41 · (17,500/12,000) L/(C·d) = 128 L/(C·d)

Process technology: For blackwater, in particular, the elevated influent concentration leads to high required elimination rates, e.g., > 91 % for nitrogen removal. In case the deammonification process is disturbed, the influent nitrogen concentration to the blackwater module increases up to 205 mg/L and up to 190 mg/L to the activated sludge tank (after pre-clarification and sieve). This corresponds to a required denitrification efficiency of > 96 %. Various concepts for denitrification were considered: simultaneous, intermittent denitrification, and pre-denitrification. Simultaneous denitrification is not possible under the given conditions. To reduce space requirements, the activated sludge tank is planned with a relatively high water depth and low base area. For the chosen tank geometry, the aeration density would have been very high during times of maximum nitrogen load, leading to a bubble wall. Under this condition, it would have been impossible to implement the circulation flow necessary for simultaneous denitrification. Pre-denitrification is not advisable for the high level of required denitrification efficiency: an internal recirculation that is 22.7 times larger than the influent flow is necessary. This would mean a massive relocation of oxygen from the nitrification tank into the denitrification tank, possibly limiting the denitrification process. Moreover, it can lead to an increased aerobic degradation of easily biodegradable organic substances in the denitrification step, increasing the required external organic carbon dosage by about 5 %. For intermittent denitrification the cycle time would be 1.2 h and values under 2 hours are not recommended (ATV-DVWK, 2000). Cascade denitrification with influent distribution is possible but was not chosen because of the higher requirements for automation. In the end, a combined pre- and post-denitrification has been implemented (see Figure 3). An oxygen concentration near the saturation concentration in the filter chamber is expected. Hence, the return sludge is pumped to the nitrification tank, so that the oxygen is used for aerobic degradation. Therefore, the aeration of the nitrification zone might be reduced. Moreover, a limitation of the denitrification, due to high oxygen concentrations, is avoided. An internal recirculation between nitrification and pre-denitrification is needed not only for the transfer of nitrate but also for activated sludge. The sludge concentrations in the pre-denitrification and in the nitrification chamber will differ. The C/N ratio in the influent is relatively low; therefore, dosage with an external organic carbon source would probably be needed, in any case.

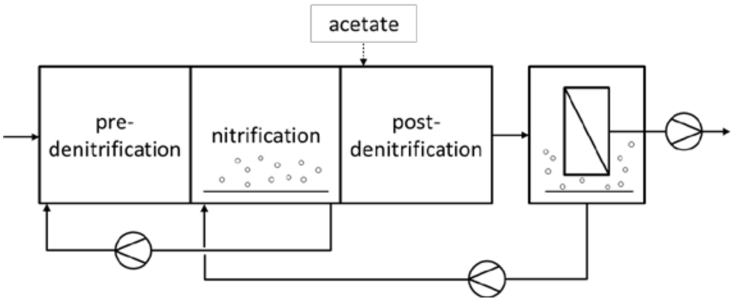

Figure 3 Process scheme of blackwater denitrification in RRC Qingdao ShiYuan

Discharged nitrogen load: Within the semicentralized supply and treatment system, the total amount of discharged water is reduced by water reuse. Moreover, the legal limits for effluent quality are given as a maximum pollutant concentration. This means that pollutant discharge to the receiving water body is reduced (see Figure 4). To evaluate the advantage of the semicentralized system in Qingdao ShiYuan, it is compared to the conventional system with the same inhabitant specific wastewater flow and loads. Two process schemes for the conventional system are calculated. Conventional system I has the same process technology as the blackwater module and includes an anaerobic digestion (without co-substrate). This allows an evaluation of the impacts of the chosen material flows (source separation, co-substrate). For conventional system II, anaerobic sludge digestion is not assumed, because this is currently not common in China's wastewater treatment plants. Hence, there is no pre-clarification but rather simultaneous aerobic sludge stabilization. For the conventional system (I+II) and the blackwater treatment, the total nitrogen (TN) effluent load is calculated with an effluent concentration of 14 mg/L, which was assumed for the design calculation.

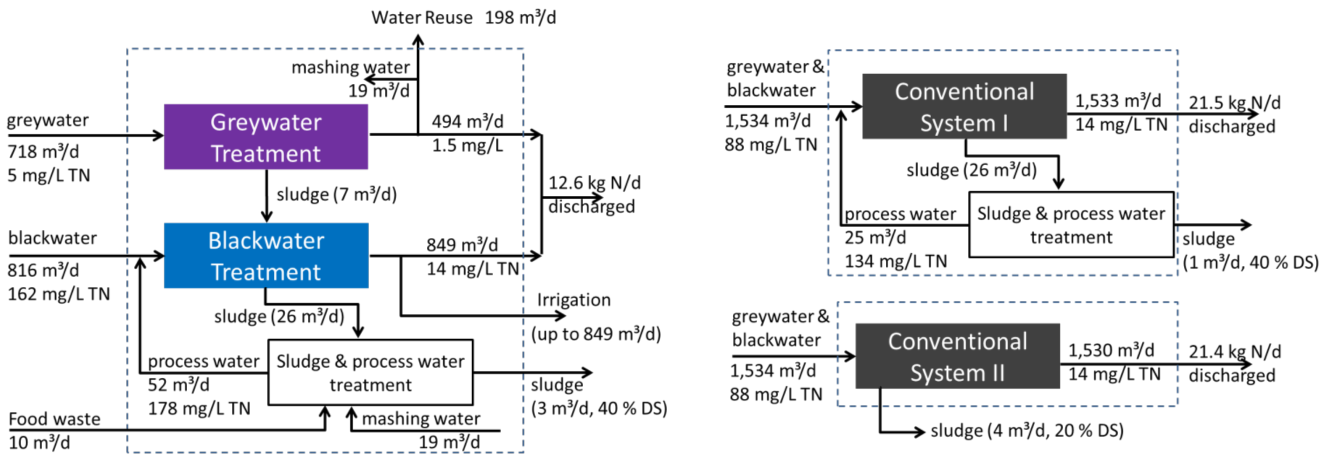

Figure 4 Comparison of discharged nitrogen load for the RRC Qingdao ShiYuan and for a conventional system

Greywater includes only wastewater streams from showers, wash basins and washing machines, whereas the nitrogen rich streams from toilets and kitchen sinks are collected as blackwater. Hence, the greywater influent to the RRC Qingdao ShiYuan is expected to already fulfill the legal limit for TN (15 mg/L GB 18918-2002). Following biological treatment, this leads to a very low effluent concentration of 1.5 mg/L TN. The reduction of TN in the greywater treatment is calculated as biomass intake; denitrification does not take place.

Compared to the conventional system (I&II), the calculated discharged nitrogen load of the RRC is 40 % lower. The load will be reduced further when treated blackwater is used for irrigation. This results, in part, from the smaller amount of discharged water. However, nitrogen is concentrated in blackwater, leading to considerably higher concentrations and, therefore, to increased requirements for nitrogen removal efficiency. In the RRC, 91 % (132 of 145 kgN/d) of the nitrogen load is removed (denitrified or bound in sludge), whereas, in the conventional system I and II, 85 % (117 of 139 kgN/d) and 84 % (114 of 135 kgN/d), respectively, is eliminated from the water phase. Higher influent TN loads to the wastewater treatment in the RRC and conventional system I are the result of return loads due to the process water from sludge treatment.

The higher removal rate in the semicentralized system leads to greater treatment efforts, compared to treatment within conventional systems. Due to the source separation, the C/N ratio in blackwater is low; the effect is increased by the nitrogen-return load in the process water. Compared to the conventional system, the nitrogen-return load is higher in the RRC, due to the co-digestion with food waste (see Figure 4). The blackwater treatment, as well as the wastewater treatment in conventional system I, includes a pre-clarification (with pre-precipitation). This further reduces the C/N ratio in the influent to the biological treatment. For blackwater treatment, as well as for wastewater treatment in conventional system I, dosage with an external carbon source is necessary (see Table 2). For blackwater, the ratio of nitrate ($NO_{3,D}$), which has to be denitrified, to BOD is higher; thus, more COD has to be dosed. Although the higher nitrogen-return load increases the effort for blackwater treatment, the co-digestion with food waste results in a noticeably higher production of electricity (more than 6 times higher than in conventional system I). For conventional system II (without pre-clarification), the available BOD is sufficient for denitrification. However, the higher load to the biological treatment step leads to a considerably higher required activated sludge tank volume ($V_{biol.}$) and a greater demand for air (Q_{air}).

Table 2 Comparison of semicentralized RRC with conventional systems (12,000 PECOD,100)

		SEMICENTRALIZED RRC		CONVENTIONAL SYSTEM	
		greywater	blackwater	I (anaerobic sludge treatment)	II (aerobic sludge stabilization)
$COD_{influent,biol.}$	mg/L	185	807	493	783
$TN_{influent,biol.}$	mg/L	5	149	81	88
$NO_{3,D}$/BOD		0	0.34	0.27	0.14
COD_{dosed} [1)]	kg /d	-	290	203	-
Q_{air}	Nm^3/d	52	640	628	827
$V_{biol.}$ (required)	m^3	199	759	800	1,806
electricity production [2)]	kWh/d	3,188		502	-
discharged TN load	kg/d	0.7	11.9	21.5	21.4
discharged TP load	g/d	163	280	506	505

[1)] calculated according to ATV-DVWK A-131E with 5 kg COD/kg$NO_{3,D}$

[2)] with 420 L biogas/kg oDS for sludge, 720 L biogas/kg oDS for food waste, 6.5 kWh/m3 biogas, $\eta_{el.}$ 35 % for CHP

To reduce the needed COD dosage for denitrification, the (partial) by-pass of the pre-clarification for blackwater treatment should be considered. This will be examined during operation of the RRC in Qingdao, and a final decision will depend on the actual blackwater composition, the N return load and the removal efficiency of the primary clarifier.

Energy balance

The flow-specific electric energy demand of blackwater and greywater treatment is given in Figure 5. Considerably more energy is needed for the blackwater treatment, due to higher pollutant loads, especially of nitrogen. For greywater, nitrification is not needed, and even the COD load is low; thus only 5 % of the energy for greywater treatment is used for the oxygen supply (see Figure 5). Due to oxygen transfer with the return sludge from the external filter chamber to the activated sludge tank, the required aeration might be further reduced. However, the low level of aeration is not sufficient for thorough mixing of the aeration basin and additional mixers are installed.

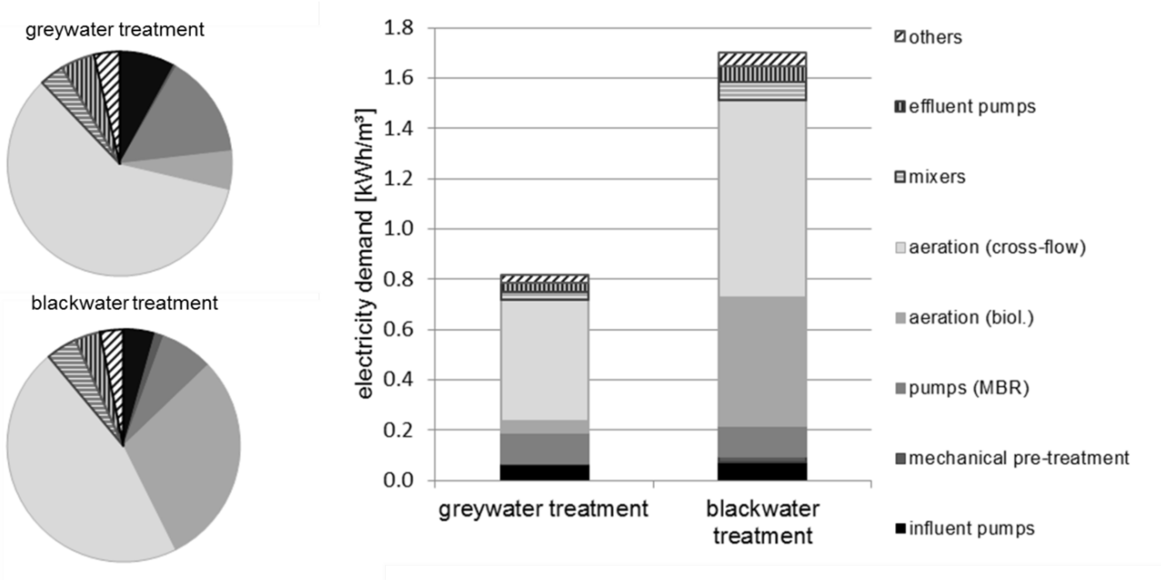

Figure 5 Electricity demand and its distribution for black- and greywater treatment in the RRC Qingdao ShiYuan

The flow-specific energy demand for cross-flow aeration of the greywater module is approximately 40 % lower than that for the blackwater module. This is due to a higher flux of the greywater filtration (19 L/(m^2·h)), compared to the blackwater filtration (11 L/(m^2·h)). The blackwater treatment consists of two parallel lines that can be operated separately. To have the same capacity in both lines, an even number of modules was installed (eight, because six would not have been sufficient). The electricity consumption could be reduced with the help of an operational strategy in which some of the modules will be operated at high flux and the active modules will be changed periodically (to prevent sludge settling in inactive filter chambers).

The average electric energy consumption for municipal wastewater MBR built after 2010 in China is 0.5 kWh/m3 (range: 0.4 - 0.6 kWh/m3) (Xiao et al., 2014) and thus smaller than the calculated consumption for the RRC Qingdao ShiYuan. However, the calculation of the energy demand for the RRC is based on considerably higher concentrations for blackwater than those typically occurring in Chinese wastewater treatment plants (see Table 1), due to source separation, co-digestion, and low assumed water infiltration into the sewerage system. The specific energy demand lies within the range of the consumption for six MBR plants in France, Spain, and the USA, as reported by Barillon et al. (2013) (0.8 to 2.4 kWh/m3). Some of the tap water in Qingdao is produced by seawater desalination. The desalination process needs 3-4.0 kWh/m3 (Ghaffour et al., 2013); therefore, substitution with service water produced in the RRC corresponds to energy savings. In addition, due to the treatment near to the user, energy for water conveyance is saved.

Figure 6 compares the electric energy demand for the treatment processes of an RRC reference design (Bieker et al., 2010) with the calculated plant-specific optimal value for the electricity consumption within the RRC in Qingdao ShiYuan. Compared to the reference design, the calculated energy demand for the RRC increased, mainly due to the use of MBR instead of SBR; Bieker et al. (2010) based their estimation on the assumption that treated blackwater will be discharged. Therefore, the SBR process would have been able to comply with the required effluent standard (GB18918-2002). For the location in Qingdao ShiYuan, the treated blackwater is reused for irrigation; hence, higher standards (especially regarding hygienic parameters) have to be met. Thus, the blackwater is treated with an MBR, which needs considerably more energy. The blowers for cross-flow aeration of the membrane modules need nearly 50 % of the total energy required for blackwater treatment (see Figure 5). If the energy demand for cross-flow aeration, permeate and back-flush pumps is subtracted from the total electricity consumption for the blackwater treatment, the result is with 21.6 kWh/(C·d); in other words, less than 10 % higher than the estimate (20 kWh/(C·d)) of Bieker et al. (2010). The difference can be explained by site-specific boundary conditions (e.g., required head of influent pumps) as well as higher sludge recirculation rates in the MBR system. For greywater treatment, the estimate of Bieker et al. (2010) and the current calculation for the RRC in Qingdao ShiYuan are consistent (an MBR is calculated for both the reference design and the RRC Qingdao).

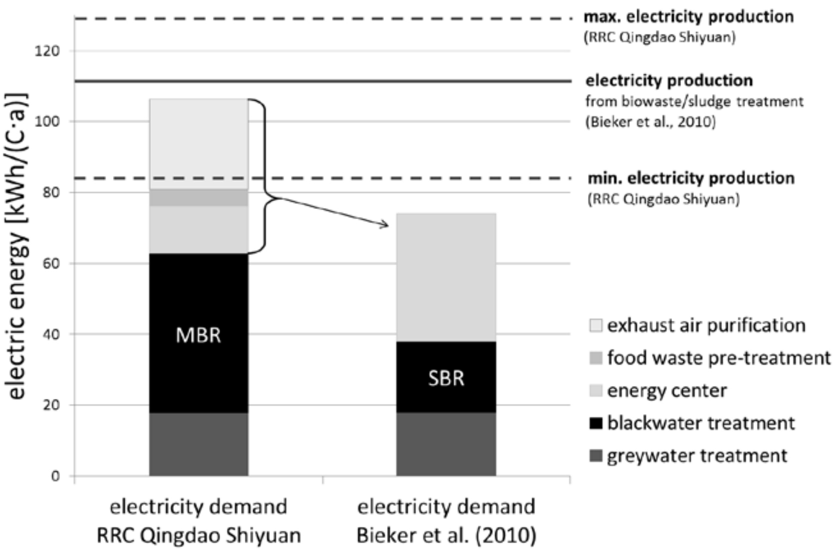

Figure 6 Comparison of estimations by Bieker et al. (2010) with planning data of the realized RRC in Qingdao ShiYuan

Bieker et al. (2010) summarized the energy demand for the pre-treatment of biowaste, the treatment of sludge and waste, as well as for the exhaust air purification, under the term "energy center". By contrast, the energy demand of the "energy center" of the RRC Qingdao ShiYuan includes only the treatment of sludge and food waste (digestion, sludge dewatering, biogas treatment); food waste pre-treatment and exhaust air purification are calculated separately (see Figure 6). Compared to the estimates of Bieker et al. (2010), the energy demand increased; electricity consumption for exhaust air treatment was underestimated. The current, more detailed calculation for the RRC Qingdao shows that the exhaust air fans are the largest electricity consumer within the RRC. Therefore, in future similar projects, the planning of the exhaust air system should receive special attention. Energy-efficient machine techniques and the reduction of the exhaust air volume flow are key elements. It is advisable to encapsulate point sources for odor and to cover all open tanks, to reduce the required indoor air exchange rate.

Bieker et al. (2010) estimated an electric energy production of 110 kWh/(C·a); therefore, an energetically self-sufficient operation of the RRC is possible. The estimation was based on the collection of household biowaste in the catchment area. In Qingdao ShiYuan, food waste from canteens and restaurants are co-treated, instead of biowaste. Food waste has a higher specific biogas yield than biowaste. Thus, a greater biogas production and, correspondingly, greater electric energy production is calculated. Because of uncertainties regarding the composition of the food waste and operation parameters, such as the maximum organic volumetric load, a possible range for the electric energy production is calculated for the RRC in Qingdao, assuming different food waste amounts as well as a lower electrical efficiency level for the combined heat and power plant. A self-sufficient operation seems possible (see Figure 6). Nevertheless, it has to be taken into account that the electric energy consumption is a calculated optimal value linked to site specifics. In operation, the machinery might not run in the ideal operational range, due to load fluctuations, or the chosen machines have lower energy efficiency than calculated. Therefore, the actual electric energy consumption might be higher. A monitoring program for the operation of the RRC Qingdao ShiYuan is planned, to validate the results of the calculation.

Conclusion

SEMIZENTRAL can contribute to a resource- and energy-efficient urban infrastructure. The site-specific adaptation of in- and output streams significantly influences the process design, which, in turn, affects the entire system's resource and energy efficiency. Challenges for intra-urban plants may arise from compact construction design. Moreover, exhaust air treatment for emission protection plays an important role in terms of energy consumption and should receive more attention during planning. The average daily energy requirements can be supplied by using biogas. With respect to China's current energy mix (large proportion of fossil fuel), this represents a contribution to greenhouse gas reduction. By providing service water, fresh water resources are protected and the energy consumption for water service is lowered. As with reuse, less water is discharged, and fewer nutrients and less COD are discharged, as well. Because, in China, untreated sewage sludge is usually disposed to landfills, the applied sludge treatment process reduces methane emissions and allows the use of stabilized sludge and its nutrients for nurseries, golf courses, or agricultural purposes.

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Onsite Water Systems at Grove Library, Western Australia: Lessons Learnt for Decentralised Systems

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Abstract

The Grove Library is recognised as an iconic building in Western Australia in terms of the 'Environmentally Sustainable Design' (ESD) systems incorporating a sophisticated Building Management System (BMS) in charge of monitoring and to some extent controlling the water and energy usage in the building and landscape irrigation systems. Since the beginning of the operation of the building in 2010, some breakdowns with mainly wastewater and rainwater systems caused dissatisfaction and frustration for the operators and managers of the building. This study is an attempt to capture the lessons learnt in the Grove Library operation and introduce the root causes of these issues with the building. The main methods used in this study are data analysis from logged data in the BMS and referencing an independent evaluation study on the water systems. Over the course of this study it was revealed that a number of factors had lead to this situation at the Grove, including lack of adequate maintenance of the systems due to inadequate budget available, BMS sophistication and no systematic handover training for the operators and managers of the systems, and lack of any documentation or Operation and Maintenance manuals for the systems.

Keywords: Onsite, decentralised, water systems, wastewater systems, recycling.

Introduction

The Grove is a recently completed facility in the Perth suburb of Peppermint Grove in Western Australia, consisting of a library, community learning centre and administration offices. The design of this building and its energy and water services are highly innovative and a number of awards were achieved. Nevertheless some major problems were encountered in commissioning and operation of both its simple and complex systems.

A fully integrated water management system was implemented on this site to optimise water efficiency by maximising the use of recycled water. All wastewater was separated into brownwater (toilet and kitchen), greywater (showers and hand basins) and yellow water (urine stream) in order to provide for more effective treatment and reuse of each stream. This allowed water and nutrient inputs to be optimized, within a sewered urban area. More specifically, the yellow water was to provide a liquid fertiliser suitable for direct injection into the subsurface irrigation network (fertigation) at the required times and volumes according to vegetation type and seasonal demand. A nutrient and water balance was designed for the site based around this yellow water fertigation system which was operated by a sophisticated computerized building management system (BMS). Regulations for on-site wastewater treatment systems were based on disposal requirements (i.e area and soil type) rather than any rationale for maximizing beneficial nutrient uptake. The implications of the current design standards both at a state and national level such as AS/NZS 1547 (2000 – subsequently updated in 2012) with respect to both excessive disposal field sizing and volume estimations of wastewater from this type of facility were described previously in Dallas *et al.* (2011). This project challenged assumptions upon which these design standards were based and comprehensive metering was installed on all the treatment and reuse systems in the facility to ensure that long term data for improved design rationale could be obtained.

In order to construct a water and wastewater balance for The Grove the following staff and visitor numbers were provided by the client: office space for 25 permanent staff and between an estimated 775 (low occupancy) and 975 (high occupancy) visitors per day, principally visitors to the library. Any peak loads in excess of the design capacity of the brown and greywater treatment systems were designed to automatically overflow to sewer while yellow water was to be collected up to a limit of 30,000L after which it would also overflow to sewer.

The project was completed and operating since 2011 and this paper will present findings on lessons learnt for decentralised urban water systems for climate resilience.

Rainwater System

The Grove's rainwater system's design was comprised of 6 in-ground concrete tanks and 11 above-ground steel tanks in the basement of the building. Rainwater storage was designed to meet 100% of the water demand for internal usage, saving up to 730,000L per annum (Dallas, *et al.*, 2009). The total capacity of all the tanks was 254,000L which was carefully designed to meet the internal demand considering the high and low occupancy rates of the building (Josh Byrne & Associates, 2011a). Figure 1 presents a schematic diagram of how rainwater was distributed at The Grove.

The rainwater was used internally after going through the UV disinfectant and micro-filtration units that treated the water for potable use (Josh Byrne & Associates, 2011a). There was the provision for a mains water supply as a backup in case of a fault with the system or shortage of rainwater supply.

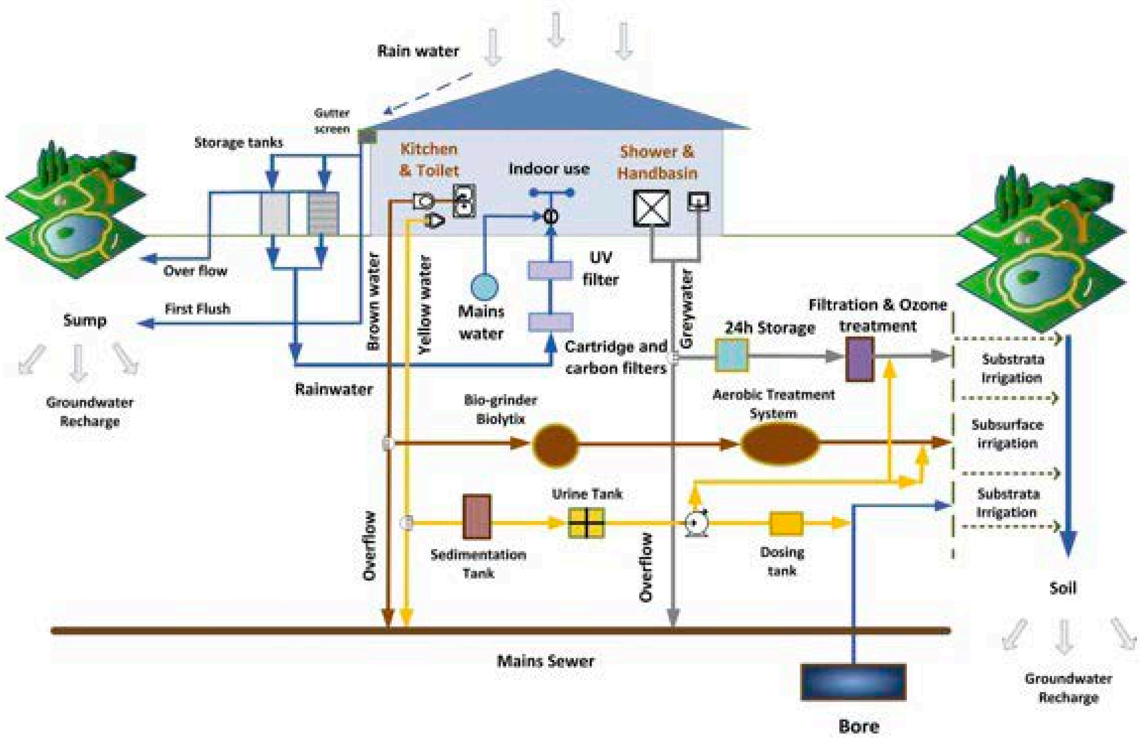

Figure 1 Schematic design of integrated water systems at The Grove (The Grove Precinct, 2012)

Wastewater Systems

The innovative wastewater system at The Grove was designed to separate the wastewater into greywater (GW), brown water (BW) and yellow water (YW) streams on-site. In this case the greywater was the wastewater from showers and hand basins; the brown water was from toilets and the kitchen; and the yellow water was from male urinals. It should be noted that local regulations prevented installation of urine separating toilet pans for females available from Europe. Each of these wastewater streams was treated and reused onsite to provide part of the landscape irrigation and supply of nutrients for the plant requirements (Josh Byrne & Associates, 2011b). A projected saving of over 700,000L per annum of water was expected to be achieved by this innovative wastewater system (Dallas *et al.*, 2011). Figure 1 is a schematic representation of the wastewater systems from production to the irrigation.

Yellow Water System:

The Yellow Water (YW) system included three urine tanks, one sedimentation tank and one pump tank (Figure 2). Urine entered any of the three urine tanks after going through the sedimentation tank. When either of the tanks was full, it was closed to mature for six months (Dallas, et al., 2011) during which time maximum pathogen removal occured (Eawag, 2007). After the maturing period was passed, the maintenance contractor would activate the pump to draw the matured YW, sending it to the pump tank from which the pump would suck the liquid out before pumping it to the irrigation line. The YW component would act as the fertilizer providing the Phosphorous and Nitrogen to the landscape. Figure 2 presents the schematic design of how the YW was injected into all irrigation sources (bore-groundwater, BW and GW).

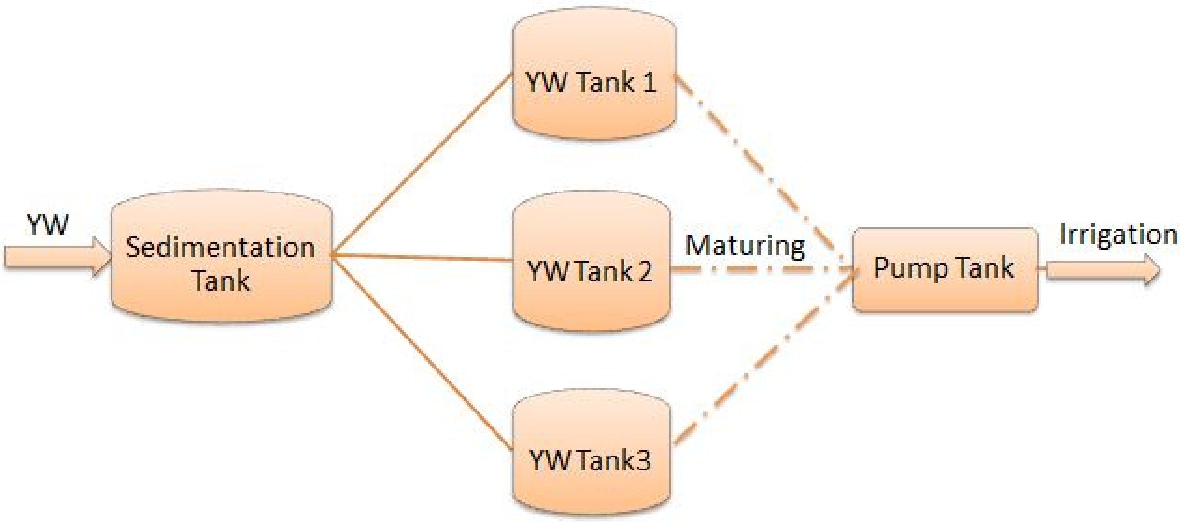

Figure 2 Schematic of the yellow water system at The Grove (The Grove Precinct, 2012)

Greywater System:

The Greywater (GW) system was comprised of a sedimentation tank, a pump tank and an ozonation unit (Figure 3) to treat the greywater for substrata irrigating (Zone 8 in Figure 8). There were two pumps in the GW system, one to pump the water from sedimentation tank to the pump tank, and one from the pump tank to the irrigation system. The ozonation process ensured that all the bacteria and other macro-organisms were destroyed before being pumped out to the irrigation line. The GW was intended for irrigating the exotic plants spreading over about 240 m2 of the landscape.

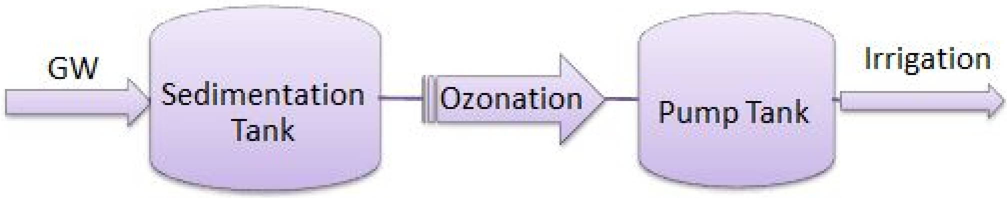

Figure 3 Schematic of the greywater system at The Grove (The Grove Precinct, 2012)

Brown Water System:

Biolytix provided the BW treatment system at the Grove. This system was comprised of one Biogrinder and two Biolytix filtration units (Figure 4). The BW entered the Biogrinder tanks first and was then split evenly between the two Biolytix units where the BW was treated by an aerobic process using macro-organisms such as earthworms, beetles, and mites (Biolytix, 2013). The Biogrinder was connected to the BMS to ensure that no more than approximately 1,000L/day of wastewater entered each Biolytix unit to avoid overloading (The Grove Precinct, 2012). The system sizing was sufficient to handle a typical daily wastewater flow; more than 90% of all BW could be treated by the Biolytix system with the minimal volume being diverted to the sewer (The Grove Precinct, 2011). The treated BW was used for subsurface irrigation to the lawn area. The 400 m2 of lawn area was designed to be watered by BW using subsurface irrigation (Zone 8 in Figure 5). The drip-line for subsurface irrigation was placed 100mm below the lawn as per Western Australian Department of Health (DoH) regulations (DoH, 2009).

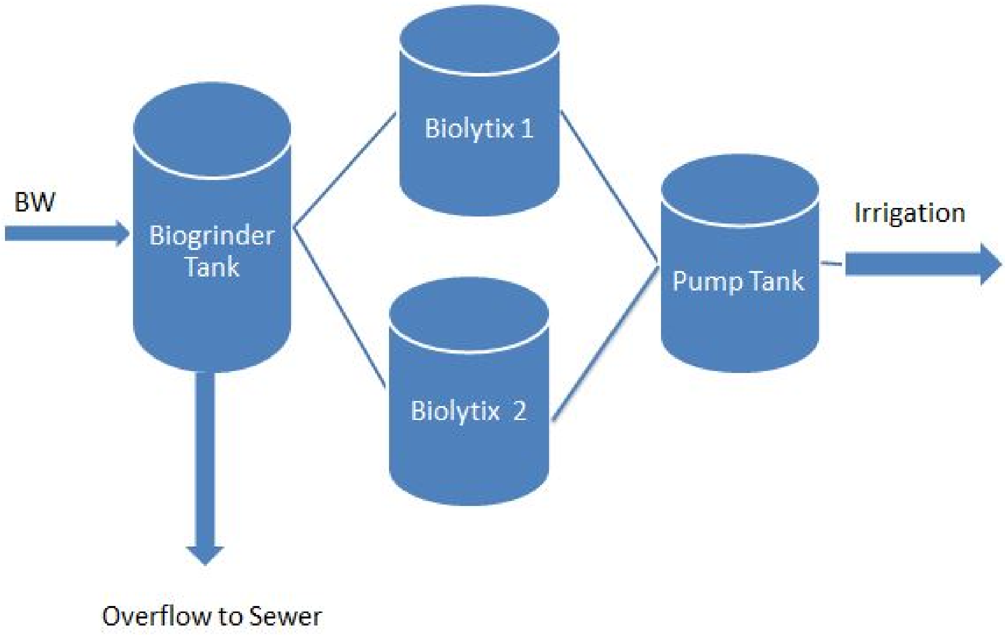

Figure 4 Schematic of the brown system at The Grove (The Grove Precinct, 2012)

Irrigation System

The landscape irrigation was based on a drip-line tubing setup that minimised the quantity of water necessary for watering the plants by avoiding the evaporative and wind losses from typical sprinklers. Different hydro-zones were allocated to different planted areas with respect to their location and water requirements.

Table 1 lists the hydro zones for different sections of The Grove's landscape, while Figure 5 displays the zoning of The Grove's landscape. The zone numbers (1-9) in Figure 5 correspond to those in Table 1. The water sources for all the zones were mainly from wastewater or groundwater from the bore. This hydro-zoning with drip-line irrigation was to optimise usage of water, saving about 700,000 L of groundwater from the bore per year (The Grove Precinct, 2011) compared with conventional irrigation methods.

Table 1 Irrigation line zoning at The Grove, adapted from Anda (2012)

ZONE	IRRIGATION
1 Native Shrubs	Bore + YW
2 Sedges (Treatment Cell)	Bore + YW + SW
3 Sedges (Dampland)	Bore + YW +SW
4 Native Shrubs	Bore + YW
5 Native Shrubs	Bore + YW
6 Native Shrubs	Bore + YW
7 Trees	Bore + YW
8 Fruit & Exotic Garden	GW
9 Lawn	BW

Figure 5 Landscape of The Grove with irrigation hydrozones, the map is adapted from Huxtable (2012)

Building Management System

The automated system at The Grove in charge of monitoring and to some extent controlling the ESD systems was referred to as the Building Management System (BMS). The BMS was installed by Honeywell; integrating all the ESD energy, HVAC, alarm and water systems into one automated 'smart' setup. This version of BMS was outdated being of 2007 vintage, so was limited in accessing data and setting up sensors (Refer to section "3.1. BMS Performance"). There are two computerised control stations located at The Grove from which the BMS can be accessed, one being in the Shire's office and the other in the car park area. The system is designed to display the status of each ESD system (Figure 3) and its historical trends. The BMS has the capability of both controlling and monitoring the lighting, alarm, and HVAC systems. Water systems, on the other hand, can only be monitored and the controlling of them is not supported through the current BMS.

Methods

This study investigated water systems and wastewater technologies at The Grove, by using two methods principally:

1) by analysing data for each system taken from the logged data in the BMS;
2) by considering findings from an independent evaluation of the water systems conducted by a contractor.ñl

Data analysis provided a good understanding of the historical trends of these systems to identify the cause of breakdowns. The BMS data analysis was combined with discussions with library and council staff regarding their observations of systems operation as well as an independent evaluation by an irrigation contractor.

Results

Brown water system:

Since mid-2012, the Biolytix system was shut down due to clogging of the pump and flooding of the surrounding area. As a consequence, the Biolytix biological treatment components were effectively 'dead'. Filter matrices became dry and no signs of biological activity were evident on inspection (Earth and Water, 2013). This leads to the decision of bypassing all the BW to the sewer without treatment.

Figure 6 presents the operation of the Biolytix since the beginning of its operation. It can be seen that the system become out of operation in mid-2012. Before then the operation of the system had not been operated effectively either. The failure of the system's operation can be traced in Figure 7. The importance of maintenance on the satisfactory operation of the BW system is evident.

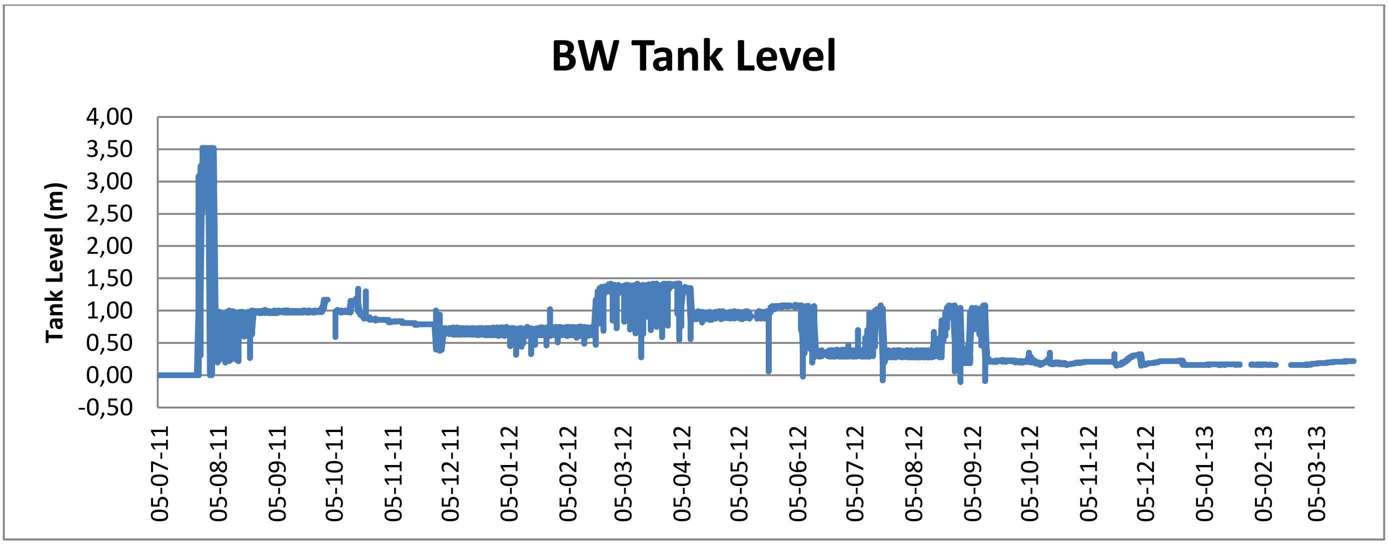

Figure 6 Historical trends of brown water tank level for the period of July 2011 to March 2013

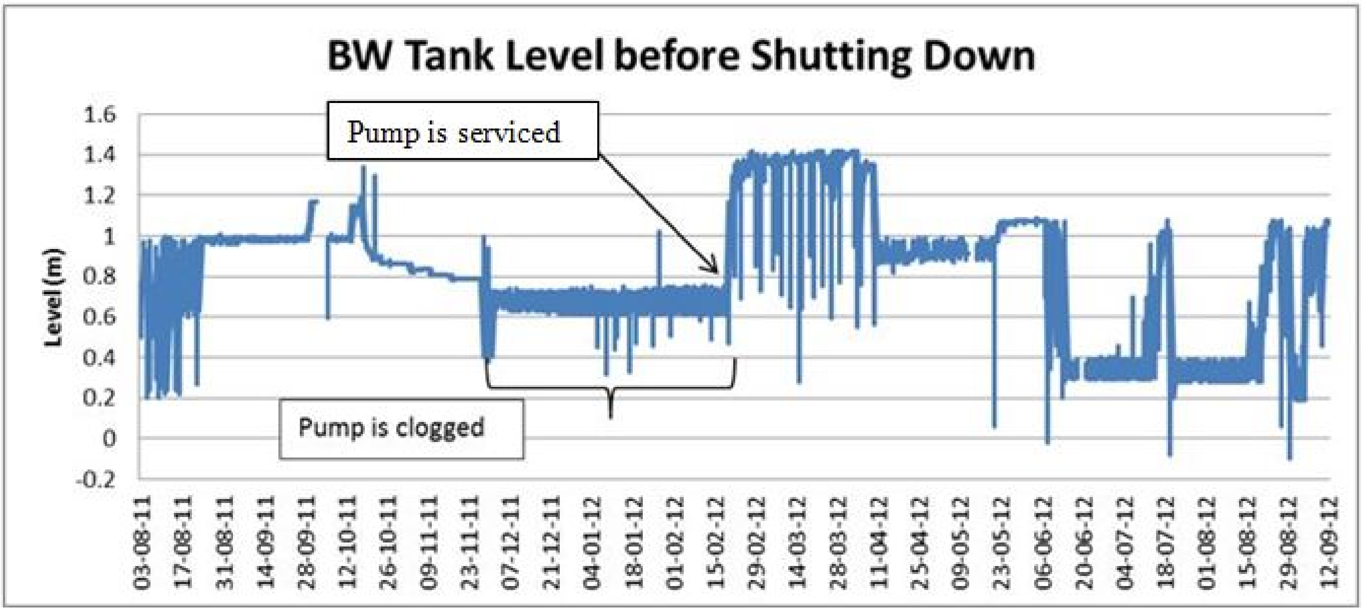

Figure 7 Historical trends of brown water tank level for the period of August 2011 to September 2012

Greywater system:

Although the GW system operated satisfactorily, it was not used in the garden after a damage to drip-line setting as a result of heavy machinery operation in the garden in 2012. One issue with the greywater system was very little greywater production which did not encourage the return on investment for the decision makers to fix the drip-line, instead the decision was to use conventional sprinklers to be installed and used since then. This decision would require use of scheme water instead of the recycled waste water in the garden, hindering the expected savings of water onsite. Thus the Grove has not been successful in meeting the projected savings of water.

In addition to the above mentioned issues, Earth and Water P/L reported the following problems with the greywater system in their inspection of the site: “Although the discharge pump is running, the tank was empty and no low level/run dry protection was evident. No regular maintenance program is in place for irrigation dispersal system. Parks and gardens staff are not comfortable with the maintenance and testing of the system due to perceived high technology, lack of training and misunderstood health risks from potential contact with treated effluent. Supplementary plantings are required throughout the dispersal areas to optimize the landscaping and recreate the “joy of gardening” for the staff and gardeners.” (Earth and Water, 2013).

Yellow water system:

The collection of urine into the YW system was satisfactory initially; however there was a delay in utilising the matured YW to the irrigation system. This was mainly due to managerial actions needed to be taken. Earth and Water explains the collection and distribution system in Grove being relatively simple and probability of any significant issues to be present was minimal. However, the YW system and process required ongoing monitoring and management to ensure urine in storage tanks was adequately aged and ready for injection. Although the treated urine was passed its resting phase and ready to be used as a fertilizer in the garden at the time of writing this paper, this had not put in practice. Application of urine as a source of fertilizer is a relatively new practice and requires a sound knowledge of water chemistry and calculation of correct dosing rates to achieve the desired nutrient concentration in the field. Manual shut-off valve / bypass to sewer was not readily accessible and could potentially be damaged. All these require ongoing inspection and maintenance when necessary.

Rainwater system:

As described by Earth and Water the UV purification unit of the rainwater system was changed since the initial commissioning of the rainwater system. Whilst the bacterial / pathogen risk from rainwater was considered to be low, the new system and current configuration did not provide for automatic isolation of the rainwater supply in the event of UV lamp failure or other system faults that may compromise the rainwater sterilisation process. The new UV relay and associated wiring needed to be harnessed in a conduit and a waterproof junction box. New power supply relay installed to UV system controller needed to be made safe and relocated to facilitate easier servicing and change-out of the UV lamps. No pressure gauges upstream or downstream of the filter cartridges to assess service requirements were present and current changeover/switching device was no longer being manufactured. Suitable replacements would necessitate modifications to the existing copper pipework when this unit failed. Data from rainwater and scheme water flow meters were also not being regularly monitored to verify the rainwater pumping system was working, or to determine consumption patterns and volume of scheme water use that was being offset by harvested rainwater. Option to disable the pumps via a new cable to pump electrical junction box from the UV open/closed contact failure relayed in the filter room; rather than the BMS system.

Figure 8 presents water tank levels' changes during 2011-2013 ascertaining the malfunction of the tanks' water level sensors in providing the correct data. No variation in the tanks' levels was observed, except for a very short period of time, within two months of the start of the Grove's operation. This did not correlate with the rainfall events for this period (Figure 9).

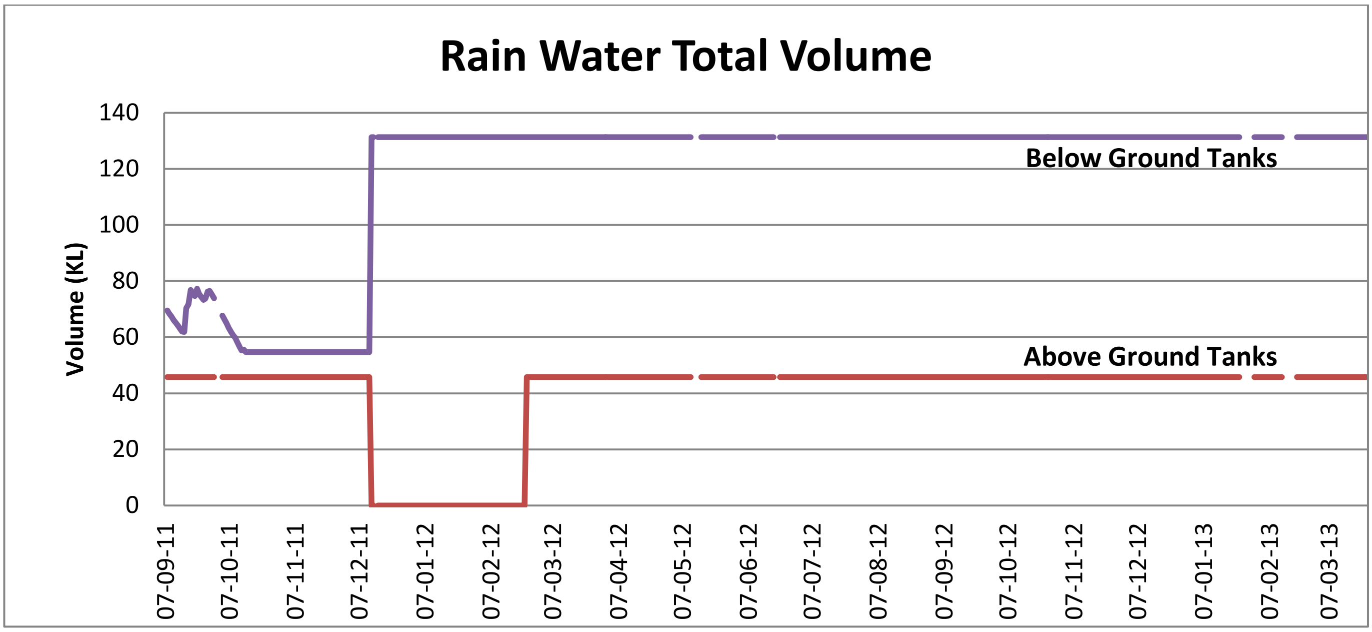

Figure 8 Historical trends of rainwater tanks' levels for the period of July 2011 to March 2013

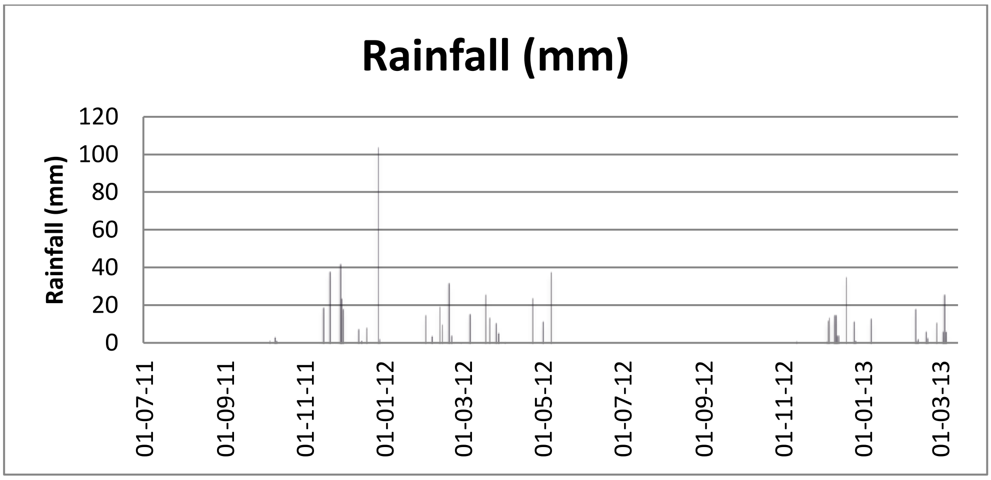

Figure 9 Rainfall events during the period of July 2011 to March 2013 (Bureau of Meteorology, 2013)

Irrigation system:

Manual scheme water irrigation valves were installed as an emergency to keep turf alive on effluent dispersal areas. Scheme water irrigation was being used to irrigate garden beds where bore water was immediately available. Operation of the bore and solenoids via BMS did not allow for easy system check and general maintenance of the irrigation system by the Shire's Parks and Gardens staff. Exposed drip-lines, dead plants, general lack of maintenance of irrigation system and landscaped areas was noted. Recycled water flush valves have been used on a number of bore-irrigated garden beds - causing confusion. Bore and/or scheme water irrigation appeared to be the preferred method due to unreliability of effluent dispersal.

BMS:

This special version of the BMS was a vintage dated back to 2007 which posed difficulty in providing access to the data and analysis. This resulted in limitations in accessing the data stored in it. The extent of data, both recorded and stored in the BMS, was massive; however access and extraction of them was not an easy or self-explanatory process; and no document or report existed on-site to explain the process. A newer version of the BMS was proposed by Honeywell enabling access to data extraction called the "Energy Manager Server". The current BMS license did not enable upgrading to the new server, thereby requiring the complete and costly replacement with the new server.

Another issue with the BMS was that only specialized operators could use it efficiently and it was not easy for the BMS system to accessible to gardeners, field staff or even a facilities manager, who needed to know about so many aspects of the building. In short, the people who were in charge of the BMS operation were not trained and did not have experience in this area, thus the BMS had put an additional layer of complication over the new technologies.

Discussion

The Grove was designed to be a unique building to showcase top of the range environmentally sustainable systems with high level of integration in one whole precinct. This translates into the fact that that the design of the systems has utilised specialised initiatives that can be seen in very few places in the world. Therefore only a handful of companies had the expertise in providing maintenance and support in case of breakdowns with systems. This concept was more evident with rainwater and brown water systems with higher maintenance requirements compared to other systems. Thus the breakdowns and dissatisfaction against these systems can be prevented from the beginning.

One complication in regards to the operation of the water and wastewater systems in the Grove was the budget assigned to maintenance and operation of these systems. Given the high level of design and the costs associated with that, a high level of appreciation and support from operators and councils assigning budget needed to be in place to ensure optimum operation. Although the initiators of the Grove's project were appreciative of this unique design and integration of the systems in place, a well-organised handover to new managers was missing. The result of this lack of training and preparation for the value of the Grove's design was insufficient support at times of breakdowns in the first place, and lack of budget allocation to overcome this. Consequently, optimum maintenance of the systems as specified in the design was missing which lead to breakdowns of the systems and more dissatisfaction and distrust of the managers.

On the other hand, one aspect in the design of the Grove was incorporation of all systems into one Building Management System (BMS). Although the BMS was programmed and designed aiming to automate and integrate the operation of all systems into one control station, the high sophistication involved in its operation prohibited its operators who had not been trained methodically to use the BMS effectively. The hand over to new operators was not planned and documented well ahead either. This resulted in managers' frustration and their lack of trust in not only the BMS but also the ESD systems, the result was less budget assigned for maintenance or retrofitting wastewater systems.

Documentation is another area of importance. One example showing the ignorance for this matter in the Grove is manuals. Upon investigation, it was not possible to locate the O&M manual for the water and wastewater systems in form of either a hard or a digital copy. Also it was not possible to locate any instruction or manuals on using the BMS anywhere accessible for the operators. This poor documentation created more complication especially when new staff or operators were to operate the systems. Another matter arising with the BMS was that the field people and gardeners who were familiar with the operation of each individual ESD system were not required to use the BMS and check the operation of the systems. This meant that any abnormality in water levels in tanks or pump station detected by the BMS were not monitored by the people familiar with systems.

The result was BMS complexity, insufficient handover/training and no operators' interaction with more breakdowns resulting in more dissatisfaction/distrust in these leading edge ESD systems.

Conclusions

The Grove has utilised best practice ESD features for a 'green' building. The water, energy, HVAC and alarm systems were to showcase sustainable design in a public building. The BMS design was meant to control all of these systems at one station in order to fully automate their operation. Savings on energy, water and greenhouse gas emissions were expected to be achieved through the design and effective operation of these ESD systems. At the operational level, however, some breakdowns resulted in the anticipated performance and savings not being achieved. The breakdowns with the rainwater and wastewater systems resulted in the employment of mains water internally and externally, thereby hindering achievement of the anticipated scheme water savings. Irrigation suffered from damaged lines and turfed areas that required a re-setup of the drip-line for irrigation. The high sophistication level of the BMS and absence of an accessible operation manual at The Grove resulted in dissatisfaction for its operators. Moreover, the BMS did not have a capable reporting system enabling the performance of the ESD water systems, in accordance with their environmental benchmarks, to be determined.

The responsibility of running the Grove lay with the Council and was seen as a thankless task for the staff when faced with the difficulties of managing cutting edge technology. Training and educating the people running the systems was essential. Also upgrades and developing the systems would improve their performance and reliability. Better training manuals and simple but effective drawings and maps would help support gardeners, building service staff and contractors, resulting in a better outcome for the building and gardens. It was challenging for the BMS system to be accessible to Gardeners, Field Staff or even a Facilities Manager, who needed to know about so many aspects of the building. The BMS had put an additional layer of complication over the new technologies, masking issues and thereby resulting in failure. In order to have such a sophisticated system, interaction between Shire personnel, maintenance staff and the BMS should have been established. This was because the ESD systems were designed to showcase the best design, but in order to have them operated according to their design, regular maintenance was essential. Presence of support from the Shire was critical because this organisation influences the budget for the continual operation of the systems. On the other hand, presence of a methodical training program and handover procedure for the Shire and operators of the BMS and the ESD systems was critical to achieve appreciation and support for the existence of these systems at The Grove. If this relationship was established, breakdowns and faults could be largely avoided and managed to enable the optimal performance of the building. This would provide a chance for the community to appreciate the sustainable design systems and provide confidence for more widespread adoption.

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Preserving the water resources by reducing the abstraction for urban uses

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Keywords: Water, energy, short loops, reuse, Syracuse project, Windhoek, Singapore, New York.

Context

In a context of global warming and reduction of water resource availability, an increasing part of the cities have to optimize their water supply by reducing their abstraction on traditional resources. New resources are mainly linked with:

- Desalination;
- Rainwater harvesting and reuse;
- Greywater treatment and reuse;
- Wastewater treatment and reuse.

Moreover, we have focused our attention for more than a century on a single water quality that is drinking water quality. However, most of the water uses in households doesn't necessitate that high water quality. One of the solutions consists of considering different water qualities for different uses (Lafforgue et al, 2013). But it necessitates adapting regulations and technical schemes, including specific treatment, dual networks, and/or decentralized systems. Indeed, for instance, reuse of treated wastewaters is generally strictly regulated, with potential restriction of uses. It is forbidden to use it for drinking water supply in France, whereas it has been effectively used for decades in Windhoek (Namibia) for supplying drinking water network.

New scheme of water management illustrated by dedicated cases

Syracuse project is dedicated to short loops and synergies within and between waters, energy, and waste cycles in urban areas. It includes 10 studied sites in the world, from which two cities are on the forefront of water management in a water stressed environment, Singapore and Windhoek.

Since its independency in 1965, Singapore has been structuring its urban water cycles so as to become self sufficient. It implies dual network (one for drinking water and one for industrial supply), rainwater harvesting (that covers up to 65% of the city's watersheds area), desalination, limitation of water demands, and wastewater treatment and reuse. But it has adverse impact on energy balance that Singapore tries to solve (Lenouvel et al, 2014, Lafforgue and Lenouvel, 2014).

Windhoek is located in a dry weather area far from the sea. Its water supply involves classical but limited available resources (surface water from three dams located up to 200km from the city, and underground water close to the city but with a limited capacity). In order to extend the water supply beyond that level, City of Windhoek (CoW) has developed dedicated approaches that include dual network (one for irrigation, one for drinking water), wastewater treatment and reuse for drinking water, managed aquifer recharge (with drinking water produced in excess during the rainy years), and limitation of water demand (Lafforgue and Lenouvel, 2014).

These two cases are really interesting to compare, and they illustrate the potentialities at the scale of a city (Lafforgue et al, 2015).

But when working at the scale of a building, other kind of problems appear that have to be managed. A critical issue is the economic equilibrium of the project that not only depends of the capital and operational costs, but also of water pricing and inciting actions... But other key aspects can strongly impact the efficiency of the project. For instance, the population behavior and/or operational constraints can partially counteract the positive effects of the new water management. Dedicated cases such as Battery Park in New York City can be used to illustrate some specificities of the water cycle at the building scale (SAFEGE, 2012; Lafforgue et al, 2014).

These different cases illustrate the problems that have to be solved on the track of a more sustainable city. They include:

- The energy management in the urban water cycle
- The constraints linked with the use of different water qualities and networks
- The mixing of short loops and centric network
- The economic viability of the new scheme
- The institutional and regulation aspects
- The social and cultural aspects
- ...

Each case is different and solutions must be site specific, but strong improvement can be obtained on water management. For instance, Singapore water supply was 100% covered by surface water from Malaysia whereas it has dropped to 40%, and the city objective is to be self sufficient in 2060. Moreover, wastewater reuse enables cities such as Singapore and Windhoek to cover 20 to 30% of their needs. It means a strong reduction of water abstraction from natural resources.

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3.3 Governing and Financing Urban Water Services

Water and Cities – Finance, Innovatioin and Governance to ensure Sustainable Futures - OECD – Environment Directorate (Keynote)

Authors: H.Leckie and X.Leflaive

In OECD countries, cities have achieved high levels of protection against droughts, floods, or water pollution, and a vast majority of city dwellers enjoy reliable water services. This remarkable performance derives from distinctive combinations of infrastructures, business models and institutional arrangements. However, whether and how such combinations are fit for future challenges is unclear. The economic, social and environmental costs of water security are increasing, driven by urban growth, competition among water users, urban and agricultural pollution, and climate change. Existing infrastructures are also ageing and need to adapt to new contexts. In addition, city dwellers have rising expectations as regards the quality of water services and water security.

Can these challenges be addressed with the current business models and financial resources? What are the opportunities that derive from innovative technologies and practices? How can we tap into the potential benefits of co-operation between cities and their rural environment? What governance arrangements are required? The presentation provides answers to these questions, drawing on the report Water and Cities: Ensuring Sustainable Futures. The report argues that cities in OECD countries face significant revisions of financial, technological and governance arrangements.

While some cities have already gained experience with managing this transition, more needs to be done to scale up and expedite change. Both local and central governments have a role to play in order to use to the best advantage the initiatives of a variety of stakeholders, including the private sector, households and rural communities.

New Challenges and Solutions for Financing Projects in the European Water Sector

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General

The European Investment Bank, together with the relevant EU institutions, follows closely recent policy developments, especially those related to water scarcity and droughts, flood management, and adaptation to climate change. Our lending policy takes these policy drivers into account when defining its actions.

In the European Union the importance of the water sector has been reflected in the EU's environment and development policies. Water is one of the most regulated sectors in the EU. The key regulatory instrument, the Water Framework Directive, requires the Member States to achieve "good ecological status" for all river basin bodies of water by 2015. It is based on the polluter pays and cost recovery principles.

Outside the EU, a central component of EU development policy is directed towards achievement of the water and sanitation targets of the United Nations Millennium Development Goals. Water projects are therefore key drivers to support environmental protection and sustainable communities – one of the European Investment Bank's main lending objectives within and outside the European Union. We aim to maximise added value to water projects through careful and innovative project preparation as well as advisory and technical assistance activities. This is particularly true in regions and countries where climate conditions give the sector an even greater importance.

Our long-term loan financing to public and private clients can cover investment in the entire water cycle: water resources and supply (for households, industry and agriculture), wastewater collection, treatment and disposal, coastal erosion, flood control and protection. The key aspects of our lending policy in the water sector are:

1) River basin approach: To strengthen the link between water resources management and provision of water services to users, we work closely with water resource management entities, such as river basin authorities. We support regional initiatives and cross-border investment programmes which comply with the principles of Integrated Water Resource Management.
2) Sector development: The water sector is often fragmented, so limiting the ability to provide services. We support sector consolidation, including the development of viable utilities and regional service providers, and we seek ways to secure appropriate financing terms for such entities.
3) Climate change: For us, adaptation is a key area of intervention for mitigating the detrimental impacts of climate change, in particular on water resource availability and quality.
4) Water efficiency: Efficient allocation of water, addressing scarcity issues, ensuring the viability of service providers, and increasing the efficiency of their services.
5) Additional supply requirements: Developing new water supplies is often necessary to address imbalances between demand and supply, particularly in water-scarce regions, and we support new water supply projects (e.g. water desalination plants and dams). This is under certain conditions, such as: proof that water efficiency and demand-side management have been considered and implemented; an options analysis has been undertaken; and the projects are consistent with our environmental and social policy.
6) Wastewater and sanitation services: The provision of wastewater collection, treatment and disposal services is essential from an environmental and public health point of view. It requires significant investment to comply with EU and national law. We support wastewater collection and treatment systems in the EU and in partner countries, together with other financing institutions, national governments and local organisations.
7) Research and innovation: We support research and development of appropriate technologies and the use of research outputs in project preparation and implementation.

The EIB lends to public or private utility companies, national or local authorities or directly for project finance deals. It can lend up to 50% of investment costs for individual projects. On average its lending makes up 30% of the investment cost of water projects. The EIB has been the largest source of loan financing to the global water sector to date as compared with other international financing institutions. In the ten-year period 2004 to 2013, EIB direct lending to water-related projects, including irrigation and sewerage, amounted to some EUR 26bn of which 89% was for schemes in the Member States of the European Union.

A total of 300 major water supply, sanitation and flood protection projects were financed during this period, 75% of which were located in the Member States of the European Union.

Climate Risk and Vulnerability Assessment for a complex water investment programme.

Climate risk and vulnerability assessment (CRVA) is a process, which helps the project promoter do the following:

- consider in a comprehensive way how the project is vulnerable to climate variability and change,
- assess related risks to the success of the project,
- identify relevant adaptation options (structural, operational and/or organisational) to build climate resilience,
- if necessary, reassess some aspects of project feasibility in the light of these options and develop a subsequent optimised, more resilient project scope.

The climate risk and vulnerability assessment seeks to assess whether the project is robust and resilient to climate risks. The level of residual risk that is acceptable needs to be an explicit outcome of the Promoter's risk management framework. Should deficiencies be identified, the CRVA shall (i) demonstrate to project financiers that climate change risks and vulnerabilities have been appropriately assessed and (ii) identify the list of possible adaptation options that could strengthen the project.

The rationale for CRVA from the financiers' perspective is that it has become a requisite element of a broad due diligence process that specifically assess whether a project is robust and resilient to climate-related risks. It helps minimise reputational risks for the financier and to avoid negative financial impact which may result from the operation of the project over its lifetime. Moreover, CRVA may identify a viable pipeline of adaptation measures that could be financed through the loans.

As far as the Promoter is concerned, CRVA should help ensure business continuity by identifying potential vulnerabilities that may materialize over the life of the assets. Through the identification and implementation of adaptation options the promoter may provide an adequate response and avoid negative financial impacts.

The objective of water utilities is to provide continuously safe drinking water to their customers and collect wastewater and treat it to the acceptable standard. In fulfilling this objective, water utilities operate complex network assets located in a dense urban environment. Their investment policy and assets management processes impact on the tariffs paid by the customers. Climate risk and vulnerability assessment for such comprehensive investment programmes requires a specific approach and thorough understanding of the system, and in particular its key processes and associated critical infrastructure. Project boundaries for the CRVA will generally extend beyond the infrastructure or other activities included by the project. Defining these boundaries is crucial to ensure that a sufficiently broad perspective is taken when assessing the ways in which climate-related hazards may affect the project. CRVA is a cross-cutting process addressing all the aspects of the core business processes of the water utility. For a complex investment programmes with numerous sub-projects an appropriate grouping of the assets and processes needs to take place, taking into consideration the spatial dimension of the programme. The assessment which in essence builds on a risk management models, may be based on a logic framework dividing the system into on-site assets and processes, inputs, outputs and transport links. It should be noted that strong water utilities have already in place their risk management framework that need only to be extended to analyse climate related risks.

Climate risk and vulnerability assessment should be seen as a participatory process that engages both internal stakeholders as well as the relevant external stakeholders. Cities and regional authorities, emergency management, civil protection, are among those stakeholders. In the financier's experience their inputs to the CRVA process proved to be valuable and enriched the assessment with the external views, but also declarations of cooperation and share of data.

Finally, a key element for the Financier is the assessment of the adaptive capacity of the system that encompasses project and institutional environment in which it is to be implemented. Such an assessment should take into account, among others, institutional capacity (including risk management, change management, project management, decision-support instruments, assets management); systematic processes currently in place to identify sensitivity, exposure, critical assets, vulnerabilities, and measures to address them; awareness of climate vulnerabilities of the assets and organization; emergency and contingency plans (and processes to adjust them when revised climate change data are available. On the external side, it should pay particular attention to consideration of climate aspects in planning instruments, (e.g. urban planning, river basin plans, flood risk management plans), building codes and operating standards and practices that take the relevant climate variables and hazards into considerations; capacity of the entities involved in managing prevention and emergency activities; available insurance.

The presentation will illustrate the theoretical consideration with a case-study of a CRVA undertaken for a complex investment programme of a water utility – AQUANET, the water and wastewater operator of the city of Poznan. AQUANET belongs to the most successful operators in Poland. Poznan is Poland's fifth largest city, located on the Warta River in west-central Poland, with a population of 750,000 residents in the agglomeration, covering an area of 261 km^2. It is an important centre for trade, industry and education, hosting regular international trade fairs. The programme comprises investments in the water supply system, the waste water collection and treatment infrastructure as well as storm water components. It includes, among others, modernisation of 5 water treatment plants, construction or upgrading of 90km of water mains, construction or rehabilitation of 225km of sewers, rehabilitation or modernisation of 4 wastewater treatment plants.

Keywords: lending policy, climate change, risk assessment, adaptation.

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Abstract

Climate change and urbanization are among the most significant trends of the 21st century, affecting global natural resources such as water, economic development, and human well-being. The Unite Nations estimates that between 2011 and 2050 the world population will grow from 7 to 9.3 billion and that the population in cities will increase from 3.6 to 6.3 billion, while the number of people living in rural areas will decline. This means that the growth in the world population will be absorbed by the cities. The necessity of cities adapting to these trends calls for radical changes in urban water management. In this paper baseline assessments, i.e., City Blueprints have been carried out for 45 cities and regions in 27 countries, mainly in Europe. The assessments showed that cities vary considerably with regard to their water management. This is also captured in the Blue City Index® (BCI), the arithmetic mean of 24 indicators comprising the City Blueprint®. Theoretically, the BCI has a minimum score of 0 and a maximum score of 10. The actual BCIs in the 45 cities and regions varied from 3.5 (Kilamba Kiaxi in Angola) to 8.5 (Helsingborg in Sweden). The BCI was positively and significantly correlated with the Gross Domestic Product (GDP) per person, the ambitions of the local authorities regarding water management, the voluntary participation index (VPI) and governance indicators according to the World Bank. The study also demonstrated a very significant correlation between the BCI and the University of Notre Dame Global Adaptation Index (ND-Gain). The impacts of water scarcity and floods in cities are discussed. It is concluded that cities need to start investing in adaptation and mitigation measures based on a long-term vision and strategy and by sharing best practices. The longer political leaders wait, the more expensive adaptation will become and the danger to citizens and the economy will increase.

Integrated settlement- and infrastructure modelling to support strategic planning of transition processes

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Abstract

Settlements and infrastructures are characterized by high path dependencies, functional dependencies, high capital lock up and long lifespans. Regardless to that settlements and infrastructures must be constantly adapted to new conditions. This is especially true in drastic changes in demand conditions and in the requirements that are imposed on settlements and infrastructure. Examples for this are strong growth processes as they appear in the course of global urbanization processes. Shrinking processes show a special problem category. They appear in European countries but also worldwide. Adaptation requirements also arise by changed social value systems which portion out a bigger meaning, for example, to the environment protection, to energy saving aspects ore to climate change issues. Necessary adjustments must be long-term oriented and strategically applied. This requires an integrated approach taking account of settlement and infrastructure development options. In this paper a methodological approach to assess adaptation options of wastewater infrastructure within the existing building stock will be presented. The example focuses on costs of transition-paths. In the result spatially differentiated adaptation options are presented and assessed by costs that can be used to define both, infrastructure and settlement strategies out from an integrated view.

Keywords: Infrastructure Adaptation, Settlement Adaptation, Integrated Approach; LCC, Transition Management

Transition of water tariff models: impact on household costs and inner-city cash flow

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Abstract

New drinking water tariff models have been under discussion for many years in Germany because of decreasing water consumption in the past and an expected decline in the future. Within the scope of this work, the effect of a modification of a water tariff system on the expenses of households in around 200 cities and communities in Baden-Württemberg will be presented. Calculations will help determine the potential cost adjustments for one- and multi-person households. These will depend upon settlement structure, and will be applied for four different water tariffs and five different fixed price components. Using the City of Stuttgart as an example, the above-mentioned study will analyze the changes in costs within 23 city districts so that the change in inner-city cash flows can be understood. The results demonstrate that the impacts of a tariff conversion on the costs of individual households, amongst other things, depends heavily upon the chosen fixed price component, the household size (number of occupants per household) and the size of the residential building (number of households per building). A transition of water tariffs cannot be recommended without further investigations. Whether and how an adjustment is locally reasonable under social, ecological, economic and further water-related issues should be checked with an objective criteria catalogue. A transition of water tariff models should be thoroughly examined, carefully prepared and implemented step-wise.

Keywords: “water tariff” “drinking water”

Governing Future Water Services: New Institutional Arrangements to Improve the Implementation of System Innovations

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Keywords: system innovation, water services, implementation, cooperation model, governance

Extended Abstract

Technological developments in the last 15 years indicate great potential to fundamentally change urban water services, one example being New Alternative Sanitation Systems. Therefore, the introduction of novel water services should be accompanied by (at least some) institutional analyses especially when they imply system innovations. This applies changes in material and energetic constellations as well as interference in relation between utilities and their clients (end user).

Within the framework of the BMBF projects[1] “KREIS” and “netWORKS”, which are both located in Germany, a first step consists of identifying probable innovation obstacles. Challenges of implementing system innovations include e.g. that responsibility structures

[1] Both projects are part of the BMBF-funding measure "Smart and Multifunctional Infrastructural Systems for Sustainable Water Supply, Sanitation and Stormwater Management" (INIS).

are becoming more complex since the warranty for water services is resting on more shoulders than before. Wherever efficiency gains are intended by bundling water, energy or waste management infrastructure systems, a simultaneous coordination of different operators is required that that may potentially excel the range of tasks the hitherto entrusted institutions are assigned with. Further, it has to be dealt with medium to long term documentation problems in order to avoid incorrect connections within dual water systems and a false usage of service water instead of drinking water. At other times, key stakeholders like the health authorities are causing problems for acceptance which can further obstruct the implementation of requested innovations (and thus the new water services).

Subsequently, the examples of heat recovery from waste water, greywater reuse, and the shift to vacuum toilets will be used to present cooperation models (based on institutional arrangements) which could contribute to a smooth (and possibly sustainable) application of the water services. If these cooperation models are to function successfully, it is vital to develop and apply novel forms of communication and cooperation between the heterogeneous actors. Thus, in order to develop optimal local alternatives, the system leader (e.g. the municipal water enterprise) and the coordinator both need to manage the various players during planning, implementation and operation of the innovation. Accordingly, the poster presents basic requirements necessary to overcome obstructions to innovation and to achieve a good governance of the urban water services.

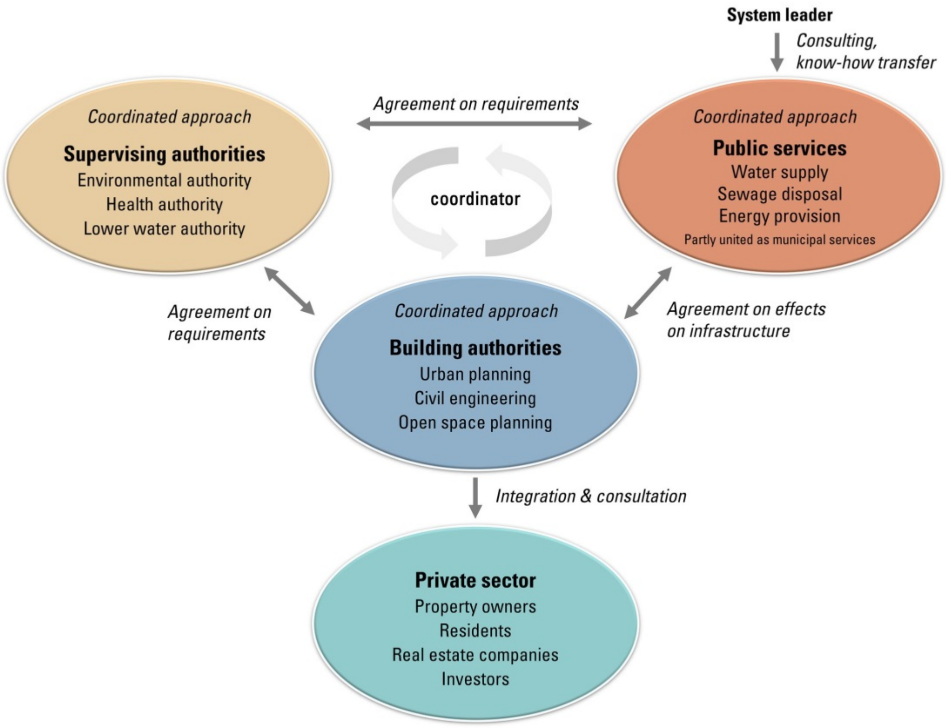

Figure 1: cooperation model for planning phase (Source: own layout)

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3.4 Planning Future Urban Water Services - Strategies & Tools

The Future of Urban Water: Scenarios for Urban Water Utilities in 2040

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Abstract

The Future of Urban Water: Scenarios for Water Utilities in 2040 depicts four plausible scenarios for the future of urban water utilities in 2040. Using Sydney as a reference city, the report explores how a wide range of social, technological, economic, environmental and political trends could shape our urban water future. By understanding drivers and planning for the future, water utilities can create more engaging customer experiences, enhance the liveability of urban areas and get more out of their current and future assets. The scenarios can be used to explore the viability of different strategies, inspire innovation and assist in long-term planning for more sustainable and resilient urban water systems. We believe our population will be best served if water authorities migrate towards a hybrid model which incorporates greater decentralisation and autonomous management of water supply, greater participation of additional service providers and smarter management of the water grid.

Keywords: Urban Water, Future Utilities, Sydney, Australia, Social, Economic, Environmental, Political, Technological

Introduction

Water is a precious and increasingly critical resource. The World Economic Forum's "Global Risks 2014" report identifies water crises as one of the top five global risks posing the highest concern. Water crises were ranked as the third biggest risk in terms of impact; however, strictly speaking, four of the identified top 10 risks are water-related — water crises, climate change mitigation and adaptation, extreme weather events, and food crises (World Economic Forum 2014). Despite this, water issues are often overlooked or misunderstood, and there is a need for better awareness of their social, economic and environmental impacts.

Global Water Situation

Water scarcity is a vital challenge that must be faced in the coming years, but it is not the only challenge confronting global water supply. Pollution, rapid population growth and urbanisation are major factors posing fundamental challenges to the global water cycle, with a particular pressure on the urban water supply. Since 1950, cities have increased their water usage five-fold, not only through population growth but considerably through increased per capita demand. Cities increasingly struggle to access enough water supplies to sustain their population, and currently, half of the world's cities with more than 100,000 inhabitants are situated in areas experiencing water scarcity (Richter et al 2013). Meanwhile, there is increased decoupling of urban and rural systems and a diminishing holistic consideration of the global water cycle, with urban areas being considered as isolated entities. For cities to succeed in a world characterised by resource issues and constraints, we must recognize that cities don't exist in isolation.

Overlaying and intensifying all of these pressures is climate change, including rising temperatures, extreme weather events, rising sea levels, and reduction in river flows and groundwater levels. The exploding global demand for "water-heavy" goods including food and technological products is another critical factor, with agriculture already responsible for around 70% of freshwater withdrawals globally (UN Water 2014). The 2030 Water Resources Group predicts a global gap between safe freshwater demand and supply of 40% by 2030 if business-as-usual water management continues, thus not supporting the predicted population (2030 Water Resources Group 2013). With a possibility for water depletion and increasing competition through scarcity, new thinking and new ways of managing water become fundamental.

Australia: Current Situation

Challenges for water utilities in Australia include: meeting future demand for water in a changing climate, managing diverse sources of supply, ensuring the health of waterways and ecological systems, maintaining the affordability of water services and reducing the carbon footprint of urban water supply and use. For urban water utilities, this means making innovation and investment decisions that maximise opportunities to provide services of value, while mitigating future risks and uncertainties.

Australia utilises over 50% of its water consumption for agricultural purposes and the remainder for household, industrial and commercial consumption. However, in urban areas, the main driver for demand remains the population, and thus population growth (Australian Academy of Technological Sciences and Engineering [ATSE] 2012). Despite Australia being the driest populated continent, the greatest amount of water per capita is used in global comparison (Savewater undated). Rainfall supplies most water sources in Australia, but future patterns of rainfall are likely to be highly variable and unpredictable due to the effects of climate change. Consequently, equitable access to sufficient water supply presents a key challenge (ATSE 2012).

Drivers of Change: Urban Water

The key drivers of change for the future of urban water fall into five categories: social, technological, economic, environmental and political.

Social. The global population is expected to reach around 9.5 billion in 2050. An estimated 90% of population growth is expected to occur in the cities of the developing world. This rapid urbanisation means that by 2050 around 70% of the global population will be urban dwellers. Australia's population is expected to rise 60% by 2050, from 23.3 million today to 37.6 million. Sydney and Melbourne's populations are projected to jump 60% to 80% to reach almost 8 million inhabitants each (Joyce 2013). Population growth and urbanisation pose great challenges to utilities — they must serve more people while facing greater scarcity of resources. There will be a need to manage and influence demand through behaviour change and to increase the efficiency of the system, which involves understanding its pinch points, investigating new technologies and providing incentives for behaviour change.

Another factor is an ageing population, due to an increase in life expectancy. In Australia over the next 40 years, the proportion of the population over 65 years will almost double to around 25%. At the same time, growth in the population of traditional workforce-age is expected to slow to almost zero (Australian Government undated). This demographic change could lead to the need for different or shifting services, such as water for health care provision.

The digital lifestyle increasingly links consumers' lives to the internet. Smartphones are becoming the hub of our digital lifestyles, allowing us to constantly connect to social media, work and leisure activities. This connectivity also means that traditional models of ownership are changing. The trend towards a shared economy of service provision rather than product ownership means, for example, that consumers are increasingly likely to purchase access to a car rather than buy their own car. With growing connectivity and smart technology, people will be able to monitor the consumption and cost of water in real time. More awareness of the issues could lead to increased scrutiny of water utilities and pricing of services. The availability of data provides an opportunity to educate customers about consumption and managing resource use. The possibility of technology to allow urban water trading could result in changes to demand system characteristics.

Technological. Smart infrastructure responds intelligently to changes in its environment to improve performance. It is estimated that the market size for smart grid technologies will almost triple by 2030. Smart water networks could save the industry US$ 12.5bn a year. In Israel, data analytic company TaKaDu takes information supplied by sensors and meters and can spot anomalies in its behaviour, from a small leak to a burst water main.

Many organisations are already using big data techniques and advanced analytics to manage complex processes and supply chains. It is expected that there will be a 4,300% increase in annual data generation by 2020 (CSC 2012). The analysis of big data can provide valuable information to help identify innovation opportunities, transform the management of assets, enhance interaction with customers and suppliers, and make sure that key risks to a business are proactively managed.

Advanced technologies and innovation can enable breakthroughs in tackling pressing global challenges, such as reducing environmental footprints, using less and cleaner energy, and decreasing water usage and waste generation. New technologies are promising to transform wastewater into a resource for energy generation and humidity into a source of drinking water. Nanotechnologies are currently being used to develop solutions to three different problems in water quality. One is the removal of industrial water pollution from groundwater. The second concerns the removal of salt or metals from water. The third involves a nanofilter to remove virus cells from water that standard filters can't eliminate. Nanotechnology will change the methods used to purify water and therefore the infrastructure required for water treatment.

Economic. Infrastructure finance has become a global business. While most infrastructure investments are local, the sources of finance are increasingly global. The Organisation for Economic Co-operation and Development (OECD) has estimated that around US$50tr would be needed worldwide in the period to 2030 to satisfy the global demand for infrastructure (OECD 2006). However, accessing sources of funding is an increasing challenge. In the United States, for example, water infrastructure investment is not keeping up with demand. If current trends continue, the investment needed by 2040 will amount to US$195bn and the funding gap will be US$144bn (American Society of Civil Engineers, 2011).

The cost of infrastructure could lead to the financial recycling of assets and capital, where old assets are sold or leased to fund the new. It could also lead to greater application of the circular economy, which will help stretch resources through end-of-life recycling and reuse. New technologies and processes are increasing our ability to recycle more and more material goods.

As business strives to differentiate itself and customer expectations increase, the need to innovate around the consumer experience is becoming a critical factor for good design. More and more companies are tapping into the public's intellectual capital by "crowd-sourcing" product ideas and solutions. In exchange they are giving creative consumers a direct say in what gets developed, designed or manufactured. Crowdfunding is expected to add at least 270,000 jobs and inject more than US$65bn into the global economy by the end of 2014. The industry is expected to grow 92% in 2014 (Clifford 2014).

The desire for greater choice and more customised services can lead to greater complexity. For water utilities this could mean a different way of doing business that challenges traditional thinking and processes to include more engagement with the public, more transparency, shared ownership/IP, responding to new ideas, forming partnerships, and engaging with customers through social media.

With increasing scarcity and cost of natural resources, efficiency is a driving force for manufacturing companies. Manufacturing expenditures on raw materials, energy and water can be as much as 50% of total manufacturing costs. Green manufacturing can improve energy productivity and operational efficiency by switching to less water-intensive equipment and minimising waste. Another way of increasing efficiency is through coopetition. Coopetition occurs when companies forge alliances across traditional boundaries, for example in order to share common costs. Coopetition could enable utilities to be more agile through the sharing of experiences and by not holding a monopoly on good ideas, as pooled resources can drive efficiency and innovation. Coopetition could move the idea of the smart house and smart city closer to reality.

Urbanisation is one of the key factors affecting growth in energy demand. World energy consumption is projected to grow by 56% between 2010 and 2040. Approximately 90% of global power generation is water intensive (UN Water 2014). Therefore, a country's energy mix has fundamental implications for its water industry. Furthermore, resource recycling, such as waste-to-energy or waste-to-product, offers an opportunity for growth as well as opportunities for private sector involvement.

Environmental. Climate change has led to changes in climate extremes, including increasing temperature variability and more heat waves with record high temperatures. It also includes increasing rainfall variability with heavier, shorter-duration events along with extended droughts. Sea level rise is also a concern as around 10% of the world's population lives in coastal areas less than 10 metres above sea level, and is therefore vulnerable to rising sea levels.

Climate change policy has developed around two themes: mitigation and adaptation. Mitigation is tackling the causes of climate change through the reduction of greenhouse gas emissions. Adaptation is adjusting to the impacts of climate change, by reducing vulnerability and increasing resilience. Both bear an economic cost, and both approaches will shape efforts to avoid the worst of climate change. Water utilities need to assess their stormwater and sewer systems capacities due to intensifying storms and increased rainfall. The requirement for systems to be resilient could lead to a new lens for decision-making, looking at new risks with new measurements.

Green infrastructure is the network of green and blue spaces — such as parks, agriculture, woods, rivers, ponds — in and around cities. Benefits of increased green infrastructure include the reduction of flood risk, improved health and wellbeing, as well as providing a habitat for wildlife. Extensive green networks can be formed over time to create an encompassing "city ecosystem" that can support the sustainable movement of people, rebuild biodiversity and provide substantial climate change adaptation.

Ecosystem services are benefits arising from natural ecosystems such as water purification, groundwater recharge, preservation of biodiversity, pollination and the decomposition of waste. In urban areas, solutions like urban wetlands will need to become more commonplace as essential hard-working city components to deliver storm protection, buffering and filtration, cleaning and purifying urban water through natural processes. These features can also support attractive and significant wildlife areas to increase a city's biodiversity (Arup 2014). Large-species trees also form a vital component of a green infrastructure city ecosystem, as they deliver multiple benefits, including acting as carbon sinks and intercepting rainfall to increase the capacity of underlying soils to absorb water.

Pollution is the release of chemical, physical, biological or radioactive contaminants to the environment. When it rains, dense concentrations of paved surfaces channel water into storm sewers that ultimately empty into natural waterways, carrying pollutants from cities. Integrating natural systems into the built environment enables the capturing and storing of water for reuse and removing pollutants.

Political. Water security is the capacity of a population to access sufficient water to meet all its needs and to limit the destructive aspects of water. It involves both the productivity and destructivity of water. By 2030, almost half of the global population of 7.5 billion people is predicted to live in areas suffering from severe water scarcity. Compared to current figures, this reflects an increase of over 1 billion people experiencing a lack of water (The World Counts [A] undated). Water pricing is being recognised as an acceptable policy instrument to respond to increasing water scarcity. Diversifying water sources helps to secure water supply systems against droughts and floods. Alternative supply options include recycling existing water, such as sewage and stormwater, as well as manufacturing new water through desalination.

Water policy and regulation are typically determined on a state or national rather than international level. In Australia, state and local governments have the ability and opportunity to integrate urban water planning more effectively with urban development planning in order to increase efficiency and create more liveable urban environments (Water Services Association of Australia 2013).

Humankind is producing more waste than the environment can absorb. More than 400 million tonnes of hazardous wastes — wastes that can cause substantial threats to our health and the environment — are produced each year (The World Counts [B] undated). Minimising waste can increase efficiency and save resources and energy. Although waste minimisation is often the top priority for governments, in most countries the focus remains on recycling.

A strong international consensus now exists among scientists that human-made climate change is a reality and warrants serious action. Global public opinion varies on the issue. If it were to shift markedly, for example in response to a major climate change event, then politicians may force through aggressive legislation to constrain emissions further. Changing customer expectations on levels of service could force a policy intervention.

Methods

Scenarios provide a unique opportunity to explore and compare alternative plausible futures. They are an effective engagement and communication tool that enables us to gain a better understanding of possible pathways towards the future of urban water utilities, including the role of different stakeholders and alternative system designs.

Future scenarios build upon a well-grounded understanding of current and future trends and global benchmarks. They present a tool for strategic thinking through which we are able to make sense of uncertainty and explore future options. Scenario modelling enables businesses to develop robust and resilient business strategies as well as meaningful stakeholder engagements. The scenarios in this report are intended to picture possible future worlds while describing the challenges and opportunities facing the water sector specifically, as well as the global water cycle in general. Scenarios assist in identifying and developing actions and strategies towards achieving a preferred future.

The variation in future urban water utility systems and experiences largely reflects two critical variables: the extent of centralisation and integration in future urban water utilities. Figure 1 illustrates how the scenarios represent the different outcomes from these variables.

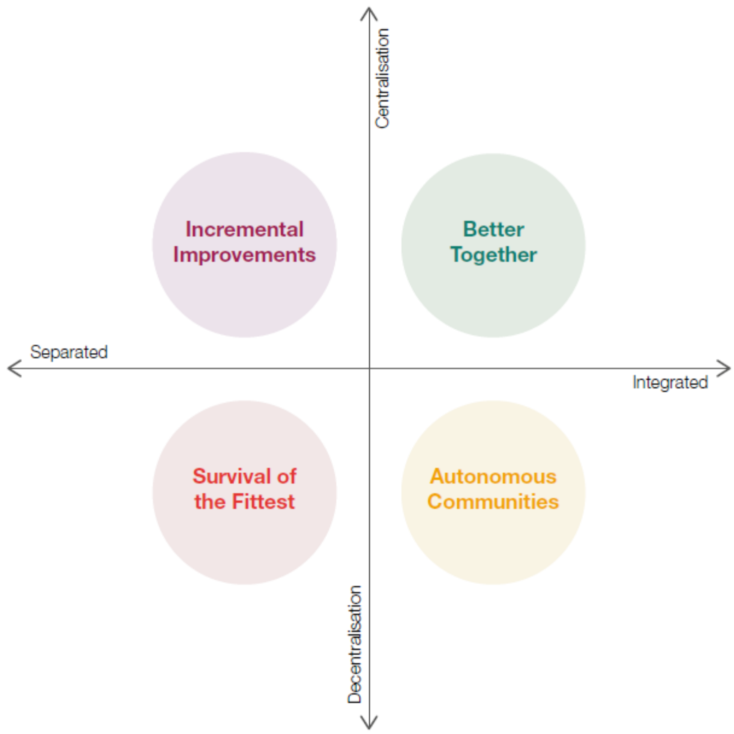

Figure 1 Scenario variables

Incremental Improvements

Incremental Improvements describes a world with little change to existing assets and operations. A centralised water supply system with a separated provision of utilities.

The global economy is growing, albeit slowly. Governments and businesses have not done enough to curb greenhouse gas emissions and the effects of climate change are becoming increasingly severe. We continue to break temperature records and extreme weather events are increasingly common. Cities are facing problems to source adequate food for their growing population. Australia is experiencing an increase in droughts with more frequent hot days and nights. Sydney is faced with reduced precipitation and increased summer heat waves. Climate change adaptation measures are local and reactive. Through not recognising macro-trends, an opportunity has been lost to address broader outcomes. Energy is expensive and there is still an over-reliance on fossil fuels, both at the global and national level. A failure in reducing greenhouse gas emissions has led to a higher than expected sea level rise, posing huge challenges to Sydney. However, due to the implementation of new and advanced technologies, it became possible to adapt to the consequences of climate change.

Sydney has kept its infrastructure investments to a minimum to retain profits under restrictive pricing, resulting in deteriorating systems and rising operational costs. Australia's relatively tight regulatory environment has created barriers to new entrants across the utilities sector, exacerbated by expensive energy while transporting and treating water and wastewater still requires large amounts of energy. Almost no collaboration between utilities is happening and customers are disengaged. Those investments happening in regard to water use efficiency and security of supply are mainly driven by resource constraints and regulatory pressures. However, as utilities are still operating in isolation, an effective overarching strategy of reducing resource consumption wasn't implemented as of yet. Businesses are still only reacting to financial incentives and legislation.

The water sector has used demand management through usage restrictions to manage capacity and performance during supply constraints. As to support this management, smart technologies are implemented in small parts. Furthermore, some parts of Sydney have installed energy and water efficient infrastructure, together with incremental developments in green infrastructure. Sydney has installed smart metering in households, which helped in reducing domestic water consumption. Because of climate change a handle on customers' behaviour is kept and some disposal targets and grades have been implemented. This has brought about incremental improvements to the performance of existing assets and systems despite disengaged customers not caring enough about water issues and still embracing in an established throw-away culture. Water planning is heavily compromised by a lack of agreed and clear objectives for utilities and by political intervention in planning options and decisions. Infrastructure considerations are still left behind in the urban planning sphere. This results in Sydney's water system still operating in a more linear, rather than a circular way. Utilities are still primarily focusing on water supply and cost control without fundamentally rethinking consumption patterns.

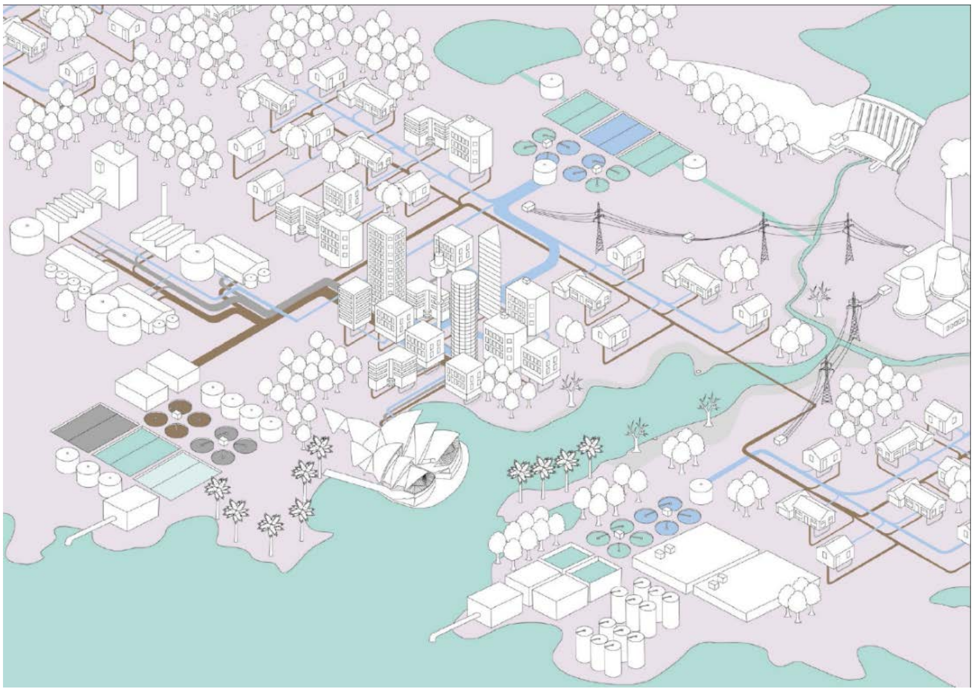

Figure 2 Incremental improvements scenario

Better Together

Better Together pictures a scenario where industry and utilities better collaborate across a centralised system. A centralised water supply system with an integrated provision of utilities.

Continued globalisation and investment in new energy technologies have boosted the global economy. There have been a series of coordinated and binding efforts, globally and regionally, to curb carbon emissions and limit environmental impacts. However, Australia is still experiencing reductions in precipitation long after greenhouse gas emissions have ceased.

Sydney's planning system is driven by a commitment to integrated planning as well as strict regulations to ensure compliance with global targets. Resource use is monitored and there is a drive for reuse and recycling. Sustainable, renewable resources have been identified and exploited and there has been a concerted drive towards zero waste and the circular economy. Australia became a strong player in wind and solar energy and strong local governance ensured that Sydney has become a low-carbon city. The city has minimised its energy and water use and its waste generation and thus halved its greenhouse gas emissions. Recycled water, stormwater harvesting and reuse became a standard. Seawater desalination is being increasingly used as a reliable source of water. Due to the implementation of new techniques as well as early actions on infrastructure improvements, Sydney is now able to meet a considerable amount of its water demand through local sources and its infrastructure and dam capacity is able to keep up with population and demand. Green infrastructure is increasingly favoured over man-made, engineered solutions with a focus on liveable urban habitats, achieving a better infrastructure resilience and stormwater management, linking urban and rural areas.

Infrastructure hubs were implemented across the city and as a result there has been greater industry collaboration, especially within the water, food, energy and waste sectors. Significant strategic and coordinated investments have been made to network utilities, in order to maximise synergies by integrating assets and sharing information and protocols more effectively. Small-scale water reuse is also happening on the household scale, but the majority of services are still provided through central suppliers and their resources.

Complex and integrated water supplies are managed by smart grids and systems. Advanced technologies for water capture, storage and monitoring are widely deployed. Smart metering is implemented across Sydney, resulting in growing use of real-time data. Customers, households, industries and the landscape are integrated, resulting in Sydney operating as a big living organism. The customer experience is focused on improved transparency and efficiency, and, as a result there has been a reduction in demand, as people are engaged with the utility providers and the system and are careful about their resource usage. Events and campaigns around behaviour change are held and people are briefed on how to live green. However, governments still rely heavily on policy to change how businesses work and how people live their lives. Individuals were forced to scale down consumption. The cost for infrastructure has shifted to the consumer, which meant rising energy and water prices.

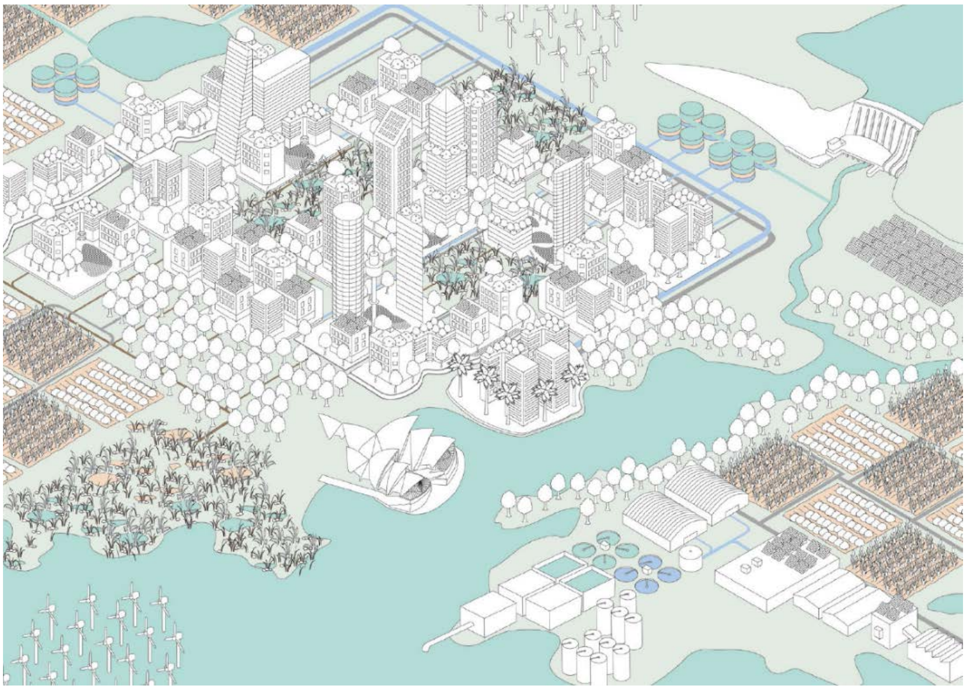

Figure 3 Better together scenario

Autonomous Communities

Autonomous Communities is a world in which households, communities and industry developed independence in water collection, processing and distribution while considering the interrelation of water, energy and food systems. A decentralised water supply system with an integrated provision of utilities.

The international community has coordinated efforts to combat advanced climate change. While weather patterns remain unpredictable, it is widely thought that the worst of climate change has been avoided. Despite the fact that a global agreement on the necessity to combat climate change was reached early in time, no binding global deal was achieved. Thus, communities started to look for solutions on the local scale and customers realised that a disconnection from the system might be beneficial for them. This has led to a focus on alternative energy and autonomous systems.

Although greenhouse gas emissions have been halted and the economy has shifted to a green economy, Sydney still has to deal with the impact of global warming, due to the huge amounts of emissions that have been put into the air in earlier times. High prices and constrained supply forces individuals to maximise efficiency and decrease their dependence on national utilities. As a result, urbanisation has been stabilised in favour of a more sprawled way of living. More focus is put on existing assets, with resettling taking place and people being closer to where their commodities are produced along with commodities being increasingly produced closer to existing settlements.

These new systems are often at the scale of households, communities, and industry clusters. Production and consumption are driven by the desire to be autonomous and operate on the local scale. A spirit of a circular economy is driving all decision-making. People are better harnessing linked systems, with food production, water and waste treatment and energy production being operated in a closed circle. Local renewable energy generation and decentralised grids have superseded coal, gas and oil.

Sydney has become a more resilient city with individuals adjusting creatively to the unavoidable consequences of climate change. Communities increasingly embrace urban agriculture, growing food on and between buildings. Houses and apartment blocks have their own water harvesting, recycling and purification, and recycled water became a standard. Through treating and sourcing water locally, Sydney was able to significantly reduce the amount of energy and infrastructure needed to perform these tasks.

Power resides at the community level, utilising computer-based collaborative tools. Independent customers are operating connected or disconnected small water networks. Communities engage with the water industry for trading, information, system design, and maintenance. There is, however, no supplier of last resort. Sydney has become more informal. Individual customer relationships are facilitated through open data, crowdsourcing and the sharing economy, benefiting from favourable attitudes towards data sharing. DIY and collaborative consumption is prospering and users are more acquainted and willing to use resources according to availability. Sydney's communities managed to achieve a closed system with little water going to waste. They are focusing on conserving, efficiency and reuse of water. Monitoring, sensing and metering is deployed and people's skills and talent is harnessed to its full extend. A strong focus is put on alternative means of water treatment such as reed beds and wetlands, aeration and solar water disinfection.

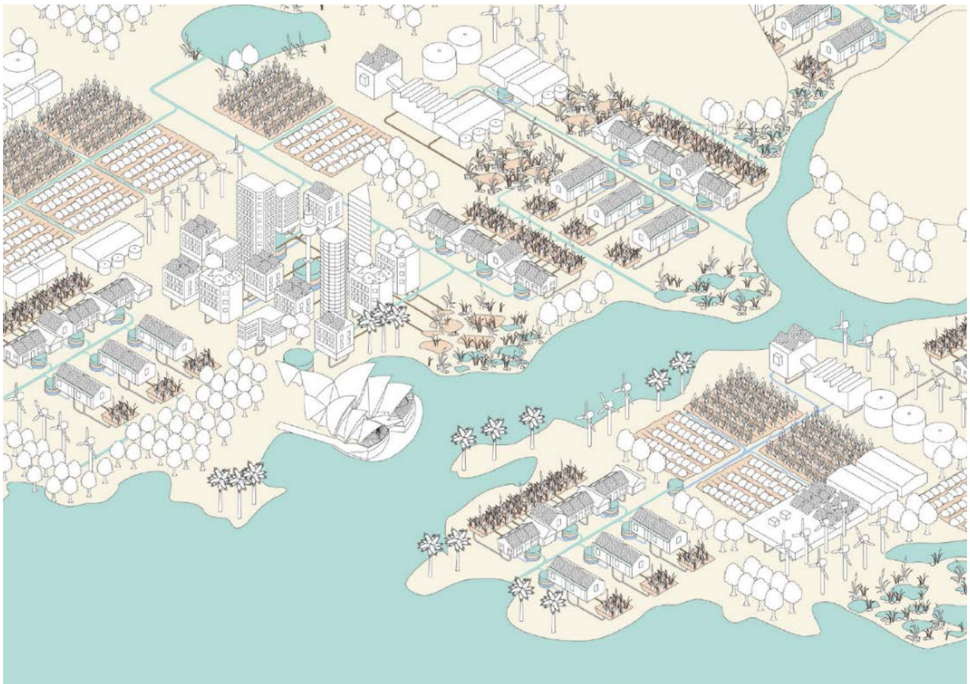

Figure 4 Autonomous communities scenario

Survival of the Fittest

Survival of the Fittest paints a scenario with greater competition for limited resources and restrictions to supply with high disparities in usage behaviour and access. A decentralised water supply system with a separated provision of utilities.

The global economy is in a prolonged period of recession. We are experiencing a world that woke up late to climate change, a world with greater water stress and resources only available for those who can pay for it. Many countries have already overpumped and depleted their aquifers and have reached or gone past peak water. Australia is faced with insecure water supply and an increasing amount of droughts. As a global agreement failed, tough measures have been adopted regionally to combat climate change. Resource use is strictly regulated in a world short of food and land.

Sydney is experiencing severe water shortages with periodic supply disruptions and population growth has been restricted by availability of water and land. The environmental system considerably suffered from environmental degradation and depletion. During this time competition for capital and investment has been acute. Poor economic and environmental conditions have created clusters of haves and have-nots within the Australian society. As a result of water scarcity, Sydney has implemented strong restrictions on consumption and supply, forcing conflicts for water and resources at the local scale. The government thus enforces more decision on people's lifestyles. Life in Sydney is tough and major parts of the formerly flourishing city centre of Sydney have been abandoned in people's search for available resources. Thus, large-scale resettling is happening which resulted in the urban population being lower than estimations predicted. The black market for water is a reality and informal economies are prospering. For those who weren't fortunate enough to build-up their own system, with no regards to planning or legal rights, water rationing and a constant fight for water and resources are daily fare.

The lack of cooperation has limited opportunities for the efficient management of networks, while simultaneously suffering from a lack of skills and talent. Government planning and policy has proved woefully short-termist with just enough of the basic infrastructure being maintained. However, the major part of an ageing water infrastructure is in need for upgrade, putting increasing pressure on capital needs. Local water supply and treatment companies compete for control over critical infrastructure and sources of supply. At the community level, no one is willing to share resources anymore. Groundwater is used with little concern for others, people use as much as they can once they have access. All available sources are identified and exploited and consumer behaviour is driven through accessibility. Despite increasing resource scarcity, consumption hasn't been cut down, it is just distributed unequally and all resource usage is driven by who is the fastest and who can pay for it.

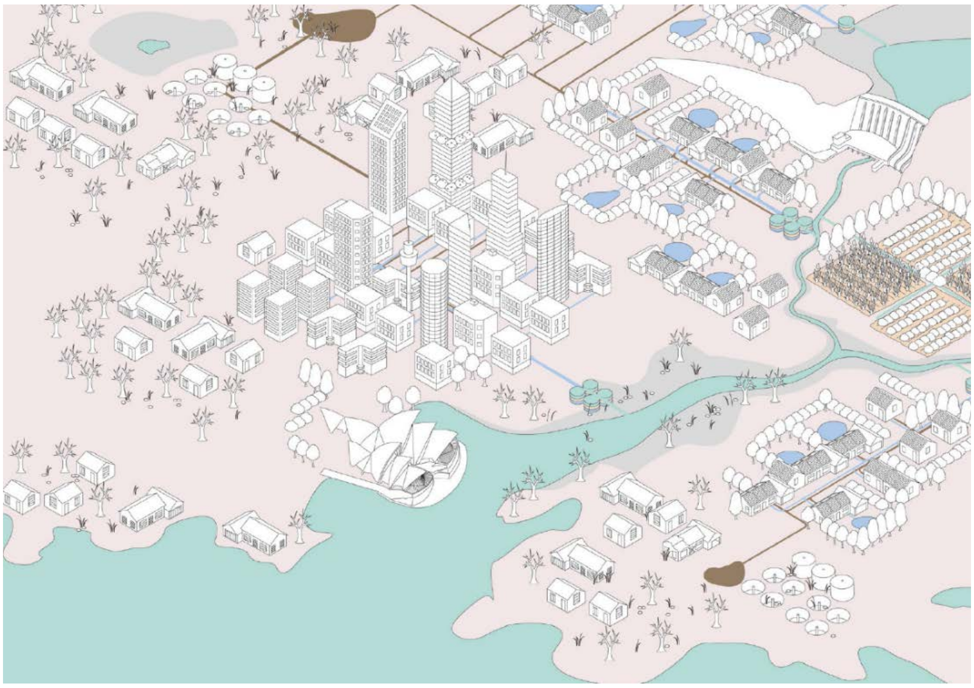

Figure 5 Survival of the fittest scenario

Results and discussion

Each of the scenarios carry implications for urban water utilities, in particular concerning customer experience, infrastructure and governance. The impact on each of these aspects of urban water utilities has been explored in the context of each scenario.

Incremental Improvements - Implications

Customer:

- Focus on customer services that are user-centric and that provide greater personal choice and control over service levels and pricing;
- Expansion of water services that focus on meeting the requirements of individual customers and that engage people at the community level; and
- Demand for higher levels of transparency and information in relation to metering, billing and customer satisfaction.

Infrastructure:

- Increased deployment of digital infrastructures and data analytics to manage, reduce or eliminate system peaks and fluctuating demand patterns;
- Deployment of sensing technologies and metering to increase the quantity and quality of system information and enable real-time applications for asset management and customer service; and
- Greater focus on existing assets, energy performance, and integrated infrastructure as part of maintenance and operating plans.

Governance:

- Higher levels of coopetition and integration between water, energy and telecommunication companies with a focus on integrated planning and maintenance;
- Focus on deregulation and greater competition, both within the water sector and across complimentary utilities; and
- Strategic focus on upgrading, improving and digitising existing assets in order to achieve better customer engagement and service feedback.

Better Together - Implications

Customer:

- Emphasis on creating a seamless customer experience across multiple integrated utilities, including shared billing, pricing and customer services;
- Focus on maximising customer satisfaction and engagement through digital experiences, gamification and community-based water systems; and
- Exploitation of synergies between multiple utilities and service offerings, with a focus on finding more efficient ways to meet customer requirements.

Infrastructure:

- Integration and sharing of assets and infrastructure across multiple utilities, including water, energy, waste and telecommunications;
- Creation of smart and self-learning water distribution networks that is enabled by sensors and automation across water collection, processing, distribution and consumption; and
- Implementation of green infrastructure solutions on a city and regional scale, with a focus on minimising the impacts of droughts, flooding and storm water.

Governance:

- Better cooperation between urban utilities through collaborative planning, integrated asset management, shared protocols and open data;
- Emergence of third-party service providers that focus on integration and cooperation between customers, systems components and utility providers; and
- Increase in prices for service provision in order to enable investment in infrastructure improvements, coupled with a higher number of investments that are shared by multiple utilities.

Autonomous Communities - Implications

Customer:

- Greater focus on services that enable customers to manage and maintain autonomous water systems at building, community or cluster level;
- Shift from customers that pay for the delivery of services to those that pay for the cost of installing and maintaining local infrastructure, either individually or collaboratively; and
- Utility services focus on assisting with end-user system design, installation, information, maintenance and emergency response.

Infrastructure:

- Provision of planning and infrastructure services that enable communities to develop, run and maintain autonomous urban water systems;
- Shift to clusters of autonomous and self-regulated water networks that operate at a building or community level, independent of the wider grid; and
- Increased deployment of digital infrastructure to facilitate resource trading and information sharing across a large number of autonomous urban water networks.

Governance:

- Governance and operation of autonomous systems and small-scale water networks through cooperatives, virtual networks and community platforms;
- Change in legislation and building regulations to enable greater autonomy and smaller-scale applications in water collection, storage, treatment and distribution; and
- Increase in small- and medium-sized utilities that focus on providing information, system design, installation, and maintenance services to autonomous communities.

Survival of the Fittest - Implications

Customer:

- Development of applications to provide customers with real-time data and information about water consumption, availability and pricing;
- Increased disparity in the type of water services delivered to urban customers as service models are increasingly influenced by variable pricing and service packages; and
- Usage of smart technologies within households, industry and networks to enforce, monitor and control efficient use, distribution and recycling of water.

Infrastructure:

- Expansion of technology and systems to manage and minimise the impact of extreme fluctuations in water availability, including fast shifts from too much water to too little;
- Focus on advances in decentralised and centralised water storage solutions, coupled with intelligent demand management and higher water recycling and reuse rates; and
- Increased focus on monitoring and reducing illegal water trade and theft, coupled with a reduction in leakages and wastage across the existing network.

Governance:

- Implementation of differential water pricing and services according to availability of supply, service plans, and customer behaviour;
- Greater focus on autonomous and community-based water systems, where service and infrastructure levels are determined by private investors and income power; and
- Resettlement of communities and industries into areas where resources are available and risks associated with urban water scarcity are reduced.

Conclusion

The explored drivers of change and future scenarios studies reflect the necessity for water utilities to be prepared to operate and succeed in a world that will likely be utterly different than the world we are experiencing today. Cities across the globe will increasingly have to focus on local water sourcing, reuse and recycling in order to sustain their population. Consequently, they have to move away from their reliance on external sources while considering the global water cycle. Water utilities need to be prepared to serve more people in the future while simultaneously dealing with an increasing scarcity and competition for resources.

An early response to increasing energy and resource prices, through the development of efficient processes and smart systems, could leverage off Sydney Water's market position. Not least through consequences of climate change, more resilient systems are needed. This offers the chance for water utilities to increasingly act as service providers for the development of autonomous systems. Furthermore, increasing investment in green infrastructure, primarily for stormwater management, would offer the opportunity to access and directly treat a new, currently underutilised water source. Water utility providers increasingly need to look at solutions through a different lens. Additionally, green infrastructure offers the possibility to turn waterways into parks and to provide natural capital and amenities to citizens rather than seeing water treatment as a technological process, separated from nature. Urban water utilities worldwide could thus shift away from water provision as hidden services towards a more visible service, a key contribution to public life.

Another opportunity area to tap into represents the engagement in behaviour change interventions in order to better influence and manage demand. More and more data availability through increasing digitisation offers opportunities for investments in real-time monitoring of network utilisation in order to enhance operations and asset management. To better deal with future challenges, water utility providers will have to favour integrated solutions over siloed interventions. This provides the chance for water utilities to play a fundamental role in the shaping of healthy and water-sensitive cities.

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From Vision to Action: Roadmapping as a strategic method and tool to implement climate change adaptation: the Example of the roadmap "Water Sensitive Urban Design 2020"

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Abstract

As the central product of the BMBF-KLIMZUG-funded Joint Network and Research Project (JNRP) “dynaklim – Dynamic adaptation of regional planning and development processes to the effects of climate change in the Emscher-Lippe region (North Rhine Westphalia, Germany)” the Roadmap 2020 “Regional Climate Adaptation” has been developed by the various regional stakeholders and institutions containing specific regional scenarios, strategies and adaptation measures applicable throughout the region. This paper presents the method, elements and main results of this regional roadmap process by using the example of the thematic sub-roadmap “Water Sensitive Urban Design 2020”. With a focus on the process support tool ‘KlimaFLEX’, one of the main adaptation measures of the WSUD 2020 roadmap, typical challenges for integrated climate change adaptation like scattered knowledge, knowledge gaps and divided responsibilities but also potential solutions and promising chances for urban development and urban water management are discussed. With the roadmap and the related tool, the relevant stakeholders of the Emscher-Lippe region have jointly developed important prerequisites to integrate their knowledge, to clarify vulnerabilities, adaptation goals, responsibilities and interests, and to foresightedly coordinate measures, resources, priorities and schedules for an efficient joint urban planning, well-grounded decision-making in times of continued uncertainties and step-by-step implementation of adaptation measures from now on.

Keywords: Water sensitive urban design (WSUD); integrated roadmapping; urban flooding; city planning; integration of knowledge, process innovation

Future initiative "Water in the city of tomorrow"

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Abstract

The conversion of the Emscher system will make the former open wastewater sewer of the industrial era disappear. What used to be spaces people avoided are being transformed into desirable locations; living and working along the Emscher waterways is becoming an attractive proposition. The Emscher conversion is therefore not "only" the largest water management project in Europe, but is also contributing to mitigating the population outflow, and supporting the success of the structural change into a service and high technology location. Holistic planning processes combine the requirements of the conversion of watercourses with those of urban and open space development, while taking into account the need to adapt to climate change requirements and demographic shifts, deriving the greatest possible benefit from the equally tight financial and spatial resources of the region. The future initiative "Water in the city of tomorrow" was started in 2014, developing and extending the partnerships required for the tasks planned, particularly between the water management industry and the urban planning authorities. With the aid of a GIS-assisted cooperation module, especially effective approaches can easily be identified, developed into specific plans of action, and justified, as shown by the experience of the first municipalities.

Keywords: urban drainage, climate change adaptation, heavy rainfall, urban heat islands, integrated planning, GIS systems, water sensitive urban design

Structural change and the Emscher conversion

The catchment area of the Emscher is 865 km2 in size, and comprises the central zone and the majority of the land area and population of the Rhenish-Westphalian industrial region, including major cities such as Dortmund, Bochum, Essen, Gelsenkirchen, Oberhausen and Duisburg. With a population density of approx. 2,700 per km2, a development rate of over 60%, and a drained surface ratio of approx. 40%, the Emscher region is one of the most densely populated conurbations in Europe. For historical reasons, the wastewater produced (sewage, stormwater) is almost entirely routed into the combined sewer system.

The Emschergenossenschaft manages the natural catchment area of the Emscher, including its tributaries, and as a self-governing waterboard under special law is responsible for sewage disposal, flood protection, stormwater management, groundwater management, and other water management tasks. The integrated handling of these tasks and the associated management of the river basin has grown historically, and was already in practice in the Emscher region before it was propagated by the European Water Framework Directive.

The extensive structural change in the Emscher region began in the 1970s, and sees the coal and steel industries that dominated up to that time increasingly being replaced by the service sector and high technology. This process of change is decisively supported by the conversion of the open wastewater sewers of the Emscher system into ecologically improved watercourses (Fig. 1).

Figure 1: The Borbecker Mühlenbach as a concrete open wastewater sewer (left) and one year after the ecological improvement (right)

Within the framework of the Emscher conversion project, the Emschergenossenschaft is investing around 4.5 billion euros by 2020 in modernising and expanding wastewater treatment plants, construction of 400 km of sewers, building around 190 stormwater treatment and retention basins, and the ecological improvement of 350 km of watercourses. The Emscher conversion project is the largest water management project in Europe, due to the size of the catchment area, and due to the large number, complexity and interdependency of the tasks involved, and forms a clearly visible element of the structural change in the region. Examples from the region which have drawn cross-regional attention and which confirm the creative potential resulting from the structural change include e.g. the *Lake Phoenix* in Dortmund and the *Krupp-Park* around the *ThyssenKrupp Quartier* (main administration) in Essen (Fig. 2).

Figure 2: ThyssenKrupp Quartier in Essen, former heavy industry site

Water balance requires a "return to the past"

Achieving the water management objectives of the Emscher conversion, i.e. generating good ecological potential for the clean watercourses being created, will fundamentally depend on how successfully the water balance in the catchment area can be returned to closer-to-natural conditions, having been immensely overloaded by a high proportion of sealed surfaces and the dominance of the combined sewer system. Since the start of work on the reconstruction of the Emscher system, Emschergenossenschaft has therefore been intensively advocating close-to-nature stormwater management, including on existing properties (Becker et al. 2009), and providing funding subsidies for the implementation of corresponding measures. Experience from two decades now of this culture of subsidies have shown that for many potential stakeholders, the funding, saved fees and creative effects achieved by the open management of stormwater represent sufficient incentives to implement such projects. The Future Convention for Stormwater concluded with the Emschergenossenschaft in 2005 by all municipalities and the Ministry of the Environment aims to manage 15% of the stormwater currently drained through the sewer system in a close-to-natural manner (Stemplewski et al. 2006) until the completion of the reconstruction process in 2020. Thus far, 6.3 percentage points have been achieved (Fig. 3.) Although this success is still a little lower than expectations, it shows the wide range of possibilities in the region. However, a coordinated approach to the planning and implementation of measures is still too seldom seen.

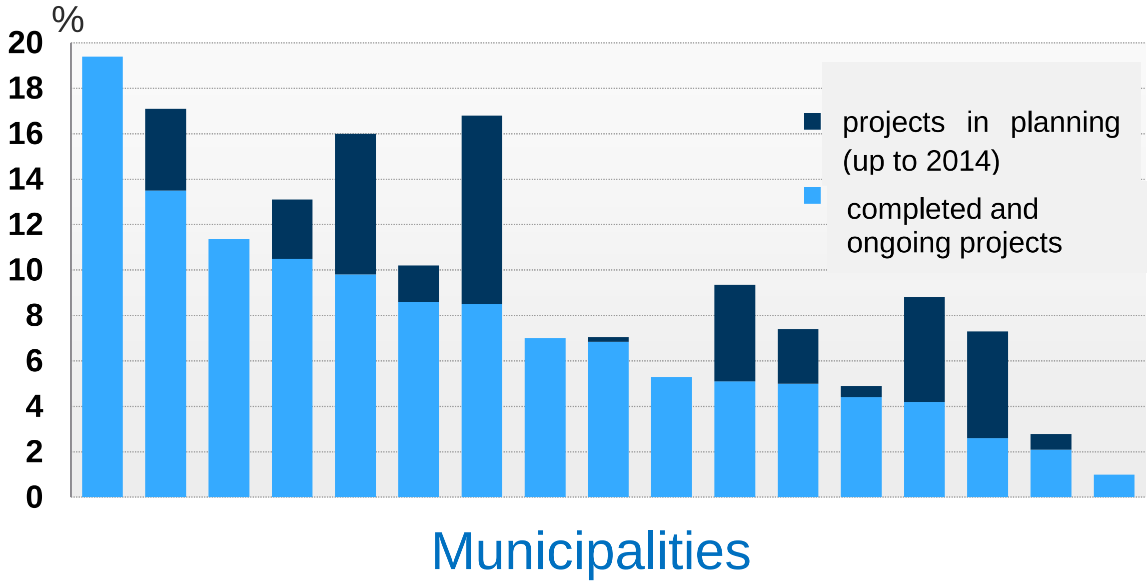

Figure 3: Close-to-natural drainage level of the Future Convention for Stormwater, as of 12/2014

Many challenges – joint problem-solving strategies

The experience of the last two decades furthermore shows that while the underlying motivations behind close-to-natural drainage projects are different from the perspectives of (municipal) water management, urban planning and climate change adaptation, the efforts made to manage water, and particularly stormwater, are extensively identical in their coverage (Juchheim/Ortmann 2009). Through joint consideration of objectives and ideas in urban and open space planning, it is possible to find and in particular finance projects together with the water management, especially with urban drainage planning, that are attractive, efficient, and effective for many different objectives (Fig. 4). This appears to be urgently needed, as the Emscher conversion, consequences of climate change, and not least the demographic changes are fundamentally changing a number of boundary conditions: climate change demands new strategies for adapting to new boundary conditions, because extreme weather events are increasingly resulting in flooding and overloading of the existing drainage infrastructure (Schmitt 2006), and periods of heat are generating new requirements for the cooling and ventilation of cities. Together with the demographic change, the successful and progressive economic structural change emerges new space requirements and usage patterns. In order to again prove its adaptability, responsible planners and decision makers in the Emscher region must again enter into regional and municipal planning processes with a coordinated and integrated plan.

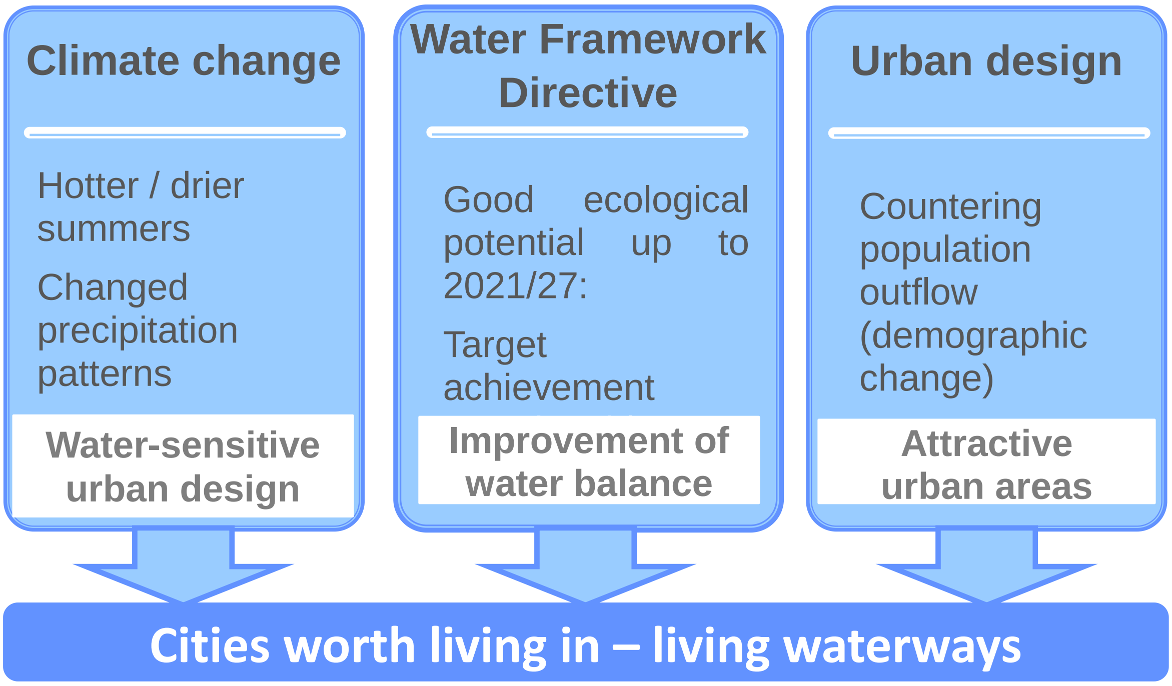

Figure 4: Different "driving factors" with the same objectives

For over a century, the Emschergenossenschaft has been coordinating regional and local interests and requirements in issues relating to water management for the entire Emscher region. The successful structures that have grown out of this also form the basis for present and future tasks in the river basin. Since 2006, the *Masterplan Emscher Future* has been the central dialogue tool for all participants and for all measures connected with the Emscher conversion. As an adaptable planning platform, it ensures a sustainable consensus between the stakeholders, and creates impulses for new projects (Emschergenossenschaft 2006). Many of the projects anchored in this plan have since been implemented with impressive results, e.g. the Lake Phoenix in Dortmund, the BernePark in Bottrop (Fig. 5), or the bridge over the Rhine-Herne Canal at the Kaisergarten park in Oberhausen (Emschergenossenschaft 2014a). The expansion of this tried-and-tested cooperation for the systematic interconnection of urban and open space planning activities, with subject areas such as stormwater management and ecological development of waterbodies is a promising means of generating and implementing multifunctional projects. For purposes of urban and open space development, this opens up in particular opportunities for using water management activities as the starting point for innovative and integrated development and design concepts. As a waterboard, Emschergenossenschaft can take over the role of "facilitator", thus having a key role in integrated urban and open space development, allowing its own interests to be pursued in a targeted manner, and in some cases more efficiently than previously (Raasch/Spengler 2014). Many measures that are available for fulfilling the requirements of the EU Water Framework Directive can simultaneously fulfil the requirements of urban planning and municipal drainage. Given that the municipalities in the

Emscher region have no leeway in their budgets for measures that exceed the scope of the absolutely essential, holistic planning with extensive support is not only reasonable, but is indispensable for the development and implementation of any kind of projects. In order to identify potential synergies between the aforementioned fields of activity, however, good communication is required between the stakeholders involved, as are the experience and awareness that the partnership is valued and that it advances one's own interests. All of these conditions have been fulfilled by the work over recent years.

Figure 5: BernePark in Bottrop, former wastewater treatment plant location

The pioneering city of Herten: water management and urban design, hand-in-hand

The project "Integrated water management as a motor for urban and open space development in Herten" was developed in 2013 by Emschergenossenschaft and the municipality of Herten, delivering an exemplary close interlinking of water management and urban and open space development activities. The objective was to bring together urban and open space planning tasks with infrastructure activities, systematically linking them with stormwater management and development of waterbodies, and thus achieving multiple benefits/synergy effects (Emschergenossenschaft 2014b).

Like most municipalities in the Emscher region, Herten has also recorded a decrease in population over recent years. For the urban developers, this represents an opportunity to pursue new approaches in the open spaces created, and to rectify defects in the urban planning. Considerations relating to demographic change, to the city of short routes and meeting places, urban landscapes as spaces for well-being and movement, climate adaptation, biodiversity, participation and cooperation are taken into account as much as the networking of green infrastructures and the water systems that are frequently located in the same green corridors. Together the citizenry and political bodies will in future be applying the "green through blue" development concept to focus the attention of planning and urban development on the open spaces of the city as a whole, and on its watercourses in particular.

ZUGABE – Together we all win

In order to facilitate the comprehensive exchange of information between the various stakeholders in the administration, water management / drainage planning and civil society required for such holistic approaches, the cooperation between the Emschergenossenschaft and the City of Herten developed the "ZUGABE Cooperation Module": the acronym stands for ZUkunftschancen GAnzheitlich BEtrachten ("considering future opportunities holistically"). This GIS-based tool supports the dialogue between the technical areas by preparing and compiling the available data on infrastructural, urban and open space planning and water-related aspects in such a way that synergy effects can be systematically identified and analysed. This joint process for collecting the corresponding information ensures a significant gain in understanding. Since the module additionally classifies the data stored in terms of significance, it is easier for technical planners, members of the public and politicians alike to identify priorities in a clearly comprehensible manner (Fig. 6).

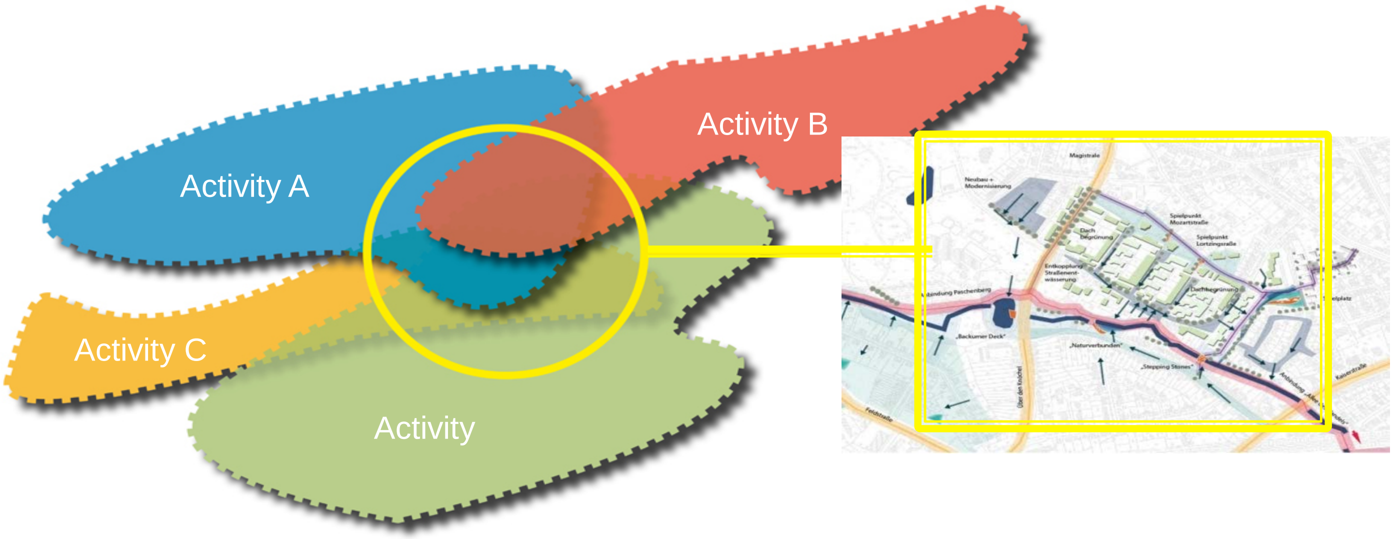

Figure 6: Functional principle of the ZUGABE cooperation module

Despite the good cooperation that already existed within the Herten administration before the model project as well as between Herten and Emschergenossenschaft, the first applications of the ZUGABE module surprised all participants. It quickly became clear that the benefits were not restricted to the stormwater-related aspects. All municipal departments, e.g. road maintenance, urban drainage, parks maintenance, urban land use planning etc., are thus enabled to see the relevance of their own projects for their colleagues' departments, and to approach their colleagues in a spirit of cooperative and holistic action.

With the module, used in Herten as a prototype, it was possible to explicitly identify how consideration of the cultural conditions and residential structures as a whole can make stormwater management and ecological improvement of waterbodies into a stimulus and development incentive for urban and open space planning for the city as a whole. The integration of decentralised stormwater management concepts into urban planning developments will support the systematic approach of the "Green City of Herten" more strongly than in the past: "green through blue" is the central strategy, and simultaneously the motto of the quality campaign for Herten, with a focus on decentralised stormwater management, development of waterbodies, modern urban infrastructure development, and attractive residential neighbourhoods, with a view to intelligent cooperation projects and taking advantage of synergies. Regular workshops conducted by ZUGABE form the foundation of this holistic approach.

From a pilot project to the river basin: Emscher Dialogue and the future initiative "Water in the city of tomorrow"

During the Emscher Dialogue "Water in the city of tomorrow" on April 30th 2014 in Bochum, the prospects resulting from the interaction between integrated water management and urban and open space planning were identified by means of kick-off talks, an information stand presenting the results from Herten, and in discussions between the 180 participants. Under the motto "Experts are needed", they thoroughly discussed what interests of their own they had brought to the event, exchanged experience, and drafted recommendations on a total of 10 subjects. The event thus represented the prelude to the future initiative of the same name: on 15 May 2014, all Emscher municipalities, the federal environmental ministry and Emschergenossenschaft signed a declaration of intent to cooperate for the "Water in the city of tomorrow" initiative (Emschergenossenschaft 2014c) (Fig. 7). This future initiative expands the spatial and content-related applicability of the previous Emscher Future masterplan, reinforces and promotes the commitment to the Future convention for Stormwater from 2005, and will in a culture of dialogue

- intensify the planning cooperation in an innovative planning culture,
- optimise the effectiveness with which scarce financial and human resources are used, and thus
- improve the effectiveness and sustainability of efforts to boost living conditions in the region.

Figure 7: Signing of the future initiative "Water in the city of tomorrow" on 15 May 2014 in the BernePark in Bottrop

Cooperation with federal State's support

The success of the pilot project in Herten has made an important contribution demonstrating the advantages of the holistic approach, and has roused the interest of other Emscher municipalities in the application of the ZUGABE cooperation module. With funding from the Ministry of Climate Protection, Environment, Agriculture and Consumer Protection in North Rhine-Westphalia, this positive response allowed the further development of the prototype into an easy-to-use tool in the second half of 2014.

Since then, and again with financial support from the environmental ministry, ever more municipalities have been preparing the available data for use in the ZUGABE module, and in each case the shift from scepticism to interest, and ultimately to enthusiasm, has repeatedly been observed, as it had been the case in Herten. This process can be documented through the attitudes of the individuals who make the critical contribution to the success of the application by providing data: "we all know about each other's plans here anyway" turns into "it's interesting how much is going on in our city", and "I don't have anything to contribute" becomes "yes, I've got information we could add to that, too". The decisive factor for initial progress, and hence for the success of the cooperation as a whole, is not to expect perfection from the first (intermediate) results. The more data can be considered at the same time, the more significant the overall picture will be; but even data from only few different areas can be worth considering together, especially because this promotes the change in attitudes described above.

For the future initiative "Water in the city of tomorrow", the high attractiveness of using the ZUGABE module for purposes other than stormwater management, means that in future the majority of municipal developments will already be considered under the perspective of decentralised stormwater management at an early stage. ZUGABE can also be used for public participation processes, e.g. for developing scenarios with members of the public, because it not only delivers individual planning proposals, but also represents a tool for developing perspectives and presenting in-depth justification of decisions.

With the signing of the declaration of intent on 15 May 2014, an important step was made towards more profound cooperation. As supplements to this, responsibilities, new forms of cooperation, and specific projects are being identified and agreed within the framework of individually designed bilateral agreements. This brings a hitherto unknown quality to the intensity, scope, and binding nature of the cooperation and the coordination of measures between the Emschergenossenschaft and its member municipalities, as well as within the municipal administrations. The State of North Rhine-Westphalia has not only approved of the content of the future initiative, but has also authorised financial support for its implementation. Consistent with this, a corresponding grant programme is intended to combine financing from the European Regional Development Fund and the wastewater charges of the State of North Rhine-Westphalia for measures under the EU Water Framework Directive on a situation-specific basis.

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The change towards more sustainable stormwater management practices: a contextual perspective

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Keywords: Stormwater, management, sustainable, green infrastructure

Introduction

There is a growing need for more sustainable stormwater management practices, e.g., due to the need to treat stormwater, increased accidents of flooding in urban areas due to the ongoing climate change, more paved surfaces with increased runoff, and/or aging infrastructure (e.g., Chocat et al, 2007). Yet, the change from traditional to more sustainable solutions is moving slowly. When planning for any type of stormwater system, agreement is needed on a number of aspects among many different interest groups. In an extensive literature review, Brown and Farrelly (2009) found that the barriers for change are largely contextual aspects rather than technical. However, there is limited knowledge and understanding of the importance and relevance of contextual factors influencing the change towards sustainable stormwater management practices. Consequently, more knowledge is needed on different actors' perceptions on the hindering and supporting contextual factors influencing change in stormwater management.

Objective

The objective of this work is to identify 1) what factors that hinder respectively support the implementation of more sustainable stormwater systems, and 2) what different stormwater actors perceive is needed in order to increase the implementation rate of more sustainable stormwater systems.

Method

In order to capture the perceptions of practitioners, an online questionnaire was distributed to some 1300 professionals (predominately managers) representing 5 municipal departments across all 290 Swedish municipalities. 400 respondents completed the form between April and June 2011, representing 227 municipalities. Most respondents were from the water department (34%), the urban planning department (25%) and the environmental department (21%). The responses from these three main groups (n=319) were selected for statistical analysis is in this study.

Results

The results of this study consist of a compilation and evaluation of a number of contextual factors, with regards to the respondents' perception of each factors importance for increased implementation of more sustainable stormwater systems. Contextual factors include e.g., urban planning; existing wastewater system; legislation; municipality organization; the occurrence of a municipality stormwater strategy; competence in the municipality; costs of construction; operation and maintenance; the solution's functionality; security issues; public health issues; and social amenity.

Discussion and conclusions

The question of which contextual factors being important or not, for the increased implementation of sustainable stormwater systems, is discussed. One important question to be discussed is how results of the present study could be implemented in the planning process in order to increase the use of more sustainable practices to manage stormwater.

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A Resilience Planning Framework for UK Water Companies: A Case Study Example and Consideration of 'Next Step' Issues and Challenges

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Abstract

This paper presents the background to the development of the current resilience planning framework used by UK water utilities to assess levels of resilience and to make a case for future expenditure planning. This considers Ofwat's original flood-risk framework, developed as a direct response to the UK flooding events of 2007 and the current 2013 all-hazards framework that was developed as part of a collective project funded by UKWIR (UK Water Industry Research Ltd). The practical application of these frameworks and lessons learnt are highlighted through a case study example for one of the UK's leading water companies. A recent development in the use of systems analysis tools for exploring system resilience is also presented and the paper is concluded by presenting views on the key challenges the industry will face when making a business case for resilience.

Keywords: Resilience, All hazards, Risk-based planning, Flood risk, Service risk, System analysis

Background drivers: why do we need a case for resilience?

It seems that resilience only becomes topical after the occurrence of an extreme event and major adverse consequences have resulted. There is a level of inertia to be overcome before action is taken. Perhaps this is because the events are perceived as 'one offs' and will never happen again, rather than being a lesson on what can be expected over the longer term. However, increasing focus on climate change and an apparent increase in severe weather related events across the globe means that resilience and climate change adaptation are being taken more seriously by engineers, scientists, policy makers and the public. Consequently, there is increasing momentum behind the aspiration to be better able to understand and prepare for the 'unexpected'.

A key trigger for the UK water sector was the well documented flood events of the summer of 2007 and the ensuing enquiry and recommendations developed in the Pitt Review – Lessons from the 2007 floods (http://www.cabinetoffice.gov.uk/thepittreview). These included demands for improved quality of flood warnings; a wider brief for the Environment Agency and stronger technical capability for local councils; better lessons learnt from the international community and a number of other specifics that have helped change the UK's approach to flood resilience.

Since then, there have been a number of extreme weather events and the UK has seen significant damage to infrastructure, property and life due to flooding, wind, coastal erosion and cold. As a result, there have been calls to make the national infrastructure more resilient and thereby ensure the continuation of essential services during and after periods of extreme hazard (The Cabinet Office, 2011: https://www.gov.uk/government/publications/keeping-the-country-running-natural-hazards-and-infrastructure).

What is resilience? The term resilience has some ambiguity and it is useful to have a working definition. However, the authors believe that resilience has a number of 'dimensions' and can be ascribed to assets, systems, customers, solutions, processes etc. We also believe that rigid definitions are not that helpful and some flexibility in how we describe resilience is important. Some interesting definitions in the literature include:

- Resilience is the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions - resilience includes the ability to withstand and recover from *deliberate* attacks, accidents, or naturally occurring threats or incidents (USA Presidential Policy Directive 21)
- Resilience is the ability of assets, networks and systems to anticipate, absorb, adapt to and / or rapidly recover from a disruptive event (2011 UK Government, Cabinet Office Keeping the Country Running).

The Australian Government (2010, Critical Infrastructure Resilience Strategy) proposes a broader definition of resilience based on the concept of building a resilient nation, in which:

- Australians are better able to adapt to change, where we have reduced exposure to risks, and where we are better able to bounce back from disaster.

This also raises the question as to the definition of critical infrastructure and the Australian government helpfully provides a definition: *'those physical facilities, supply chains, information technologies and communication networks which, if destroyed, degraded or rendered unavailable for an extended period, would significantly impact on the social or* *economic wellbeing of the nation or affect Australia's ability to conduct national defence and ensure national security'.*

What are the key risks? In the UK, initial work in the water sector focused on flooding of critical assets and this is the focus for the case study later described. However, our current methodology is based on a set of principles, one of which is to consider an 'all hazards' approach to resilience planning. These hazards include:

1) Weather extremes and periods of prolonged heat and cold etc..
2) Natural disasters
3) Sabotage
4) Natural deterioration and failure impacts
5) Change factors including climate, growth and urban creep

Not all companies will focus on all of these, but the basis of the planning approach should be to consider the 'bigger picture' and prioritise the factors that present the greatest potential risk

What are the needs? By inference, resilience management is a process that involves identification and estimation of resilience hazards, consideration of the associated risks (to people, property and the environment) and identification and justification of a planned programme of interventions to mitigate the risks. This is a risk assessment process and one of our needs is to develop an effective framework and decision support process that will help inform resilience needs. A key challenge and opportunity is to link resilience planning into a broader asset management framework that adopts a more holistic approach to identifying risks and balancing needs. Figure 1 illustrates this concept:

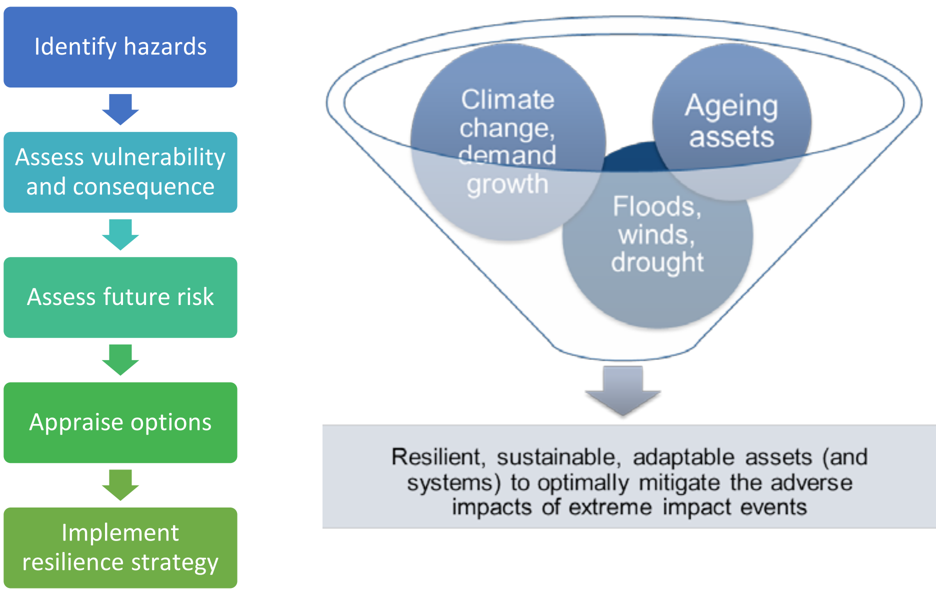


Figure 1 integrated resilience planning and decision making process

The Service Risk Framework (SRF)

Subsequent to the events of 2007 and the flooding of the Mythe water treatment works, which left 350,000 people in parts of Gloucestershire, UK, without water for over 2 weeks, Ofwat commission a study entitled: Asset resilience to flood hazards: an analytical framework (Halcrow 2008: http://www.ofwat.gov.uk/pricereview/ltr_pr0912_resilfloodhazglos.pdf). This framework was developed to provide a structured approach to support expenditure plans and to highlight good practice methodology. It was designed to enable companies to assess resilience needs of their assets alongside other expenditure needs by means of a fully monetized cost benefit analysis. The primary risk being considered in this approach was the inundation of critical water company assets and the damage costs and service losses that would be experienced by customers if water could not be supplied or wastewater treated.

The approach is summarized Figure 2 and is typified by a risk assessment methodology consistent with the general asset management planning approached by the UK water companies in support of their 2009 Periodic review (PR09).

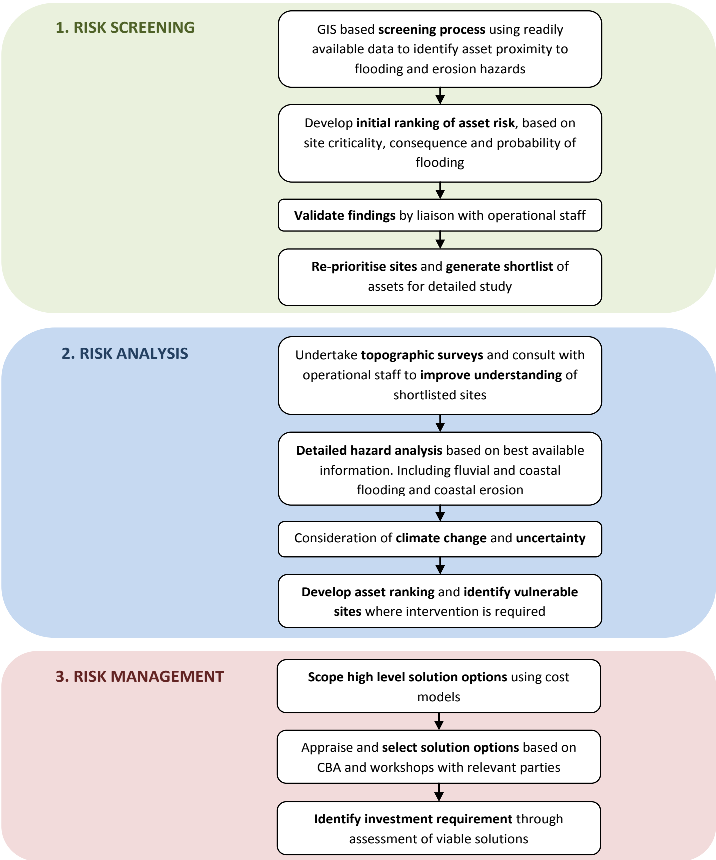


Figure 2 Key elements of the Service Risk Framework

The key elements can be summarized:

1) Estimation of the nature, probability and extent of the hazard
2) Identification of the critical assets that may be impacted by the hazard
3) Vulnerability assessment
4) Failure modes and consequence analysis
5) Consideration of change factor impacts (e.g. climate, growth, asset deterioration)
6) Identification of mitigation options
7) Whole life cost-benefit analysis
8) The overall process is iterative and uses a prioritization approach to focus the analysis

The monetised cost benefit analysis is particularly important because this enables comparative investment quantification and prioritisation across different expenditure drivers. To do this, the framework quantifies service losses and uses economic methodologies such as willingness to pay to assign loss values.

The framework was partially applied at PR09 and was further developed and applied for a number of UK water companies for PR14. A key development over this period was the work sponsored by UKWIR (UK Water Industry Research Ltd) in 2013, which developed a more extensive 'all hazards' resilience planning framework and which recognised the need to expand the scope of the original Service Risk Framework that was flood hazard focused.

The UKWIR resilience planning framework

This framework was developed on behalf of UKWIR by the CH2M authors of this paper. The framework incorporated a number of key principles, as developed by Mott MacDonald for Ofwat in 2012, and CH2M's UKWIR framework is outlined in Figure 3. This framework drew together the use of a set of underlying planning principles and the integrated and iterative SRF approach. The principles that inform the framework are:

PRINCIPLE	REQUIREMENT
Principle 1	An all-hazards approach to resilience planning
Principle 2	Proportionate resilience strategies embedded into corporate governance
Principle 3	Third party engagement
Principle 4	Resilience planning focused on risk to service outcomes
Principle 5	Customer preferences and environmental acceptability for different levels of resilience
Principle 6	Broad consideration of intervention options for resilience
Principle 7	Using cost benefit analysis to support significant decisions
Principle 8	Preparedness for response and recovery
Principle 9	Continuous improvement in resilience planning

It is of note that getting effective third party engagement when considering resilience issues that cross geographic and company boundaries is still a major issue and hampers some efforts to mitigate resilience issues. A chief part of this communication barrier is addressing the mechanism for funding investigation delivering solutions. This may sound a small issue, but it can be a major hindrance to optimizing solutions involving combinations of local, national, private and public organisations.

Not only does the planning framework encourage consideration of these principles, it also recommends a structured risk-based approach aimed at prioritizing efforts to best effect. It also encourages a system wide and asset focused consideration of risks and this is particularly important in understanding overall reliability and resilience.

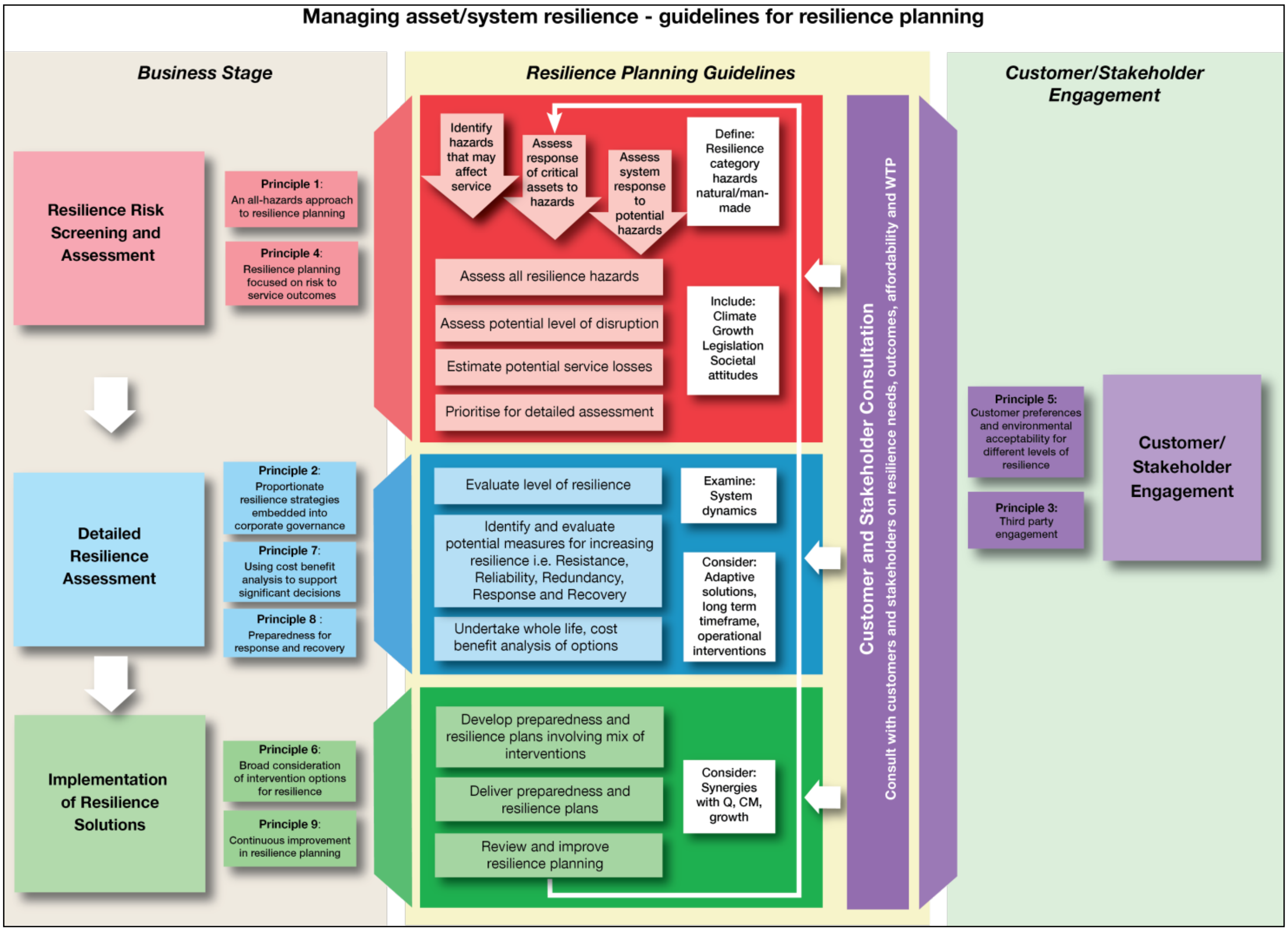


Figure 3 The UKWIR 2013 resilience planning framework

This framework was used successfully by a number of UK water companies for the PR14 business plan submission and continues to evolve as experience develops.

Yorkshire Water critical infrastructure resilience case study

In common with the UK National Risk Register and the National Climate Change Risk Assessments, Yorkshire Water identified flooding of its assets as a strategic risk today, with a potentially increasing risk profile over time as the climate changes. In order to continue providing services to customers whatever the weather, Yorkshire Water needed to understand and manage the risk of flooding to assets and to the services we provide.

Halcrow (now part of CH2M HILL) were commissioned by Yorkshire Water to implement the SRF. This work was carried out between 2010 and 2013. It began with an appraisal of the SRF and then a full scale application to Yorkshire Water's water and wastewater production assets. A risk based scoring approach was used to screen assets, which took into account proximity to potential hazard and criticality of the assets. This analysis was facilitated by using GIS mapping and proximity analysis techniques and the outputs were validated in workshops with key operational staff.

The process steps were:

1) Flood hazard screening of assets, based on the proximity of asset to Environment Agency (EA) flood zones
2) Initial prioritisation based on risk (consequence and probability)
3) Workshop-based validation of prioritisation with YW operations team
4) Re-prioritisation of sites for data gathering
5) Shortlist (c. 170) sites for further more detailed analysis
6) Topographical surveys and consultation to improve understanding of asset vulnerability
7) Detailed risk assessment based on analysis of flood return periods, asset critical levels and historic flooding
8) Consideration of climate change and uncertainty
9) Ranking of site resilience
10) Solution workshops and intervention cost benefit analysis (CBA)

These key elements are applied in an iterative risk assessment and management process.

The first stage of the process was screening of assets which was done by overlaying Environment Agency national flood mapping onto asset and site locations. The second stage was where the bulk of the activity was focused and is summarized in the following process flow diagram:

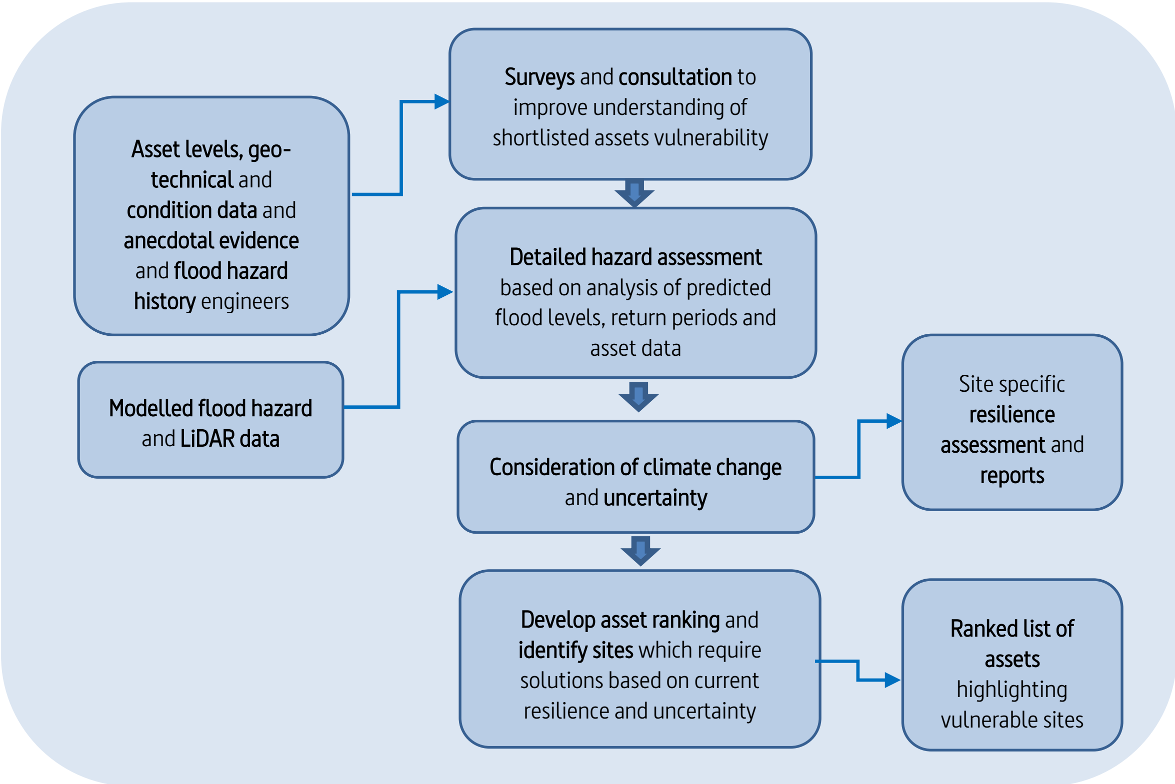
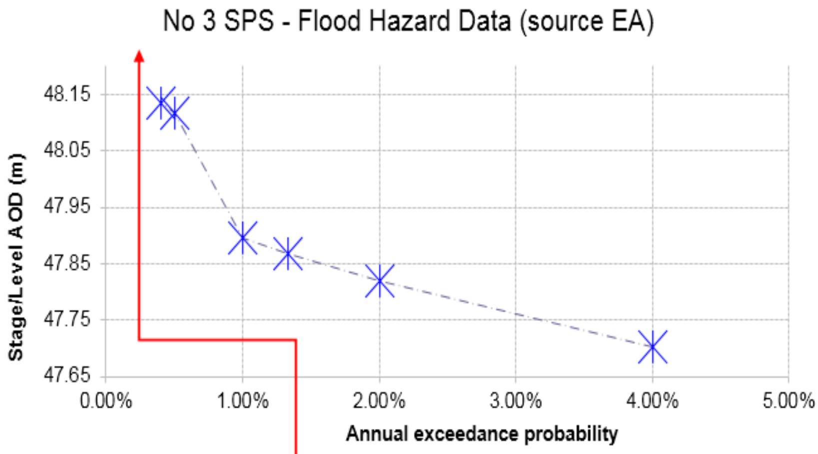


Figure 4 SRF risk analysis process elements

A risk scoring and workshop process was used to select priority sites for detailed analysis and this comprised topographical survey to identify critical asset levels e.g. door thresholds, instrument panels, top of open process tanks and filters. Fluvial (and where appropriate, pluvial) flood model data was used to examine the relationship between hazard return period and potential for damage to the critical assets and processes on site. The resilience for the key site components was estimated in terms of the annual exceedence probability as illustrated:

This analysis was carried out on all of the priority sites and estimates of the costs and benefits of providing a base level of resilience for an AEP of 1 in 200 (0.5%) for all of the vulnerable assets on the site. To do this, solutions were 'costed' and the service benefits estimated using Yorkshire Water's risk scoring matrix.

The output from this analysis was a site specific estimation of the mitigation options required to provide the target level of resilience and quantification of the service loss avoided. Climate change uplifts were incorporated into the solution designs.



Item	Level mAOD	Picture ref	Approximate Resilience 1in X years	Risk Level
MCC panel	49.00	1A	>250	
	49.40	1B	>250	

Figure 5 estimating resilience for critical asset components

This approach was used to produce a cost benefit ranking based on the net present value of the resilience solution which could be compared and prioritized against other asset management investments. It is of interest to note that the industry is still debating whether or not to make decisions based purely on the cost benefit analysis e.g. the NPV (net present value) or CBR (cost benefit ratio) or should there be a minimum standard of resilience to be implemented for all of our critical assets? If we believe it is the later we need to establish who will pay in those situations where the costs are dis-proportionate to the benefit in terms of damages or service losses avoided.

Using simulation tools for assessing system resilience issues

The work for Yorkshire Water was very interesting in that it demonstrated that the framework developed was suitable for quantification of critical asset resilience and allowed equitable investment decisions to be made irrespective of the risk driver. It also linked resilience planning into the asset management approach used by the company. It was also found that site based staff were able to contribute to the process, helping to embed resilience thinking deeply into the organisation.

As part of the work, we also started to consider the issue of the resilience of the overall system. For example, when considering a large water supply zone, there are often a number of strategic supplies, trunk mains, pump stations and treatment works and the question would be whether or not compensatory supply volumes can be provided from other sources should a major asset fail. Building on the asset focused resilience work for Yorkshire Water, we have been trialing the use of system simulation techniques for exploring this question. To do this, we have tested and developed the use of the CH2M HILL **Voyage ™** system simulation tool. This is a bespoke configuration of the ExtendSim software.

In essence, this involved creating a representation of an area of the system in Voyage which included water supply and demand characteristics, operational constraints, storage and reliability of key assets and pipes. The trial area and the component assets are shown in the following schematic network system:

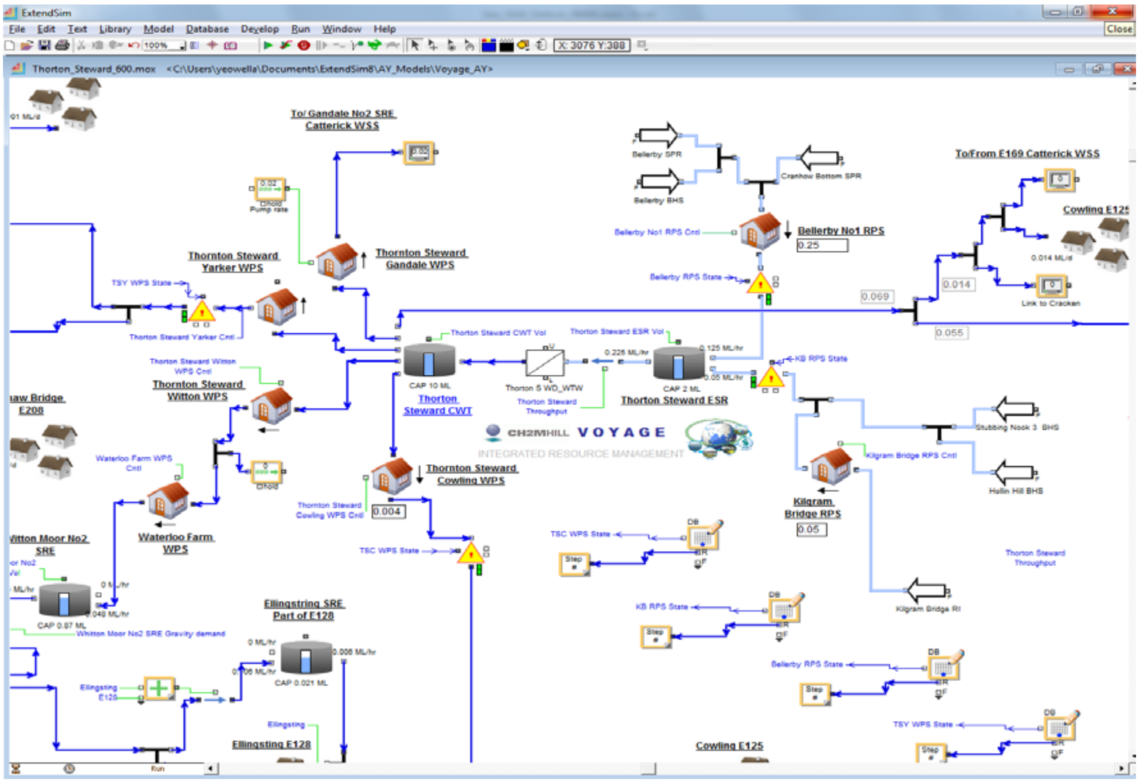


Figure 6 Voyage tool system model example

Our **Voyage**™ tool has been used to look at system dynamics and assess loss-of-service risk in complex systems where interconnectivity, demand, deterioration and operational regime all influence the risk potential. Simulation analysis was used to look at assess complexity and uncertainty. These system reliability and simulation tools appear to offer the potential for quantifying the service resilience of a strategic water supply system to external hazards and to explore the risk mitigation options at different points in the system and life of the assets. The modelling approach may include aspects of configuration, demand and supply patterns, storage, control and feedback, operation activities and response.

It is early days for using these tools to look at the combination of the effects of internal and external hazards, deterioration and changes in supply and demand, but the potential is clearly significant. We were able to assign failure characteristics to specific assets in the system and model the effects on availability of supply at various points. An example of an analytical output is shown in Figure 7, which compares the average annualised pattern of system outages for alternative emergency supply configurations:

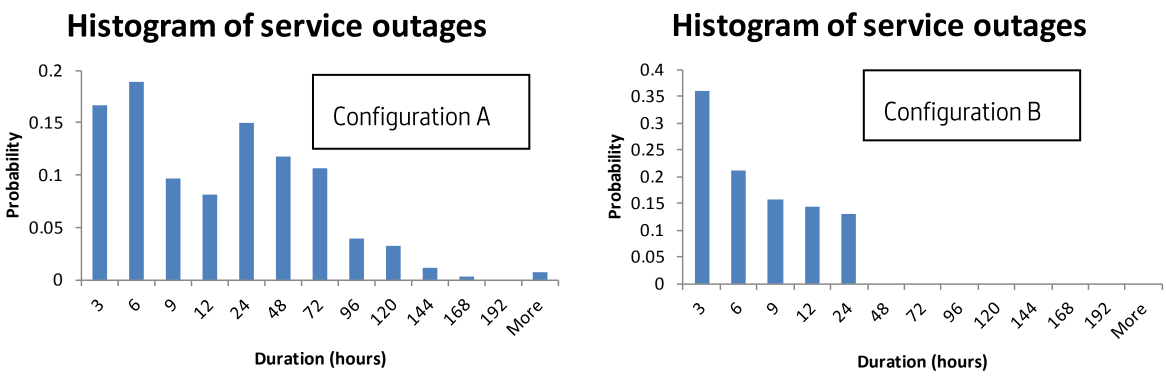


Figure 7 Service outages associated with alternative system configurations

It can be seen in this simple example how the duration and probability of service outages can be influenced by the system configuration (resilience) and this provides encouragement that these tools will be of great value in exploring resilience and planning adaptations and interventions.

Looking forwards: key challenges for the Cities of the Future

We have explored some working definitions of resilience, looked at risk based resilience planning in the UK and considered how systems analysis may help with complex resilience assessment and management. Nonetheless, there are a number of issues and challenges that will need to be resolved before resilience planning and management becomes a mainstream and effective process:

1) How do we best convince decision makers and funding bodies to invest in mitigation of very low probability but high consequence events when budgets are already stretched thin dealing with short term needs?
2) How can we encourage wider stakeholder engagement and action to deal with multi-stakeholder resilience issues?
3) How do we optimise our adaptation and resilience strategy when dealing with climate change uncertainties and complex interactions and inter-dependencies across systems and services?

Each of these is a difficult question to answer and there are many more such unanswered challenges to address. There will need to be concerted action and joined-up thinking if we are to make progress and this is against a backdrop of many other pressing needs to be considered. Perhaps we can afford some optimism now that resilience and sustainability are the focus of attention in at least some quarters and analytical tools and strategies are emerging that will help us identify and address the challenges. However, perhaps we cannot afford to be complacent when in some parts of the world local politicians and businesses are not even acknowledging the fact that climate change is a real issue.

Thinking Catchments: a holistic approach to asset management in the water sector

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Abstract

The hypothesis of this work is that the application of life-cycle thinking at a catchment scale will assist in the evaluation of natural capital and the integration of natural assets into the asset management portfolio of water industries. Drawing from literature on asset management and ecosystem services, this paper demonstrates the need for a holistic asset management strategy in the water sector. Through a detailed analysis, an approach coupling Integrated Catchment Management and Life Cycle Thinking is proposed. Within the paper, the background to the challenges facing the sector is described, followed by an analysis of the methods used to define the approach and the techniques required to undertake the analysis. The main focus of the work is the water sector in the UK. In order to evaluate the approach collaboration is undertaken with Wessex Water Services Ltd.

Keywords: asset management, ecosystem services, catchment, life cycle thinking.

Introduction

The industrial sector, and industries focused on commodity management have recognised the considerable indirect and direct impacts they have on natural capital and the role the latter plays in their viability. Despite this interdependent relationship and natural assets being fundamental for human wellbeing and economic growth, natural capital is inadequately valued compared to social and financial capital. It is the view of the authors that by valuing natural capital business could benefit and improve. To achieve this, it is necessary to have a means to value natural capital. A major challenge at present is the absence of a stantardised methodology or of a framework which adequately reports or accounts for natural capital (i.e. Earth's natural assets- soil, air, water, flora and fauna and their resulting ecosystems services) in the global financial system, as an economic, ecological and social asset.

As a result, a number of initiatives, methodologies and tools have emerged over the last few years, most of them being from the industrial sector (Maxwell et al., 2014). Private and public sectors are encouraged to create the conditions necessary to maintain and enhance natural capital, whilst governments develop relevant regulating frameworks (Natural Capital Declaration, UNEP, 2012). For the water sector, the Urban Water Blueprint report (McDonald and Shemie, 2014) shows how investing in nature can help addressing current challenges in drinking water security provision. This work applies a structured methodology at a city level in order to evaluate a set of solutions to the growing number of water-related issues.

Asset management in the water sector

Services in the water sector depend heavily both on natural assets (e.g. water), as well as on the function and performance of physical assets. Indeed, there has been a drive by regulators across Europe to improve the quality of the aquatic environment, most recently in response to the Water Framework Directive (WFD, 2000/60/EC). Achieving WFD water quality standards would bring significant social and environmental benefits. Thus, there is a growing case for understanding the dependencies water industries have on natural assets, the risks and opportunities associated with this relationship and their real value.

In the UK water sector, asset management strategies (Kwok et al.2010a), are the key drivers of current practice and future planning. Based on the guidelines provided in each strategy, asset management has evolved over the past years, and is being used to form a structural framework to meet regulations and improve business efficiency (Too, 2011). Following the definitions for asset management and asset systems as described in the British and International Standards, PAS 55/ BSI ISO55001, water industries (e.g. Waternet in Netherlands and Wessex Water in the UK) have created frameworks underpinned by systems thinking, to secure the provision of qualitative services to their customers and assets' viability. The boundaries of these systems are drawn where the physical asset systems (e.g. capital, operation and refurbishment costs of infrastructure) is at the centre, whilst the wider environment is treated as an externality.

Nevertheless, for asset management to become a true value-adding pursuit within a corporate framework, it must be primarily concerned with filling a strategic role. Asset management strategies have evolved from the specific conditions in which the organisation operates (Woodhouse 2006). According to literature (Palmer 2010), energy policy, climate change regulation, capital costs and strategic resources are the major challenges affecting the future of their asset investment. Facing these challenges, the water industry may need to adopt a more integrated approach in their asset management strategies and investment plans. This need for an integrated approach is highlighted in a recent report published by the UK Water Industry Research (UKWIR, 2014). The findings from the report are aimed at encouraging the UK water industry to work collaboratively with stakeholders of the watershed (i.e. the boundary between separate hydrological catchments) areas under their service in order to fully consider and seek to achieve a balance between social and environmental costs (e.g.. wider environmental impacts of carbon emissions, increased bills etc.) of their services at a local scale. They are advocated to define their strategic goals around a different center other than the physical asset, for example the environment, or society, in order to ensure alignment with the UN Natural Capital Declaration and meet the requirements for truly sustainable solutions.

Hypothesis & Aim

The hypothesis of the research presented in this paper is that the application of life cycle thinking at a catchment scale could prove a valuable tool for the evaluation of natural capital and the integration of land as a part of the physical asset management portfolio for water industries. The research demonstrates that a wider context that considers benefits provided by the natural environment (i.e. ecosystem services approach) needs to be adopted and a holistic structured approach introduced, whilst justifying the reasoning for the selection of each method. Integrated Catchment Management (ICM) and Life Cycle Thinking form the basis of the research. To evaluate the approach, collaboration is undertaken with Wessex Water Services Ltd for a selected catchment (case study). The outcomes of the research project will be embedded in their strategic plan for the Asset Management Programme 6 (AMP6, 2015-2020), which proposes an innovative programme, emphasising the mix of conventional end-of-pipe investment with novel approaches, such as catchment (land) management solutions.

The following sections of the paper give an insight to the methods used to create a holistic asset management strategy in the water sector. The methodological choices are described and the use of the concepts formulating the basis of the work is justified, followed by a description of the selected case study.

Methods

The work links various disciplines which range from asset, water and environmental management, to ecosystem services, cost estimation and systems thinking, offering transdisciplinary research.

Transdisciplinarity is a goal-oriented process rather than a knowledge production process per se (Walter et al., 2007, Krimsky, 2000). It is a way of placing the research problem, topic, or question at the centre of research process or a "new way of thinking" (Giri 2002), which has emerged as a way to address complex issues and requires innovation and flexibility (Leavy, 2011). A systems view is a powerful concept to be used in complex research projects (Schwaninger et al., 2007).

The design of transdisciplinary research requires an evolving methodology that follows an iterative or responsive process (Wickson et al., 2006) and ensures that the research questions stay at the centre of the research process. Moreover, the design strategy should be holistic and involve a synergetic approach to research (Leavy 2011).

The methods applied are selected in relation to the specific issue under study and for their utility in eliciting or analysing data. Transdisciplinary research often involves multi- or mixed-methods designs, constructed in service of the research goals, as they provide a practical and holistic approach to research problems, emphasising pragmatism (Hesse-Biber & Leavy 2011). Therefore, the use of each method informs the use of the other methods, rather than being simply additive.

Transdisciplinary research topics may be organised around a "site", i.e. a conceptual space where disciplines assemble (Krimsky 2000). Thus, situational context becomes important in studies of the concrete real world, whose results need to be comparable or transferable. This is a strong argument for the use of the case study method in transdisciplinary research projects (Walter et al., 2007).

Case studies aim to illuminate the general by looking at the particular. The rationale behind concentrating efforts on a single case is that there may be insights to be gained from looking at the individual case that can have wider implications (Denscombe 2010). Many of the features associated with a case study are not necessarily unique; however, when combined, they give the approach its unique character.

Transdisciplinary research can largely be evaluated with respect to effectively addressing the issue, its focus on the research objectives and using appropriate strategies (Leavy, 2011). The case study method can serve evaluation needs by being able to assess outcomes and test hypotheses (Yin 1993). To achieve that, a major prerequisite is development of causal relationships, which will then become the main vehicle for developing generalisations.

Life Cycle Management tools (e.g. LCA, LCC) could prove useful for water-related transdisciplinary research, provided their iterative character in the sustainability assessment of impacts of a product/system/activity using both quantitative and qualitative tools. Case studies can illustrate how effective life cycle management approach (i.e. joint use of LCA and LCC) could become in practice, when used to evaluate sustainable alternatives for product systems (Klöpffer et al., 2008).

Results and discussion

In this section, the approach created is described through and analysis of the underpinning literature. The various findings from the different literature domains are then assembled to build the rationale of the approach. The selected case study is then used to ascertain whether the concept and specific tools are applicable.

The Catchment as a System

Catchment management is about using land in ways that benefit the water environment. Historically, water authorities in the UK organised themselves at the river basin scale in order to control land use around water sources and prevent contamination of groundwater. However, after privatisation (in 1989) the focus shifted to upgrading water and sewage treatment infrastructure to provide greater guarantees that drinking water and effluent standards would be met within short timescales (Rouse, 2013). Nevertheless, there has recently been an upsurge interest in catchment management, as a less resource-intensive way to protect water bodies (UKWIR, 2014).

Catchments are the natural boundaries for water bodies (i.e. the natural water cycle), wherein the ecosystem functions related to water take place. Such a regional territory consists of a number of natural, semi-natural and artificial landscapes, composed of a mosaic of interacting ecosystems (or subsets). Regional watersheds have been characterised as pertinent spatial units for studying the interactions between humans and the environment (Billen et al., 2011), since they have historically acted as determinant factors of settlement location choice or agricultural and commercial activities. Therefore, the catchment is a single integrated system which includes both natural elements (biosphere) and infrastructure (technoshpere). In other words, the three sustainability pillars (environment, economy, society) co-exist and interact within the boundaries of a catchment. Sustainable Development recognises that social and economic progress should be simultaneous and integrated with the vitality of supporting ecosystems (World Commission on Environment and Development, 1987).

There is a growing recognition that to meet the goal of sustainable catchment management, there is a need for improved 'integrated' catchment management (ICM) (Macleod et al., 2007). ICM is a conceptual framework rather than a fixed formula for solving water-related problems that requires different conceptualisations of catchment processes (Macleod et al., 2007, Toit 2005). The use of appropriate scientific tools that would enable the integration between policies, science and their implementation is essential for sustainable catchment management.

To achieve an integrated approach, the specific characteristics of the distinct subsets comprising the watershed and their interactions should be identified and thoroughly studied. Sustainably managing an integrated system conveys the sustainable management of each of its elements, not only individually, but also as a whole. The interdependencies and interconnections among the elements of a system need to be identified in advance. The integration of water utility systems in the frame of a catchment is essential for their capacity to support human well-being (Everard 2012). Water infrastructure integrates multiple pressures from the catchment within it is built, and thereafter it becomes disproportionately vulnerable to climatic, hydrological, chemical, ecological and morphological pressures that affect its performance and service delivery.

The main water environment problem in the majority of the river basins districts (RBD) in the UK is water quality issues (Martin-Ortega et al., 2012). The agricultural sector is the major contributor to diffuse pollution. Significant improvements to farm practices are therefore needed to protect water quality. Nevertheless, the assessment of sustainable resource management and the design of relevant policies should occur at a local level and involve alliances of a wide range of stakeholders (Herath et al., 2007). Towards this direction, water industry in the UK is encouraged to work collaboratively with stakeholders of the catchment areas under their service (UKWIR, 2014), in order to fully consider and seek to achieve a. wider environmental and societal benefits of their services at a local scale.

Life Cycle Thinking

In the context of progress of sustainability science, life cycle thinking (LCT) may play a crucial role (Sala et al., 2013a, 2013b). Applying LCT offers a way of incorporating sustainable development in decision-making processes (Valdivia et al., 2013). This means going beyond the traditional introverted focus of industries and taking into account the environmental, social, and economic impacts of a product/activity over its entire life cycle and value chain.

The main tools widely used to date to cover the sustainability pillars are: Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and social LCA. The latter is out of the scope of this work. Life Cycle Assessment (LCA) is a technique used to quantify the environmental impacts associated with all the stages of a product, service or process from cradle-to-grave. An LCA must be carried out in accordance with the technical norms established by the ISO (ISO 14040 and ISO 14044). LCA is an engineering tool that studies a whole system, highlights areas where the efficiency of existing systems could be improved and allows comparisons between alternatives.

In the water industry LCA has been applied at a strategic and/or regional level, at project and process level and at a very specific level (Friedrich et al., 2007). LCA has proved well-suited for application in the water sector and has been characterised as a particularly useful tool for organisations wishing to look holistically to the environmental impacts, investigate alternative solutions, and go beyond regulatory compliance (Siebel et al., 2008, Narangala and Trotter, 2006).

The economic counterpart of LCA is Life Cycle Costing (LCC). LCC is an assessment of a product's cradle-to-grave costs and is a traditional way of accounting the total costs of built assets (e.g. equipment, infrastructure). The current need to include 'externalities' (costs borne by other bodies) of the systems under study have driven methodological improvements in LCC and the development of concepts suitable for an assessment of the economic implications of a product life cycle in a consistent sustainability framework (e.g.

environmental LCC). For water industry, external costs may be those related to land use, environmental conservation or prevention of pollution.

As described previously, there are a number of techniques and approaches that are pertinent to achieve a holistic asset management strategy. In the next section, the creation of the holistic asset management strategy is provided.

Creation of holistic asset management methodology

The present research project introduces holistic asset management (HAM) as a key element for effective and sustainable management of water resources. The catchment scale is adopted as appropriate for the application of HAM (Figure 1.1). Catchments are envisaged as hybrid and complex systems. Their limited boundaries allow for the capture of interdependencies between biosphere and technosphere and the identification of key-issues affecting the efficiency of the system and its capability to meet statutory standards. The principles of Integrated Catchment Management (ICM) form the ground of the methodology. The selected approach enables sustainable management of water resources for a range of uses and several stakeholders; thus the 'synergetic' tackle of the pre-identified key issues of a catchment.

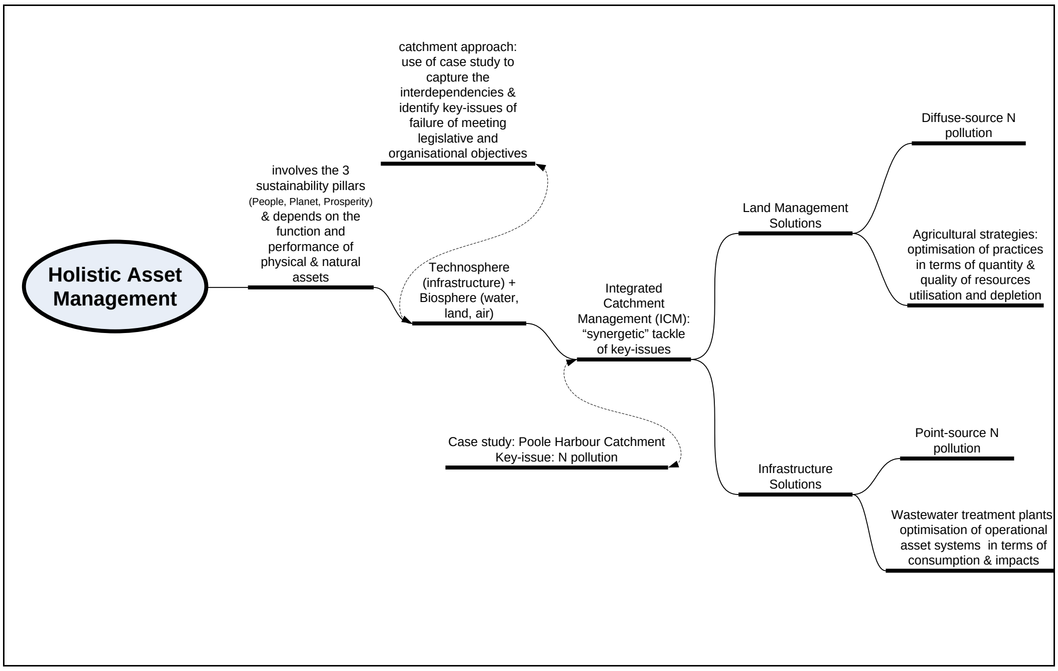

Figure 1. The rationale of the research project: holistic asset management through integrated catchment management.

In order to test the approach to AM on a pragmatic basis, an action research framework is selected. Poole Harbour Catchment is used as a case study to the check the applicability of new tools and methods. The main objective of the work is to provide sustainable solutions to tackle diffuse nitrogen pollution deriving from agricultural activities. The project evaluates diverse scenarios and proves whether it is beneficial for Wessex Water to invest in land conservation and internalise land as part of its physical assets; thus, include land management in its strategic asset management planning.

The novelty of the approach is the application of life cycle thinking at a catchment scale. Outcomes will be formed with the joint use of life cycle management tools (e.g. LCA and LCC) and based on the assessment of both environmental and financial aspects. The synergetic use of these methods provides a holistic means of assessing benefits and damages of a system in a format that is easy to communicate. It also allows various options to be investigated and the most sustainable solution to be selected for future implementation. A portfolio presentation of the results from the application of a joint LCA and LCC conceptual model will evince the trade-offs of each of the land management option and assess the impacts and costs of its implementation in long-term.

The case study: Poole Harbour Catchment

The test-bed for the application of HAM is a well-studied catchment within the service territory of Wessex Water. The Poole Harbour Catchment (PHC) is a rural (80% agricultural land use) catchment located in the Dorset area (South-West England). The area contains many sites of local, regional, national and international importance and is designated as protected area under a number of conventions. The PHC was selected as a pilot catchment to participate in the Catchment Based Approach Initiative (CBAI) launched in 2012. Investigation of the environmental status of the watershed and identification of pressures within its boundaries reviled nitrogen pollution as its key environmental issue. The Nitrogen Reduction Strategy (NRS) report (2013) recommends that action should be taken to ensure future urban and rural development does not result in a net increase in nitrogen load.

According to their current strategic planning, Wessex Water Services Ltd has focused on infrastructure solutions (i.e. nitrogen removal wastewater treatment plants) to address the problem and meet statutory standards, managing to achieve large declines in the discharge of inorganic nitrogen from point sources. Despite the actions taken, the combined influence of background factors and current nitrogen management in the catchment cannot yet result in a decline in the water's nitrate concentrations. Therefore, land management solutions may prove more efficient, since it seems that land status influences the performance of the built assets and company's service delivery.

Life Cycle Thinking in the Poole Harbour Catchment: scenarios under evaluation

In order to assess the value of the adapted strategies in the catchment, it is crucial to identify the relations between its various elements. The catchment under study is described as an integrated system, based on the consequential relationships among its diverse elements with the use of a modified flow chart (Figure 1.2, scenario A0). It provides an insight to the water circulation in the Poole Harbour Catchment (PHC) and assists in explaining the relations and interdependencies among its elements, both natural and artificial. The sketch is a simplified representation of the stages of the urban water cycle within the boundaries of the catchment under study. The origin of the water available for use in the urban cycle is both surface and groundwater. In order to serve the scope of the research project, it is supposed that, after abstraction and treatment, water is allocated only for agriculture and urban use (households). Each of these two categories produces different wastewater, in terms of its quality and quantity, as well as character, referring to the differentiation between diffuse pollution (agricultural wastewater) and point pollution (households/wastewater treatment plants). The wastewater produced by the urban parts of the catchment is transferred and treated in the wastewater treatment plants through the pipeline network. After treatment (Stage 4), effluent of certain quality is poured in the Poole Harbour. Water allocated to the agricultural sector is used for irrigation, farming and livestock. The return flow to the environment follows the natural water cycle in two directions: infiltration to the chalk aquifers and/or surface run-off in the rivers. The quality of this effluent is controlled by the intensity of the agricultural activities. Surface water outflows in the Harbour, contributing to its nutrient load. The infiltrated water reaches the aquifers and is then abstracted (Stage 1) to re-participate in the urban water cycle. Its quality

–in terms of nutrient content- may influence the operation of the water treatment plants (Stage 2), in terms of energy and chemical consumption. The remarkable slow travel time of water in the chalk aquifer (1m/year) enhances the need for using techniques that could capture the life-cycle of the natural processes occurring in the catchment.

The scenarios under evaluation are formulated to serve research, industrial and policy purposes. Two potential agricultural strategies (A1, A2) will be tested and evaluated for their effectiveness to reduce diffuse nitrogen pollution in the catchment and will then be compared with its current status (A0). The benchmark is the reduction of diffuse pollution by ≈550 tonnes of N/year across the catchment. The selected strategies represent suggestions made in the NRS report. These include the establishment of winter crops (wheat winter production) and the adoption of site-specific management along the catchment. The outcomes of the strategies under investigation will be compared with those of conventional practice, such as the construction of a wastewater treatment plant. Scenarios will not be formulated regarding the point-source nitrogen pollution, as it does not contribute more than 15% of the total nitrogen load. Further to this, both aforementioned scenarios (A1, A2) assume the operation of the existing nitrogen removal wastewater treatment plant at the current level of efficiency (7mg N/l discharge quality), which results in 330 tonnes of N/year. The table included in Figure 1.2 summarises the parameters associated with both scenarios.

In order to ensure that the scenarios would be rigorously compared before any conclusions for their value are drawn, functional unit -equal to 1 m^3 of water-, systems boundaries and impact categories assessed are the same for all the scenarios evaluated. The selected variables are the drivers of the data requirements for the research project. Further methodological choices will be made and tailored to fit the joint LCA and LCC framework.

Land Management Strategies	Benchmark (N load, tonnes/year)	Diffuse pollution (N load, tonnes/year)	Pot-source pollution (N load, tonnes/year)	N-removal treatment plant discharge effluent quality (mg/l)	Environmental Assessment			Economic Assessment		
					Method	Parameters	AoP*	Methods	Parameters	AoP
Current status (A0)	2280tn/yr	1950 tn/yr	330 tn/yr	7 mg/l	Life Cycle Assessment (LCA) & Water Footprint Assessment (WFA)	Water consumptive &degradative use, land cover, soil deterioration, air emissions, chemical	Resources efficiency, Ecosystems	Life Cycle Costing (LCC) & evaluation tools	benefits for the environment, efficiency, response time	Resources efficiency, Ecosystems
Scenarios										
Winter cover crops (A1)	1730 tn/yr	1400 tn/yr	330 tn/yr	7 mg/						
Site-specific management (A2)	1730 tn/yr	1400 tn/yr	330 tn/yr	7 mg/						

*AoP= Areas of Protection

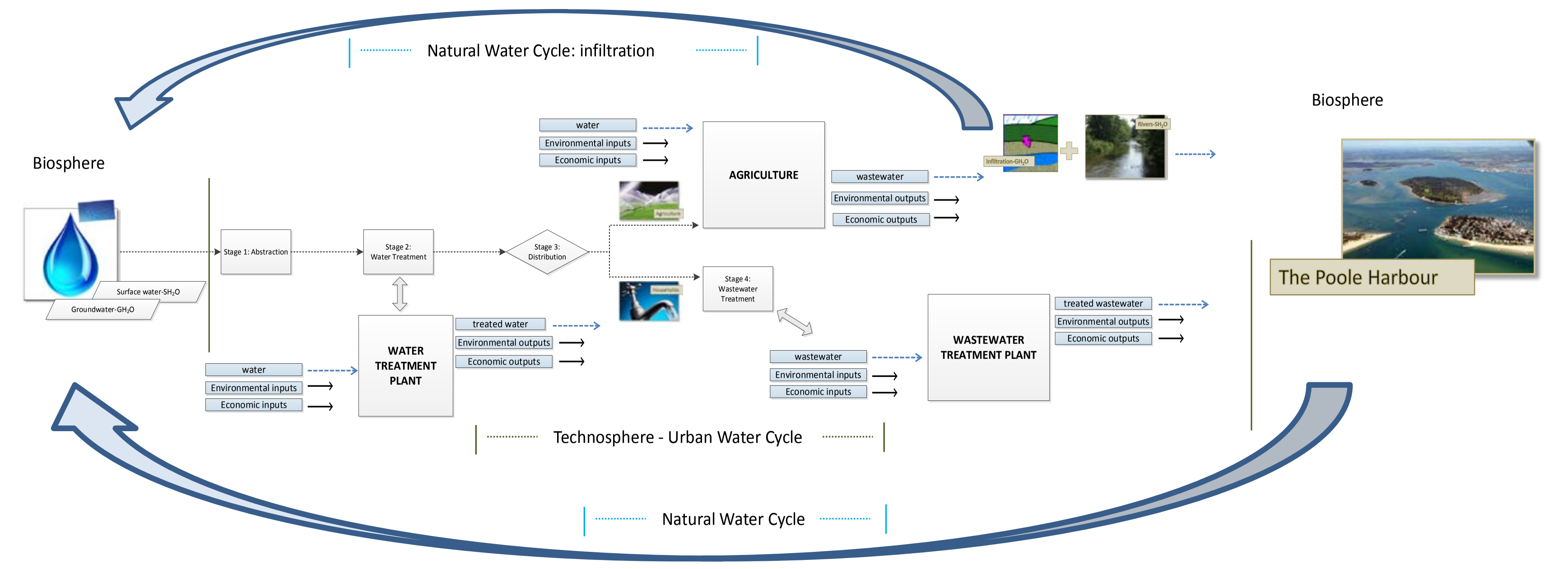

Figure 2: Schematic representation of the current status of the Poole Harbour Catchment (scenario A0)

Conclusion

The paper outlines a new approach to asset management in the water sector. The approach applies life cycle thinking at a catchment level. Drawing from literature from diverse fields, the underpinning research shows the need for a holistic approach to asset management and stresses that strategic planning of water industries should be based on an integrated management, which aims at the original reduction of the pollution, instead of its sterile tackle, under the legislative 'distance-to-target' threat. Methodological choices are made in order to pull together life cycle assessment (LCA) and life cycle costing (LCC) for the selected scale. Scenarios for different land management strategies have been formulated and are being examined for the Poole Harbour Catchment. The environmental impacts and costs for each scenario are calculated based on the joint LCA and LCC framework as formed for the needs of the research project. A portfolio presentation of the results will highlight trade-offs and assist in the evaluation of the outcomes of its strategy. Valuation methods and tools have been selected to serve the scope of the project. The most sustainable and pragmatic 'modus operandi' will be applied to the selected pilot catchment, as part of the strategic asset management plan of Wessex Water Services Ltd. The structured conceptual approach and the evaluation of diverse scenarios aim to prove whether it is beneficial for the industrial partner to internalise land as part of its asset management portfolio and how conservation strategies could have a material impact on both ecosystem and provision services at a catchment basis.

The adoption and implementation of the suggested holistic asset management (HAM) approach is orientated to tackle pre-identified key-issues at a catchment scale. It could be seen as an innovative tool to meet legislative standards and even go beyond regulatory compliance. The structured methodology involves all three sustainability pillars (People, Planet, Prosperity) in a format that is easy to communicate to policy-makers and replicate to other cases. On the down side, its implementation may be more complicated compared to the conventional end-of-pipe investment solutions adopted to date. Moreover, its outcomes involve higher risks. Nonetheless, the benefits for the environment and the customers can be significant.

In the grounds of a demanding and challenging urban and rural context, UK water industry is struggling to balance between costumers' provision, statutory requirements and performance indicators. In order to pull together the pieces of this jigsaw puzzle, water companies could swift the centre of their strategic goals around the environment or society. The catchment-based approach could assist at joining the pieces and revealing the bigger picture, whilst engaging a wide range of stakeholders. The application of Life Cycle Thinking at this scale of analysis could be a step towards achieving balance between social and environmental costs of different management strategies. A structured framework could also assist 'external reporting' to regulatory bodies, whilst the adoption of a common methodology for assessing, evaluating and calculating environmental benefits and costs could drive to the implementation of truly sustainable solutions.

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The use of the Infrastructure Value Index to communicate and quantify the need for renovation of urban water systems

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Abstract

Urban water systems continue to age, accumulating renewal deficits, in spite of the effort made in recent years in terms of awareness, scientific and technological developments, capacitation and renovation itself. One of the key existing bottlenecks for a change in policies, mindsets and practices is COMMUNICATION. Difficulties exist within the utilities providing the services, both in communication between decisional levels and between departments. Major difficulties and deficiencies also exist in communication between stakeholders, particularly utilities, political bodies and the society. How to transmit the need for investing in renovation of existing infrastructures at an adequate pace, when the lack of renovation does not have a short term impact on the quality of service to users? How to transmit that if considerable investments in renovation are not made at present and evenly over the years to come, we are preventing our children and grandchildren to have access to the services that current modern societies take for granted? TRUST provides steps forward with this regard, one of them being the focus of this paper – development of the concept of IVI (Infrastructure Value Index) and of a software tool to support creating awareness, assessing the long-term impact of renovation policies and assist in stakeholders' negotiations.

Keywords: Long-term planning, asset management, vertical and linear assets, rehabilitation, investment planning.

Using cost-benefit considerations to evaluate infrastructure asset management data quality and availability

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Abstract

The availability of appropriate data is a cornerstone in the planning of sustainable water services, and in order to ensure that the planning process in a water utility are supported by adequate data quality (DQ), one must explicitly plan for it. An important principle for achieving adequate DQ is to ensure that the benefits of the data are maximised (Rokstad et al. 2013, Murphy et al. 2008, Lin et al. 2006) – this principle gives way to the application of a cost-benefit consideration (Rokstad et al., 2015). CCTV condition assessment of sewers is a expensive source of data, as it requires costly equipment and is labour-intensive (performing inspections, interpreting and coding the observations), but nevertheless crucial for managing the condition of a sewer network. Such data provides knowledge about the current condition of the sewers, and can in combination with deterioration models be used to forecast the future distribution of conditions and make inference about the condition of unobserved sewers. CCTV data is therefore instrumental for diagnosing a sewer system with respect to condition. The presentation aims at answering the following research question: How do the current benefits of CCTV data collection manifest themselves when diagnosing the condition of a sewer system, and how can these benefits be improved?

Keywords: data quality, infrastructure asset management, cost-benefit

3.5 INIS: A German Research Cluster on Water Infrastructure

How can urban water infrastructures contribute to a sustainable urban metabolism?

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Abstract

This talk explores the role of urban water and wastewater infrastructures (UWIS) in the transition of cities towards resilience and sustainability. We give an overview of material and energy flows mediated by UWIS in context of urban metabolism. Then, we discuss the urban landscapes and the potential contribution of urban water management to more resilient urban ecosystems. Before this background, we present an integrated concept for water, energy and nutrient reuse, which also contributes to resilient and nourished urban landscapes and improves urban (micro)climate.

The first part gives an overview of material and energy flows mediated by UWIS in context of urban metabolism. Urban water and wastewater infrastructures (UWIS) are an essential part of every cities metabolism. Their main function is to guarantee public health and safeguard water resources. But due to the resource consumption and the emission of UWIS, they are connected to many environmental problems. This includes energy related problems, such as the depletion of fossil energy resources and climate change, as well as water quality and quantity related problems, such as eutrophication, hygiene and persistent pollutants.

Wastewater flow streams contain large amounts of “resources”: Water, Carbon C, Ni-trogen N and Phosphorus P. This provides an opportunity for water and nutrient recy-cling and energy harvesting (reuse of “internal” resources). Currently these opportunities are not fully exploited and there are large non recovered potentials.

Besides the resources, wastewater flow streams also contain a multitude of pollutants. The wastewater pollutant load is a mirror of society: it contains heavy metals and organ-ic micropollutants, such as disinfecting and impregnating agents, flame retardants, pharmaceuticals. Some of them have persistent, bioaccumulative or toxic properties and are not fully biodegradable with the current technical setup. Effluent and sludge are important pathways for many pollutants, as well as for antibiotic resistent pathogens. The presence of pollutants is a challenge for water and nutrient recycling.

On the way to a sustainable metabolism of cities, restructuring energy systems, reusing nutrients and reducing emission of anthropogenic pollutants are important challenges. All of them involve UWIS.

In the second part we discuss the urban landscapes and the potential contribution of urban water management to more resilient urban ecosystems. Before this background of flow stream and landscape perspective, we present an integrated concept for water, en-ergy and nutrient reuse, which also contributes to resilient and nourished urban land-scapes and improves urban (micro)climate. Thinking outside the box of traditional grey infrastructure approach and sectoral disgregation, water infrastructures can also fulfill valuable services for urban landscapes and urban (micro) climate. We propose a hybrid technical and biological system, with engineered urban landscapes that can provide mul-tiple functions: biomass production for bioenergy, aesthetics, livelihood for urban fauna (habitat, shelter, nesting and feeding grounds), nutrient reuse, water treatment and stor-age and water evaporation for improved urban climate, while at the same time keeping up hygienic standards and improving the urban pollution balance. A multi-functional infrastructure can integrate infrastructure services for water and energy with urban land-scapes and their ecosystem services.

To conclude, we show possible transition pathways and give an overview of drivers and barriers for these new concepts in part 4. This contribution gives an overview of the preliminary results of the project “TWIST++: Paths of transition for water infrastructure systems: Adapting to new challenges in urban and rural areas” supported by BMBF

Keywords: data quality, infrastructure asset management, cost-benefit.

Comprehensive scenario management of sustainable spatial planning and urban water services

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Abstract

Adaptations of existing central water supply and wastewater disposal systems to demographic, climatic and socio-economic changes require a profound knowledge about changing influencing factors. The paper presents a scenario management approach for the identification of future developments of drivers influencing water infrastructures. This method is designed within a research project with the objective of developing an innovative software-based optimisation and decision support system for long-term transformations of existing infrastructures of water supply, wastewater and energy in rural areas. As drivers of water infrastructures engineering and spatial factors are identified and predicted by different methods and techniques. The developed scenario-manager enables the generation of scenarios by combining different drivers. The scenarios are integrated into the optimisation model as input parameters. Furthermore, for the result of the optimisation process – an optimal transformation strategy for water infrastructures – can have impacts on the existing fee system. Adaptation possibilities of the present fee system are presented and generalised as recommendations for the adaptation of a future water fee system.

Keywords: demographic change, development of fees, scenario management, transformation of water infrastructures.

Sustainability controlling for urban water systems

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Abstract

Drinking water supply and wastewater disposal structures are designed to fulfil their tasks for a long-term period. However, at the moment no instrument exists that allows for identifying and assessing sustainability risks systematically and deducing measures for risk prevention and reduction. This paper addresses this shortcoming and introduces the NaCoSi sustainability controlling as a valid and easily established methodology. It is developed in the context of the collaborative project NaCoSi.

Keywords: sustainability controlling, sustainability risk, urban water management, water provision, waste water disposal

Introduction

Climate change, demographic changes and spatial developments are drivers that challenge the urban water and sewerage service providers. Interfering with the increasing legal requirements and technical innovations, the dynamics and complexity of changes threaten the reliability and sustainability of water supply and wastewater disposal.

Urban water service providers use several management tools in order to respond to the various challenges (Arnold/Pieper 2014: 161). Although the management tools adequately tackle their field of application, they do not focus on central threats of a sustainable corporate development. Neither environmental management, quality management nor technical security management, risk management or benchmarking account for comprehensive, cross-sectional risks or for long term risks.

The BMBF collaborative project 'Sustainable Controlling for Urban Water Systems' (NaCoSi) aims at developing and exemplarily implementing methods and tools to identify, analyse and evaluate sustainability risks. With the help of sustainability controlling, authorities and companies in charge should be able to adjust strategic decision-making in regard to sustainability targets.

The following paper outlines the approach and tools that comprise the NaCoSi sustainability controlling. Building on the framework of risk management by ISO 31000 and ISO 31010, the sustainability controlling's first step is the definition of sustainability targets. Then, an analytical framework is established that allows for identifying risks. Third, tools are introduced that help to analyse and evaluate risks in a comprehensive form. Furthermore, the tools should give permission of drawing conclusions regarding risk prevention and reduction.

Risk identification based on sustainability targets and causal chain analysis

The NaCoSi sustainability controlling follows the idea of assessing the corporates situation against a bundle of feasible sustainability risks. The challenge is to reveal the specific exposure to these risks and deduce the need for action – might it be precautionary measures or strategies to reduce the potential damages. With an iterative process from risk identification via risk analysis and evaluation to problem-oriented development of measure for risk attenuation, the aim is to facilitate a continuous process of learning in the water sector.

In science and practice, sustainability concepts for urban water and sewerage supply take multidimensional target systems as a starting point (Kahlenborn/Kraemer 1999; Palme/Tillman 2009). Thus, the sustainability controlling is based on a target system that balances long-term development perspectives with economic, ecologic and social targets (figure 1). As business risks accrue from the possibility of missing entrepreneurial goals, sustainability risks result from missing the sustainability goals. Therefore, sustainability risks are characterised on the one hand by the probability of failing a sustainability-relevant target and on the other hand by the extent of damages related to it.

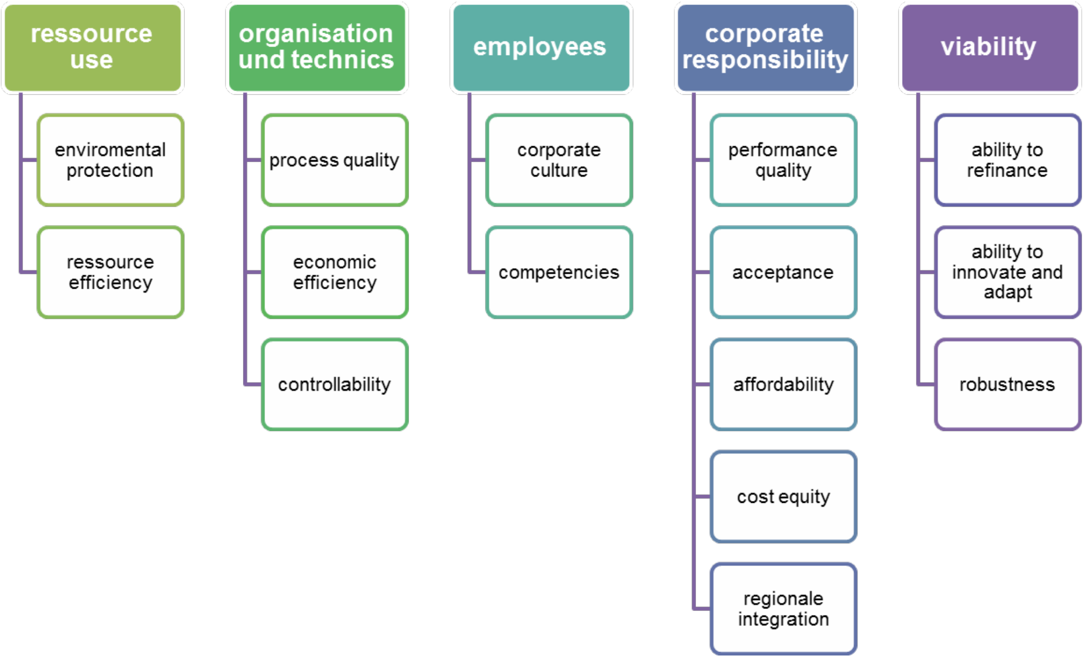

Figure 1 Sustainability goals incorporated in NaCoSi sustainability controlling

The analytical framework of sustainability controlling is based on a risk database. It connects sustainability risks with drivers by causal chains and systematises those pathways. Standard problem-solving approaches of risk management (e.g. IEC/FDIS 2009) rapidly lose their effectiveness when facing complex cause and effect relations. Hence, an approach has been developed that allows modifying the level of complexity.

First, the complex networks underlying causes and effect relations of risks is disintegrated in short, unbranched pathways. As a result, a straight-line modular system is formed to model relationships between causes and affected sustainability targets (fig. 2). Currently, more than 300 pathways are described in the risk database. The system is open-ended and can be expanded. This means, the approach is open to future developments and new challenges.

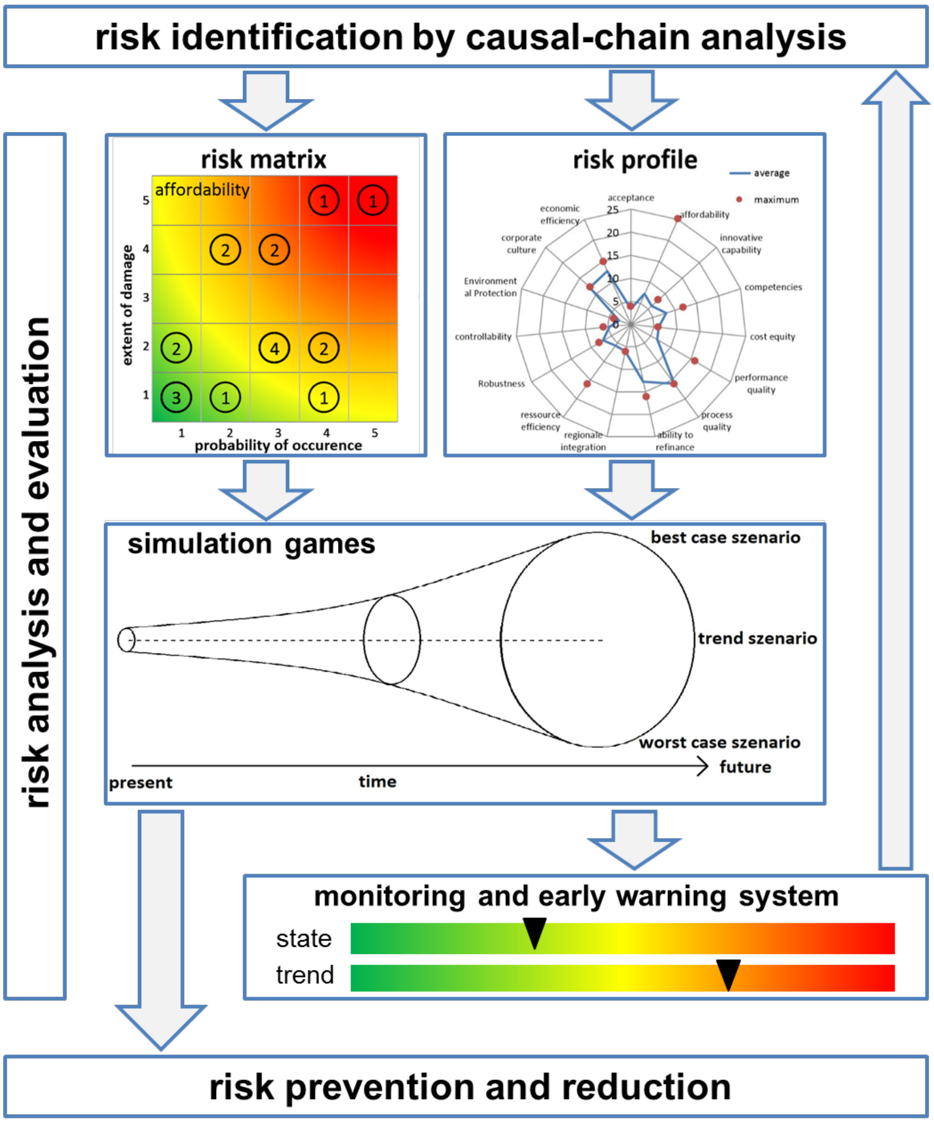

Figure 2 Tools for NaCoSi sustainability controlling

Second, by overlaying the straight line pathways, even complex cause-effect-relationships can be characterised: Applying network analysis methods or classification rules it can be analysed whether a certain cause affects several sustainability targets and whether a sustainability target is affected by various causes.

The pathways have been created on the basis of literature and expertise. They include feasible risks and causes that not necessarily apply to all water and sewerage providers simultaneously. In order to identify risks on a company level, a questionnaire is used to check, which of the causal chains are of relevance to a company. Regarding each risk, there are three aspects of interest. First, the companies should determine their recent position in terms of their sustainability targets. This is done indicator-based, i.e. for each causal chain an indicator was set with critical threshold levels regarding target compliance. Threshold values have been deduced for each individual pathway drawing on legal limits, technical rules and norms as well as on benchmarking results. Second, the company should identify the probability of exceeding the thresholds in the future while taking into account the causes behind the risks. Third, the providers should assess the extent of damage caused by these deviations.

Tools for risk analysis and evaluation

The identified risks are further analysed, evaluated and visualised using four tools: risk matrices and risk profiles together with scenario-based simulations and a monitoring tool (figure 2).

The aim of the risk matrices and the risk profiles is to refine the sustainability risks on a more aggregated level. The risk matrices are used to sum up the risk information regarding each of the sustainability goals. They inform about the number and severity of partial risks towards each sustainability target, offer an overview of the causal links behind and of the different causes, the target is exposed to. In the same time the target specific risk is determined by help of aggregation rules. A contemplation of each single risk matrix allows for a more in depth analysis. Based on this, risk profiles enable to achieve a comprehensive risk statement on company level. Aggregating the target specific risks in a radar chart, the resulting risk profiles provide an overview of all potentially hazardous sustainability risks.

Both, risk matrices and risk profiles provide important information for analysing and evaluating risks as they specify main risks, compare them and raise understanding of the causes behind. To get further insights into the interferences of risks and their drivers, the NaCoSi sustainability controlling is enhanced with scenario-based simulation games. In the project, research and practice partners cooperate in a series of workshops. Together they aim at further evaluating risks, processes and underlying causes. Building on this, problem-oriented options for risk prevention and reduction are identified.

Participatory scenarios that refer to the interaction of the causal chains and that picture and comprise the anticipated possible future developments are the methodological backbone of the simulation games (Bergmann et al. 2010, Klabbers 2000). Both, the research team and the participating companies contribute to the scenario process in order to identify the nexus between sustainability risks and their impacts.

The fourth tool for risk assessment is a so called monitoring tool. Acknowledging the company-specific risks and vulnerabilities, this tool allows tracing changes of important performance figures. The monitoring tool is directly connected with the indicators assigned to the respective causal chains. In addition to monitoring the development, the tool can be used as an early warning system. It derives trends from the time series of indicator values and points towards deviations from targets that might cause sustainability risks.

Discussion

The NaCoSi sustainability controlling with its target-oriented approach and its four tools will help service providers in the urban water management to identify and assess the company-specific sustainability risks systematically. On this basis it is possible to decide whether to take action in risk mitigation. Then, long-time risks or cross-sectional risks could not only be included into strategic management decision but also be used for communication with customers, citizens and stakeholders.

The NaCoSi sustainability controlling links factual knowledge about cause-effect-relations and information on performance figures with subjective estimates regarding future effects. This challenge must be met by all approaches that have to predict and assess future developments. However, by applying the four different tools the NaCoSi sustainability controlling limits the possibility of misjudgements because it allows for reflecting the results from different perspectives. The findings provided by the tools overlap and complement each other regarding identification, analysis and evaluation of sustainability risks. The tools check and confirm each other's results mutually.

The bunch of management and controlling approaches that are already available is supplemented by the NaCoSi sustainability controlling. It draws on the data and information provided by the other approaches. In the course of the project, the data enquiry has been centrally and internet-based organised by a research partner. In the water sector, this kind of outsourcing is commonly used in the benchmarking process. For instance, the aquabench online platform processes the data of more than 1,200 companies. This approach may be quite helpful for the sustainability risk controlling to gain momentum in future. However, it is not a prerequisite for companies to foster sustainability controlling.

Outlook

The analytical framework, the tools and their integration in a controlling system is currently underway. With the completion of the NaCoSi project in April 2016, a valid and easy to established methodology for sustainability controlling will be created. By using synergy effects from existing management approaches and the four tools for risk analysis and evaluation, urban water management companies can get an easy and individually tailored access to the methodology. The objective is to support the companies on their way to a long-term sustainable performance.

The approach provides different levels of organisational learning processes: (i) at the team level, if the data acquisition is done jointly between different divisions within a company; (ii) at a corporate level, if the NaCoSi sustainability controlling is established as an ongoing process with generation of time series; (iii) on a sectoral level, if there is a facilitation of the NaCoSi sustainability controlling by a benchmarking approach that allows to compare the risk profiles and action strategies between different companies (confidentiality has to be provided). Main learning content here is to recognise sustainability as an integral component of a company's performance.

Acknowledgement

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Storm water balance for the cities of the future

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Abstract

During the last decade water sensitive urban design (WSUD) has become more and more accepted. However, there is no tool or option to evaluate the influence of those measures on the local water balance. To counteract the impact of new settlements, planers focus on the increasing runoff by infiltration systems. This leads to on-site measures and an increasing non-natural groundwater recharge. Software tools which evaluate or simulate the effect of WSUD on the local water balance are still needed. The authors developed a tool named WABILA that could support planers for optimal WSUD. The tool is based on simplified regression functions for established measures and land covers. Results show that WSUD has to be site-specific, based on climate conditions and the rural water balance.

Keywords: water balance, model, WABILA

Improving Urban Drainage in face of climate and demographic change: interim results of the joint research project KURAS (Concepts for urban rainwater management, drainage and sewage systems)

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Abstract

Climate and demographic change are generating a demand for adapted urban drainage and stormwater management concepts which guarantee safe disposal while also contributing to the solution of environmental problems closely linked to urban hydrology. Whereas innovative strategies and measures to adapt urban drainage to present and future challenges abound, the knowledge basis for decision-making is deficient. There is a lack of both specific information regarding the benefits and risks of these approaches and tools to support complex decision-making processes. Furthermore, policy, incentive systems and distribution of responsibilities need to be reviewed against the backdrop of new or adapted approaches. These issues are addressed by the KURAS research project, which extensively examines, characterizes and catalogues the effects of a broad range of measures to manage stormwater and wastewater on various spatial scales. KURAS endeavors to improve existing or provide new decision-support tools and formulate recommendations to improve the institutional framework and the planning process. Finally, KURAS aims to develop realistic and implementable sustainable management concepts for stormwater and wastewater by focusing upon representative urban quarters in Berlin, Germany, and by cooperating with the key urban stakeholders throughout the project duration.

Keywords: Urban drainage, wastewater management, stormwater management, climate change, demographic change, risk and benefit analysis, decision support, stakeholders

Introduction

For purposes of flood protection and the protection of human health, the safe disposal of wastewater and rainwater is indispensable in urban areas. To date, management concepts have relied mainly upon collecting and conveying wastewater and rainwater in combined or separate sewer networks – either to a wastewater treatment plant or directly into a receiving water body. In Germany and elsewhere, such conventional systems have rendered an invaluable service since the middle of the 19^{th} century. More recently, however, these systems have increasingly been associated with negative impacts and performance problems. In the event of heavy rainfall, stormwater runoff can lead to significant impacts on receiving water bodies regarding hydraulics (Krejci et al. 2004), trophic state (SenGUV 2002), toxic impacts (Burkhardt et al. 2009) and bathing water quality (Oppermann 2011). During dry spells sewerage flow stagnates, promoting corrosion, blockage and odour nuisance (Hillenbrand et al. 2010). In Berlin, storm events are expected to increase substantially in the coming decades as a result of climate change (CSC 2013). It is likewise predicted that changing demographics will continue to reduce drinking water demand and resultant wastewater (Möller & Burgschweiger 2008). These changing conditions are magnifying the negative impacts of urban drainage, thereby generating a demand for new or improved urban drainage concepts for Berlin and similarly for other cities in temperate regions.

Numerous strategies for adapting urban drainage and decreasing the above described negative impacts of high and low flow situations exist and are applied in practice. These include on the one hand the optimized control and management of central wastewater systems (compare Oberlack, Kirchheim & Scheer 2006) and increased storage and treatment capacities for stormwater at the catchment level. On the other hand these include decentralized stormwater management approaches which increase infiltration, evapotranspiration and stormwater reuse at the building or city-quarter level. By reinstating a more natural hydrological cycle, the latter approaches are attributed the ability not only to reduce flooding and river degradation but also to improve landscape and habitat quality, the urban climate and resource efficiency (Montalto et al. 2007, Matsuoka and Kaplan 2008, SenStadt 2011, US EPA 2011). The greatest potential for improving urban drainage seems to lie in combining approaches according to the particular setting. For this, decision-making, planning and policy need to be improved and adapted (Nickel et al. 2014). Performance information which would allow a quantitative and comparative assessment of the multiple effects of the various measures is scattered or incomplete and not available as a basis for decision-making. Further investigations that examine in greater depth the effectiveness and associated risks of the various measures are needed to optimize the strategies and increase confidence. Many newer approaches to urban drainage affect not only drainage planning but building, open space and environmental planning was well, necessitating a far-reaching and often unprecedented integration of planning processes and of a broader range of stakeholders in decision-making. Finally, relevant policies, incentive systems and responsibilities may need adjustment to enable the implementation of new approaches.

Facilitating decision-making, adapting policies and creating incentives for improved urban drainage and stormwater management in the face of changing conditions are therefore central goals of the interdisciplinary, Berlin-based and three-year research project KURAS, "Concepts for urban rainwater management, drainage and sewage systems". KURAS is funded by the German Ministry of Research and Education (BMBF) under the funding measure "Smart and Multifunctional Infrastructural Systems for Sustainable Water Supply, Sanitation and Stormwater Management" (INIS). The KURAS consortium encompasses 15 partners from research, practice, and public administration, including the Berlin Senate Department for Urban Development and the Environment and the city water utility Berliner Wasserbetriebe. The consortium is lead jointly by the Technische Universität Berlin and the Berlin Centre of Competence for Water. Outreach to and integration of important stakeholders is accompanied by the German Institute of Urban Affairs (Difu).

Methods

Characterization of management approaches

Facilitating decision-making necessitates a more thorough understanding of the available management options. A key element of the project is an extensive and cross-scale characterisation of a broad selection of management options and concrete measures and their effects on sewer systems and the wider urban environment. The measures under analysis range from the optimization of sewer systems (separate and combined), e.g. surge flushing, intelligent pump control and intelligent inflow into the wastewater treatment plant (to name but a few), to rainwater management options on various spatial scales, such as green roofs, swales and retention ponds. Figure 1.1 depicts the focus of the KURAS project on both measures to improve the wastewater system and to manage stormwater closer to the source. Some examples from the wide range of management approaches and measures under consideration are shown in Table 1.1.

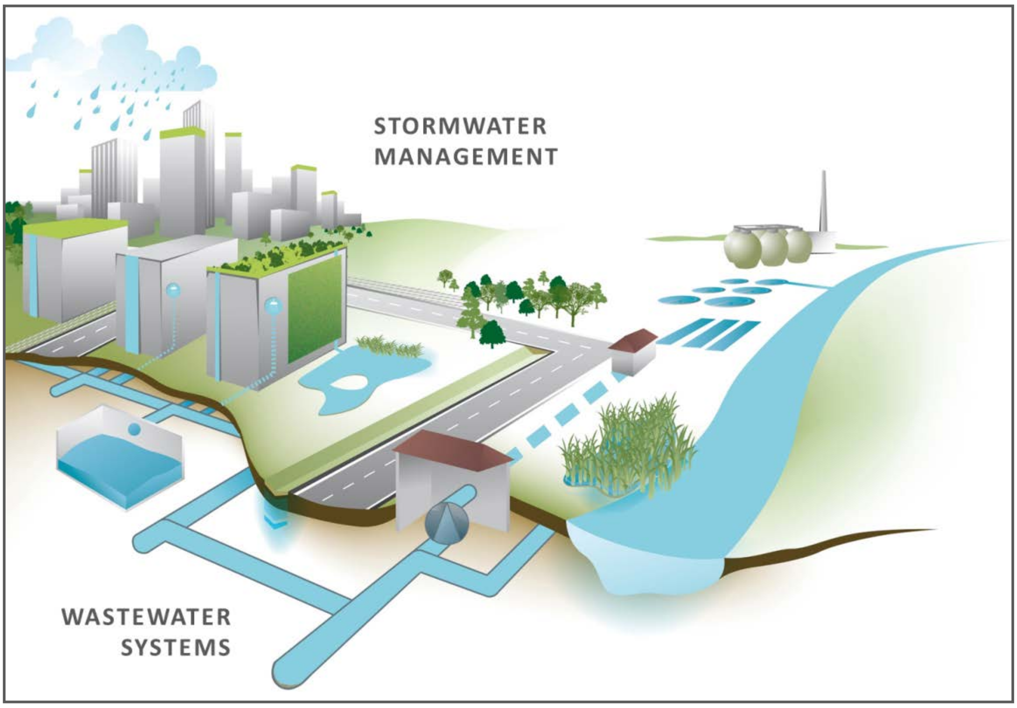

Figure 1 The interdisciplinary research project KURAS focuses on adapting urban drainage to meet existing and future challenges posed by climate and demographic change. Graphic: Kompetenzzentrum Wasser, Berlin.

Table 1 Some examples of the extensive list of management approaches and measures analysed in KURAS

Wastewater systems	- increased storage, - temporary flooding of uncritical spaces, - cascade techniques in sewer system, - surge flushing of sewer system, - intelligent pump control, - optimized operation of wastewater treatment plant for high-flow situation
Decentralized stormwater management	- green roofs and facades, - rainwater use, - infiltration, - pervious surfaces, - artificial ponds

Although not all-encompassing, the set of effects to be evaluated is likewise extensive, including impacts on the environment (e.g. water or biodiversity), on residents (e.g. quality of open spaces, urban climate, odour nuisance or flooding risk) and on economic factors (e.g.

costs, distribution of costs, resource consumption) (Table 1.2). Each effect is to be described by a small set of indicators. Gaps in available date are to be filled by undertaking additional experimental and monitoring programs. Data will be collected in a joint database and made generally available upon completion of the project.

Table 2 Examples of effects on the environment, on residents and on economic factors analysed in KURAS

Environment	- state of surface waters - state of groundwater - biodiversity
Residents	- urban climate - flooding risk - health risks - odour nuisance - quality of open spaces
Economic and technical factors	- corrosion of / deposits in sewer system - resource use - direct costs - cost distribution from a stakeholder perspective

Model areas and management strategies

To gain a better understanding of the actual potential to improve urban drainage, representative model areas in the city of Berlin will provide the backdrop for developing tailored management strategies that combine approaches. The model areas chosen should represent the heterogeneity of the status quo with a view to the current technical systems in place (e.g. separate and combined sewer systems), the urban and natural environment which define the conditions enabling or prohibiting the implementation of specific management approaches (such as building typology, urban spacial structure and utilization, hydrogeological situation) and the issues and problems to be addressed (such as sewer corrosion or blockage, combined sewer overflow, urban climate). The model areas should likewise render the research outcomes applicable to other urban areas.

For these model areas, alternative and realistic stormwater and wastewater management strategies will developed, analysed and improved with the goal of achieving a higher overall level of system sustainability compared to the present situation, also considering possible climate and demographic trends up to the year 2050. The developed management strategies will undergo an extensive evaluation based upon the effects (Table 1.2) and their indicators and data basis described above. To this aim, various modelling approaches and platforms will be employed to calculate and understand the accumulated effects that can be achieved by combining measures to meet specific problems.

Stakeholder involvement

The implementation of new management approaches on various spatial scales, particularly the decentralized measures for managing stormwater listed above, requires the acceptance and collaboration of those actors responsible for urban drainage today (in this case the water utility and city administration). It also necessitates the participation of or affects stakeholders hitherto not involved in the decision-making and planning process to date. The latter group includes "new" decision makers such as district administration offices responsible for urban spatial planning, road maintenance, environmental protection, and facility management, but also property owners, architects and urban developers. It also includes those stakeholders that might be affected in a positive or negative way, such as tenants. Finally, it includes institutions or persons responsible for public interests (environmental, social, etc.). These stakeholders each bring with them their own responsibilities, interests and experience. Understanding and balancing out the different perspectives is critical to identifying sustainable management strategies.

Cooperating with key stakeholders throughout the project duration is a central element of the KURAS project. The intended stakeholder input is fourfold:

1) Particularly the district administration offices, but also other stakeholders, manage data and possess knowledge specific to the model areas which is indispensable for developing realistic stormwater management strategies.
2) Together with the identification of the predominant problems in the model regions, a prioritisation of stakeholder interests provides the point of departure for strategy development.
3) Based upon these specific strategies, the potential risks associated with them, existing financial, legal, administrative and knowledge-related barriers to their adoption and possible steps to overcome these risks and barriers need to be identified.
4) Finally, a discussion of the modelled outcomes should lead to improvements to the developed management strategies, but also to a better understanding of benefits which can be achieved via alternative management approaches so that these can be weighed against the risks identified.

Stakeholders will be involved at different stages via information events, bilateral discussions, ongoing KURAS Stakeholder Workshops, and other forms of exchange such as questionnaires, etc.

Management tools, Planning and Policy

Based upon the outcomes of the previous steps, decision-support tools (software tools, information data base) and planning guidelines will be developed for various target groups (e.g. water utilities, planners and architects). Furthermore, recommendations will be made to adapt policy and incentive schemes in support of sustainable management strategies for stormwater management and urban drainage.

Results and discussion

During the first half of the three year project, the focus of the KURAS consortium has been upon data collection, definition and description of the model areas, and on the preparation of models and platforms (such as Infoworks tool for hydrological modeling) to help evaluate the impacts of management strategies. The selected measures for rainwater and wastewater management (see examples provided in Table 1.1) have been catalogued in the form of profiles containing information on mode of operation, legal requirements, specifications, examples of implementation, etc. These profiles provide a common basis of understanding within the project, but will be published upon completion of the project. Extensive data on the effects of measures upon the environment, residents and economic factors has been collected in a joint database which currently contains above 1,000 entries. Monitoring programs are ongoing to fill gaps in data and will continue throughout the project. Although a complete list of all performance indicators applied to measure the effects of management options has not yet been published, Matzinger et al. (2014) provide a preliminary overview of indicators chosen to demonstrate the effects of stormwater management options along with a description of data available from previous examples of implementation. It was found that the range of costs and effects for a given management option can be very large, indicating a high dependency on local settings and specifics of implementation. It will be important to consider this circumstance when developing management strategies for the model areas and modelling their accumulated effects.

Three representative model areas in Berlin were selected. The analysis and documentation of the status quo, with the aim of characterising the water infrastructures in place, the predominant management problems and the general feasibility of alternative options, is currently coming to a close. One model area in the innercity district of Wilmersdorf (approx. 31 km2) was selected primarily to evaluate measures to improve the wastewater system. This area is drained in part by a combined and in part by a separate sewer system, making it possible to evaluate and compare measures in both system types. Over 99% of the wastewater collected is directed to the same treatment plant so that effects of management strategies upon treatment facilities can be directly accounted for. The area displays pronounced problems arising from both high-flow and low-flow situations. Two smaller and distinctly different models areas (see criteria provided in chapter "Methods" above), each the size of approx. 1 km2, were chosen primarily for the evaluation of the potential effects of stormwater management options, such as improved urban climate, reduced stormwater runoff and associated effects upon water bodies, increased biodiversity and quality of open spaces, etc (Table 1.2). One of the two models areas also lies in the district of Wilmersdorf to facilitate synergies between these two management foci.

Future scenarios have been developed which delineate possible effects of climate change (storm events, drought, etc.) and population trends (water consumption) for the planning interval until 2050. These provide the basis for evaluating the effects of alternative management strategies and for optimizing these strategies not only in comparison to the status quo but also considering possible future developments.

Based upon these preparatory steps, the planning and evaluation of exemplary stormwater and wastewater management strategies in the different model areas is underway with first results to be expected within the year 2015. The involvement of stakeholders in the planning process specifically regarding stormwater management strategies was initiated with a well-visited information event in the first quarter of 2015 (~ 50 participants) and an initial questionnaire to obtain an overview of the workshop participants existing knowledge and goals regarding stormwater management (return rate ~20 %). Among the participants were representatives of all relevant stakeholder groups. Based on participation, city and district administrations and actors from urban development demonstrated the greatest interest. It proved most difficult to reach private property owners and those parties who may be affected by alternative stormwater management strategies but have little to no decision-making power. Both discussions and questionnaire results seem to point to a basic understanding of the multiple and concurrent objectives of stormwater management. Common motivations relate to improving the state of surface waters, the urban climate and landscape quality. However it became equally clear that the participants ascribe quite different potentials to these approaches, ranging from “we do all that already” to “there is a great need for implementation”. The need to address risks involved with decentralized stormwater management approaches was highlighted. Further needs for action were seen in improving planning, policy, and dialog amongst the relevant actors. Whereas these are initial observations that need to be confirmed and expanded, they generally underline the value and pertinency of the KURAS stakeholder process. A second workshop to more systematically query and prioritize stakeholder goals is planned for mid April 2015.

Conclusion

Although the results presented here are broad and display all characteristics of work in progress, some preliminary and/or general remarks can be made.

1) The scope of options and measures available for wastewater and stormwater management is broad. KURAS postulates that by combining approaches according to the particular setting the greatest potentials can be released (no one-size-fits-all solution). The magnitude remains to be demonstrated, as does the compatibility between various types of approaches. The KURAS modeling results will inform this learning process.
2) Amongst relevant stakeholders, a common understanding exists of the need to improve urban drainage. Views regarding the best means of attaining this goal diverge significantly and often display bias, thereby confirming the goal of KURAS to improve the framework for decision-making and facilitate dialog.
3) Alongside the valuation of potential benefits, a transparent and informed discussion regarding potential risks of various approaches to wastewater and stormwater management and means of abating these will be indispensible to achieving a higher overall level of system sustainability, the central aim of the KURAS project.

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3.6 Territorial & Urban Planning

Design with Water: a conceptual planning framework for improving the resilience, wellbeing and biodiversity of our cities.

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Abstract

The relationship between water, technology, cities and the natural world is complex and has shifted over time and across geographies. Water has underpinned and shaped human development, both enabling and sustaining life and at times threatening it through scarcity or excess.

Water has often been treated as a service or utility that needs to be provided at least cost, or as a hazard that can has been managed progressively through the use of hard infrastructure, working against natural systems. Whilst this has been effective in managing risk and improving basic public health it has led to a fundamental disconnection between water and the planning and design of other city systems, such as transport, healthcare, housing, education and the economy.

Current challenges linked to ecosystem protection, urbanisation, resilience and climate change, together with a renewed understanding of the benefits of integrated, ecological demand that we place water at the heart of policy and planning. We need to capitalise now on the opportunity to design with water once again with the aim of improving urban wellbeing, increasing resilience and enhancing wider ecosystems under a changing climate.

This paper tracks historical perspectives and discusses the paradigm shift that is occurring in water management, it goes on to discuss various recent and current research before discussing how Arup have explored these themes through their design with water framework.

Keywords: water, design, water urbanism, water sensitive urban design, integrated design, planning, cities, ecosystems, health & wellbeing.

Green Infrastructure in New York City: The case of the Bronx River

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Abstract

The research presented analyzes initiatives and actions carried out and developed in New York City to improve environmental conditions through the wider diffusion of green infrastructure. The effectiveness of mechanisms related to bottom-up approaches are evaluated, considering initiatives implemented by local community organizations, grassroots associations, and citizen groups in the field of green infrastructure. To investigate these aspects and the relationships between the policies of public bodies at the Federal, State and City government levels and local communities (i.e. bottom-up and top-down approaches), the case of the Bronx River was analyzed. The Bronx River is an urban river located in the South Bronx, a low income, polluted neighborhood in the northern part of NYC that has long been characterized by its many environmental and social inequities. From the 1970s, many restoration measures have been directly implemented or pushed by the local community; today, local community organizations and NYC Departments work together to improve the environmental and social conditions of the neighborhood to reduce ecological imbalances of the River, which is surrounded by a greenway and parks, and is maintained with the efforts of citizen volunteers.

Keywords: Green Infrastructure, local community, policies, urban river, sustainability, urban design

Introduction

The majority of the world's population today lives in urban areas (Luederitz et al., 2013) and is responsible for 70% of global carbon emissions and nearly 70% of energy consumption – an increasing trend for both (International Energy Agency, 2008) with land converted to urban areas projected to triple by 2030 (Seto et al., 2012; United Nations, 2012). Furthermore, global greenhouse gas (GHG) emissions have increased 70% in the last 40 years (Rogner et al., 2007) and environmental problems within cities have significant consequences for human health, citizens' quality of life, and urban economic performance (Commission of the European Communities, 2005). This is due in large part to urban areas' high vulnerability to climate change related flooding and heat waves (Commission of the

European Communities, 2005). As also stated by Grimm et al. (2008), while human lifestyles, consumerism, and unsustainable material production lead to alterations at multiple scales in urban systems, they also generate negative effects in residents' everyday lives.

Owen (2010) states that, in the United States, people living in cities consume less energy compared to people living in suburbs or rural areas; also according to Hamin and Gurran (2009), a denser urban environment could reduce the emissions connected to transportation needs and building energy use, and consequently their impact on climate change (Ewing et al., 2008); compact development add population to already developed places, concentrating human related activities and helping to protect underdeveloped and sensitive lands and maintaining viable habitats in the remainder (Farr, 2008). Therefore, through sustainable urban design, the negative effects of anthropic activities on the environment can be reduced, and environmental issues for human health and quality of life can be mitigated.

Vegetation can restore the environmental quality of dense urban areas by reducing the Urban Heat Island (UHI) effect, improving air quality and energy performance of buildings, and fostering biodiversity (Dunnett and Kingsbury, 2008; Farr, 2008; Ottelé et al., 2010; Taha, 1997). Green infrastructure (GI) includes natural, semi-natural, and artificial networks of multifunctional ecological systems within, around, and between urban areas (Sandstrom, 2002; Tzoulas et al., 2007). This includes waterways, wetlands, woodlands, wildlife habitats, greenways, parks, and other natural areas that support native species, maintain natural ecological processes, sustain air and water resources, and contribute to the health and quality of life for communities and people (Benedict and McMahon, 2001; European Commission, 2010). Today, more than 40% of the total land in urban areas is covered by impervious surfaces as roads, parking, and buildings (Benedict et al., 2006). Green infrastructure at city scale is therefore important to improve environmental conditions. When green infrastructure is proactively planned, developed, and maintained, it can guide urban development by providing a framework for economic growth and nature conservation integrating urban development, nature conservation, and public health promotion (Schrijnen, 2000; Tzoulas et al., 2007; Van der Ryn, 1996; Walmsley, 2006).

European environmental policies so far have achieved important results at both Member State level and internationally. The normative framework of Member States can vary significantly, greatly impacting the effectiveness and flexibility of territorial management tools (Giachetta, 2013). The United States has a different approach to Europe in this field; with a less prescriptive normative framework (e.g. five states have not yet adopted the Department of Energy's Building Energy Codes Program; U.S. Department of Energy, 2014), several associations, organizations and public bodies work to improve environmental conditions in dense urban areas through the integration of green infrastructure. This community involvement can play a very important role in the field as many initiatives to improve ecological conditions of cities depend on the participation of urban citizens (Francis and Lorimer, 2011).

The main objective of this research is to study and analyze initiatives and actions carried out and developed to help improve environmental conditions in cities; it considers especially bottom-up approaches and the relationships between the policies of public bodies at the Federal, State and City government levels and local communities (i.e. bottom-up and top-down approaches). The case study of the Bronx River in New York City is analyzed to investigate these aspects.

Rivers and streams are critical to almost any green infrastructure systems (Benedict and McMahon, 2001); urban waters take on large amounts of pollution from a variety of sources (e.g. industrial discharges, wastewater, trash, and polluted stormwater runoff), creating public and environmental health hazards (Office of Water, 2014). The Bronx River is an urban river located in the South Bronx, a low income, polluted neighbourhood in the northern part of NYC that has long been characterized by its many environmental and social inequities (Loria, 2009; Maantay, 2000). From the 1970s, many restoration measures have been directly implemented or pushed by the local community; today, local community organizations and NYC Departments work together to improve the environmental and social conditions of the neighbourhood to reduce ecological imbalances of the River, which is surrounded by a greenway and parks, and is maintained with the efforts of citizen volunteers.

The presented research includes a broad survey of local newspapers dating to the 1970s was carried out, as was bibliographic analysis and research on plans released by local community organizations and NYC Departments over the past 40 years. All the aspects analyzed in this research have also been deepened thanks to consultation with several experts in the field and referents from community groups, among others.

The river and the neighborhood

In this paper the case of the Bronx River is presented. The Bronx River runs through the New York City (NYC) borough of the Bronx and southern Westchester County in New York State; this corridor begins near Valhalla, N.Y., and flows south for 23 miles through Westchester and Bronx Counties before emptying into the East River (Bronx River Alliance, 2006; www.bronxriver.org).

The Bronx River has been used for human activities since at least the time of the Mohegan Indians, who inhabited the mainland peninsula that came to be called the Bronx, and used its numerous freshwater waterways for drinking water, food, transportation, waste removal, and recreation (Kadt, 2011). It was in the 1840s that railroad construction turned the valley into an industrial corridor (New York City Dep. of Environmental Protection, 2010) and, with industrialization, power was turned to the production of tobacco, paint, cotton, rubber products, and the River to flushing away waste and providing water for industrial processing (Kadt, 2011). Mills operating along the River decreased its water quality, and dams harnessing the River's power impeded the ability of anadromous fish to spawn upstream. When mills started to close, the Bronx River's water quality became more of a concern, however, the combined sewer and stormwater infrastructure (combined sewer overflow, or CSO) continues to be usable to transfer all the sewage to treatment plants, especially when it rains, causing water pollution to this day. In addition, in the last decades the Bronx River had become "hidden" behind small industry, apartment buildings, roads, and junk (Kadt, 2011). The Bronx River went from a flourishing and beautiful resource to a contaminated conduit for industrial and residential wastes. As it will be shown, thanks to the efforts of the Bronx community that, in the 1970s, started to work to improve the river and the neighborhood conditions, this trend has changed (DEP, 2010).

The Bronx River winds through areas with different land use and physical characteristics. Neighborhood and community around the River are characterized by industries to the south and residential and parkland uses in the central and northern segments (DEP, 2010). The southern portion of the Bronx River has undergone an important makeover in recent years, from an industrial no man's land to an increasingly people-friendly waterfront; however, there are still many accessibility problems due to the presence of a train line and an expressway, Amtrak line and the Sheridan Expressway (DNAinfo.com New York, 2012). The central section of the Bronx River area is dominated by Bronx Park, an extensive parkland that includes the New York Botanical Garden and the Bronx Zoo, and the northern segment is mostly residential (New York City Dep. of Environmental Protection, 2010). In summation, the densely populated section of the Bronx River that passes through industrial areas shows a range of problems typical of urban rivers, while the northern part that passes though Bronx Park is mostly naturalized and well vegetated.

Human activities implemented over 400 years along the Bronx River have had a very high impact on the river ecology and on the environment. Below, a description of the main ecological and environmental imbalances, regarding stormwater management, biodiversity loss, invasive vegetation, and water quality, will be provided. The urbanization of the area around the Bronx River (which houses approximately 210,000 people) has resulted in an increase in annual stormwater runoff to the water body and has all but eliminated any natural response mechanisms (e.g. tidal marshes, buffer zones) that could helped absorb this hydraulic load (DEP, 2010). According to McDonnell and Larson (2004), impervious surfaces such as rooftops, parking lots, and roads cover more than 60% of the River's upland areas and inhibit the watershed's natural hydrological function. Due to stormwater runoff, water goes directly into the River through sewers and drains and is not be intercepted by vegetation or absorbed by soil (Dunnett and Kingsbury, 2008). This results in disturbed flow patterns within the river channel that cause flash floods, erosion, low habitat value, high water temperatures, low base flow, and excessive sedimentation(Bronx River Alliance, 2006a). This is not the only problem related to human activities; other examples including dams located in the Bronx Park section that work as barriers to fish passage, floating waste as debris, and sewage, inputs of which lower dissolved oxygen (DO) levels and limit the growth and survival of aquatic organisms. Habitat degradation, the result of riparian management, channel degradation, and poor hydrology and water quality, prevents diverse flora and fauna from establishing and, as poor water quality violates health standards, these waters are also unsuitable for public recreation: during storm events, combined sewer overflows discharge untreated sewage, stormwater, and other pollutants into the River, which results in poor water quality conditions in this section of the River (Bronx River Alliance, 2006a). Combined sewer systems are designed to collect rainwater runoff, domestic sewage, and industrial wastewater in the same pipe. During periods of heavy rainfall or snow melt, if the wastewater volume in a combined sewer system exceeds the capacity of the sewer system or treatment plant, excess wastewater can be discharged directly to nearby streams, rivers, or other water bodies (http://cfpub.epa.gov/npdes/home.cfm?program_id=5).

Another important aspect is the presence of invasive vegetation, which limits the diversity of the vegetative community, contributes to bank instability, and excludes trees from the riverbank, thus limiting the supply of large woody debris necessary to create certain habitats (Bronx River Alliance, 2006a).

The ecological restoration and the greenway

The ecological restoration of the Bronx River started in the 1970s. What described below (i.e. the Bronx River restoration timing) is the result of the broad survey of local newspapers (e.g. the Bronx Press Review, Bronx Beat, Bronx Times), carried out for the research. Thomas Angotti, Professor of Urban Affairs and Planning at Hunter College and the Graduate Center, City University of New York, and Robin Kriesberg of the Bronx River Alliance ware consulted to comment the relation between politics and the trend identified by the survey.

In 1974, in response to the poor conditions of the Bronx River, local residents formed the Bronx River Restoration Project, Inc. (BXRR) and removed debris from the shoreline of the Bronx River (New York City Dep. of Environmental Protection, 2010). According to Angotti (personal communication, December 13, 2013), this trend can be related to Federal and local politics. «During the [administration of President Richard] Nixon (1969-1974) and the crisis [of] near bankruptcy of New York City in 1975, the South Bronx was written off by local and national policies as a declining area that was not worth the investment. However, the community-based efforts to improve and restore housing and communities have created a viable Bronx, which is attracting new investments for development resulting also in gentrification processes».

The first plan released by BXRR (Bronx River Restoration Plan, 1977) was sent to the White House care of the Democratic President Jimmy Carter (1977-1981). «A direct appeal to President Jimmy Carter for his aid in expediting the Bronx River Restoration program has been sent to the White House. [...] We need your help in two ways': to identify the channels through which the program can receive Federal funding and to help expedite such procedure. With your indicated interest, BXRR can become a symbol of self help to which your administration can point with satisfaction and justification [...]» (Bronx Press Review, 1977). Just a few years after the community started to work on the Bronx River, the important involvement of New York City municipality was formalized by the release, in 1979, of "Restoring the Bronx River" (Bronx Press Review, 1979).

In the 1970s, among the most important initiatives implemented to restore of the Bronx River are simple communication and community outreach. Seminars conducted by a team of ecological experts of the City University of New York examined the reasons for the current condition of the River and set long range plans for its restoration, and were organized already in 1974 by Bronx Community College (Bronx Press Review, 1974). Fairs, exhibitions, and festivals were also organized in the following years (Bronx Press Review, 1975), and the Bronx River Rehabilitation Exhibit was made (Bronx Press Review, 1977).

Activities implemented to improve the River and the neighborhood saw an interruption in the 1980s, however, but regained momentum at the end of the century. When asked about the slowing down of restoration activities near the Bronx River during the 1980s, Angotti links the trend specifically to the Federal politics: «Most political scientists would agree that [the administration of President Ronald] Reagan (1981-1989) was a real turning point in government policies away from welfare state to neoliberal state» (Angotti, 2013).

The 1990s were dynamic years for the Bronx River, going back to the1992 Bronx River Trailway Plan to create a greenway all the way along the River (New York Times, 1992). The greenway was conceived not only as a pedestrian and bicycle route, but as a linear park that would serve a population long deprived of green open space and waterfront access (Bronx River Alliance, 2006b). In this period, several groups and programs, involving both local community groups and NYC Departments, were created, including the Partnerships for Parks, a joint program of City Parks Foundation and NYC Parks founded by local activist in 1995 (Bronx River Alliance, 2006b). In 1997, the Bronx River Working Group was formed by grassroots organizations, made up of local activists who embraced the reclamation of the River and joining with Partnerships for Parks and other units of NYC Parks to draft the Bronx River Action Plan (Bronx River Alliance, 2006b).

The presidential administration of Bill Clinton (1993-2001, following 12 years of Republican Presidents Ronald Reagan and George H. Bush) and the mayoral administration of Rudolph Giuliani (994-2001) played a part in Bronx River restoration initiatives as well, explained Angotti, but not as much as the environmental justice activists in the South Bronx (T. Angotti, personal communication, December 13, 2013).

The work to restore the Bronx River was also made possible by grants and funds from NYC Parks and the Federal Government, which also funded a reconnaissance study examining flood control and the potential to restore the damaged ecosystem of the Bronx River (Norwood News, 1999; Bronx Beat, 2000).

In 2001, the Bronx River Working Group formed the Bronx River Alliance as an independent non-profit organization, working in close partnership with NYC Parks to protect, improve, and restore the Bronx River corridor to be a healthy ecological, recreational, educational, and economic resource (DEP, 2010), and to coordinate and track the implementation of the Bronx River Greenway (New York City portion, (Bronx River Alliance, 2006b). The Bronx River Alliance consists of 74 community-based and other non-governmental organizations as partners and supporters, the Federal Government (i.e. the Environmental Protection Agency (EPA)), State and local government (Bronx River Alliance, 2006a). According to Robin Kriesberg of the Bronx River Alliance, a bottom-up approach allows the community to remain involved. «Everything started from a branch of smaller groups in the area that were interested in cleaning up the river that was neglected – there was lot of dumping and it was not accessible from the community. They formed some working groups trying to address some of the issues and problems, got some funding and worked together to clean up (pulling out cars, washing machines, trash) and got the City to buy some land around the river to build public parks. From that original work, they formed the Bronx River Alliance». (personal communication, November 18, 2013).

Since the Alliance works a lot with volunteers due to a lack of money to hire so many people, they try different ways of training and involving (R. Kriesberg, personal communication, November 18, 2013). Thanks to these efforts local community organizations (as Sustainable South Bronx, http://www.ssbx.org/) coordinate volunteer activities working together with the Bronx River Alliance, planting trees, maintaining green areas, etc.

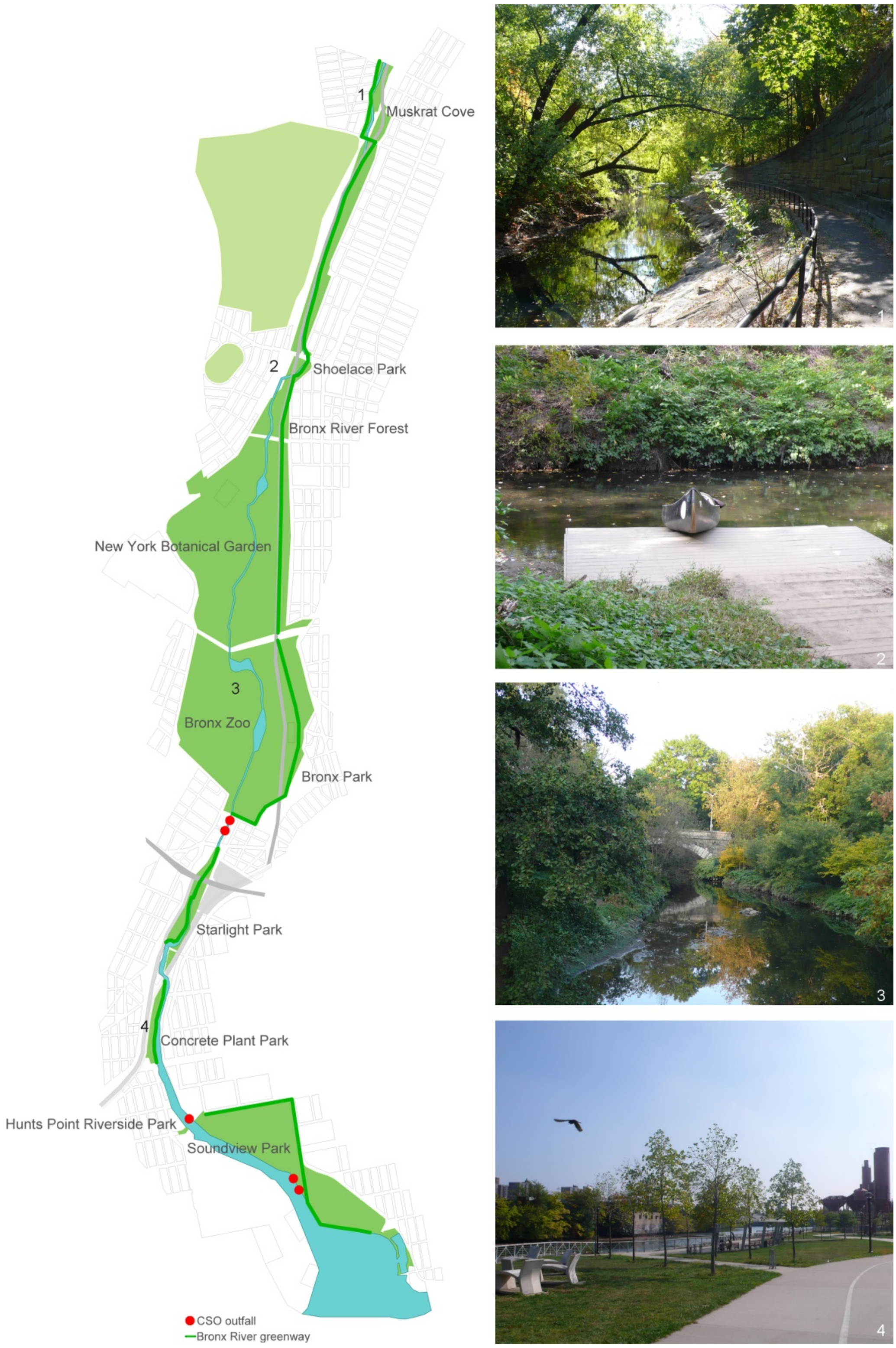
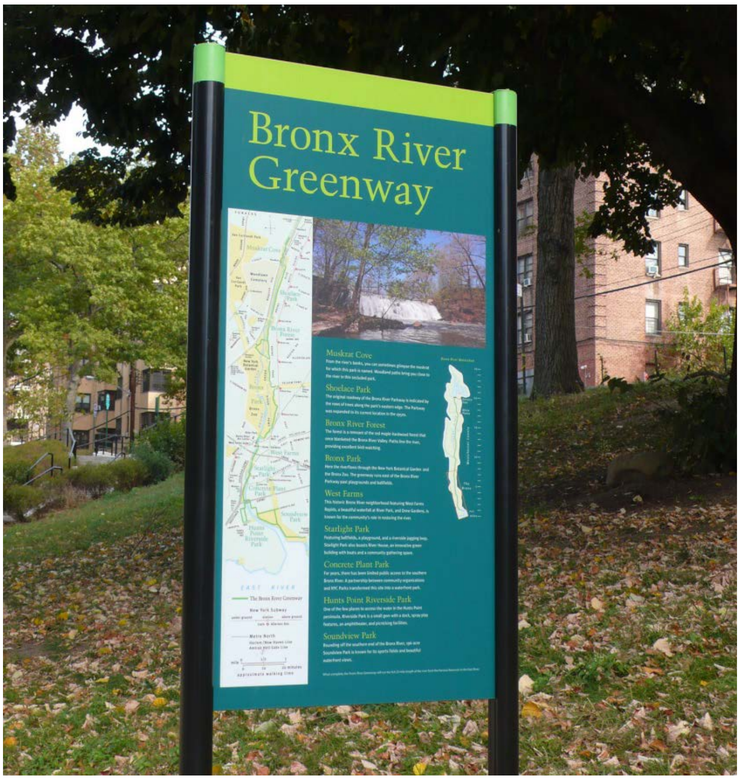


Figure 1. Bronx River Greenway, the Bronx, New York City.

Goals, strategies, projects, results

Goals and strategies implemented in and for the Bronx River address operation and maintenance procedures and related planning efforts to maximize capture of CSO and reduce contaminants in the combined sewer system for water quality. Green solutions are considered as control technologies and can be effective in restoring site hydrology to capture, infiltrate, evaporate, and detain stormwater runoff to reduce both its volume and peak overflow rate, and consequently the volume of stormwater entering the combined sewer system, while improving its quality (the "first flush" contains the highest concentration of nitrogen, other nutrients, and urban pollutants). Some common green solutions include bioretention (rain garden), vegetated buffers, grassed swales, green roofs, and increased tree cover (DEP, 2010).

In general, the main ecological goals of the Bronx River Alliance are the improvement of the Bronx River water quality via reduced direct and indirect sewage inputs and illegal discharges, and increased natural treatment of stormwater through infiltration thereby reducing direct releases from CSOs, and the improvement of hydrology in reducing erosion, sedimentation, and habitat disturbance. Biodiversity plays an important role too, with ecological goals including protecting and improving the aquatic and riparian plant and animal biological diversity and habitat through targeted removal of invasive vegetation, and increasing the connectivity between reaches and facilitating the passage of diadromous fish (Bronx River Alliance, 2006a).



Figures 2. The Bronx River greenway.

The Bronx River Greenway opened up new green space in neighborhoods and enhanced existing parks, connecting also some areas currently separated by highways, railroads, and other barriers (Bronx River Alliance, 2006b). The greenway design aims to follow ecological performance guidelines, related to landscape (e.g. increase ecological connectivity and habitat diversity, increase public amenities and quality of life, controlled invasive plant species), stormwater management, hardscape (e.g. increase smart access to the river, replace informal circulation networks with bike and pedestrian connections), streetscape, and sustainable maintenance practices. The Bronx River Greenway aims to be a sustainable transportation resource, a vehicle for the ecological restoration of the river and its banks, a catalyst for ecological restoration of the wider watershed and the revitalization of the communities along the river an educational resource, a "blueway" (a means of access to the river for boating), and a resource for a wide variety of recreation.

Through the work of local community organizations, NYC Departments, and especially of the Bronx River Alliance described above, many greened areas and a continuous, 23 miles greenway have been installed, with very important environmental, ecological, and social effects in the underserved neighborhood and on a formerly degraded River. The improvement in water quality and the actions carried out led to important results, such as a significant and measurable increase of biodiversity. In addition to ecological and environmental improvements, neighborhood conditions have also changed over the past few years, with the 2006 opening of the greenway affect[ing] land values in the watershed's neighborhoods (Bronx River Alliance, 2006b).

Although several connections along the greenway are still missing, forcing visitors to navigate crumbling sidewalks and busy roads on their way in and out, «the southern portion of the Bronx River has undergone an eye-catching makeover in recent years, from an industrial no-man's land to an increasingly people-friendly waterfront» (DNAinfo.com New York," 2012).

Conclusions

The case of the Bronx River demonstrates how effective a collaboration between local community organizations and public bodies can be in a low income community, [and] in a neighborhood with many social and environmental issues, while favorable conditions are important (e.g. the policies of President Bill Clinton and Rudolph Giuliani), the environmental justice activists of the South Bronx have played the most important role. Everything started with a branch of residents cleaning up the river 40 years ago, passing through protests of local community organizations, over time better organized, pushing the City and the State to work for the project. A long history of work, fights, plans, and efforts to involve the city for funds and grants, teaching, outreach activities, took where they are now: the Bronx River Alliance consists of 74 community-based and other non-governmental organizations working together keeping a community based structure.

The role played both by the community and the public bodies involved is fundamental; on one hand, the main credit for the change of trend belongs to the Bronx community, on the other, the support (economic especially) at City, State and Federal level allowed the initiatives to be implemented.

Following community priorities may bring about important results, providing projects with State and City resources that would not be possible otherwise: in the case of the Bronx River, the community still plays a fundamental role since NYC cannot maintain all the green areas and requires the cooperation of volunteers. Local community organizations work to involve residents; their work is very effective because of its bottom-up approach, and because it is responsive to the interests of citizens. Therefore, in the case of the Bronx River, relevant mutual benefits we obtained through an effective collaboration.

The Bronx River and its surrounding area have undergone an important makeover in recent years, going from, in some segments, an industrial no-man's land to an increasingly people-friendly waterfront; from a polluted river to a beautiful stream; from asphalted to park. There remain, however, many accessibility, ecological, and environmental issues related to transportation and industries and any future improvements will also thanks to the collaboration of citizens and volunteers.

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Rivers as social assets in urbanised areas: A cost-benefit analysis for bathing in the river Ruhr using contingent valuation method

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Abstract

The project "Sichere Ruhr" (Safe Ruhr) explored the economic and social aspects for legal swimming in the river Ruhr that is currently forbidden. The Ruhr area is one of the most densely populated regions in Europe, and there is a demand for recreational swimming in the river. Both, benefits and the costs of bathing in the Ruhr have been determined for different bathing scenarios: natural bathing, designated swimming areas and river pools. Furthermore, explanatory factors and motives related to the population's preferences and willingness to pay have been examined by these bathing scenarios using the contingent valuation and the contingent ranking method in a survey. All three bathing scenarios have in common that their implementation would have positive net present values and be supported by the public.

Keywords: contingent ranking, contingent valuation, cost-benefit analysis, environmental economics, willingness to pay

Introduction

Rivers are experiencing a revival as valuable assets in urbanised areas. They are no longer regarded primarily as receiving bodies for waste and storm water, but esteemed for their ecological and recreational value. In various places such as Copenhagen, Munich, Berlin, the metropolitan Ruhr area and other European metropolitan areas, rivers have been investigated for their bathing potential. The lower Ruhr River is located in a densely populated and industrialized area in Western Germany. Due to upgrades of sanitary infrastructure, such as waste water treatment plants, combined sewer overflows and a decline of industrial production, the surface water quality of the river Ruhr has constantly been increasing over the past decades. Therefore, a growing demand for bathing in the river Ruhr has been postulated by society. Currently, there is still a ban on swimming in the Ruhr and its lakes. For bathing in the Ruhr new measures and further upgrades of wastewater treatment plants (WWTP) and combined sewer overflows (CSO) must be implemented in order to meet the requirements for an improved water quality for bathing (Merkel et al., 2015). In order to enable future bathing in the lower Ruhr from January 2012 to March 2015 the project “Sichere Ruhr” that was funded by the German BMBF (Ministry of Education and Research) RiSKWa research program (Risk management of new pollutants and pathogens in the water cycle) explored conditions for the future use of the river Ruhr as recreational water and drinking water source. Working in close cooperation with the authorities of the city of Essen the aim is to implement bathing locally and to transfer the results of the project to other rivers in Europe. In addition to hygienic aspects, an economic analysis is carried out in the project. The main objective of the economic evaluation was to analyse whether bathing in the Ruhr River would be a positive or negative contribution to public welfare. Therefore, contingent valuation for measuring the economic value –i.e. the willingness to pay for enabling future bathing – has been used. Contingent ranking was used to reveal the respondents' preferences with regard to three possible bathing scenarios: nature bathing, designated swimming areas and river pools. For the economic evaluation four case studies have been analysed. A cost-benefit-analysis was carried out comprising both the results of the contingent valuation and the evaluation of the costs for bathing in the Ruhr.

Material and methods

Investigation area

Actually, the river Ruhr is not designated as bathing waters, because it does not continuously comply with the specifications of the EU bathing water directive, even though its water quality has continuously been improving during the last years. The river is mainly used for drinking water supply and as receiving water body for discharges of WWTP and CSO. The microbial hygienic situation of the river was investigated in one part of the river called ‘lower Ruhr’ that reaches from local areas Essen-Werden to Mülheim-Styrum in the federal state North Rhine-Westphalia. In the middle of this section, the artificial lake “Lake Baldeney” is used for recreation purposes. The whole investigation area includes the cities of Bochum, Essen, Hattingen, Heiligenhaus, Mülheim an der Ruhr and Velbert, which are within a radius of twelve kilometres around the Lake Baldeney.

Bathing scenarios

One component of the project is to involve the general public, stakeholders and shareholders. For this purpose, possible bathing scenarios were carried out in a two-day workshop in April 2013. Three bathing scenarios were developed: natural bathing (scenario a), designated swimming areas (scenario b) and the concept of river pools (scenario c). The minimum requirements for bathing water quality are the same for each scenario. Differences are identified in the existing bathing equipment and infrastructure. Regarding the legal aspects, the scenario natural bathing will not be compatible with the current legal situation (EC, 2006; GV NRW, 2007).

Cost-benefit-analysis

The bathing scenarios have been used to perform an economic evaluation of bathing in the Ruhr and its lakes in terms of a cost-benefit analysis. The objective of a cost-benefit analysis is to evaluate the recognized positive and negative effects of a project and thereby transfer private and social costs and benefits in monetary terms. As a result, information is obtained, whether projects have a positive or negative value contribution to social welfare. Formally, the analysis does not differ from the net present value concept, but takes into account that all costs and benefits are considered. For further assessment of the cost-benefit analysis it is assumed that the benefits from the project will occur with a time lag after investment. An alternative indicator is the benefit-cost-ratio (Environmental Protection Agency, 2010).

The benefit of bathing in the River Ruhr: To determine economic benefits of public goods, the economic sciences use the concept of total economic value. The total economic value consists of two main elements: use values and non-use values. Many public goods are highly valued for their direct use, although direct use may be only one of several components contributing to their overall value. For example, rivers can be used for swimming, fishing or enjoying water sports. So these activities contribute to the rivers direct use value. But goods may also be valued for their existence and availability in the future. These potential future benefits constitute an optional value which is part of the aggregated use values as well. The other value component, known as non-use value, captures those elements of value that are unrelated to a current, future, or potential use: Bequest value refers to benefits from ensuring that certain goods will be preserved for future generations, and existence value reflects benefits from simply knowing that a certain good or service exists. Summing up, the total economic value expresses the degree to which a public good satisfies individual preferences. Thus, total economic value can be measured by the amount of money that an individual is willing to pay for a good (Bateman et al., 2002).

Contingent valuation and contingent ranking: Contingent valuation (CV) is an evaluation method for the determination of the total economic value. Using this method in population surveys, hypothetical situations (here: bathing scenarios) are described and the appreciation of the people for each of these hypothetical situations is queried. The appreciation that reveals to support one specific bathing scenario is expressed by the willingness to pay. Through the use of contingent valuation, it is also possible to evaluate the value of future use in monetary terms, since it can be assumed that the usage behaviour of the population will change in case of a water quality improvement. Contingent valuation is an approved method for estimating non-use values but can be applied for use values as well. Both, the contingent valuation and the contingent ranking (CR) rely on survey responses. However, contingent ranking is a methodology to determine preferences or preference rankings of public goods (here: preferences for a specific future bathing scenario). Criticism of contingent valuation stresses warm glow and free-riding as possible causes for biased willingness to pay figures. Another challenge that plague non-market evaluation studies is the respondent's opportunity of strategic behaviour (Bateman et al., 2002; Pruckner and Hackl, 2003; Liebe, 2007). In order to undertake a reliable CV exercise and to asses consistency of CV findings, these challenges have been adapted by the survey design and statistical outlier analysis.

Survey design

In order to determine the benefit of bathing in the Ruhr, a representative telephone survey has been conducted with over 1,000 households during September and October 2013. The survey sample covers the population living in private households, full age with primary residence in the investigation area. The sample for the representative population survey contains private fixed lines, which have been selected determined by the Gabler-Häder-Process (Gabler and Häder, 2002). The focus of the survey was on determining the preferences for the bathing scenarios and the representative people´s willingness to pay for bathing in the Ruhr. Further explanatory factors and motives for the willingness to pay and preference were investigated. Users are people who knew the Ruhr and its lakes before receiving the data of the survey.

Willingness to pay: It was made clear to the respondents that values for all three bathing scenarios would be elicited. This was undertaken using a direct open-ended question asking the respondent to state their maximum WTP for the bathing scenario in question. Efficiency in the elicitation of willingness to pay can be increased if repeated questions are used (Liebe, 2007). In the bidding game format, for example, respondents are iteratively asked to state their maximum WTP. The game ends when the respondent switches from “yes” to “no”.

Cost estimates of bathing in the River Ruhr: The cost estimates are exemplarily performed on four case studies and then extrapolated for the whole project region. For the scenario b the calculation is specifically made to three potential local swimming areas. Since there can be twelve potential bathing areas at the Ruhr, the results from the specific calculation of the case studies can be extrapolated to this number. For the bathing scenario c the case study is located at the Lake Baldeney. For this bathing scenario the result from the case study is extrapolated to two possible river pools in the investigation area. The cost estimation is based on the finding that the total costs would consist of two elements: costs that are independent of the bathing scenario (measures to increase water quality, upgrading of sewage treatment plants, combined sewer overflows, etc.) and those costs depending on bathing infrastructure, waste management, transport infrastructure, sanitation, safety and communication, etc. per bathing scenario. In addition, the potential size of the swimming area, the length of the beach, and existing infrastructure affect directly the costs of a swimming area as well. Figure 1 illustrates the distinction between base costs, bathing-scenario-related costs and their determinants.

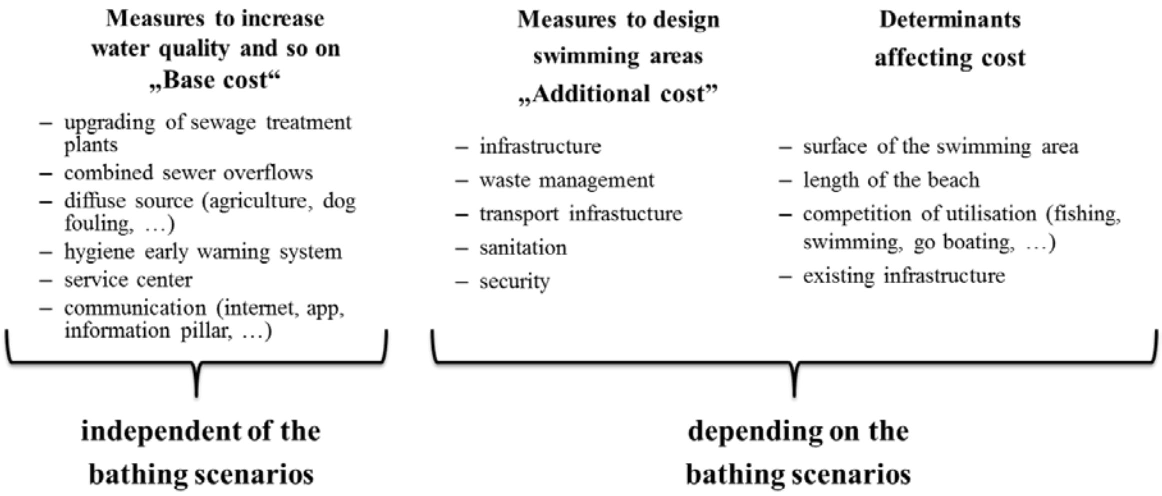

Figure 1 Method for cost estimation

Boundary conditions and main parameters: Two general types of costs need to be considered in the analysis: the capital expenditure (CAPEX) and the operational expenditure (OPEX). In the following cost assessments CAPEX are considered from the first year on, whereas OPEX are calculated from the second year. As water infrastructures are long-life assets, the period of analysis is about 60 years. As inflation takes place within this time horizon, costs in future periods defined on the basis of today's price levels need to be multiplied with the so called inflation factor. The goal of social discounting is to compare benefits and costs that occur at different times based on the rate at which society is willing to accept such trade-offs. If costs and benefits can be represented as changes in consumption profiles over time, then discounting should be based on the rate at which society is willing to postpone consumption today for consumption in the future. Thus, a discount rate of 3% for both benefits and costs was assumed (Schönbäck et al., 1997). Table 1 summarizes the main parameters of the cost-benefit-analysis.

Table 1 Main parameters of the cost-benefit-analysis

PARAMETER	ASSUMPTION
Planning period	60 years
Distribution of costs	CAPEX from the first year
	OPEX from the second year
Distribution of benefit	from the fourth year
Discount rate	3%
Inflation factor	1.50%

Results and discussion

Representative population survey

In total 1,010 interviews were completed. Table 2 displays the socio-demographics of the sample. Concerning the distribution of gender the sample has a ratio of 50.57 % female to 49.43 % male. This shows only minimal deviation from the population in North Rhine-Westphalia: female: 51.29%; male: 48.71%, so that there is no systematic bias by gender in the survey (IT NRW, 2014). Also for the distribution of age no non-random distortion of participation could be detected in the sample. The comparison with data in 2014 shows minimal, therefore negligible differences (IT NRW, 2014). Overall, the request to the sample to represent a reduced image of the population in the investigation area can be redeemed based on the characteristics of gender and age to a sufficient extent.

Table 2 General characteristics of respondents

CHARACTERISTICS	FULL SAMPLE
Sample Size	1010
Male; female	49.43 %; 50.57 %
Years of education (mean)	14.22
Employed (full or part-time); not employed	61.49 %; 38.51 %
Age (mean)	48.97
Houshold size (mean)	2.8
Income	< € 1,000: 6.02 %, € 1,000-2,999: 50.04 %, > € 3,000: 43.95 %

Ranking of bathing scenarios and willingness to pay: Choosing between three suggested bathing scenarios respondents clearly preferred designated swimming areas (42 %) over river pools (31 %) and nature bathing opportunities (22%). Only 3 % of the respondents voted to leave everything as it is (bathing prohibited). About 55 % of all respondents expressed their willingness to provide an additional financial contribution to enable bathing. Of the full sample, 45 % were unable to state a WTP. The answers were classified in six categories (table 3) with no commonly cited reason standing out, perhaps due to the fact that the exercise was too hypothetical or too difficult. The results also contained reasons like no existing willingness to pay, no direct use and lack of confidence in politics and decision-makers. Some respondents even stated a rejection for a WTP for further tourism in the region.

Table 3 Mean reasons for no willingness to pay

REASONS FOR NO WTP	STATED (NUMBERS)	NOT STATED (NUMBERS)
Other	269	191
No existing willingness to pay	124	336
No direct use	108	352
Lack of confidence in politics / decision makers	40	420
Rejection for further tourism	24	436
Don't know	6	454

Outliers: Attributes were used to filter the warm glow effect, free rider behaviour and protest answers. The answers to these questions listed in table 4 were supposed to help separating the amount of payments for measures at the Ruhr from those intended for general measures in environmental protection. People who have significantly higher willingness to pay more often underlie the warm glow effect. Thus, if a warm glow effect is observed in the survey, contentious values of the willingness to pay can be identified and removed. The testing for free rider behavior showed no significant bias. This is consistent with recent research demonstrating that strategic behavior is increasingly occurring in the background (Liebe, 2007). In addition, the WTP exceeding the value of € 500 were compared to the stated income of the respondent. But if these WTP is corresponding to a higher-than-average mean income, all of these amounts will theoretically be possible and therefore not excluded. Table 5 displays the results of the outlier analysis.

Table 4 Outliers: warm glow effect, free riding and protest answers

ATTITUDE	EFFECT
I have a commitment to the environment, so a donation is nothing special. A donation to the environment gives me a good feeling.	If these two statements have been accepted, the warm glow effect was identified.
Good water quality in the Ruhr is my right; I don't have to pay anything for it. I refuse to assess nature and landscape with money.	If these two statements have been accepted, protest answers were identified.
We just asked you for an annual payment. Also conceivable, however are different payment models. Which of the following payment models would you prefer as a citizen? Please select your 2 favourites: [...] I do not care, as long as others make a contribution.	If this favourite payment model has been selected, free rider behaviour was identified.

Table 5 Outliers and influence on WTP

SAMPLE	BATHING SCENARIO			INFLUENCE ON WTP
	Scenario a	Scenario b	Scenario c	
	WTP (mean, size)	WTP (mean, size)	WTP (mean, size)	
Full Sample	44.60 (444)	51.81 (455)	42.38 (445)	-
Sample excluding protest answers	44.22 (377)	51.38 (378)	41.83 (380)	marginal influence
Sample excluding warm glow effect	39.27 (369)	47.63 (370)	36.87 (369)	decrease
Sample excluding free rider behaviour	44.26 (430)	51.84 (429)	42.09 (433)	marginal influence
Sample excluding protest answers, warm glow, free rider behavior	39.05 (355)	47.95 (355)	36.67 (355)	decrease

Use and non-use values: To identify the motivation for the willingness to pay, an open question has been raised ("Why would you be willing to pay the amount you mentioned?"). Then the answers of the respondents were classified by the interviewer in six categories (table 6). The most frequently cited reason for an individual contribution is the own use of the Ruhr as bathing river, as well as the option to swim in the future. The reasons followed are the existence value and the possibility of use for future generations. These results indicate that the WTP consists of both elements mentioned (use and non-use values). In the present analysis a distribution of use values is revealed with N = 333; to non-use values with N = 253. The increase of the image of the region is less important for the respondents than the subjects mentioned above (N = 72). These findings also provide an indication of reliable payment amounts that are mentioned and add additional plausibility to the argument that the contingent valuation method can estimate meaningful differences between use and non-use values (Johnston et al., 2003; Liebe, 2007).

Table 6 Mean reasons for willingness to pay: use and non-use values

REASONS FOR WTP	STATED (NUMBER)	NOT STATED (NUMBER)
Direct use	189	349
Option value	144	394
Existence value	135	403
Bequest value	118	420
Image increase for the region	72	466
Other reasons	94	444

Bid function describing responses to the CV WTP questions: Following other studies and recognised guidelines (Liebe, 2007; Batemann et al., 2006) a validity testing was undertaken through the estimation of multivariate bid function. A variety of potential explanatory variables were investigated with the best fitting model of WTP reported in Table 7 (Neskovic and Hein, in preparation). In the survey a number of attitudinal questions employing Likert scales (1= not important and 5 = very important) were asked to assess respondents' perceptions of water quality, environmental commitment or risk sensitiveness. The bid function described in Table 7 takes general WTP responses for the scenarios. In line with assumed variables the findings of estimated coefficients have expected signs. The negative sign of the coefficient estimated for the variable number of children indicated that WTP decrease with increasing number of children. A further negative significant relation was found with the variables unemployment and the reason for respondent's visit in case of enjoying the nature or fishing. This seems also highly plausible, because those respondents with unemployment have lower WTP. Further, those with other reasons for visiting than bathing would have a lower WTP. The variables number River Ruhr visiting have a significant positive relation to the WTP, besides the cases where the number is very high and >50 times. One possible explanation for this result might be professional visits. Finally a significant positive relation between the variable environmental commitment and WTP was found.

Table 7 Logistic regression of bid function describing responses to the CV WTP questions

EXPLANATORY VARIABLE	COEFFICIENT	STANDARD ERROR
Gender	-0.03	0.26
Age	-0.16	0.01
Number of children	-0.04 (**)	0.18
Years of education	0.06	0.05
Activity status		
Student	-0.39	0.78
Pensioner	-0.62	0.46
Unemployed	-1.53 (**)	0.49
Income		
€ 1.500-2.999	0.06	0.40
> 3.000	0.39	0.43
Assumption to water quality	-0.08	0.90
Environmental commitment	0.47 (**)	0.90
Risk sensitiveness	-0.04	0.90
Number of River Ruhr visiting		
1-5	1.22 (*)	0.57
6-11	1.67 (*)	0.63

12-50	1.21 (*)	0.57
>50	1.19	0.60
Distance from responders respondent's residence to river		
Very close	-0.62	0.33
Near	-0.58	0.32
Farther	0.81	0.89
Occupancy	0,00	0.01
Reason for respondents' visit		
Water sports	-0.70	0.41
Enjoying the nature/ fishing	-0.60 (**)	0.27
Bathing	0.01	0.76
Constant	1.75	1.09
Logistic regression		
Log-likelihood	-222.38	
Wald statistic	78.38	
Number of observations	415	
(*) Significant at the 1% level, (**) significant at the 5% level		

The benefits of bathing

Several parameters influence the accuracy of the estimate of the mean willingness to pay for the investigation area around Lake Baldeney: First, the probabilistic approach sets certain requirements for different ways of interpretation, case numbers and scattering. Thus, a point estimate could not be made reliably. Instead, confidence intervals were calculated, which include different bandwidths depending on the number of cases and scattering. Hence, there was always a 'worst case' (the lower limit of the confidence interval) and a 'best case' (the upper limit of the confidence interval) to look at. Taking into account this assumption, the true value of the average maximum willingness to pay per year and person for the entire sample and for all respondents was calculated. The share values defined by the confidence intervals were as well as the worst and best case scenarios multiplied by the general population of the investigation area (1,256,468 inhabitants). According to this, a total estimate of a maximum annual willingness to pay (= benefit) per year has been calculated within the interval of € 24.0 million to € 32.4 million in case of the preferred bathing scenario "designated swimming areas" around Lake Baldeney. To identify the benefit-cost-ratios per bathing scenario, the willingness to pay of all bathing scenarios has been calculated. The following table 8 summarizes these results.

Table 8 Willingness to pay in Euros per bathing scenario in the investigation area

BATHING SCENARIO	WTP CONFIDENCE INTERVAL	SIZE	WTP IN THE INVESTIGATION AREA
Scenario a	15.43 – 21.56	822	€ 19,387,301 – 27,089,450
Scenario b	19.14 – 25.75	823	€ 24,048,798 – 32,354,051
Scenario c	14.46 – 20.19	822	€ 18,168,527 – 25,368,089

The costs of bathing

For the evaluation of the costs, data from findings of the project Sichere Ruhr (Merkel et al., in press; Tondera et al., submitted; Mälzer et al., submitted; Lahdo et al., in press), literature and expert interviews have been collected and analysed. Table 9 summarizes considered cost items per bathing scenario. Many of these cost items are optional to design a swimming area. In scenario b the calculation shows that annual costs of the case studies have a similar amount of about € 350,000 to € 400,000. Differences can be found in the land properties. However, buildings (office, kiosk, changing rooms) have cost-increasing effects, so that one of the case studies causes higher investment costs than the others. Further cost drivers are outdoor facilities and transport infrastructure. However, in all three case studies these components will roughly be equal, especially if both the beach, fenced and green spaces must be created as well as investments in road signage and parking areas. In the scenario b the base costs for bathing water quality have a huge impact (85 %) on (total) project costs. 15 % of these costs depend on the design of designated swimming areas. The annual costs of a river pool in the scenario c amount to approximately € 2.0 million. Cost drivers are mainly the provision of transport infrastructure, bathing safety, leisure activities, the investment and maintenance of the grounds and buildings. In the scenario c, the base costs account for about 90 % of the total project costs. This proportion is higher than in the scenario b. The remaining 10 % is dependent on the design of a river pool.

Table 9 Developed cost items for the case studies

COST POSITION	COST POSITION
Land properties	**Supply infrastructure**
Clearing work	Drinking water
Excavation	Electricity
Buildings	**Disposal infrastructure**
Office / kiosk / changing rooms	Sewage
Grill station	Rainwater
Sanitary	Waste
Outdoor facilities	**Transport infrastructure**
Bar grate	Road signs
Beach creation	Car parking spaces
Sand	Bicycle rack
Sand cleaning machine	Water safety
Showers on the beach	Lifeguard (and assistant)
Simple wooden deck chair	Water sampling
Green areas	Flagpole
Lawn	Flags
Jetty	Watch tower
Leisure time facilities	**Life buoy**
Table tennis	Floating line
Football goals	SOS telephone
Beach volleyball court	First aid box
Playground	Oxygen cylinder with resuscitator
Barbecue areas	Stretcher
	Rescue board
	Binoculars, horn or megaphone with siren

Benefit-cost-ratios

The benefit-cost ratios and net present values were positive for all possible bathing scenarios (scenario a: 5.3, scenario b: 5.5, scenario c: 4.5). In order to verify the robustness of the assessment results different sensitivity analyses (figure 1) were conducted with the basic parameters. The results indicate that changes in the willingness to pay have the biggest impact on the benefit-cost ratio. For example, even if the net present value of the benefits is the half of the most conservative estimate of the willingness to pay, this will not result in a benefit-cost ratio < 1. This shows that the assessment results are quite robust. Furthermore the preferred bathing scenario 'designated swimming areas' always shows the best benefit-cost-ratio compared to the other scenarios.

Conclusion

Overall, the study was quite successful in disclosing bathing in the River Ruhr as being important to the residents. The majority is willing to provide an additional financial contribution to the implementation of necessary measures. These results are based on a representative survey and reflect an aggregated residential opinion. To perform an economic evaluation on the cost of the bathing, base costs and additional costs have been identified and projected to the investigation area for three bathing scenarios. The cost-benefit analysis showed that swimming in the Ruhr is highly recommended in terms of the public welfare. The benefits exceed the associated costs even under very conservative assumptions. A main objective of the present study was to investigate the preferences of residents in the region lower Ruhr that expands from Essen-Werden to Mülheim-Styrum for different bathing scenarios. Choosing between three suggested bathing scenarios, respondents clearly preferred designated swimming areas (42%) over river pools (31%) and nature bathing opportunities (22%). Only 3% of the respondents have an interest to leave everything as it is (bathing prohibited). The results of the project will be compiled into a general guideline (Schoenemann and Jardin, in preparation). Furthermore, an interest group "bathing in the Ruhr" was founded in the city of Essen. This interest group will pursue this topic beyond the end of the project and provides to implement the project results (Merkel et al., in press).

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Integrated water management in Reunion Island Ecocity

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Abstract

The ecocity of la Reunion covers an area of 5,000 ha and more than 200,000 inhabitants within 3 municipalities (Saint Paul, Le Port, La Possession) with an additional 100,000 inhabitants expected by 2045.

The level of integration is particularly high as the project covers the full life cycle of urban development from territorial policy making to execution assistance within a 10-year framework agreement managed by a multi-disciplinary team of urban planners, engineers and economists.

Among all essential subjects related to sustainable urban development, water management is critical as the West Coast Territory of la Réunion suffers acute water shortage. It shows a fragile coastal environment, lacks space to receive new infrastructures and is exposed to a very high level of risk of flooding and marine submersion.

The integrated water management developed within the project covers 3 aspects:

- Inventing new processes of urban design and territorial management allowing for sustainable development
- Generating a sustainable development framework, working on 3 levels : Managing resources at West Coast Water Basin scale, upgrading utilities and networks at Ecocity scale, promoting bioclimatic and resilient design at urban bloc scale.
- Fostering innovation

Keywords: urban development, governance, participative process, resilience, services, climate change, resources, water recycling, bioclimatic design, urbanism, tropical, island, Eco neighborhood

Introduction: building an ecocity on a tropical island

The Reunion Island Tropical Eco-city is the largest and most ambitious Eco-city project in France and certainly in Europe, and the first of its kind in a subtropical context.

On the narrow corridor at the foot of the volcanoes, the urbanized area hosts a flourishing multi-ethnic society in an outstanding natural landscape listed as UNESCO World Heritage. It is however exposed to land scarcity, shortage of all kinds of resources, transport saturation, chronic unemployment and climate change.

The Eco-city is a pioneering project accompanying a public collectivity throughout the full life cycle of the regeneration of its territory turning 3 separate urban areas into one integrated sustainable city.

The eco-city of la Reunion covers an area of 5,000 ha and more than 200,000 inhabitants within 3 municipalities (Saint Paul, Le Port, La Possession) with an additional 100,000 inhabitants expected by 2045. The project focuses on 2 aspects: harnessing large-scale and long-term equilibriums (integrated management of water, transport, energy, environment, etc.) while concretely accompanying operational developments at the smaller scale and fostering innovation throughout the local economy and society.

Methods

Integrated project management

A thorough understanding of the logic of the full framework agreement at the heart of the project life cycle management is essential.

The “Territory of the West Coast” identified a part of its territory nearly continuously urbanized that could, in the long run, truly become a full scale city. It successfully applied to the national label “EcoCity” providing the setting of virtuous developments within the city and a global sustainable development follow-up. An international urban design competition led to the appointment of a multi-disciplinary team to manage the project over 10 years within a so-called “framework agreement”.

This specific contractual framework is an essential element for the success of such projects. Standard contracts usually define a strict and limited scope, generally dividing the project into many stages and several technical compartments all subjected to specific tendering processes. The conventional approach intrinsically compartmentalizes the urban development process and introduces rigidity in a context in which changes and surprises of all sorts will inevitably occur (political changes, discovery of new constraints, emergence of new needs through a participatory process, technological breakthrough, etc.).

This framework agreement, however, simply defines a general geographical and broad thematic scope with a set of initial subjects that can then be translated into specific "subcomponents" to which the project execution team shall propose a specific methodology and engage into sub-contracts. Should a new subject arise, a new corresponding component could be defined. This flexible frame makes it possible for a single homogeneous team to follow the full life cycle of the project starting with strategic urban planning (setting up a strategic master plan ("Plan Guide"), a sustainable development framework, an urban project management structure, etc.) down to execution and works follow up. This allows for a true transversal approach and makes it possible to merge all technical fields, as well as softer aspects such as quality of life, public spaces ergonomics, equity, innovation, human development, etc.

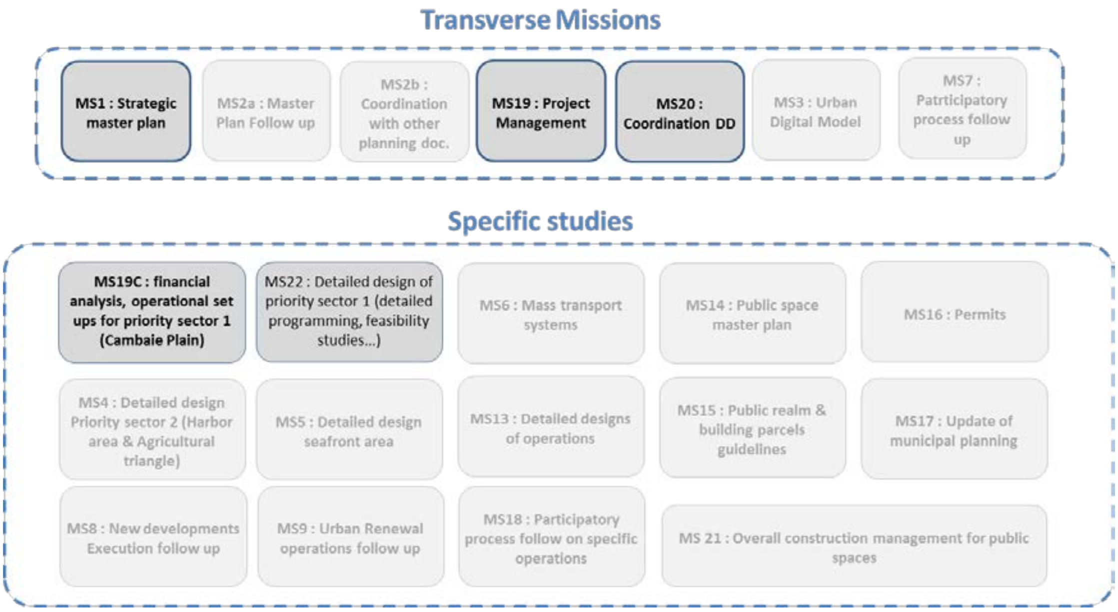

Figure 1 Content of the framework agreement of the Ecocity of la Reunion (in bold, missions started, January 2015)

To achieve a sound urban design harnessing the full extent of the complexities of the larger territory over the long term, it was first necessary to build up a multi-disciplinary but integrated team where urban planners work hand in hand with engineers, sociologists, economists at all stages of the project.

Over 20 “referent experts” have been appointed tasks covering usual subjects such as water management, energy, waste, mobility, land contamination management, etc. , as well as biodiversity, leisure and culture, etc.

It is not enough to simply gather a team of experts; it is essential to also create an appropriate working space where they can collaborate. All experts should be managed as a single team, sharing and exchanging with one another at all time.

One frequent stumbling block is that early stages of projects require a very wide range of expertise while information is scarce and financial resources limited. The response is in management and organization. The team in the present case was structured to mirror the evolutions that the project would require over time.

Proper organization of the project owner is essential. No collectivity is prepared to manage such a large-scale territorial project in all the fields required by sustainable development. Each collectivity has its own historical administrative structure and in-house competences. It would be a terrible waste of resources to build an ad-hoc extensive team to manage the project while it is impossible to maintain organization as it was previously set to manage small scale independent projects.

A very deep analysis of the internal organization of the West Coast Territory was driven over more than one year to understand not only the general organization chart and distinctive roles of all players, but also to evaluate the strengths and weaknesses, habits, ambitions and hidden skills within an organization of over 260 people, closely related to over a thousand civil servants and local representatives within the municipalities.

Moreover, the ambition of the project calls for a wide variety of external partners: Regional institutions, NGOs, private companies. The global project management system needs to integrate all of this diversity.

The internal organization of the West Coast Territory was adjusted as follow to match with the needs of the management of the eco-city project:

- **Clear coordination processes were defined between the eco-city master plan and all regulatory planning documents**. dedicated spaces were created to ensure sufficient information/decision sharing
- **New collaboration spaces** were created to be dedicated to the follow-up of innovative projects that require the participation of external partners of all sorts not usually represented within the West Coast Territory’s institutions. **Thematic Comities** (COTHEM) and **Territorial Comities** (COTER) were invented to gather all relevant players around a preeminent subject or geographical sector.

- An **overall steering process** was established including existing steering bodies, complemented by a scientific committee gathering all senior expertise within the different administrative bodies
- A **dedicated body was established to manage the Eco-city project**: With a CEO at the level of a first rank CEO of the West Coast Territory (thus a permanent member of the higher board of directors) and with its own support staff and two teams : one team dedicated to innovation management and coordination with the other administrative bodies and the specific projects they manage; one team dedicated to the follow up of the execution of major projects, directly placed under the responsibility of the Eco-City Board

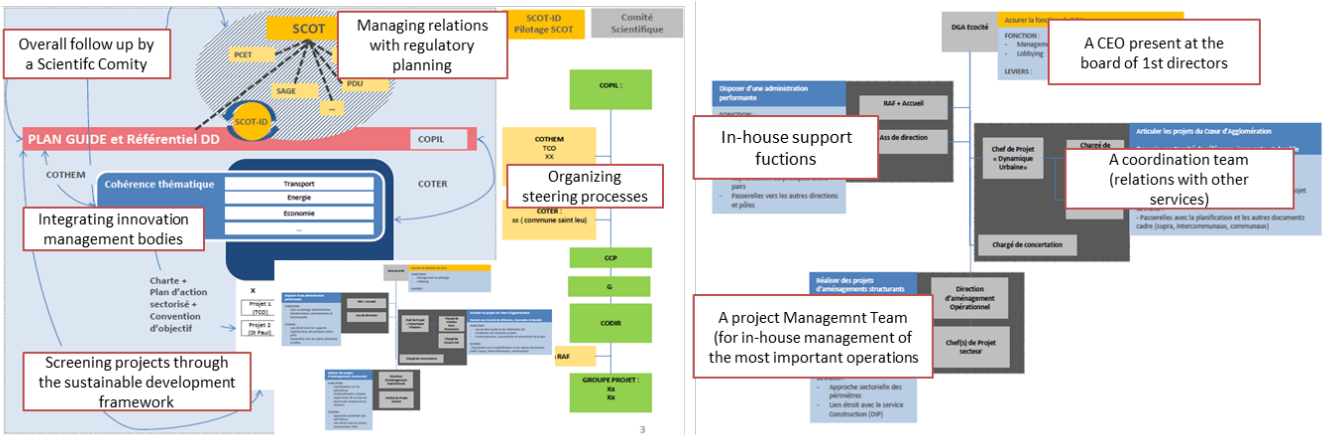

Figure 3 (left) principle of integration of the project within overall organization of the collectivity / (right) organizational chart of the new Ecocity project department

A sustainable development framework for an ECO-design process

In order to strengthen the above-described organization and ensure a satisfactory integration of sustainable development requirements, a set of tools was created within a "sustainable development framework".

The framework is made of four components:

- **A Knowledge Base** centralizes all of the data on the territory in an unbiased way on all subjects, containing as many different outlooks as possible.
- A shared **follow up table of sustainable development issues** gathering all emerging topics throughout the life of the project and allowing to check how they are or are not taking into account in the design processes
- A **thematic grid of analysis** covers all aspects of sustainable development and prefigures a global modeling of the territory and its systems

- An **evaluation and operational management tool** integrates a bench of indicators displaying the level of ambition and actual level of performance of the project, while action sheets provide an operational framework allowing for smooth implementation of the strategic guidelines

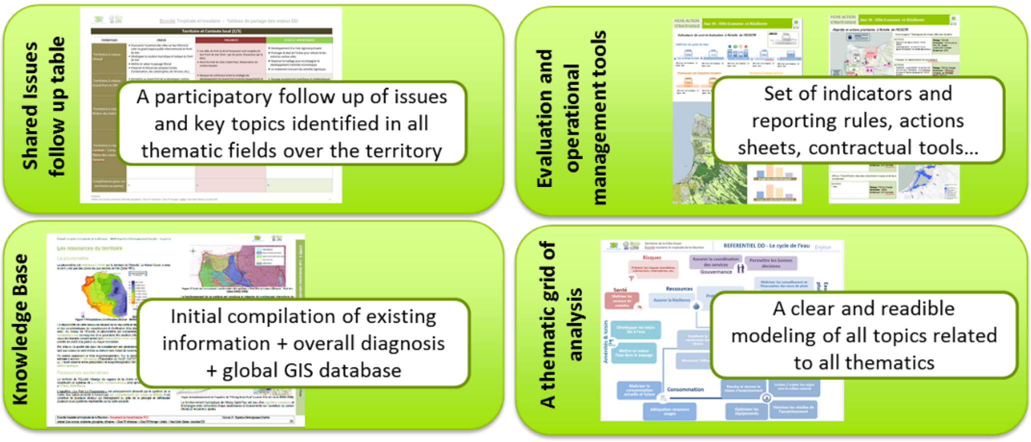

Figure 5 The 4 components of the sustainable development framework

The project started with an unusually broad collection of information. In the era of "big data", we are now surrounded by a tremendous amount of information of all kind. We now have the means to manage the flow and make valuable analysis of the raw inputs. The method here was to assemble the maximum of sources regardless of their origin and nature (planning documents, technical studies, business plans, market analysis, annual reports from operators, etc.

The first stage of information harvesting ended up with the gathering of over 4,000 documents. These were then screened and tagged and eventually read through when relevant. All potentially useful information was then compiled into a general diagnosis covering over 20 themes and 80 general topics.

Shared with technical experts of the project team, and with all external key players, the diagnosis eventually ended up describing quite accurately the functioning of the territory (the specific case of water will be dealt with below in the "results" chapter) both macro and micro whenever a component appeared to deserve further attention. It also pointed out interesting experiences and ongoing initiatives, stakeholders, which would have been disregarded in a conventional analysis.

In addition, the second stage of data gathering is now underway, including the strengthening of a GIS database following the same principle of open and unprejudiced collection. For now, it remains a static and technical oriented data management, but real time and citizen-based data integration is planned in the coming stages.

Out of the diagnosis, major stakes, strengths and weaknesses were extracted and shared within a participatory tool. The "Issues follow-up table" was initiated and opened to all stakeholders allowing to the appropriation of the same stakes by all players and identification of a dozen new relevant topics that had been forgotten. In the end above 150 distinctive topics were spotted.

The relevant topics for the sustainable development of the territory were then cross-analyzed by the experts to be translated into a systemic mapping and an overall analysis grid. In the end, 6 strategic axes were defined as the political orientation for the master plan; each of the axes was associated to 4- 5 themes, each of them translated as a system into 3-5 main priority stakes.

That approach ensured the building up of a clear and shared grid of evaluation of the ecocity project. For each of the stakes, at least one indicator is defined along with a reporting procedure. The evaluation dashboard thus generated shall allow for a concrete follow-up of the performances of the ecocity.

The selection of strategic indicators (as opposed to operational indicators), is traditionally a source of long debates very often ending up into a bench of numbers and figures little considered and all the less utilized to concretely drive urban projects. The method applied here strives to be as pragmatic as possible. It consisted in an initial benchmark of existing and already followed indicators all over the territory. It was discovered that over 1,000 indicators of all sort already existed, more or less pragmatic and utilized. All were then categorized, and sorted by nature, area of interest and above all by entity responsible for its follow up.

It is essential to understand that indicators can be of a very different nature. Many attempts have been made in recent years to define sets of indicators covering all aspects and stages of sustainable urban development projects. All have failed to convince project owners and regulation bodies.

There is no such thing as a set of indicators that would be exhaustive and readable at the same time – to necessary conditions to be usable. In the case of Reunion Island Ecocity, it was simply decided to select one indicator by strategic stake. The indicators do not need to cover all aspects of a given topic but only to provide an estimation of the "general trend".

More detailed evaluations are in fact necessary and much more detailed sets of indicators shall be proposed in the further stages of the project, but in a progressive manner, as operational needs are identified. A global modeling of the city systems is proposed for the next stages of the project.

Key players working together towards a CO-design process

The investigation about the existing organization of the West Coast Territory and its relations with its numerous partners showed how multiple the forces driving the development of the territory were.

A first diagnosis of on-going projects ended up with the identification of over 300 initiatives of very variable nature and level of maturity. It also showed that, because of the complexity and the extent of the geographic and thematic scope, it was nearly impossible for the administration to assess the relevance, level of priority and capacity to realize these projects in the short, mid or long term. It was especially difficult to highlight the relations that may exist among these projects and would allow for pooling and sharing, optimizing and avoiding conflicts at execution stages. An interesting experiment was carried out during the first months of the mission. Shortly after finalizing the inventory of the 300 on-going projects obtained mostly through one-to-one meetings with each director of services, a seminar was settled gathering all projects managers of the TCO (a dozen managers). Each ongoing project was written down on a post-it. A large empty map of the ecocity was stuck onto the wall with four areas representing the level of maturity of the project: "at idea stage", "currently studied", "under implementation", "finalized". All project managers were asked to come and pick the post-it that concerned them and paste it in the right area.

Figure 6 Post-it experiment and its results: the 300 on-going projects of the TCO by categories

The experiment led to the following conclusions: several major projects of the territory were left and were in fact not followed within the West Coast Territory, many projects were either merely imagined (but actually followed by a project manager) or stuck into endless feasibility studies, most of the projects, including some major ones were not apprehended the same way from a department to another, several projects that should have been related were separated and project managers had no exchanges with each other.

The result was of no surprise nor was it a sign of bad management within the administration. It simply translates the full extent of the difficulties large collectivities are now facing as it is expected from them to keep track of more and more different simultaneous projects whereas the baseline of sustainable development requires a transverse and integrated management.

Among its missions, the project execution team is developing a comprehensive interrelated planning of all operations. Such planning usually only take into account major works and decisive permits procedures ensuring a smooth implementation of the project. In the case of the eco-city, it was decided that sustainable development supposes a broader use of the operational planning progressively including interesting – though not technically vital – innovative/positive projects (for their incubation/catalyzing potential). For example, it is essential to check the right coordination between the implementation of a new public transport system and the finalization of a major new urban development. On the contrary, the implementation of an industrial ecology pilot program on the harbor industrial parks whose aim is to identify potential synergies of material and energy sharing does not directly impact the feasibility of the urban development operations. However, it represents a very positive image for the eco-city, lessons might be learnt curving infrastructure planning on the long term, etc. The general operational planning of the eco-city should doubtlessly be extended to such elements.

Results and discussion

Dynamic but Resilient Urban Programming

Managing the project with a truly integrated team of urban planners, programmers and engineers made it possible to truly take into account water balance constraints within land-use planning. Until now, there has never been a fully integrated water management process at the scale of the West Coast Territory. The West Coast Territory Development Master Plan (SCOT) and the local Water Management Scheme (SAGE) take access to water resources into account, but there is no real iteration process between water management master planning and land-use planning.

Until now, domestic uses, green spaces irrigation, industrial activities have been supplied indistinctively with drinking water. First studies demonstrated that existing water resources would not be enough to cover the future needs (above 18,500 m3 of extra daily needs by 2045 just for domestic uses and services), while resources are already nearly saturated.

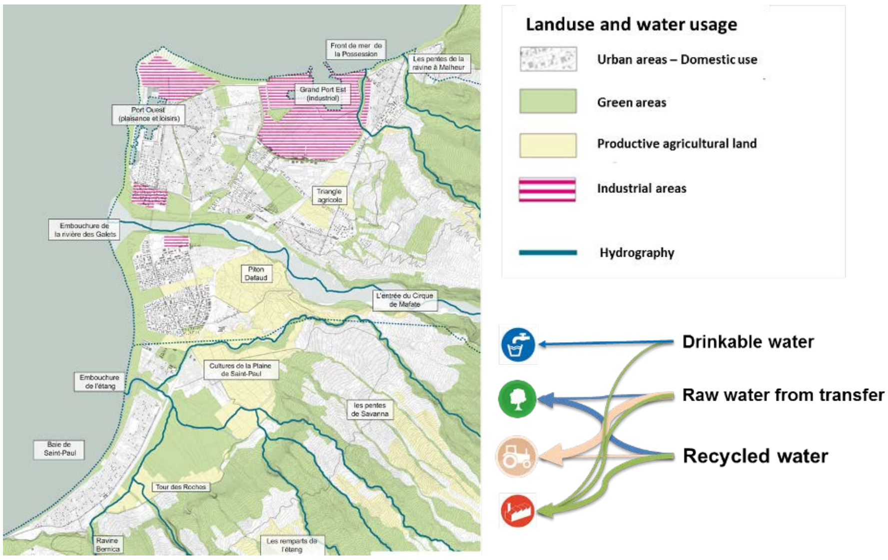

Figure 7 Landuse map in relation with water usage

Major new green urban parks – some of them including agricultural production – are thus located close to new alternative resources. The Northern park of Cambaie New Development is next to the wastewater treatment plant of Saint Paul, which is equipped with a water recycling process.

The general operational planning of the eco-city ensures that implementation of required infrastructures can be realized in accordance with the ambition of the planned urban developments.

During workshops that were organized and open to many stakeholders, the problem of the management of behavioral changes came up very frequently. The local administration is worried that Reunionese habits may be hard to curve. And that a more responsible management of the water resources might be more difficult than it would seem in theory. Water consumption in la Reunion is among the highest in France (>200l/d against <100l/d in Mainland). It was found that no detailed studies had ever been made to try and explain this over-consumption. Though probably related for example, to the importance Reunionese attaches to individual gardens, it seems obvious that sound water management starts with actions on the consumption side. To lead behavior changes, the West Coast Territory has a long history of public awareness campaigns regarding waste management in the poorer districts. The public awareness team could be asked to extend the campaign on water saving.

Sustainable urban engineering and water management systems

Water management systems are still managed at municipality level, each of them drawing its own independent water supply and wastewater management master plans. A basin comity makes sure that there is a consistency between the long-term perspectives of the various master plans. A global mid-term planning is realized within the local Water Management Scheme (SAGE). However between the two levels of documents: one being very operational and the other very strategic, it sometimes proves difficult to ensure a complete vision of the functioning of the water management infrastructures. For example before the eco-city project, there was no assembled map of water infrastructures.

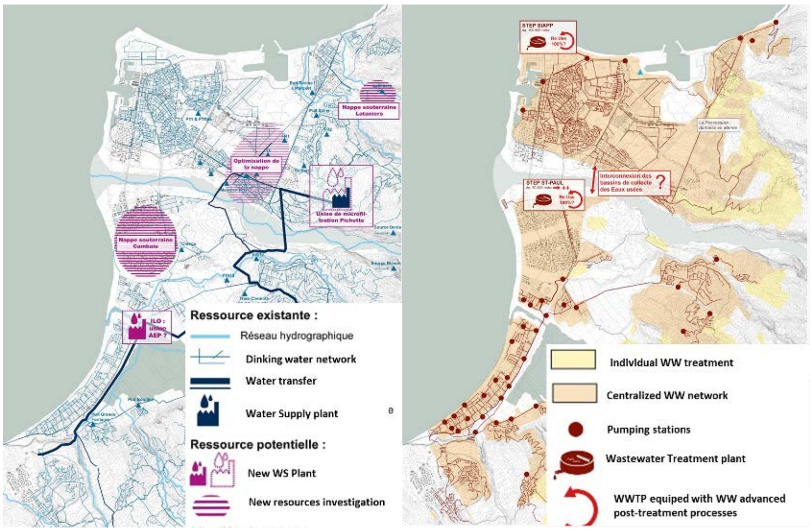

Figure 8 water supply and wastewater networks

An important impact of an integrated approach at eco-city scale can already be felt in the area of water recycling. For several years, the municipalities of le Port and Saint-Paul have been testing advanced wastewater post treatment processes on their wastewater treatment plants. The initiatives have however remained mostly un-used as local sanitary authorities are reluctant to consider most of possible utilization of the recycled water. They prefer to apply very restrictive rules while the results of the experiment showed a very high and constant quality of the treated water. The eco-city project changed the paradigm when it put together the two individual projects into one plain and simple ambition: the eco-city shall recirculate 100% of its wastewater. The two anecdotic technical experiments instantly became a major and rather vital project for the territory, completely changing the local political orientations.

Progressive implementation of the sustainable development framework had as a consequence to bring together several aspects of water usage.

The eco-city is to become a garden city to meet Reunionese needs to live in close relation with nature. In la Reunion, gardens, parks or any kind of greened public space is a pretext for family gatherings, picnics, outdoor sport, etc. It is part of the way so many different cultures and ethnic groups live peacefully together. Greening the until-now hot and arid area is essential to provide the residents with sufficient shading and natural cooling. The extent of the need of green spaces irrigation was therefore largely increased.

Economic development in the area depends on leisure and tourism development. Water plays an important role in attractiveness of the territory. Specific studies are conducted to generate water-oriented new public amenities, eventually large-scale aquatic amusement parks could be considered.

The territory includes several major and fragile natural habitats: The equilibrium of the national reserve of l'Etang Saint Paul, the seashore, the gullies, etc. were taken into account to make sure new water intakes would not hinder their ecological minimum supply.

Reunion Island was struck several years ago by a very strong epidemic of Chikungunia, a vectorial sickness inoculated by mosquitoes. Specific prescriptions are to be made regarding standing water and potential mosquitoes nests.

Several regulations apply at various stages of projects and various components of urban operations – they are rarely put in perspective with each other. The eco-city project gives an opportunity to cross several outlooks and propose sound solutions properly dealing with all issues.

Risk Management by Ecological landscaping

The territory of the eco-city is characterized by a strong exposition to natural risks, mostly related to water. Numerous gullies cross the eco-city in many points, most are dry apart from major storms but there are violent flows during cyclonic events. The Galet River's embankments at the center of the eco-city were worryingly damaged by the last cyclones and now undermine development. As a result regional authorities decided to forbid any further developments in the area, blocking extensive available land in a context of land scarcity.

In the same way, several areas of interest for construction are inaccessible for development due to flooding risks related to poor management of the gullies. Eco-city hydraulic engineers worked hand in hand with the urban planners to build hydraulic models capable of testing each alternatives of urban design. The parametric hydraulic modeling allows dynamic iterations and early changes within the urban design.

In the past several major projects of the West Coast Territory had their permits rejected for insufficient integration of natural risks. As part of the overall project management and sustainable development framework, the eco-city built up a strong partnership with regional environmental authorities (DEAL) to work hand in hand in the definition of satisfactory solutions, anticipating future requirement of the authority.

One of the most sensitive areas of the eco-city is its seafront. Along the littoral of the eco-city, the Indian Ocean presents very strong hydro-sedimentary movements in that area which lead to the setting up of a fragile equilibrium between coastline decline during major cyclonic events and its reconstitution by natural sedimentation. Even more complex lateral currents shape the outlets of the rivers and gullies and eventually ending up filling them with sand and dirt potentially impeding evacuation of water flow during rain season.

It was decided that the development of the eco-city shall focus on totally preserving the functioning of the ribbon of dunes.

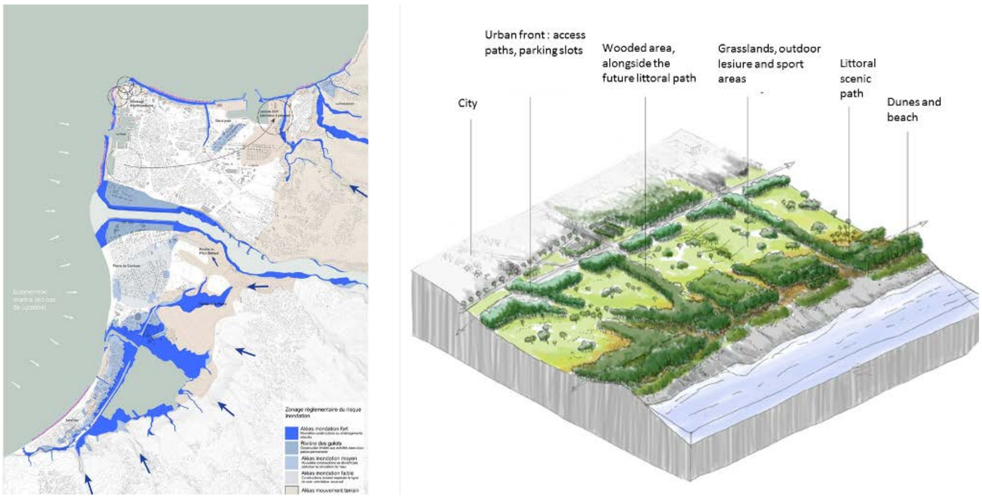

Figure 8 (left) map of natural risks within the ecocity / (right) design principle for the seafront

Conclusion

The approach developed for the project of eco-city of Reunion Island is built upon a strong focus on project management and organization associated with an ambitious sustainable development framework. The project benefits from a new kind of more open contractual framework. It allows more flexibility, broader integration of usually separated subjects and more continuity within the urban design process.

A participatory process made it possible to take advantage of existing initiatives and local dynamics while allowing punctual projects to integrate wider schemes.

After two year of implementation, it proved to be an efficient way to generate a more resilient urban design and to globally enhance urban engineering.

Several paths are to be investigated in the coming stages of the project, including: full systemic modeling of the territorial systems; and implementation of an even more dynamic and interoperable territorial database feeding the urban design team with an even better understanding of the characteristics of the territory

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Water sensitive urban planning - Strategies for adaptation to climate change in the densely populated Ruhr area

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Keywords: climate change, sustainability, urban planning, flood protection, multifunctional land use, participation.

Background

Global warming is a huge challenge to municipal infrastructures and the anthroposphere. The main findings of climate change studies (e.g. IPCC, 2012) with respect to urban drainage are increasing storm water intensities throughout Europe and the risk of flooding. At the same time extreme rainfall events are observed already. Figure 1 shows an event in the year 2014 with a rainfall intensity of 100 l/m2 and more in a few hours. These events have a statistical return period of more than 100 years. As a consequence huge damages occurred in the urban systems.

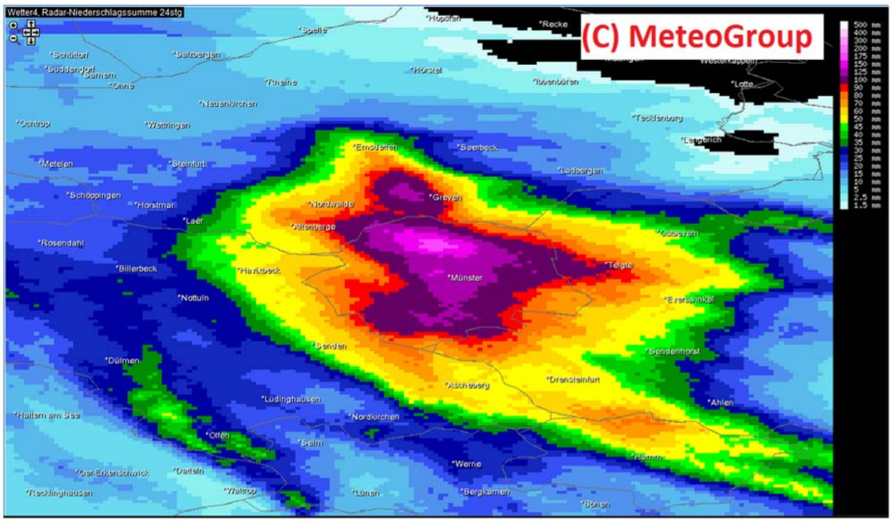

Figure 1 Extreme Rainfall, Radar Image,
Münster, North-Rhine-Westphalia
(Source: www.wetter24.de)

The approach presented here is an assessment of the problems arising from demographic changes, migration and quickly changing weather patterns on the water system in general and with particular focus on the sewerage system and flooding. In order to distinguish this approach of already applied methods of "integrated water management" we chose the systematic of a water sensitive urban design and planning process (WSUD, Wong and Brown, 2009).

The results of a research project (KlimaNet - Wassersensible Stadtentwicklung 2010) on city planning in this context are actually transferred into practice within the City of Bochum. The presentation focuses on the outcomes of the research project in which social scientists, city planners and engineers worked closely together as well as on the upcoming steps to bring these findings into application in the Ruhr Area.

Water sensitiv urban planning and multifunctional land use

In general, the principle of water sensitive urban planning is based on a combination of environmental engineering planning approaches and urban- and landscape planning requirements under consideration of the interests of all parties involved (Figure 2). It represents a holistic approach to storm water management that aims at a sustainable urban development. The frequently discussed measures concern infiltration, temporary storage, delayed runoff and rainwater harvesting. Additionally, multifunctional land use such as temporary storage of runoff in open spaces or parks is considered during the planning process of urban areas. If water sensitive urban planning is applied on a large scale, there will be several positive effects such as increasing groundwater recharge rates and decreasing flooding frequency. Additionally, costs may be reduced by avoiding building measures in the centralized drainage systems and synergy effects in planning and operation of multifunctional facilities.

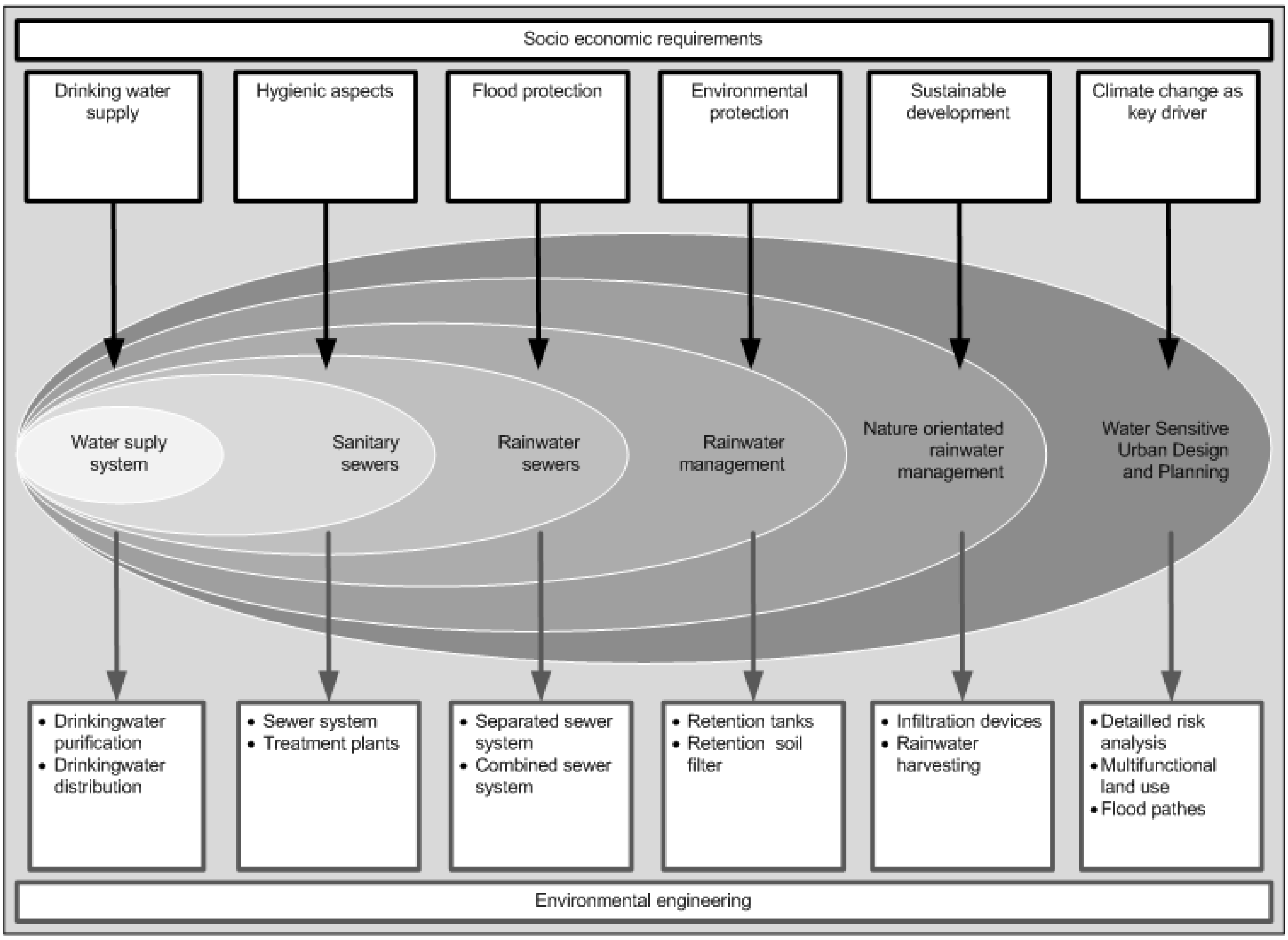

Figure 2 Steps towards a Water Sensitive Urban Planning (according to Wong and Brown 2009)

Multifunctional landuse and storm water runoff

In the future the discharge after extreme rainfall events can't be drained in the centralized sewage system (Figure 3). Even if such events will happen more frequently the upgrading of the sewerage systems is not affordable for municipalities under severe financial limitations as they are in the Ruhr area.

Figure 3 Urban Flooding after extreme rainfall event, Bochum Harpen

Besides climate change, the increasing urbanization in metropolitan areas can be identified as the main driver for the increase in flooding problems. The compression of the settlements and the additional sealing of pervious areas overloads existing drainage systems gradually. Figure 4 illustrates the pilot area in Bochum Harpen in 1930 and nowadays. It is shown that large areas were built during this period. The existing drainage system of open ditches and concrete sewers was built step by step by the way.

Figure 4 Urban sprawl, historic map (1930, left) and nowadays (right)

In order to solve the flooding problems, the impact of urbanization must be reversed. Therefore, decentralized infiltration and storage devices should be constructed to reduce runoff (WSUD measures). Additionally, the directed discharge of the storm water runoff across the surface in the urban catchment is required. The streets and squares will be flooded; however, the aim using streets as emergency flood paths is the protection of the buildings and the infrastructure in the cities. Additionally to the directed discharge, decentralized storage structures are required to limit the consequences of overflows. The storage capacity will be implemented in the existing structures or the natural environment. It is expected, that the directed flooding of public parks, public squares (e.g. market square, soccer fields) or the reconstruction of hidden urban creeks and ditches is useful to adapt the urban infrastructure to the consequences of the climate change.

The impact of this adaptation measures on the catchment area in Bochum Harpen has been analyzed by using the 1D-2D Calculation-Tool Mike Urban Flood (Danish Hydraulic Institute, dhi). Figure 5 illustrates the results of these calculations. It is shown that using streets as emergency flood paths or hidden creeks and ditches for flow routing helps to protect the environment against the consequences of flooding.

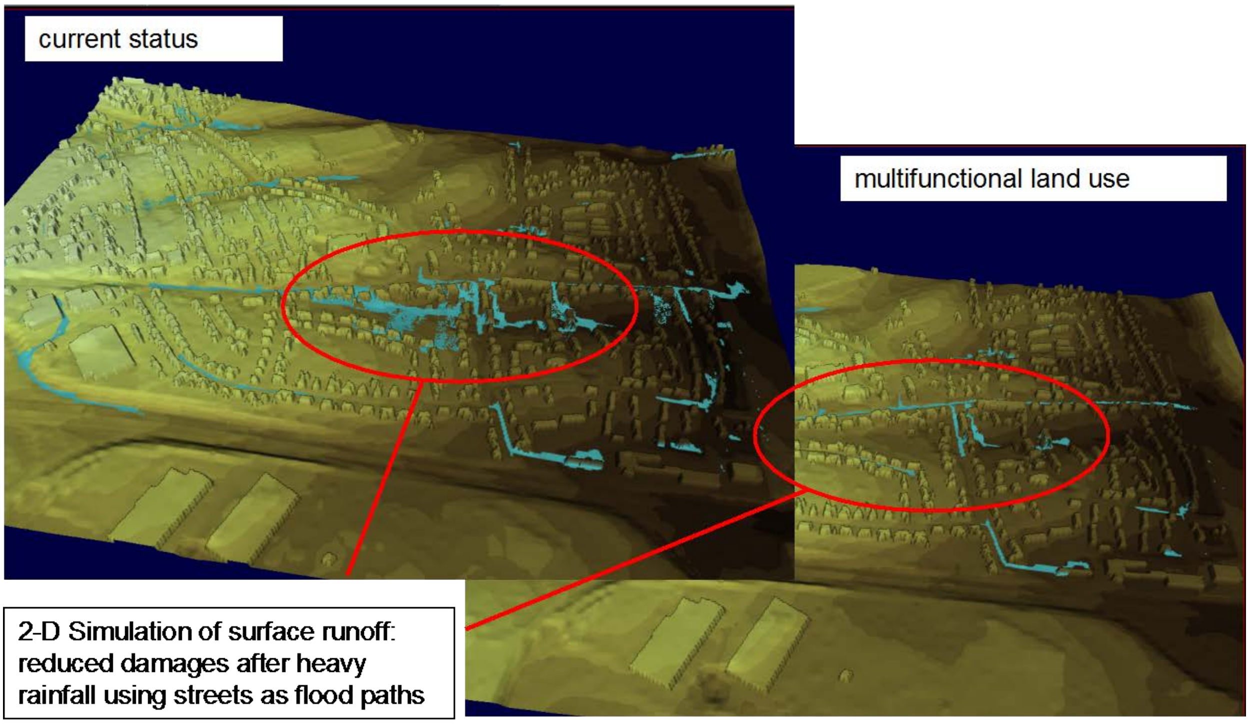

Figure 5 Streets and hidden creeks as emergency flood paths, Bochum Harpen, Ruhr Area.

Process of Implementation

Now the process is starting to implement the system in the real environment. Hence a main road crossing will be reconstructed as a flood path and connected to the receiving water body in spring 2015. Additionally reconstruction measures by opening a hidden creek and rebuilding as an emergency path will help to protect the residential population. The reconstruction measures will include both at public areas and also at private ground.

The following chapter gives an overview about the different adaptation measures which are planned to protect the local citizens and the urban infrastructure against flooding.

Overview

In order to solve the flooding problems, numerous individual measures in an integrated way of planning (Jardin, 2014) are necessary. Only the combination of reducing the direct discharge in the environment, building storage devices on the surface and in the underground, extension of drains and building emergency floodpaths allows to manage the run of after heavy rainfall events. The general plan of all measures is shown in Figure 6.

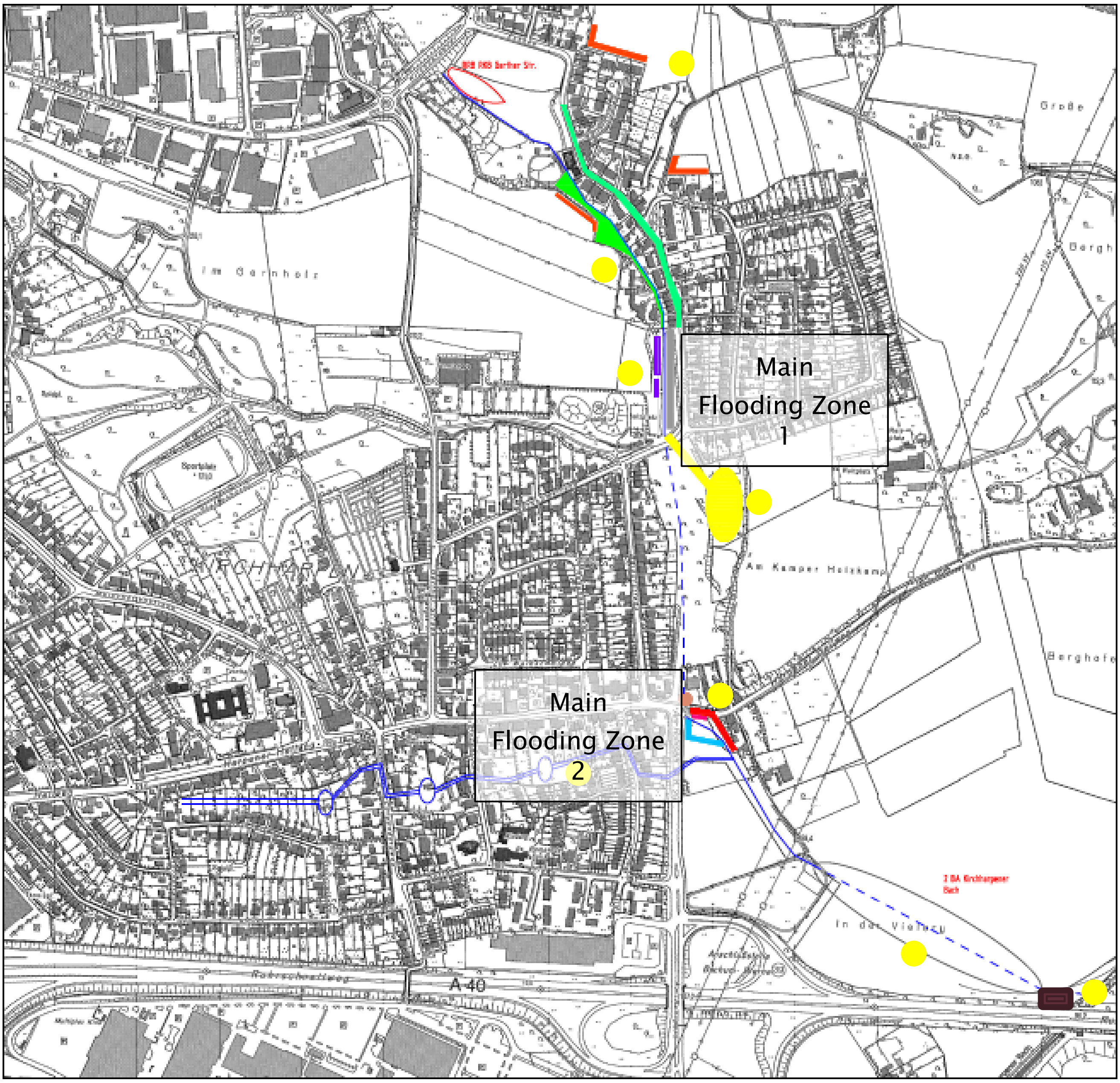

Figure 6 General plan, flood- and storm water management, flash flood prevention

To reduce damages in flooding zone 1 the measures no. 1 to 4 are designed. The measures no. 5 to 7 will reduce the damages in the city centre of Bochum Harpen (flooding zone 2). Therefore a major road crossing in Bochum Harpen is completely rebuilded (measure no. 5). Measure no. 8 is necessary to limit the discharge of combined wastewater into the receiving water body, which is re-cultivated in the direct neighborhood (measure no. 7) of the stormwatertank to reach the aims of the water framework directive (WFD, 2000).

The following enumeration (cf. figure 6) gives more information about the different measures.

1. Wide field margins and natural infiltration ponds

To limit the discharge of the natural environment (fields, grassland) into the settlement, field margins and dams are created. The discharge is stored into natural swales or percolates into the underground. This measure helps to reduce flash floods or mud flows from the natural environment into the urbanized area after extreme rainfall events.

2. Removal of flow obstacles in ditches

Flow barriers of garden waste or similar obstacles reduce the hydraulic performance of drainage ditches. Often the residential population built up those obstacles themselves. The purification of the trenches and the removal of obstacles with help of the residential population increases the flow efficiency of the system.

3. Reshaping of the natural cross section in a small creek

The receiving water body in flooding zone 1 limits the performance of the hydraulic system. Reshaping of the natural cross section in a small creek increases the hydraulic performance and reduces the overflow volume out of the sewer system.

4. Natural floodplain

After extreme rainfall events, the overflow out of the sewer system and the discharge from the natural environment leads to flood events with the consequence of heavy damages in the built environment. Connecting the built environment to a natural floodplain by usage of an emergency flood path helps to reduce those damages.

5. Enlargement of the combined sewer system, construction of an emergency overflow structure, efficient gullies and street inlets to route flash floods directly into the green corridor

One key measure to prevent flooding in the center of Bochum Harpen is to enlarge the combined sewer system, the construction of an emergency overflow structure and additionally to built an emergency flood path on the surface of the main road crossing. This helps to avoid overflows out of the sewer system after typical rainfall events (design storm). After extreme rainfall events the overflow out of the sewer systems will path the streets in Bochum Harpen and will be routed on the surface directly to the green corridor besides the street. There the surface runoff is routed directly into the receiving water body (cf. figure 7).

6. Hidden creek (trench) on private ground as an emergency flood path

Just as important as measure 5 is the construction of a central drainage ditch in Bochum Harpen as an emergency flood path. The ditch is in the centre of a small valley on private ground, where in 1930 a natural water body runs. This emergency flood path is necessary to avoid flooding and damages at private houses in the western part of Bochum Harpen after extreme rainfall events.

7. Re-cultivated water body

To reach the aims of the water framework directive (WFD, 2000) the receiving water body “Kirchharpener Bach” is re-cultivated. By the way the hydraulic performance of the receiving water body and the natural storage capacity has been enlarged.

8. Stormwatertank with overflow structure, combined sewer system

As a end of pipe measure a stormwatertank will be constructed to reduce the discharge of the combined drainage system into the receiving water body after heavy or extreme rainfall events. This measure helps to achieve a good ecological status in the receiving water body and also to reach the aims of the WFD.

In the end additional sewers will be increased in the sewer network in addition to the measures presented here to enlarge the hydraulic performance of the system. These individual actions are not listed here on.

Detailed planning process

Figure 7 Green and blue infrastructure: efficient gullies and street inlets to catch flash floods, ditches as rainwater drains, emergency floodpaths (Source: Siekmann, 2105; Umweltbüro Essen, 2014)

For the implementation of the measures presented a more detailed planning and realization process is necessary. Figure 7 shows different measures which have already been implemented in Bochum Harpen. So the emergency flood path on the surface of the main crossing in Bochum Harpen has already been implemented. Also the efficient inlet system is installed as immediate measure (Figure 7, on the top, left side).

In the next step the combined sewer system will be enlarged and the emergency overflow structure will be constructed in the system. Additionally it is necessary to built the trench in the centre of the small valley of Bochum Harpen (Measure no. 6) to route flash floods after extreme rainfall events out of the built environment without damages at the buildings. All these measures will be implemented in the system in the year 2015. The planning process is running.

After this step Bochum Harpen is on the way from a drained city, as Wong and Brown described (2009), to a water sensitive city, where all aspects of the urban water cycle and the people involved are considered (Figure 2).

Public participation

To follow the path from a drained city, as it is well known in the public, to a water sensitive city it is important to engage the people affected by the beginning of the planning process. In order to implement measures on private property, citizens must act themselves.

Only if the population accepts the implementation of the measures, a successful planning process can be anticipated (Heinen and Hunecke, 2012). Currently, the city of Bochum defines concrete forms of collaboration with concerned citizens. Therefore cooperation agreements will be developed to ensure both the construction as well as the future operation of the facilities. It is planned that the citizens monitor the daily operation of the plants themselves and take simple work to repair itself. Only if extensive repairs are required, the City of Bochum will intervene.

Figure 8 Public participation, open council and roadshow (Source: KlimaNet – Wassersensible Stadtentwicklung, 2010)

Conclusions

Traditional end of pipe solutions built in concrete are not the most desirable method to adapt to the increase of extreme rainfall events. For complete protection of the built environment these measures must be supplemented by further measures. Economic and population changes demand flexible and sustainable solutions wherever possible. The Water sensitive urban planning process (including measures like multifunctional land use, emergency flood paths, flood mapping) is feasible to overcome this dilemma for urban drainage challenged by expected severe rainfalls. Furthermore, it should be an integral part of urban planning on the city level.

The example Bochum Harpen shows that the implementation of a water-sensitive planning in a densely populated area such as the Ruhr Area is possible. The experience with the implementation of this pilot project will be used in the future for further action by the city of Bochum and the Ruhr Association. The extension of sewers in a traditional way will be combined with natural measures of storm water management and flood management of heavy rainfall runoff on the surface in terms of multifunctional land use. The example shows that for each application its own solutions has to be found. As a key element the public participation has been identified while implementing the measures. Only if the population is involved in the identification and the planning process of measures in time, measures on private ground can be linked into the overall concept for public benefit.

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3.7 Engineering Future Urban Water Services

High density urban environments: Mechanisms for delivery

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Abstract

Green infrastructure (GI) retrofit into high density urban environments can be delivered via a number of funding and governance mechanisms. The most appropriate mechanism is dependent on required delivery timelines, the City's overarching political and regulatory environment, the types of outcomes required and the receptiveness of beneficiaries to providing in-kind funding or ongoing management.

Analysis from GI retrofit projects in Melbourne, New York and Wales planned and delivered at various scales shows that an integrated approach to delivery that links and connects policy across 'silo-driven' cultures can achieve long-term benefits. It also shows that although contexts may vary, approaches to implementing new GI should always use the resources, delivery mechanisms and policy context that is currently in place.

Keywords: green infrastructure, water sensitive urban design, urban renewal, urban planning

Introduction

It is increasingly clear that the retrofitting of GI is becoming increasingly common in high density urban environments around the world. From increasing tree canopy cover in Melbourne's streets, parks and iconic laneways, to retrofitting 578 rain gardens into New York City streets, to installing sustainable urban drainage features into Welsh schools as part of a catchment wide intervention.

At the core of many GI projects is improved stormwater management, and water itself can be the integrator that highlights the interdependencies between individuals, settlements, their hinterlands and global systems. A shared stakeholder interest in water management can be the key to facilitating collaborative, holistic approaches to policy, planning and design.

The drivers for water-focused GI type projects differ from location to location and stakeholder to stakeholder. These include reducing flows into combined sewer systems to reduce associated spills from high rainfall events, improving water quality and flow patterns in receiving waterways, reducing property damage and inconvenience associated with urban flooding, improving the overall amenity and functionality of our cities, reducing energy and carbon usage, supporting the health and wellbeing of residents, improving habitat and biodiversity outcomes and enhancing resilience to climate change (see Figure 1.1). Other residual benefits such as improved air quality and microclimate are also increasingly being documented and understood.

Delivering this type of infrastructure into highly populated settlements differs significantly from installing these types of infrastructure into green or brownfield developments. Key issues for delivery include: competition for limited space, the costs associated with working in high-density environments, clashes with existing services, public health and safety, educating residents about the functional requirements of these different looking types of infrastructure as well as involving them in the design process, and determining and then funding the party responsible for long term maintenance. However, all of these projects are delivered with one key consideration in mind, namely, making better places.

Lessons learnt from planning for and delivery of these types of projects in various developed cities in the UK, Australia and the USA show that there are a number of ways these types of infrastructure can be delivered and land uses targeted. This may be done by incremental opportunistic installations sequenced to take place with other infrastructure upgrades, large scale streetscape retrofits which are centrally funded, and a suite of projects at various scales which form part of a larger initiative.

Regardless of who is delivering the intervention and its primary purposes, all GI projects will produce a wide variety of direct and indirect benefits, and in order to be successfully delivered, require a number of elements to be considered at the outset. This includes a shared vision coupled with a commitment to multidisciplinary collaboration and the use of innovative funding models.

Methods

Previous research conducted by Arup (2014) as part of the 'Cities Alive' initiative laid out the case for GI in our cities (see Figure 1) while also acknowledging that the delivery of GI in urban environments is complex.

A comprehensive framework was developed (see Figure 1.2) to guide delivery of successful GI initiatives and the following key requirements identified:

- Overarching vision - All delivery should be underpinned by and contribute to a large-scale strategic vision. This vision should identify the assets, opportunities, risks and vulnerabilities for a given context.
- Collaboration - Increasingly, GI is being seen as a concept which unites a range of disciplines and interests, and that facilitates collaborative working. Crucially, in the context of GI, competing priorities can often complement each other.
- Evidence - Preparation of a GI project should be underpinned by evidence. The aim is to ensure that interventions are appropriate to their context. Evidence is particularly important to understand the value of a city's natural resources to enable future planning for enhancement potential.
- Tools and Design Stage - Planning plays a vital role in the delivery of projects and will be triggered in many interventions involving new and existing development. Designers working in multidisciplinary teams should seek to ensure that GI and its subsequent maintenance are integral to individual projects, and always linked into the wider vision and framework for that city.
- Management - Management and maintenance of GI should always be a key consideration from the outset of a project. This is crucial for the longevity of a project and for securing the full potential of interventions.
- Funding - Traditionally, local authorities provided funding for the delivery and management and coordination of GI. Increasingly, this type of funding is more difficult to secure, leading to new, creative and innovative ways for funding and use of available resources. Considering funding for maintenance and management from the outset will help deliver long-term benefits. Cost reduction and recognition of the value of existing assets are also important.
- Importance of city leadership - Demonstrating the value of GI and the variety of scales and types of interventions possible is crucial. Political champions are important in setting and promoting a vision whereby GI adds to the quality of a city and differentiates its offer by attracting investment. Professionals negotiating to achieve new or improved assets should understand the economic context in which they are working and promote the multiple benefits of GI.

Results and discussion

The following case studies were analysed to determine how these various initiatives respond to the criteria for success.

Urban Forest Strategy, Melbourne Australia

The City of Melbourne (CoM) has increasingly recognised the vital role which biodiversity and the natural environment play in the health and wellbeing of its cityscapes. To help drive sustainable urban development, Council has implemented a range of strategies to support GI delivery, including the Urban Forest Strategy and Growing Green Guide.

The City recognises that the integration of GI within traditional built form can provide a range of environmental and eco-system benefits by enriching air quality, improving water quality, supporting healthy biodiversity and reducing stormwater runoff.

Melbourne is renowned for its iconic laneways; many of which were transformed from forgotten backstreets into vibrant and bustling cultural hubs through a series of precinct activation projects in the early 1990's. The success of Melbourne's laneways, along with the emergence of 'laneway culture,' is now cited internationally as a best practice in urban revitalisation.

As part of the evolution of Melbourne's laneways, the city is now developing an assessment methodology, which will enable it to assess the greening opportunities in its laneways. Each laneway will then be assessed and opportunities spatially mapped and inputted into the CoM's asset management system. Delivery of opportunities will be incremental and opportunistic, based on leveraging other asset management activities taken to optimise delivery of GI into existing work programmes.

Newtown Creek GI, Brooklyn, NY, USA

The NYC Department of Environmental Protection (NYCDEP) is leveraging the use of GI to reduce combined sewer overflows (CSOs) and to meet and exceed the water quality standards of NYC's waterways. The NYC Economic Development Corporation (NYCEDC) is managing the delivery process on behalf of the NYCDEP to achieve the goals set forth in the NYC GI Plan.

Retrofitting the public right of way with 578 "Bioswales" or "Stormwater Green Streets" within 531 acres of the Newtown Creek watershed in Brooklyn, NY is a core component of achieving this goal.

Site selection and design needed to be completed within one year, and construction completed within three years. Rollout is underway with specific tasks to achieve this goal including civil engineering, tributary analysis, site selection, mobile data collection, GIS data management, detailed engineering design and design services during construction.

Dŵr Cymru Welsh Water's Rainscape Initiative, Wales

Dŵr Cymru Welsh Water (DCWW) is responsible for the sewer network across Wales. The organisation is using GI, branded Rainscape, rather than traditional grey infrastructure solutions to manage surface water. The issues being addressed include: network flooding, spills from CSOs, high wastewater treatment and pumping costs, and general hydraulic under-capacity in the system.

Stebonheath Primary School previously contributed 59l/s into the combined sewer network (1 in 5 AEP). The school grounds offered little in the way of green space and localised flooding was common. A GI scheme at the school brought with it the potential to turn an otherwise bland playground into a green, vibrant, and exciting educational resource.

Collectively, 100m3 of sustainable attenuation volume has been constructed at the site, limiting peak flows into the sewer system to just 6 l/s (1 in 5 AEP).

Analysis of these projects examines how they address the key components which are considered crucial for GI project delivery:

Overarching vision

Melbourne: The CoM's "Total Watermark: City as Catchment" sets a clear vision and associated targets for stormwater management within the city catchment noting "our vision is a healthy city in a healthy catchment. We want the whole of Melbourne's community – residents, workers and businesses, to think about water and its role in our future, to help create a healthy city in a healthy catchment."

The strategy notes that rapid climate change is resulting in less, but more intense bursts, of rainfall and that the city must ensure that it uses the right water for the right purpose while minimising flood risk.

The strategy sets a number of targets at the 2018 and 2030 timescale including a 30% reduction in Total Nitrogen contributed to the waterways from the municipality of Melbourne's catchment (baseline year 2000). This vision and strategy along with CoM's Urban Forest Strategy has driven council programs such as Greening Melbourne's Laneways and the Greens roofs, walls and façade programmes across the city.

New York City: In 2010, NYC developed its GI Plan which presented a comprehensive framework and strategy for implementing GI in the city. The vision encapsulated within this Plan has since been used to develop a process to deliver GI across the city.

The GI Plan was a key part of PlaNYC, which was a sustainability initiative released in 2007 by Mayor Michael Bloomberg, which was intended to strengthen the economy, adapt to climate change, and enhance quality of life to create a "Greener, Greater New York."

Wales: DCWW's vision is to lead the way in developing and using new, innovative solutions to manage the amount of surface water entering its sewers.

DCWW have branded this initiative RainScape and developed a 20-year strategic delivery plan, which uses retrofit GI measures to separate or attenuate surface water before it enters the sewer. The plan is supported by targets and budgets including a commitment to invest more of up to around £80 million by 2020 to support the core goals of:

- Reducing the risk of sewer flooding and pollution, whilst also helping to increase capacity in the sewer network; and
- Supporting economic development and protecting customers against climate change.

Collaboration

Melbourne: working across departments and using existing asset management systems to incorporate GI will be crucial to the success of GI delivery. From treating trees as assets and valuing them for insurance purposes to ensuring that future GI interventions are visible in asset management software, the city is proactively assessing and mapping opportunities and making this information available to the delivery arm of Council.

CoM has also worked collaboratively with surrounding councils, Melbourne Water and Government agencies in the development of its WaterMark and Urban Forest Strategies.

New York City: The design of GI is truly a multi-disciplinary effort encompassing civil engineering, landscape architecture, geotechnical engineering, traffic engineering, environmental engineering, etc. Moreover, any work within the Public Right-Of-Way requires collaboration amongst multiple agencies.

In New York City, the Department of Transportation (DOT) manages streets and sidewalks, while NYCDEP manages stormwater and combined sewer runoff, and the Department of Parks and Recreation (DPR) manages trees and landscape within public lands. In addition to these city agencies, utility agencies are very prevalent in terms of electric, natural gas, cable television, telephone, fibre optic, fire department communication, etc.

To guide collaboration NYC DEP developed the GI Design Standards. This required input from DOT in terms of sidewalk treatment and appropriate siting criteria to ensure unimpeded access for pedestrians and cars. DEP also needed input from DPR on the appropriate trees and planting species within the design standards to ensure performance during rain events. Regulatory coordination was also required to ensure that approvals and permits for GI work within the Public Right-of-Way were acceptable by all regulatory agencies.

DEP developed a program to deliver GI across the city using area-wide contracts. With DEP undertaking ownership of the area-wide contracts, they sought partnerships with other city agencies to manage and administer the area-wide contracts. Such organisations include not only DPR but the Economic Development Corporation (EDC) and the Department of Design and Construction (DDC). In addition to the area-wide contracts which focus on Public Right-of-Way installations, DEP have also partnered with other public agencies such as the

Schools Construction Authority and the NYC Housing Authority to implement GI within other NYC properties.

Wales: The use of GI interventions by a water company for this purpose is unique in the UK. The assembled project team, which comprised of DCWW (the client), Arup (the designer) and Morgan Sindall plc (the capital delivery partner), worked collectively to address key challenges such as planning policy, a lack of real life examples and design guidance, and delicate construction within an existing Victorian built environment.

Formal Memorandums of Understanding between key stakeholders on two of the initial projects were useful to legitimise the input from each party and clarify expectations. Multi-organisation steering groups also enabled issues to be highlighted and resolved and provided a forum for communication. Attendees are empowered to take action to assist the project's progress. Discussions on Legal issues over ownership and maintenance, often blockers to these types of schemes, were started early and followed up at every steering group meeting to ensure resolution and long term adoption and maintenance agreements with CCC have been formed.

Evidence

Melbourne: The CoM engaged Arup and other supporting specialists to develop a comprehensive GI assessment framework to identify opportunities within individual laneways and produce an opportunities mapping layer. The objective of the framework is to identify, understand and prioritise interventions which respond specifically to key issues found in individual laneways such as solar access for vegetation, access for waste delivery and existing business operational requirements.

A series of pilot investigations and installations have been undertaken to understand the success of the proposed interventions. The assessment framework also draws on extensive research undertaken on the performance of GI by several Australian research organisations.

New York City: Currently DEP are managing several area-wide contracts across the city to deliver thousands of bioswales within city streets. To get to this point in their program, DEP started by implementing pilot projects to develop design standards to ensure they were achieving the performance necessary to management stormwater and also to ensure the standards met the requirements of all city agencies. Since 2011, DEP has increased its knowledge and understanding on the technical aspects, costs and benefits of GI.

In 2012, DEP publicised the 2012 Pilot Monitoring Report to present the progress and monitoring results from their pilot projects. DEP's monitoring program focused on the functionality of the GI practices and the impact to runoff rates and volumes along with water and soil quality and establishing maintenance requirements. As more evidence was attained from their pilot and demonstration programs, the program was adapted and then expanded by an order of magnitude to gain city-wide implementation.

DEP continue to research the co-benefits of GI and have noted that more than 100 references have been reviewed to support their internal co-benefit analysis which will help to demonstrate the cost savings and social benefit GI will provide NYC.

Wales: Following extensive catchment-wide investigations, data collection and hydraulic modelling undertaken between 2010 and 2011, a suite of over one hundred GI schemes were identified for implementation as part of a long term catchment strategy to address flooding and river pollution in Llanelli (see Burry Inlet Investigations, UK Water Projects 2012).

The selection of three priority pilot schemes was based on a multi-criteria analysis comprising key indicators such as surface water reduction, resolution of flooding, whole life costing, ease of construction and carbon footprint. The three chosen projects, Queen Mary's Walk, Stebonheath School and Glevering Street are all located in central Llanelli and are each serviced by a public combined sewer network.

The sites are considered typical of the urban environment that has evolved within the catchment resulting in a highly impermeable response to storms where rainfall quickly arrives within the sewer network. With the Rainscape project being a first on this scale in the UK, locally based evidence was not always readily available before construction. Consequently, data collection that could feed into other UK schemes has been a priority on this project. For each scheme constructed, a full ecosystem services assessment pre and post construction has been carried out. Also, flow monitoring in the sewer network has been completed to assess the flow removal. Early indications show flow removal rates compared to that of before the schemes show in excess of 70% peak and volume flow reductions.

Tools and Design Phase

Melbourne: Melbourne Water as the drainage authority in the City has produced a series of guidance documentation to assist local authorities in GI delivery. This includes a comprehensive WSUD Guidelines (2013) produced in conjunction with the CoM and costing data to help ensure that this type of infrastructure is adequately costed into future capex and operational budgets. Software tools such as MUSIC allow for ready assessment of GI types to understand pollutant removals, while standard engineering drawings produced by surrounding municipalities such as the City of Moreland ensure consistency of delivery.

An opportunities assessment framework has been developed for CoM to identify GI opportunities at the laneway scale. This drew on a multidisciplinary team of environmental and civil engineers and environmental scientists, landscape architects, water sensitive urban design specialists, horticulturalists and arborists, urban designers and transport planners. Each discipline's contributions help ensure all aspects are considered in the framework.

New York City: NYCDEP, along with their partner agencies, have developed tools to enable other city agencies and consultants to deliver GI to their required standards. For example, standard construction details and geotechnical investigation procedures have been developed by DEP and widely available for use. DOT have prepared site selection criteria to ensure that the GI practices within the Public Right-of-Way remain clear of pedestrian accessibility requirements, emergency egress and a myriad of street furnishings. Similarly, the DPR have identified tree species and prepared planting palettes that are based on varying land use typologies of the city environment.

These tools are critical in ensuring City requirements are met and in achieving consistency across multiple neighbourhoods. Arup has also developed customised tools to help deliver these projects in a more efficient manner, such as customised mobile data collection tablets for site selection, web-sharing platforms and augmented reality for community outreach.

Cardiff: Detailed software modelling showed that Stebonheath Primary School previously contributed 59l/s into the combined sewer network (1 in 5 AEP). The school grounds offered little in the way of green space, and localised flooding was common.

Design proposals for Stebonheath were refined through interactive sessions with the staff and pupils at the school. The final design consisted of a selection of basins and planters, whereby attenuation volume was maximised through the use of innovative storage products, such as Silva Cell, designed to increase soil void ratios.

Collectively, $100m^3$ of sustainable attenuation volume has been constructed at the site, limiting peak flows into the sewer system to just 6 l/s (1 in 5 AEP). A key challenge faced at Stebonheath School was the programme. Construction was limited to just six weeks to fit within the summer holiday period. This leant itself to off-site fabrication; for example, bespoke downpipe timber planters which were delivered to site in two halves, generating $14m^3$ of attenuation volume within a matter of hours on site.

Management

Melbourne: Generally, local government has a lead role in management of catchments of a size of less than 60 hectares. In existing high density urban environments, local governments thus typically take the lead in GI delivery at the street and precinct scale while Melbourne Water take control of regional drainage assets. This arrangement is relatively well defined and understood, and ongoing management arrangements are well documented in existing guidance documentation.

Specialist contractors are emerging with the skills to maintain this type of infrastructure for optimum performance.

New York City: Developing a maintenance program is one of the more critical elements in creating a successful city-wide GI program. DEP have partnered with DPR to plan and implement a maintenance program, and by the end of 2013, Brooklyn, the Bronx and Queens each had one fully staffed five-member GI maintenance crew. DEP will continue to manage this maintenance program by employing a full-time manager.

Wales: Adoption can be a critical barrier for many retrofit GI projects with cost, responsibility and maintenance often being the three key issues. This was overcome in Llanelli by working with Carmarthenshire County Council (CCC) from inception. Discussions and agreements started with the GI overall strategy; this then progressed to agreeing to individual detailed site layouts and the use of bespoke technologies.

Long term adoption and maintenance agreements with CCC were negotiated for ongoing functionality. In addition, much of the GI installed at local schools is maintainable by the school pupils instilling a sense of ownership whilst benefiting both the school and DCWW.

Funding

Melbourne: In Melbourne, the goal of the programme is to prompt incremental change and GI rollout to support existing long-term strategies. An innovative funding approach is using existing Asset Management systems and leveraging off the back of existing works programmes (e.g. drainage system upgrades) so that only minor incremental costs associated with GI delivery are attributable. By understanding the additional costs and using them in the economic analysis, the business case for investment becomes much clearer and highlights the opportunities that could be missed if not pursued in a temporal fashion. Operational and maintenance costs are also being increasingly understood and factored into Council budgets and operational plans.

New York: On March 8, 2012, DEP signed an agreement to reduce combined sewer overflows (CSOs) using both green and grey infrastructure. DEP are developing Long Term Control Plans (LTCP) to reduce CSOs and improve water quality to standards set established with the Federal CSO Policy and the US EPA Clean Water Act. Over the next 20 years, DEP is planning on $2.4 billion in public and private funding for GI installations. DEP have prepared studies demonstrating the financial benefits of GI in comparison to traditional grey infrastructure for CSO reduction (which include large underground tunnels or wastewater treatment plant upgrades). Funding will largely come from DEP; however, there has been shared funding across multiple city agencies in terms of the management of design contracts and the maintenance of future GI practices.

Wales: At the beginning of 2011, DCWW announced a £15m investment, funded through its flooding and pollution budgets, targeting the top ten highest priority schemes capable of reducing peak storm water runoff entering the combined sewer by 25%. Implementation of the strategy is now underway with three constructed GI schemes showing the benefits resulting from a newly integrated, sustainable and resilient approach to water management.

Most recently, DCWW has agreed to a £230m loan facility with the European Investment Bank to cut costs, keep bills lower and continue its investment programme, including its RainScape programme. As cost savings have been demonstrated over traditional grey infrastructure approaches, funding for maintenance will come from existing budgets.

Importance of City Leadership

Melbourne: Proud of its ranking as the world's most liveable city, Melbourne is consistently exploring ways to enhance its urban environment for residents and tourists alike. City

Leadership is committed to enhancing life and liveability in the city and sees the greening of the city as a key component of this. This support is evident both in the language used by elected City leaders, Council officers and supporting policy documents. Overarching strategies such as the Urban Forest strategy are consistently publically supported by the Lord Mayor and other elected representatives.

New York: The 2010 GI Plan established the vision for a sustainable strategy for clean waterways in NYC. The Plan was developed during the tenure of Mayor Michael Bloomberg who was instrumental in pushing forward sustainability for NYC. Mayor Bloomberg led the creation of PlaNYC in 2007 to strengthen the economy, adapt to climate change and enhance quality of life to create a "Greener, Greater New York." Much of the thinking and influence in the 2010 GI Plan spawned from PlaNYC.

The 2010 GI Plan was prepared by NYC DEP during the tenure of Cas Holloway as NYC DEP Commissioner. Cas Holloway created new initiatives in DEP including appointing DEP's first Deputy Commissioner for Sustainability, and his leadership helped to facilitate the onset of the Plan. When Cas Holloway departed NYC DEP (to work directly for the Bloomberg administration), Carter Strickland succeeded Holloway as Commissioner and continued to prioritize GI (including launching the $2.4 billion investment across the next 20 years).

Wales: Although initially led by DCWW, the RainScape programme has and continues to be widely supported by a number of organisations such as Natural Resources Wales and Carmarthenshire Council. A number of public launch events for the projects have been held and attended by elected City Leadership, and media coverage has been strong.

Conclusion

The idea of bringing GI-led design into a more influential role in the design of cities is a significant opportunity to influence the structure and design of the urban environment to respond to future needs. It can introduce a new ideology based around an ecosystems approach that can contribute to the health, resilience and prosperity of a city.

Water plays a key role in the delivery of GI through restoration of rivers and waterways, WSUD element retrofit, and vegetation/ tree planting to reduce run-off and manage microclimate. These new elements can form part of larger green grids which can be inhabited by community orchards and edible planting, play areas and recreational space.

Though contexts may vary, approaches to implementing new GI and urban landscape explored in these case studies should always use the resources, delivery mechanisms, and policy context available today while design of GI must always be appropriate to its context and draw on the best available data.

Delivery mechanisms will differ depending on the underlying goals: improving the quality of existing spaces or creating new assets which contribute to the wider network; large scale investment or smaller incremental projects; temporary, phased or permanent interventions. In all of these scenarios, multi-functionality and connectivity are crucial.

Delivery of GI has been somewhat piecemeal in the past. In the future, we should consider GI from the outset of any urban project or strategy. It should not be an independent driver for development, but a solution to a range of issues. Connecting multiple functions and securing benefits will meet a range of existing and future needs.

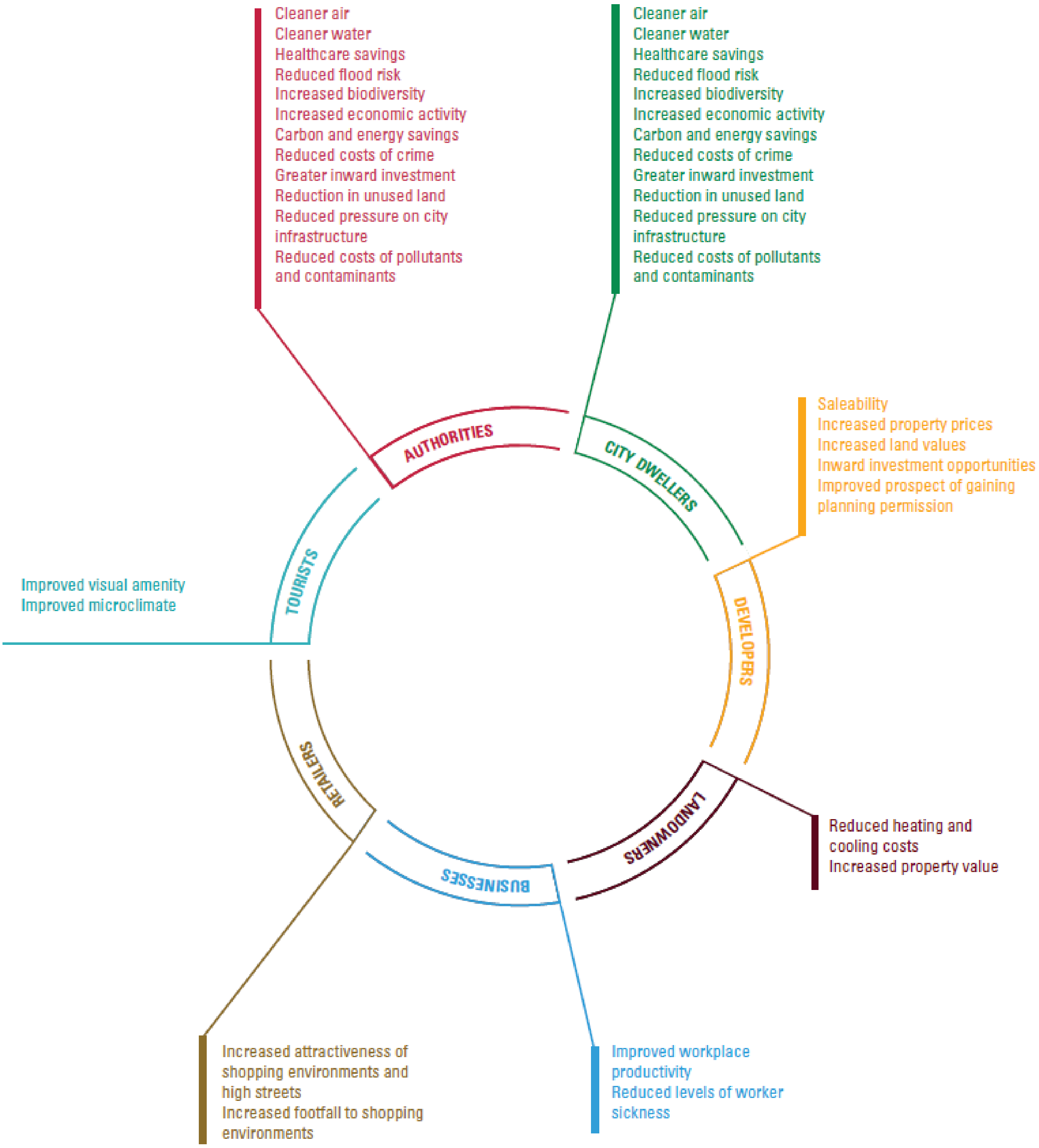

Figure 1 the Case for GI © Arup

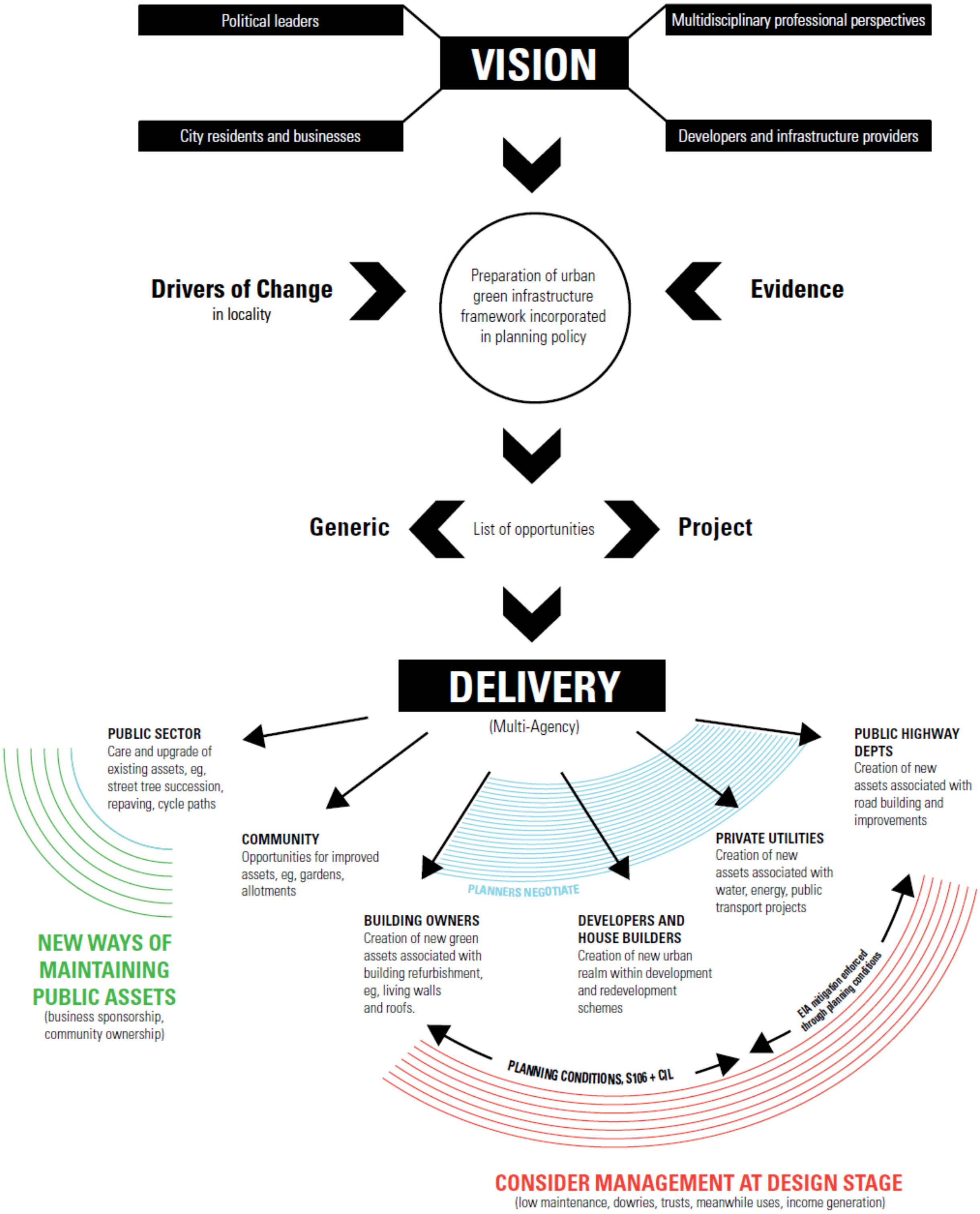

Figure 2 GI Delivery Framework © Arup

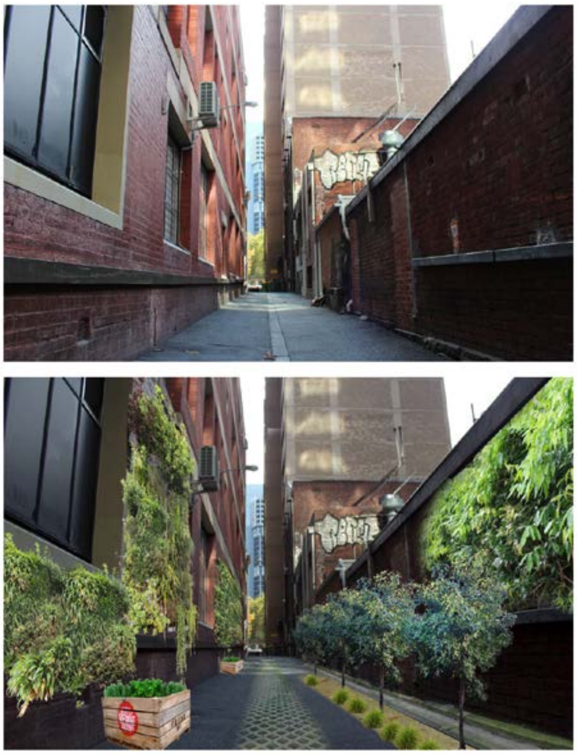

Figure 3 Retrofit of Melbourne's Laneways © Arup

Figure 4 Playground at Stebonheath School after scheme implementation (© Arup)

Figure 5. Right of way bioswales in NYC
(source: NYCDEP)

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Infrastructure solutions for fast growing cities – dimensions of adaptability requirements and urban resilience

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Abstract

The development of the world's population is characterized by two trends: absolute population growth and rapid urbanization. The consequences are various, tremendous – and will confront spatial planning as well as in infrastructure planning with one major challenge: the enormous resource- and energy needs of the new developing urban agglomerations. Those and further such as demographic developments or climate change have considerable impacts on grid-bounded infrastructures. SEMIZENTRAL is an infrastructure approach focussing on fast growing urban regions. The approach offers an integrated solution in order to increase resource-efficiency as well as flexibility and adaptability – with the aim to cope with and overcome the arising challenges of our future urban environments.

Keywords: adaptability, urban resilience, urbanization, infrastructure

Introduction

According to the United Nations, the 21st century is the "century of cities" (UN-HABITAT 2006). In 2007, for the first time ever, more than 50% of people worldwide lived in urban areas. And this development is going on: In 2050, 6 billion people or $^2/_3$ of the world's population will live in cities. Urban growth is primarily a phenomenon of the developing and emerging countries whose economic growth occurs in the growing urban agglomerations. While the old world is "shrinking", cities in Asia and Africa follow a speed of growth which is unique in the history of mankind. Figure 1 gives an impression of the celerity urban regions grow worldwide. It shows the number of people the cities grow – by hour.

Figure 1: The speed of urban growth (adapted from Burdett / Rhode 2007, modified with data from UN 2011 and 2014)

E.g. for the city of Shanghai this has tremendous impacts in all spheres of life. Focusing on the impacts on grid-bound infrastructures, the figures are impressive: The city grows by (more than) 585,000 people per year, which means there is an additional demand for at least77,000 m water needed every day. That implicates to have and serve the needed sources, the water purification, the transportation, the grids and facilities for water supply and for wastewater treatment. And right there on the spot in the city where it is needed. This dynamic is unique and the same are its effects and impacts.

What makes centralized infrastructures a "dinosaur"?

Conventional centralized infrastructure systems for water supply and wastewater treatment comprise a whole city area or at least main parts of it. They are strictly separated from each other (to assure hygienic impeccability), can look back on and profit from more than 100 years of system's experience and utilize economies of scale. At the same time they are highly path dependent: The system inherent grid-systems fix 70 to 80 % of the system's overall capex, cause the body of the system's overhead costs and determine the system spatially and in its capacity for their whole life span. And the sewers and pipes have the longest lifespan in the infrastructure system by far (and due to the high share of capex also the longest amortization period): more or less 50 years. A challenging combination considering the mentioned urbanization and urban growth rates of several hundred thousand people per city per year on the one and the rising demands for water and energy on the other hand: Who knows what growth rates will be realized the next 50 years? And where exactly in the city will all those people live? Metaphorically spoken centralized infrastructure systems of the Asian scale (several hundred thousand up to several million connected units) are a kind of dinosaur: huge, powerful, potent and mastering. The question to answer is, if the rapidly changing conditions in fast growing urban regions will be the right “habitat” of those dinosaurs in the future.

In context of this paper the understanding of “centralized infrastructure systems” is based on the definitions of Rudolph (2004) and Wilderer (2004): Conventional sectored systems without general interlinks between water (supply) and wastewater (disposal) serving a whole city or mayor parts of megacities. Main characteristics besides the sector separation are the focus on ‘disposal’ instead of resources and end-of-pipe concepts, realizing grid-systems within the city in order to transport the wastewater in outer regions for treatment – and vice versa in context of the water supply.

This leads to different system-inherent advantages and disadvantages: One main advantage of centralized infrastructures is the (full) use of economies of scale. The specific costs in capex as well as in opex are relatively lower. Professional monitoring and operation are assured and the hygienic requirements are safely fulfilled. In comparison there are also disadvantages like the high overall investment costs, the dilution of the wastewater flows and therefore the tremendous increase of wastewater volumes by mixing and transporting it with tapwater. The implementation of huge grid systems, in water supply as well as in wastewater disposal causes a “puzzle” of hundreds and thousands of single elements[2], differing in size, investment volume, lifespan, material, need for maintenance, etc.. The challenge is that they all need to go together properly in order to run the system right (cp. Larsen et al. 2005). Additionally, the system has a big spatial extent: Thousands of kilometers of pipes and sewers have to be planned, built, paid, and operated. The distances between the points of origin and treatment hamper the options of reuse – for economic and ecologic reasons. Furthermore, line losses can be (or usually are) another economic factor.

Besides the investment and the scale of centralized infrastructures, there is another challenge this “dinosaur” has to cope with: the limited planning security. A centralized wastewater treatment system for e.g. several million Capita needs a lot of information in the planning phase like connected capita, densities, water demand, etc. And as the grid needs to be the first running part of the overall system, also the spatial allocation of the connected units and their demand resp. their consumption has to be estimated before. But those data may change over the lifespan of the treatment plant and definitely will over the lifespan of the grid. With the celerity of change, forecasting gets more and more challenging which means they face inaccuracy and wrongness because of uncertainty of development within long periods. Figure 2 illustrates the development of Shanghai’s central business district Pudong, comparing the situation in 1990 on the left with that one in 2010 on the right.

[2] The sewer system of Berlin has a length of about 9,600 km – the distance between Berlin and Beijing. About 45% are used for the transport of wastewater, 35% for rainwater, the rest are combined sewers. Their diameters differ between 20 cm and more than 4 meters, the material range comprises stone, concrete, synthetic materials, and combinations of all.

Figure 2: Urban growth in Shanghai – the example of Pudong: 1990 vs. 2010 (Chris 2010)

The probability that long-term prognosis go wrong is high and with the rise of the capex volume of a project, the risk of failure increases in parallel. In centralized infrastructures we have high investments and high path-dependencies due to the rigidity of the grid.

Methods

This paper focuses on the discussion of potentials of the SEMIZENTRAL approach according to urban resilience. Are there differences, eventually advantages of the approach compared to conventional infrastructure systems?

In the following the general approach of SEMIZENTRAL Germany is described and discussed in the context of urban development and its impacts on technical infrastructures in water and sanitation. Technical specifications of the first implementation of the system (in Qingdao, China) can be found in Tolksdorf et al. 2015 in this book.

Furthermore, the terms of resilience, flexibility and adaptability as wells as the “urban resilience principles” are introduced. An analysis of the potentials of SEMIZENTRAL in this context finalizes the paper.

Results and discussion

SEMIZENTRAL Germany is an infrastructure approach for fast growing urban regions. It focusses on the need for an increased resource-efficiency. Two main aspects characterize the approach in comparison to conventional systems: The scale and the integration of the normally separated sectors water supply, wastewater treatment and waste treatment.

The scale of an integrated semicentralized supply and treatment systems is guided by the principle “as small as possible as big as necessary” (Böhm et al. 2006), coping with the ambivalence of sustainability with regards to economic as well as social and ecologic interests. In contrast to conventional wastewater treatment plants, the treatment of waste and wastewater in semicentralized supply and treatment systems is carried out in so-called semicentralized Resource Recovery Centers (RRC) which are located close to the consumers in order to minimize transporting distances. This physical closeness requires the necessity of being “as small as possible”: The contiguity of housing on the one hand and treatment units on the other demand a small footprint of the RRC due to land costs and development pressure. But the main focus in scale is the idea to provide infrastructure “on demand”. Centralized systems (in growing urban regions) are designed for growth. Therefore they have to be too big, when they get in operation. Depending on the scale and estimated growth rates, (more or less) large parts of the grid system are run off-peak – with all technical and financial disadvantages. SEMIZENTRAL is different. The approach focusses on scales between 20,000 and 100,000 connected Capita. This offers the characteristic advantage to build the infrastructure district-wise when needed (cp. Figure 3). Just in time. With nearly fully load from the beginning. That offers the fundamental benefit of a lower overall investment with a faster payback – and therefore much higher planning and financial safety.

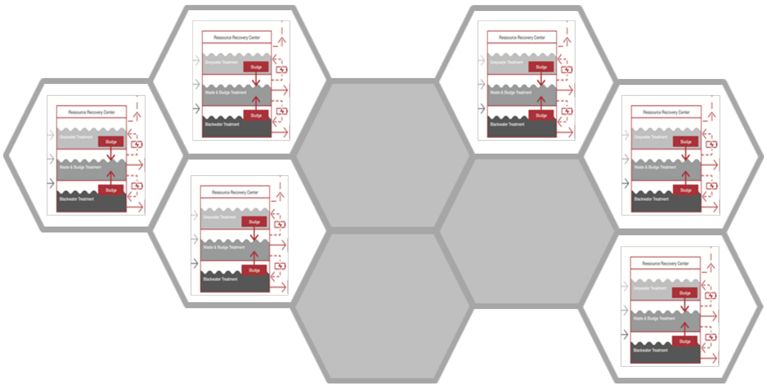

Figure 3: District-wise infrastructure development according to the actual demand

All treatment steps and units are established in one building only. This way, floor space requirements for treatment (and thus investment costs for land purchase) are reduced and disturbing emissions are prevented. Secondly, emissions need to be reduced to a minimum, odour as well as noise and air pollution. These requirements can be met best with in-house solutions. Besides the realized SEMIZENTRAL Resource Recovery Center in Qingdao (cp. Tolksdorf et al 2015, in this book) there are several further examples for those ‘encapsulated’ solutions for wastewater treatment, as for example the Yannawa Wastewater Plant in Bangkok, the Changi water reclamation plant (China) and the NEWater factory in Singapore (cp. Bieker et al 2011).

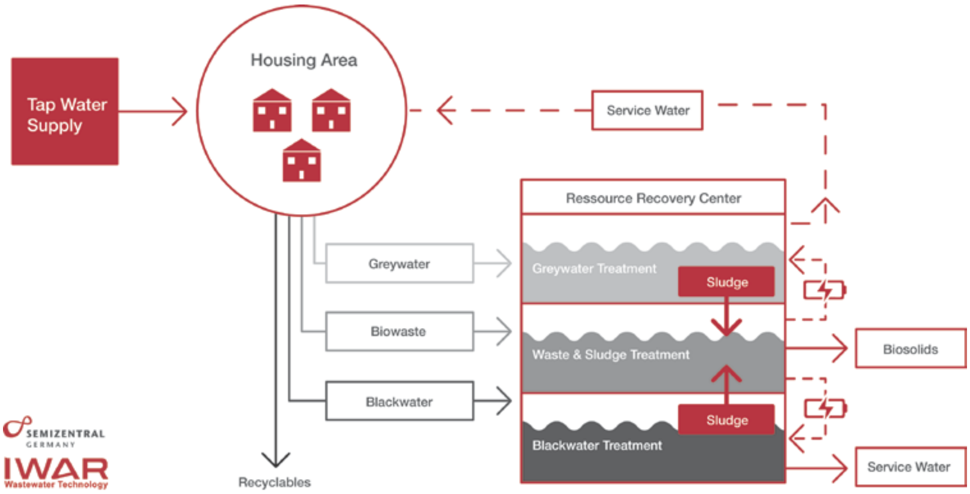

Figure 4: SEMIZIENTRAL Germany – the general material flows

One of the key components of SEMIZENTRAL is the reuse after treatment and disinfection. This way, the daily demand for fresh water is reduced as well as the amount treated wastewater to be discharged into water bodies. In addition significant savings in energy are another advantage. In each household, wastewater flows from showers, hand washbasins and washing machines are collected separately as greywater. They are conveyed separately from the blackwater of kitchens and toilets (cp. Figure 4). Grey- and blackwater are drained to the Resource Recover Center and treated for being new resources: The greywater is treated to serve as toilet-flushing water within the households while the blackwater is treated separately in order to serve for different purposes, like street cleaning, firefighting or irrigation purposes. Basically, the SEMIZENTRAL approach is process-neutral: The treatment technologies are not determined by the approach, but specified by the reuse purpose of the different water and material flows.

The Resource Recovery Center is divided into three technical units (cp. Figure 4), called “modules”. Modules 1 comprises the greywater treatment and module 2 the blackwater treatment. The third, module 3, is the treatment unit for the arising sewage sludge from module 1 and 2. Together with biowaste from the adjoining settlement areas the sludge is digested. The anaerobic process produces biogas, which can be used for the production of electricity and heat. The conceptual interlink of water and wastewater is given by the reuse of aspect, increasing of the overall system’s efficiency: Water savings of 30 to 40% of the household’s demands are achieved by substituting tapwater for toilet flushing with service water (and depending on the reuse-quota of blackwater recycling rates up to 100% are possible), and the biogas produced by the integrated treatment of sludge and biowaste results (on a balance sheet) in an energy self-sufficient operation of the Resource Recovery Center.

For an overview of tecnical details in treatment design and operation (including optimization strategies for the further increase of energy-efficiency) cp. Tolksdorf et al. 2015 in this book.

The aspects of flexibility, adaptability and resilience – what does SEMIZENTRAL better than conventional systems?

Williams (2007) defines urban resilience as the "capability to prepare for, respond to, and recover from significant multi-hazard threats with minimum damage to public safety and health, the economy, and security" of a given urban area. Urban areas worldwide face new challenges in the context of urban growth, resource scarcity and climate change, e.g. changing precipitation regimes, hot / dry spells, and reduced local water resources. All these impacts influence the local design and configuration of water and sanitation infrastructure systems.

In order to evaluate conventional systems and alternatives like the SEMIZENTRAL approach, a set of criteria is needed. Therefore the own definitions of flexibility (design phase) and adaptability (operational phase) with the "resilient design principles" of Applegath et al. (2012) are combined. Williams' (2007) "capability for [action]" can therefore be divided into two states: ***Flexibility***, taking place in the design phase, gives a system the ability to "prepare [a system] for" in order to "respond to" changes. ***Adaptability*** of an existing system under operation on the other hand assures that the system is able to "recover from" impacts of changes, which haven't been prevented.

In addition, Applegath et al. (2012) frame 6 planning and design principles in order to create greater urban resilience.[3]

1) **Diversity**

   The diversity of systems reduces the potential negative impact to the whole city of the failure of any one particular system.

2) **Redundancy**

   Redundancy increases resilience, taking in consideration that redundancy reduces efficiency.

3) **Modularity and Independence of System Components**

   Resilience capacity is increased when system components have enough independence that damage or failure of one component is designed to have a low probability of inducing failure of other components in the system.

4) **Feedback Sensitivity**

   The feedback sensitivity describes a system's ability to detect and respond to changes in its constituent parts. The more quickly a system can detect and respond

3 In order to reduce complexity in context of this paper only infrastructure-relevant aspects within the different principles are depicted.

to changes throughout the system, the greater is its potential for effectively coping with these changes.

5) Capacity for Adaptation

Systems and infrastructure that are designed to quickly adapt to changing conditions and requirements increase the overall resilience capacity.

6) Environmental Responsiveness and Integration

The resilience capacity of a city is increased by how responsive and integrated its systems and functions are with its natural systems, services and resources. Environmental responsiveness and integration do not only reduce the cost of creating and maintaining technical infrastructure, but reduce the relative probability of infrastructure suffering significant negative impacts from the increasing environmental impacts associated with climate change.

Table 1 illustrates the evaluation of the different systems according to the above resilience principles. In table 1, the evaluation is separated for the impacts on the "single system", e.g. one treatment unit including the grid-system, and those for the "overall system", the whole city system.

Table 1: Comparison of performance between SEMIZENTRAL and conventional centralized systems in context of Urban Resilience Principles

		SEMIZENTRAL single system	**Conventional, Centralized Infrastructure** single system	**SEMIZENTRAL** overall system (whole city)	**Conventional, Centralized Infrastructure** overall system (whole city)
1	**Diversity**	**intended** each specific for local needs	**possible** in technical details	**definitively**	**possible** in technical details
2	**Redundancy**	**possible** but expensive	**possible** but expensive	**realisable** by connecting systems	**possible** but expensive
3	**Modularity and Independence of System Components**	**inherent in the system**	**not intended** systems works only ass a whole	**definitively**	**not intended** systems works only ass a whole
4	**Feedback Sensitivity**	**possible**	possible	**possible**	possible
5	**Capacity for Adaptation**	**conditionally**	conditionally	**definitively** by building on demand	conditionally
6	**Environmental Responsiveness and Integration**	**definitively** highly increased resoure-effiency	generally possible	**definitively** highly increased resoure-effiency	generally possible

Applying the principles on the SEMIZENTRAL approach, the following differences according to the approach's potentials of resilience (compared to conventional centralized systems) can be outlined: One basic issue of SEMIZENTRAL is the consideration of the local/ regional situation, to build up a specific design for each case in order to fit the local needs best possible. Therefore the **diversity** of the local ("single") systems is virtually endless. The reality will restrict this infinite choice by financial aspects, which are defined by the choice of technologies on the one, but most of all by the aspect of design-costs on the other hand. Each individual tailor-made solution has its price. The point of intersection between the design-costs and the saving potentials in terms of case-optimization will be the limiting point for the system's diversity. Nevertheless, the diversity in semicentralized systems in comparison to conventional sectored centralized systems can be assumed to be significantly higher – at least within the overall system. While the conventional approach is supposed to comprise just one spatially congruent single system, the overall system SEMIZENTRAL is made up of several single units (cp. Figure 3), all (at least slightly) different.

The differences between centralized and semicentralized systems in terms of **redundancy** are not as prominent as in terms of diversity. Redundancy is primarily factor of additional 'double' equipment and therefore a matter of cost. That is independent from the system's scale or integration ratio, therefore the conventional and the semicentralized approach perform equally. But regarding the overall system, the SEMIZENTRAL approach offers further potentials. By connecting different SEMIZENTRAL single units, redundancy can be achieved to a certain extent by using existing buffering capacities of each single unit.

Modularity is one of the basic principles of the SEMIZENTRAL approach. In this point the advantage of SEMIZENTRAL compared to centralized systems is very obvious. Both the single system and the overall system are designed in units, which can be operated (more or less) independent from each other. On the overall system's level the only interlinkages may exist in terms of redundancy.[4]

In **feedback sensitivity** there are no differences between the two approaches: In both scales relevant detectors need to be implemented in order to enhance the systems feedback sensitivity.

The situation is similar in terms of **adaptation capacity** - on the single level. Also here mechanisms need to be considered during the design phase in order to be able "to respond" during operation. What makes the advantage for SEMIZENTRAL is the fact, that the overall system is not designed and built at one point in time, but designed and build one by one. Therefore, changes occurring over time can be considered in the design of later SEMIZENTRAL single units. Changes might arise from shifting water demands, an unexpected shift in the (local) urban development (cp. Bieker et al. 2011), demographic changes or so called "black swans" (Taleb

[4] In centralized systems modularity also exists - within the treatment units. Facilities of the compared size are designed and operated in parallel treatment units, which offer a specific buffer capacity. In comparison to SEMIZENTRAL, those buffer capacities only exist within the treatment facilities and therefore only 'at the end' of the system.

2010), events with dramatic impacts which are not foreseeable today. All those can have an impact on infrastructure systems while already built. SEMIZENTRAL can contribute with its district-wise approach to make infrastructures more transit-supportive.

In terms of **environmental responsiveness and integration** the system inherent resource-efficiency of SEMIZENTRAL is one final point for the approach towards improved urban resilience. The reduced water abstraction, caused by more efficient use of water and reuse is one first step towards more natural oriented infrastructure solutions. It might help to enable cities to cope with the available local water sources by less abstraction and assured high quality treatment.[5]

Conclusions

SEMIZENTRAL Germany was developed to offer a suitable infrastructure concept and solution for fast growing urban regions. At a first glance this seems to be a topic for civil and process engineers only. But it is not. Urban development is a worldwide trend with implications for more than 50% of the world's population and severe impacts on the quality of life for people all over the world. Water and sanitation infrastructure development is only one part in this development process – but it has implications on spatial planning and design issues, too.

According to urban resilience it is not a question if change happens. Just its modality and the strength of impacts are uncertain. In fact it is the question, if we want to only react or if we want to actively design the future by designing urban environments which can cope with change and can be adapted to different demands and requirements. Not once or twice but ongoing, as needed in the lifespan of the systems.

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Rotterdam Innovative Nutrients, Energy and Watermanagement Local treatment of wastewater and reuse of nutrients, energy and water

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Abstract

Sewer mining approaches are potentially interesting for rapidly urbanizing areas worldwide. Municipal wastewater is not only a nutrient rich source, which is available in constant quality, it is also excessively available worldwide. The Rotterdam Innovative Nutrients, Energy and Water management (RINEW) project was started to investigate the possibilities to recover and reuse water, nutrients and energy locally in a demo installation in the Rotterdam area. Within the RINEW project ceramic nanofiltration (CNF) is applied after pretreatment by sieves to produce reusable water directly from sewage. In the following treatment steps phosphorus and energy are recovered by a pellet reactor, and anaerobic digestion. Within the demo installation already 50% from total suspended solids (TSS) and 30% of organic matter (COD) was recovered in the pretreatment step. From the recovered cellulose paper is produced. With subsequent CNF treatment TSS and COD are further concentrated.

Keywords: Reuse; wastewater treatment Nutrients, Energy Water (NEW), Ceramic Nanofiltration,; Urban improvement

Introduction

Daily people produce a lot of waste water by use the toilet, take a shower or do our laundry. In the Netherlands this accounts for 120 liters a person a day on average. The produced waste water contains a lot of valuable raw materials like nutrients, energy and water. But how can we make use of the value of waste water within an urban area?

Evides Waterbedrijf is the water company that supply drinking water to 2.5 million clients. The goal of Evides is to supply safe and tasty drinking water to the clients meeting the strict quality standards, and to close the water chain by purifying wastewater in an innovative and sustainable way. The city of Rotterdam formulated ambitions on sustainability for the redevelopment of former harbour areas (Merwe-Vierhaven) to create a circular economy by developing a sustainable residential area with clean tech businesses in the near future. Transforming an area from harbor to city gives the opportunity to make new choices about how to design and develop a city. Within the described ambitions local treatment and reuse of wastewater should be implemented. This was the breeding ground for the Rotterdam Innovative Nutrients and Energy Water-management project (RINEW). A demo installation is in operation for more than half a year (since September 2014) on raw sewage in Harnaschpolder WWTP near Den Haag (The Hague). In 2015 the demo installation will be moved to the city of Rotterdam, to an agricultural company to further validate the concept and locally apply the obtained products. In this way the RINEW concept contributes to a circular economy and resilient urban areas.

The RINEW project is a cooperation between the city of Rotterdam, the water-boards Hollandse Delta and Hoogheemraadschap van Delfland, Evides Waterbedrijf and Delft University of Technology

Transforming harbor to city

In cooperation with private companies, the City of Rotterdam and the Rotterdam Port Authority create special, innovative living and working areas in the city port area in the coming 20 to 40 years, thus reinforcing the economic structure of the city and the port.

The development of the old harbor area called Stadshavens Rotterdam is embarked upon from the socio-economic urgency to make the city and port resilient and to increase its economic competing power. The current port area of 1600 ha at the boundaries of the city of Rotterdam will be transformed to a place of clean tech businesses and residential areas in the next decades. By realizing a first-class quality region as the hub of sustainable innovations, with a direct link to education and the regional labor market, an attractive business climate for international companies is created. Stadshavens Rotterdam is “Creating on the edge”.

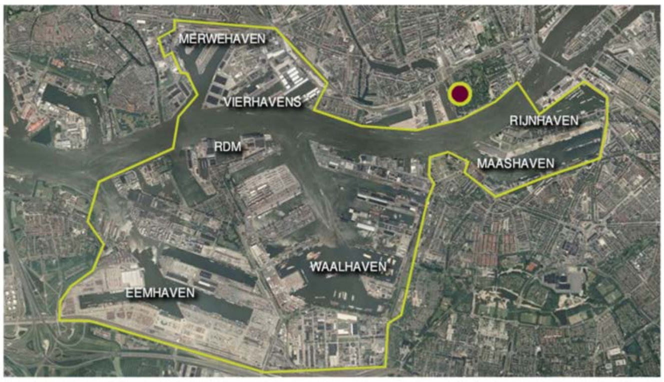

Figure 1. The 1.600 hectare of port to be transformed to city

Ambitions of Stadshavens

The transformation from port to city gives opportunities to make new choices about how to design and develop a city. The city of Rotterdam formulated ambitions about the design and transition of the area. These ambitions, which were the breeding ground for the RINEW concept, are:

- circular economy: reuse the remaining elements from other processes;
- local treatment of wastewater: “treat waste water locally, so it doesn’t have to be transported over the long distances to a wastewater treatment plant (WWTP) which will eventually run out of capacity”.

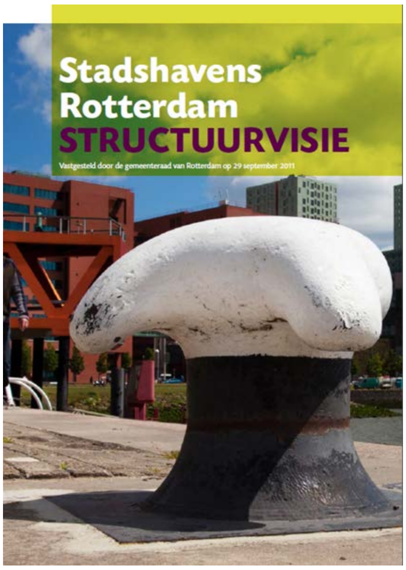

Figure 2. Vision & Strategy document Stadshavens Rotterdam

RINEW is a new concept for waste water treatment on a local scale. The goal of RINEW is to develop an innovative and sustainable concept in which Nutrients, Energy and Water will be recovered. The recovered materials will be used locally within the city of Rotterdam.

RINEW, the research

The research focusses on the innovative combination of new and conventional techniques to make locally waste water treatment possible and sustainable, and recover the various raw materials, energy and water. The treatment concept consists of a screen to remove particles >6mm. Followed by a fine-sieve and band-sieve to collect cellulose. After the cellulose recovery the water is pumped into the ceramic Nano filtration membrane (CNF). With CNF high retention of neutral molecules >400 Da and high selective retention of specific charged molecules (such as sulfate and phosphate) can be achieved. It retains well micro-organisms, herbicides, pesticides, pharmaceuticals, chlorinated compounds and humic and fulvic acids; it also separates well oil and fatty components from water.

This research is not a first attempt to use nanofiltration for direct waste water influent filtration. However, previous study reported that stable operation was not achieved and the nanofiltration polymeric membrane got fouled irreversibly instantaneously. By applying ceramic material more effective cleaning procedures are possible. A proof of principle has been shown by the Delft University of technology.

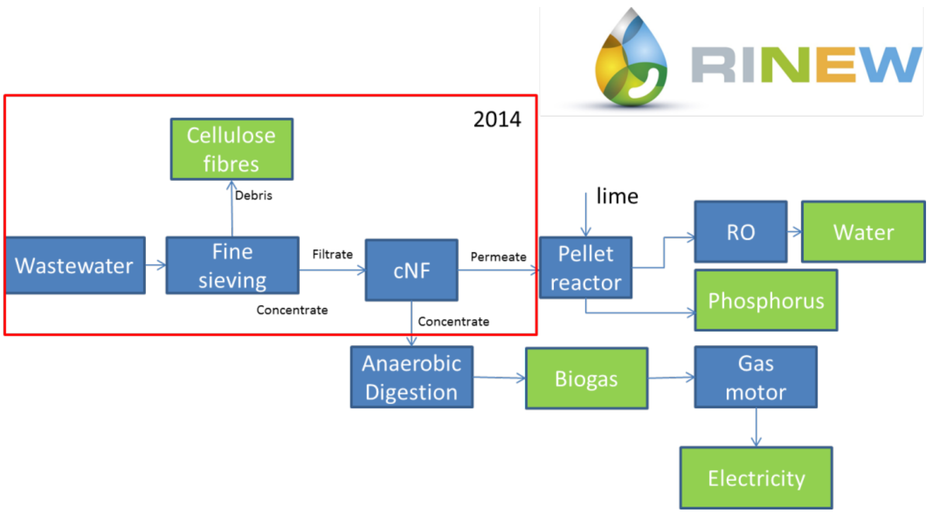

Figure 3. Scheme of research installation

The RINEW concept was tested first at the Harnaschpolder WWTP. All the research facilities are available there, as well as the different stages of wastewater such as influent, sludge and effluent.

RINEW, the results, so far

The results of the research so far are:

- pretreatment (sieves);
- CNF is suitable for direct waste water treatment;
- CNF produces water up to 300 L/h (current demo installation);
- stable operation can be obtained with frequent chemical cleaning;
- cellulose is retained from the waste water, with a good quality.

Figure 4. Result for different sieving techniques to retain cellulose from waste water

RINEW, next step

Currently the CNF operates stable and the next step can be made. The following step is to extend the treatment with a pellet reactor to recover phosphate. In a next step the CNF permeate van be treated by reverse osmosis. The remaining concentrate will contain ammonium which might be recovered. The concentrate from the CNF and debris obtained from sieves after cellulose removal will be treated in an anaerobic digester where biogas will be produced.

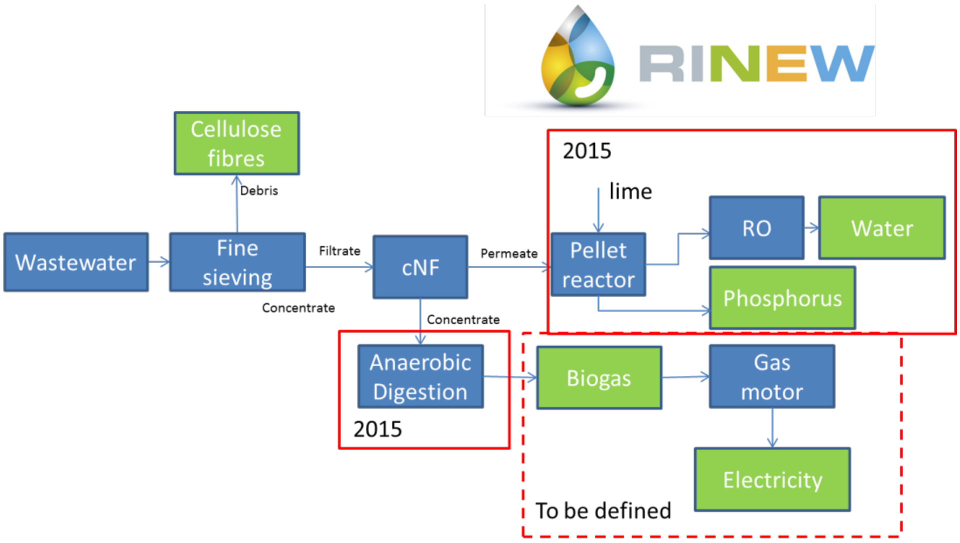

Figure 5. Scheme of next steps

When the whole installation operates stable, the research will be continued at a domestic agriculture initiative within the city of Rotterdam. The recovered water will be delivered for their hydroponic system and their fish farm.

By closing the water cycle within a isolated area we will show that local wastewater treatment and circular economy are realistic scenarios within domestic areas. This concept is expected to be more important in the future, especially in cities like Rotterdam.

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Impact assessment of point and non-point sources of water pollution on a small urban stream

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Abstract

The paper presents a study of the impact assessment of point and non-point pollution sources on a small urban stream, the Botic creek, which flows through rural as well as urban area. The monitoring was focused on basic physical and chemical quality of water, heavy metals concentrations in water as well as bed sediment and on hydroecological assessment. Both, non-point as well as point sources impact were identified. The most significant pollutants are nutrients originating from non-point sources (farming), which increase concentrations of N and P compounds in the section of the creek in rural area. As the main point source of heavy metals in bed sediment of the stream, road traffic was identified, though some characteristics of aquatic environment (reduction conditions given by eutrophication) can support remobilization from sediments and increase of metals concentrations in water in sampling sites unaffected by road traffic. Also morphological changes of the stream channel were identified resulting from urban drainage as a set of point sources, which makes an achieving of at least good ecological status impossible.

Keywords: point and non-point sources, chemical status, impact assessment, small urban stream.

Introduction

Water is a substantial part of the environment and it is essential for all living beings in the Earth. However, economic development of human society is associated with deterioration of water resources in both quantitative as well as qualitative perspective. In spite of the fact that the Czech Republic gives high attention to water protection, significant point and non-point sources of water pollution still exist.

One of the most significant point sources is urban drainage. The quality of the aquatic environment is often strongly modified in chemical, morphological as well as biological parameters as a result of waste water and storm water drains. Not only industrial waste water, but also storm water from urban areas can be a source of dangerous pollutants (e.g. heavy metals and other specific pollutants from building and roofing materials) (Anderson et al, 2004). Storm runoff from polluted paved surfaces in urban areas is, besides agricultural activities, also a part of non-point source (or diffuse) pollution which brings a variety of contaminants to receiving water bodies. Other source of water pollution listed among point as well as non-point sources is the automobile traffic, which is considered to be one of the greatest pollutant sources globally (Perdikaki and Mason, 1999). While regulatory and technical innovations (e.g. unleaded gasoline, fuel-efficient engines) have cut back on the emissions of certain contaminants in recent decades, the improvements have often been offset by increasing automobile traffic. In addition to chemical changes, the point sources mainly can cause morphological changes in receiving waters, especially in the case of small urban streams, where during rain events storm water drains, combined sewer overflows and surface runoff can significantly increase the natural discharges. Changes in the chemical quality and morphology of streams affect aquatic biota and consequently terrestrial organisms including human.

For impact assessment a specific type of the aquatic environment, a small urban stream, has been chosen. This type of waterbodies is quite common in rural as well as urban areas in the Czech Republic and naturally provides suitable living conditions for wide range of aquatic, but also terrestrial, species. However, this is also environment easily vulnerable, very sensitive to anthropogenic impacts causing qualitative as well as quantitative changes leading to deterioration of chemical and ecological status.

Methods

Description of study area

As a study stream for impact assessment of point and non-point sources a small urban stream, the Botic creek, was chosen. This stream is the biggest tributary of the Vltava River in Prague area (geographical situation, potential sources of pollution and sampling sites in Figure 1 and Table 1). Its total length is 34.5 km and catchment area 134.9 km^2. Flow rate Q90d and Q355d respectively monitored in the estuary is 0.520 m^3.s^{-1} and 0.077 m^3.s^{-1} respectively. First half of the stream (approximately 15 km) runs through rural area. Agricultural activities predominate in this part of catchment and several originally small villages are situated there. Recently, during last decade, huge building development occurs in this area. Number of inhabitants in some of these villages increased several times (from several hundreds up to 10 thousands inhabitants). Moreover, an impact of road transport is possible to assess in this part of catchment, since the main motorways of Central Europe run through this area and are drained through retention tanks to the Botic creek or to its tributaries.

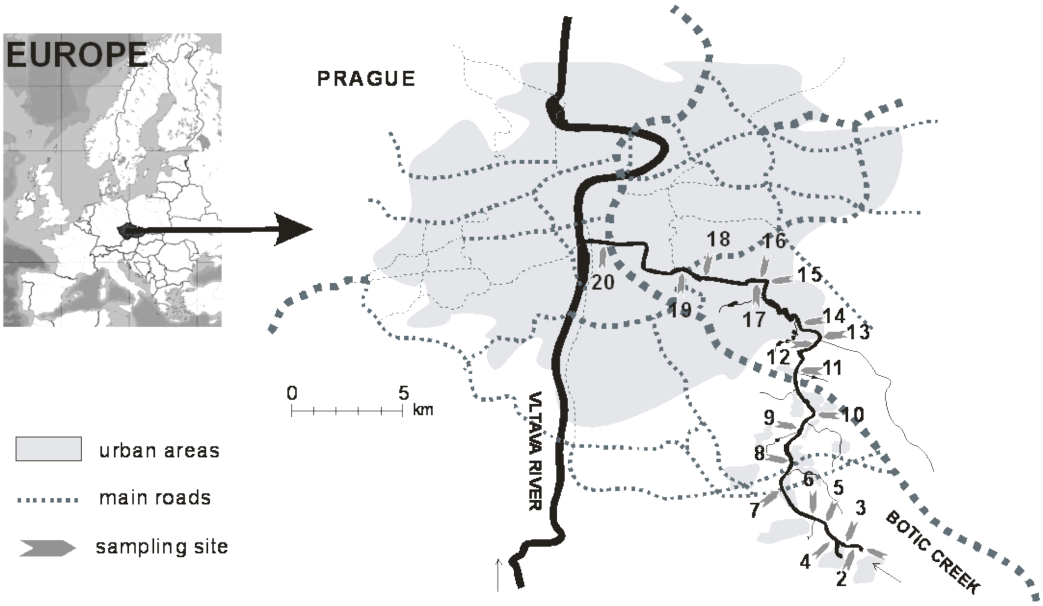

Figure 1 Geographical situation of study area

On this stream several small ponds and reservoirs are situated. The biggest and most important is the Hostivar reservoir, which is situated just in the entrance of the creek into Prague area. The Hostivar reservoir impacts the second part of the stream qualitatively as well as quantitatively. In Prague area, there is combination of several effects on the stream. Urban drainage with 26 combined sewer overflows (CSOs) and even higher amount of storm water drains (SWDs) brings to the stream pollution originating in heavy traffic and industrial as well as residential areas of the city. 20 sampling sites directly impacted by some potential pollution sources were selected for this monitoring. Their brief characterization is given in Table 1.

Table 1 Description of sampling sites

SAMPLING SITE	LOCALITY DESCRIPTION	DISTANCE FROM SPRING IN KM
1	spring	0.00
2	below 1st pond	0.50
3	above village Cenetice, surrounded by farm fields	1.30
4	below 1st tributary and village Cenetice	2.00
5	above 2nd tributary	3.70
6	below 2nd tributary	3.75
7	close to Prague highway ring, cottage area in surrounding	5.15
8	below 3rd tributary	5.95
9	below 4th tributary	6.40
10	above the Pruhonice garden	7.40
11	below retention pond for highway runoff	13.80
12	above 5th tributary	17.20
13	below 5th tributary	17.50
14	below retention pond of SWD - runoff from housing estate area	17.70
15	below CSO 1, app. 1 km below the Hostivar reservoir	23.20
16	below SWDs above CSO 2	23.90
17	below CSO 2	24.00
18	car repair shop	26.30
19	below SWDs from heavy traffic area, below the Hamersky pond	28.00
20	above pipeline	34.20

Monitoring of water quality

For assessment of chemical quality, water as well as sediment samples have been taken. Directly in situ values of pH, conductivity, dissolved oxygen (DO) and temperature were monitored using of multimeter HACH LANGE. Water samples for analyses of other basic chemical indicators: COD, Cl^-, NH_4^+-N, NO_3^--N, NO_2^--N, PO_4^{3-}-P, were sampled into PE bottles and the same day analyzed in laboratory using HACH LANGE cuvette tests (methods fulfill European standard and are comparable with classical laboratory analyses). Other PE 100 mL bottles were used for sampling of water samples intended for analysis of heavy metals (HM) Cd, Cr, Cu, Ni, Pb and Zn. These samples were stabilized in laboratory by addition of 0.1 mL of HNO_3, kept refrigerated prior to analysis, which was performed later using atomic absorption spectrometry method with graphite furnace atomization (GFAAS). The third type of water samples have been taken for Hg analysis, using of PE 100 mL bottles prepared before sampling by addition of 1 mL HNO_3 and 0.1 mL of $K_2Cr_2O_7$ solution as stabilization agents. Also these samples were refrigerated before analysis, which was later performed using of the Advanced Mercury analyzer (AMA). For sampling of bed sediment material, a plastic spoon and PE boxes of volume 500 mL were used. Sediment samples were frozen up to -20°C and frieze dried under vacuum conditions. After that a sieving procedure was conducted in two steps: 1. to obtain material for metals analysis, the sieve of 0.6 mm mesh was used; 2. to analyze grain size distribution, sieves 0.2 and 0.063 mm mesh were applied. Besides grain size analysis (distribution of fractions <0.063 mm - fine, 0.063-0.200 mm - middle and 0.200-0.600 mm - course), also organic matter (OM) content as a loss on ignition (LOI) was analyzed for better understanding of metals behavior in sediment. Prior to analysis of metals Cu, Cd, Cr, Ni, Pb and Zn, sieved sediment samples (fraction <0.600 mm) were subjected to extraction procedure according to EPA 3051 (mixture of HNO_3 and H_2O_2) using of microwave digestion technique with controlled pressure. After filtration and dilution of digest into defined volume, Cu, Cr, Ni, Pb and Zn were analyzed by AAS with flame atomization (FAAS), for Cd analysis GFAAS technique was used. Analysis of Hg was performed directly from solid sediment samples (fraction < 0.600 mm) by AMA. From microbiological indicators, coliforms, Escherichia coli and enterococci were analyzed using of method Colilert (fulfils standard ISO 7899-2 and ISO 9308-1:2014). For this type of analysis water samples were sampled into special sterile 100 mL bottles.

Obtained values of chemical and microbiological indicators in water were compared with Environmental Quality Standards (EQS) given by Czech Governmental Order no 23/2011. For evaluation of metals concentrations in sediment, US EPA criteria, toxicological benchmarks: TEC (Threshold effect concentration) and PEC (Probable effect concentration) for Cd, Cr, Cu, Ni, Pb and Zn and LEL (Lowest effect level) and SEL (Severe effect level) for Hg were applied, because suitable criteria for sediments are missing in the Czech legislation.

Since metals concentrations in sediments are usually associated with organic matter content and the amount of fine fraction, as a lot of studies confirm (e.g. Qu and Kelderman, 2001, Soares et al, 1999, Keldrman et al, 2000), these characteristics of sediment were taken into account for interpretation of results.

Hydroecological monitoring

Hydroecological monitoring was performed according to actual Czech methodology HEM - Hydroecological monitoring (Langhammer, 2013), which fulfils requirements of the Water Framework Directive (WFD 2000/60/EC) and is recommended by the Ministry of the Environment of the Czech Republic.

Results and discussion

The Botic creek in Prague area has been monitored since 1999, in a section about 2 km long below the Hostivar reservoir where the impact of urban drainage: CSOs (named here as CSO1 and CSO2) and SWDs, was assessed mainly with respect to concentrations of heavy metals (Kominkova and Nabelkova, 2007 and Nabelkova and Kominkova, 2006). During more than 10 years of this monitoring changes of water quality and HM concentrations in sediments particularly were observed because of the reconstruction of CSO1 and the flood in 2002 (Nabelkova et al, 2005). In 2014 the monitoring was extended to the whole stream with the aim to identify point as well as non-point sources of water pollution. In the first phase 37 sampling sites were set out to catch all potential pollution sources. After first sampling, based on obtained results, the number of sampling sites was reduced to 20, since it was not possible to realize so extensive sampling during one day, under identical weather conditions. The stated sequence of 20 sampling sites was monitored during one year.

Basic parameters of water quality

Table 2 shows minimal and maximal monitored values of basic physical and chemical parameters along the whole stream and compares them with EQS (Czech Gov. Order 23/2011). Values which do not fulfil EQS are presented in bold type. Some of parameters were problematic occasionally and based on weather conditions: dissolved oxygen and COD in some sampling sites below ponds in late summer, chlorides in sites impacted by road traffic after rains in winter season and bacteria during wet weather. The most problematic parameters, exceeding EQS regularly, are nutrients analyzed as NH_4^+-N, NO_3^--N and PO_4^{3-}-P. Whereas nitrogen compounds (NO_3^--N particularly) are in elevated levels for the whole year, phosphorus is problematic only in late summer and autumn. Figure 2 shows concentrations of PO_4^{3-}-P in all studied sampling sites during one sampling date in January and one date in October. In winter, beyond some few sampling sites, concentrations of phosphates are in zero values. In late summer and autumn concentrations exceed EQS in the whole stream with an exception of two sampling sites. Phosphorus is propagated from the spring area, where a small pond inhabited by a numerous flock of ducks is situated and where phosphates concentrations are the highest from the whole stream.

Table 2 Basic physical and chemical parameters of water quality of the Botic creek: minimal and maximal measured values compared to EQS (Czech Gov. Order 23/2011).

PARAMETER	UNITS	EQS	MINIMUM	MAXIMUM
pH		*6-9*	6,4	8,7
conductivity	mS/m	*110*	1,9	83,9
DO	mg/L	*>9*	**5,9**	16,1
temperature	°C	*<29*	2,6	15,1
COD	mg/L	*26*	1,8	**50,7**
Cl^-	mg/L	*150*	4,2	**496**
NH_4^+-N	mg/L	*0,23*	0,03	**0,90**
NO_3^--N	mg/L	*5,4*	0,7	**11,1**
PO_4^{3-}-P	mg/L	*0,15*	0	**2,46**
coliforms	Cfu/mL	*4000*	580	**>25000**
E. coli	Cfu/mL	*2500*	70	**>25000**
Enterococci	Cfu/mL	*2000*	576	**>25000**

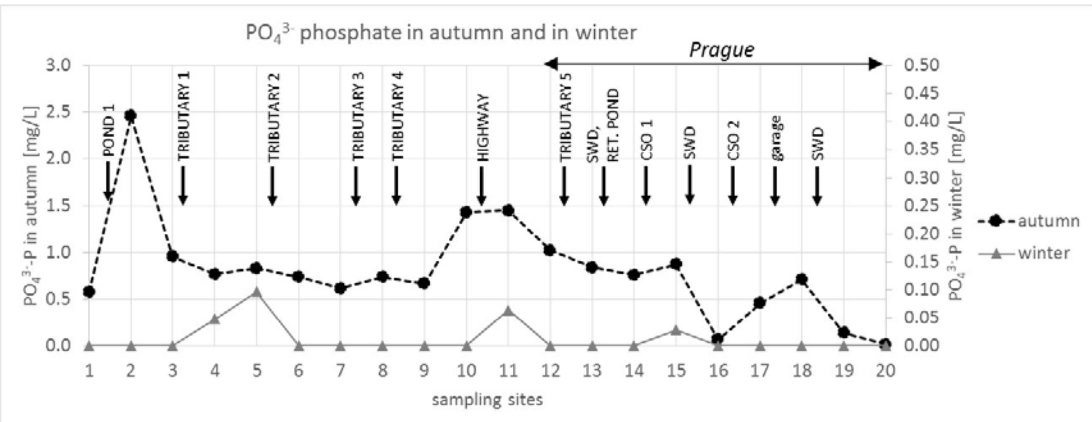

Figure 2 Concentrations of PO43--P along the Botic creek during sampling in autumn (October) and winter (January)

Figure 3 shows typical progress of concentrations of NH_4^+ and NO_3^- nitrogen along the stream. Nitrates, as a more stable from these two parameters, are in values exceeding EQS and keeping a comparable level from the spring to the estuary with no specific point source identified. Ammonium nitrogen has more fluctuating progress along the stream with some visible patterns: a. some villages in rural area surrounded by farm fields increase ammonium concentrations and non-point sources impact is evident in this case (the continuous increase of concentrations among sampling sites 2, 3, 4 and 5); b. runoff from highway is evident point source of ammonium in sampling site 11. Association of this pollutant with trucks traffic confirms e.g. Fraser (1998), Stumm (1996) and Whitehead (2007); c. urban area, even with urban drainage as a set of point sources of pollution, does not mean worsening of this particulate parameter. It can be concluded that, in the case of nutrients, rural area is stronger pollution source then urban area.

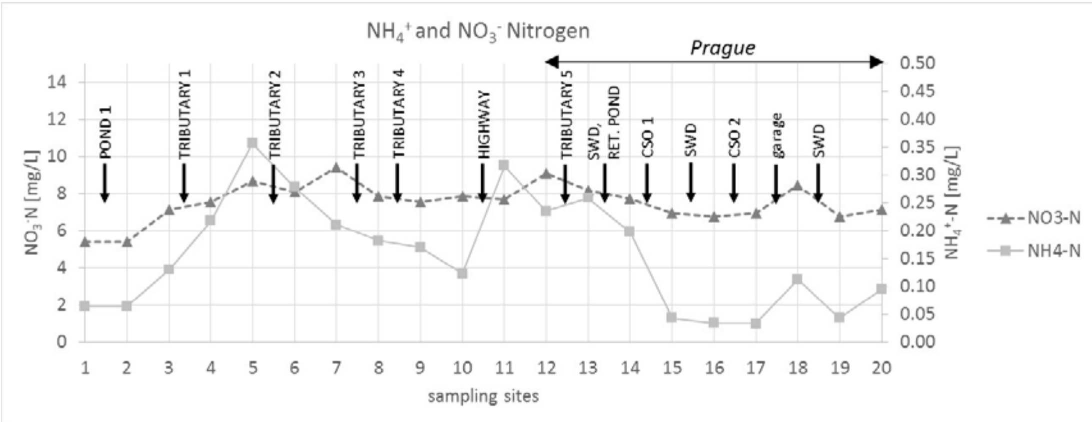

Figure 3 Concentrations of NH4+-N and NO3--N along the Botic creek during a selected sampling date (11.2.2015)

Contrary to nutrients, a gradual increase from the spring to the estuary can be readable in the case of conductivity, the parameter expressing an overall load by ionic compounds (Pitter, 2009), as it is presented in Figure 4. One of the parameters effecting conductivity the most are chlorides. Their concentrations are critical, exceeding EQS, during winter, when deicing salts are applied in roads and urban areas (see Table 2 above). Gradual increasing of chlorides along the stream is visible from the Figure 4, though it presents concentrations, which are not directly affected by deicing (sampling in this case was performed in untypically warm and dry January) and do not exceed EQS. Nevertheless, a sedimentation tank for highway runoff (above sampling site 11) can be identified as the most significant point source of chlorides even during months when deicing salts are not applied.

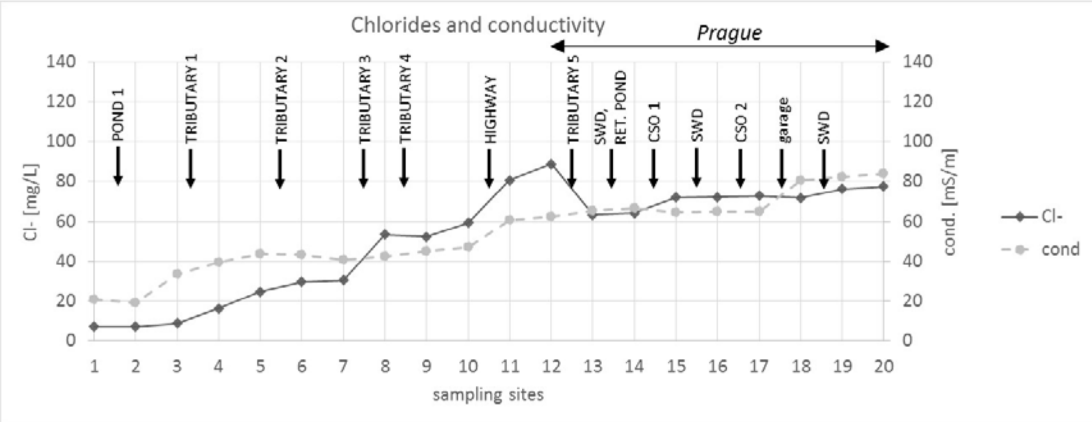

Figure 4 Concentrations of chlorides and conductivity along the Botic creek during a selected sampling date (11.2.2015)

Heavy metals monitoring

Metals concentrations in water. Monitoring of heavy metals in this study followed and broadened a long term observation conducted in a short section of the Botic creek in Prague. The newly obtained data confirmed previous results (Kominkova and Nabelkova, 2007 and Nabelkova and Kominkova, 2006) and findings of other published studies (Qu and Kelderman, 2001, Stead-Dexter and Ward, 2004) about metals behavior in aquatic environment, i.e. heavy metals prefer binding into solid phase. Concentrations in water are in low levels and do not create long term risk for the aquatic environment. EQS (Czech Gov. Order 23/2011) for particular metals are: 0.3 μg/L for Cd, 14 μg/L for Cu, 18 μg/L for Cr, 20 μg/L for Ni, 7.2 μg/L for Pb and 92 μg/L for Zn. In all sampling sites measured values were almost always below these limits, only in sampling site 2, situated in spring area below the small eutrophic pond (as mentioned above, because of duck population), concentrations of Ni reached and Pb exceeded their EQS during autumn sampling, as it is visible from Figure 5. In the sampling site 2, also other metals show higher concentrations in water compared to sampling sites down to the stream, surprisingly even higher than in sites directly impacted by urban drainage. On the contrary, concentrations of metals in sediment in sampling site 2 do not significantly increase or are even lower than values measured elsewhere along the stream, as Figure 6 presents. This phenomenon can be done by strong eutrophication of the duck pond during sampling in late summer which causes higher concentration of organic substances (COD in sampling site 2 is twice higher than in other sites) and lower concentration of dissolved oxygen (values lower than 6 mg/L in this particulate site). According to Pitter (2009), lack of dissolved oxygen can lead to reduction conditions and consequently to remobilization of metals from solid to liquid phase.

A short term increase, and potential acute risk for aquatic biota, is predictable during acute events, e.g. rain events, mainly in sampling sites impacted by highway and road runoff, CSOs and SWDs (Anderson et al, 2004). Nevertheless, no elevated values of metals concentrations in water were detected below these point sources during regular sampling.

Among heavy metals, Mercury keeps an exceptional position because of its strong ability to bioaccumulate and especially because of its extraordinary toxicity (e.g. Sanei et al, 2012, Southworth et al, 2000). The Czech EQS (Czech Gov. Order 23/2011) for Hg in water is quite strict: 0.05 μg/L. All analyzed values in the whole Botic creek exceed this limit by more than an order. Compared to some international criteria, e.g. EPA National Recommended Water Quality Criteria (EPA-822-R-02-047, 2002), the most of analyzed values do not exceed concentration defined as Criterion Continuous Concentration (CCC), to which an aquatic community can be exposed indefinitely without resulting in an unacceptable effect: 0.77 μg/L. The most problematic point source of Hg seems to be surface runoff from heavy traffic area. The highest concentration of Hg in water was analyzed in sampling site 19, which is directly impacted by SWDs from roads. Contrary to sampling site 11, impacted by highway runoff through retention pond, site 19 is situated in urban area, where stream is channelized and lack of sediment material for Hg binding results in higher concentrations in liquid phase.

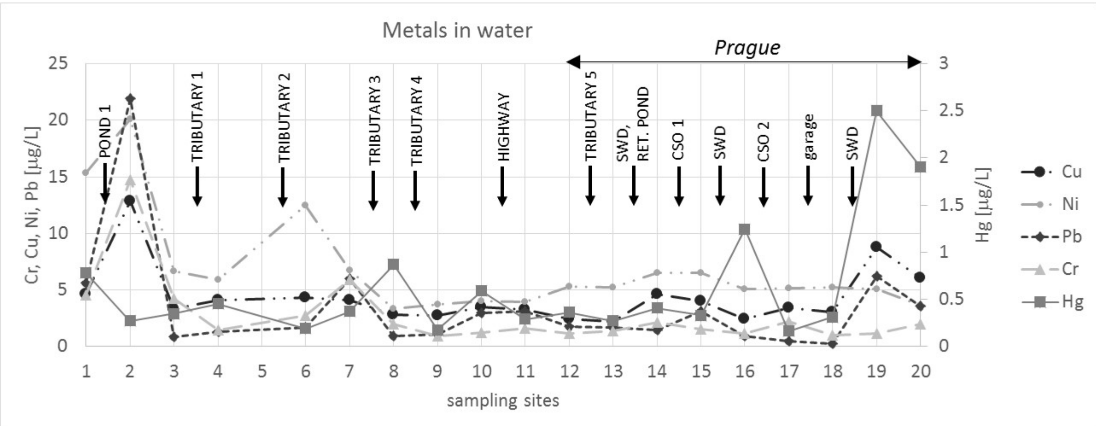

Figure 5 Concentrations of metals in water along the Botic creek during a sampling date in late summer

Metals concentrations in sediments. Sediments quality is better indicator for assessment of chronic pollution than water quality in case of specific pollutants that prefer binding into solid phase (Stead-Dexter and Ward, 2004). Especially small urban streams, where water quality changes very quickly, confirm this statement. On the other hand, there can be a lack of sediment material for sampling in these streams, mainly in urban areas where streams are often channelized. Heavy metals belong to the group of pollutants that are, in aquatic environment, quickly bound into solid phase (sediments and suspended solids) if it is available (Soares et al, 1999). They are known also for their feature to bind into fine particles (Kelderman et al, 2000). Some countries, the Czech Republic including, implement EQS for metals in sediments which are given for a small grain size fraction, e.g. less than 20 μm. Usually, these criteria are not applicable for small urban streams, as the Botic creek, because it is impossible to sample required amount of sediment material for metals analysis. That is the reason, why American EQS were chosen for this study. EQS for sediments are presented in Table 3. Observed metals concentrations in sediments are lower than both chosen EQS.

Only in sampling site 18 concentrations of Cu, Pb, Zn and Hg always exceed stricter criterion TEC (LEL for Hg). A car repair shop situated nearby this sampling site is identified as a main source of metals pollution.

Table 3 American EQS for metals in sediments: Threshold effect concentration TEC and Probable effect concentration PEC for Cu, Cr, Cd, Pb, Ni and Zn and Lowest effect level LEL and Severe effect level SEL for Hg (ES/ER/TM-95/R4).

		CU	NI	PB	ZN	CD	CR	HG
TEC (LEL*)	mg/kg	28	39.6	34.2	159	0.592	56	0,2
PEC (SEL*)	mg/kg	77.7	38.5	396	1532	11.7	159	2

**EQS for Hg*

As an example of progress of metals concentrations in sediments along the whole stream, a sampling date from late summer is presented in Figure 6. For better understanding of binding behavior of metals in particulate sampling sites and consequently for correct interpretation of results with respect to pollution sources, analyses of grain size distribution and organic matter content of analyzed sediment samples were performed, as Figure 7 shows for the specific sampling date in late summer. As Figure 6 shows, in spring area of the Botic creek the highest concentrations of Cd from the whole stream were analyzed, though not higher than EQS. Since no evident source of Cd was found in this area, the reason should be searched in sediment features. The relation of higher concentrations of metals in sediment with fine particles was mentioned above and also connection with higher organic matter content is confirmed by literature (Qu and Kelderman, 2001) and both is evident in the first three sampling sites, as Figure 7 shows, although correlation coefficients does not confirm it (0.34 for correlation with OM and 0.1 for correlation with grain size <63 μm).

For some pollution sources, higher HM concentrations are expectable and in some cases are confirmed in the Botic creek. E.g. highway runoff increases sediment concentrations of Zn, Cd, Hg and Cu in sampling site 11 compared to site 10. This increase can be supported also by higher OM content that can be associated with retention tank through which highway runoff is lead into the creek. Impact of highway runoff on metals concentrations in receiving waters can be confirmed by Perdikaki and Mason, 1999. Other potential source of HM in urban streams is urban drainage. Older observations in the Botic creek in the section 2 km long below the Hostivar reservoir, where are CSOs and SWDs (sampling sites 15, 16 and 17), often showed values exceeding EQS for mainly for Cu and Zn, in some cases also for Pb. As a source for Cu and Zn, building of new houses in residential area in the catchment and using of Cu and Zn as roofing materials was assumed (Nabelkova and Kominkova, 2006). The current monitoring does not confirm the previous results. CSOs and SWDs do not increase significantly concentrations of metals in sediments of impacted sampling sites and EQS are not exceeded. This improvement could be attributed to washing of sediments by floods (last bigger was in this creek in 2013, smaller are regularly each autumn, when the Hostivar reservoir is partially emptied) and to reconstruction of sewer net and CSOs which was done a few years ago. As the most significant source of metals in the Botic creek sediment, a car repair shop is judged. In sampling site 18, which is nearby, concentrations of Cu, Hg, Cd and Pb in sediment increase several times compared to previous sites and exceed EQS.

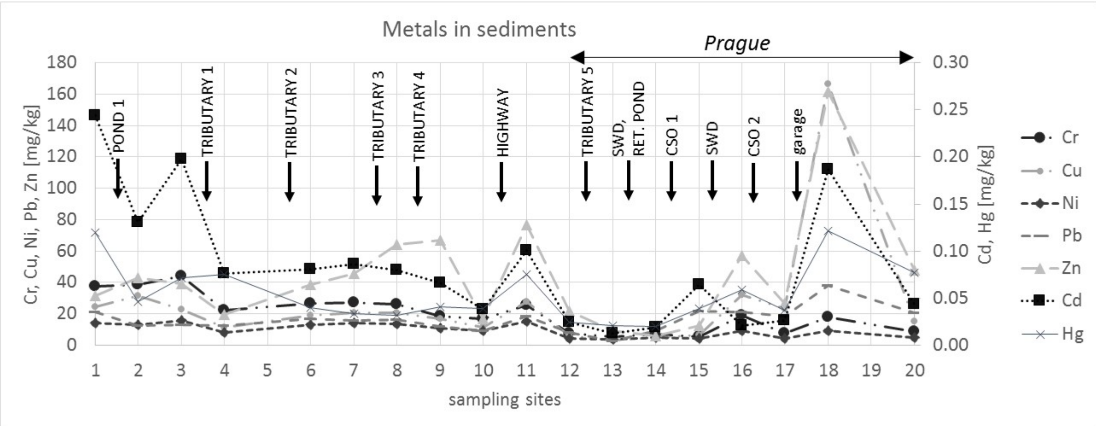

Figure 6 Concentrations of metals in sediment along the Botic creek during a sampling date in late summer

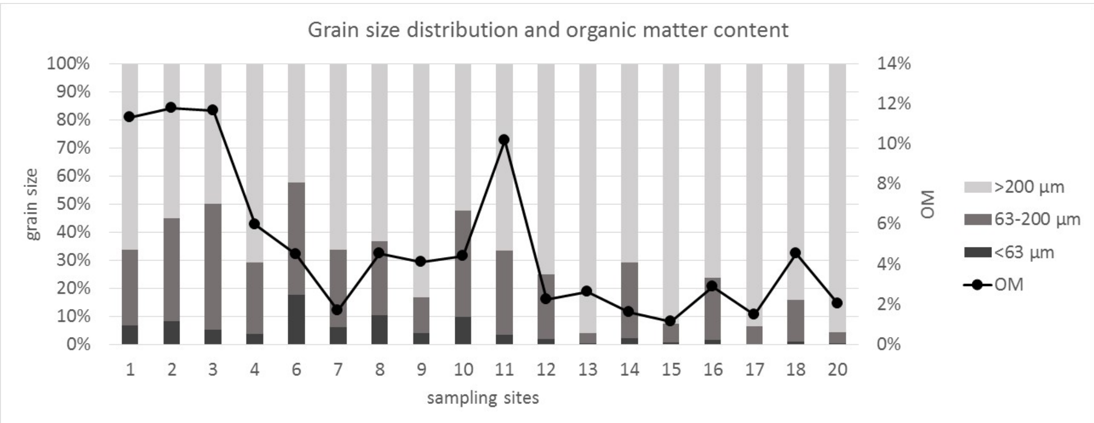

Figure 7 Grain size distribution and organic matter content of sediments along the Botic creek during a sampling date in late summer

Hydroecological monitoring

Hydroecological monitoring was conducted according to actual Czech methodology HEM - Hydroecological monitoring (Langhammer, 2013). The whole stream was divided into 81 sections in which hydromorphological characteristics: hydrological regime (quantity and dynamics of water flow, connection to groundwater bodies), river continuity and morphological conditions (river depth and with variations, structure and substrate of river bed and structure of the riparian zone) were evaluated. A half of these sections was characterized by High or Good status and 19 by Moderate status. The rest, most of them in the Prague area, has to be classified as poor, partly because of tubing of some sections, but mainly because of permanent morphological changes of the stream channel caused by high discharges during storm events as a result of CSOs and SWDs outlets. The requirement of WFD 2000/60/EC, to achieve at least good ecological status, is not possible to fulfill because of conditions given by strongly urbanized area. Ecological potential instead of status should be evaluated in this part of stream.

Conclusion

The impact of point and non-point pollution sources is evident in the whole length of the studied small urban stream, the Botic creek, both, in its part running through rural area and in the section flowing through urbanized area of Prague. As for basic physical and chemical water quality, a gradual increase of loading by ionic compounds (according to conductivity) can be observed from the spring towards the estuary. However, rural area revealed as stronger pollution source than urban area in the case of nutrients (N and P compounds), which have been identified as most significant pollution of the stream originating mostly in farming as a non-point source. Road traffic was confirmed as the main point source of heavy metals. In spite of their strong affinity to bind into solid phase (sediments) in aquatic environment, remobilization into liquid phase and increased concentrations in water were observed under some circumstances: reduction conditions as a consequence of eutrophication and a lack of sediment material can cause elevated metals concentrations in water. Hydroecological monitoring confirmed impossibility to achieve at least good ecological status (required by WFD 2000/60/EC) of the Botic creek in the section running through Prague partly because of morphological changes given by urban drainage as a set of point sources.

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Cost-benefit analysis of flood resilience strategies to cope with global change impacts. Application to the Barcelona case

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Abstract

This paper presents the results of a flood damage assessment taking into account the effects of drivers such as socio-economic trends and climate changes. A first stage of this work consisted on creating a detailed flood damage assessment for the case study area. The implementation of a new 1D-2D coupled model was used to obtain flood depths and new stage damage curves were developed to estimate the direct tangible damages. Then, combining the hazard and vulnerability levels by using a GIS-based toolbox, the expected annual damages (EAD) of the area could be obtained. For a time horizon centred in the year 2050, several future scenarios of climate and socio-economic changes were created. Using the previously developed tools, the EAD values of the several future scenarios were obtained for the Raval District. The comparison between future and current damages presented increase ratios that ranged between 1.5 and 4. This is why several adaptation strategies were modelled. By undertaking a cost-benefit analysis, the effectiveness of the strategies was assessed, and a prioritization of the most adequate ones for each scenario was done.

Keywords: urban flooding; impact assessment; depth damage curves; flood resilience strategies; cost-benefit analysis.

Introduction

Urban areas are, due to the concentration of population and economic activities, one of the most sensitive regions to natural hazards. The concentration of people in cities increases their opportunities as well as their vulnerabilities to natural hazards and climate change impacts (Djordjević *et al.*, 2011). Consequently, the assessment of urban flood impacts is an issue of high interest, specially taking into account the framework that the European Flood Directive (EC, 2007) has developed.

This paper presents a part of the CORFU (Collaborative Research on Flood Resilience in Urban areas) project focusing in the Raval district of Barcelona (Figure 1), which aims to quantify the cost-benefit of resilience measures for different scenarios of socio-economic and climate changes.

In early stages of this work, a methodology to determine flood damages was developed (Velasco *et al.*, 2013). Depth damage curves and a detailed 1D-2D coupled model were created (Russo *et al.*, 2013), in order to accurately describe direct tangible damages of the Raval district.

Barcelona presents a classic Mediterranean climate with cool winters and even warm summers, occasionally suffering heavy rainfalls of great intensities and flash floods events. The yearly average rainfall is 600 mm, but the maximum intensity in 5 minutes corresponding to a return period of 10 years is 202.47 mm/h and it is not rare that 50 % of the annual precipitation occurs during two or three rainfall events. The Intensity Duration Frequency (IDF) curves were recently updated on the basis of a rainfall series data of 81 years (from 1927 to 1992 and from 1995 to 2009). On the basis of these IDFs new project storms with several return periods were obtained for the design of the sewer network (Rodríguez *et al.*, 2013).

The Raval district of Barcelona is located in a hollow area of the city (Figure 1). With almost 50,000 inhabitants in an area of 1.09 km^2, it is a densely populated area with approximately 44,000 inh./km^2. The district area is highly impervious with several vulnerable elements (such as schools, hospitals, museums, historic buildings, etc.).

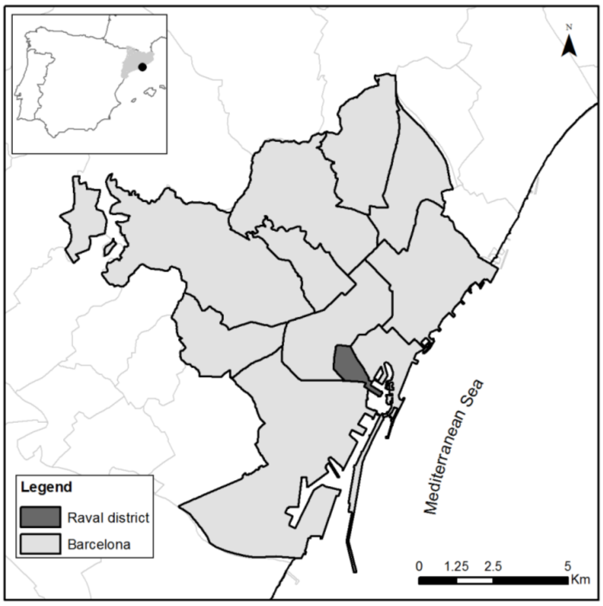

Figure 1. Administrative limits of Barcelona and representation of the case study area, the Raval district.

This area suffers from flooding problems when heavy storm events occur. These problems are caused by the excess of surface runoff and the poor capacity of the sewer system in some of the upstream basins in the city. In addition, the hydrological response time of Raval district catchment is very short (less than 30 minutes). As a result, there is significant hazard for the vehicular and pedestrian circulation, as well as economic damages in terms of goods and properties.

Methods

Damage calculation

As stated in the introduction, a methodology to determine flood damages was developed in early stages of the CORFU project (Velasco *et al.*, 2013). In order to carry out an urban flood damage assessment, three key elements are required: depth damage curves, detailed flood depth maps and land-use maps. It is worth noting that, the model outputs (i.e. water depth in the streets) have been converted into water depth inside the buildings.Furthermore, to ease the calculation of the final flood damage maps, a GIS-based toolbox has been developed (Hammond *et al.*, 2012). This toolbox enables to automatize the three following steps, increasing the speed of the post processing of data and so, easing the simulation of several events:

1) Read the value of water depth in each building from flood hazard maps;
2) Interpolate this value in the stage-damage curve to obtain the relative cost;

3) Multiply the relative cost by the area, obtaining the total damage value per each block.

Finally, a shape file with the total damages is obtained, being able to calculate the total costs that have been caused by the extreme rainfall event. This process can be easily repeated for several flood-driven events.

Expected annual damage

By calculating the damages for different return periods, the expected annual damage (EAD) of the studied domain can be obtained, being able to express to which extent is the area affected by floods.

EAD is an estimate of the average flood damages computed over a number of years (Arnell, 1989) and it is obtained by integrating the relationship between the expected damage for an event and its probability (Dawson *et al.*, 2008).

Since it is difficult to accurately define the relationship between the probability of a flood event and the damage it would cause, the most common methodology to calculate EAD consists on simulating several events of different return periods (which means that they have a different probability associated) and calculate the damages for each case. Then, by calculating the area under the curve that these points define, the EAD can be obtained.

In this study, three events have been selected in order to calculate the EAD of each scenario (DHI, 2002). These events correspond to an extreme event (T = 100 years), a precipitation event that starts to create some damage (T = 1 year) and an intermediate one. Since the Barcelona sewer network is predominantly designed to cope with a 10-year return period event, this will be the third return period used (T = 10 years). Such rain events have been simulated by using the hyetographs developed from the IDF curves (Rodríguez *et al.*, 2013).

Future scenarios

In order to undertake a long-term cost-benefit analysis of several resilience strategies, a combination of different future scenarios of climate, adaptive capacity and socioeconomic aspects is developed. These future scenarios are centred in horizon 2050.

There are two business as usual (BAU) scenarios, in which no adaptation strategies will be implemented, but have two different climate scenarios. The other future scenarios cover a several plausible futures and imply different levels of adaptive capacity. Of course, these scenarios must be related and compared to the current situation or baseline scenario, which represents the nowadays flood risk situation in the Raval district.

The scenarios defined in Table 1, are going to be used for the cost-benefit assessment of resilience measures. There will be two future climate situations (a pessimistic scenario, showing the most extreme results, and an optimistic one) and two different levels of adaptive capacity (low: non-structural strategies; and high: structural strategies).

The climate change scenarios were taken from a previous research project (Rodríguez *et al.*, 2013). 84 daily rainfall series were simulated for the period 2000-2099 in Barcelona. These series were obtained for six stations located in the metropolitan area of Barcelona using the information provided by five general circulation models under four future climate scenarios of greenhouse gas emissions and applying statistical downscaling methods.

Table 1. Combinations of the possible scenarios for the Raval district.

COMBINED SCENARIO	CLIMATE SCENARIO	SOCIOECONOMIC SCENARIO	ADAPTIVE CAPACITY
Business as usual 1	Pessimistic	Medium	None
Adaptation 1	Pessimistic	Medium	Low
Adaptation 2	Pessimistic	Medium	Medium
Adaptation 3	Pessimistic	Medium	High
Business as usual 2	Optimistic	Medium	None
Adaptation 4	Optimistic	Medium	Low
Adaptation 5	Optimistic	Medium	Medium
Adaptation 6	Optimistic	Medium	High

Since the effects of climate change are uncertain, and some of the scenarios obtained even consider reductions in extreme precipitation (i.e. climate change factors smaller than one), the optimistic scenario has been considered as if there would be no changes in extreme precipitations due to climate change. On the other hand, the pessimistic scenario was created using the most extreme results provided in that study. These two climate futures and their climate change factors are presented in Table 2. The future rainfall scenarios will be obtained by multiplying the design storms with its corresponding uplift factor. Therefore, the shape of design storm will remain the same, and the climate change factor will be used as a scale parameter that proportionally modifies each five minute block of the hyetograph.

Table 2. Uplift factors of selected scenarios of climate change for 2050.

SCENARIO	RETURN PERIODS		
	1	10	100
Pessimistic	1.08	1.12	1.15
Optimistic	1.00	1.00	1.00

For defining socio economic scenarios for the Raval District in 2050, it is assumed that its economic development reflects the regional development of Catalonia. In total there are three different scenario variants associated with different economic growth paths (high, medium and low growth).

The value of assets and damages caused by flooding will change over time due to socio-economic development as well as changes in the type of contents, construction materials and mitigation measures. The approach followed consists in increasing the total value of exposed assets as a linear function of the urban cover and the gross domestic product (GDP), as it has been previously applied in several studies (Jongman*et al.*, 2012).

Table 3. Simulated GDP per capita (in €) in the Raval District and ratio of exposed assets.

YEAR	HIGH GROWTH	MEDIUM GROWTH	LOW GROWTH
2010	21,689	21,686	21,648
2050	41,098	36,260	33,163
Ratio of exposed assets in the Raval	1.89	1.67	1.53

To apply this on the Raval District, the depth damage curves that were estimated for 2010 have been adapted to represent the damages in 2050. Considering that the case study focuses on a clearly delimited and very developed district, and assuming that the local population will not increase, the ratio of exposed assets per unit area in the Raval District can be yield as below:

$$Ratio\ of\ exposed\ assets\ per\ unit\ area = \frac{GDPpc_{2050}}{GDPpc_{2010}} * \frac{Pop_{2050}}{Pop_{2010}} * \frac{Area_{2010}}{Area_{2050}}$$

$$= \frac{GDPpc_{2050}}{GDPpc_{2010}}$$

Consequently, the future value of exposed assets in the Raval solely depends on variations in the GDP per capita. The ratio of exposed assets in the Raval is calculated for the different socio-economic growth paths. Table 3shows the results.

Adaptive capacity

Two different levels of adaptive capacity were considered in this study. The measures proposed in the adaptation scenarios include structural and non-structural measures upstream and inside the Raval district.

The low adaptive capacity scenario represents the minimum adaptation that will be needed to cope with the several climate futures. It evaluates whether dedicating only low resources to the improvement of the adaptive capacity is enough or not. The measures implemented should be non-structural, and only focusing on vulnerability and risk reduction.

Given that in the Raval district there is a long history of flooding, it is quite common that the owners protect their own properties. The most common strategy is to use wooden panels called flood boards (with a height of 50-55 cm)that prevent water entering into the properties. The implementation of these protection measures is done by updating depth damage curves. There will be no damages until 50 cm, and then once the board is overtopped the damages will grow linearly until the damages of the original curve for 55 cm are reached. After this point, the new damage curve will follow the same pattern as the original curve.

The medium level of adaptive capacity consists of SUDS (Sustainable Urban Drainage Systems), and specifically green roofs. Green roofs were the chosen technique because the Barcelona Municipality promoted their implementation during the last decade and is implementing them in several areas of the city. Moreover, the *Agència d'Ecologia Urbana de Barcelona* (Urban ecology Agency) published a specific study about the implementation of potential urban roofs in Barcelona. Green roofs were introduced into the model specifying their surface portion in each subcatchment and defining their hydrological parameters to define infiltration losses.

The high adaptive capacity scenario considers classical structural measures (new pipes and one storage tank) to reduce flooding problems in the Raval district. Specifically new simulated structural measures were:

- 3 pipes in the upper part of the city to reduce runoff coming from upstream areas;
- 3 pipes in Poble Sec district to reduce runoff in the Raval coming from Parallel St.;
- A storage tanks of 23,000 m^3 to store local runoff generated in the Raval district.

Cost-benefit analysis

A cost-benefit analysis of the different adaptation measures was conducted considering the scenarios that have been defined in

Table 1. Results from this cost-benefit analysis provide insights on the economic efficiency of the different adaptation measures against the background of the different scenarios since the economic value of the potential impacts is analysed jointly with the costs of implementing and maintaining the adaptation measures.

Within the scope of this analysis, benefits are defined as the reduction in the expected annual damages to buildings and their contents that presumably is going to be achieved by implementing the considered adaptation measures. Costs are analysed by taking into account the initial cost of setting up or constructing the respective measure – the capital costs (CAPEX) – and any costs that are required to operate and maintain the adaptation measure, which are the operational and maintenance costs (OPEX).

To be able to assess the impact of the different adaptation measures on the EAD separately from the impact of other scenario parameters (such as different socio-economic pathways or different climate scenarios), the BAU scenarios are compared to the different adaptation scenarios with the same parameters except for the adaptive capacity. That is, for obtaining the benefits of the scenarios Adaptation 1 and Adaptation 2, their EADs are compared to those of BAU1, while for estimating the benefits of Adaptation 3 and Adaptation 4, the scenario used is BAU2.

Flood protection and adaptation measures at the same time reduce damages and require expenditures throughout the entire considered time horizon (i.e. the year 2050). In order to be able to compare costs and benefits of the adaptation measures and to evaluate their cost-effectiveness, the cost-benefit analysis thus is based on the Annual Equivalent Costs and Benefits. To calculate the Annual Equivalent Costs and Benefits, in a first step the Total Present Value of the costs and the benefits must be obtained, using a discount rate that in this analysis is considered of 4.0%. In a second step, the Annual Equivalent Costs and Annual Equivalent Benefits of each scenario are calculated and then, the Net Benefits of an adaptation strategy can be obtained as the difference of the benefits and costs of the different scenarios.

Thus the value of the net benefits reflects the value of the avoided EADs minus the cost of implementing and operating the respective adaptation measure as compared to the business as usual scenario. Net Benefits are calculated both in terms of the Present Value of total Net Benefits and the Annual Equivalent Net Benefits that are generated over the entire time horizon.

Results and discussion

As it can be seen in Table 4 and Figure 2, damages for the several scenarios have been calculated using the previously developed methodology and data. To compare the different results, the EAD values can be observed. Comparing the EAD of the baseline scenario and the two BAU scenarios, considerably high increasesare observed (of course, this increase is more important for the BAU 1, because it considers a pessimistic climate future). This means that the combined effects of climate and socioeconomic changes might imply increases in the levels of hazard and vulnerability, and hence, flood risk.

This justifies the implementation of adaptation strategies that aim to decrease either hazard or vulnerability and consequently risk. As mentioned, two different types of strategies have been implemented, representing low and high levels of adaptive capacity. Again, using the values from Table 4 the effectiveness of the applied structural measures can be assessed.

As it can be seen from the results of Adaptation 1 and Adaptation 4 scenarios, the non-structural strategies are very efficient for events with low return period. On the other hand, for events of higher return periods such strategies are not able to prevent flood impacts so efficiently. Otherwise, scenarios Adaptation 3 and Adaptation 6 show that structural strategies are able to cope with flood impacts at all levels. Specifically, it can be observed that these measures reduce the damages for a 100 year event to values which are even lower than the ones obtained for the baseline scenario.

Comparing the EAD values of the six adaptation scenarios, it can be clearly concluded that the high adaptive capacity level implies higher benefits. This means that the flood impacts are more efficiently reduced with structural strategies compared to the non-structural ones. Nevertheless, given that the benefits of these strategies must be compared to their costs, a cost-benefit analysis was also carried out for the Raval District (this assessment has an important limitation, because whereas the costs of the structural measures were fully computed, their benefits were only measured in the Raval District,but actually they benefit a much bigger area of Barcelona).

Table 4. Damages and EAD of several scenarios for the Raval district.

RETURN PERIOD (YEARS)	1	10	100	EAD
PROBABILITY	1	0.1	0.01	
Damage for baseline scenario	78,846 €	1,615,738 €	19,156,196 €	1,697,299 €
Damage for BAU 1 scenario	211,846 €	8,369,323 €	45,642,494 €	6,292,056 €
Damage for Adaptation 1	0 €	3,266,670 €	35,461,156 €	3,212,754 €
Damage for Adaptation 2	56,143 €	6,398,101 €	44,402,370 €	5,190,431 €
Damage for Adaptation 3	7,005 €	275,258 €	10,478,002 €	610,915 €
Damage for BAU 2 scenario	131,654 €	2,718,048 €	32,400,065 €	2,862,681 €
Damage for Adaptation 4	0 €	191,470 €	23,773,122 €	1,164,568 €
Damage for Adaptation 5	24,278 €	2,030,046 €	28,695,007 €	2,307,073 €
Damage for Adaptation 6	5,818 €	71,540 €	3,253,262 €	184,427 €

Figure 2.Flood damages for a rain event of 100 year return period in the Raval district, for the baseline scenario (left), the BAU 1 scenario (centre) and the adaptation 3 scenario (right).

As it can be seen in Figure 3, the total present value of costs and benefits of the six adaptation strategies have been calculated. As stated earlier, the benefits represent the reduction of the EAD compared to the corresponding BAU scenarios, whereas the costs refer to the addition of the CAPEX and OPEX costs. Observing these two variables, some conclusions can be extracted very straight-forward: structural strategies imply higher benefits than the non-structural ones, but their costs are also much greater than the other ones. Consequently, the net benefits of the non-structural strategies (Adaptation 1 and 4) are larger.

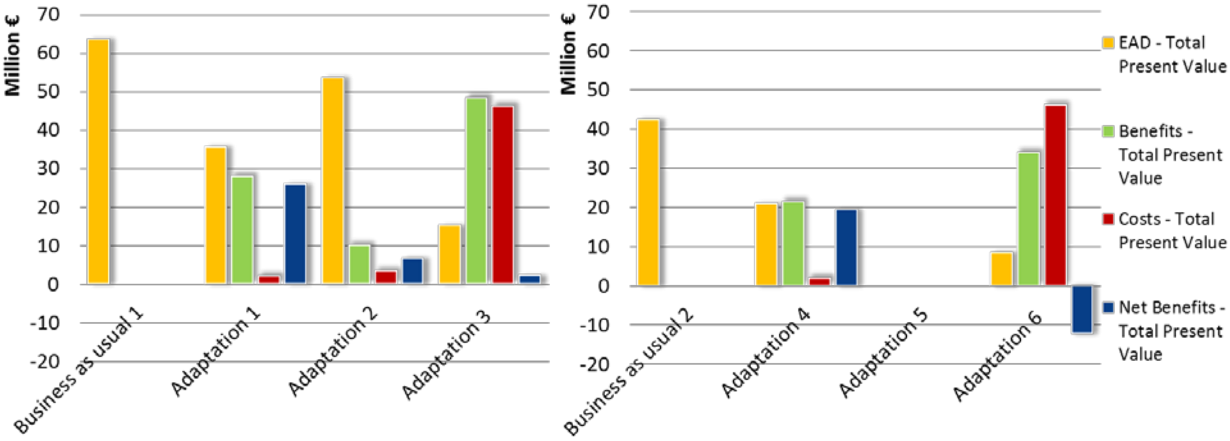

Figure 3.Results of the cost-benefit analysis: Total Present Value of EADs, benefits, costs and net benefits of the several scenarios for the horizon 2050 and a discount rate of 4.0%. Benefits are only focused in Raval District while in some cases they have a wider extension.

Given that the costs of the strategies do not depend on the climate scenario, the net benefits of each pair of scenarios present rather different trends. For the adaptation 1 and 4 scenarios, the first one reaches a net benefit of 25,993,978 €, whereas the second one achieves a value of 19,541,755 €. For the other two scenarios, given that the costs of the structural strategies are very significant, their net benefits are very different: adaptation 3 presents a value of 5,455,729 €; whereas adaptation 6 presents negative “benefits” of -12,221,800 €. Again, in this second case, the analysis only considers the benefits in the Raval District, while these infrastructures benefit a much bigger area.

Consequently, several conclusions can be driven of this study. The non-structural strategies present higher net benefits than the structural ones, due to their low cost. However, the structural strategies can better cope with flood impacts, but at higher costs. Nevertheless, the economic benefits of these strategies are only related to the Raval District. By extending the domain analysed, the results would be different.

Conclusions

The methodology presented allows to undertake an exhaustive economic damage assessment. By including future scenarios, the need for adaptation is identified. Therefore, several adaptation strategies implemented, and their costs and benefits are simulated.

The results presented in this paper focus on Raval District and have considered structural and non-structural measures implementation. Structural strategies can better cope with flood impacts (in terms of mitigation of economic losses and hazard and risk reduction), but at higher costs.

Acknowledgement

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Innovative technologies for an optimal and safe closed water cycle in Mediterranean tourist facilities

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Abstract

The project with the title “demEAUmed” demonstrates and promotes innovative technologies for an optimal and safe closed water cycle in Euro-Mediterranean tourist facilities. A resort placed in Catalonia, Spain, is considered the DEMO site, where a representative part of all inlet and outlet water flows will be characterised, treated with proper innovative technologies, and reused to reduce overall tap water consumption and also the carbon footprint of water management through an integrated approach at demonstration level. Alchemia-nova contributes with a greywater purification system through an indoor plant-based constructed wetland. For the plant-based wetland a vertical cascading set-up was employed combined with a sub-surface horizontal flow. A test unit with three levels of cascading plant container lines with three meters length has been installed at the laboratory of alchemia-nova and has been tested under conditions that simulate the demonstration site. This unit already shows promising results. The COD parameter for example, has been reduced from an initial influent value of 450 mg/L by over 95% to a value of 10 mg/L. In relation to Spanish/EU-legislations the effluent of the vertical ecosystem can be used for toilet flushing, irrigation of private garden, golf irrigation,

groundwater recharge and laundry, at the studied load of greywater pollution level and flow input.

Keywords: vertical ecosystem, water management, indoor water purification, tourist facilities, constructed wetland, biologic wastewater treatment

Introduction

In Mediterranean countries water resources are limited and unequally distributed in space and time. For this reason, public administration tries to improve water management, water pricing and water recycling policies to enhance and ensure water supply and achieve a sustainable water management.

In these countries, tourism is one of the most important economic activities. Tourism is highly dependent on freshwaters resources and their final use: showers, spas, swimming pools, gardens, golf courses, etc. Currently hotels and tourism/recreational enterprises should strengthen their commitment to environment protection and resource preservation by promoting best practices in water consumption, for example by monitoring and reusing grey waters. In addition, water reuse policy should be promoted and enforced in order to guarantee long-term sustainability of this important economic activity in Mediterranean countries. DemEAUmed answers tourism needs and will improve the efficiency of water use and reduce the energy cost. DemEAUmed will face two key challenges: the importance of tourism economy and the characteristics of water scarcity of the area. The project will be a critical platform for promoting the use of sustainable and innovative technologies in other Euro-Mediterranean tourist facilities not at last also in the light of the global tourism market.

Reduction of freshwaters consumption in hotel facilities, green and recreational areas, etc. is achieved by using alternative water sources, such as ground water, treated rainwater or the reuse of treated greywater and/or wastewater. Taking into account the specific water quality/quantity requirements of the different areas of the Euro-Mediterranean resorts, as well as current and future compliance with water regulations, demEAUmed will suggest the best solutions (www.demeaumed.eu). An exhaustive environmental and socio-economic assessment will be developed and advanced monitoring and control systems and a decision support tool will be also implemented to define the best water management system.

Different proven water treatment technologies at pre-marketable level will be properly combined to treat and adapt the different water bodies to the resorts' requirements, so that reduction in freshwater-consumption and a reduction in negative environmental and socio-economic impacts will be guaranteed. The main demonstration site of demEAUmed, where the different technologies will be tested, will be at Samba Hotel, a representative 4-stars hotel chain located in Lloret de Mar, Girona, Spain. It is a large resort with 441 air-conditioned rooms, green areas and exterior pools, conference rooms, bar and restaurant.

Alchemia-nova contributes to this project with a plant-based greywater purification unit. It is an integrated indoor constructed wetland ecosystem. The Vertical Ecosystem will be tied into the greywater treatment cycles of the building and will support significant potable water savings by reusing water flows on site, for example for flushing toilets. This ecosystem technology is based on subsurface water flow through the root zone of plants (Vymazal, 2011; Regelsberger et al., 2009). The investigated plant species function in symbiosis with rhizosphere specific microorganisms providing intrinsic water cleaning abilities (Nolde, 2000) and will demonstrate that there are no negative odours or microbial impacts on the air or water treated by the system. In fact, it will help to remove VOC`s (volatile organic compounds) from the ambient air, and also will demonstrate that this plant based water treatment technology is applicable to buildings in regions of all climate conditions. As an educational side benefit, it will demonstrate tangibly the importance of wetland ecosystem services in relation to clean water for the planet and humanity.

The project will be an important showcase contributing to strengthen the relationship between water and tourism sectors - for the benefit and optimization of both of them-, and become a platform to promote the use of sustainable innovative technologies in the sector.

Finally, demEAUmed will also contribute to attain the main goals of European Innovation Partnership on waters: water reuse and recycling, water and wastewater treatment, including recovery of resources and water-energy nexus, and supports two crosscutting priorities: water governance and decision support systems and monitoring.

Methods

The laboratory scale plant-based greywater treatment unit imitates real life conditions of the DEMO site and is monitored for the following: cleaning performance, microbiological factors, chemical pollutants, reliability and maintenance demands and energy demands. For the constructed plant based wetland a vertical stage wise set-up was employed combined with a sub-surface horizontal flow. The laboratory small-scale wetland consists of three floors (figure 2), connected by water conducting tubes. A pump based on time controlled operation feeds (grey)water into the top floor. Water flows in a sub-surface horizontal manner, meandering through the rhizosphere substrate and pushed by gravity down to the next floors. In order to improve the aerobic symbiosis of roots and microorganisms air is injected continuously through perforated hoses at the bottom of the plant containers into the water. As an additional side-benefit air-pollutants are also removed from the air through this ventilation system. Many harmful air-pollutants are known to be metabolized in the root zone (Wolverton et al., 1989). The appropriate inorganic substrate has a large surface area, such as expanded clay that offers as much colonization space for microorganisms as possible (Stottmeister et al., 2003). And it must be inorganic and stable, so that it is not biodegraded over time and cloak pipes. The coarse inorganic substrate also results in an irregular water flow, which helps to increase the interaction between microorganisms and water pollutants. The investigated plant species are specifically suitable for this indoor constructed wetland system and also have some decorative qualities (see figure 1). Several tests for flow rate, influx/efflux, substrate, pH and others were conducted. With sensors from S::can and Thermo Scientific following chemical parameters are tested either online or at regular intervals: COD, BOD, NO_{3-}, NH^{4+}, TSS, (UV-VIS spectrometry) pH, Temperature, DO and Conductivity (electrodes coupled to meters). For pharmaceutical analytics external laboratories were commissioned. Another test was to see what happens if the water supply to the unit is cut off for longer periods (for example if pumps are defect).

Figure 1: Actual picture of the test unit in the laboratory, called Vertical Ecosystem

A water sampling campaign was done in June 2014 in the SAMBA hotel to get preliminary water quantity and quality data. Composite samples from the different streams were analysed for standard chemical parameters and some micro pollutants (pharmaceutical compounds). The sampling points at the hotel relevant to the indoor constructed wetland technology were the greywater tank and shower water and lavatory effluent. Simulated greywater imitating the quality of the expected flows at the demonstration site was used for the laboratory experiments, as well as light conditions simulating the minimal light availability at the DEMO site were used. Simulated greywater is mixed using hygiene products like soaps, shower gel, shampoo, conditioner, tooth gel, deodorant, cosmetics, body lotion, lavatory cleaning products, dust from a vacuum cleaner, citric acid to adjust pH and curing salts) was prepared at the laboratory of alchemia-nova in Vienna. The salts are added to increase the electrical conductivity parameter and simulate a higher salt content as seems to be the case at the hotel in Spain, as well as to provide some nitrates to the mixture. The hotel located on the Mediterranean shore uses drinking water that comes partially from desalination plants or groundwater, which seem to have a higher base salt content than the drinking water in Vienna, which comes mostly from natural springs in the close by alps.

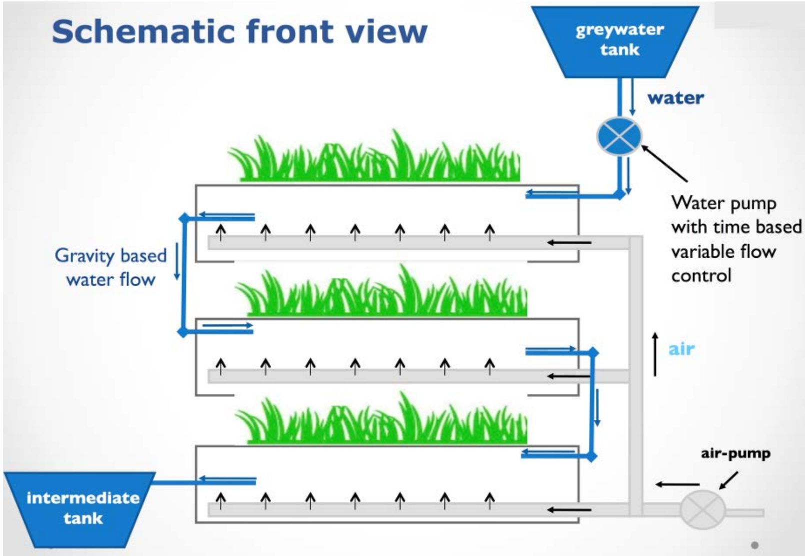

Figure 2: schematic front view of the vertical constructed wetland unit for indoor use

The water flow is regulated in such a way that a volume of 250 to 300 L/d is pumped through the laboratory small-scale test wetland. To obtain a higher cleaning performance, a longer retention time of the water in the treatment unit is desirable (Vymazal, 2011). For this reason, the water is pumped intermittently through the treatment plant. More than 70 plants in different combinations were tested. 15 species like marsh plants (*Typha*, *Iris*,...), graminoids (*Carex*, *Cyperus*,...), tropical and subtropical plants (*Ficus*, *Spathiphyllum*,...) were selected as they provided the best results. All these plants have in common that they can grow in inorganic, hydroponics like substrates and tolerate the pollution load of greywater, which is used for the laboratory test, have positive water cleaning interactions and have some decorative value.

The effluent from the Vertical Ecosystem was then analysed for water quality defining parameters and compared to the initial values from the synthetic greywater to allow a performance appraisal.

Results and discussion

Table 1 compares values of key water quality parameters (reference values for pollution loads) for the synthetic greywater mixed at the laboratory in Vienna for test purposes and the values for the final outflow from the Vertical Ecosystem unit after the water has been treated. In addition, for comparison purposes, the same parameters for normal tap water at the laboratory location in Vienna are presented, to better allow a performance appraisal of the unit. Pollution abatement and water cleaning performance is considerable.

Table 1: Synthetic grey-water (inflow), effluent water and tap water in Vienna

		simulated greywater	effl. after treatment	Vienna tap water
PARAMETER	**Units**	**GW Tank**	**cleared water**	**faucet**
Conductivity	µS/cm	1402,00	1404,80	252,30
pH	-	7,16	7,46	7,84
COD	mgO_2/L	209,94	9,58	4,19
BOD	mgO2/L	189,41	4,99	1,62
TOC	mgC/L	60,55	3,20	1,15
TSS	mg/L	75,91	3,61	3,87
$N\text{-}NH_4$	ngN/L	0,00	0,00	0,00
$N\text{-}NO_3$	mgN/L	4,41	0,64	0,00

For a better insight, the averaged values at each sampling point for selected parameters are presented next. COD (chemical oxygen demand) and BOD_5 (biological oxygen demand) are very important in order to assess the cleaning performance of the system. Our sampling points are the greywater tanks with the synthetic mixture, after 175 L rhizosphere (1^{st} floor), after 350 L rhizosphere (2^{nd} floor) and after 525 L rhizosphere (3^{rd} floor). After the first cleaning stage a drastic reductions in the COD and BOD parameters can be observed, then these decreases level off in an approximately exponential manner in the next 2 stages and at values of about 10 mg O_2/L for COD and 5 mg O_2/L for BOD_5 further decreases do not seem practical anymore for a reasonable size (=root area) of the unit (figure 3). Similar conclusions can be drawn with the TSS (total suspended solids) parameter.

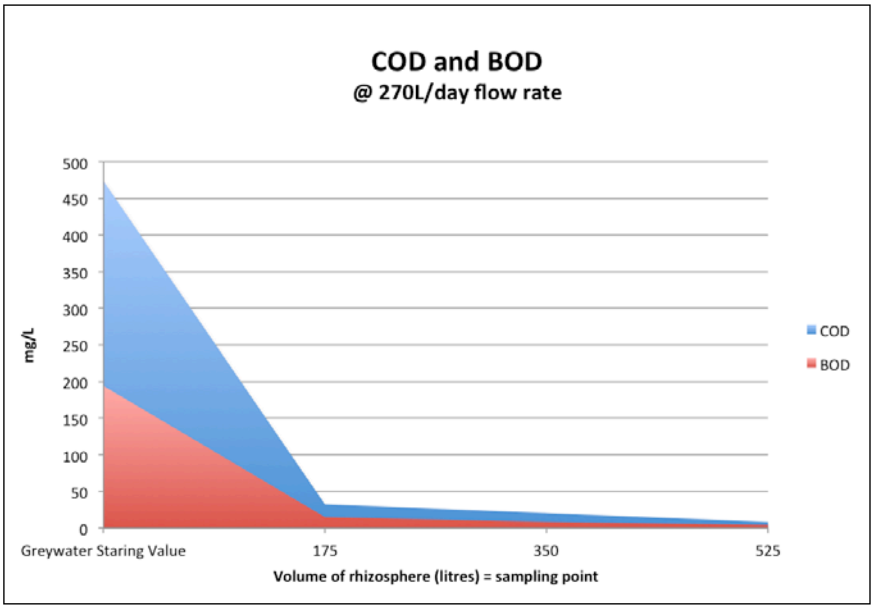

Figure 3: Cleaning performance of the Vertical Ecosystem (COD and BOD)

The results of the measurement of the dissolved oxygen (DO) in the water indicate that most of the biological decomposition of the organic load in the greywater takes place in the first stage. Microbial respiration processes consume most of the DO and even the active inflow of air into the root area cannot prevent a certain depletion of DO in the water. Only during the second and third stages of the unit can the air that is pumped into the unit compensate for respiration losses and an almost as high level of oxygen saturation is achieved in the treated water as was the initial value of the fresh (grey)-water, at between 80 and 90 % of oxygen saturation.

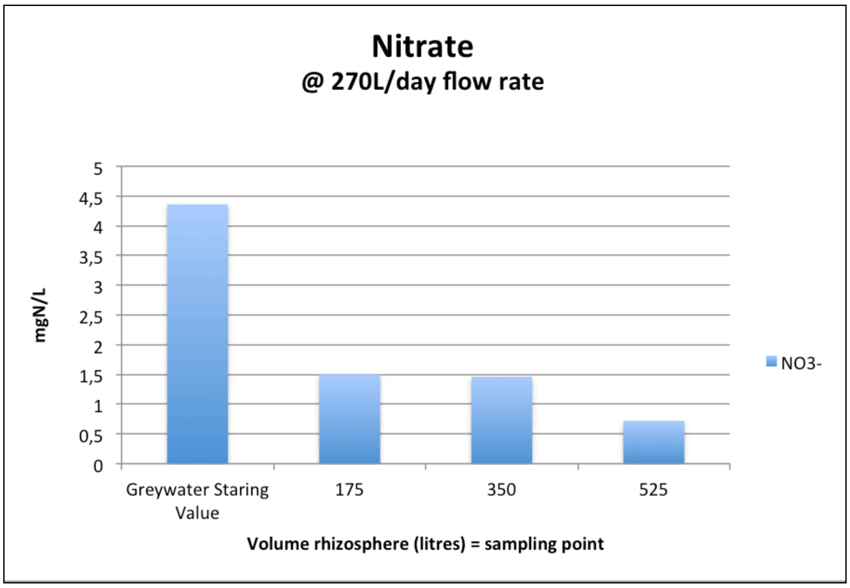

Figure 4: Cleaning performance of the Vertical Ecosystem (NO3-)

The Vertical Ecosystem takes up nitrate very readily. The strongest cleaning performance is achieved during the passage of water through the first floor. After stage 3 only small measurable amounts of nitrate could be found (figure 4). It has been difficult to simulate a measurable amount of ammonium in the greywater mixture, particularly since the greywater tank itself is oxygenated, despite the fact that different possible sources have been tested. Whenever small amounts could be measured in the fresh greywater, none could be measured at any of the unit stages outflows.

The parameter of conductivity is one that that does not evidence a satisfactory behavior at the Vertical Ecosystem. The conductivity of the effluent treated water is as high or even slightly higher than the conductivity of the influent greywater (figure 5). Some conductivity increases can be attributed to the breaking up of pollutants into smaller polar components like acids. But there seems to be an unwanted salt insertion from the substrate. This indicates that some of the substrate components used have a high anorganic salt component, which is not washed out in a short time. This also motivated the search for plant species that would be adequate to grow in the unit and also absorb or and accumulate salts in their tissue. Further, the salt amount in the greywater receipt will be adjusted somewhat lower, since the conductivity parameter in our simulated greywater is higher than that seen at the hotel demonstration site.

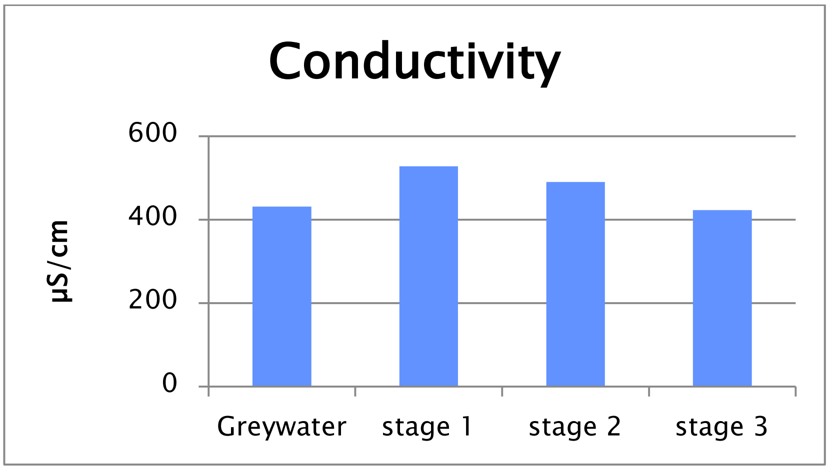

Figure 5: Behaviour of the conductivity parameter in the Vertical Ecosystem unit

First tests with pharmaceuticals were also done. A common painkiller (acetaminophen) was selected as test parameter. Our initial mixture was 16 mg pill powder from the drug store preparation "Mexalen rapid, 500 mg" in 500 L greywater tank (figure 6). With an initial concentration of about 8000 ng/L in the greywater, acetaminophen was not detectable (with a detection limit of 50 ng/L) in the effluent of the unit. However, these tests have just begun, and several repetitions and confirmation are needed. Initial results are definitely very encouraging.

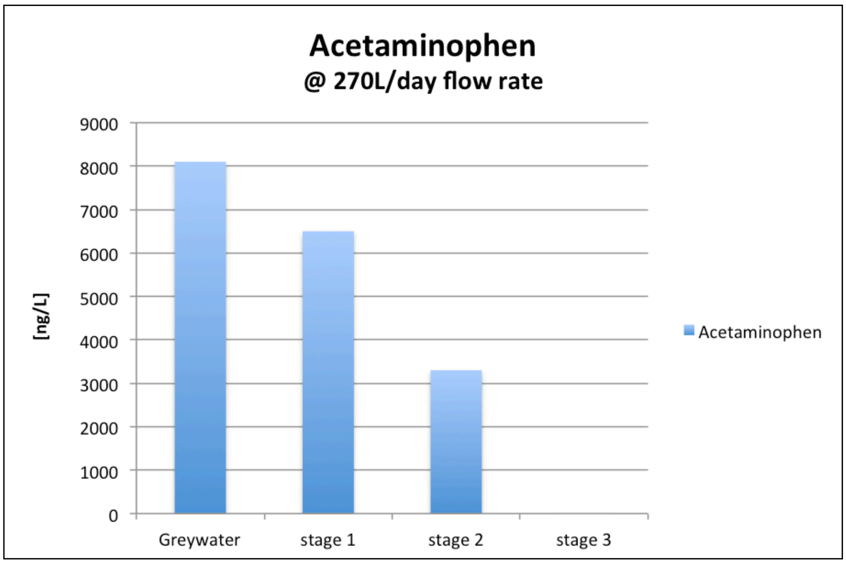

Figure 6: Cleaning performance of the Vertical Ecosystem (Acetaminophen)

After about 5 days without water inflow the root area dries up and the plants start to show signs of water deficiency (the coarse substrate used is notoriously bad a retaining water over longer periods). This test was stopped when it was obvious that further continuation would lead to serious negative impact on some plants and this would make the test unit unusable for representative experiments for a longer time. Provisions will be taken to ensure that the demonstration unit will have a secured water supply with gaps no longer than 3 days. During this test it also became evident, that the unit with its plants evapotranspirate about 8-10 L/day of water (with about 0,5 m^3 of root area).

Conclusion

Based on Table 1 a considerable cleaning performance of water was achieved by the Vertical Ecosystem. In relation to Spanish/EU legislations, preliminary results seem to indicate that the effluent of the Vertical Ecosystem can be used for toilet flushing, irrigation of private garden, golf irrigation, groundwater recharge and laundry, at the given load of greywater pollution and flow rate input (see Table 2). Microbiological tests for key indicator species are still pending, but the target water streams at the demonstrations site at the hotel did not show any problems with microbiological load, probably because those water streams get chlorinated quite intensely.

Table 2: Pertinent regulatory guidelines for water quality for on-site recycled water compared to the results from the Vertical Ecosystem unit

		CATEGORY 2			CATEGORY 3		CATEGORY 4	
			Groundwater recharge		Irrigation			
USES		Laundry	Direct injection	Localized ground percolation	Private garden irrigation	Golf irrigation	Toilet flushing	Vertical Ecosystem results
LEGISLATION (If present)	European	91/271/EC	91/271/EC	91/271/EC	91/271/EC	91/271/EC	91/271/EC	
	Spanish		RD 1620/2007	RD 1620/2007	RD 1620/2007	RD 1620/2007	RD 1620/2007	
KEY Parameters	Escherichia coli (CFU/100 mL)		0	1000	0	200	0	??
	Intestinal nematodes (egg/10 L)		1		1	1	1	??
	Legionella (CFU/100 mL)				100	100	100	??
	COD (mg/L)	125			125	125		7,9
	BOD_5 (mg/L)	25			25	25		3,82
	TSS (mg/L)	< 60	10	35	10	20	10	3,61
	Conductivity (µs/cm)				6000	6000		423
	Total Nitrogen (mg/L)		10	10				
	Nitrate (mg/L)		25	25				1,5
	Turbidity (NTU)		2		2	10	2	0,3

Further steps will be the optimization and modification of the laboratory unit to better resemble the demo version and to increase the flow rate. Tests with higher chlorinated mixtures as well as laundry water effluents are planned for the future, as well as some microbiological tests.

For the demEAUmed project, the incorporation of advanced monitoring and control systems and a decision support tool will ultimately define the best water management solutions for different specific practical cases by means of a database built upon the considered technological solutions. The Vertical Ecosystem and the data gained from concluded and on-going tests is an important part of this decision support tool.

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5 POSTERS

5.1 TRUST Results

Quantitative Assessment of Future Sustainability Performance in Urban Water Services using WaterMet2

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Keywords: WaterMet^2 model, metabolism performance, quantitative indicator, sustainability framework, urban water services.

Extended abstract

Urban water services are likely to face challenges in the future, mainly due to population growth, climate change, increasing urbanization and ageing infrastructure. These factors are expected to impose significant strains on the performance of urban water services. This would subsequently decrease the capacity and quality of services in the urban water system (UWS) and thus negatively affect different dimensions of the sustainability framework (i.e. economic, environmental, social, asset and governance) presented by Alegre *et al.* (2012). Performance of future sustainability in the UWS can be evaluated by using simulation of metabolism-based processes in the urban water cycles over a pre-specified horizon. The WaterMet^2 model developed in the TRUST project quantifies the metabolism-based performance of the integrated UWS (Behzadian *et al.* 2014a). The integrated modelling of the UWS implies the whole processes and components in an urban area related to water flows as a complex and interrelated system. A mass balance approach of water is followed within the system. Figure 1 illustrates the main flows and storages modelled in WaterMet^2 comprising of four main subsystems.

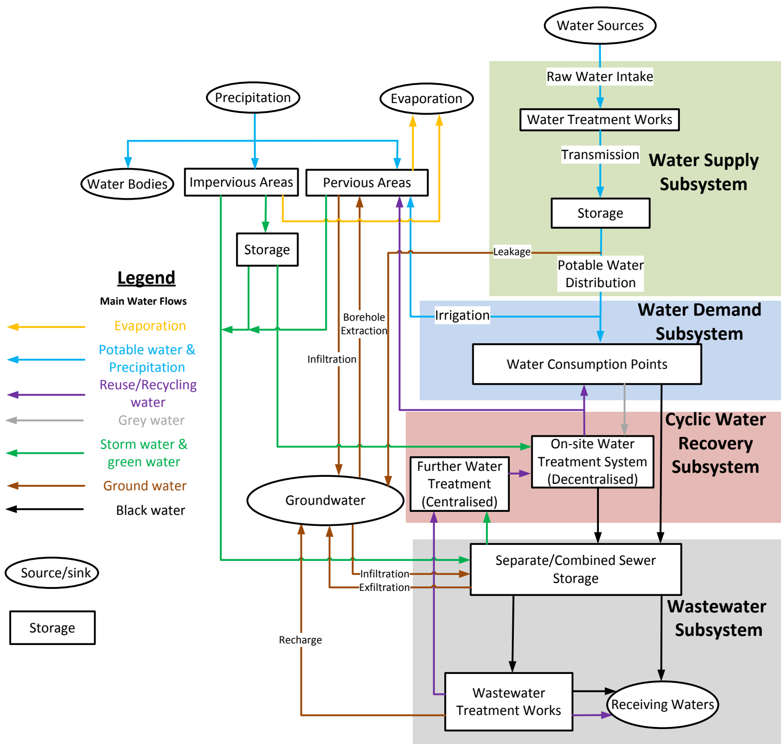
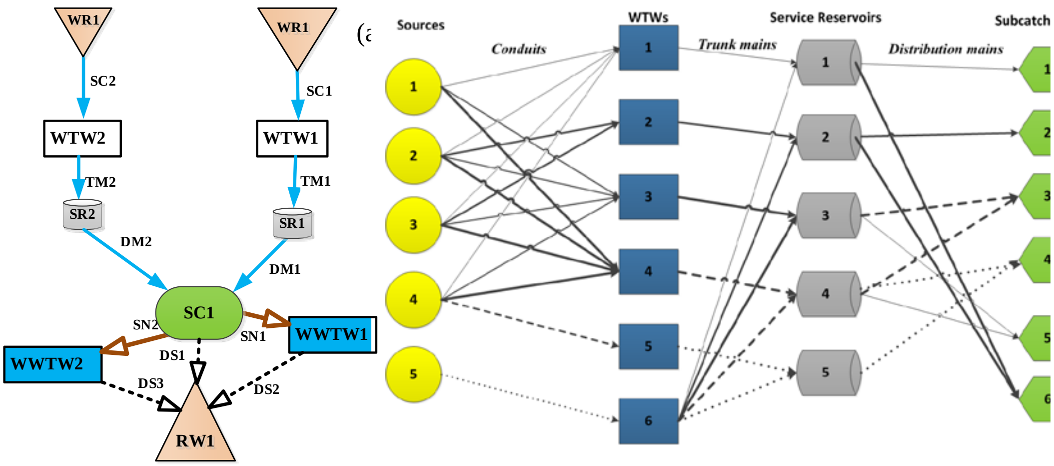


Figure 1 Main flows and storages in the WaterMet2 metabolism model (Behzadian et al. 2014a)

WaterMet^2 enables the calculation of quantitative key performance indicators (KPI) of urban water services over a long-term planning horizon. These KPIs encompass various aspects of water systems sustainability such as cost (economic), GHG emissions (environmental), water supply reliability (social) and leakage (assets) WaterMet^2 can support various intervention strategies by calculating the relevant quantitative KPIs which can be used for a multi-criteria decision analysis in a decision support system framework. The overall KPI values (calculated on a per-capita basis) obtained from the UWS can be used for comparing sustainability indicators of water services among different cities. The comparison of KPI values in the main UWS components reveals the critical components for which appropriate intervention options should be undertaken.

The capabilities of developed WaterMet^2 model are demonstrated here in two real-world case studies of UWS (i.e. a northern European UWS and Kerman UWS in Kerman city, Iran) shown in Figure 2. Further information of modelling the case studies can be found in Behzadian *et al.* (2014a) and Behzadian and Kapelan (2014) for the northern European case and Nazari *et al.* (2014) for Kerman case.



(b)

Figure 2 Schematic representation of main components in the WaterMe2 model for: (a) Northern European city UWS (b) Kerman UWS; Note that WR=water resource, SC=supply conduit; TM=trunk main; SR=service reservoir; SN=sewer network; DS=; WWTW=wastewater treatment works; RW=receiving water;

The WaterMet^2 model is able to successfully simulate the trend of metabolism-based performance in both case studies over a long-term planning horizon. Results also show a comparison of the most critical components with the highest contribution to each KPI value between the two case studies (Behzadian *et al.* 2014b and Nazari *et al.* 2014). This can lead to an effective exploration of potential intervention strategies in order to alleviate the negative environmental aspects and improve the social and asset-related aspects of the future sustainability without incurring high capital investments and operational/maintenance expenses.

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How to assess sustainability of urban water cycle systems (UWCS). Development of a metering methodology

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Keywords: Urban water services, Sustainability assessment, TRUST

Extended abstract

During the TRUST project, it appeared to be important to reach a common understanding on the term “sustainability”. In classical definitions it is referred to the social, economic and environmental dimension of asset management. However there are no established standards on measurement of the achievements of sustainability for urban water cycle systems. Since TRUST is dealing with “Transition to Sustainable Systems for To-morrow” it has been necessary to define a link between the ultimate objectives as the above mentioned dimensions and traditional systems for performance assessment and benchmarking

The framework of sustainability of TRUST thus consists of the dimensions, objectives, criteria and metrics. Additional to the classical “triple bottom line” TRUST proposes two more dimensions, governance and infrastructural (assets) as the main instruments to achieve required services with regard to security of people (social), the economy and the environment. Thus the TRUST general definition is: *“Sustainability in urban water cycle services (UWCS) is met when the quality of assets and governance of the systems is*

sufficient to actively secure the water sector's needed contributions to social, environmental and economic development in a way that meets the needs of the presents without compromising the ability of future generations to meet their own needs"

Sustainability assessment of urban water cycle services in TRUST includes the dimensions of social, environmental, economic, assets and governance sustainability. The assessment should in particular provide insights in how to improve the management and development of infrastructure and governance, as part of a strategic transition process towards 2040, in order to positively influence the end dimensions of social, environmental and economic sustainability (Figure 1). The assessment is made operational by critically and carefully examining a chosen set of performance metrics/indicators and how they comply with a predefined set of sustainability objectives and criteria (Table 1). The performance metrics/indicators may be quantitative and/or qualitative, and are specifically chosen in order to account for the particular context and challenges of a given urban water cycle system, in a medium- and long-term transition context. The UWCS sustainability assessment method must be transparent, valid and holistic, and should make use of metabolism and life-cycle assessment perspectives when this is needed. The assessment method should be inclusive and flexible with respect to stakeholder involvement and decisions regarding target setting and trade-off as part of a multi-criteria decision analysis process.

In TRUST a risk based procedure for the assessment of sustainability has been developed. In this context, risk is defined as likelihood and consequences of deviations from a sustainable development with respect to resources spent and impact on environment. The procedure may be explained by the following steps:

1) Establishment of possible scenarios (e.g. population growth, impact of climate change, performance of water infrastructure
2) Risk assessment for the scenarios, e.g. by fault tree analysis for events and corresponding consequence analysis
3) Calculation of water system metabolism, e.g. resource flow, emissions and the associated life-cycle impact on the environment
4) Tools for prioritizing alternative interventions

Methods and tools for this procedure has been developed in TRUST and are explained in parallel presentations

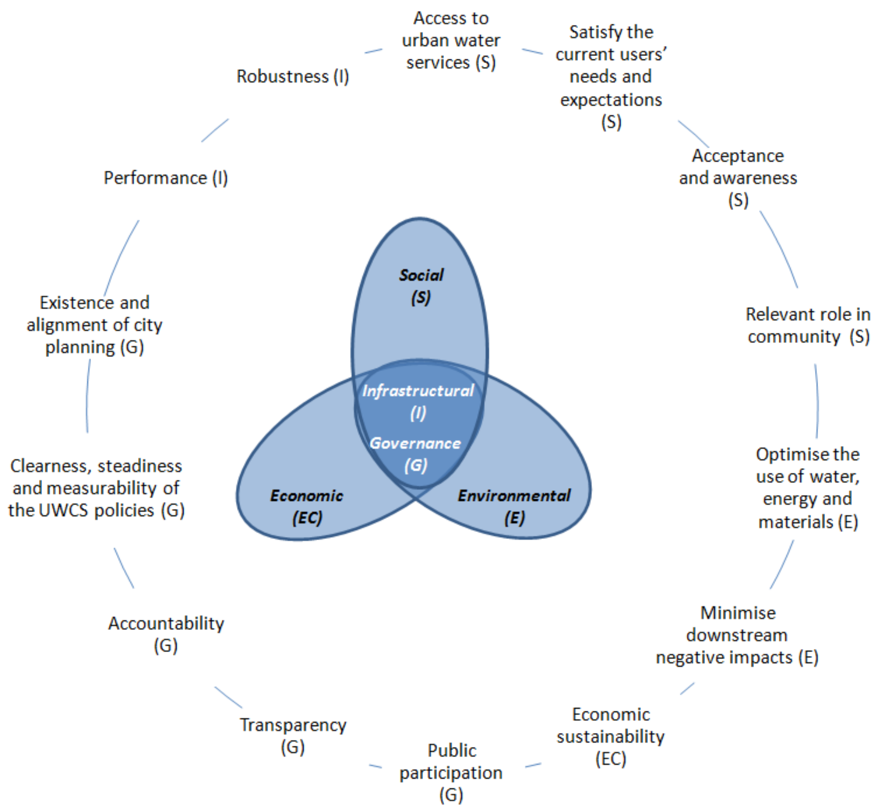

Figure 1 Dimensions and objectives in urban water cycle sustainability

Table 1: Dimensions, objectives and criteria of the UWCS sustainability (example)

DIMENSIONS	OBJECTIVES	CRITERIA	METRICS
Social	Effectively satisfy the current users needs and expectations	Quality of service	Interruptions, drinking water quality, flooding of properties
Environment	Optimise the use of water, energy and materials	Efficient use of water	Leakage, leakage best practices, reclaimed water, use of grey water, rainwater harvesting
Economic	Ensure economic sustainability of the UWS	Investment	Innovation, maintenance and replacement of assets
Governance	Transparency	Availability of information and documents	Check list of best practises
Infrastructure	Robustness	Reliability	Replacement/rehabilitation, storage capacity, treatment utilisation

Metabolism-modelling approaches support long-term sustainability assessment of urban water service. Scenario 2040 for Oslo as model city

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Keywords: Urban water services, Sustainability assessment Key performance indicators, mass-balance based modelling, WaterMet2 model, TRUST, Dynamic Metabolism Model

Extended abstract

There is a large need for a holistic long-term sustainability approach in decision-making in water and wastewater utilities. Models of the urban water system metabolism may be a useful instrument for the analysis of needed resources and discharges for to-days situation and alternative development patterns. Two supplementary approaches to urban water metabolism have been developed and tested in TRUST, the WaterMet2 and the Dynamic Metabolism Model (DMM). The testing, which have taken place in Oslo, have shown a high potential to support assessment of sustainability in to-days solutions and with regard to directions towards the future. More tests have recently been conducted in Reggio Emilia, Italy.

The models defines likely risk-motivated scenarios and utilises selected metrics/indicators to provide an understanding of the impact of alternative interventions to meet the scenarios towards a time horizon that in the TRUST case has been selected to 2040. The scenarios addressed are population growth, impact of climate change, degradation of infrastructure and increased requirement of service level. A corresponding list of possible interventions to address the scenarios has been developed.

The assessment of metabolism connected with the scenarios and intervention options form a basis for choices/selections which utilities would like to make depending on their priorities, targets and benchmarks they would set for themselves. There are differences in WM2 and DMM, which make them useful in different contexts – situational, circumstantial etc. WM2 offers different spatial and temporal resolutions, and is thereby useful in contexts where utilities would like to focus on sub-catchments within the city to understand and solve specific problems. DMM is based on conventional resource-flow analysis and presents annually-aggregated values for the entire urban water system, though it is possible to derive corresponding indicators for the individual sub-systems as well.

Both models have been tested for an environment inspired by the situation in Oslo. Still the results does not comply completely with the rationale for decisions in this city, they are rather generic examples of typical outputs from this type of analysis.

The relevant interventions analysed are shown in table 1. They include water supply (upstream) and wastewater systems (downstream)

Table 1. Relevant interventions analysed

INTERVENTION	SCALE
Water supply	
a. Reduction in per-capita demand	% reduction
b. Reduction of network leakages	% reduction
c. Installation of microturbines upstream	50 m head, 22 Mm3, turbine efficiency 90%
d. New raw water source	
Wastewater	
e. Upgrading and changes to wastewater transportation system	Increase rehab rate from 1,3% in 2016 to 1,6% in 2014
f. Upgrading and investments at sewer treatment plant	Investments, depreciated over 30 years

Figure 1 presents results obtained from the models by calculations of the different interventions or combinations of interventions. Changes in operational and maintenance procedures or process improvements may lead to a reduction in GHG emissions

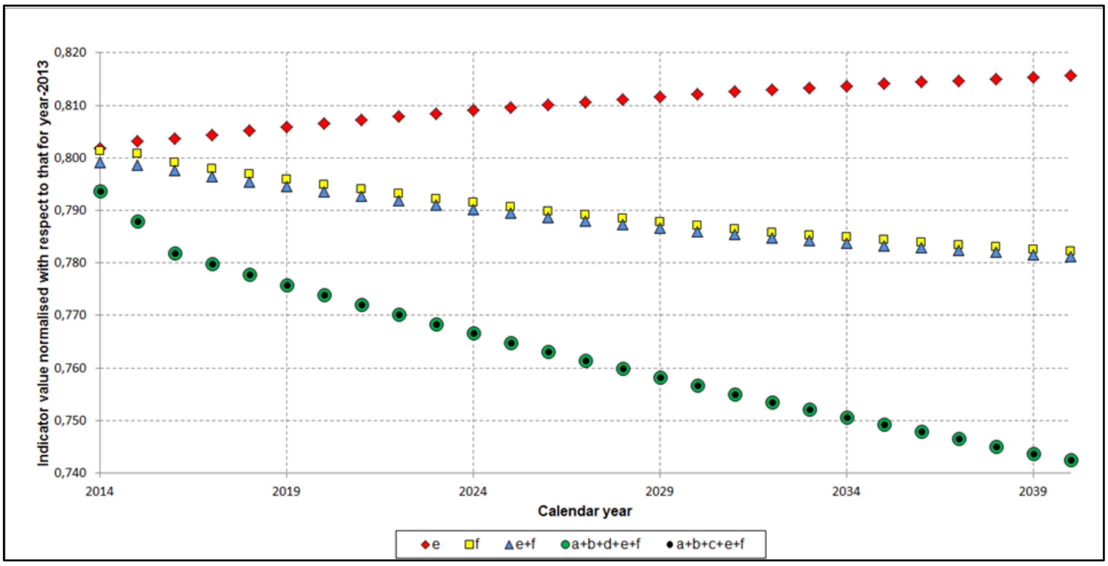

Figure 1: Change in GHG emissions per capita ('e', 'f', 'e+f', 'a+b+c+e+f' and 'a+b+d+e+f')

It can be seen that the greatest reduction in specific GHG emissions occurs in the two grand upstream-downstream combinations, a+b+c+e+f and a+b+d+e+f. The trends for both these combinations are exactly the same and they overlap each other in Figure 1. However, the capital expenses in the case of the former are much less than in the case of the latter. Thus, if the purpose is just to bring down the specific GHG emissions as much as possible, then the utility would go for the combination a+b+c+e+f. However, other development goals may compromise this solution.

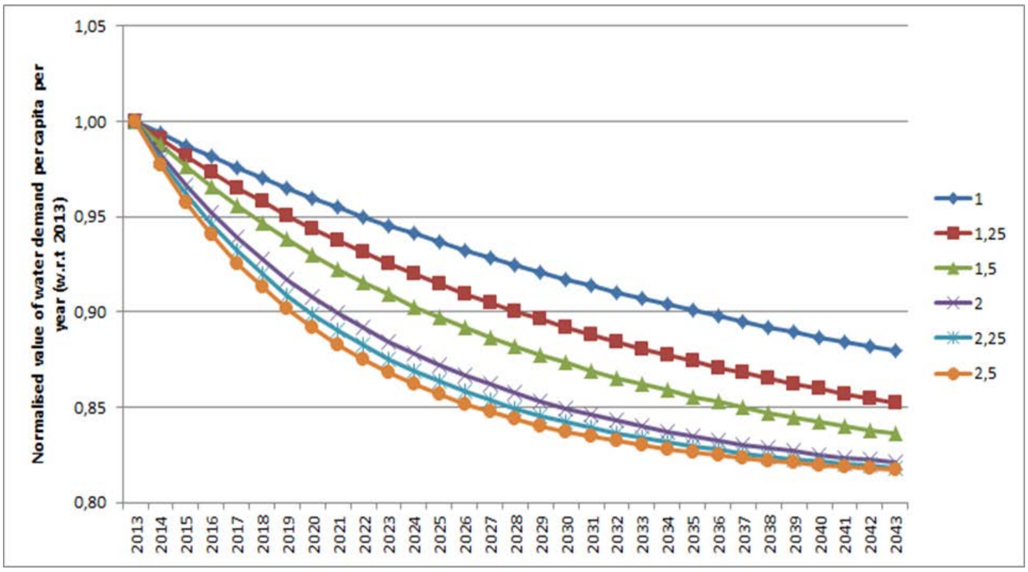

Figure 2: Intervention 'g' - Effect of degrees of rehabilitation on the water demand per capita per year, in the water distribution system (Each line represents one particular annual rehabilitation percentage).

From Figure 1 we can see that implementation of intervention e on water network rehabilitation isolated seen will increase the GHG emission. This is intuitive, since this activity will mobilise the use of energy. However, the reason for rehabilitation is not reduction of GHG, but to maintain or rather improve the performance of the network. Figure 2 shows the impact of rehabilitation on water demand. This is further outlined in Figure 3, which shows the effect of degrees of rehabilitation on the annual capital expenditure. It can be seen that for a high rehab rate, the cost saving will appear only after several years.

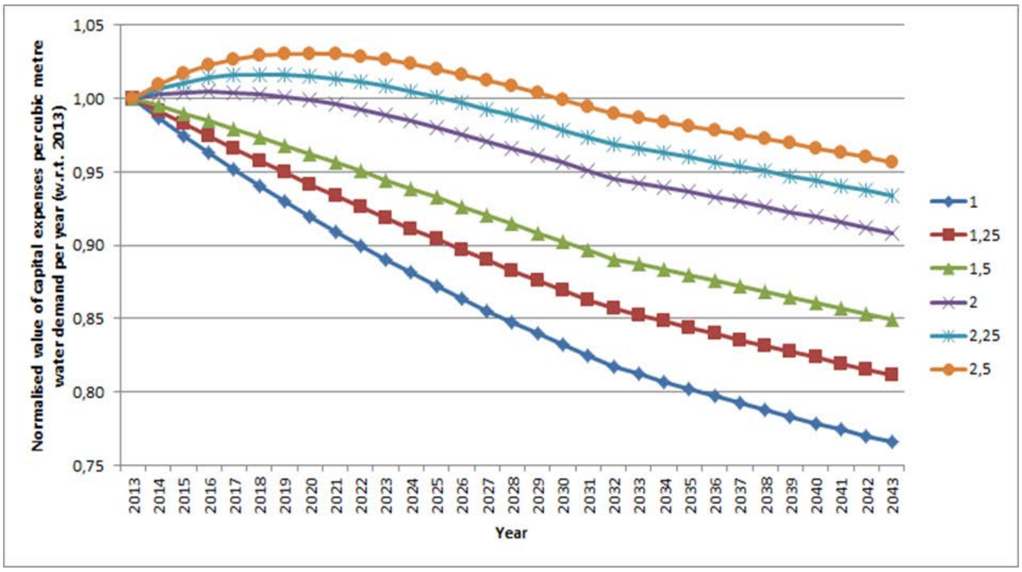

Figure 3: Effect of degrees of rehabilitation on annual capital expenditure per cubic metre water demand in the water distribution system. (Each line represents one particular annual rehabilitation percentage).

The outcome of the calculations is summarized in table 2. Here the effect of leakage reduction by rehabilitation on the use of treatment chemicals becomes evident. A rise in the rehabilitation rate from 1% to 2.5% has conspicuous impact on the relative value of this indicator in year 2040.

Table 2: Relative values in year-2040 for selected systemic indicators to demonstrate the effect of rehabilitation and consequent leakage reduction in water pipelines (normalized with respect to 2013)

INDICATOR FOR THE WHOLE SYSTEM	REHABILITATION RATE IN %					
	1%	1.25%	1.5%	2%	2.25%	2.5%
GHG emissions per capita (CO2e kg)	0.944	0.928	0.918	0.908	0.905	0.904
Total energy consumption per capita (kWh)	0.86	0.833	0.817	0.801	0.798	0.796
GHG emissions per cubic metre demand (CO2e kg)	1.073	1.088	1.097	1.105	1.105	1.105
Total treatment chemicals per capita (kg)	0.822	0.8	0.787	0.775	0.773	0.772

Reference: TRUST D34.2 Scenario 2040 for Oslo as model city; G Venkatesh, S Sægrov and H Brattebø, October 2014.

Policy Guidance Material for the transition to sustainable urban water cycle services of tomorrow – A handbook for policy makers

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Keywords: urban water governance, water policies, strategic plan, sustainability

How to facilitate change towards sustainable urabn water management?

Policy makers are challenged with rising and emerging change pressures on traditional urban water management practices and infrastructures. Changing social, economic and environmental patterns will affect the urban water services of tomorrow - the backbone of our society. With a no-change vision, urban water services fall into severe risk of collapse in the medium or long term in many countries of the world where they are currently taken for granted. Transition processes to sustainable urban water services are adaptation measures beyond infrastructural changes. Coping with future uncertainties and increasing challenges requires sustainable urban water governance practices facilitating the ability to change.

Informed policy makers drive the transition process

The Policy Guidance Material (PGM) of trust is intended to provide policy makers with information and assistance for shaping the transition towards sustainable urban water services of tomorrow.

The PGM: Guidance Material for Policy Makers

The PGM assists policy makers in designing and refining strategic plans for sustainable urban water management. Statements of relevant government, ministry and regulator representatives across Europe provide insights into current thinking around desirable urban water futures and remaining institutional barriers. Analysis of existing water policies and strategic plans revealed the importance of visioning the desired state contributing to the definition of objectives (van der Zouwen et al., 2012), the need to assess of the current state of sustainability and for refined consideration of future uncertainties. This guide highlights aspects of effective institutional frameworks (van de Meene & Brown, 2009) the trust sustainability assessment framework (Alegre et al., 2013), financial sustainability and the general principles of resilience, flexibility and adaptivity in terms of urban water systems to support decisions on the selection of appropriate technology options and network configurations. The proposed guideline on strategic planning is aimed to assist policy makers in designing transition pathways in non-conventional ways, exploring the potential of multi-stakeholder expertise, communication and interactive supporting self-assessment tools and a roadmap guideline (Hein et al. 2012) developed within trust being innovative instruments (Figure 2) to assists in different stages of decision making processes at different institutional levels.

Key messages for policy makers

To achieve sustainable urban water services, it is essential:

- to consider diverse views and interests: integrated planning of water services - broad stakeholder participation,
- to have a long term vision of the service,
- to take into account all dimensions of sustainability,
- to consider the complexity of the system and interdependencies with other natural and anthropogenic systems (Pahl-Wost et al. 2007),
- to gain experience from considering past decisions (Pahl-Wost et al. 2007),
- to consider future uncertainties and the limits of predictability,
- to ensure that service objectives and targets are permanently met in the transition path while implementation and adaptation of objectives.

trust

Figure 1 The trust Policy Guidance Material as ebook.

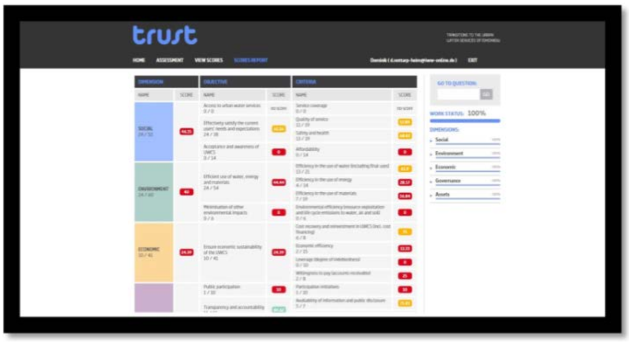

Figure 2 Web based TRUST sustainability self-assessment tool. The policy guidance material provides access to the innovative interactive decision support tools, developed within trust (Alegre et al. 2013).

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Cost effective inline condition assessment of water pipelines

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Keywords: Inline condition assessment, cost-effective rehabilitation.

Introduction

Reliable condition assessment of water distribution and district heating pipelines has a major effect on the cost-effective management of buried infrastructure. Identifying pipes in good condition is as important as identifying those that are structurally poor, as significant direct and social costs can be saved by delaying rehabilitation and focussing efforts elsewhere. In an age of ever-increasing population and environmental change, resource sustainability is vital and optimum maintenance of utility networks means less material waste and fewer carbon dioxide emissions whilst maintaining high levels of service.

As a partner in the European Commission-funded *TRUST* project, the SME Breivoll Inspection Technologies (BIT) compiled a detailed report on system development, method applicability and pipeline condition data for modelling purposes. Using its *PipeScanner* and patented Acoustic Resonance Technology (ART), BIT has inspected over 63km of water and district heating pipelines (or some 10500 pipe segments) in various European countries. Each inspection provides high resolution data on pipe thickness, pipe topography and both internal and external corrosion. The *PipeScanner* can pass through water filled metallic pipes from 300-600mm in diameter without the need for prior cleaning.

Art and the pipescanner

Acoustic resonance technology is a proprietary technology developed by DNV and licensed to BIT for buried water pipes. An array of transducers send out acoustic pulses and the resulting resonance tails are analysed to give the thickness, distance from the transducers and distinguish internal and external corrosion (fig 1.1). The *PipeScanner* is inserted into a pipe via a hatch or special entry pipe and can scan for up to 750m in each direction.

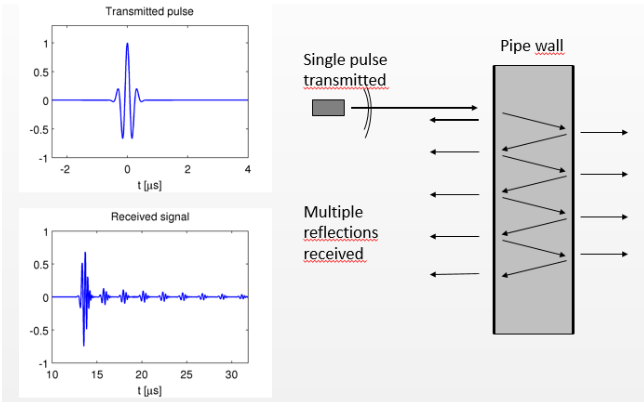

Figure 1. ART principal

Inspection results

The raw data are processed using PARS (Pipe Analysis and Reporting System) and three main plots are produced (fig 1.2). Of particular importance, is the continuous nature of the inspection allowing detailed measurement at the pipe segment (typically 4-6m) level. Often there are significant variations in thickness and levels of corrosion from segment to segment or even within the same segment. This may be because of production variance or localised environmental conditions.

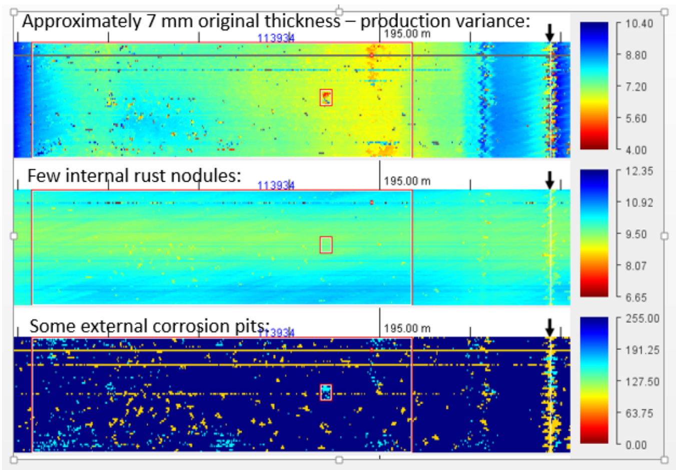

Figure 2. PARS scanning plots (thickness, distance and pitting)

Cost effectiveness

Direct cost savings from online inspection fall under two categories – costs saved because of avoided failures (*i.e.* spotting critical weaknesses) and costs saved because some pipes are in a much better condition than expected and rehabilitation can be deferred by many years. Oslo VAV, BIT's largest client with over 27km of inspections, produced a breakdown on savings based on the results provided by BIT (fig 1.3). Besides the direct costs, savings from indirect or social costs (*e.g.* damage and disruption) can be significant and by only replacing pipes that need replacing, the environmental impact is reduced.

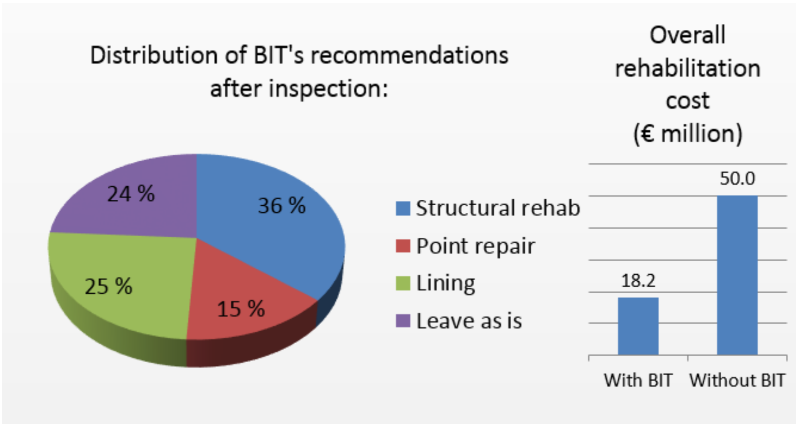

Figure 3. Cost savings example (Oslo VAV)

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5.2 Governing and Financing Urban Water Services

Scenario planning and long term investment planning for drinking water company for the year 2050.

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Keywords: asset management, investment planning, scenario planning, transition

Introduction

Evides water company supplies drinking water to 2.5 million consumers in the southern part of the province of Zuid-Holland and Zeeland in the Netherlands. In addition Evides Industry Water provides water solutions to large industrial clients in the Netherlands, Belgium, Germany and China. The drinking water is produced at ten production plants, with an annual production of 160 million m^3/year and transported to the drinking water clients along 14,000 km of pipelines.

Back ground

In the “60 and “70 the water company developed quickly. The increase in drinking water consumption resulted in mayor investments in drinking water treatment plants and pipeline infrastructure. These assets have a limited life span. This results in decisions about investments in these assets in the next 5 to 10 years. Do we continue with the current proven technology or do we want to renew the technology and assets. Making the right choices is important because the investments are substantial and have a long term technical and financial impact.

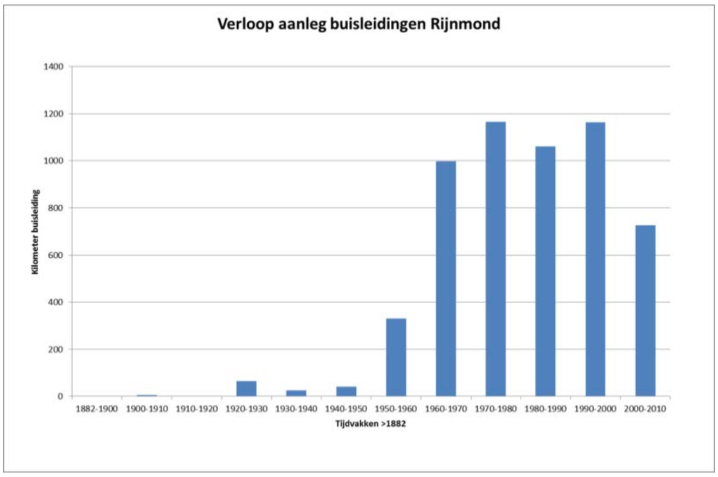

Figure 1. Pipeline infrastructure construction over the years.

Material and Methods

In the project Evides 2050 scenario planning techniques were used to compose four possible futures. These techniques consist of assessing trends based on their predictability and impact, leading to selection of two main trends which will impact the future. In our case this results in four scenarios which differ in the factors abundance versus scarcity and in strong presence of the government versus low involvement by the government.

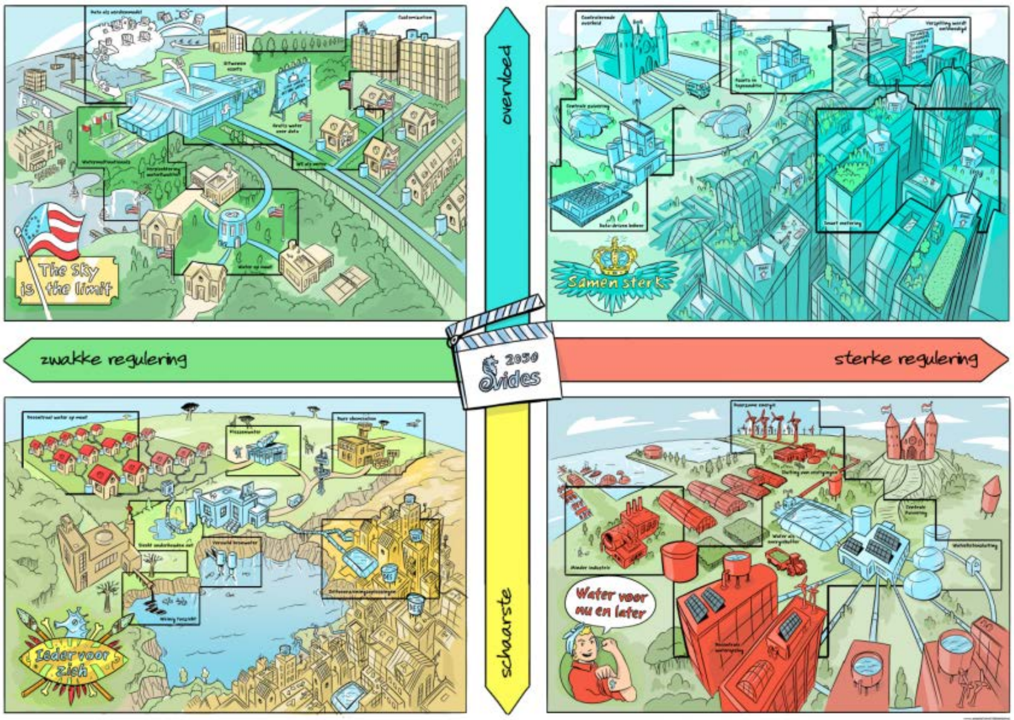

Figure 2 Illustration of the four scenario's made for the project E2050

These scenarios are used to determine which parts of the current system and policies are sustainable for the future developments and which are not. Each part of the system and the policies are reviewed in each of the four scenario's. This gives an overview of the sustainable aspects of the current organisation and which aspects must be changed.

This "stress test" gives input for the decisions about the long term investment planning.

Results and Conclusions

Due to the work performed, alignment of the long term investment plan with the strategic options for the future can be presented. In this way the effect of strategic choices and technical implementation can be translated into a financial foresight, making it possible to plan ahead for major investments.

Trends and developments will be monitored. Relevant early warnings are indicators that certain trend will or will not develop as foreseen. This gives the opportunity to reconsider the foreseen decisions about investments.

The first version of the long term asset management plan is based on the 1 to 1 replacement of all current assets at the end of their technical life time. This implies the system of production sites and underground infrastructure does not change over time.

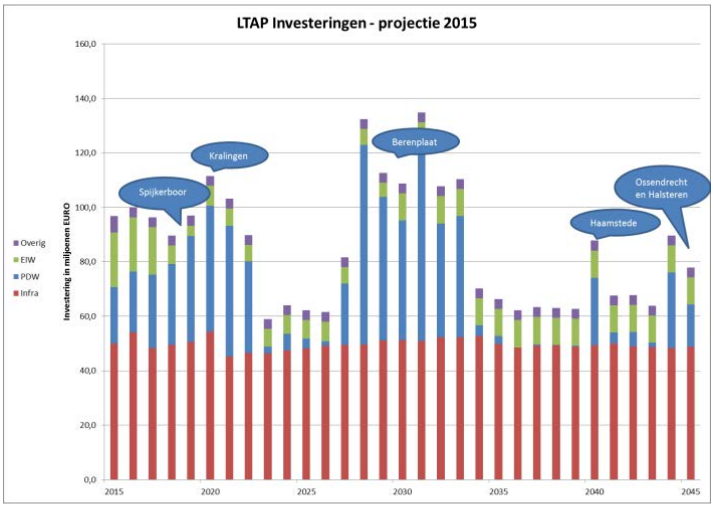

Figure 3. Long term investment plan for the period 2015 – 2045, with starting point 1:1 replacement of capacity.

However, in the parallel project Evides 2050 scenario planning was used to foresee which challenges the future holds for the water sector. In the next months the current LTAP (as shown in figure 1) will be matched with the foreseen developments. This might result in a different outcome of the long term investment plan. For example when the scenario's show that small scale productions sites are more suitable in a scenario, the large investments will be spread over several smaller investments.

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A tool to design efficient and fair water tariffs for Urban Water Services

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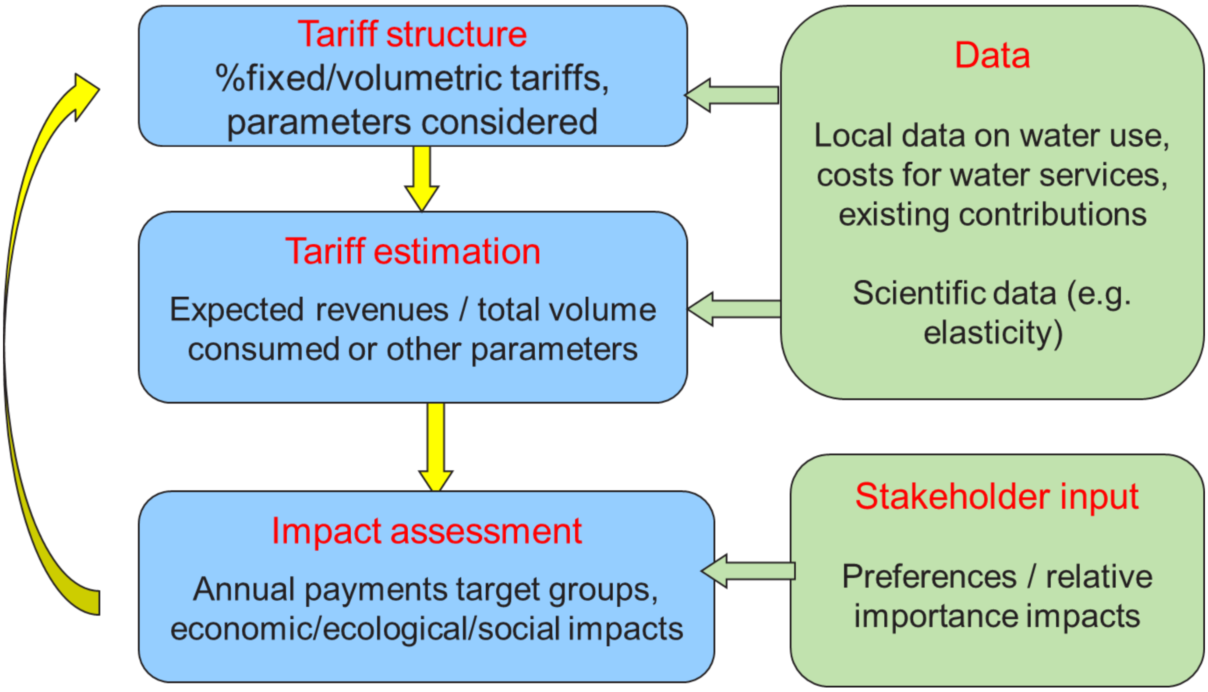
Keywords: sustainable water management, financing, water tariffs, affordability, cost recovery, WFD

Abstract

At the request of the major public and private stakeholders in Flanders, Belgium, Vito developed a tool to assess impacts of alternative tariff structures. As the costs for water services are dominated by fixed costs, and largely driven by peak demand or discharge, an efficient and fair recovery of these costs requires a careful design of water tariffs. A delicate balance is required between economic aspects (cost recovery and administrative costs), ecological aspects (incentives for an efficient use of water services) and social aspects (a fair and affordable water bill for the different groups of users). This tool is used by stakeholders for the review of tariff structures for urban water services (drinking water supply and water sanitation).

The method uses a stepwise, quantitative assessment (figure 1). The starting point is the definition of alternative tariff scenarios, with different mixes of fixed and volumetric tariffs and different parameters to be used for billing (one block vs. multiple block tariffs, size households, social correction mechanisms, ...). In a next step it is assessed how the actual tariffs change due to the alternative tariff structure. Starting from the assumption of a budget neutral total revenue stream or a predefined increase of revenues, tariffs can be derived from very detailed information on the composition of consumers (amount of households and residents, enterprises), their water uses and their annual payments. This is performed on the level of individual water companies. Once tariffs are estimated, the impact on the annual payments by specific target groups (e.g. 1-person or 5-person households) can be estimated. Specific indicators include sensitivity of cost recovery to water savings or long term evolutions in households composition (economy), marginal prices and incentives

to perform water savings (ecology), the relative differences in annual payments between small and large households and between regions and the impact on household expenditures for low income categories (social).



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5.3 Planning Future Urban Water Services - Strategies & Tools

Smart Water Distribution System: The Etxebarri Case Study

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Keywords: Smart Water Distribution, Network efficiency, Leakage detection.

Abstract

This paper presents how the efficiency of a water distribution network can be assessed and improved by using smart metering technology and model-based simulation. Consorcio de Aguas Bilbao Bizkaia (CABB) water utility is leading a demonstrative case study for the audit of the networks. They are deploying 20,000 smart meters in Etxebarri, so that a full water balance analysis can be completed. During 2013, the Infrastructure Leakage Index (ILI) in Etxebarri has been 11.92 on average. The objective is to achieve values lower than 7. On this effort, a new modelling-based approach has shown to be useful. It consists of computing the correlation between the Fault Indicator Vector and the Fault Signal Matrix (FSM). The former represents the real leakages measured in the system while the former evaluates how the pressure distribution would be when applying leakages at different points. The correlation presents high values when the FSM correctly resembles the real leakages. A simulation example has shown that the method presents consistent results when an important leakage is to be localized.

Introduction

Water scarcity is becoming one of the main problems in Europe. The increasing water demand together with the effects of the climate change is provoking lower water levels in lakes and reservoirs. The water utilities, the water industry, and the water consumers are called to make a more responsible and efficient use of water.

The Water Framework Directive (WFD) has as an ultimate objective to achieve a good ecological status of surface, coastal and groundwater. On this purpose, several articles demand the implementation of new instruments and ICT tools for improving the water quality and the water services. The water utilities provide fresh water to municipalities taking care of the water bodies and treating the water back to the medium. They are also called to make an efficient use of water and to reduce the water losses to the minimum. Water loss represents a major fraction of non-revenue water (NRW): more than 65% of NRW arises from unauthorized water consumption, meter inaccuracies and leaks from the water mains source-to-taps infrastructure (IWA, 2000).

The use of smart monitoring systems together with modelling tools has a great potential to assist water utilities in the localization and assessment of water losses. In this sense, Mandel (1998) and Almandoz et al. (2005) presented a direct approach based on the water network simulation. An alternative inverse approach consists of formulating leakage detection as a parameter estimation problem (Pudar and Liget, 1992; Ligget and Chen, 1995; Kapelan et al., 2003; Wu and Sage, 2006). Other approaches based on data-driven methods have also been analyzed. They include methods as the one in Romano et al. (2013) or the decision support systems as TaKaDu (Armon et al., 2011).

This paper presents the application of advanced mathematical methods (Meseguer et al., 2014; Quevedo et al., 2011) for the assessment and localization of the leakages in Etxebarri Case Study.

The Etxebarri Case Study

The Etxebarri Case Study is analyzed as a pilot experiment for improving the water network management in the short-term and long-term perspective.

Etxebarri Case Study

The paper presents the results of a first full-scale application of Smart Water Distribution (SWD) techniques. The pilot covers an area of 3,26 km and a population of 9,171 inhabitants distributed in five neighborhoods and an one industrial area. Figure 1 shows an scheme of the water distribution network provided by the water utility Consorcio de Aguas de Bilbao Bizkaia (CABB).

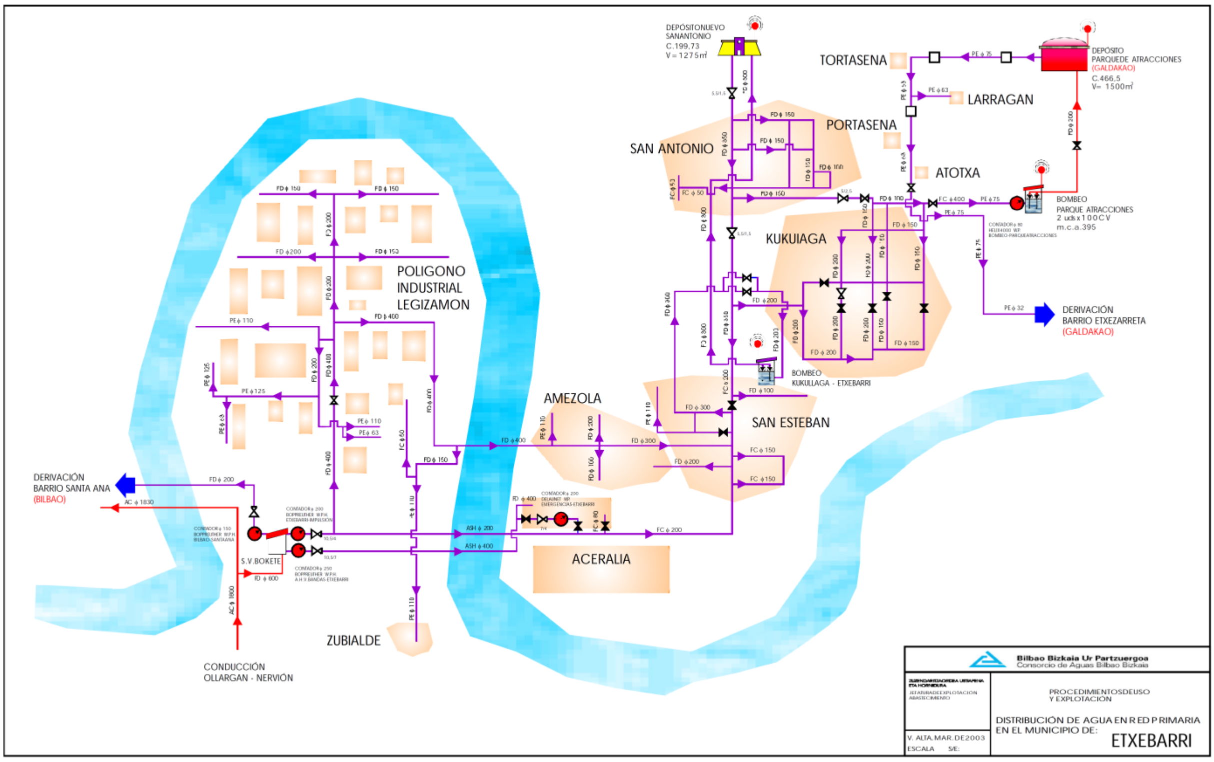

Figure 1: Scheme of the Water Distribution Network in Etxebarri (Biscay, Spain) provided by the CABB water utility

Smart Metering Technology

The CABB water utility is deploying a Smart Water Infrastructure composed by: smart meters, accumulators and repeaters (to characterize the water demand); a set of water flow meters and pressure regulating valves (to characterize the water network). Figure 2 shows, as an example, the type of smart meters being deployed. The monitoring system tracks in real time the network performance thanks to the real time communication system of the new devices.

Figure 2: Itron smart meters: Model Flodis (left) and Flostar M (right), communicated by radio with the water utility.

The deployment of this technology represents an important improvement from the current status in other municipalities where meters are “walk by”. In these cases, the meters are read once every three months and the measurements of 30% of them are estimated.

Materials and methods

This section shows the methodologies and techniques used to evaluate the efficiency of the Etxebarri Water Network which combine the analysis of in-site monitoring data and the results of modeling simulation tools. The Etxebarri Case Study has been modeled using EPANET 2.0 software (EPA 2000).

Assessment of the water network efficiency

Leakage detection and remediation has been encouraged by international associations (AWWA 1999, IWA 2000) and it is on the agenda of most of the water utilities in Europe. The system performance evaluation is generally made by completing the water balance equations that generally is based on the terms shown in Table 1.

Table 1: Main components proposed in water audits for the assessment of the network efficiency

FLOW RATE ENTERING THE SYSTEM	AUTHORIZED CONSUMPTION	BILLED AUTHORIZED CONSUMPTION	BILLED METERED CONSUMPTION
			Billed Unmetered Consumption
		Unbilled Authorized Consumption	Unbilled Metered Consumption
			Unbilled Unmetered Consumption
	Water Losses	Apparent Losses	Unauthorized Consumption
			Customer Meter Inaccuracies and data handling Errors
		Current Annual Real Losses (CARL)	Leakage and Overflows from the Utilities Storage Tanks
			Leakage on Transmission and Distribution Mains
			Leakage on Service Connections up to the Customer Meter

The Infrastructure Leakage Index (ILI), defined by the International Water Association (IWA) has become a standard for technical water audits. The ILI is defined as (Eq. 1) the Current Annual Real Losses (CARL) divided by the Unavoidable Annual Real Losses (UARL) which implies going into the lowest level of detail in Table 1. Note that UARL are the lowest technically achievable annual real losses for a well-maintained well-managed system and is the likely lower bound on water losses.

$$ILI = \frac{CARL}{UARL} \qquad \text{Equation 1}$$

The equation used for the evaluation of the *UARL* is (Eq. 2):

$$UARL = (18 \times Lm + 0.8 \times Nc + 25 \times Lp) \times P/86400$$ Equation 2

where:

Lm is the length of the network (*km*)

Nc is the number of supply connections

Lp is the length of private supply connections (*km*)

P is the average network pressure (*meter of column of water*)

Model-based leakage localization methodology

The model-based leakage localization method follows the methodology presented by Mesenguer et al. (2014). The leakage detection procedure is performed by comparing pressure data of certain network nodes with their estimation using the simulation of the mathematical model.

The methodology defines a *binary fault indicator vector,* ϕ (Eq. 3) that compares the ideal simulated network without losses with the real measurements:

$$\emptyset k = \begin{pmatrix} p1(k) & \hat{p}_{10}(k) \\ \vdots & \vdots \\ p_{ns}(k) & \hat{p}_{ns0}(k) \end{pmatrix}$$ Equation 3

where p_i is the pressure associated with the pressure sensor *i* and $\widehat{p_{\iota 0}}$ is the predicted pressure value associated the pressure sensor *i* under a scenario of free leaks.

The theoretical *Fault Signature Matrix*, *FSM(k)*, represents the theoretical pressure disturbances caused by all potential leaks and has as many rows as inner pressure sensors, *ns*, and as many columns as potential leaks, *np*. The *FSM(k)* represents the sensitivity matrix of the system and is computed as (Eq. 4):

$$FSM(k) = \begin{pmatrix} \frac{\hat{p}_{1f_1}(k) - \hat{p}_{10}(k)}{f} & \cdots & \frac{\hat{p}_{1f_{np}}(k) - \hat{p}_{10}(k)}{f} \\ \vdots & \ddots & \vdots \\ \frac{\hat{p}_{nsf_1}(k) - \hat{p}_{10}(k)}{f} & \cdots & \frac{\hat{p}_{nsf_{np}}(k) - \hat{p}_{ns0}(k)}{f} \end{pmatrix} \quad \text{Equation 4}$$

where $\widehat{p_{\iota f J}}$ is the predicted pressure associated with pressure sensor *i* when a nominal leak of size f is forced in node j and $\widehat{p_{\iota 0}}$ is the predicted pressure associated with the pressure sensor *i* under a scenario free of leaks.

Once, the ϕ_κ *vector and FSM(k)* are computed, the correlation matrix in Eq. 5 will detect the potential leaks since those locations in the net will show the strongest correlation with their simulated counterparts. In other words, those potential leaks whose theoretical signatures (columns of *FSM(k)*) have the biggest correlation values with the fault indicator vector ϕ_κ point out the most probable nodes to have leaks.

$$\max(\rho_{\emptyset,FSMj}(k), \qquad j = 1, \dots, np \quad \text{Equation 5}$$

where $\rho_{\emptyset,FSMj}(k)$ is the obtained correlation between the fault indicator vector, ϕ_κ and the *jth* column of the theoretical fault signature matrix, *FSMj*, associated with a potential leak in *j*.

Results

Evaluation of Etxebarri Network Efficiency: Definition of the baseline

The Consorcio de Aguas Bilbao Bizkaia (CABB) has measured different indicators in the Etxebarri Case Study. As a baseline of the study, the network efficiency was assessed by evaluating the network mass balance in 2013. Figure 3 shows the Infrastructure Leakage Index (ILI). It can be seen that the ILI values varies between 10 and 12.

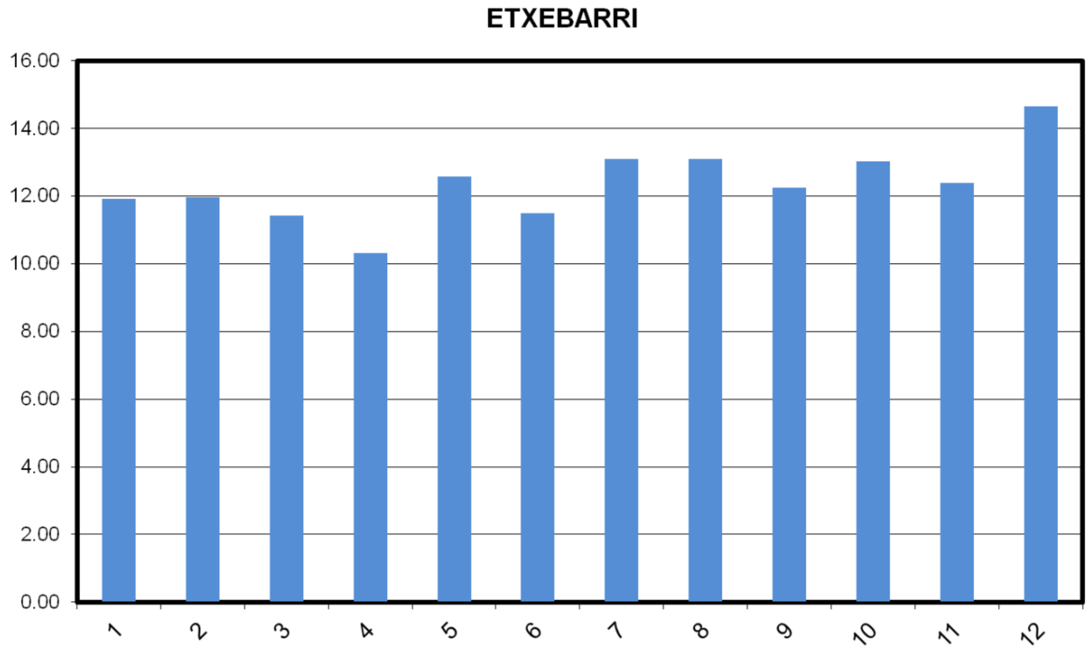

Figure 3: Infrastructure Leakage Index registered in 2013 at Etxebarri Case Study by the CABB water utility

The yearly average values of the network are shown in Table 2. Note that the average computed ILI is 11,92. The CABB has the objective of having ILI values lower than 7, by employing smart meter technology and improving the leakage detection system.

Table 2: Etxebarri average efficiency indicators in 2013, provided by Consorcio de Aguas Bilbao Bizkaia (CABB)

ETXEBARRI	L	NC	LP	P	UARL	RT	ILI
	30,12	722	4,38	64,4221	0,92	62,21%	11,92

Hydraulic simulation model of Etxebarri Case Study

The Etxebarri Case Study has been implemented in EPANET 2.0 open software. Figure 4 shows the simulation outlook, and outlines the four main consumption patterns identified in the town (Figure 5).

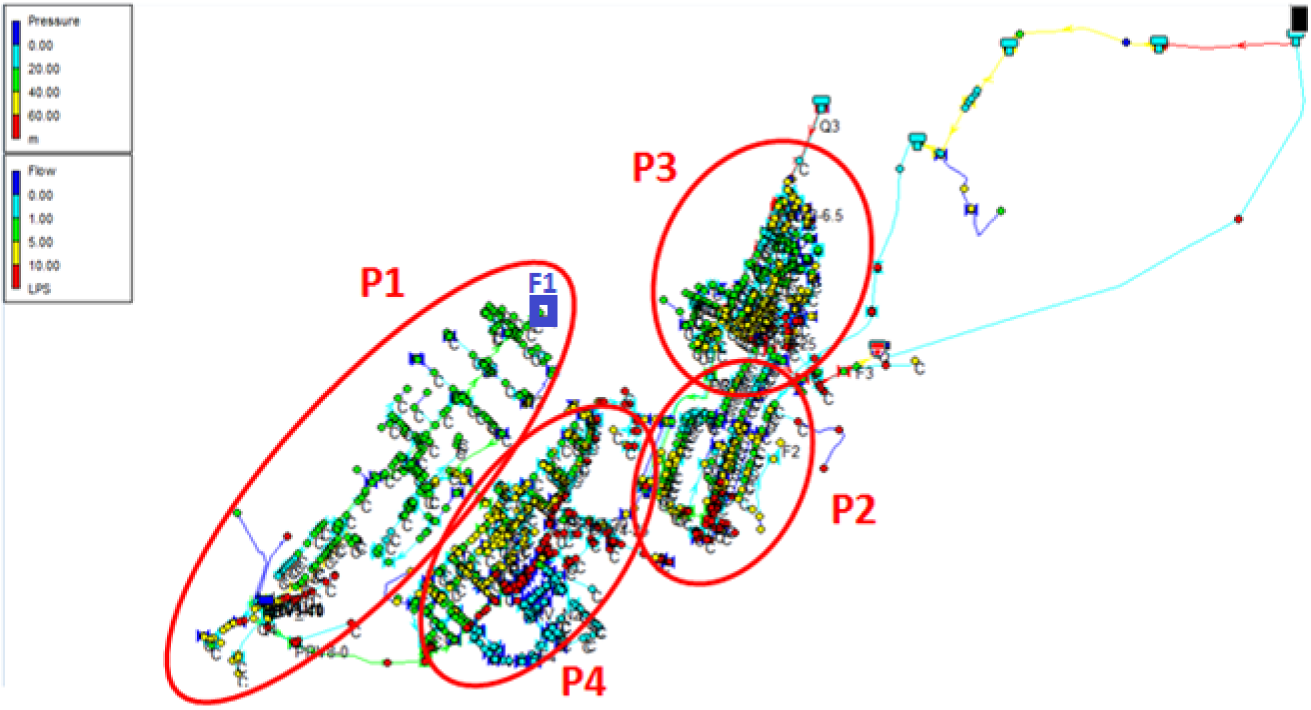

Figure 4: Etxebarri Case Study simulation in EPANET 2.0 (EPA, 2000) with the four main consumption patterns (P1, P2, P3 and P4).

The consumption patterns at Etxebarri Case Study are shown in Figure 5. It can be easily seen the different behavior of the four different areas: P1 for example shows a more smooth pattern corresponding to regular activity of an industrial area while Patter 2 and Pattern 3 correspond to small neighborhoods with a predominant domestic consumption.

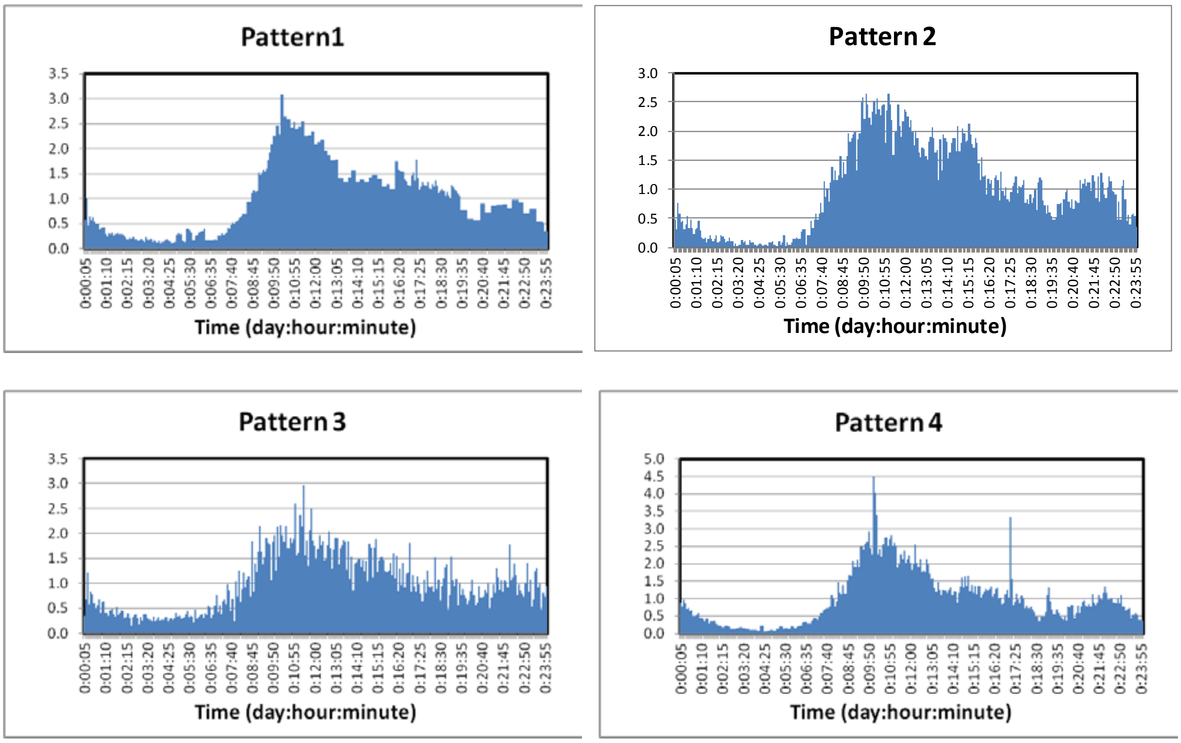

Figure 5: Consumption patterns of Etxebarri (Pattern 1, Pattern 2, Pattern 3, and Pattern 4)

The EPANET software performs well and is generally used for the operation of the network. As an example, Figure 6 shows the water consumption pattern (green curve) and the water supply profile (red curve) during an average day. It can be seen that the Night Flow Analysis shows that around 9.5 l/s are lost in leakages.

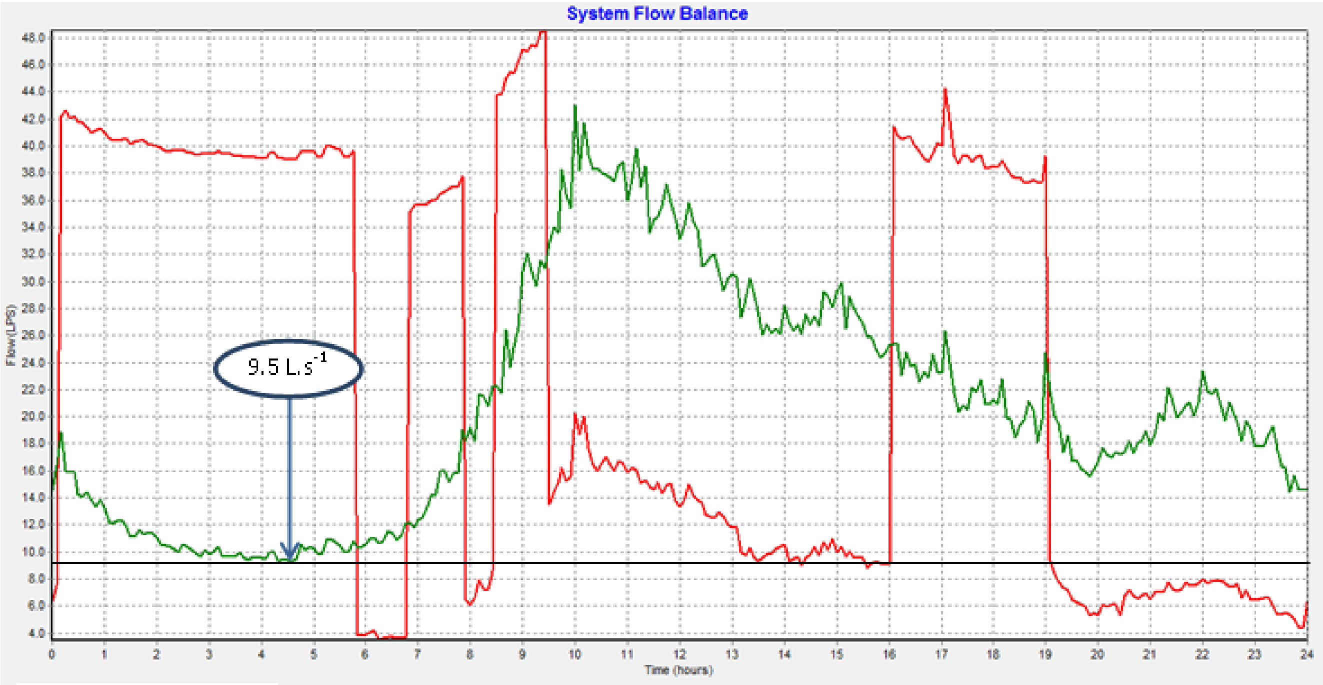

Figure 6: Flow water demand and Etxebarri Case Study simulation in EPANET 2.0 (EPA, 2000)

Leakage detection system

The leakage detection system is verified in the Etxebarri network by simulating four leakages, one per pattern zone. Table 3 shows the simulated results. The column CF presents the pressure results in four nodes per pattern when the leakages are included; the column SF shows their counterparts without pressure. In the columns on the right we artificially simulate a leakage in node 213f-va, 1aee-b, 19e0-b or 16b0-b alternatively. The first conclusion is that the four consumption patterns correspond to four independent subsections of the network. For example, when a leakage is applied in Zone 3 (Pattern 3), the pressures in Zone 4 and Zone 1 (Pattern 4 and Pattern1) are affected, green in the table; while the pressures in Zone 2 (Pattern 2) are not affected, and shown in red in the table.

Model-based localization of the leakages is applied to determine where the leakage F1 (Figure 4) is. Table 4 shows the correlation matrix computed over the Fault Indicator Vector and the Fault Signal Matrix (Eq. 5). The Fault Indicator Vector (Eq.3) in computed in CF-SF column in Table 3, while the FSM is computed in Table 4. The correlation terms are shown in the last row of Table 4. Its maximum value (0.826) indicates that F1 is close to 213f-v2 node, which can be verified in the network topology (not clearly seen but available in Figure 4).

Table 3: Simulation results when applying simulated leakages in different zones of Zone 1, Zone 2, Zone 3 and Zone 4

	CF	SF	CF-SF	Zone 3 - Pattern 3				Zone 2 - Pattern 2				Zone 4 - Pattern 4				Zone 1 - Pattern 1			
				213f-v2	1aee-b	19e0-b	16b0-b	224d-v1	cc6-b	7207-b	475b-b	19a4-b	6b21-b	4f86-b	6ab7-b	463c-b	4b88-b	1281-a	2205-v2
Zone 3																			
213f-v2	22,42	24,76	-2,34	24,64	24,76	24,76	24,76	24,76	24,76	24,76	24,76	24,76	24,76	24,76	24,76	24,76	24,76	24,76	24,76
1aee-b	40,66	40,68	-0,02	40,68	40,64	40,68	40,68	40,67	40,67	40,67	40,67	40,68	40,68	40,68	40,68	40,68	40,68	40,68	40,68
19e0-b	34,92	34,96	-0,04	34,95	34,95	34,88	34,96	34,94	34,94	34,94	34,94	34,96	34,96	34,96	34,96	34,96	34,96	34,96	34,96
16b0-b	-0,42	-0,11	-0,31	-0,21	-0,21	-0,21	-0,21	-0,25	-0,25	-0,25	-0,25	-0,11	-0,11	-0,11	-0,11	-0,11	-0,11	-0,11	-0,11
Zone 2																			
224d-v1	56,45	56,49	-0,04	56,49	56,49	56,49	56,49	56,03	56,03	56,43	56,46	56,49	56,49	56,49	56,49	56,49	56,49	56,49	56,49
cc6-b	64,44	64,47	-0,03	64,47	64,47	64,47	64,47	64,31	64,31	64,41	64,44	64,47	64,47	64,47	64,47	64,47	64,47	64,47	64,47
7207-b	52,62	52,68	-0,06	52,68	52,68	52,68	52,68	52,62	52,62	52,62	52,65	52,68	52,68	52,68	52,68	52,68	52,68	52,68	52,68
475b-b	33,93	33,93	0	33,93	33,93	33,93	33,93	33,91	33,91	33,91	33,85	33,93	33,93	33,93	33,93	33,93	33,93	33,93	33,93
Zone 4																			
19a4-b	15,37	15,37	0	15,37	15,37	15,37	15,37	15,37	15,37	15,37	15,37	14,03	15,37	15,37	15,37	15,37	15,37	15,37	15,37
6b21-b	40,12	40,12	0	40,12	40,12	40,12	40,12	40,12	40,12	40,12	40,12	40,12	39,87	40	40	40,11	40,12	40,11	40,11
4f86-b	42,17	42,18	-0,01	42,18	42,18	42,18	42,18	42,18	42,18	42,18	42,18	42,18	42,06	42,05	42,05	42,17	42,17	42,17	42,16
6ab7-b	73,33	73,34	-0,01	73,34	73,34	73,34	73,34	73,34	73,34	73,34	73,34	73,1	73,34	73,34	73,34	73,34	73,34	73,34	73,34
Zone 1																			
463c-b	37,79	37,84	-0,05	37,84	37,84	37,84	37,84	37,84	37,84	37,84	37,84	37,84	37,82	37,82	37,82	37,74	37,83	37,83	37,83
4b88-b	36,74	36,74	0	36,74	36,74	36,74	36,74	36,74	36,74	36,74	36,74	36,74	36,73	36,73	36,73	36,73	36,42	36,73	36,73
1281-a	35,63	35,64	-0,01	35,64	35,64	35,64	35,64	35,64	35,64	35,64	35,64	35,64	35,62	35,62	35,62	35,63	35,63	35,15	35,62
2205-v2	41,92	41,92	0	41,92	41,92	41,92	41,92	41,92	41,92	41,92	41,92	41,92	41,9	41,9	41,9	41,92	41,92	41,91	41,81

Table 4: Correlation matrix between the Fault Indicator Vector and the Fault Signal Matrix

Zone 3 - Pattern 3				Zone 2 - Pattern 2				Zone 4 - Pattern 4				Zone 1 - Pattern 1			
213f-v2	1aee-b	19e0-b	16b0-b	224d-v1	cc6-b	7207-b	475b-b	19a4-b	6b21-b	4f86-b	6ab7-b	463c-b	4b88-b	1281-a	2205-v2
-0,12	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,00	-0,04	0,00	0,00	-0,01	-0,01	-0,01	-0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
-0,01	-0,01	-0,08	0,00	-0,02	-0,02	-0,02	-0,02	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
-0,10	-0,10	-0,10	-0,10	-0,14	-0,14	-0,14	-0,14	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,00	0,00	0,00	0,00	-0,46	-0,46	-0,06	-0,03	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,00	64,50	0,00	0,00	-0,16	-0,16	0,10	0,13	0,06	0,03	0,00	0,00	0,00	0,00	0,00	0,00
0,00	0,00	0,00	0,00	-0,06	-0,06	-0,06	-0,03	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,00	0,00	0,00	0,00	-0,02	-0,02	-0,02	-0,08	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-1,34	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,25	-0,12	-0,12	-0,01	0,00	-0,01	-0,01
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,12	-0,13	-0,13	-0,01	-0,01	-0,01	-0,02
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,24	0,00	0,00	0,00	0,00	0,00	0,00	0,00
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,02	-0,02	-0,02	-0,10	-0,01	-0,01	-0,01
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,01	-0,01	-0,01	-0,01	-0,32	-0,01	-0,01
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,02	-0,02	-0,02	-0,01	-0,01	-0,49	-0,02
0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,02	-0,02	-0,02	0,00	0,00	-0,01	-0,11
0,826	0,07	0,005	0,059	-0,08	-0,08	0,022	0,023	-0,09	-0,12	-0,15	-0,15	-0,09	-0,09	-0,09	-0,13

The consistency of the methodology to localize leakages is clear after seeing the numerical results. Further research will be carried out to identify new leakages in the other zones (corresponding to different consumption patterns).

Conclusions

This paper presents how the efficiency of a water distribution network can be assessed and improved by using smart metering technology and model-based simulation. Consorcio de Aguas Bilbao Bizkaia (CABB) water utility is leading a demonstrative case study for the audit of the networks. They are deploying 20,000 smart meters in Etxebarri, so that a full water balance analysis can be completed. During 2013, the Infrastructure Leakage Index (ILI) in Etxebarri has been 11.92 on average. The objective is to achieve values lower than 7. On this effort, a new modelling-based approach has shown to be useful. It consists of computing the correlation between the Fault Indicator Vector and the Fault Signal Matrix (FSM). The former represents the real leakages measured in the system while the former evaluates how the pressure distribution would be when applying leakages at different points. The correlation presents high values when the FSM correctly resembles the real leakages. A simulation example has shown that the method presents consistent results when an important leakage is to be localized.

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Holistic Water Cycle Approach for Assessing and Monitoring Greenhouse Gas Emissions in Water and Wastewater Utilities - Thailand, Mexico and Peru

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Keywords: Water utilities, urban water cycle, energy efficiency, greenhouse gas emissions, CO_2 balance, climate change mitigation, performance assessment.

Abstract

Introduction

With growing pressure on a more holistic urban water approach, balancing technical, environmental, economic, and social criteria, it becomes critical for water and wastewater utilities to take action towards energy efficiency and mitigating greenhouse gas (GHG) emissions.

Project

The project Water and Wastewater Companies for Climate Mitigation (WaCCliM), implemented by *Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ)* and *The International Water Association* (IWA) on behalf of the *German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety* (BMUB) is to use GHG reduction technologies to improve the carbon balance of water and wastewater utilities in Mexico, Peru and Thailand while maintaining or improving service levels. This paper discusses the tool that is being developed to assess the baseline and monitor the impact of the energy efficiency and GHG reduction measures.

Methodology

The urban water cycle components within the utility boundaries (Figure 1) are investigated. The starting point for improving GHG standards is to establish a GHG baseline. The project considers both direct emissions (scope 1) and indirect emissions (scope 2) according to current Greenhouse Protocol (WBCSD and WRI, 2004; IPCC, 2013). The method to estimate emissions in the project countries must be simple yet sound, overcoming limited data availability and data quality. Direct emissions are estimated based on the type of wastewater infrastructure and basic operations information. The energy consumption (indirect emissions) is estimated per component, comparing the values with a benchmark to identify both high consumption and inefficient components. Pre-identified components are further investigated to identify inefficiencies, while keeping in mind that components inside and outside the utility boundaries may also have an impact on efficiency and GHG emissions.

To address direct GHG emissions, the project team will look to develop new simple indicators to complement current GHG protocols, better benchmark reduction in GHG emissions, and help fill a significant gap in monitoring progress towards direct emissions reduction.

To assess the performance of each component as real consumed energy, performance indicators are required. The IWA indicators developed for water supply (Alegre et al., 2006) and wastewater services (Matos et al., 2003) are widely accepted. A subgroup of indicators, focused on energy consumption and the quality of service correlated with the energy used, are selected and complemented with new metrics whenever necessary. From that sub-set of indicators, key indicators are selected to monitor performance. Based on key indicators a value is estimated for each component and compared with baseline values.

Conclusions

A holistic approach, considering the whole urban water system's performance at the component scale, is critical for defining a representative baseline of water and wastewater utilities GHG emissions and their potential for being reduced. The results of the baseline study and indicators developed will make a significant contribution for optimizing water services and monitoring long term gains in terms of GHG mitigation. The assessment and monitoring methodology is intended to be further disseminated to utilities within each country, after having been tested in the pilot utilities.

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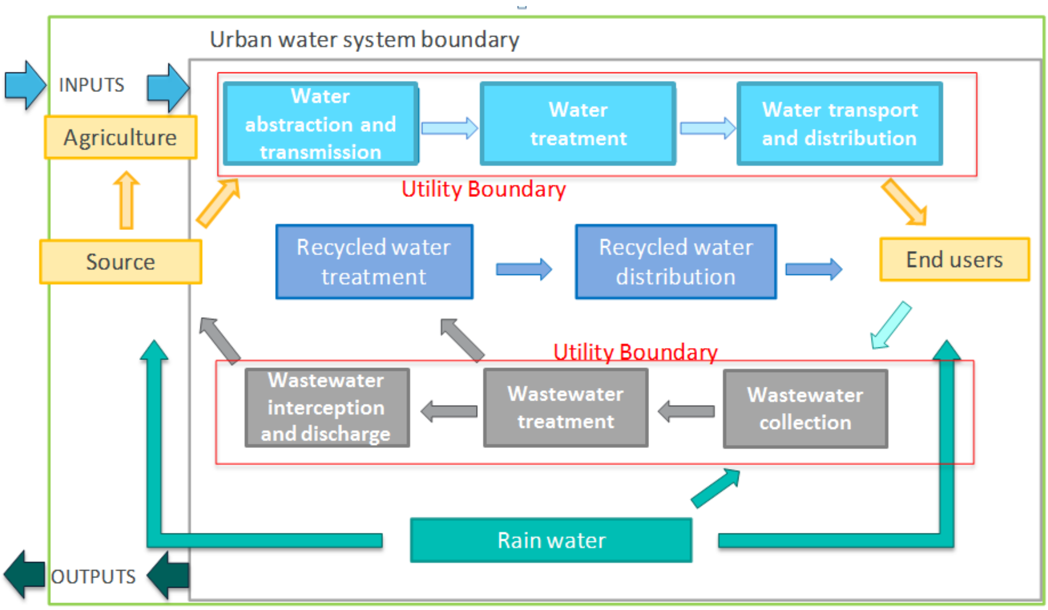

Figure 1. Scheme of the urban water cycle, its components and boundaries.

5.4 INIS: A German Research Cluster on Water Infrastructure

nidA200: a sustainable concept for decentralized wastewater treatment based on algae mass cultures

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Keywords: decentralized wastewater treatment plants (WWTP), algae mass culture, laboratory experiments, full-scale realization

Introduction

In Germany, more than 95 % of inhabitants are connected to high quality central wastewater treatment plants (WWTP). But considering all aspects of sustainability, centralized wastewater treatment is not always the best solution. For some rural areas or special applications like hospitals, hotels or nursing homes sustainable concepts for decentralized wastewater treatment are needed. The concept developed by the nidA200 project is based on alternative sanitary systems, co-treatment of organic waste and the cleaning capacity of algae. Based on this, full-scale realization will be possible. This abstract focuses on first laboratory results regarding the cleaning capacity of mass algae cultures which will be implemented as last treatment stage.

Cleaning wastewater with algae

Algae cultures are able to ingest and accumulate micropollutants, to eliminate pathogen germs, and to recover nutrients (Abdel-Raouf et al. 2012, Muñoza & Guieysse 2006). The nidA200 mass algae culture will be able to support the aerobic part of the WWTP significantly. Gained algae biomass can be used for biogas production.

First results of laboratory experiments

To prepare a mass algae culture for future use on the plant, two mixed algae populations from environmental sources (small lakes, WWTP) were cultivated in two photobioreactors (PBR). To supply the algae with nutrients, the water was changed daily. Specific mixed water from a municipal WWTP with nitrogen and phosphor concentrations very similar to greywater was used. By decantation of the clear water supernatant and thereby disposal of floating algae a culture of fast growing, effective nitrogen-assimilating and fast sedimenting algae was selected. Based on this culture extensive experiments were started to determine all relevant factors for full-scale realization (e.g., dry matter (DM) optimum depending on light intensity, influence of seasons, nutrient assimilation). One of the core results is the growth rate of the cultures, determined by the increase of DM (see Figure 1.1). Overall a good production of algae biomass was measured, as expected with highest levels during summer months. But even during winter months at least 25 % of the maximum summer growth yield was achieved. These results provide the opportunity to run the algae cultures over the entire year on the plant even in Northern Europe.

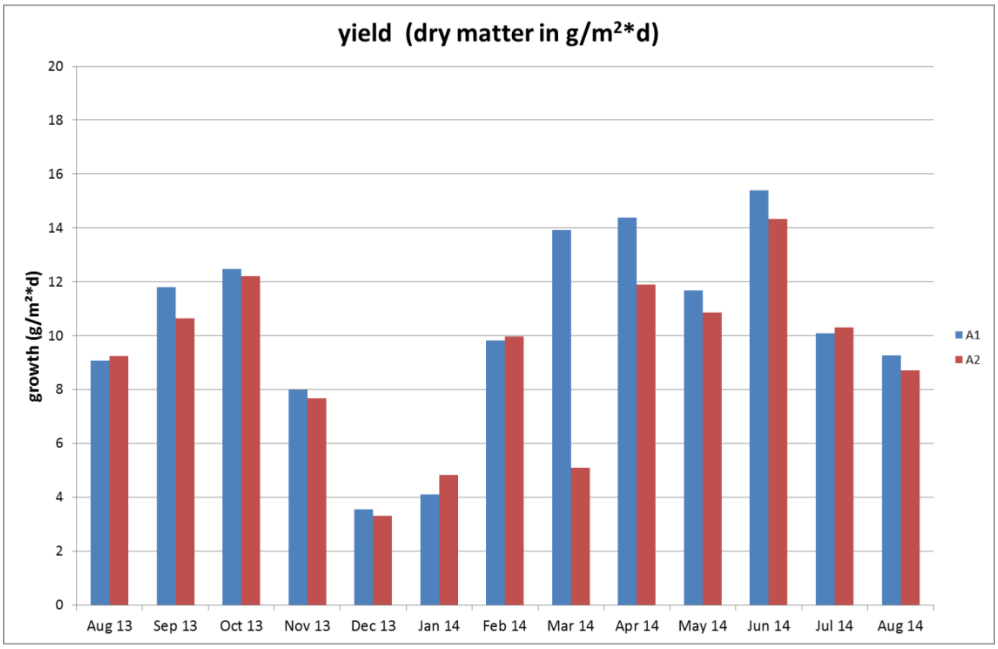

Figure 1. growth rate of algae cultures A1 and A2, determined by the increase of DM

To show the effective nitrogen assimilation of the algae cultures ammonium was measured shortly after giving the "greywater" in the water phase of the PBR. Most of the ammonium is assimilated by the algae cultures during the first hour, nearly everything is ingested after 2.5 hours (see figure 1.2).

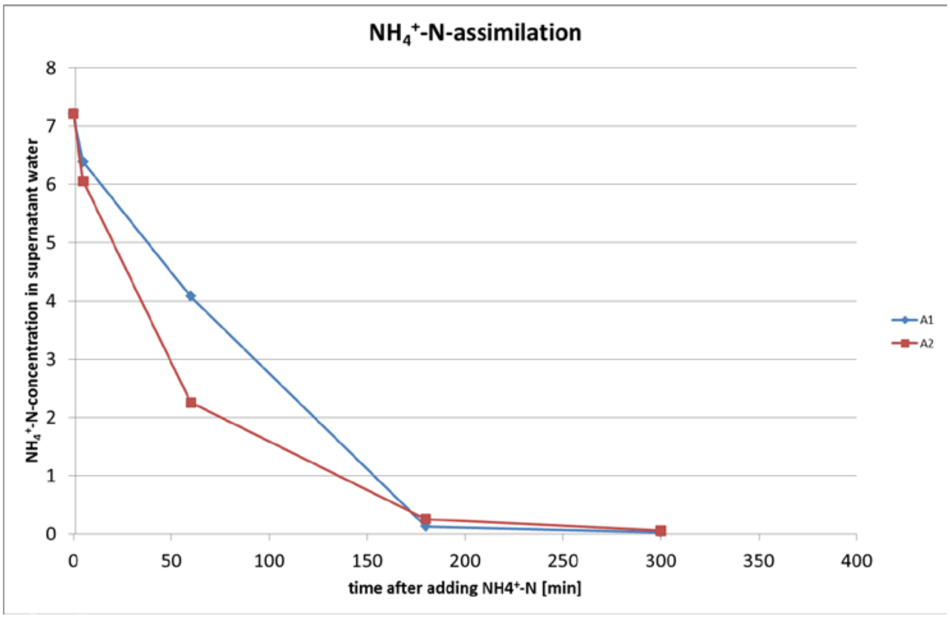

Figure 2. assimilation of NH_4^+-N

Conclusions and outlook

The present results are promising, based on this full-scale realization seems to be feasible. By optimizing all influencing factors further increases of biomass production and nitrogen assimilation capacity are expected with upcoming experiments. In the nidA200 project mathematically-dynamically simulations and microbiologic analyses (elimination of pathogenic microorganisms) complete the concept and will lead to an optimized operational mode of the plant.

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5.5 Engineering Future Urban Water Services

In-line monitoring corrosion sensor in water distribution networks

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Keywords: Internal corrosion; EIS; in-line monitoring; cast/ductile iron pipes; corrosion sensor.

Introduction

The several problems that distribution systems can exhibit throughout its useful life motivate the research and development of new methodologies to avoid or anticipate them. Electrochemical Impedance Spectroscopy (EIS) has been used to characterize the nature and the evolution of the internal deposits generated inside the cast iron pipes in water distribution networks. Besides, tests in ductile pipes have been performed in order to analyze the sensitivity of the device to cement mortar losses.

The main goal of the present project is to evaluate the capacity of this sensor to monitor the actual obstruction state of the grey cast iron pipes and the ability to follow the aging process of ductile iron ones.

Materials and methods

The project has been developed in two different stages: first of all, a laboratory phase (You et al., 2013) where the feasibility, reliability and sensibility of the EIS technique to monitor the evolution of internal deposits were proved. In a second stage, a pilot (Figure 1) was set up in order to test the sensor under more realistic conditions (Lagunas et al., 2014) using grey cast and ductile iron pipes. Water from the distribution network of Barcelona was used as electrolyte in the whole of the experimental work. While grey cast pipes were tested in laboratory and in the pilot, the ductile ones where only used in the pilot.

A heavily obstructed grey cast iron pipe was studied in the laboratory. Several reductions of the corrosion products were performed with the aim of checking the capability of the sensor to follow the variation/changes of corrosion tubercles. A second pipe (100 mm of diameter and also corroded) was installed in the pilot. Having analyzed it for several weeks, it was polished and re-installed in the device.

For ductile iron pipes, a new pipe of 20 cm long was used in the pilot. The inner diameter was 100 mm and a 3 mm wide cement mortar layer coated its wall. The main idea was to perform an accelerated aging test by removing consecutively different percentages of cement during the six months the experimentation lasted. Four mortar extractions were done into the ductile pipe (0.66% of the total mortar amount, 6.25%, 37.66% and 100%).

Electrochemical assays and water quality parameters monitoring

The electrochemical tests were carried out in three non-destructive steps: measurement of the Open Circuit Potential (OCP) and Corrosion Potential (E_{corr}); measurement of the Polarization Resistance (Rp) and registration of the electrochemical impedance spectrum. All the procedure was undertaken in both, laboratory and pilot scale.

The OCP evolution provides information about the state of the interface between the working electrode and the electrolyte. The Rp measurements were registered by means of a very slow potential sweep of ±5 mV around E_{corr} (applying the Ohm's law). Its value, is related to the global resistance of the pipe to corrosion and, hence, it is also related to corrosion rate. For the EIS spectrum, a 10mV AC voltage was applied on E_{corr}. 20-15kHz - 2mHz frequency range was analyzed (10 points by decade of frequency were measured). By means of EIS, the Electrolyte and medium resistances (R_s) can be assessed. All tests were carried out using a Biologic Multipotentiostat VMP2 (Bio-Logic, France).

Conclusions

The suitability of the experimental device, based on the direct analysis of cast and ductile iron pipes, have been demonstrated with the aim of obtaining information about the deposited layer formed on the internal wall of the Barcelona water distribution network. The evaluation of the usefulness of the EIS technique to follow the pipe's internal deposit has been carried out.

For grey cast iron pipes, reduction of corrosion tubercles led to changes into the Nyquist plot since their contribution was lower. When the tubercles were removed, the resistance (Z', Ω) decreased (Figure 2). It was also reported that the tubercles layer protect the pipe from corrosion. We assumed that, somehow, it acts as a passivation layer. In ductile pipes, the sensor was able of detecting the detachment of the mortar layer: the less mortar, the less global resistance. It is worth noting that the device can detect the moment when the very first piece of mortar is lost.

Tests have demonstrated that EIS is quite sensitive to the changes in nature, structure and thickness of the internal deposits generated inside the pipe (in grey cast ones). Although further investigation is needed, the sensor has proved to be a promising tool to be used within the asset management field.

Figure 1. Pilot installed in the water network.

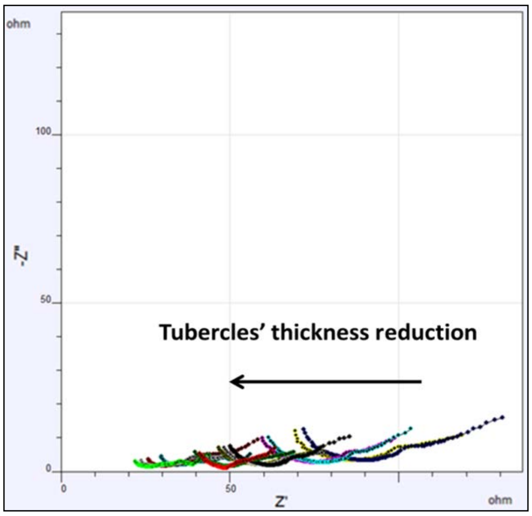

Figure 2. EIS results for grey cast iron pipes (reduction of tubercles).

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Innovative digital methods for the use of inventory data for an improved operation and maintenance management of public utilities

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Keywords: digital, operation, maintenance, management tools

Digital operation and maintenance management

The goal, achieving further optimizations in operation of public utilities requires the use of new methods and innovative technologies for the handling of planning and inventory data. Most plants are planned with one software (mainly CAE-Systems), the maintenance tasks are managed with another software system, the manufacturer documentation is stored in document management system and the operations data is held in process control systems. This variety of existing software systems makes it difficult to handle and manage all information, keeping it updated.

Therefore, the prerequisite is the consolidation of the diverse systems in one data base. The consolidation must be carried out constantly and workflow supported even in the presence of manifold system environments so that a mobile use of digital data of Engineers for design, plant modernization, commissioning on the one hand and on the other of plant personnel in the operation and maintenance field makes sense.

Thereby today the challenge is not only to have all system data digitally available, but to use the enormous amount of data also location-dependent, personal related as well as task oriented and to keep all data up to date.

The mobile system PRAMOS® developed by PWT Wasser- und Abwassertechnik GmbH demonstrates an innovative technical realization of a modern operation management.

Under the utilization of existing inventory systems, data for interactive use are provided mobile to the users in daily application.

Object identification can be done with RFID, QR-Codes, barcodes or using the object name. Augmented reality is another, more sophisticated way of identification. From a mobile device the context to the currently visible plant equipment is displayed with the relevant data only.

Particularly the opportunities in the field to edit executed maintenance tasks, data collections, as-is states, safety instructions etc. and to return the collected data to the existing systems are a decisive advantage for simplified processing and further use and analysis. This allows more efficient execution of the daily tasks and ensures greater transparency to document the operators' obligations.

Safety instruction can be given before the execution of a work task, ensuring a safe working environment and observing all relevant laws.

Navigation helps finding objects even if they are hidden in the forest or on a big industrial site.

Of course all important documentation and even explanatory videos for maintenance can be displayed on the tablet. This helps the technician executing his job and can also be used for training of new colleagues.

The information gathered during the operation of the plant supports important analysis of data, for example for asset management and modification of the maintenance strategies to extend operational life of machinery.

Figure 1. The use of augmented reality for object identification is just one feature of PRAMOS®.

Figure 2. Existing data becoming available for daily maintenance and operation with PRAMOS®.

Figure 3. See how PRAMOS® works, follow the link to our product video.

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Development of an Inline Monitoring System for Waterborne Pathogens – An Innovative Approach for the Surveillance of Raw and Drinking Water Hygiene

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Keywords: Pathogens; raw water; drinking water; monitoring

The relatively old age of municipal water infrastructures and external processes such as climate change or demographic trends create new challenges for Germany's public water sector. Public water supply services rely on complex technical systems including raw water abstraction facilities, water works and distribution networks which typically contain intermediate storage tanks, pumping stations and (often interconnected) pipelines. Therefore, potential contamination sources for raw or drinking water are numerous. Moreover, for (pathogenic) microorganisms there is a risk of re-growth after water treatment. Rapid and continuous monitoring systems for waterborne pathogens could greatly help in detecting and managing such contamination events.

Currently established monitoring systems rely on the detection of bacterial indicators by cultivation on nutrient media. In state of the art approaches, viruses can be monitored by an inoculation of cell cultures and the subsequent detection of cytopathological effects. However, cell culture systems do not exist for all waterborne viruses. Because of the relatively long time needed, such methods do not allow rapid alarms and are poorly suited for continuous or investigative monitoring (Bruma & Tofan 2008; Fong & Lipp 2005; Jasson et al. 2010). Alternatively microorganisms such as bacteria or viruses can also be identified on the basis of nucleic acids. Polymerase chain reaction (PCR) methods are currently well established in medical diagnostics, but require relatively complex analytical steps in the laboratory (Lim et al. 2005; Ibekwe et al, 2002; Fu et al. 2005). Therefore, they are poorly suited for a simple and automated water quality monitoring. Isothermal amplification assays are a suitable alternative, as they require only simple laboratory equipment and offer shorter amplification times. Thus, they allow for rapid and automated detection systems (Asiello & Baeumner 2011).

We here describe a hygiene online monitoring system (HOLM) that is being developed in the project EDIT ("Development of a Concentration and Detection System for the Inline-Monitoring of Pathogens in Raw and Drinking Water"). Since waterborne pathogens pose a thread even in very low concentrations, enrichment prior to the nucleic acid based detection is necessary. The challenge lies in the combination of macro processing steps that can concentrate samples of tens to hundreds of liters to volumes of less than 1 ml, with processing steps on the microliter scale that allow the detection of microorganisms and viruses by molecular biological methods (Kunze et al. 2014). For macro concentration, ultrafiltration is used as it does not require a complex preparation for the simultaneous concentration of bacteria, viruses and protozoans (Morales-Morales et al. 2003). The next stage, monolithic affinity filtration allows to selectively adsorb target pathogens onto monolithic columns (Pei et al. 2012; Lengger et al. 2012). Via an innovative automated lab-on-chip system the pathogens are further micro concentrated from 1ml down to 10 l and then lysed (Lui et al. 2009; Podszun et al. 2012; Puchberger-Enengl et al. 2011). Subsequently the nucleic acids of the target organisms are extracted within the same chip. Finally, the target nucleic acid is detected by a multiplex amplification assay, using the recombinase polymerase amplification (RPA) method, on the automated microarray platform MCR3 (Kunze et al. 2014).

Table 1: Target organisms for the HOLM system developed by the EDIT project

BACTERIA	VIRUSES	PHAGES
- **Escherichia coli** - **Enterococcus faecalis** - **Pseudomonas aeruginosa** - **Campylobacter jejuni** - **- Klebsiella pneumonia and Klebsiella oxytoca**	- Norovirus GGI-II - Adenovirus 40,41,52 - Enteroviruses	- MS2 - PhiX174

Besides a sufficient sensitivity and selectivity for the target organisms, a newly developed monitoring technology needs to be sufficiently user-friendly and capable of integration into existing warning and control systems used by municipal water providers (Langer et al. 2014).

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Water Related Energy Consumption in Water Supply and Wastewater System in Bangalore city and low Energy Water Supply Options

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Keywords: 'Water related energy consumption', 'Water-Energy Nexus', 'low energy water supply options'.

Abstract

Water related energy consumptions vary from city to city and there are limited studies on water related energy consumptions in a city as quantification of such energy is difficult due to lack of data and its difficulty in quantification. This paper discusses the quantification of water related energy in Bangalore water supply and wastewater system using water use cycle which provides a robust accounting of energy use at every point from water extraction to end use. The study found that the energy intensity of whole water use cycle for Bangalore very intensive when compared with cities in USA and Australia and that alternate water supplies like reuse of wastewater, stormwater and rainwater harvesting can be low energy water supply options for the city. Further the energy consumption of existing water supply system can be reduced significantly through reduction of water loss through leakages in distribution system and conveyance which contributes over 50%.

Introduction

Water and energy are two limited resources and the key elements for the growth and development of a city (UNEP 2012). The water related energy consumption in a water supply and wastewater management system is increasing and reduction of such water related energy consumptions and finding alternate water supply options have been essential for a sustainable water supply and wastewater management system. A better understanding of the water related energy consumption in water use cycle and its nexus can help integrated resource planning that optimizes the use of limited resources. Bangalore (also called Bangaluru, the capital of Karnataka State) is the third largest populous city and fifth populous urban agglomeration in India and recently has turned into a 'mega city' in 2014 (Jnnurm 2009, CDA 2007 and indianonlinepages 2014). The current population of Bangalore (the capital of Karnataka State of South India) exceeds 10 million and the figure is expected to reach 12.5 million by 2021 (Census of India 2011 and indiaonlinepages.com).

Being situated in an arid region, Bangalore is naturally water scarce. The city has highly variable and uncertain rainfall, limited surface water and storage facilities to meet its water demand of rapidly growing population (CSE 2011, Lele et al 2013 and CGWB 2011) and groundwater is highly polluted by nitrate, pathogen and other contaminants (Mehta et al 2013). Presently the city brings water from a far (about 100 km away from the city and 500m) river source called the Cauvery river which is a water stressed and dispute river basin shared by the Federal States of Kerala, Karnataka, Tamil Nadu and the Union Territory of Pondicherry in Southern India. Due to climate change impacts and other factors, the monsoon water which is the main source of water of the river is reducing and the river has got physical water scarcity (water use is more than renewable water). The Cauvery River Water Disputes Tribunal (a body established under the *Inter-State River Water Act 1956*) has allocated Bangalore city with 1,470 million megalitres per day (MLD) of water from the Cauvery River and there is no further scope for additional water withdrawal. Withdrawal of water from the river through pumping, its treatment, distribution and collection of wastewater and treatment and disposal require huge energy and the cost of it has become a burden for the water utility. Still the city cannot meet its water demand for the people. The water is available only for a few hours a day which is strikingly different from any other country in Asia. Water from a tap for 24x7 hours is a dream to the poor and even those who are rich and have piped water connections receive water for only a couple of hours a day or on alternate days or three or four times a week. (World Water Bank 2013). BWSSB supply water from 90-110 lpcd but the people receives much less from 60-70 lpcd at the end and the slum people get much less than this or even no water (CSE 2012 and Lele et al 2013).

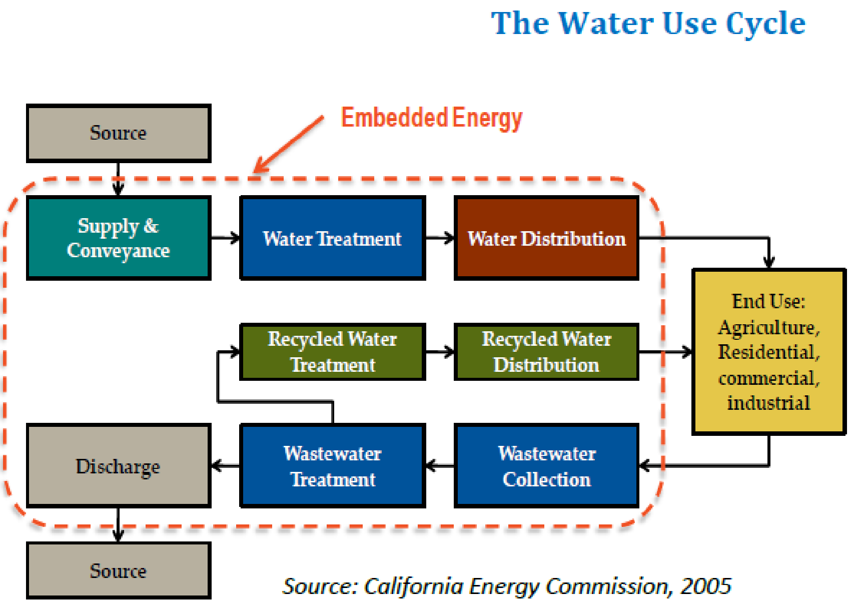
The city faces again power shortages from 100 MW to 600 MW daily. The daily demand of energy is 2,300 MW and it uses one third of the state's total power produced. Power comes from hydro, thermal (coal, gas and diesel) and central generating stations for thermal/nuclear and non conventional energy projects. BESCOM gets 12% of the state's hydro power (BECOM 2012). The city experiences daily power cuts upto 3 hours during crisis period. The Karnataka State Govt's admission in the Assembly is that 'It cannot supply power round the clock in the backdrop of water level dipping in hydel reservoirs'. 32% of the State's power comes from hydropower and the Bangalore city is fully dependent for its energy on the State power. The State is again over dependent on hydel power to meet its power shortages (The Times of India 2014).

It is therefore very important to know the water related energy consumptions of Bangalore city water supply and wastewater system and find alternate solution for water supply and reduce energy consumption of existing system as well.

Methodology

A thorough literature review was carried out using related scientific journals, books, technical reports, new articles and databases. The literature review has helped identify a systematic approach to calculate water related energy consumption. The water use cycle has been used here to calculate total energy consumption of Bangalore water supply and wastewater system which provided energy use at every stages of water cycle.

The literature review has helped identify primary data to be collected from the field and quantify water related energy.



Results and conclusion

The energy intensity of Bangalore Water Supply and Wastewater System was found as 2.44 kWh/kL which is higher than that in cities in USA (1.7 kWh/kL) (Water in the West 2013) and Australia (1.9 kWh/kL) (Kenway 2011). The analysis showed that the energy intensities of wastewater, storm water and rainwater are less than that of existing water supply and wastewater system and this reveals that for Bangalore, reuse of wastewater, stormwater and rainwater can be less energy intensive. It was also investigated that the energy intensity of Bangalore water supply system can be further reduced through leakage prevention, improved metering, timely repair and billing system. In 2013 about 135 GL water was lost in the system. Both BWSSB and BESCOM are carrying this loss in terms of energy and water supply to the city people. This is the water that BWSSB is paying to produce but is not producing revenue. Decreasing this loss can help the utility increase revenue and decrease embedded energy use and its cost. Saving this amount of water, could save monthly 26.4 GWh electricity which could be used to ease load shedding (power cut) in Bangalore, avoiding conflicts over the Cauvery river not to talk about other implications such as GHG emission and effects on ecology. The limitation of this study was lack of consistent and segregated data related to energy use in some stages of water cycle and lack of field data base. Improved and accurate results can be obtained using more consistent and segregated data in the water use cycle.

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De-chlorination of drinking water by forced aeration

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Keywords:De-chlorination, Drinking water, forced aeration.

Abstract

Shock chlorination is a well-known practice in swimming pools and domestic wells. Using this technique in drinking water purification facilities is extremely limited because of the difficulty of removing high chlorine concentrations in water distribution systems or in its production facilities quickly. In order to use this method in drinking water industry a shock de-chlorination method should be introduced as an introductory for producing microorganism and biocides free water. De-chlorination using natural stagnant aeration is the safest known method if compared with chemical and charcoaling methods. Unfortunately, stagnant aeration described to be a slow process. Therefore, developing a process for accelerating de-chlorination by aeration would pave the road for using shock de-chlorination in drinking water industry.

Forced air bubbling is proposed to be a suitable technique for de-chlorination but there is lack of data that supporting such process. The theory behind that is air bubbling has the advantages of higher mass transfer area, higher Reynolds number across the bubble water interface, and higher mass transfer concentration gradient as the bubbling presents a continuous fresh bubbles. All of these three factors proposed to accelerate aeration to a far extent.

A 20 cm diameter, 1 meter height column provided with air sparger was designed to collect the desired data was used in this study. Trichloroisocyanuric acid, sodium hypochlorite and chlorine gas were the three familiar sources of chlorine that used to investigate their response to air bubbling.

Chlorine gas was the fastest and safest chlorine source to be dechlorinated. It dropped down from 200 ppm to 0.02 ppm within 4 minutes or zero ppm within 6 minutes using an air flowrate of 9 l/min. Sodium hypochlorite decreased from 200 ppm to 0.02 ppm within 6 minutes using air flowrate of 9 l/min. Trichloroisocyanuric acid found to be the slowest chlorine source responding to de-chlorination. It decreased from 200 ppm to 0.02 ppm within 8 minutes using an air flowrate of 9 l/min.

Shock de-chlorination by aeration found to be a promising method that opens the horizon in front of using shock chlorination in drinking water industry as an introductory to produce free microorganisms and free biocides drinking water.

NEW strategy: Should we recycle separated urine?

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Keywords: urine, management, recycling, economic, struvite, highways

Introduction

Urine, otherwise known as yellow water is produced daily by all inhabitants of towns and villages. Whether we like it or not, with its production are associated hard facts. One of them is the fact, that although the yellow water represent less than 1% of the total volume waste water from households, are the source of 80% nitrogen and at least 11 % phosphorus from the total amounts of these nutrients found in domestic wastewater. It is thus waste, or valuable source of the nutrients? If we look at this issue from the perspective of strategy NEW (nutrients, energy, water), then the second option is correct. Where is it possible, we shoud separate urine directly at the source, and recycle it. This entails distinct advantages. For example, we can name a lower value on the inflow and thus better outflow values. Smaller volumes of wastewater treatment plants and often the omission of certain stages of treatment. If we take as an example rest areas along highways, fuelling stations or festivals. Wherever there can be easily separated urine in a concentrated form which is ideal for recycling. Currently we can observed an increasing number of the waterless toilets, which prevents further dilution. This fact only helps this strategy. Nowadays, separated urine, a valuable source of nutrients N, P, K, is exported illogical to wastewater treatment plants, where we pay for its treatment a considerable price. According to the strategy NEW, we can better use separated urine. It´s possible produce a soil conditioner or a highly regarded phosphorus fertilizer, struvite. In this study will be elaborated economics and management of handling with the yellow waters based on the model example of highway rest areas, where will be separated urine. Separated urine will be recycled in the form of struvite.

Situation in Czech Republic

In the Czech Republic there is not legally allowed to use human urine for direct fertilization. Problematic is also the use of fertilizer produced from human urine. But the fact remains that the urine is an excellent source of nutrients. However, there are a number of projects that focus on the production and marketing of fertilizers from recycled materials. We can mention, for example the project P-rex (http://p-rex.eu/). Recently was based also Phosphate platform, which aims is to recycle nutrients legislative support. There are also companies that deal with recycling of phosphorus in the form of struvite from wastewater. For example, the Canadian company Ostara. Therefore, we believe that can be recycled also separated urine. For this purpose, they are ideal highway rest areas with restaurants. Another source may be, for example music festivals. Wherever there is a large amount of urine in a short time. For this reason, it is very difficult to build a functioning sewage treatment plant just at motorway service stations. Such WWTP are burdened with the problem. Urine contains large amounts of ammonia, which is toxic at higher concentrations. The content of organic substances in the water is not sufficient for biological treatment. In most cases these WWTP are not working correctly, or is necessary to add external organic substrate. The reason is obvious. Because, the yellow water comprises less than 1% of the total waste water from households, are the source of almost 80% nitrogen and at least 50% of the total phosphorus amounts of these nutrients found in domestic wastewater. [1]

Reasons for separation of urine

The main reasons for the separation and purification of yellow plants in European countries:

- Reduction of nutrient with respect to subsequent problems with eutrophization with regard to the costs associated with the removal of their consequences
- Minimize the amount of run-off of nutrients in WW with regard to the economy of clean water, especially reducing the concentration of nitrogen cheaper cleaning process
- Strain the inflow parameter input to the WWTP, which makes it possible to consider other, less economically advanced technologies such as wastewater treatment plants. Domestic wastewater at

- Recycling nutrients contained in urine as fertilizers - phosphorus reserves are falling and the price of phosphate and nitrate fertilizers repeatedly increasing [1]

Social barriers, public perception

Using separation technologies may be on first impression associated with operational problems (odor, difficult operation, health risk), residues disposal options and constraints, significant additional costs

waterless urinals compared to installing a standard toilet, difficulty in retrofitting existing buildings, cultural acceptability and institutional courage. This article shows that these problems can be overcome and that the technology is appropriate, marketable, environmentally beneficial, can reduce greenhouse gas emissions, and is economically feasible.

Health risk

In 2013 were performed, within the project: From waste to the resources, first experiments with separation of yellow water (urine) and their hygienisation. The next step in this experiment was verify their fertilizing effects in a field experiment and crystallization of phosphorus fertilizers in bioavailable form of struvite and the use of solar energy for decrease the amount of the water and prepare soil conditioner, which is rich to nutrients N,P,K. Because fresh urine can be a source of various pathogens, depending on the health of producers, or it may be contaminated with feces, is needed before further handling urine hygienization. The simplest method is the storage for several months. WHO Handbook for disposal of excreta determined period of stabilization for 6 months at 20 °C [2]. It was founded by experiment, during which was clean urine of male origin, collected in music festival in Brno. The volume of urine 10 m^3 was stored in tanks and regularly monitored. The key parameters were microbial indicators given by the czech legislation and contents of nutrients N, P, K. The results show the following two tables.

Table 1. Microbial indicators monitored in urine during hygienisation

MICROBIAL INDICATORS	1. MONTH (CFU/100 ML)	6. MONTHS (CFU/100 ML)
Enterococus	85	0
Escherischia Coli	0	0
Salmonela	negative	negative
Thermotolerant coliforms	0	0

For successful crystallization like is used for example by the canadian company Ostara, you must achieve at least phosphorus concentration of 50 mg/L, (according to Chris Howarth from the company Ostara), yellow water which meets the listing. The resulting fertilizer Crystal Green® - based struvite then containing 5% nitrogen and 28% phosphorus. Using the technology can be recycled 80% to 90% of dissolved phosphorus from waste water and 20% ammonia. In our model example, we measured 180 mg of phosphorus per liter [11].

Table 2.: Nutrient content in urine after 6 months storage

PARAMETER	UNIT (MG/L)
Total P	180
Kjeldahl Nitrogen	2200
Nitrate nitrogen	< 0,2
Potassium	301
COD_{Cr}	2280

Model example

In our model case, we have tried to outline some of the savings resulting from the separation of urine at highway rest areas and waste water treatment plants. We chose a motel and gas station of the medium size, situated on the route between the two largest cities in the Czech Republic on the highway D1. According to the information from gas station service and motorest personnel, weekly stops here about 9,000 visitors and roughly 5000 uses the toilet. According to the german rules: ATV-DVWKA-131E, Dimensioning of Single-Stage Activated Sludge Plants and the EPA wastewater treatment manual and czech national standard for the design of small wastewater treatment plants: ČSN 75 6402we designed model WWTP. It is not possible to publish the full calculations and design of the plant. It would be beyond the scope of this article. For brevity, we present only the essential characteristics.

In the second case, the model is calculated for same area with the difference that is separated male urine through a special accessory. Our solution consists from waterless urinals which enable you concentrating urine and special tanks produce by the company ASIO l.t.d. AS-URINE. This tanks were developed within the research project and are intended primarily for storage and sanitation urine. They are equipped with internal partition which divides the tank into two halves. The volume of the tank is computational designed by a program, which is based on long-term monitoring of urine production. Half tank volume is sufficient for 6 months of operation. Then the content is stabilizing and hygienized in the meantime, the other half tank is filled with urine. Hygienized urine is after six months exported and used as a soil conditioner or may be use for struvitu crystallization.

Model example 1, technology descrition:

WWTP 1: Biological activation (WWTP AS - VARIOcomp 150 N), for EO 150, the average daily flow of 19 m^3 / day, with fine bubble aeration. Waste water flows into settling tanks, sewage treatment plant, which also serves as a reservoir of excess sludge. Here are trapped sediment and floating debris. In the area of activation of the WWTP is mechanically purified water biological refining. In settling the WWTP leads to sedimentation of emerged sludge flocks and subsequently treated water. The thickened sludge from the bottom of the settlement tank returns automatically to the activation. Part of activated sludge from the activation of such excess sludge is drawn into the sludge tank.

Model example 2, technology description:

WWTP 2: Biological activation (WWTP AS - VARIOcomp 80 N) for 80 EO, the average daily flow of 12.0 m^3/ day. Description of the technological wastewater treatment plant in this case is very similar to the first case. With the only difference that due to the separation of urine will be a significant loss of volume tanks, necessary for biological treatment. In this calculation we calculate the separation of male urine. This means urine from 720 visitors per day. Unlike the first variant, there is a reduction in the input load parameters, especially total nitrogen and total phosphorus. Water deprived of urine will contain enough nutrients needed for biological treatment. Is not necessary to propose plant for nitrification as phosphorus and nitrogen remaining in the waste water will be used as a nutrient for bacteria. This saves even chemicals needed for precipitation of phosphorus and activation tank is reduced by about half. Drain parametrs were derived from Government Regulation: 23/2011 Coll. amending Government Regulation no. 61/2003 Coll., On indicators and values of permissible pollution of surface waters [7]. Parameters were based on the standard 61/2003 Coll. required to reach on the outlet:

BOD = 40 mg/L

COD = 150 mg/L

$N\text{-}NH_4$ = 10 mg/L

SS = 50 mg/L

Table 3.: Demands on the equipment and comparison of the two model situations

BASIC EQUIPMENTS	WWTP 1	WWTP 2
Activation tank	20 m^3	10 m^3
AS-URINE		16 m^3
Settlement tank	4 m^3	4 m^3
Sedimentation tank	6 m^3	6 m^3
Waterless urinal (8 piecies)		8 pc.
Average urinal (8 piecies)	8 pc.	
Water for flush	547 m3	
Total price	24 200 €	21 120 €

This very simple example shows that separation of urine is cheaper capital costs to address the situation. Investment costs are even lower. With this system it will be possible to build a functional sewage also at highway rest areas. Separation system with storage reservoir for urine AS-URINE and waterless urinals are cheaper than conventional wastewater treatment plant. In addition, we can save every year on water for flushing 1610 €.

What do we do with the separated urine?

The average person produces enough urine per year to cover 300-400 m2 of land to a level of 50-100kg/ha of nitrogen.Some of the yearly values of the nutrients are: 3.5kg of nitrogen, 0.5kg phosphorus, 1.0kg potassium, 0.5kg sulfur, 40g magnesium, 100g calcium [8]. For use of separated urine we have two options. Since this is a great fertilizer, in which is also the phosphorus in plants accessible form, we prefer recycling before removal. Urine is also after long-term storage in the reservoir sanitized. Our model example involves the use of urine as a soil conditioner. Urine diluted with water in ratio 1: 1 can be used for fertilization of corn grown for silage as a substrate for biogas plant. In that case, there can´t be impediment social barriers. Instead, that the operator of the highway rest stops paying for the removal of urine and its disposal, the farmer takes the urine for free. Urine get added value and the farmer saves money for the purchase of commercial fertilizers.

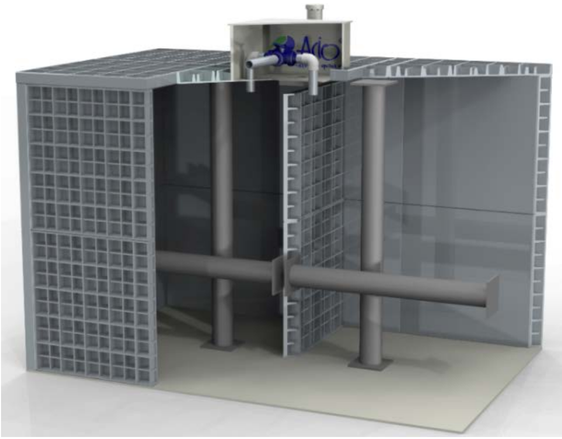

Figure 1: AS-URINE

Should we recycle urine to form of struvite ?

The threat of depletion of phosphate in the near future, leads to the need for introduction of recycling technologies where the most interesting ways of recycling of the concentrated liquid sources seems crystallization to form of struvitu [11]. Recovering 1 kg of struvite from a wastewater treatment plant will minimise sludge handling and disposal and reduce the operating cost by 0,82 €. The payback period of a struvite plant processing 55 000 m3/d of waste stream could be less than five years. Recovery and storage of struvite will close the phosphorus loop in the soil–crop–animal–human–soil cycle and pave way to ecologically sustainable future [9]. According to the information provided on the website Ostara is the total cost for struvite recycling 5,28 €/kg P. Production costs of diammonium phosphate is around 3,5 €/kg P_2O_5 (DAP) [10]

Conclusion

The expected shortage of phosphorus is necessary to set long-term concept that would be able to gradually develop technologies and secure recycling of this essential nutrient. Were identified sources of phosphorus, which should serve as the most effective recycling. Currently, there are also quite a wide range of technology solutions, all of which have their pros and cons, and no technology does not stick out as clearly the best solution. While on a national scale recycling of phosphorus is relatively neglected in Europe and, indeed, globally beats for several years on the alarm when it was gradually established a number of platforms, lobbying movement and supported a number of projects, which are actively addressing the issue.

- In our model example we have demonstrated, that it is appropriate to separate the concentrated source of phosphorus and nitrogen in the form of urine. Some situations, such as highway rest stops, to directly encouraged. More preferably still seems to use sanitized urine before treatment to struvite. In the future we plan to assess the economy crystallization device that would work on a larger wastewater treatment plant. There would be crystallized phosphorus from sewage water and imported urine.

- ASIO l.t.d. as a company promotes technology NEW. That means in a nutshell: nutrients, energy and water. Within this technology, we try to recycle urine not only on motorways, but also in buildings. We are not trying to recycle not only urine, but also gray water and energy which contained. We believe that with the strategy NEW together we can form a city of the future.

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Dessin, demonstrate ecosystem services enabling innovation in the water sector

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Keywords: Ecosystem Services, water management, water quality, water scarcity, demonstration, innovation

Objectives and approach

DESSIN (Demonstrate Ecosystem Services Enabling Innovation in the Water Sector) is a FP7 supported international cooperation project that aims i) to demonstrate and promote innovative solutions to water-related challenges with a focus on water quality issues related to the implementation of the Water Framework Directive (WFD), and water scarcity, and ii) to demonstrate a methodology for the valuation of ecosystem services (ESS) as catalyser for innovation in water management with a special focus on urban areas.

The DESSIN solutions integrate technological, monitoring, modeling and management approaches for a more resource-efficient and competitive water sector in Europe. As a second key feature, an Evaluation Framework for determining and valuating changes in ecosystem services (ESS) of water bodies that result from the implementation of these solutions as well as for assessing the sustainability aspects of the mentioned solutions is developed and applied. By adopting this twofold approach, we are able to demonstrate how innovative solutions integrated in the water cycle can increase the value of the services provided by freshwater ecosystems while assuring sustainability, thus generating additional incentives and arguments for their market uptake and practical implementation. This supports innovation and competitiveness in water management by enabling a more informed selection of the most promising solutions, as regards their impact on the ecosystem and their economic implications.

Demonstration activities

DESSIN is centered around a suite of carefully selected sites across Europe, representative of global major water challenges, where we bring together public and private water management organisations and end-users, technology providers (SMEs), supporting RTD experts and relevant public authorities to demonstrate this approach. At five representative sites across Europe the potential of a range of innovative solutions to tackle two major water challenges (water quality and water scarcity) and to increase the value of ecosystem services of the water bodies is demonstrated. This demonstration activity is the very heart of DESSIN and integrates the technology solutions as well as the Ecosystem valuation approach developed in DESSIN. The five full scale demonstrations including their main objectives are presented in separate posters, in addition to a general overview of DESSIN goals and approaches. The DESSIN demonstrations contribute to ecosystem services related to water quality (the Emscher and Hoffselva demonstrations) and water scarcity (Westland, Athens and Llobregat demonstrations).

Emscher demo site

Over a century ago, the sparsely populated Emscher region with a landscape of water meadows was transformed into an industrial conurbation, and the untamed Emscher turned into a man-made system of open waste waterways. With the decline in the mining industry, a further structural change began, with traditional heavy industry giving way to the services and high-tech industries. These developments are also reflected in a changing Emscher. In future, wastewater will be completely channeled through closed conduits and the river and its tributaries will be re-converted into natural waterways. For this purpose a total length of about 400 km of sewers and 290 CSO structures with a total volume of 485.000 m are to be built until 2017. Currently, 136 CSO structures have been built and a total length of about 100 km out of 350 km of water courses have been ecologically revitalised. The remaining 250 km will be revitalised until 2020 to complete the Emscher reconversion project. Within the demonstration at the Emscher demo site, the problem of CSO treatment in highly urbanized areas with limited available space is addressed. Focusing on the overall water quality, two innovative approaches are implemented and tested. One approach (cross-flow lamella settlers) addresses the improvement of treatment efficiencies of existing CSO tanks by improving the removal of particulate matter. The other one (ADESBA-real time control) is a fully automated real time control system that optimizes the use of existing CSO storage volume with the focus on water quality of receiving waters.

Hoffselva demo site

The demonstrations at the Hoffselva demo site are innovative solutions enabling local treatment of CSO overflows with the aim to improve the water quality and ecosystem services in this peri-urban catchment with 25 000 population covering an area of 1427 ha in the western part of Oslo. The sewer network consists of a separate system in the upper part and a mainly combined system in the middle and lower parts. The water quality in Hoffselva is poor due to pollution from 22 CSOs discharging into the river during rain events. The utility owning and operating the sewer system, VAV, has measured high numbers of bacteria, and elevated concentrations of nitrogen and phosphorus in the middle and lower part of the river flowing through the area with a combined system. An analysis of the sewer system has shown that many of the pipes in the area have capacity problems during rain and also that the CSOs discharge far too often. In the demo cross-flow lamella settlers for local treatment of CSOs and a high rate filtration system with specially designed filter media to capture debris, organic material and particles are applied.

Westland demo site

A challenge for the horticulture sector in the coastal Westland region in the Netherlands is a shortage of fresh water in dry seasons. Storing abundant fresh water in the underground during wet periods could provide a solution. However, the aquifer in the subsurface is brackish and recovery efficiencies are generally low. Recent innovations in well design and operation and in monitoring and real time control have tackled this problem. This was demonstrated in a pilot installation which was recently completed. Freshwater supply from brackish aquifers is nationally recognized as a potentially important water management tool to fulfill the demand of freshwater. DESSIN demonstrates the potential to further improve the efficiency of freshwater supply from brackish aquifers by combining aquifer storage and recovery (ASR) and desalinization with an innovative well design. Currently, the demonstration site already enables the flexibility to scavenge deeper upcoming brackish water (using the Freshkeeper) and to feed a reverse osmosis (RO) treatment system. Supply of freshwater from brackish aquifers is a promising ecosystem service that may be upscaled and applied in other agricultural (horticulture) areas or for assuring drinking water production in coastal aquifers. Important aspect of the application of the hybrid ASR/RO systems in coastal aquifers is the impact on the regional groundwater quality and WFD goals.

Athens demo site

The city of Athens has suffered rapid (uncontrolled) urbanization resulting in few urban green spaces which coupled with a series of peri-urban forest fires in the last decade have resulted in a severe degradation of its environment and the quality of life of its inhabitants. The public good approach to quality of life, offered by urban and peri-urban green spaces is all the more important due to a more general quality of life degradation which is the result of an ongoing financial crisis. What is seen as priority is the deployment of innovative management options and technologies for reuse needed to irrigate (primarily) green urban areas, embedded within an ongoing 37M euro project for wastewater reuse. The demonstration looks into (modular and mobile) sewer mining for distributed reuse within the urban environment, exploiting state-of-art ICT solutions for distributed monitoring and management. The demo also examines a major component of ESS provided of particular importance to arid climates: the mitigation of heat island effects due to irrigation of urban green. The demo presents a unique opportunity for (a) drastically increasing reuse within the highly constrained urban environment (b) improving urban quality of life through improved ecosystem services and (c) creating a new market for SMEs that can provide this service to, for example, local municipalities, while using the existing centralised sewerage network of the water company as a source for their resource (raw sewage). This is expected to create a win-win scenario for water companies since they will be able to sell untreated sewage, while also minimising the load to their centralised treatment facilities.

Llobregat demo site

Barcelona Metropolitan Area (BMA) as other Mediterranean regions is facing recurrently and increasingly severe water scarcity periods. On 2008 Barcelona BMA suffered from the last chapter of drought, which was used as an example to illustrate the problem with water scarcity and drought in the EU by the European Environmental Agency (EEA). To face with this, operators, politicians and scientific community joined efforts to push Managed Aquifer Recharge (MAR) complementary solutions in the Llobregat Aquifer, as the hydraulic barrier against sea water intrusion, the continuous operation of infiltration ponds in Sant Vicenç dels Horts and a best regulation of groundwater abstraction. Sociedad General de Aguas de Barcelona (SGAB) is the main water operator in the BMA, supplying more than 3 million inhabitants, with an average density of 5.093 hab/km . They pushed for the Aquifer Storage and Recovery (ASR) in the middles 60s, to guarantee groundwater availably (currently, 10% of water supply comes from the Llobregat Aquifer in the BMA). ASR facilities are located nearly the Drinking Water Treatment Plant (DWTP) of Sant Joan Despí. 12 reversible wells (equipped with injection and recovery systems) are able to inject 75,000 m^3 of freshwater per day, coming from the surplus of the DWTP potable water. After almost 40 years under operation, currently ASR facilities are operated below their capacity because of the adjustment of DWTP operation to satisfy supply needs (less surplus of potable water). The solution tested in the Llobregat demo site is to make flexible ASR systems to deal with different quality injection waters with the aim of improving aquifer water quantity and quality. In consists in the change of traditional way of operation based in a conservative and restrictive view of injecting produced drinking water (high-costly and energy and chemical reagents demanding). Moreover, the injection of alternative water coming from different steps of the treatment train, will allow operators inject major quantities of water by improving both economic and environmental costs of the process.

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7 TESTIMONIALS FROM CONFERENCE PARTICIPANTS

"The things that I found most interesting and inspiring at the same time in the conference were the diversity of actions that we can take in the water sector to build and transform our cities into more sustainable ones. Also, the integration with design enhances furthermore the benefits of embedding the water in the city, and provides additional social and ascetic benefits that are often forgotten by engineers!"

Ana Galvão, Instituto Superior Técnico, Lisbon, Portugal

"What we should focus on next:

Assessing the value of green infrastructure, identifying who pays / who benefits; recognizing the multi-purpose uses of green infrastructures, such as social inclusion... develop asset management plans that value natural and built assets for the services they provide.

Swimmability in City: that was a new topic which deserves more attention in the future

Methods to bring stakeholders together to transition roles and responsibilities to enable the CoF agenda (three pillars of our Urban water Charter: "water shapes cities"; "regenerative" ; "integrated") - work with social scientists, change management experts.

Applying the regenerative approach (circular economy) allows to reduce operational costs and provide for better maintenance of assets (through the new financial resource)."

Corinne Trommsdorff, IWA Cities of the Future Programe

"For me the most relevant insight of the conference to get am impression how the challenges related to water management will change in the cities of the future, and how new approaches in water management can help to increase the sustainability and quality of life."

Daniel Karthe, UFZ Leipzig, Germany

"Change of the water system begins with small steps. If we don't make the first step, no changes will be made. Mr Willy Verstreate promoted to talk about taboos to make the change possible, that's the first step to change."

Sebastiaan van Eijk, EVIDES, Netherlands

"In my view the most relevant feature of the Conference was its wide scope. You covered almost all urban water aspects from a very wide perspective: Technical issues, economic issues, administrative issues, ecological issues, planning issues,...

No issue was analyzed in depth, that is for sure, but you provide a general overview of the actual state of the art and, mainly, on future trends.

Therefore my summary should be: "Urban water: State of the art and future trends"

Enrique Cabrera Marcet, Polytechnical University of Valencia, Spain

"To me the key learning outcome of the TRUST conference was the advantage of setting a long-term vision on the desired sustainability improvement of the urban water services."

Jos Frijns, KWR Watercycle Research Institute, Netherlands

"The IWA Cities of the Future Conference was the perfect opportunity to discuss OECD's recent work on water and cities in the context of financing, innovation, and governance. It was very interesting to see what, how, and where projects have been successful in the field, in particular, those focused on investment in green infrastructure, urban stormwater management, and the transition to decentralised infrastructure."

Hannah Leckie, OECD

"TRUST has timely delivered useful tools to enable the change from 'hard' to 'soft' water design frameworks. But we forgot to reach out to the world of urban designers. The conference confirmed the key role of water in cities with connections to many other sectors (energy, food, waste), and with strong ties to the citizens. The interface between the physical and digital world is becoming important. Models, data and ICT helping to design and operate water sensitive cities with involvement of the public."

Theo van den Hoven, KWR Watercycle Research Institute, Netherlands

"I enjoyed the conference very much. What surprised me most was Hamburg' s challenging proposal for a new water tariff with a greater flat rate. The demonstration case at Hamburg Wasser also considered other alternatives for achieving a more sustainable drinking water supply system, such as using housing water meters instead of meters at every flat. This case should make us wonder if sometimes when we take steps towards a more efficient, fair or precise system is this innovation affordable in the future? Is it profitable (in a holistic sense)? Will we be forced to turn back to basics when these concerns decrease? Researchers must have a basic economical background and must dive into it in every project. Before our conclusions, enjoy turning everything into numbers and consider different scenarios."

José Serrano Paradinas, Canal de Isabel II Géstion S.A., Spain.

"A very good event I think - lots of delegates but not enough from cities & utilities (but you may have expected me to say that) - there doesn't seem to be sufficient "user pull" for many of these DG RDI programmes, though there's lots of "researcher push" - it's only by having a much more integrated funding system that this will ever be resolved so that ideas can flow from blue sky to market and use without all the stop start issues associated with different and isolated funding schemes."

Mike Farrimond, TRUST Project Advisory Committee, United Kingdom

"The continuing challenge that I see is engaging urban water utilities to use the tools and technologies that will help them face future challenges, such as climate change and population growth. Programs like TRUST reflect a significant investment by the European Commission and the greatest payback will be when urban water utilities, using these tools, are successful in meeting these challenges of the future."

Daniel J. Murray, U.S. EPA and TRUST Project Advisory Committee, USA

"My personal feeling from conference is pleasant. At the beginning, when I read the conference program, I was afraid that I am absolutely out of conference topic. But beyond, participants showed great interest in all presentations, including mine. I learned some new terms and possible ways how to achieve sustainable water systems. I confirmed to myself what is known for a long time: even for good suggestions and designs to succeed a multidisciplinary approach is necessary. In water management not only engineers, chemists, biologists (this trend we try to keep in our department), but also quite different professions are essential: architects, economists, lawyers. And this definitely will not be easy to apply.

Other thing what I realized is about organization of conference: it is much better to have not more than one section at the same time. Even topics, which can sound unfamiliar, can turn to be very interesting."

Jana Nábělková, CTU Prague, Czech Republic

"The whole event and atmosphere was exceeding good and I enjoyed the interval sessions which were very informative. Linking the Cities of the Future theme and TRUST project worked very well and were very complementary. I am particularly interested in the themes of asset management, resilience and integrated planning and there were plenty of examples of where researchers and practitioners were tackling these challenges and making good progress.

The idea of creating a unifying vision around the concept of a living city was very powerful and has inspired me to think about how we can get better collaboration and collective buy-in to creating sustainable futures and resilient cities."

Paul J. Conroy, CH2M Hill, United Kingdom

"I am very satisfied that we managed to demonstrate so many good outcomes of TRUST and exposed the potential it brings for improved management of urban water systems. The complementary examples provided by the many in particular German projects brought even wider perspectives of the current opportunities. It also shown that we do carry out a lot of research with practical implications, that to-days researchers in general have a mature attitude to make a difference."

Sveinung Sægrov, NTNU, Norway

“To me, the broad scope of the conference was a bonus. Many different topics were addressed and I got new ideas on a couple of issues. This resulted in a tight timing of the presentations and limited room for discussion, though. But in retrospective, I appreciate the decision to go for a broader scope instead of more detailed in-depth discussion.

There were many examples that applied research within defined projects has some limitations, because actual implementation and change in the water sector take more time than usually available within that type of project [...]. Many presentations highlighted the need to better think about the social context, institutional and governance frameworks of urban water infrastructures. I think that there are many opportunities where engineering and social sciences can benefit from closer collaboration. “

Stefan Geyler, University of Leipzig (translated by David Schwesig)

„Urban planning and development for the future need to be re-invented. In a best-case scenario, it would be all out of one hand (instead of 5-10 different organisations). There are new economic models available to optimise follow-up costs of stormwater events. In the future, ageing/deterioration models will become a standard component for improved and more sustainable rehabilitation strategies.”

Thomas Nelle, Gelsenwasser AG, Germany (translated by David Schwesig)

TRANSITIONS TO THE URBAN WATER SERVICES OF TOMORROW

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