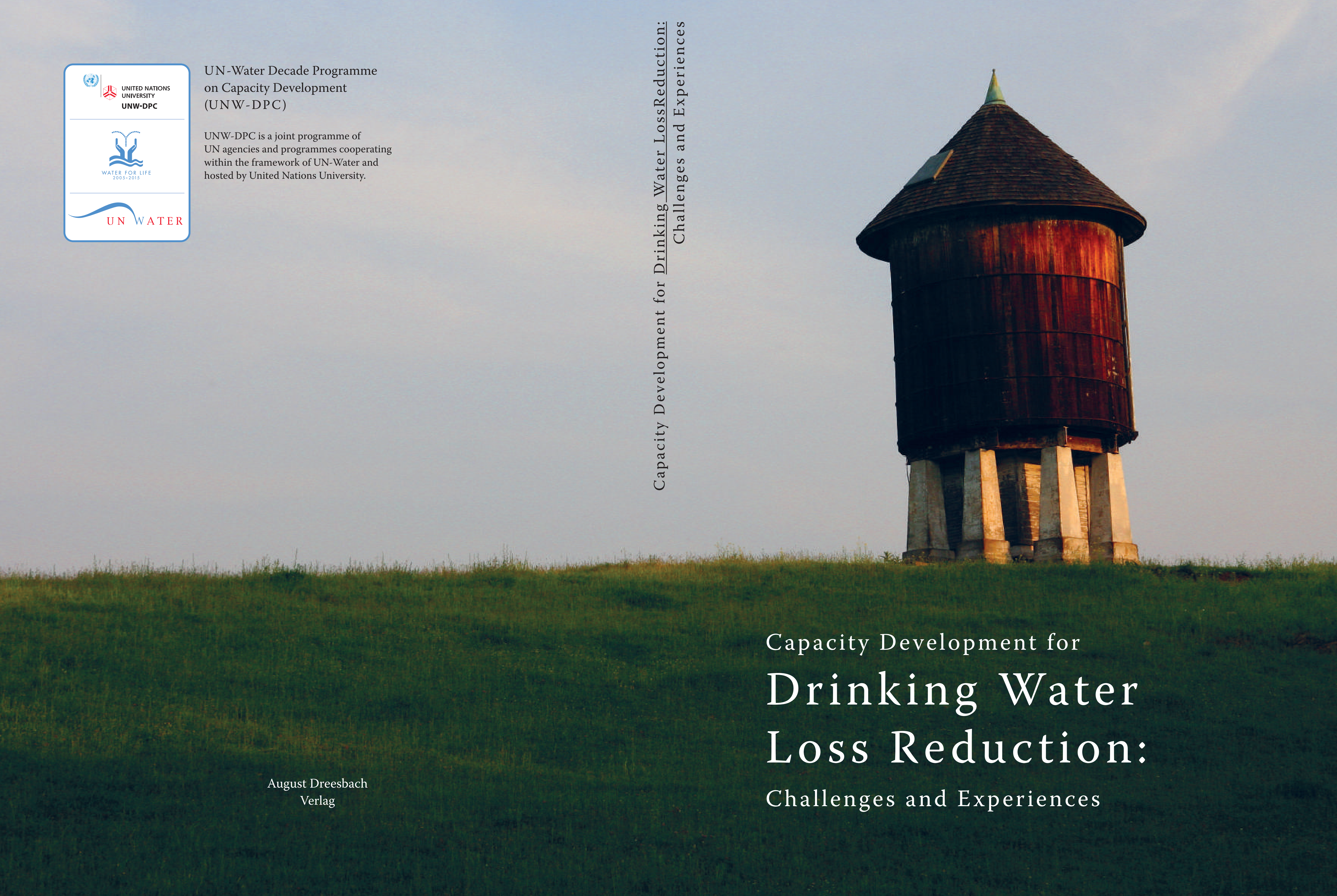

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WATER FOR LIFE 2005-2015

UN WATER

UN-Water Decade Programme on Capacity Development (UNW-DPC)

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Capacity Development for Drinking Water LossReduction:
Challenges and Experiences

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UN-Water Decade Programme on Capacity Development
(UNW-DPC)
United Nations University
UN Campus
Hermann-Ehlers-Str. 10
53113 Bonn
Germany

Tel +49-228-815-0652
Fax +49-228-815-0655
www.unwater.unu.edu
info@unwater.unu.edu

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FOREWORD

Reza Ardakanian
Founding Director, UNW-DPC

Water efficiency, and particularly drinking water loss, is a widespread issue which has significant financial and environmental repercussions. However, awareness regarding the scope of the problem and available solutions is lacking. To contribute to addressing this need, the UN-Water Decade Programme on Capacity Development (UNW-DPC) is pleased to present you this book. It is one of the results of three years of cooperation with UN-Water members and partners, regional collaborators and a group of experts in the UNW-DPC Working Group on Water Efficiency. The cooperation started with the organization of an international workshop on "Drinking Water Loss Reduction: Developing Capacity for Applying Solutions" together with UN-HABITAT on 3–5 September 2008 in Bonn, Germany. As a follow-up of the recommendations of this workshop and in order to address the issue of water loss reduction at the regional level, UNW-DPC organized in further cooperation with UN-HABITAT three regional workshops on capacity development for improving water efficiency, "Water Loss Reduction in Water & Sanitation Utilities", with the objective of developing capacities to better equip decision makers to address the problems of drinking water loss. The regional workshops were organized between November 2009–January 2010 in Mexico for Latin American countries, in Bulgaria for South East European countries, and in Morocco for Arab countries (total number of participants is 429, representing 60 courtiers). A further workshop for Africa is planned in 2011.

My thanks go out to the contributing experts whose ideas and experiences are to be found in this publication.

The first chapter of this report outlines the various problems and needs related to water efficiency, starting with an introduction given on the scope of the tasks before us on various aspects related to improving human development and well-being, particularly as they are related to the Millenium Development Goals (MDGs). Chapter one also discusses technical, political and institutional challenges for water loss reduction in specific cases in South Eastern Europe.

After laying out various aspects and dimensions of the problems in water loss reduction and water efficiency, the second chapter introduces options for actions and solutions; first with an introduction to the benefits of finding solutions, and then with relevant and useful real best practice case studies from around the world, with significant focus spent on the issue of benchmarking. Two special sections focus entirely on the use of new technologies, including GIS.

The third chapter goes on to make the financial argument for water loss reduction and includes information on the economics of the issue. A central tenet of the book is the argument that water loss reduction can have real economic benefits and value, despite added investments that are needed.

Finally, chapter 4 goes on to discuss the capacity development that can and should be possible (as is essential) in the achievement of greater water efficiency. Social learning models have a role to play, as do comparisons of best practice across regions.

I would like to take this opportunity to express our gratitude to the Federal Government of Germany for its financial support, provided through the Federal Ministry for Economic Cooperation and Development (BMZ) and the Federal Ministry of Education and Research (BMBF), as well as the project-based support from the Federal Ministry of Environment, Nature Conservation and Nuclear Safety (BMU). We would also like to thank our collaborators within UN-Water on this topic, especially UN-HABITAT, and the local cooperation from partners such as the Bulgarian Water Association (BWA), Asociacíon Nacional de Empresas de Agua y Saneamiento de México (ANEAS), and the Arab Countries Water Utilities Association (ACWUA).

CHAPTER 1

Günter Klein is currently director and professor at the International Center for Sustainable Development (IZNE) at the Bonn-Rhine-Sieg University of Applied Sciences. He was the founder and head of the Water Initiative Strategy Office at the DLR (German Aerospace Center) in Bonn, Germany. He has worked as a consultant for UNU-EHS and as a director and professor with a special assignment (water and sanitation, the global public good, strategies for implementing MDG 7) at the German Federal Agency for Environment Protection in Dessau, Germany. From 2001 to 2005, he held the position of Head of Office in the newly founded European Centre for Environment and Health, World Health Organization, Bonn. Prof. Klein holds a doctorate degree in Sanitary Engineering from the Technical University of Darmstadt, Germany. He is a member of the UNW-DPC Water Efficiency Task Force.

Atanas Paskalev has a PhD from the University of Architecture, Civil Engineering and Geodesy in Sofia and has over 35 years of experience in the field of water supply, sewerage, water treatment and related activities. He is Manager of Aquapartner Ltd and also vice-president of the Bulgarian Water Association (BWA) and a member of the International Water Association.

Miroslav Tesarik is a civil engineer, graduated from Prague Technical University, with a specialization in water constructions and water management. His former engagements include the Prague Project Organization, Water Research Institute, and Prague Water and Sewarage Company. He currently works with the Danish Hydraulic Institute a.s. in a position of project manager and hydraulic specialist.

CHAPTER 2

Dagmar Bley studied Geography with a focus on Hydrology at the Free University of Berlin, and has a PhD in sediment transport. After working for several years on basic hydrological research, she joined a large consulting engineering company in the field of water supply and water management in 1994, where she held an executive position for 8 years. From 2002 onwards, she has been working in the field of science administration, especially on environmental sciences. In 2007, she became a Science Officer at the Project Management Agency of DLR (German Aerospace Center) in Bonn, which supports Germany's Federal Ministry of Education and Research in developing concepts for international collaboration in the fields of water management and climate change. Within this task, Dr. Bley especially worked for the Water Strategy Initiative Office. She is a member of the UNW-DPC Water Efficiency Task Force and published several papers on Water Loss Control.

Ismail Demirel is the head of the SCADA branch at Antalya Metropolitan Municipality, Antalya Water and Wastewater Administration (ASAT), in Antalya, Turkey. His background is in geological engineering. However, he has a wide experience in SCADA systems for drinking water distribution networks. He worked for many years in this field with the Ankara Metropolitan Municipality and with the Antalya Metropolitan Municipality.

Stefan A. Haffner worked as scientific staff member at the Water Initiative Strategy Office at the DLR (German Aerospace Center) in Bonn, Germany, and at the Center for Development Research at the Rheinische Friedrich-Wilhelms-University of Bonn, Germany. He was scientific staff member of the GLOWA Volta Project and worked as a consultant and project manager for different institutions like the government of North Rhine Westfalia and the federal government of Germany, as well as for institutions of development cooperation like INWeNT and others. He graduated with a diploma in Geography, Sociology and Psychology.

Günter Klein (See Part 1)

Bojan Ristovski is an electrical engineer, specializing in the management of water resources and water services in water utilities. He has been an active member of the IWA Water Loss Task Force (WLTF) since its foundation and is active in promoting the WLTF techniques and methodologies in Macedonia and across the Balkans. Currently, he holds the position of Director of Leak Detection Department, On-Duty Center and Call Center in J.P. Vodovod i Kanalizacija-Skopje, Macedonia (Public Enterprise Water Supply and Sewerage-Skopje, Macedonia).

Stuart Trow has a Civil Engineering degree from the University of Newcastle upon Tyne in the UK, and 32 years of experience in the UK water industry. These include 30 years involved with technical issues on water distribution systems, particularly leakage and losses. He now works as an independent consultant in the UK and internationally.

Max Hammerer graduated as an engineer for Electro-Techniques in Klagenfurt, Austria. He is a consultant for maintenance and operation management in water and wastewater companies. Specialties include implementation and supervision of network documentation by GIS, water loss reduction processes, failure statistics, inspection service and condition-based rehabilitation strategies. He is President of the Associations CEOCOR sector C and Danube Water Competence Center DWCC.

Karl-Ulrich Rudolph is double educated, holding doctorate degrees in water engineering and in environmental economics. Before joining the University of Witten/Herdecke, Germany, as director of the IEEM (Institute of Environmental Engineering and Management) and becoming the CEO of the CEEM (Consultants for Environmental Engineering and Management, Prof. Dr. Rudolph GmbH), he worked for the operations of the GfA GmbH, a large sewage treatment plant company, as member of the Deutsche Bank Advisory Board, and as Supervisory Board Member for the Berlin Water Works. Prof. Rudolph has published 301 articles in books and referred journals, and received various awards (namely the DIESEL Medal in gold, the “1986 Award” for Commercialisation and Privatisation of Water Management, and the 2006 Global Competition “Innovations in Water, Sanitation and Energy Services for Poor People” carried out at the World Bank, Washington). He is an Honorary Member of the VpA, which in 1994 merged with the BDE (Water & Waste Industry Association of Germany) and a Guest Professor at the NEU – National Economics University of Vietnam, Hanoi. Since 12/2009, he has been the co-ordinator of the UNW-DPC Water Efficiency Working Group.

Alan S. Wyatt is an environmental engineer and manager with over 25 years of experience in international development assistance programs and projects. He has worked extensively on projects in the areas of water supply and sanitation, urban environmental management, and renewable energy in the U.S., Europe, and 15 other countries in sub-Saharan Africa, North Africa, Central America and Asia. He has authored over 50 technical publications. Most recently he has been managing technical assistance and training programs in water supply and sanitation, local environmental management, municipal management and infrastructure project finance. He currently serves as director of business development for the International Development Group. He has a MS in Environmental Engineering, School of Public Health, University of North Carolina at Chapel Hill; BS in Mechanical Engineering, College of Engineering, Cornell University.

Elisabeta Poçi graduated in 2004 and holds a Diploma on Environmental Engineering, Water Treatment Specialty. Since her graduation she has been working for the Water Supply and Sewerage of Albania, where she serves as the Program and Training Manager to the Association. Ms. Poçi has been engaged as well in her job as a part-time lecturer at the Faculty of Civil Engineering since 2005.

Hani Sewilam joined UNW-DPC as a programme officer in 2010. He worked at the RWTH Aachen University in Germany from 2002 to 2010 as a Deputy Director for the Department of Engineering Hydrology. He has managed numerous international capacity building projects in 12 countries. In 2008, he established the first North African Regional Center of Expertise on Education for Sustainable Development (RCE Cairo). Dr. Sewilam worked for the Egyptian Ministry of Water Resources and Irrigation as a coordinator for development projects with several UN organizations. He has more than 19 years of professional experience in the water field, eLearning and capacity building. He has authored many peer-reviewed scientific papers and book chapters and served as a consultant and reviewer for several international research and development organizations. Dr. Sewilam holds a PhD in Water Resources Management (Civil Eng.) from the RWTH Aachen University, an MSc in Irrigation Management (Civil Eng.) from Southampton University as well as a Diploma and BSc in Irrigation and Environmental Engineering.

Chapter I – Problems and Needs

MAIN CHAPTER MESSAGES

› It is time to share experiences and join forces towards the delivery of the common goal of "water for all."

› No wealth and no health without understanding the role of safe water!

› The following aspects should be visible for all stakeholders:

» The economic benefits of proper water systems maintenance

» The positive political power of adequate water supply

» Appropriate solutions for any economic, climatic or cultural context

» A convincing approach to enhance human capacity towards valuation of water as the essential element for all life processes

1 Solution Oriented Capacity Development towards IUWM: Focus on Water Loss Reduction

Günter Klein
Bonn, Germany
[guenter.klein@dlr.de]

Keynote at the International Workshop on Drinking Water Loss Reduction (3-5 September 2008, Bonn, Germany)

Abstract
Water supply on a global scale faces three major challenges:
> The Water and Agriculture Challenge
> The Water and Industry Challenge
> The Water and Urbanization Challenge

For each of these fields the prognosis seems to be daunting: How can we expect or create stability in light of poverty, climate change and demographic change? However, in each of these areas there are examples to be found of excellent performance at high economic efficiency and good feasibility.

For the 50% of the world's population that is presently living in urban settings, water supply is crucial for life and health. Through individual and institutional capacity development, many cities across the world have enabled their citizens to co-operate effectively to achieve a safe and reliable supply of water. However, roughly a third of all the water provided to urban drinking water distribution systems is either lost through leaks, or not included in the revenue and financing system. This pattern can be changed. Since its establishment in 2007, the UN-Water Decade Programme on Capacity Development (UNW-DPC) has undertaken numerous activities together with members and partners of UN-Water in order to tackle this crucial issue. Among other endeavors, it established a working group on the topic, composed of experts who have come together to provide feedback for this book. An international conference and series of regional workshops on the issue, culminating in a video, has cemented the importance of the topic.

These and other workshops, such as the 2007 "Control of Water Loss in Distribution Systems", are about sharing experiences and joining forces towards the delivery of the common goal of "water for all". Five tasks are crucial for this process:

Nr. 1: Make the economic benefits of proper water systems maintenance visible to all stakeholders;
Nr. 2: Make visible the positive political power of adequate water supply for all;

Nr. 3: Make the better choice the easier choice;
Nr. 4: Find appropriate solutions for any economic, climatic or cultural context; and
Nr. 5: Find a convincing approach to enhance human capacity towards valuation of water as the essential element for all life processes.

1.1 INTRODUCTION

No wealth and no health without understanding the role of safe water!

One of the key elements to success in all countries and societies in the world, past and present, is the proper handling of water. Experiences gained in many industrialized countries over the past centuries need to be studied and made public. Sustainability will only be achieved when global societies work together to avoid the repetition of past mistakes, especially those which have caused irreversible harm to natural resources. The ways in the past in which many industrialized countries have chosen to solve water quality and availability problems, and the ways in which these solutions are presently implemented – or not implemented – given new challenges such as ageing societies and climate change, also pave the way for future learning approaches towards meeting the global challenge (Exner et al. 2008).

Ongoing and long-standing debates about a human right to water, which recently culminated in the United Nations Human Rights Council Resolution on human rights and access to safe drinking water and sanitation, passed in September 2010, indicate that there might be a new and innovative approach: The essential needs of human beings cannot be hidden behind legal or economic criteria. Basic preconditions for life include safe and reliable water supply. This is not negotiable, either between individuals, or between countries.

It is therefore essential that water resources everywhere in the world are handled as part of the global heritage of life. Living systems are open systems, with various entry points for resources and energy. Where it is necessary, organisms and living structures organize their use of resources with the highest amount of efficiency. Living structures of human beings, like urban agglomerations, have to organize their use of water resources in a similarly efficient way. Ensuring adequate water supply and control of water loss is as important for urban systems as it is for individual organisms. Without water supply we cannot live longer than three days; with unhealthy water humans won't survive much more than their first three months. With enough water of sufficient quality we can live to be 100, and our urban systems can survive many centuries, as long as the water supply is not destroyed. Like the veins in our body, the water distribution system of any urban agglomeration has to be kept clean and without leaks.

With this in mind, the United Nations has increased concerted efforts towards putting water at the top of development and human rights' agendas. One result is the inter-agency mechanism known as UN-Water, which is composed of representatives of 28 United Nations organizations. The United Nations organizations include those responsible for major funds and programs, specialized agencies, regional commissions, United Nations conventions and other entities within the UN system. Other organizations outside of the United Nations are also partners in UN-Water.

Another important activity is the international observance of World Water Day on March 22nd every year, which is an initiative that grew out of the 1992 United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro. Past World Water Days have focused on water scarcity (2007), sanitation (2008) and water quality (2009), among many other important themes. The theme for 2011 is a very appropriate and timely one: "Water for Cities", with a renewed focus on the links between urbanization and water.

A major important step in the international acknowledgement of the prominence of water issues came in 2005, when the World Water Day 2005 marked the start of a new UN International Decade for Action on water. The Water for Life Decade 2005–2015 gives a high profile to implementing water-related programmes and the participation of women. Now, past the middle of this decade, as we race to 2015, the UN hopes that the decade will boost the chances of achieving international water-related goals and the United Nations Millennium Declaration. One of the offspring of the decade is the UN-Water Decade Programme on Capacity Development (UNW-DPC), the office of which is hosted in Bonn by the United Nations University.

With an increased understanding, the aims of a workshop on World Water Day 2007 led us towards healthy and human urban water management approaches.

1.2 MEETING THE WATER AND SANITATION TARGET? THREE BIG CHALLENGES

UN World Water Day 2007 stood under the heading: "Dealing with water scarcity". While the "average" policy maker and journalist would associate this problematic challenge with illustrations of desertified landscapes, or with farmers looking sadly at their dying plants during drought periods, the focus of solution-oriented professional work is more and more directed towards three major fields of action, focusing on where water scarcity has been created:

- The Water and Agriculture Challenge
- The Water and Industry Challenge
- The Water and Urbanization Challenge

This approach takes the water issue away from problem analysis and description of catastrophes. It leads, instead, towards solution-oriented work in a global partnership. And it will provide orientation to those institutions and organizations who teach the future constructors and managers of water systems, engineers, accountants or plumbers.

Each of the three big challenges has to be understood to be inextricably linked. No progress will be achieved in the long run on any of these fields without taking the other two seriously into consideration. It will be of crucial importance to develop a future-oriented understanding of a constructive and productive relationship between land use and industrial and agricultural use of water as part of the global, regional and local water cycles, in comparison to the perceived, or provoked, competition for water resources. It has been sufficiently and convincingly demonstrated that conflicts, and even armed conflicts around water, have been and will continue to be artificial (Shuval et al. 2006).

Technical and economic excellence wanted!

However, at the same time, we need to recognize the need to deal with each of these challenges individually, and case by case, in a technically and economically professional and adequate way.

There is no doubt that huge regions are suffering most from wastage of water due to inappropriate structures for agricultural irrigation. The technical and organizational solutions are available but not widely implemented.

There is also no doubt that economic growth and industrial development need water of adequate quality and sufficient quantity. Technical solutions exist, and have been applied, for ensuring economic growth and raising water efficiency, thus decoupling industrial expansion from water demand. Increasing the production of steel, cars, paper or any other product does not need increasing amounts of water: The majority of successful economies have increased their product output and at the same time reduced water consumption, in many cases by one or two orders of magnitude, and in some cases down to almost zero.

Optimizing internal processes – for securing external support

In the former two fields, the link between productivity and provision of water of an adequate quality and quantity has been well described, or, vice versa, the lack of success due to failure of appropriate water management is obvious.

The understanding of the economic and ecological value of efficient water use in urban systems seems to be less developed. The aim of this workshop was, therefore, to raise awareness that

> Water stress in many agricultural settings has been created by water abstraction for urban agglomerations' water supply;
> Discharge of sewage from urban agglomerations has disrupted regional water cycles and has polluted water resources substantially;

- Construction for dwelling and transport has closed land surface, thus converting areas that had been collecting water or storing it into areas of rapid water discharge;
- Water availability for urban agglomerations is strongly dependent on undisturbed functions of aquatic systems in its surroundings; and
- In the overall context of IWRM, integrated urban water management (IUWM) plays a major role – either by wise use of (their own) existing resources, or instead, by wasting them and exploiting other peoples' resources for life.

Thus, by stabilizing these peri-urban functions, urban systems can avoid entering a self-damaging cycle, which in fact needs to be arrested. One major contribution towards this end is the efficient use of water within the urban system, and prevention of avoidable loss through an Integrated Urban Water Management approach. Distribution systems can be maintained and managed such that less than 10% of water loss is economically and technically feasible. Higher losses are not only ecologically questionable and a violation of human rights and global targets like the MDGs, but they are at the same time economically damaging. A global learning exercise is needed to make the tools for solving the problems related to this challenge available for the management of any city – small towns as well as the big megacities and urban-industrial agglomerations.

The only productive way of water-related interaction is cooperation. Therefore, this article is directed towards progress in common sense, good governance and the necessity to cooperate – to the benefit of all. Adequate cooperation for water, instead of competition, has only winners; no losers. This approach needs the competence of all stakeholders, and their full understanding of their respective gains in the long run. Many ideas have been developed and published in various languages and countries, but the vast majority of actors do not yet have access to the most appropriate capacity development tools.

This chapter is about a new attempt of the world community to enhance the capacity of all professionals involved, from the plumbers and farmers to the water systems managers and decision makers at the local or national level, driven in part by UN-Water networks and the global water partnership commitment under the MDGs.

1.2.1 IUWM – integrated urban water management – a feasible approach worldwide?

As described above, the water system management under the IWRM approaches needs to take all aspects into account. However, at each individual point of the global system, adequate and specific action is needed, and excellent performance at any point of action is necessary. We have, therefore, focused this paper on one of the three big challenges for the following reasons:

Solution-oriented work needs resources – not much, but well targeted

Many cities across the globe have gathered a magnitude of wealth and economic dynamics in their modern centers. Here, provision of sufficient water and sanitation seems not to be an issue, and it is not at all a question of economic feasibility. The cost for water supply in these centers is negligible in relation to the economic turnover business enjoys in these places. However, many of these urban centers suffer from bad maintenance of distribution systems, sometimes combined with poor compliance with financial regulations. In the majority of cases, a suitable system for water pricing has not even been established.

As can be shown through an analysis of many cities in industrialized countries, the most excellent urban systems of control and maintenance do not consume more than some 2–3% of the average income. A new economic analysis is needed: cheap is excellent, and excellence is cheap!

One must ask oneself why the reality is so sobering. What is missing?

Lack of collaboration at the urban-rural interface

The loss due to leakages and the economic loss due to unaccounted water flow amounts to an order of magnitude between 25 and 50% of the total amount of water that is collected and distributed. In many of the 100 megacities with about five or more million inhabitants, some 250 to 500 million m^3/ year of clean and safe water are either lost or not paid for. Saving just those losses caused by leakage would be sufficient to provide another 10–20 million people with safe water services.

While some big urban water suppliers, such as in Germany, manage to keep their losses below 5%, there are far too many other places where neither a system of continuous maintenance nor an effective system for leakage control has been established.

MDG Goal 8: Develop a global partnership for development

Environmental health interventions can make a valuable and sustainable contribution towards reducing the global disease burden and improving the well-being of people everywhere.

Many interventions can be cost-effective and have benefits beyond improving peoples' health; such as helping to alleviate poverty and reduce gender inequalities. Yet in fact the opposite has happened. Instead of implementing such a solution-oriented approach, additional problems have been created. Compensation for these losses has been taken from outside. The construction of new dams, abstraction of groundwater and competition with local suppliers and farmers in the peri-urban belts puts additional stress on those people who provide the human resources for the economic progress and success of the central urban areas. It should be noted that these processes were not just "happening", but they were actions implemented on the basis of decisions against a more sustainable and future-oriented approach (Exner et al. 2008).

Models of cooperation between the urban and the peri-urban and the surrounding communities, who provide the ecological basis for water and food supply, have been implemented. The successful ones have been based on a case-by-case analysis and cooperative decision making process. Case studies can be shown, having been implemented for many decades and proven successful (e.g. Ruhr Verband in Germany http://www.ruhrverband.de/ruhrverband_en/html/index.html). It is in the interest of the world community to look at the potential of these case studies for averting future cases of stress and competition at the urban-rural interface.

For this reason, UNW-DPC has started focusing on good urban cases of water loss reduction in various regions around the world, starting in September 2008 with an international workshop on "Drinking Water Loss Reduction: Developing Capacities for Applying Solutions" together with UN-HABITAT, the results of which can be found in UNW-DPC's Proceedings publication No. 1. After this workshop and the subsequent establishment of a UNW-DPC Working Group on Water Efficiency, UNW-DPC organized a series of regional workshops on the topic of water loss reduction, with the aim to document available know-how and best practices and to recommend new approaches for more efficient management in the field of water and sanitation with a focus on water loss reduction. These workshops also encouraged follow-up projects and the establishment of communication between the policy makers, water managers and researchers, as well as the providers of technical solutions.

The first of these regional workshops, for Latin American countries, was co-organized by UNW-DPC and UN-HABITAT in November 2009 in Leon, Mexico; the second was for South East European countries held in Sofia, Bulgaria, also in November 2009; and the third for Arab countries held in Rabat, Morocco, in January 2010. Results from the first two regional workshops have been published in the UNW-DPC "Knowledge" series publications No. 3 (Latin America) and No. 4 (South Eastern Europe). A further regional workshop for Africa is planned in 2011, and the results of the workshops to date have been displayed in a UNW-DPC video on "Water Loss Reduction in Cities Around the World", which will be debuted in its Spanish, French and original English versions on World Water Day 2011 in Cape Town, South Africa.

1.2.2 Capacity development – solution oriented towards the effective control of water loss

The need to control the loss of water and to attach importance to the sustainable maintenance of water supply all over the world, particularly in urban areas (with old and fragile pipes), is becoming more and more well-defined in the domain of science and stakeholders. The example of cities like Teheran where the unaccounted flow of water amounts to some 250–300 million cubic meters out of the 1 billion cubic meters provided every year, or the capital district of Mexico, with impressive water losses of 12.8 m^3/s (roughly 360 million cubic meters per year) applies to many other cities across the world. This magnitude of between 30% and 50% of loss rate reflects the extent of the avoidable stress.

In the case of professionally operated plants, the unavoidable operational and technical loss (dishwater, pipe bursts, accidents, etc.) amounts to around 5–12%; in the case of institutions under top management with implemented strategies and technologies, it can decline to below 5% (e.g. Gelsenwassser AG). Cities that suffer from bad maintenance of distribution systems (e.g. due to an insecure political situation), document losses from permanent fraction and leakages of between 30% and 40%. Even countries with reliable water resources can be put into a difficult situation by dry seasons (e.g. South England 2007) or pressure fluctuation (Eastern Europe); additionally, illegal withdrawals amplify the problem.

The costs for distribution systems and employees for maintenance and care normally amount to more than 50% of the water pricing. Without this investment, an adequate water supply would not be conceivable and the consequential charges would be incomparably higher (illnesses, downtime, loss of confidence).

The cost for reconstruction and maintenance of sustainable distribution systems reaches into the billions, which at first glance looks tremendously high. However, regarding the social and financial burden on households on one side, and on the other side the fact that the costs of adequate operation and maintenance of water supply systems are well below 1% of the median income all over the world, there is the need for transparency showing the true cost, regardless how the institutional arrangement of managing the system is structured. Privatization of publically-driven water supply services is not automatically a helpful strategy. This is especially true when urgently needed sustainment of water systems is carried out by a municipality which may be financially weak and short of professional staff.

1.2.3 Linking technical progress with global networks for capacity development

Many cities across the world have developed long-term strategies towards the reduction of water losses. In order to support the fulfillment of the Millennium Development Goals, control of leakage and water losses needs exchanges of experience. Therefore, for example, the UNW-DPC strives to bring together providers of innovative technical tools, water supply companies and technical and organizational managers from around the world who are willing to engage in a partnership for capacity development under the following topics:

> Cost benefit analysis of maintenance, leakage control and detection of unaccounted flows;
> Illustration of concepts for sanitation of distribution systems, case studies, benchmarking and indicators;
> Declarations of international cooperation and work programs for capacity development to control and minimize water loss, target group-specific training programs (modules), and regional conferences;
> Reports based on successful application (and failures) in sanitation and permanent operational reliability;
> References to successful sanitation projects and application of modern technologies; and
> The development of concepts for group-specific training modules for application in eLearning and training workshops.

Sharing experience and creating indicators for good performance will hopefully enhance the willingness of those in charge of building and maintaining water distribution systems to improve their own local situation. In order to facilitate that on the basis of convincing knowledge, the focus of UNW-DPC's workshops and other activities will continue to be directed towards solution-oriented capacity development on:

> Economic aspects of drinking water loss reduction within Integrated Urban Water Management (IUWM);
> Technical and structural interventions for long-term rehabilitation of drinking water distribution systems;
> Political and administrative solutions; and
> Tools for capacity development.

The future orientation of UNW-DPC will be directed towards

> Regional workshops;
> Training modules and eLearning curricula;
> Sessions on drinking water loss reduction at major world forums such as WWF, World Water Week and World Water Day.

1.3 ASSESSING NEEDS AND DESCRIBING TARGET-ORIENTED TOOLS – FIVE TASKS

The activities of UNW-DPC over its first three-year phase of activities from 2007–2010 has helped to identify the following tasks and areas of urgent action in capacity development:

Task Nr. 1

Make the economic benefits of proper water system maintenance visible to all stakeholders:

> Consumers, who need and deserve reliable water supply 24 hours a day, every day;
> Finance managers of cities or water supply companies, who are responsible for reliable water supplies;

> Industry managers, whose success in business is dependent on a functional infrastructure and a healthy workforce;
> Regional managers, who are in charge of infrastructure and physical planning; and managers of financing institutions (including international development banks), who need to depart from non-sustainable and short-sighted funding strategies.

These tasks still need to be structured and delivered. Around the world, both capacity development and education in economics are still trapped by old-fashioned attitudes of "competition rather than action in partnership". And a new focus needs to be given to the so-called "environmental economy". When a small group of "greenish" economists struggles to get its approach of analysing social and long-term costs of action, (or "in-action", as it were) to the forefront of economic policy making, it is confronted with two traditional schools: Those who try to handle the fall-out of misleading competition strategies by sharpening their own (and useless) tools, and those who build their thinking upon the motivation and optimization of hedge fund and interest management, thus making more money out of money, and as a (wanted) side effect pushing for the drainage of resources from public and state financing.

Task Nr. 2
Make the positive political power of adequate water supply for all visible

This needs new training approaches for policy makers at all levels. Sharing experiences with other cites, either under long-term stable conditions (e.g. like Gelsenwasser in Germany) or under political and economic transition (like Dresden or the WAL Lausitz in Eastern Germany, former GDR, or Budapest, Hungary, during the transition from the Cold War period into the accession into the European Union), which can demonstrate the power of safe water supply as a tool for promoting social stability and social justice. And this has been demonstrated to be feasible within "human" time horizons: Not centuries of hope, but a few years or one decade of action. It is the strong wish of the public, and simultaneously the strong wish of each individual and family, to build their lives and the health and well-being of their children upon a sustainable and reliable supply of safe water: 24 hours a day, 365 days a year. Based upon existing studies, the feasibility and the economic sustainability of safe and reliable water under all political and economic conditions can be communicated to managers and policy makers in charge. This message needs to be carried into the educational schemes of many professions, from child care, through school and secondary education, right into the learning programs of lawyers and engineers.

Task Nr. 3
Make the better choice the easier choice

Technical means have been developed which can make the lives of technical and organizational staff easier. Remote sensing instead of digging; remote data collection via satellite instead of touring through the country; in-line leakage detection and repair instead of boreholes and ditches for replacing old pipes. And of course: the ability to get safe water from the tap all the time, instead of walking and waiting for hours for unsafe water.

All these tools have been developed and applied in "wealthy countries". Even here, through political pressure, managers of water works have been scrutinized to reduce their cost, and the way to do so is to be more effective, avoid mistakes (that others had made before) and avoid well-known traps. Sharing experiences and benefitting from the experiences of others who have gone through similar challenges has created a solution-oriented professional partnership. National and local networks have gathered and distributed experience and training materials which have been made available to colleagues in partner countries, not least through effective collaboration via networks like e.g. the IWA-networks.

Task Nr. 4
Find appropriate solutions to any economic, climatic or cultural context

There is no doubt: physical laws govern the behaviour of water just like any other natural process. Human societies have no choice, and those who have the best and most sustainable progress are those who manage best to harmonize human activity with the universally valid rules of natural processes. Just as a reminder: human water use deals with some 0.2% of the annual turnover (precipitation of rain and snow on land surface, feeding groundwater replenishment, flow through rivers and lakes), and this global cycle moves not more than 0.3% of the worldwide existing fresh water resources.

The true challenge lies with local and regional management of human water use within this tremendously rich and never-ending flow of the water resource. Urbanization is one of the most dynamic human processes, with the greatest potential to improve human living conditions, but only within the limits of these naturally given rules.

Task Nr. 5
Find a convincing approach to enhance human capacity towards the valuation of water as the essential element for all life processes

Water loss in man-made water distribution systems is one of the easiest avoidable violations of natural and physical rules, among the long list of examples of non-sustainable management of natural resources. Many individuals have learned their lessons, however, and they did not find an easy approach to make happen what they felt was necessary. Institutional capacity development will be one of the key processes towards more sustainable management of water distribution systems. All hands and brains and all professions are needed to deliver this, and they need to be well trained towards the end. Academies, schools and institutions for vocational training and education have delivered a substantial collection of products. Only a few of them take the essential element of water into account – it seems to be taken for granted. Global networks for vocational training and education reach out to more than 150 countries worldwide (e.g. through UNEVOC http://www.unevoc.unesco.org/snippet.php). However, following a very recent analysis of the areas of work, very few country projects deal with vocational training in the professional fields of water supply. This limited offer needs to be expanded, and then to be grasped by local and regional authorities, thus enabling them and their staff to do an even more effective job.

UN-Water was created under the leadership of former UN Secretary General Kofi Annan, with the aim to make the many UN agencies dealing with water join their forces, their knowledge and potentials (http://www.unwater.org/flashindex.html). UNW-DPC is one of the fruits of this integrating attempt, aimed at improving capacities world-wide for serving the MDGs, all of which depend on a reliable supply of safe water (http://www.unwater.unu.edu).

Urban centres have been sources of knowledge and social power throughout human history. They have the potential to kick off a new understanding of responsibility for water resources all over the world. Half of the world's population now living in urban agglomerations needs a better and convincing approach for themselves, which will also be convincing for those living outside these agglomerations, and they should be released from carrying the burden of improper management of their resources.

1.4 CONCLUSIONS

Plugging the leaks: Learning how to multiply efficiency at low (or no) cost

According to a report delivered at a recent World Water Forum by Transparency International, roughly 30% of financial aid investment into water and sanitation has disappeared through corruption channels.

According to reports delivered by various national and international institutions, many urban water supply systems lose between 20% and 50% of the water in their distribution system, where it is mixed with leaking sewage.

Water and sanitation efficiency can be raised by closing the leaks where 1/3 of the money and 1/3 of the water are disappearing to. Without additional funds and without additional raw water, plugging the leaks means getting more and better life out of existing resources.

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2 Some Political and Institutional Challenges for Water Loss Reduction in Bulgaria

Atanas Paskalev
Sofia, Bulgaria
[aquapartner@aquapartner.com]

1 BACKGROUND

Located on the Balkan Peninsula, Bulgaria has an area of 110,911 km^2 and a population of just under 8 million residents. The average population density is 81 persons per km^2 and about 65% of them live in towns. The average annual precipitation fluctuates within the range of 500 mm up to 2,000 mm in the high mountains.

The water resources in Bulgaria are formed by the run-off of internal rivers, underground waters and part of the water of the Danube river.

The drinking water generated makes up 7–8% of the average annual river run-off, depending on the humidity during the year and averages 840,000 m^3 annually.

In Bulgaria, all 238 towns are supplied with water, while in villages it is 89.9%. The length of the constructed water supply network is 44.874 km, and the transit water supply pipelines combine to form a total of 25,375 km, but are depreciated with high levels of water loss. Water is obtained from 10 water supply dams, 146 river catchments and 2,800 wells. Water is purified in 53 PWTPs and there are a total of 5,900 water supply reservoirs and 3,850 pumping stations. This water supply infrastructure is managed by 13 companies with 100% state participation, 16 companies are jointly run – 51% state and 49% municipal participation, 21 municipal companies, 1 concession for the city of Sofia and some smaller-sized ones, as shown in > Figure 2.1.

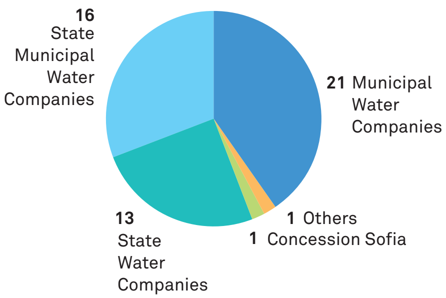


Figure 2.1

Major laws bearing on the water sector and its development are:

- The Water Act, which is constantly being developed, the last amendments related to its harmonization with the Water Framework Directive of 2000.
- Water Supply and Sewerage Services Regulation Act from 2004, which deals with price regulation, availability and quality of water supply and sewer services provided by operators.
- Water Supply and Sewerage Services Act, which is now amid discussions before being adopted and which will settle the long-standing problem with the ownership of this infrastructure and will, too, light up the introduction of the private sector.

There is a number of other laws related to the water sector, but what deserves special attention is the strategy for development of the water sector that was formally adopted by the government in March 2004.

The major objectives of the strategy are:

- The creation of conditions for efficient management of the sector,
- The creation of conditions for the introduction of the private sector, and
- The improvement of the quality of the services.

The investments needed for the water sector have been determined by experts from the World Bank and are provided in > **Figure 2.2**.

It can be seen from the figure that the low standard and income in Bulgaria would not allow a major portion of the investments to come through their inclusion in the price of the water, however optimistic, the affordability of the water prices shown in > **Figure 2.3** may be.

2.2 BRIEFLY ON THE STATUS OF WATER LOSS

The first serious step in this respect was made during the so-called "water loan" from the World Bank (WB) from 1996–2001. Under observation were 15 water supply and sewerage companies in terms of organizational, technical, financial and operational parameters.

The issue of water losses was the main focus of attention for the bank and a number of conclusions and proposals were made. Pilot zones were made and operating staff was taught. It was shown how water losses lead to less revenue from sales, bigger production costs and a necessity to raise the tariffs. A demonstration was made, too, of approximate figures in the distribution of the administrative and physical losses when the assumption of an average optimal general loss of 50% is made, as is shown in > **Figure 2.4**.
The most serious step was made with the coming into force of the regulation in 2004, with Art. 7 of section 9 explicitly "encouraging the reduction of water losses …", and, furthermore, Art. 9, para. 2 of section 4 demanding target dates: "The general losses of water in the water supply systems and

Indicative Cash Flow: 2004 to 2014 (in Millions) Based on Bulgarian Water Supply

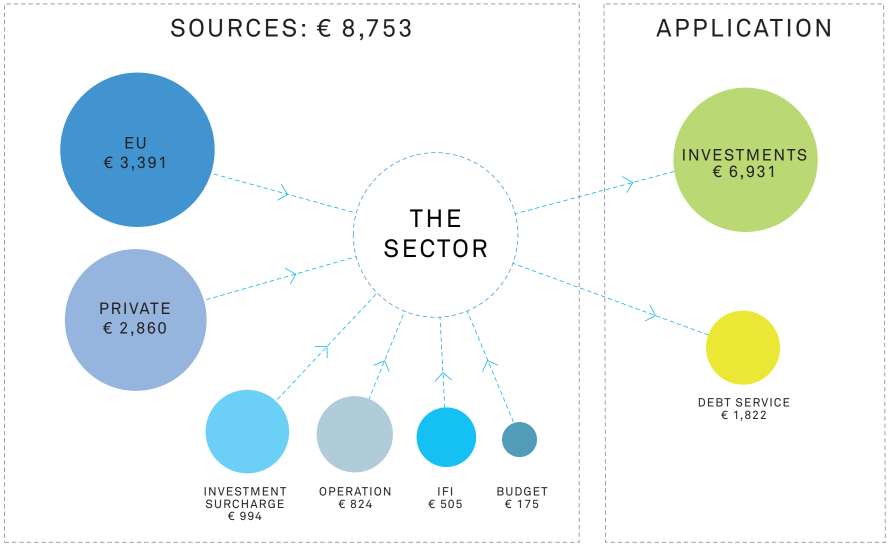


Figure 2.2

Affordability

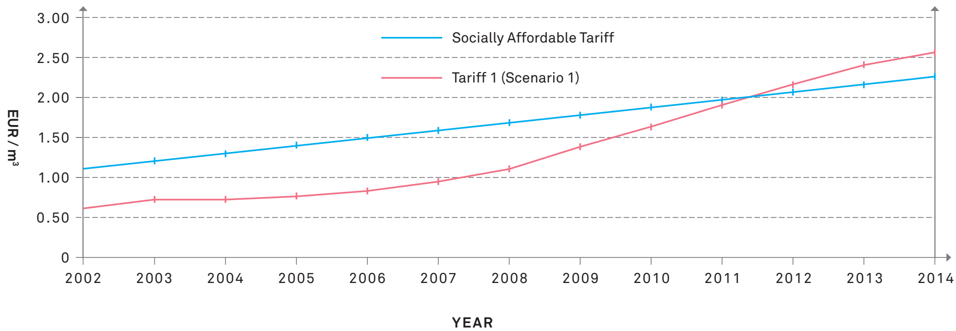


Figure 2.3

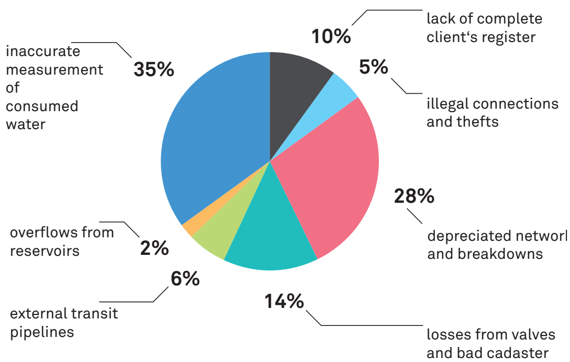


Figure 2.4

target dates for the reduction thereof", so that the water losses are key parameters to monitor. Associated with this law, a special ordinance for the particularities was adopted. At first sight, everything seemed bound to happen, but by July 2008 the average level of losses of water in Bulgaria remained approximately 60%.

2.3 THE APPROACH OF SOFIYSKA VODA AD FOR WATER LOSS REDUCTION

As early as its first year of concession, Sofiyska Voda AD developed a strategy for a reduction of loss due to unaccounted-for water. To that end, the best world practice was used, adapted to the conditions of the water supply network of the city of Sofia.

Sofiyska Voda AD aims to achieve a UFW level which allows minimal capital and operational maintenance expenses but optimal effect in reduction of losses. Depending on the site conditions, flow measuring devices using various types of measuring technologies were selected and installed.

The water supply network was subdivided into strategic water supply zones, water demand management zones (DMZ) and 234 district metering areas (DMA), of which 34 are reservoir zones, 26 transit water supply pipeline zones and 174 distribution network zones.

A strategic model of the water supply network was developed and calibration was attempted with the use of sensitive and highly productive software, SynerGEE, after which the next thing done was the development of a detailed model. A Geographic Information System (GIS) and a Supervisory Control and Data Acquisition (SCADA) were introduced. Two major work groups of trained staff were formed, one working on the problem of apparent losses, the other on physical losses.

The first group, with the introduction of the new billing software "Affinity", started implementing projects for the replacement of water meters and a large-scale programme for measuring the water demand of all types of consumers, as well as searching for illicit connections.

The second group worked on the measures for the reduction of physical losses due to overflows, break-downs and leaks, using special equipment to listen for hidden leaks. The district of Obelya was set as a pilot zone for studying and reducing the losses of water, which should then cover the whole of the water supply network. Maps of the pressure in the water supply network were developed for monitoring purposes.

2.4 SOME CHALLENGES

The Sofiyska Voda AD's approach for the reduction of water losses, as a concessionary of the water supply network, until now has created more expectations than achievements, as may be seen from the financial provisions in their regulator-approved business plan.

First Regulatory Business Plan period 2006–2008
- Capital Investment related to UFW, BGN 29.6 million
- KPI from regulator 2006 UFW=62%, 2008 UFW=54%
- Actual 2008 UFW forecast to be 58%

Second Regulatory Business Plan period 2009–2013
- Capital Investment related to UFW, BGN 63.7 million
- KPI from regulator 2009 UFW=54%, 2013 UFW=44.8%

The regulator's UFW calculation is a simple one:

$$\frac{\text{Water into supply - Billed Water}}{\text{Water into supply}} \times 100$$

There are many reasons for the Bulgarian operators' performance being below the expectations in terms of water loss reduction. Historically, following Bulgaria's emergence from a centralized economy over a long and painful transition period, a low-income population and the mentality that water is not a commodity, these factors have led during the process of switching to a market economy (and, respectively, a rise in prices), to a low collection rate of receivables and ongoing thefts. Lack of available capital investments, which, even if available, cannot be included in the price of water, leads to an impossibility to carry out all tasks of the business plans, including water loss.

Here, however, is something specific to Bulgaria, which is purely political and has to do with investments. This is the choice of the correct policy of depreciation. The assets of our Bulgarian companies are kept low, by approximately a tenth, to achieve a lower cost of water, but depreciations are the major resource for investment. No party in office would opt for a drastic rise in price for election reasons, and in this way it is hard to find a balance.

It is also easy to notice that, throughout the years, the coming into power of a different party has led to a change of the directors of the larger state-owned companies, which also entails change of other employees in key positions without the necessary inheritance of the results of their achievements.

The institutionalization of a regulator was done in a particularly abrupt way, from a political point of view: first, the regulation of the water services, which are specific, being performed jointly with the regulation of the electric power energy, heat energy and gas; and second, the appointment of mainly politically-motivated staff.

To these political challenges, one should add the incessant amendments to laws and particularly the Water Act, the latest changes being related to Bulgaria's accession to EU.

As for Sofiyska Voda AD in particular, non-achievement of expected levels of water loss has to do with a lot of other circumstances. At the time when Sofia's concession was signed, Bulgaria had no know-how and skills for leading international negotiations. The conclusion of the contract was rather a display of political will for a change in the water industry and invitation to the private sector than a precise contract with flexibility for rapid changes in its clauses in response to the rapid changes in the country itself.

In addition, the contract was signed with the assumption of risk of the rapid changes in the respective laws, which, 10 years later, is in a phase of relative stability. It is unlikely that the private concessionary would allow expenses beyond the agreed ones, unlike the other water companies, which required endless disputes in Sofia City Council.

In addition to what has been said about Sofia, the political element is further complicated by the fact that pressure is exerted not only by the changing powers in the state, but also by changes in the local authorities, bringing about further delay in the implementation of the contract, including the reduction in water loss.

2.5 CONCLUSIONS

Still a country in transition to a market economy, Bulgaria has no sufficient sustainable political will for consistent institutional changes. The problem with water loss is not yet in the sights of the political class. There is no complete understanding and will for increasing the efficiency of the activities related to water supply and sewerage, which consequently leads to the misunderstanding of the fact that the right management of the non-revenue water is actually saving investments which is a political responsibility.

In practice Sofiyska Voda even having the right strategic approach for reduction of the unaccounted for water and having the necessary knowledge and expertise for dealing with this problem turned out to be a typical example for the impossibility of its realization because of the labyrinth of political, institutional and legislative obstacles.

Finalization of the set of laws in this field gives some hopes, but additional political and legislative efforts are required to improve the laws and their enforcement in practice as well as overcoming the chronic lack of institutional capacity.

3 A Conceptual Approach to Water Loss Reduction

Miroslav Tesarik
Prague, Czech Republic
[m.tesarik@dhi.cz]

INTRODUCTION

In many cities, the water losses reach very high levels. With regard to the fact that increased leakages may have a number of causes, it is necessary to examine a range of influences and take these into account in the resultant long-term solution of leakage reduction. The conceptual approach to the leakage detection in water supply systems is a fundamental tool for the location of the leakage and contributes highly to better utilization of available water sources. The conceptual approach is also essential for minimising both investment and operational costs, connected with the water supply systems.

3.1 BUILDING OF A HYDRAULIC MODEL OF THE WATER SUPPLY SYSTEM

The model topology of the WSS was built based on AutoCAD files provided by the client. Additional information about the layout of the pipe network of the existing system was supplemented during model building, based on the operational map and the discussion with the operator.

The whole extent of the pipe network was divided for evaluation purposes into subareas, based on experiences from survey and monitoring campaign. The subareas are just logical units, not the pressure zones, while the WWS in Blagoevgrad is to a large extent interconnected. The complete final model is presented in the **> Figures 3.1 & 3.2**.

3.2 MEASUREMENT CAMPAIGNS

As the next step, the systematic measurements of flows and pressures has to be carried out.

3.2.1 Selection of supply zones with significant leakage

For screening of supply zones from a point of view of the leakage magnitude, it is necessary first of all to conduct a complex evaluation of all supply zones from the perspective of the balance of water consumption and supplied water. For this purpose, it is necessary to include all the available information. The result is an overview of all the components of inflow into the individual supply zones (domestic consumption, big consumer consumption, leakage).

On the basis of the data collection, processing and analysis in collaboration with the sewer operator, it is possible to select the supply zones with a significant leakage and finally to propose the measurement campaign, i.e. to divide the selected supply zones into measurement sections and define the necessary changes of setting of the water supply system (closing some valves etc.).

3.2.2 Systematic measurements of flows and pressures

Systematic measurements of flows are not only a basic tool for leakage quantification, but also help the operators and administrators of water supply systems to better manage the operation of the system. During normal operation, some hidden problems may not emerge, e.g. (partly) closed pipes, encrusted pipelines, hidden major failures, incorrect data in technical documentation, etc. Consequently, serious complications can appear, resulting in substandard water supply conditions, especially as regards pressure conditions in case of new water intakes from a network with already reduced capacity, during failures, planned lock-outs of pipelines, etc. Apart from mathematical model calibration, the main reason for monitoring the pipeline network is to obtain information on leakage, overall network operation and to check the pipeline network capacity. A detailed monitoring campaign can identify and locate problems, both in the main distribution system and in particular supply zones. Closed hydraulic valves, strongly encrusted sections, significant deviations from operational documentation (GIS), etc. can be identified.

In the City of Blagoevgrad, 2 portable Fluxus flow meters and 10 portable Sewar pressure meters were used for the measurement of inflow to and pressure distribution in several separable supply zones for the time span of 2–6 days.

3.2.3 Short monitoring campaigns under standard operational conditions

Monitoring, provided by the operator (the stable monitoring sites), is most often supplemented by the portable units located on the key inflows to the distribution system. These monitoring campaigns can be used for filling the gaps in the knowledge about the water supply system operation and for the basic model calibration. > Figure 3.3

Figure 3.1: Distribution system – evaluation areas

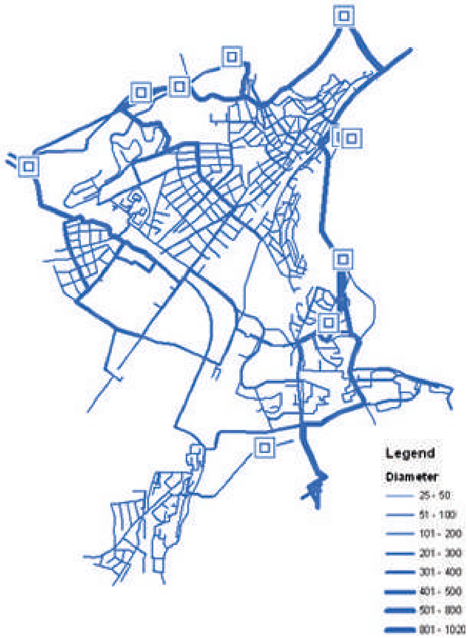


Figure: 3.2 Distribution system – pipe diameters measurement campaigns

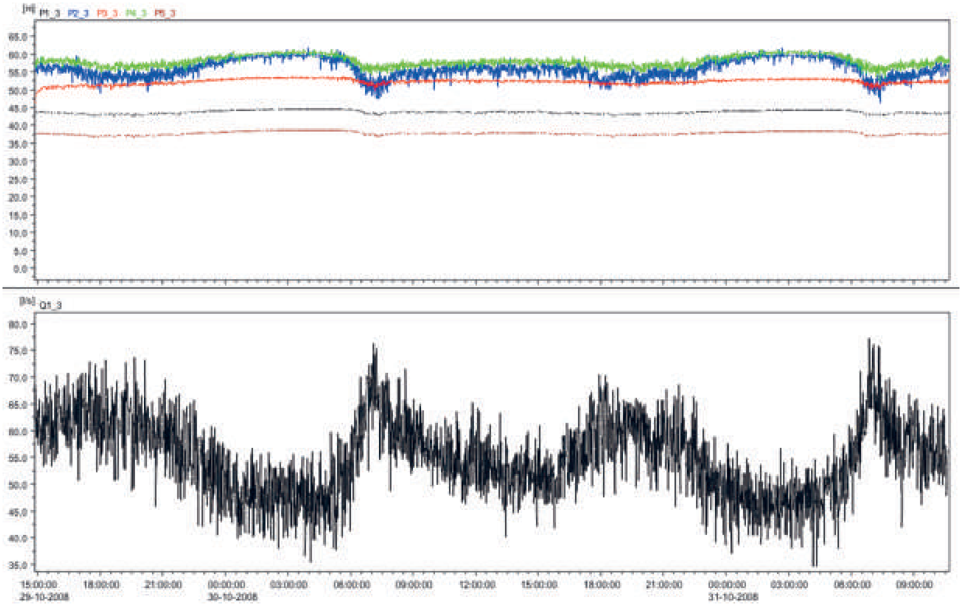
3.2.4 Special monitoring campaigns

A very effective method for detecting non-standard events in water supply networks is to use hydraulic models of the water supply network in combination with monitoring the pressure and flow conditions during non-standard loading situations, especially during hydrant tests. > Figure 3.4

Hydrant tests in selected locations are combined with pressure measurements in several places in the network. The allocation of such tests and measurements, or of other manipulations in the water supply network, is adapted to specific needs. Hydrant tests yield measured sets of pressure values for various water intakes from hydrants. Evaluation by the mathematical model can provide very detailed information on the characteristics of the water supply network, i.e. about the quality of the hydraulic connection between the place of hydrant water intake and the place of the pressure measurement.

The specification of a monitoring campaign depends on the purpose of the campaign, on information given by the operator and on the preliminary mathematical model simulations. The real conditions in the water supply network, especially the location of usable hydrants must be taken into account. Last but not least, it is necessary to evaluate and discuss with the operator potential risks to water quality, etc.

Gramada supply zone



Reservoir 7000 Istok supply zone

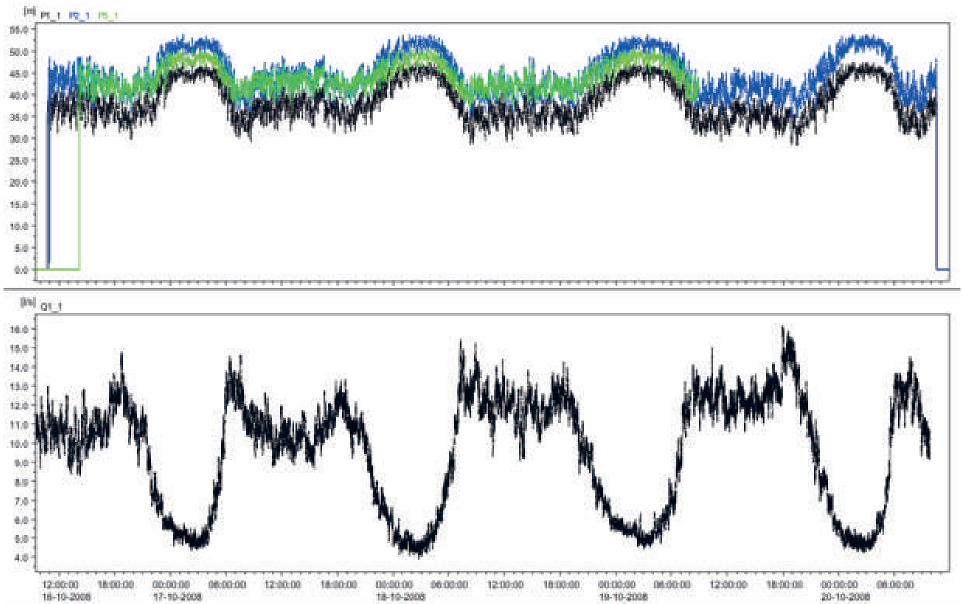


Figure 3.3: Example of measured pressures (upper part of pictures) and flows (lower part of pictures) in two supply zones in the city of Blagoevgrad

Areas	Leakage [l/s]
Osvobozdenie	2
Central City Nord	40
Elenovo	25
Gramada	2
Strumsko	30
Central City South	20
Orlova Cuka	5
Jampalica	3
Total	**127**

Table 3.1: Leakage estimate based on the measurement campaign result in the city of Blagoevgrad

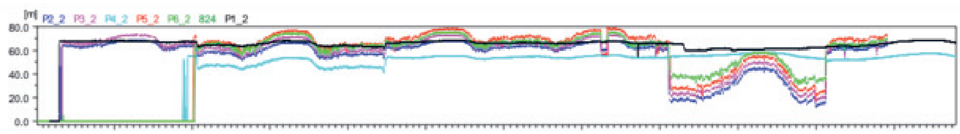


Figure 3.4: Measured pressures in the central part of the city of Blagoevgrad in the period of serious pipe breakdown and during the partial zone separation, i.e. during the non-standard operational conditions

3.2.5 Leakage detection – night measurement campaign

As stated before, the measurement of distribution of leakages in the water supply system is based on the temporary division of the piping network into measurement sections. Measurement sections are separated by closing of regular or zone valves. With this network setting the measurement of night inflows into measurement sections and measurement of pressures has to be carried out. Consequently, the leakage is evaluated in individual measurement sections with taking into account large night consumers, if there are some.

The principle for the location of the leakage is to divide the measurement sections by closing the valves into smaller and smaller parts. The manipulation with the valves must be feasible from the operational point of view, so the close collaboration with the water supply system operator is absolutely necessary. Leakage into measurement sections is then evaluated with regard to night consumption of large clients and if applicable the objectified night inflow. In addition to the actual size of the leakage [l/s], it is also possible to evaluate other leakage indicators such as unit leakage [l/s/km], which takes into account the length of the water distribution network and indicates locations of the network where subsequent detailed detection of the leakage and repair of hidden leakages will be most effective.

Based on the night minimum flows, and also taking into account the measurements, carried out in specific operational conditions, the first estimate of the leakage level for the current status supply zones was carried out in the city of Blagoevgrad. > Table 3.1

3.3 EVALUATION OF THE FUTURE REQUIREMENTS

Important inputs for the definition of the future water supply requirements are the Urban Development Plan, projected demands in the system, planned reconstruction of AC pipes and existing conceptual studies.

The major problem of the water supply system in the city of Blagoevgrad is the bad technical condition of existing AC pipes. Consequently, a huge reconstruction program has been prepared, which has to be included in the conceptual approach to water loss reduction.

3.3.1 Evaluation and optimization of pressures

Optimization of pressures is a measure which is important primarily from the perspective of the long-term impact on reduction of water leakages and the breakdown rate and increasing the life span of the network. According to experiences, a reduction of pressure by 10% causes a reduction in the breakdown rate by 25%. Optimization of pressures is thus very important for operational and investment savings. For the evaluation of the optimum pressures in the network, it is necessary to take into account the height of the housing development. Pressures of 40 m w.c. may be low in a high rise housing development, but too high for a housing development comprising family houses. > Figure 3.5

Through simulation in the model, it is possible to evaluate the pressures above the height of the housing development relatively precisely. At the same time, it is possible to evaluate the causes of the main problems which prevent optimization of pressures. > Figures 3.6 & 3.7

For the city of Blagoevgrad, a new system of conceptual pressure zones and corresponding supply zones was recommended.

The inflow measurement for supply zones should be installed at existing outflow pipes from the reservoirs, as a part of new manholes for

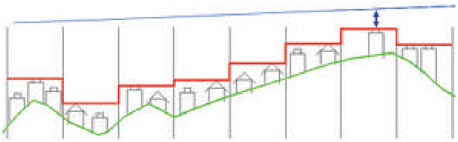


Figure 3.5: Principle of assessment of pressures in water supply systems

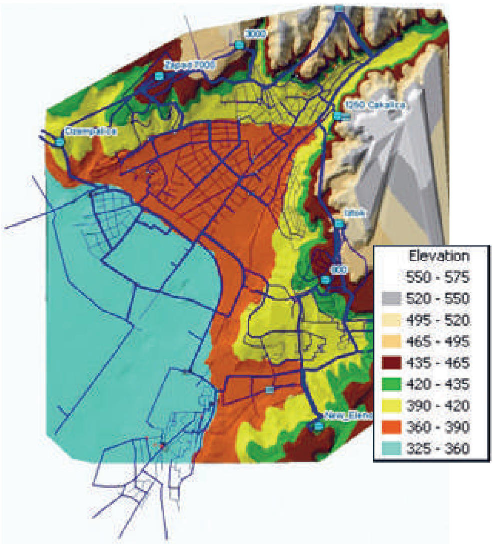


Figure 3.6: Analysis of terrain elevation

Figure 3.7: Final proposal of the supply zones

installation of pressure reduction valves. In case of gravity system, it is proposed to divide the network in several supply zones (in the city of Blagoevgrad it is a case for Dzampalica, New Elenovo, Zapad and Cakalica gravity systems).

The optimization of pressures in zones can be evaluated effectively with help of the graphical output as it is demonstrated in > **Figure 3.8**.

3.4 CONCLUSIONS

The leakage situation of individual water supply systems reflects a whole range of factors. Of these, the most significant are inappropriate material used for the construction of the water supply systems, the increasing

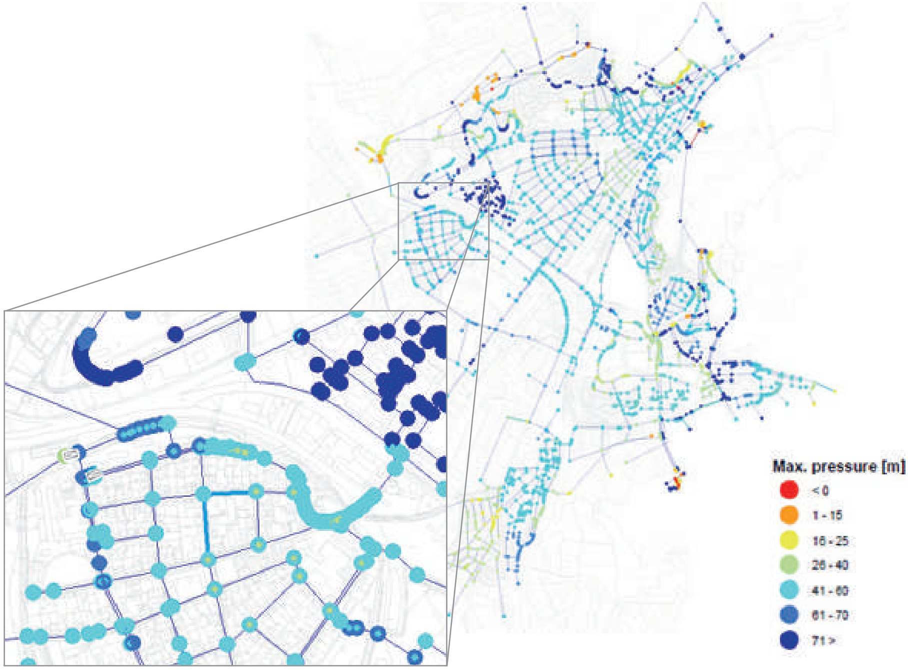


Figure 3.8: Example of the analysis of pressures for the future status in the city of Blagoevgrad

age of the water supply systems and the connected deterioration of their technical condition. This situation can be described as the historical debt in the renewal of the water supply systems. The large scale rehabilitation of the water supply pipes, which is under way in many cities, will certainly help in the overall leakage reduction and opens way in the same time to continuous leakage fighting on the more detailed scale and to optimization of pressures, described in the paper.

As it is shown for the city of Blagoevgrad, even in the case when it is difficult to define the supply zones for the existing system, it is possible to get valuable information about the level of leakage in the zones by comparatively short-term flow and pressure monitoring campaign. This is, together with the analysis of the current status of the system and future requirement analysis, a basis for conceptual recommendations, which include the draft of the pressure and supply zoning. A proper pressure zone definition, as well as a definition of locations for steady measurements of flows (supply zoning), can contribute efficiently to water loss reduction in water distribution systems.

Chapter II –
Actions and Solutions

MAIN CHAPTER MESSAGES

1 Balancing the Regional Cycles of Water leads to five fields of Enhancement of Water Efficiency (EWE) activities:

- Reduction of Leaks and Losses in water supply and sanitation systems
- Water Efficient Production in agriculture and industries
- Water Reuse
- Water Demand Management for households and the public sector
- Enforcement of Integrated Water Management and spatial planning.

2 If EWE were executed on global scale, it is estimated that approximately 60% of the current water abstraction could be avoided, without reducing water supply.

3 On the other hand, water supply could be increased through EWE without increasing water abstraction or the overexploitation of natural water resources.

4 Measuring NRW within water loss control programmes requires competences and capacities to build, operate and maintain water systems at a professional level.

4 Water Supply and Sanitation Systems – the First Point of Action

Stefan Haffner, Dagmar Bley, Günter Klein and Karl-Ulrich Rudolph
Bonn, Germany
[mail@uni-wh-utm.de]

The total amount of Non-Revenue Water (NRW) worldwide is estimated at 48.6 billion m³/a. The volume of real losses (45 million m³/daily) occurring in developing countries alone would be sufficient to supply approximately 200 million people. Close to 30 million m³ are delivered every day to customers, but are not invoiced because of pilferage, corruption, technical manipulation, poor metering, etc. The total cost to water utilities caused by NRW worldwide is estimated at $ 15 billion/a (Liemberger 2008).

Water loss occurs both in the developed world and in developing countries, either through physical losses (mainly leakage in networks) or theft of water from the system, or from water users not being properly billed, or due payments not being collected. Many of the reasons for water loss from meter error, leakage or data mishandling are based on human failings and lack of maintenance. A poor, i.e. high level of NRW can indicate that the water utility lacks the governance, autonomy, accountability and the technical and managerial skills necessary. In addition, this is often related to poor budgets for operations and maintenance of facilities that have often been granted through national budgets or multi-lateral donations, leaving the beneficiaries hoping for new grants once these facilities have been destroyed.

Reasons for water utilities not to address water loss could be:

- Political unfeasibility of admitting system leakage
- Falsifying water account records (e.g., when abstractions exceed legal permission)
- Lack of recognition that recapturing Non-Revenue Water with an upfront investment can be a profitable business with fast payback
- Lack of incentive or lobbying support for NRW reduction programmes
- Inherent mistrust of anyone outside the utility who may examine their facilities and performance.

Unfortunately, most of the (predominantly public) water utilities in many parts of the world accord water loss only a secondary priority, since the true economic and social impact of water loss has not yet been realized by policy-makers. Another major problem is that water tariffs are not cost-covering in developing countries and elsewhere, but are subsidised to help the poor, which means NRW investments may be less profitable or can even be lost. However, it is estimated that a financial burden per individual or household would account for less than 1% of the average income – worldwide. Currently, the poor pay more (WWDR 1 2003). Water loss suffers from a lack of good auditing practices and a failure to reduce leakage proactively. Water loss from distribution systems is a problem in almost all conurbations around the world, but is serious where water is scarce. It therefore deserves immediate action.

4.1 BALANCING THE REGIONAL WATER CYCLE

Following the IWA Standard Water Balance, the water in a supply system ('Supply System Water' in > Figure 4.1) consists of Revenue and Non-Revenue Water and is generated from different sources (see the blue circles in > Figure 4.1). **REVENUE WATER** is the water that has been officially (authorized) extracted and billed, provided due payments are collected. Unbilled water that has been officially (authorized) extracted is water that has been used e.g. for internal use (e.g. for flushing filters and sewers), for fire fighting or for consumers privileged because of public interest (such as military barracks, schools, religious institutions – sometimes metered, sometimes not). This unbilled water is attributed to **NON-REVENUE WATER (NRW)**.

Furthermore, besides the authorised but unbilled water, NRW consists of the water that is 'lost' in two ways:

1. Through real water losses
2. Through apparent water losses.

REAL WATER LOSSES are physical water losses from the pressurised system, up to the point of measurement of the customer – through leaks, bursts, overflows, etc. Losses after the point of measurement, although they are often significant, are excluded (IWA 2006). This may be regarded as a systematic gap and a challenge for water suppliers that can be solved.

APPARENT WATER LOSSES comprise water that has been used but not paid for. They are caused by inaccuracies in customer metering or theft (IWA 2006 & Lambert & Taylor 2010). The **WATER SUPPLY SYSTEM INPUT** might be composed from own sources and/or imported water. Whatever the input is composed of, if water is exported to other systems, the system input can be quite different from the water supplied. Therefore, 'billed authorised use and consumption' has to be split into 'billed water exported into other systems' and 'billed (registered and unregistered) use and consumption by registered customers' (Lambert & Taylor 2010).

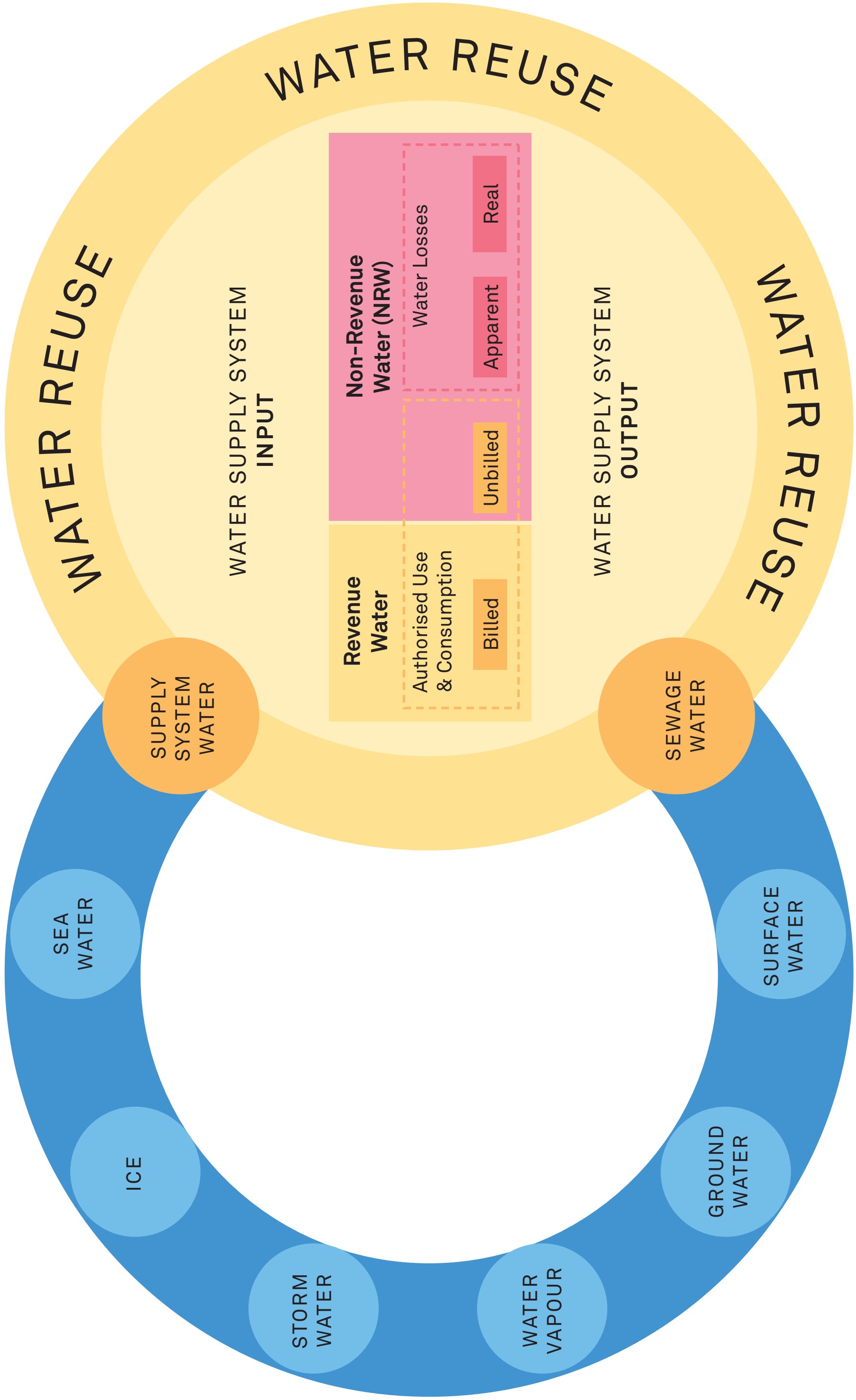


Figure 4.1: Balancing the Regional Cycles of Water

Thus, the **WATER SUPPLY SYSTEM OUTPUT** consists of the real water losses, the 'wastewater' (treated or untreated, polluted or unpolluted) and the water that could be balanced as a part of **VIRTUAL WATER**.

In the context of the management of water supply and sanitation systems, one should always have in mind that water outside these systems is also 'lost' if the whole water cycle is influenced or disturbed through factors such as deforestation or the overexploitation of groundwater. Water supply and sanitation systems depend on the quality and quantity of water that comes into the system, while simultaneously influencing the whole water cycle > **Figure 4.1**. Societies have to govern (decide and control) how much water they will allow to be extracted, when, where, and what it will be carefully used for, and afterwards, what quality of (waste) water will be allowed for discharge into water bodies under the water cycle they depend on.

This leads to simple consequences: The management of the water supply and sanitation system has to be linked with the management of environmental dynamics and the management of demands. Water loss management as one aspect of water efficiency then has to be seen as a part of integrated water management. Also, water reuse is becoming more and more a key issue of using water efficiently – e.g. within closed water cycles in industries, or with non-potable water produced from urban 'wastewater', for green land and agricultural irrigation or elsewhere (road cleaning, etc.). Besides fresh water consumption, the utilisation of reused water can be addressed when balancing water supply systems. In this context, reuse is a very important measure to enhance water efficiency, and there are many technological options (IWA 2009) and helpful guidelines for building and implementing appropriate schemes (DWA 2008, VDMA 2011).

Balancing the cycle of water use means to take five issues into account:

1. Reduction of 'losses' in water supply and sanitation systems
2. Water efficient production, mainly in agriculture and industries
3. Water reuse (for all consumer groups, as described above)
4. Water demand management, mainly for households and public consumers
5. Integrated water resources management and spatial planning.

To evaluate each internal situation of water supply systems, there are a number of assessment criteria that are useful. These criteria depend on the targets a water supply organization wishes to set regarding water losses.

4.2 MEASURING NON-REVENUE WATER

The use of targets of a water supply organization towards water loss reduction is crucial for the methods for measuring NRW. They may relate to external factors, internal operational factors, or economic reasons, and include the following:

- To ensure efficient operations
- To safeguard future water supplies
- For technical comparisons between water supply organizations, nationally and internationally, and between supply zones
- To demonstrate continual improvements to customers, in order to improve public perception
- To take account of political considerations
- To meet regulatory requirements (Trow 2009).

Therefore, different approaches to measure water losses will be suggested briefly because these help decision makers and other actors to assess the situation from different perspectives.

Volume rate

The absolute volume rate measured in m^3/d (which is equal to “megalitres per day” Ml/d) is best used for monitoring changes within a water supply organization over time, but is of no use as a performance measure (Trow 2009, p. 144).

Percentage

The percentage of NRW as a share of water produced is a commonly used indicator to benchmark NRW. While this indicator is easy to understand, it is not appropriate for benchmarking NRW levels between rural and urban utilities, or even to monitor changes over time. When absolute losses are constant, the percentage of NRW varies greatly with total water use (Thornton et al. 2008). The percentage perspective can make utilities with high levels of consumption, or compact networks appear to be better performing than those with low levels of consumption or extensive networks. **Apparent losses** can be described as the percentage of the volume of metered consumption (excluding water exported) from the total water production, or as the percentage of system input volume per connection per day (Lambert 2010) > **Figure 4.2**.

In this book, percentages are just used to clarify the rough dimensions of NRW at a certain date. Competences that take a closer look via other performance indicators on water losses and water loss management have to be developed in each respective context. Further performance indicators for real losses are required for operational and financial (functional) purposes, but also for benchmarking processes or different water suppliers (metric benchmarking) (Lambert 2010).

Process benchmarking

Depending on the density of service connections per km of mains, **litres/service connection/day** is preferred (if the number of service connections per km mains is more than 20) or **m^3/km mains/day** (if the number of service connections per km mains is less than 20) to indicate **Real Losses**.

This is appropriate for **process benchmarking** – setting targets and monitoring (Lambert 2010).

It is important to understand that process benchmarking (like other kinds of benchmarking) needs external, independent validation and auditing, otherwise (as happened in the past with publicly-owned water utilities like the East German VEB-WABs under the communist regime), process benchmarks may well be manipulated and taken as a falsified 'proof' to manipulate public opinion and political decision makers, who believe such benchmarks indicate "good performance", whereas the water service level in reality is much worse. "Benchmarks" generated through lobby groups, driven through interests of administrative functionaries, whether from public or commercial origin or from NGOs, must be taken as doubtful, unless verified by independent sources.

Metric benchmarking

The IWA Taskforce on the Water Loss Reduction Initiative (WLTF) developed the **Infrastructure Leakage Index (ILI)** and declared: "ILI was introduced as a performance measure to allow reasonable comparisons between water suppliers and between zones within the same supply organization. It has been considered for use as a target setting measure, and while this has some merit, certain issues should be taken into account. ILI is the ratio of **Current Annual Real Losses (CARL)** to **Unavoidable Annual Real Losses (UARL)**, and whilst the assumptions used to calculate these parameters are not universally accepted, they have been tested and adopted in many different situations."

ILI can be part of a target setting approach but should not be used in isolation to set targets (Trow 2009). ILI is preferable for **metric benchmarking** for real losses – comparisons between different systems – as it takes account of differences in system-specific key parameters (mains length, number of service connections, customer meter location, average pressure). ILI is not usually recommended for process benchmarking (progress towards targets for reduction of real losses) because pressure management will normally be an important part of any real loss reduction strategy. Reducing the pressure will reduce both the CARL and the UARL volumes, so the ILI (=CARL/UARL) may not change to any significant extent (Lambert 2010).

An **Economic Leakage Index (ELI)** will bring economic principles into the equation to take account of the costs of Active Leakage Control (ALC) and the value of the savings. ELI calculates an economic intervention frequency and an **Economic Level of Real Losses (ELRL)**. ELI is the ratio of CARL to ELRL (Trow 2009) > **Figure 4.2**.

In Germany, the DVGW (Association from the Gas and Water Sector) has set the following NRW standards as targets in the technical guideline W 392 (UNW-DPC 2009, Rudolph 2010) > **Figure 4.3**.

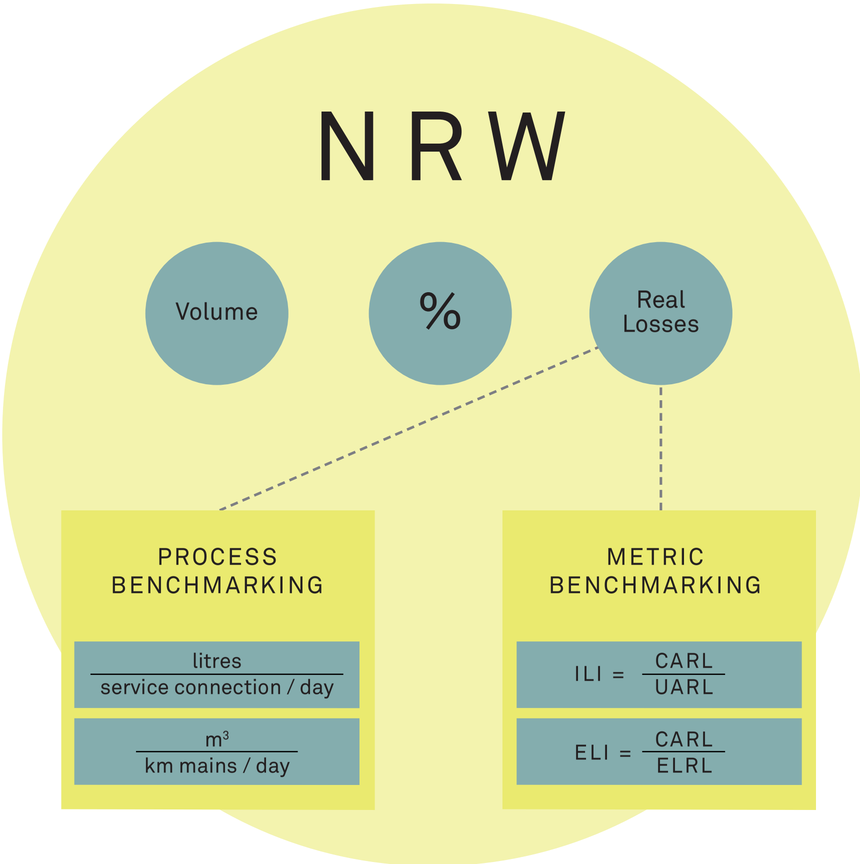


Figure 4.2: Measuring Non-Revenue Water

MEASURING NRW

ILI
> Infrastructure Leakage Index

ELI
> Economic Leakage Index

CARL
> Current Annual Real Losses

UARL
> Unavoidable Real Losses

ELRL
> Economic Level of Real Losses

4.3 HOW MUCH WATER IS 'LOST'?

Although data from various sources, aggregated on a global scale, may be doubtful in its detail, some general estimations available provide a realistic picture of NRW, like the ones displayed in > **Table 4.1**: Estimations on Non-Revenue Water. It is assumed that, in 2002, an average of 26% of the system input for 1760 people worldwide got 'lost' – most (67%) caused by real losses and 33% by apparent losses. There are significant differences between so-called developed countries and developing countries. In developing countries an average of 35% of the system input got 'lost', and in developed countries it was 15% – but these are only rough figures of average values.

According to the Asian Development Bank, the levels of NRW in 18 Asian large cities vary between less than 10% and up to 60% and sometimes more (Macintosh 2003). Of the current 884 million people worldwide who have no access to drinking water from improved sources, 37% live in Africa (WHO/UNICEF 2010), which has the lowest coverage rate of piped water of all world regions (50%). Only five per cent of the rural population in Africa receives piped water in their homes, compared to 35% of urban dwellers (UNEP 2010).

Africa Infrastructure Country Diagnostic (AICD) conducted a study in a sample of 23 countries in Sub-Saharan Africa and pointed out that the average level of NRW is close to 30% (AICD 2008). Looking into the IBNET database (International Benchmarking Network for Water and Sanitation Utilities of the World Bank Group), the average figure for NRW levels in developing countries' utilities is also around 35%, but you can find average figures of 70% and more at African utilities (Kingdom et al. 2006). "It is likely that the 35% figure is less than the global NRW level in the developing world because large developing countries with known high levels of NRW are still not covered by IBNET, and the utilities that report operating data tend to be the ones with the better performance levels, while the worst-performing utilities rarely report data or, if they do, the information is not reliable. The actual figure for overall NRW levels in the developing world is probably more in the range of 40–50% of the water produced" (Kingdom et al. 2006). (See also the workshop reports of the International Workshop on Drinking Water Loss Reduction at UN Campus, Bonn, Germany, in 2008 – UNW-DPC 2009.)

The rough estimations of > **Table 4.1**: Estimations on Non-Revenue Water show that around 33 billion cubic meters worldwide get lost every year, caused by leakages from the water supply systems. Furthermore, around 16 billion cubic meters are delivered to customers but are not paid for. Nearly 55% of the NRW occurs in developing countries where resources for financing the maintenance and expansion of water supply and sanitation systems are urgently needed, and the bad quality of water causes diseases. Round 45% of the NRW occurs in developed countries and the

WATER LOSS CATEGORY	Approximate spec. water losses q_{vr} in $m^3/h \times km$: CITY	TOWN	RURAL	Rough equivalent in %
LOW WATER LOSSES	< 0.10	< 0.07[2]	< 0.05[1]	< 3
MEDIUM WATER LOSSES	0.10 – 0.20	0.07 – 0.15[3]	0.05 – 0.10	3 – 7
HIGH WATER LOSSES	> 0.20[5]	> 0.15[4]	> 0.10	> 7

1) Hardly achievable
2) Very good maintenance, new systems
3) Achievable with technical/oprational measures
4) Maintenance not efficiently performed
5) Maintenance or/and system in poor condition, if > 30

Figure 4.3: German Standard DVGW W 392

Commonwealth of Independent States (CIS) – also there, the money that was 'lost' together with the water could have been invested in functioning water supply and sanitation systems. Conservative estimates suggest the total cost only to water utilities caused by NRW to be US $14 billion per year worldwide (Kingdom et al. 2006). Costs for society and the ecosystem it depends on, we must assume, are greater.

However, the real amount of water losses of each respective utility has to be identified because concrete initiatives towards reducing water losses have to be tailor-made. Basically, water that is getting lost includes energy and money that is getting lost. Reducing NRW therefore means generating money from increased revenues and reduced costs, and supplying more people with water and sanitation services. Estimated figures of such magnitude should attract the interest of governments, civil societies and the financial world (see also Kingdom et al. 2006).

Currently, 70% of the freshwater withdrawn is delivered to agriculture. Industry receives 20% and the municipalities 10% of the withdrawn freshwater. Using the figures in > **Table 4.2**: Efficiency Potentials worldwide, it is estimated that only 10% of the water currently used in agriculture would be needed if water efficient irrigation technologies and operations were implemented (such as advanced drip irrigation or automated pivot sprinklers instead of border dykes, uncontrolled flooding, etc.). With high-tech recycling technologies and by including the large volumes of direct cooling water, a maximum of 95% of water consumption could be

Estimations on NRW

Region	Supplied Population (2002) Millions	System input billion m³/year	NRW as Volume and as Share of System Input	Real Losses billion m³/year	Apparent Losses billion m³/year	NRW billion m³/year
Developing Countries	744.8	81.6	12 bn m^3/a	9.8	2.4	12.2
			15%	80%	20%	
Eurasia (CIS)	178.0	32.5	9.7 bn m^3/a	6.8	2.9	9.7
			30%	70%	30%	
Developing Countries	837.2*	76.4	26.7 bn m^3/a	16.1	10.6	26.7
			35%	60%	40%	
Total	**1760**	**190.5**	**48.3 bn m^3/a**	**32.7**	**15.9**	**48.6**
			26%	**67%**	**33%**	
	6300 Million People World Population (2002) (UNPOPDIV 2003, p.vi)					

* Based on a total population having access to safe water supply of 1902.7 million people, with 44% of these receiving water through individual household connections (Thornton et al. 2008, p. 523).

Sources: Thornton et al. 2008, p. 6 (Global Water Loss Volumes Estimated by the World Bank) + p. 523 (Estimates of NRW: World Health Organisation, IB-net, and authors' estimates) + own calculations

Table 4.1: Estimations on Non-Revenue Water

saved in industries in developing countries, reducing water consumption to 5%. The reduction potential in domestic consumption would be as high as 60%, leaving a "real water need" of 40% in municipalities.

This means that, on an average, from 60% to more than 80% of the currently used water could be saved and conserved. This estimation is based on the assumption that NRW can be reduced to 5% worldwide. Nevertheless, this should be considered as an optimistic target and it should be taken into account that the need for water increases with population growth and concentration in urban agglomerations, as well as with socio-economic development accompanied by rising standards in sanitation and in-house water installations.

4.4 WHAT SHOULD BE DONE TO AVOID THE 'LOSSES'?

Following the IWA standard water balance, the number of leakages and the amount of water that is getting 'lost' in water systems depends on the method of dealing with real losses and apparent losses within water supply systems.

How much water is needed?

	Freshwater Withdrawal		Efficiency Potential				Freshwater needed with efficient use			
	%	km^3	min [%]	min [km^3]	max [%]	max [km^3]	min [km^3]	%	[km^3]	%
Agriculture	70	2,681,000	60	1,608,600	90	2,412,900	268,100	10	1,072,400	40
Industry	20	766,000	75	574,500	95	727,700	38,300	5	191,500	25
Municipalities	10	383,000	30	114,900	60	229,800	153,200	40	268,100	70
Total	**100**	**3,830,000**	**60**	**2,298,000**	**88**	**3,370,400**	**459,600**	**12**	**1,532,000**	**40**
Renewable Freshwater: 43.659.000 km^3										

Sources: IMWI & Earthscan 2007, p. 70 (FAO 2006 AQUASTAT database) + Thornton 2008, p. 5–6 + own estimates and calculations

Table 4.2: Efficiency Potentials world-wide

Regarding **Real Losses** > **Figure 4.3** the quality of the leakage management depends on four basic activities:

1. Pressure management
2. Active leakage control

3. Pipe materials management
4. Speed and quality of repairs
5. And, with no. 1 to 4, the application of modern GIS (Geo Information Systems)

The Infrastructure Leakage Index (ILI) – as the ratio of Current Annual Real Losses (CARL) to Unavoidable Annual Real Losses (UARL) – could be reduced by implementing and managing these four working areas. The CARL could be reduced to the level of UARL – not below this. A utility can't eliminate all physical losses.

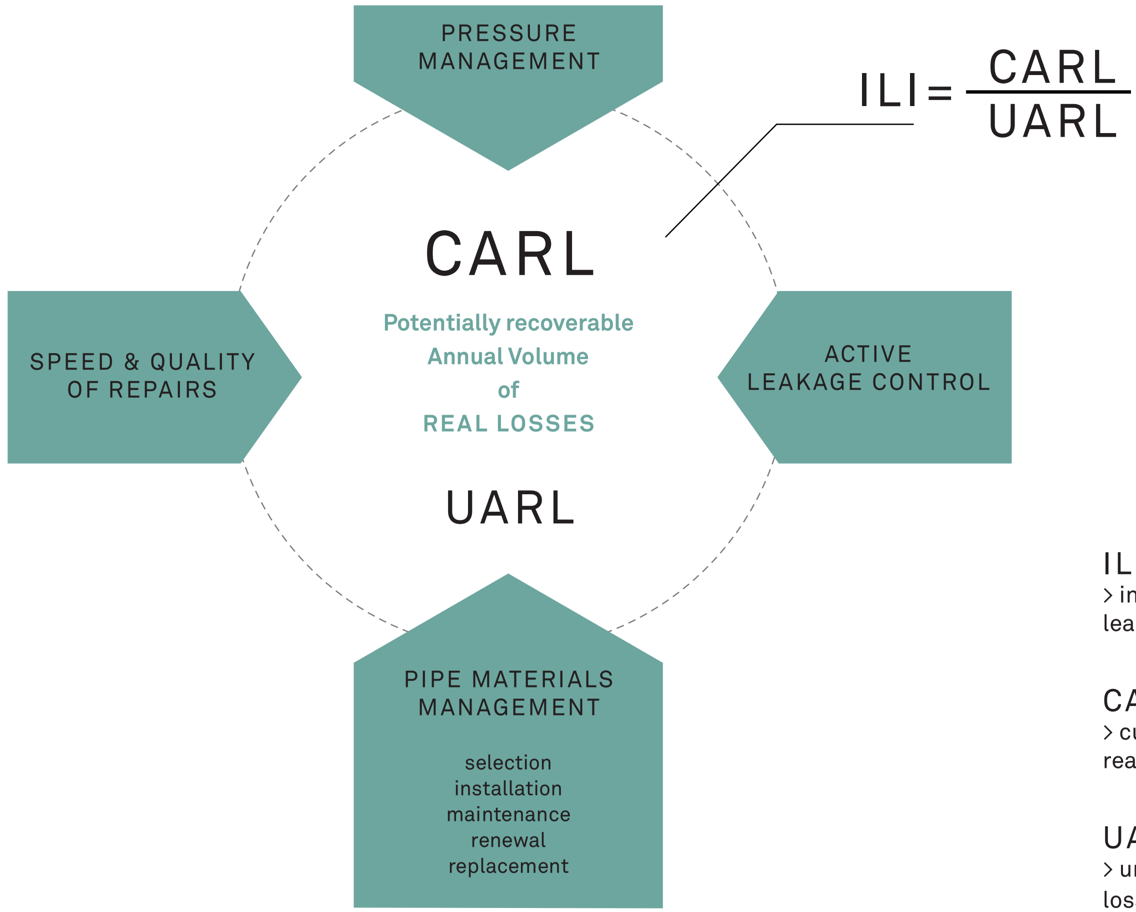
Activities in the field of real losses require investments in technical infrastructure as well as in 'human and social infrastructure'. This means, investment in the physical construction of the water systems and investments in capacity building to help the development of adequate competences and commitment of technical staff in planning, implementation and maintenance of water supply and sanitation systems. Furthermore, to govern the whole process of water loss management within a comprehensive integrated water management system, competences in the development of structures of communication and cooperation with all responsible actors in the societies have to be built. One possible starting point towards developing comprehensive leakage management could be to focus on the field of pressure management.

4.4.1 Water Loss Reduction through Pressure Management

4.4.1 was provided by ***Katja Hübschen, Dörte Ziegler, Lutz Happich,*** *Deutsche Gesellschaft für internationale Zusammenarbeit (GIZ) GmbH, Eschborn, Germany [katja.huebschen@giz.de]*

Pressure management can be defined as the "practice of managing system pressures to the optimum levels of service while ensuring sufficient and efficient supply to legitimate uses" (Thornton & Lambert 2005). The positive effects of pressure management are to decrease real water losses by reducing unnecessary or excess pressures as well as eliminating strong pressure fluctuations or transients. These factors frequently cause new pipe breaks and bursts within water distribution networks. The direct relationship between the leak flow rate and pressure means that pressure management is the only intervention method to have a positive impact on all three components of real water losses: background leakage, reported and unreported leakage.

To illustrate the connection between leak flow rate and water pressure, it is helpful to have a closer look at the problem on a smaller scale: Leakage discharge tests show that water loss from a single circular hole with 6 mm diameter (as illustrated in > Figure 4.4) in a distribution pipe at 60 m pressure amounts to 1.8 m^3 per hour or 1,300 m^3 per month. This discharge would be enough to fill an olympic-size swimming pool ($50 \times 25 \times 2 = 2{,}500$ m^3) in less than two months. The same water discharge would theoretically be enough to serve 317 inhabitants in the city of Moshi, Tanzania.



ILI
> infrastructure leakage index

CARL
> current annual real losses

UARL
> unavoidable real losses

Figure 4.3: Real Losses – Complementary leakage management activities

The impact of pressure reduction on the leak flow rate can easily be calculated, as illustrated in > **Table 4.3**.

The same equation can also be used to estimate the effects of pressure management on an entire network made out of mixed pipe materials, where the average overall leakage exponent is close to 1.0. The pressure-leakage relationship means that, as a rule of thumb, the ratio of pressure reduction approximately equals the ratio of leak flow reduction in large networks. The pressure-leakage relationship explains why it still might be economic to manage or reduce pressure in a distribution network where pressure is already low: Reducing average from 30 m to 27 m (10%) could decrease the leak flow by 5% to 15%, which could be significant in regions with scarce water resources or high leakage.

Benefits of pressure management

Pressure management can thus be an immediate and cost-effective solution for decreasing real water losses in a distribution network, even at low initial pressures. However, leakage reduction is not the sole benefit, as > **Table 4.4** illustrates.

Pressure management also offers water conservation benefits because some types of water consumption will decline due to the reduced average zone pressure, for example from taps, showers and garden irrigation systems. A study by the IWA Water Loss Task Force found that pressure reduction results in a significant decrease in new pipe breaks and bursts (Thornton & Lambert 2007). Further benefits include deferred replacements and extended service life of pipes, joints and fittings, as well as fewer customer plumbing and appliance problems.

All of these positive effects of pressure management usually result in high water savings and, thus, have very short payback times, as illustrated by figures from four large pressure management installations in Cape Town, South Africa, which are shown in > **Table 4.5**.

Besides the above-mentioned direct effects, pressure management may generate additional, indirect benefits:

- An increased number of households with access to public water supply
- An increased duration of water supply (hours/day)
- Equal and fair water supply distribution considering social constraints
- Reduced production costs and energy consumption.

However, water utilities should bear in mind that pressure management only alleviates the impacts, but does not cure the causes of water loss. Therefore, pressure management should always be seen as one component of a set of measures required for successful, long-term water loss reduction. Pressure management may be a good starting point for water utilities with high levels of leakage, due to the relatively high savings and the short payback periods.

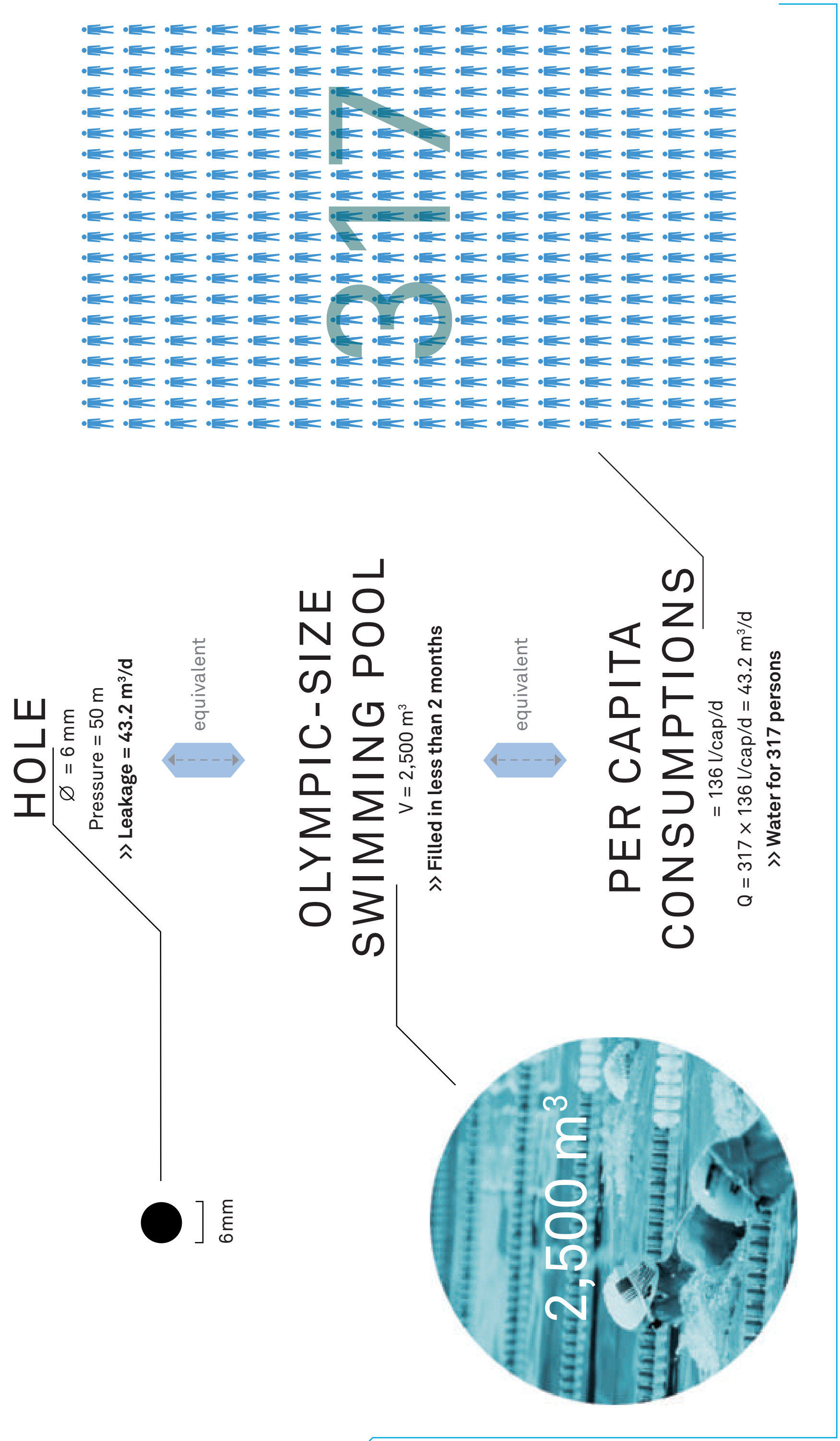


Figure 4.4: Water loss from a single circular hole with 6 mm diameter

Installing a pressure management system

There is no standard solution when it comes to pressure management. Every distribution network has its own characteristics and has to be studied individually to develop an optimal solution that takes into account technical, financial, environmental and social aspects. However, pressure management is likely to be economically efficient if two out the six criteria listed below apply to your system:

1. Real water losses > 15%
2. Losses > 200 l/day/connection
3. Pressure amplitude > 10 m (1 bar)
4. Frequent pipe bursts
5. Average age of pipelines > 15 years
6. Household connections > 2,000.

Installing a pressure management system involves the following steps: (i) selecting a suitable pressure management area and separating it from neighbouring zones; (ii) installing a Pressure Reduction Valve (PRV), a pressure sensor and a flow meter at the inlet point to the pressure management area. Additional technology is needed for advanced pressure management systems. Pressure management solutions typically involve modulating pressure by operating valves at specific local points, thus influencing water flow.

Political and financial framework for pressure management

Sustainable WLR, including pressure management, is complex and involves many aspects. Effective and efficient water management requires that political, financial and managerial aspects be considered when promoting technical solutions. Crucial factors for the success of WLR include water laws and policies, the existence of WLR strategies, the structure of water utilities, including private sector commitment and existing knowledge and information, e.g. about the water distribution network. Incentives and/or financial instruments for implementing WLR can strongly encourage WLR.

Moreover, stakeholders themselves and their structural settings can influence the progress of WLR by promoting or inhibiting it. The different stakeholders that may profit from WLR by means of pressure management include producers, owners, operators and customers. These stakeholders have to be considered and addressed when developing WLR and pressure management action plans. Public private partnerships and strategic alliances are in some cases advisable and should be considered, as they can be regarded as complementary approaches towards an integration of Capacity Development and technical implementation (> Good Practice Case 1: Pressure Management in Ain Al Basha, Jordan (GIZ, Rothenberger & Hübschen).

Calculating Pressure Reduction

Ø Hole	Pipe Material	Leak exponent	Leak flow rates at pressure of		
			50 m [m³/h]	40 m [m³/h]	30 m [m³/h]
6 mm	**Rigid** (e.g. steel, cast iron, ...)	0.5	1,800	1,610	1,394
6 mm	**Flexible** (e.g. PE, PVC, ...)	1.5	1,800	1,288	837

Table 4.3

Benefits of pressure management
Reduction of excess average and maximum pressures

Conservation benefits		Water utility benefits			Customer benefits	
Reduced flow rates		Reduced frequency of bursts and leaks				
Reduced consumption	Reduced flow rates of leaks and bursts	Reduced repair costs at mains and services	Deferred renewals and extended asset life	Reduced cost of active leakage control	Fewer customer complaints	Fewer problems on customer plumbing and appliances

Table 4.4

Pressure management
(Cape Town, South Africa)

Area	Water savings [million m³/year]	Construction costs [USD]	Value of savings [USD/year]
Khayelitsha	**9.0**	**335,000** (in 2001)	**3,352,000**
Mfuleni	**0.4**	**212,000** (in 2007)	**170,000**
Gugulethu	**1.6**	**188,000** (in 2008)	**603,000**
Mitchells Plain	**2.4**	**967,000** (in 2009)	**904,000**
Total	**13.4**	**1,702,000**	**5,029,000** (+/- 600,000)

Table 4.5

4.4.2 Water Loss Reduction through control of apparent losses

Acting in the field of apparent losses implies, besides technical components, strong social aspects to prevent unauthorized water consumption and to reinforce customer accountability. Unavoidable Annual Apparent Losses (UAAL) will mark the limit of reducing Current Annual Apparent Losses (CAAL) > **Figure 4.5**.

Four areas of intervention are relevant:

1. Installation and calibration of customer meters
2. Error prevention during data transfer
3. Error prevention during data analysis
4. Prevention of unauthorized consumption.

The activities against real and apparent losses require a comprehensive water loss control programme that comprises technical and social aspects of management to locate and reduce these water losses and thus maintain or increase revenue for the maintenance of water utilities.

Water utility managers need specific answers to: Who? What? When? Where? Why? How often? and How much? These answers are needed for each of the following aspects:

- Record keeping
- Audit/balance performance indicators and benchmark analysis
- Economic analysis
- Metering – locating, sizing, initial installation, validation, replacement
- Meter reading or Automatic Meter Reading (AMR)
- Additional system monitoring including Supervisory Control and Data Acquisition (SCADA)
- Data transfer – billing, data error analysis
- Leakage management programme
- Periodic leak detection sweeps
- District Metered Area (DMA), zone flow analysis, and other forms of leak testing
- Leak locating – method and training
- Leak repair
- Repair, rehabilitation, or replacement analysis, design and execution
- Pressure management.

It may be assumed that larger water utilities can often manage most of this work in-house. Medium-sized and small water utilities may need to utilize contracted services in order to achieve programme objectives (EPA 2010).

To give an example, the case of Phnom Penh shows that, within a timeframe of 15 years, much can be done. Enhanced system efficiency was gained, with levels of Non-Revenue Water reduced from 72% to 6%. > **Good Practice Case 2**

PRESSURE MANAGEMENT IN AIN AL BASHA, JORDAN

(GIZ, Rothenberger & Hübschen)

Ain Al Basha, a northern district of Amman in Jordan (one of the ten most arid countries in the world), was estimated to have a Non-Revenue Water (NRW) level of almost 50% in 2005. The condition of the water distribution system in Ain Al Basha (over 4,000 service connections) posed a great number of problems: the very high percentage of real water losses consumed considerable financial and natural resources and led to a limited supply of water for service customers. Furthermore, strong pressure variations within the system led to frequent new pipe breaks. Addressing this situation, a project with the objective of reducing real water losses by using effective pressure management (PM) methods and increasing the capacity of network operators was envisaged. It was implemented as a public private partnership (PPP) between the German Technical Cooperation (GTZ) and VAG-Armaturen in two phases: the technical installation of a pressure management system (Phase I) and the embedding of the PM knowledge (Phase II) from January 2007 until July 2008. The project was complemented by a further PPP of GTZ, Dorsch Consult, Seba KMT and Engicon for "Effective leak detection, repair & maintenance management for technical water loss reduction in Ain Al Basha" from July 2007 until December 2008. Both projects were undertaken in close cooperation with the Water Authority of Jordan (WAJ). In 2009, the PPP with VAG evolved into a strategic alliance, in which Jordan is one of the pilot countries where the developed 'Guidelines for water loss reduction' are being implemented (www.waterlossreduction.com).

2 NEEDS ASSESSMENT

a Analytical Capacity

> Needs and suitability analysis to identify the most appropriate network district for the system to be installed

b Technical Capacity

> Installation of a PM system in the project area and transfer of competences in the use of pressure reducing valves

> Computerized data collection and analysis of the data

> Network management and repair

c Managerial and Administrative Capacity

> Developing financing models to calculate benefits of water loss reduction

> Creation of added value for WAJ / RoI by identifying unknown network connections

d Capacity of Sharing Knowledge

> Professional partnership with WAJ employees and personnel management skills

> Institutional development and cooperation with contractors and suppliers (e.g. electricity company)

3 METHODS OF CAPACITY DEVELOPMENT

> Training courses and on-the-job instructions to embed the PM knowledge and enable the local partner to continue operating the new system

> Training of the trainers (Jordanian trainers were trained in order to sustainably incorporate PM knowledge in the WAJ)

> Improve a local training centre for water engineers in Amman to teach 400 to 600 technicians and engineers per year from Jordan and the region on how to use pressure reducing and other valves in the appropriate way

> Designing and agreeing on an individual, comprehensive capacity development strategy with stakeholders

4 IMPACT

The projects' advantages for the WAJ inter alia include:

> Increased efficiency and lower water supply costs

> Fewer pipe bursts and thus increased lifetime of pipe system through controlled and reduced pressure

> Water losses reduced (by down to approx. 40% NRW), saved water used to increase/improve water supply

> Embedded knowledge on PM within the local structure

> Sustainable capacity development of local staff

4.4.3 Water loss reduction support through Geographical Information Systems

4.4.3 was provided by ***Jan-Peter Mund,*** *University for Sustainable Development (HNEE) Eberswalde, Germany [Jan-Peter.Mund@hnee.de]*

Geospatial technology applied to manage water infrastructure networks has a great potential for water loss reduction. An important component of all water supply systems is the distribution network consisting of pipes, nodes, pumps, valves and storage tanks. Geographical Information Systems (GIS), integrated to support the management of water infrastructure networks, can help in establishing an efficient and continuous maintenance of water supply infrastructure in many ways. Water administrations, civil society institutions and the private sector can benefit from using GIS technology for planning and managing water infrastructures. A GIS-supported water network allows the spatial analysis of network data in the form of pipe parameters: length, diameter, roughness, coefficients, etc. The advantages for water infrastructure providers consist of enhanced factor productivity of assets, automation of simple tasks such as technical maintenance, pressure management, leak detection, improved water quality control and service-oriented reduced emergency response time in pipe and pump repairs. Therefore, the planning of a GIS-supported water distribution network encompasses technical raw data analysis, geospatial data integration, and optimal allocation of network components > **Figure 4.6 & Figure 4.7**.

A Geographical Information System-supported water supply system offers the opportunity to provide a customer friendly single "window". From this window, the user can access all parts and topics of the water infrastructure, ranging from technical and engineering infrastructure to water supply and pressure management or spatial leak detection and the transparent accounting for individual water supply. The advantages of up-to-date spatial GIS technologies are that various spatial and non-spatial data can be accessed and correlated in real time or near real time > **Figure 4.9**. Benefits include broadband internet and wireless data transfer technologies in the water sector. Results from geospatial data analysis of the supply network could facilitate improved maintenance, optimization and utilization of water infrastructure and consumer-friendly solutions. Such solutions include exact and transparent metering, pressure adjustment and immediate service.

GIS-based management of water infrastructure also provides a graphic communication platform between professions, institutions and organizations, donors, government ministries and local target groups. GIS technology simply allows them to map their own projects. At the same time, GIS infrastructure serves and improves overall efficiency and effectiveness. While the use of GIS maps and technology to share information has already become the lingua franca across water infrastructure

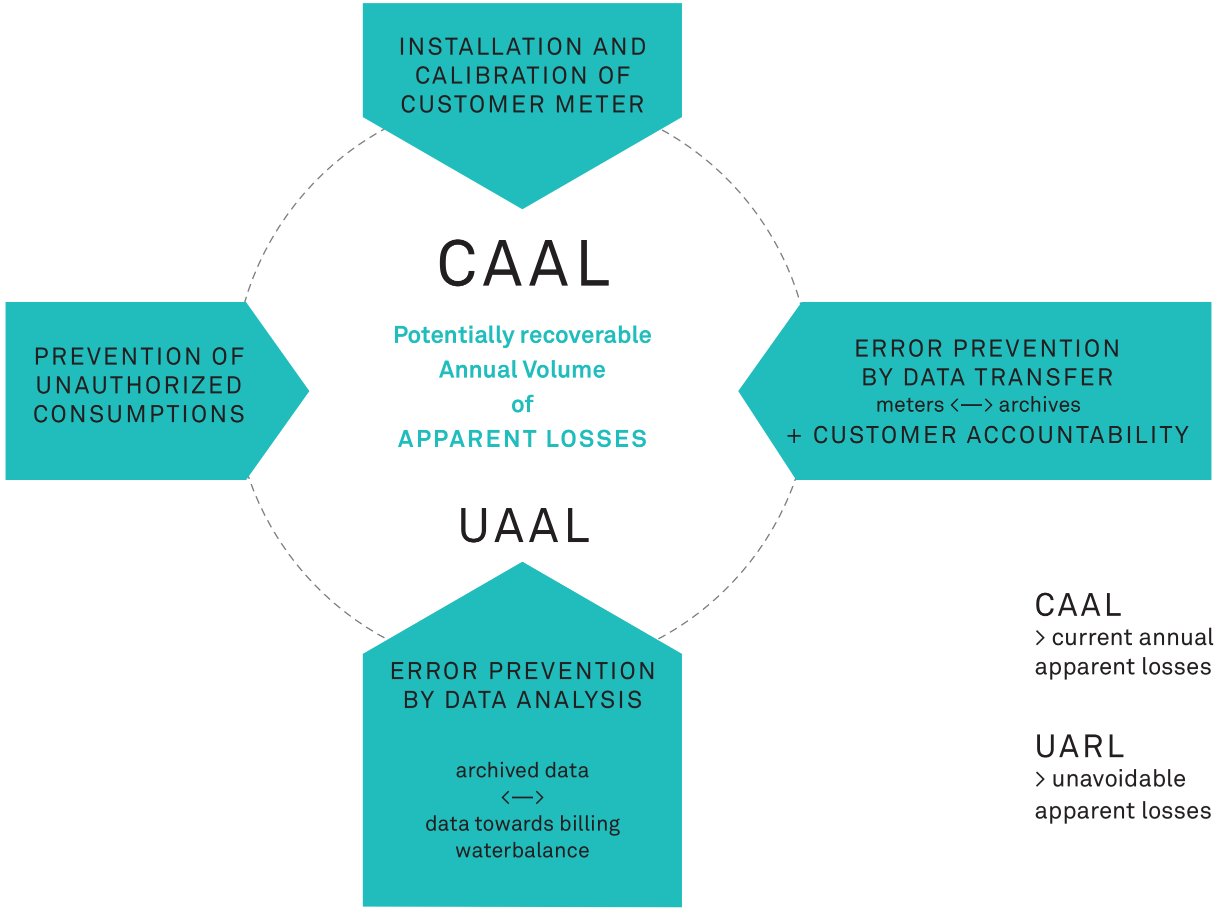


Figure 4.5: Apparent Losses – Areas of intervention

service institutions and the water engineering sector, greater capacity needs to be developed with other users. A capacity gap has developed between civil society and especially small and medium scale enterprises in developing countries on the one hand, and the fast growing geospatial community on the other.

From the technical point of view, GIS-enhanced water distribution networks involve optimal allocation of network components, spatial raw data analysis and geospatial data integration. Integrating GIS into the water network engineering allows the analysis of technical network data such as pipe parameters of length, diameter and roughness coefficients. This data could be used for further system modelling and simulation of multi-criteria conditions in the water supply chain > **Figure 4.8**.

Although the size and complexity of water supply and sewer systems vary at different locations, they all carry out the same task – to deliver water from a source to a customer and then collect, treat, and discharge water back to a surface water recipient. The management of such large scale engineering systems requires the tight integration of different data collection methods from various sensor types, modelling, near real time control and decision support techniques in order to minimize costs while complying with regulatory requirements.

Today, specialized water supply and management service providers implement sophisticated and semi to fully automated sensor networks to collect real time information from the network. In many countries such sensor web systems already survey and manage many indicators and technical parameters in the water supply chain. This requires geospatial infrastructure on multiple scales, from individual measuring instruments and sensors, to network infrastructure, to the decision support sector (DSS, > **Figure 4.9**). In particular, spatial technology and GIS methods are used for water supply modelling and multi-criteria process optimization of the water supply chain, using numerical finite modelling of groundwater and surface availability and evaluation of water infrastructure components such as water leak detectors using fuzzy logic, simulations and integrated mobile system loggers > **Figure 4.10 & Figure 4.11**.

Usually, this kind of automated sensor network web-based infrastructure takes advantage of broadband internet, wireless data transfer technologies. In a water infrastructure research project in 2005, Stoianov et al. stated that complex, highly non-linear temporal and spatial processes occur in a water distribution system, thus presenting serious challenges in differentiating between faults (e.g. leaks) and stochastic system behaviour in near-real time. Nowadays, high speed internet and wireless signal transfer capacities have improved the signal velocity, as have IT storage and processing capacities > **Figure 4.10 & Figure 4.11**.

The application of GIS technologies and geospatial software solutions such as web-based sensor networks for transparent, efficient and end-user friendly water supply chain management has been demonstrat-

THE CASE OF PHNOM PENH

(NWSC/Mutikanga)

Phnom Penh Water Supply Authority (PPWSA) is an exceptional case study in the developing world. It serves a population of about 1.5 million people in Phnom Penh, the capital city of Cambodia in Asia. During the decades of the 1970s and the 1980s, Cambodia was subject to social, political, economic, and institutional turmoil. This took a toll on the performance of the urban water sector, and PPWSA was no exception. There was inadequate skilled manpower to properly maintain and operate the existing urban water system. Institutionally, PPWSA was in limbo and its overall management was dysfunctional, with consumers receiving a very poor level of service. Although Cambodia is very well endowed with water resources, water supply in urban areas, including Phnom Penh, was erratic and unacceptable.

2 NEEDS ASSESSMENT

Phnom Penh's remarkable transformation is mainly attributed to the following key competences:

a Analytical Capacity

> Utility situational analysis that led to complete management restructuring

> Socio-economic surveys to guide tariff reviews

b Technical Capacity

> Change management: Appointment of a dynamic and charismatic general director in 1993

> Network zoning into DMAs, 24-hour leak detection and repair programme and network renewal

> Internal service contracts for Non-Revenue Water (NRW) reduction in pilot zones

> Universal metering and optimal meter replacement (integrated meter management)

c Managerial and Administrative Capacity

> USA lifting of trade embargo against Cambodia in 1992

> The landmark decree No. 52 of 1996 establishing PPWSA as a public enterprise which had to operate as a commercially viable entity

> Financial technical support from donors in 1993 for investment following internal reforms

> Financially viable and socially sensitive tariff structure put in place

> Good financial standing with net annual profits – all donors want to be part of a success story

d Capacity of Sharing Knowledge

> Changing culture of work – leadership by example, team spirit, hard work and transparent policies on employee annual appraisals, rewards and penalties, zero tolerance to corruption

> Strong political support from the government with minimal interference

3 METHODS OF CAPACITY DEVELOPMENT

> In-house training centre – for continuous staff training and capacity building at all levels

> Rewards for recognizing excellence and penalties for poor performance

> Allowing a leader time to understand the problems of the authority (plan and implement strategies)

4 IMPACT

The following benefits have so far been realized during the 15-year time frame (1993–2008):

> Enhanced system efficiency with levels of Non-Revenue Water (NRW) reduced from 72% to 6%

> Water savings of about 60 million cubic meters per year

> Number of service connections increased from 26,881 to 178,200, serving over one million people

> Utility revenues increased by over US$ 20 million per annum

Case provided by:
Mutikanga Harrison
Water Loss Control Manager-Kampala Water
National Water & Sewerage Corporation
harrison.mutikanga@nwsc.co.ug

Figure 4.6: GIS application in water supply networks

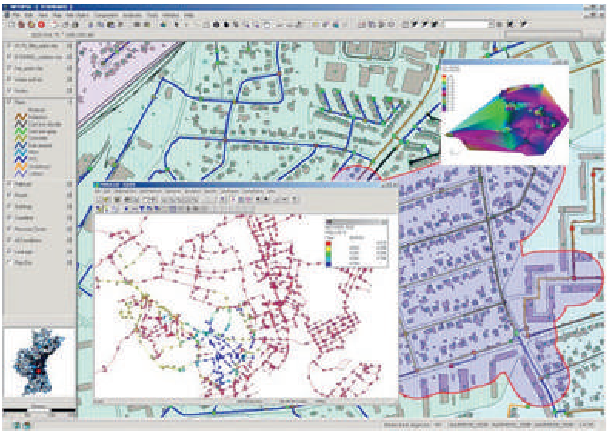


Figure 4.7: GIS managed water supply network
Source: AQUIS 7-Technologies A/S

ed to be successful in reducing water loss and improving drinking water quality on many occasions. In particular, water sector stakeholders in developing countries should begin to take advantage of the multiple benefits offered by the use of geospatial data and GIS technology in this regard. Nevertheless, improving the water sector and reducing water shortages in highly populated developing countries like India > Figure 4.12: Mapping in Chitraban, India and China has already forced engineers to think of effective ways for managing water utilities using GIS, although there is a large capacity gap. To increase individual capacities and reduce the technical and conceptual gap, various capacity development approaches and individual measures need to be implemented. If successful, they will improve the idea of integrated water resource management in local and regional water sector development in developing countries.

In addition, case studies of pro-poor water management under complex social and challenging infrastructure conditions, in particular in informal settlements and slum areas, have proven that GIS-supported participatory mapping and infrastructure network approaches provide an excellent tool to demonstrate and map the water and sanitation rationale behind a certain infrastructure project > Figure 4.12 & Figure 4.13. Such approaches have the potential to integrate neglected groups into the discussion and decision making process. In such cases, maps and visualized spatial databases figure as basic illustrated communication tools providing transparent feedback to the community about the development progress and the asset allocation, which is an important element of project sustainability (Waterkeyn 2010).

During the last decade, a great variety of proprietary software systems and GIS solutions have been implemented successfully in the water sector. This kind of implementation is cost-intensive since it includes a budget for the technical infrastructure and an additional budget to develop human resources for such water management solutions. The vast majority of products and project-oriented solutions have been demand-driven and specially adjusted technical applications. Such individual solutions are not easily transferred into different institutional or technical settings, and therefore require many capacity building and training measures.

Geospatial technologies, spatial data management, and the use of GIS software are not yet part of the curricula in secondary schools or dual training institutions. Consequently, the professional implementation of geospatial technologies requires continuous capacity building for end-users, as well as capacity development of various agencies, especially in the regional or national water sectors.

Capacity development measures in the water sector also have to bridge innovations between international water sector professionals and organize white papers and capacity assessments about geospatial data management > Figure 4.14. They also have to provide individual or group-based training and institutional development, adjusting the administrative system and legally binding interactions between different stakeholders in the water sector.

To combat water loss effectively, various capacity development approaches are already being implemented by private and public institutions as well as development agencies like the UN. Introducing GIS tools and techniques is an important step in scaling up the measures against water loss.

4.4.4 Water loss control programmes

The given examples and approaches also show that water loss control programmes must be embedded in a comprehensive water policy and should

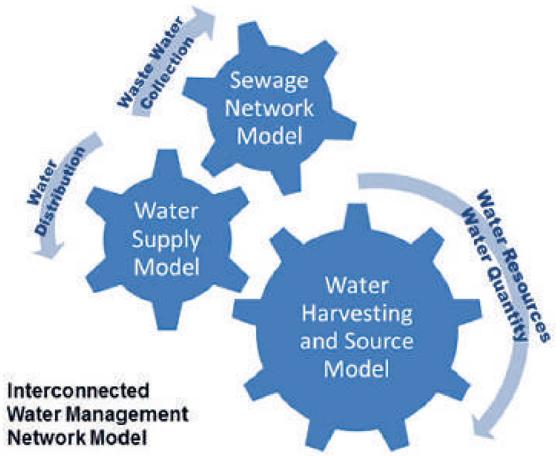


Figure 4.8: Water supply networks interlinks

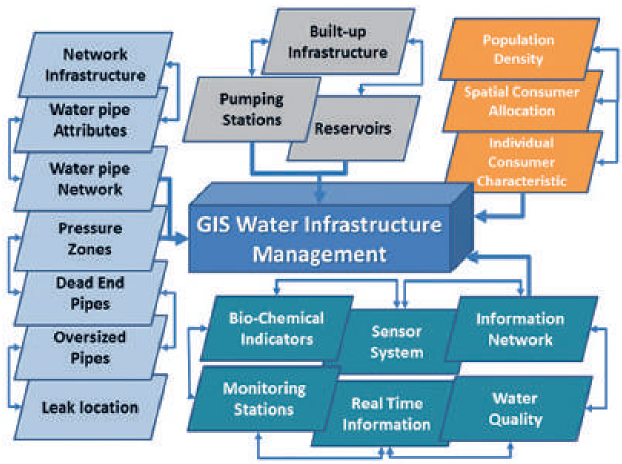


Figure 4.9: GIS water infrastructure management

be supported by the informed, committed and critical public. The public should play a central role that goes beyond simply reporting leaks promptly. Public awareness of the value of water and the willingness to pay for water supply and sanitation services is a prerequisite for the maintenance of water systems and for the detection and punishment of water thefts through social control. Incentives for optimal operating and maintaining of water systems, and information transparency, also measures against corruption, are needed as well.

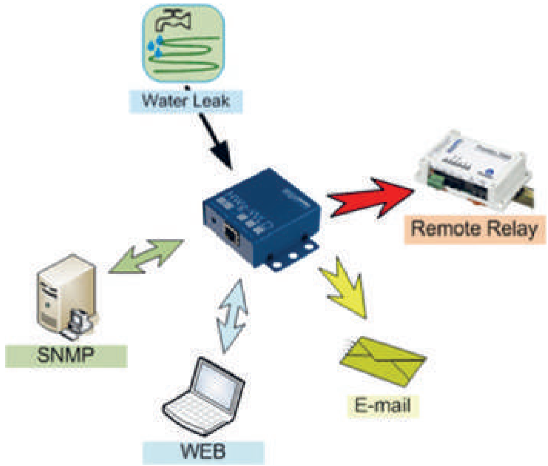


Figure 4.10: Wireless sensor network infrastructure
(Source: HW group products and solutions 2007)

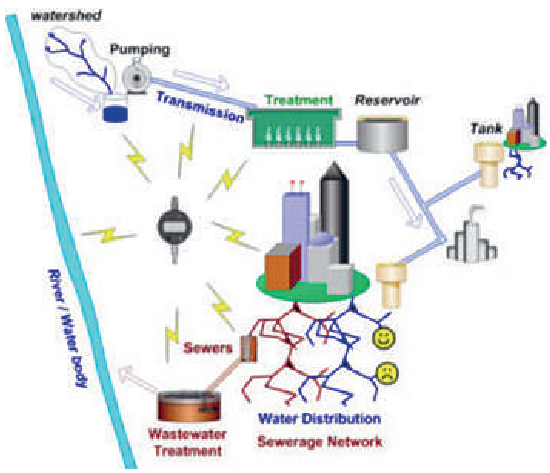


Figure 4.11: Web-based wireless water infrastructure
(Source: Stoianov 2005)

Only if the services of a water and sanitation system are paid for by all beneficiaries is it possible to maintain the system professionally in the long-term, and to reduce water prices, especially for the poor. In this sense, better is cheaper – as outlined in the following Chapter: Economics and Finance. This motto should be widely adopted – this motto should become a common consciousness.

Figure 4.12: Participatory water infrastructure mapping in Chitraban, India
(Source: Shelter-Associates 2010)

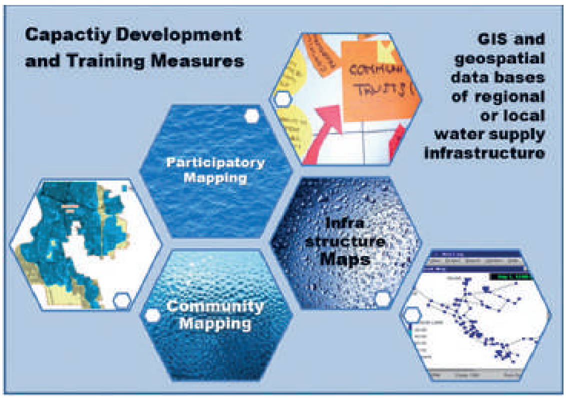


Figure 4.13: Capacity development for participatory water infrastructure mapping

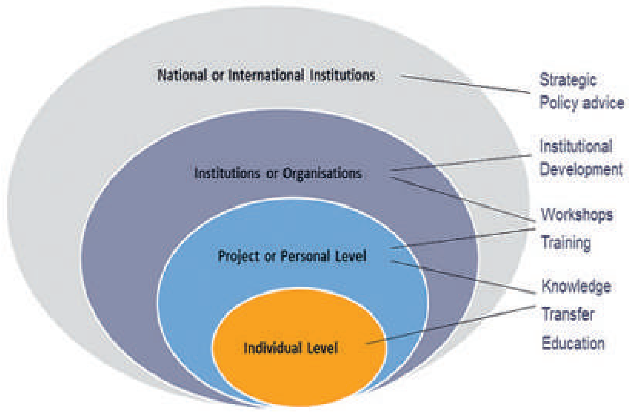


Figure 4.14: Capacity Development Intervention level

Therefore, key functions in the fight against water 'losses' are campaigns and continuous reporting by different media and journalists to increase public awareness of the value of water for health and economy, and the role of water and sanitation systems as the first point of action in dealing sustainably with water cycles. (UNW-DPC has organized three workshops in central Asia/Western Asia, Arab Countries, Latin America and the Caribbean (2007–2009) on capacity development for water and environmental journalists. Please find the key messages in the publication concerning these workshops ('Capacity Development for Water and Environmental Journalists') on the integration of public media into the development of water supply and sanitation systems, supported by the public (UNW-DPC 2010)).

Of course, the context of professional water loss control programmes is more comprehensive. As outlined in > **Figure 4.15** – the first point of action, there are more points of action such as the national legislation, different policies, etc. that have to be mobilized and aligned regarding water policy and especially water loss control programmes. As part of the overall background, the human right to water has become a central instrument in the development of water supply and sanitation systems.

As described above, large volumes of water are lost inevitably, but on top of that, very large volumes of water are wasted or stolen. Water theft and water waste would be avoidable if water supply and sanitation systems and the environment were managed properly, with well trained staff. Therefore, investment in comprehensive water-oriented structures, as a common and shared objective, is needed. In addition, professional management structures are essential, preferably with skilled managers with the organizational and financial responsibility for executing what political governance has defined as targets. For executive tasks of NRW, entrepreneurial institutions with professional, commercialised structures may be the most efficient, whereas setting targets, monitoring performance, and deciding about overall water governance is clearly the responsibility of public bodies.

The competences and capacities required to perform these tasks must be specified and developed. This is a common interest of investors and societies – to supply water and sanitation and to gain revenue as a reward for providing a service and for maintenance of the water systems (see also Ian Banda (WASAZA) 'The Zambian Experience' in UNW-DPC 2009).

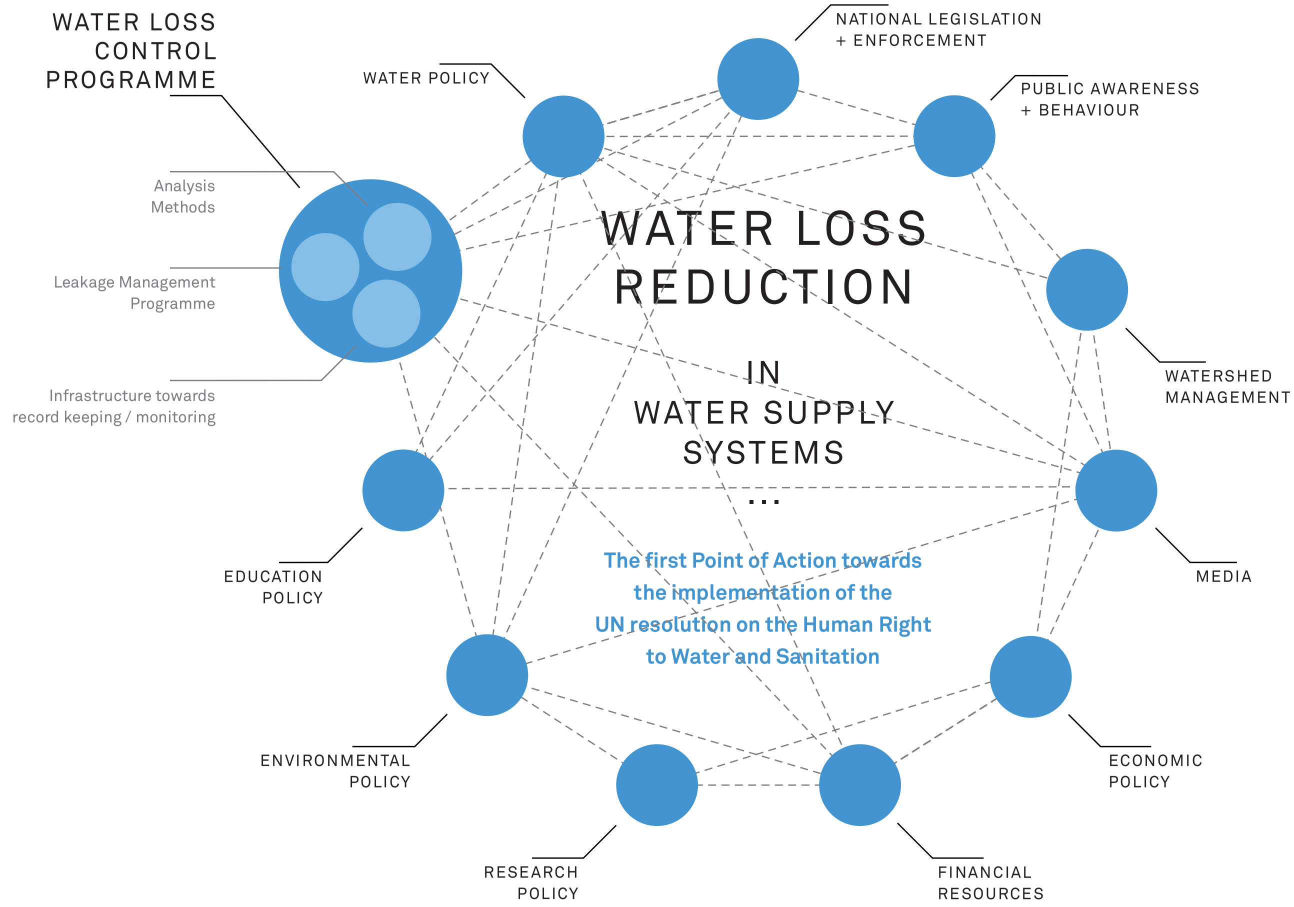


Figure 4.15: Water Loss Reduction – the first point of action

WATER MANAGEMENT AT THE VOLKSWAGEN PLANT, WOLFSBURG/ GERMANY

HISTORICAL BACKGROUND

Water recycling has a long tradition at Volkswagen. The plant in Wolfsburg was founded in 1938 and the use of rain water and cleaned processing water was included right from the planning stage, because the hydro-geological requirements were unfavourable at this location.

At first the storage basin was constructed, the core of the hydrologic cycle. It served as a collection pond for industrial and rain water and, at the same time, became an essential part for the city's flood protection. The installation of a separate sewer system and the separation of processing water from the network for drinking water provided excellent preconditions for extending the circulation system which was completed by a biological sewage-treatment plant later on.

The drinking water comes from a mountain area called "Harz" which is about 60 km away. Some wells were built a few kilometres north of the premises, because the ground water on the plant premises showed high salinity and iron content which was not suitable for technical and sanitary use.

FUNCTION

The rain water, cooling water and the purified sewage water are collected in the storage basin. Rain water from the city is fed and buffered into this basin, which is part of the regional flood protection. The water is filtered and then led into the plant's production water supply. Industrial water is mainly used for cooling within the production, but also for the sanitary facilities.

The storage basin is separated into four compartments and stores over 1.7 million m³ of water. Excess water is fed into the nearby river "Aller" after purification.

Due to the increasing legal demands for discharging sewage into the river and because of the progress concerning the treatment of wastewater, Volkswagen could raise the quality of the production water continuously over the years. Important modules for improving and securing water quality are the decentralized pre-treatment unit, the centralized treatment plant for production water from the individual production lines, the biological sewage treatment with elimination of nitrate and phosphor and the downstream final filtration. Special sewage from other VW plants is also treated in this plant due to these highly efficient processes.

Many recycling techniques are integrated into the production lines. This has the effect that besides saving water and wastewater, it is possible to recycle production material. Ion exchange and more and more ultra and nano-filtration are used. VW introduced preferably wastewater free processes, e.g. dry processing in the mechanical production.

EFFICIENCY

Due to the central circulation, the production water is used between five to seven times. There is also a decentralized circulation integrated into the production lines. Taking all this into account, VW saves a considerable amount of fresh water. The cost for our own production water is much lower than the price for drinking water provided by the public supplier. Wastewater fees and charges for water use could be reduced considerably through recycling and using the water many times.

The relatively high water temperatures up to 27 °C allow a limited use for cooling water. Lower temperatures are achieved indirectly by the cooling of compressors with production water. Main criteria for this extensive circulation are the sustainable security of supply. The multiple use of water leads to a substantial reduction of environmental burden and protects our water resources. Now, as it was in the past, we are obliged and entrusted with a responsible use of our resources – just like the ultimate aim of producing cars.

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5 Intelligent Pressure Management for Monitoring and Control of Water Distribution Systems in the UK

Stuart W. Trow
Southhampton, United Kingdom
[stuarttrow@hotmail.co.uk]

5.1 INTRODUCTION

This paper is an abbreviated and modified form of the one submitted for the IWA Water Loss 2009 by Trow and Payne.

Pressure management is recognised as a key element of a strategy for reducing water losses in water distribution systems. Flow modulation has been shown to provide added benefits in comparison to fixed outlet pressure reducing valves. However, the additional benefits do not always cover the extra cost and operational issues. This paper describes an intelligent form of pressure management developed by i2O Water Limited with support from Severn Trent Water. The benefits of the system are outlined, which include:

> Reduced losses as compared with other forms of pressure management
> More stable pressure regime producing fewer bursts
> Better customer service
> Better information to allow more efficient management of assets.

5.2 SEVERN TRENT WATER

Severn Trent Water is the second largest water company in England and Wales supplying eight million customers. It has 20 major water treatment plants and its network comprises 43,000 km of distribution mains and 2,800 DMAs. In England and Wales, water companies are required to meet statutory leakage targets set by the industry regulator OFWAT. However, in each of the two years to April 2006 and April 2007, Severn Trent missed their leakage target. It was imperative for the company not to miss any further targets to avoid risking serious financial penalties.

A programme was successfully introduced which brought leakage down from 524 MLD in the year to April 2007 to 491 MLD in the following year by improved operational management and large increases in find and fix activity. However, this has also resulted in an increase in the company's operating expenses. Over the next five years, Severn Trent is aiming for further reductions in leakage to 453 MLD and the challenge is to achieve these demanding targets without driving up operating expenses further.

Severn Trent believes that more effective pressure management can help to achieve the leakage targets in a more cost effective manner. However, this requires new methods and new technology. This was why, in 2005, Severn Trent agreed to collaborate with the start-up company i2O Water to help them to develop and test their new technology.

Severn Trent already uses pressure management extensively and has installed over 2,800 PRVs, almost all of which have fixed outlets, currently regarded as basic pressure management. The fixed outlet PRVs have brought down average pressures in the DMAs and have had a significant impact on leakage and burst rates. However, it is not possible to achieve an optimal solution with fixed outlet PRVs for the following reasons:

1. The PRVs have to be set high enough, so that, during maximum demand in the DMA when there is maximum head-loss in the network, all customers get adequate pressure. At other times of day, the PRV output pressures are too high.
2. The PRV outlet pressures are normally checked less than once every three years, as this is a laborious process requiring logging of the DMA. Therefore, a high factor of safety is needed in the setting to allow for changes to levels of demand.
3. Local operatives or technicians may increase the output pressures of a PRV, in order to solve a particular local problem or issue. Even when the issue is solved, the PRV pressure may not be restored to its correct setting.

All the above issues are leading to higher average pressures in the DMAs than necessary to maintain satisfactory customer service. There was previously no technology available to deal with the second two issues. However, there are two common techniques for addressing the first issue of varying flow related head-loss in the DMA. These are Time Modulation and Flow Modulation, known currently as advanced pressure management.

Time Modulation: This is a common technique using a simple electronic controller connected to the PRV to switch between a day and night setting. Severn Trent considered but ruled out Time Modulation for two reasons:

1. If there is a fire at night, the fire flow may be restricted due to the low setting.
2. A sudden switch between day and night settings may cause large amplitude pressure transients in the DMA which could reduce the life of the mains and may also have a negative impact on customer service by increasing the risk of new bursts.

Flow Modulation: This assumes that there is a consistent relationship between the flow into the DMA and the head-loss in the DMA. It uses this relationship to adjust the output pressure of the PRV depending on the flow rate into the DMA. A more detailed explanation is below:

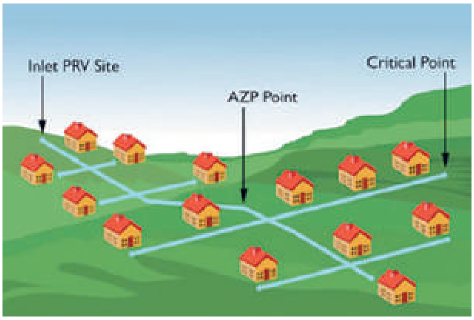

Figure 5.1: A typical DMA

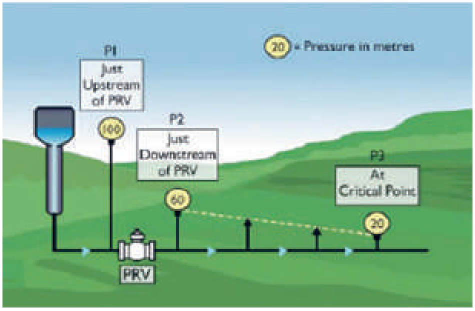

Figure 5.2: Pressures in a DMA under high demand/ flow rate conditions, i.e. during the day

> Figure 5.1 shows a typical DMA with a PRV installed at the inlet. The critical point is that point which is either at the furthest distance or at the highest elevation, or both in relation to the DMA inlet. It is the point in the DMA that will normally see the lowest pressure. There is a further point shown, the AZP point, where the average zone pressure (AZP) can be measured. The PRV drops the pressure down from the PRV inlet pressure (P1) to the PRV outlet pressure (P2). P2 is set manually after installation of the PRV. Because it cannot be varied easily, it must be set to a conservatively high level that will be safe under the worse case conditions and for future changes in the network.

> Figure 5.2 shows the system at a time of maximum demand during the daytime. The high flow rates in the pipes create a large head loss between the inlet to the DMA and the critical point. If the PRV has been set up correctly, P2 will be set high enough to provide adequate critical point pressure (P3). However, at night, when inflow is lowest, the head loss between the DMA inlet and the critical point is minimal and the pressure rises across the whole DMA until it is close to P2.

This can be seen graphically in > Figure 5.3. P2 remains stable while P3 varies considerably as the head loss across the DMA varies with changing demand.

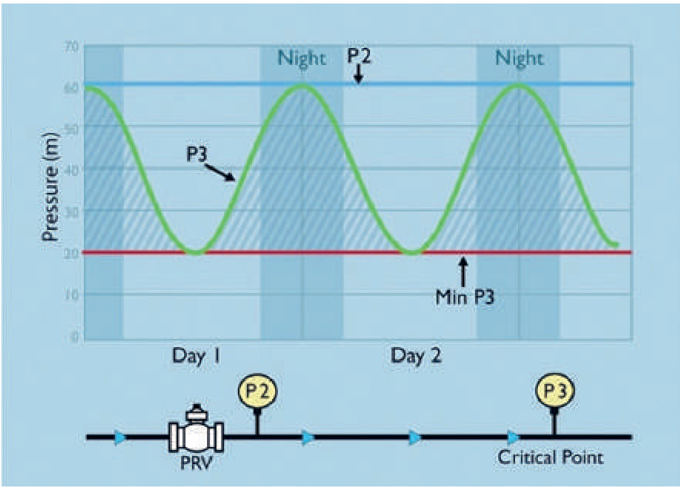

Figure 5.3: Varying critical point pressure with PRV fixed outlet pressure

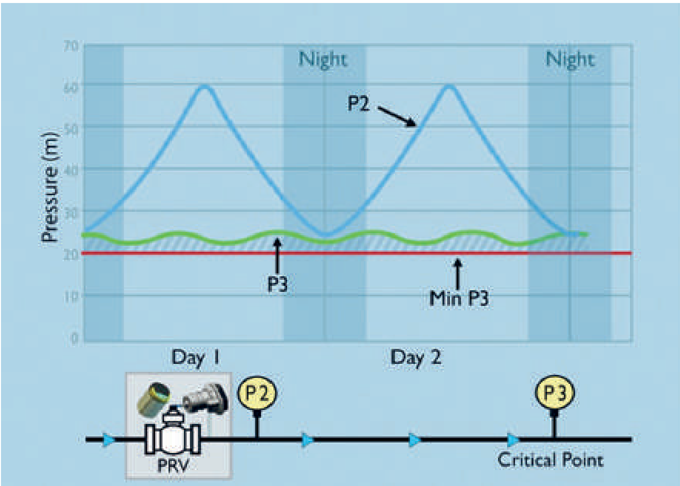

Figure 5.4: Varying PRV outlet pressure and steady critical point pressure with Flow Modulation

Using Flow Modulation, P2 is continuously adjusted (> Figure 5.4) in response to changes in flow rate, so that the pressure at the critical point (P3) is always kept just above the minimum level necessary. As the head-loss in the DMA between the PRV and the critical point changes with changing demand, P2 must be continually adjusted to achieve this. Severn Trent has some Flow Modulation but limitations in the technology have held back wider scale implementation. The key limitations are considered as follows:

1. Setting up the controllers requires specialist staff. The DMA must first be logged, then the relationship between P2 pressure and flow rate is programmed into a controller to control adjustments to the PRV. This process must also be repeated from time to time if there are changes in the DMA.
2. As with fixed outlet PRVs, the settings programmed into the table of the controller are out of date as soon as they have been entered. In particular, the DMA may have been logged in the winter with quite different demand patterns to the summer. For this reason, the pressures in the table must be conservative with a considerable factor of safety built in.

The pressure control achieved at the critical point is not always stable and can vary on some DMAs by as much as +/- 5m over the course of a day. For this reason, Severn Trent always builds in a large factor of safety when using flow modulation and would typically target 24 m minimum. The reason why the critical point pressure is not always stable is that the flow-pressure relationship is quite complex and varies over time, from day to day and from season to season, as patterns of demand change. Reliability of pressure control systems is understandably crucial. Malfunctions have the ability to interrupt supply if the PRV is inadvertently closed or to cause bursts if it is inadvertently opened. Severn Trent felt that a higher standard of reliability was required from the hardware. It was felt necessary to look at alternative ways of changing the PRV output pressure that did not rely on either solenoid valves or air pumps. Severn Trent's objective was to find technology that was capable of overcoming the above disadvantages of conventional flow modulation techniques. For this reason, they initiated the collaboration with i2O Water.

5.3 THE INTELLIGENT PRESSURE MANAGEMENT SYSTEM

The intelligent pressure management system sets out to overcome the disadvantages of existing flow modulation technology; achieving this with two principal innovations; self learning control algorithms which learn the characteristics of the DMA and adapt to changes, and a new design of PRV Advanced Pilot Valve (APV) which enables the PRV output pressure to be changed reliably, smoothly and accurately in response to electronic signals from a controller. A new pilot rail containing the APV is installed on the PRV in place of the standard pilot rail. This transforms the fixed outlet PRV into a PRV with a variable outlet that can be varied by the controller. The controller is then mounted in the PRV chamber and connected to the APV. The controller monitors the flow rates and pressures at the PRV, communicates with the server and adjusts P2 to the correct level.

A P3 sensor is also installed at the critical point. This measures the pressures at the critical point and communicates with the i2O server. A further sensor (P4 sensor) can be installed at the AZP point to send back

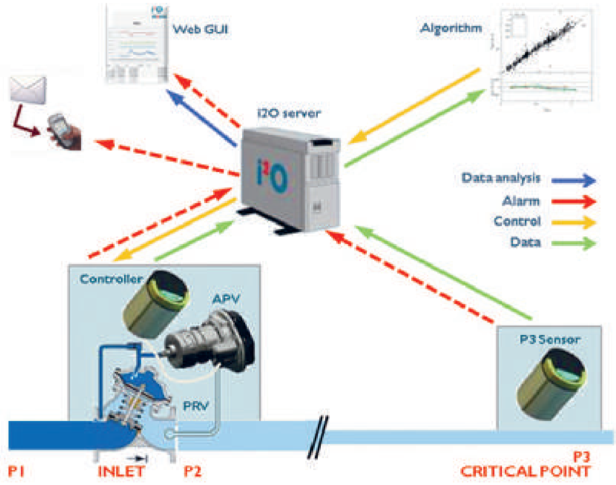

Figure 5.5: The Intelligent Pressure Management system configuration

the AZP pressures (P4). If a P4 sensor is not used, an appropriate method should be used to calculate P4.

Both the controller and the P3 sensor send their data back to the central server on a scheduled basis, typically once a day using the GSM network. During each communication, the previous 24 hours pressure and flow data (P1, P2, P3 and Q) are uploaded to the server and an updated control algorithm is downloaded back to the controller. Since pressure and flow data accuracy is essential for optimum control, both the controller

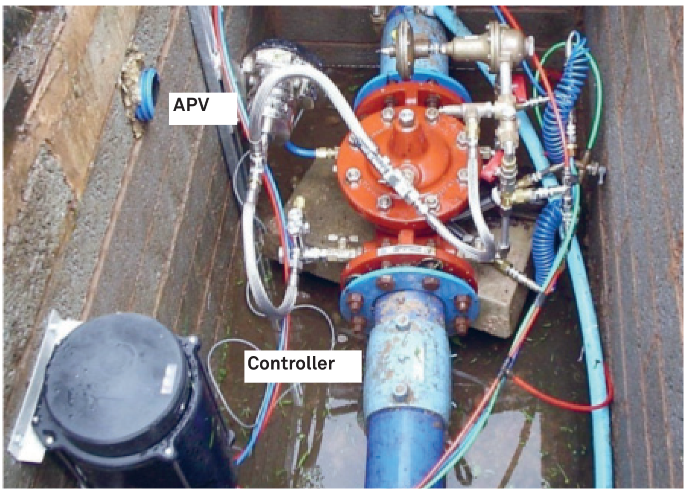

Figure 5.6: A typical installation

and P3 sensor feature advanced pressure sensing technology, with 24 bit analogue to digital converters, 0.1% accuracy transducers and high speed sampling to get a true average pressure reading. The system features SMS and email alarm functionality, both by the field devices and the central server, which can generate more sophisticated condition monitoring alarms. Data is stored on an SQL database with options for synchronising with the customer's database, and for generating WITS compatible XML files for importation into the customer's existing computer systems.

Advanced pilot valve (APV)

A potential weakness in existing Flow Modulation technology is the method of adjusting P2. This is normally done by using solenoids to pulse either water or compressed air into a bias chamber that exerts a variable force onto the conventional pilot valve spring. Such systems can experience short battery life and limited range. Solenoids used to pulse water are often unreliable due to grit in the water affecting the mechanism of the solenoid. The systems that use compressed air to actuate the bias chamber are vulnerable to flooding of the PRV chamber. The new APV is a development of the conventional sprung diaphragm pilot valve, but with an innovative feature which enables adjustment of the pressure set point with minimal energy input. This enables the pilot to be adjusted with a small electrical signal.

5.4 SELF LEARNING CONTROL ALGORITHMS

The control algorithm is a significant innovation which enables all pressure optimization to be carried out continuously and remotely from the

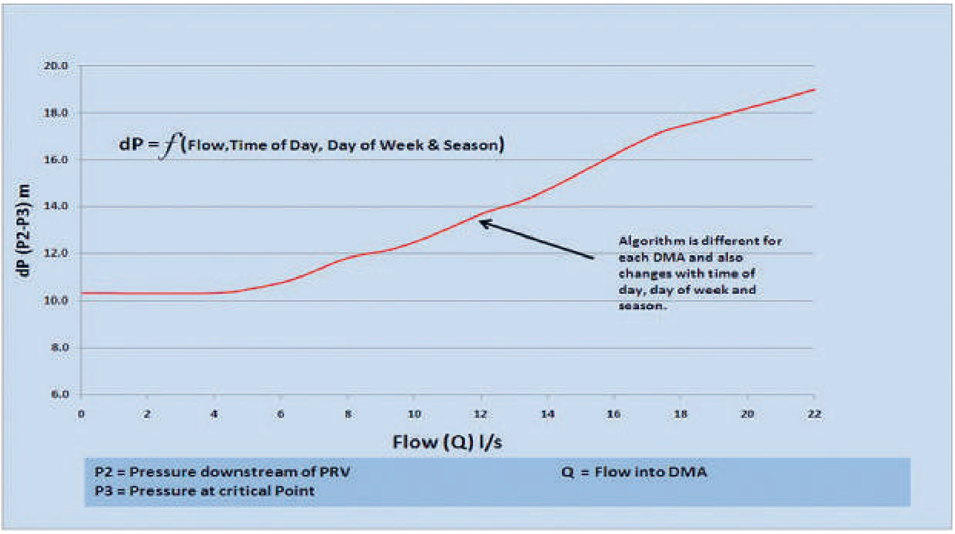

Figure 5.7: Self learning algorithm

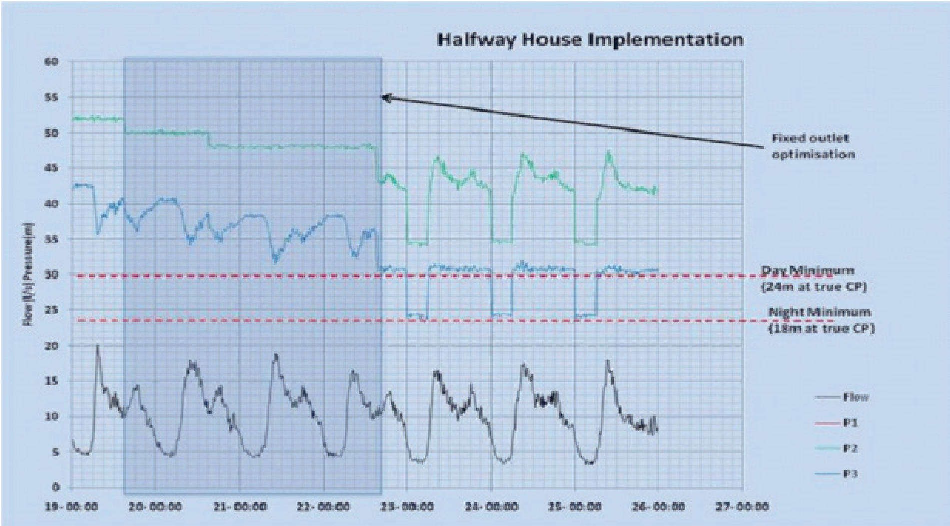

Figure 5.8: First trial site – Halfway House DMA

device. As data is accumulated in the central SQL database, the algorithm learns the relationships between head-loss, flow rate, time of day, day of week and seasonal effects. The algorithm works on confidence levels and will only start making adjustments to the control parameters when there is sufficient evidence to support the change.

The i2O system can be installed in a few hours without the need for a survey. Initially, it will maintain the existing fixed P2 pressure, and incrementally start optimization in a controlled fashion. After a period of several days, the algorithm will have optimized the control parameters such that the critical point pressures do not drop below the target critical point pressure with a 99.5% confidence level. After optimization, the algorithm will continue to monitor new data as it is uploaded to the database. This enables it to adjust parameters if the characteristics within the DMA change, due, for example, to the building of a new housing estate, or industrial change of use.

5.5 RESULTS FROM TRIAL INSTALLATIONS

In January 2008, Severn Trent tested a prototype intelligent pressure management system on one of their DMAs. The trials were carried out over a period of several weeks and showed leakage savings in excess of 25% compared with the fixed outlet PRV. By August 2008, fully ruggedized production systems were available from i2O and Severn Trent ordered six systems in order to conduct a longer term trial. Severn Trent selected a variety of different DMAs with varying levels of leakage and head-loss. The system was first installed on a medium sized DMA comprising some 2,000 mainly residential properties near Leicester. The DMA had previously been fitted with a flow modulation device, but was running at an optimized fixed outlet pressure at the time when the system was fitted. After a period of time, the self-learning algorithm had confidence to commence optimization of the pressures. Whilst the DMA was already set at an optimized fixed outlet pressure for peak summer flows, the system identified that the fixed outlet pressure could be optimized for the current winter flow patterns.

After approval from Severn Trent, the system initially optimized the fixed outlet pressure for the current season by taking outlet pressure down by 2 meters in two 1 meter steps. This initial optimization is part of a 'Soft Start' routine which has been developed recently to ensure that any significant change in DMA pressures is implemented slowly. This reduces customer complaints since the changes occur over a longer period. The system recalibrated after the fixed optimization had completed and commenced flow modulation with different day and night target pressures.

The system can be seen to be accurately controlling P2 pressures to achieve critical point pressures to within close tolerances of Severn Trent's stipulated minima. This graph more clearly shows three stages of implementation on a DMA where the PRV outlet pressure was set conservatively high:

1. **Initial period:** The system started with a period of 7–14 days of automatic calibration during which time the PRV was set to maintain the earlier conservative fixed outlet pressure.
2. **Fixed outlet optimization:** This was followed by an incremental stepped fixed outlet optimization – all managed automatically and remotely.
3. **Flow modulation:** After a recalibration, the system commenced flow modulation, with a further 'soft' incremental reduction of target pressures from 20 m to 18 m during both day and night.

5.6 CALCULATION OF LEAKAGE SAVINGS

Throughout the trial, the average zone pressure was estimated by i2O by logging at the calculated average zone point (PAZP). The PAZP was measured both before the fixed pressure optimization (P4a), after the optimization of the fixed outlet pressure (P40b), and after flow modulation had commenced (P41). Leakage was estimated before the trial started using the 'bottom up' approach, i.e. night leakage was calculated by monitoring the night line and appropriate legitimate consumption was subtracted. This initial night leakage was multiplied by the calculated hour to day factor to establish the baseline daily leakage (L0).

The effective leakage reduction was calculated using the FAVAD method L1 = L0.(P41/P40)N1. Leakage reduction was calculated both due to the fixed outlet optimization (L1a) and the flow modulation optimization (L1b) as shown on the graph above. At the time of implementation, the

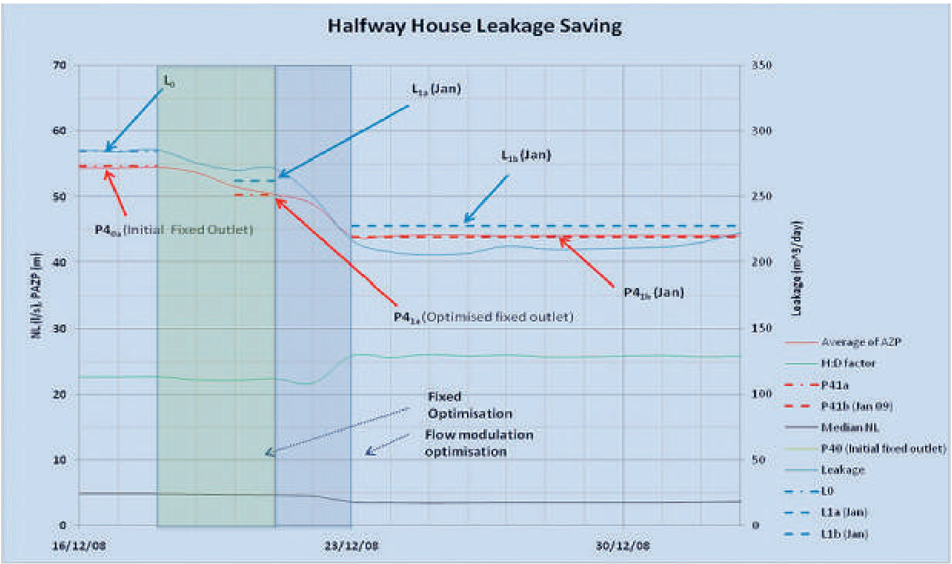

Figure 5.9: Leakage savings at Halfway House DMA

leakage L0 was 285 m³/day. After fixed outlet optimization, the leakage L1a was 262 m³/day, an 8 % reduction. After flow modulation optimization, the leakage L1b was 228 m³/day, a 20% reduction.

In light of the excellent confidence levels, Severn Trent Water has since reduced the target minimum critical point pressure to 20 m giving a 26% reduction in leakage.

CONCLUSIONS

The intelligent pressure management system has demonstrated a good control of pressures at the critical point. This has enabled Severn Trent to reduce average zone pressures, and hence leakage without effecting customer service. The system adapts to changes in the characteristics of the DMA and will ensure that the pressure will always remain optimized. This provides a more consistent service to customers. As well as the operational benefits, the system provides a wealth of data on the performance of the network under control, which is of value in the efficient management of the water company's assets. The system has so far proved to be reliable, through demanding winter conditions. A trial of a further 6 systems in 2009 resulted in leakage savings in each DMA of between 9 and 33%.

Severn Trent believes that this system has a big potential to help it achieve leakage targets more efficiently and at a lower cost than current methods of mains replacement or find and fix. Severn Trent has ordered further i2O systems as a result of the trials.

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6 Pressure Management and Active Leakage Control in the City of Skopje, Macedonia

Bojan Ristovski
Skopje, Macedonia
[bojan.ristovski@vodovod-skopje.com.mk]

INTRODUCTION

Water losses in the system are a phenomenon that all water production and supply utilities are faced with. With regards to the water supply companies in the Republic of Macedonia, leakage has been identified as a serious problem, with excessive leakage levels in many parts of the country exceeding the revenue water. The water losses are generally in the range between 40–65% of system inputs.

In regards to real losses, it has been generally accepted that there are four basic methods for their successful management: pressure management in the system, improving the speed of leak repair, active leakage control and infrastructural improvements.

This paper presents one case study, addressing two of the previously identified methods: active leakage control and pressure management.

6.1 CASE STUDY: PRESSURE MANAGEMENT (STAGE I) AND ACTIVE LEAKAGE CONTROL (STAGE II)

The city of Skopje is mainly supplied by gravity from the Rasce spring, with average input in the system of 4,500 l/s and from the well areas Nerezi-Lepenec, with total capacity of 1,420 l/s. For certain higher areas of the city of Skopje, high pressure zones have been established. The current case study refers to the water loss reduction activities in one of the high pressure zones Aerodrom-Novo Lisice > **Figure 6.1**, which supplies water to residential buildings in the settlements of Aerodorom and Novo Lisice, from the fourth floor above.

6.1.1 Pressure Management – Stage I

The first stage of this project is related to water loss reduction through pressure management. In order to determine possibilities for pressure reduction, several pressure measurements were performed and data are shown in > **Table 6.1**, as well as monitoring of the system inflow > **Figure 6.2**.

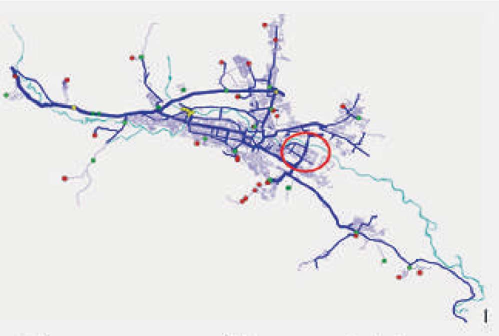


Figure 6.1: Water supply system high pressure zone of Aerodrom-Novo Lisice

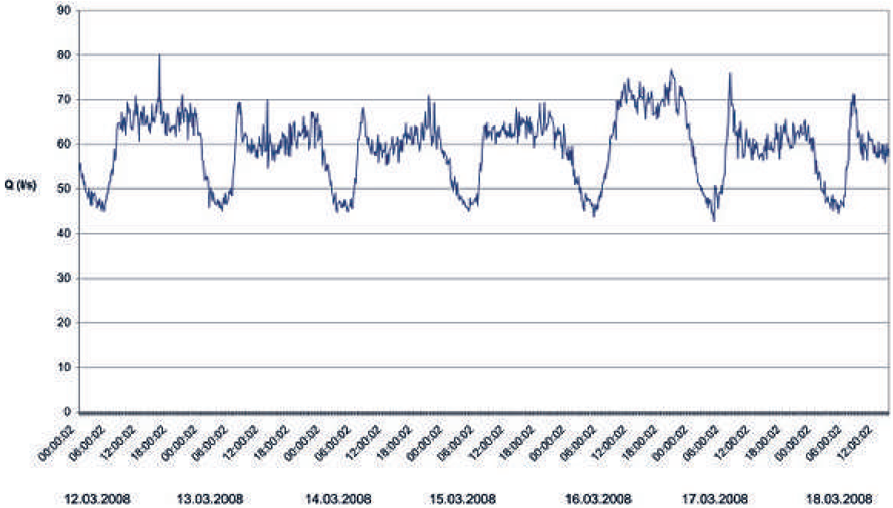


Figure 6.2: Daily inflow in the high pressure zone of Aerodrom-Novo Lisice, for the period from 12.03.2008 to 18.03.2008

Based on statistical data shown and the analysis carried out on site, it was finally concluded that the existing pressure was higher than the required one and that its reduction of approximately 2 bar was allowed, which enabled installation of PRV Φ 250 mm with constant outlet pressure on Ø 400 mm ductile-iron pipe.

6.1.2 Comparison of the condition before and after installation of Pressure Reduction Valve

In order to show the effect of Pressure Reduction, the pressure in two particular locations within examined area has been permanently monitored > **Figure 6.3 & Table 6.2**, as well as the system inflow > **Figure 6.4**.

Measuring point	Maximum Pressure (bar)	Minimum Pressure (bar)	Average Pressure (bar)
No. 2 Bojmija Street (11th floor)	5.04	4.33	4.66
No. 4 Pandil Siskov Street (6th floor)	7.04	6.62	6.85
No. 7 Blvd. Jane Sandanski (7th floor)	6.13	5.69	5.81
No. 47 Blvd. Jane Sandanski (17th floor)	3.82	3.34	3.65
No. 60 Blvd. ASNOM (6th floor)	7.24	6.87	7.08
No. 77 Blvd Vidoe Smilevski-Bato (8th floor)	6.75	6.41	6.62

Table 6.1: Pressure data before installation of the pressure reduction valve

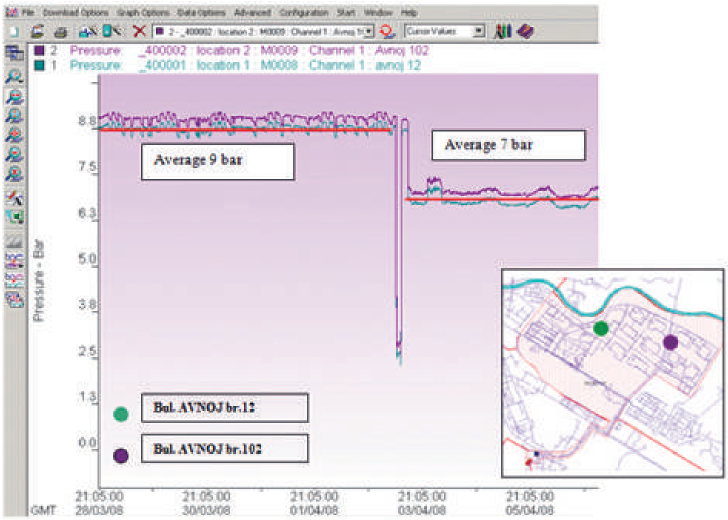


Figure 6.3: Pressure before and after installation of Pressure Reduction Valve

6.1.3 Benefits achieved with the implemented pressure reduction methodology

The archived results after the PRV installation, which is related to water savings during minimum night flow, as well as saving water for a 24-hour period, are shown below in > **Table 6.3**.

	Pressure before installation of Pressure Reduction Valve			Pressure after installation of Pressure Reduction Valve		
Measuring point	**Max (bar)**	**Min (bar)**	**Average (bar)**	**Max (bar)**	**Min (bar)**	**Average (bar)**
No.12 Blvd AVNOJ	8.96	8.48	8.76	7.18	6.57	6.76
No.102 Blvd AVNOJ	9.22	8.77	9.04	7.43	6.87	7.03
Pressure Reduction (%)						**22.83**
Pressure Reduction (bar)						**2**

Table 6.2: Statistical data of pressure monitored on the measuring points before and after installation of Pressure Reduction Valve

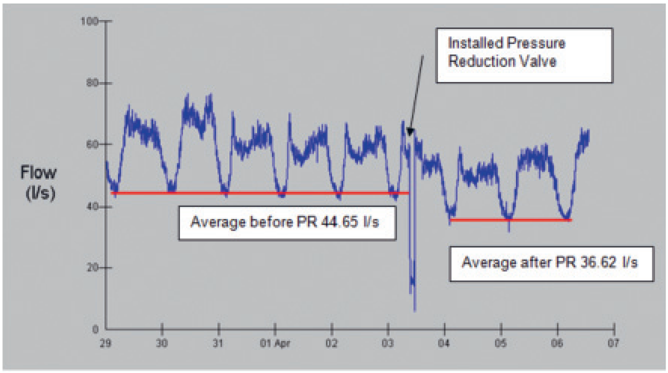


Figure 6.4: Daily inflow in the period from 29.03.2008 to 02.04.2008 and 04.04.2008 to 07.04.2008 after the installation of PRV on 03.04.2008

6.2 ACTIVE LEAKAGE CONTROL – STAGE II

The second phase of this project addresses active leakage control, which required the establishment of district metered areas (DMA) as an adequate method for leakage control. These activities were based on: field flow measurements, methodology for leakage assessment and systematic inspection of water supply network.

The examined DMA-high pressure zone of Aerodrom-Novo Lisice was divided into three sub-DMAs, which are divided between themselves with the clearly defined boundaries shown on > Figure 6.5.

Because of the characteristics of the water supply network, the established sub-DMAs are actually temporal and the flow on the appropri-

	Min night flow (l/s)	Min night flow (m³/h)	Water savings – Min Night Flow	Water savings – Min Night Flow (%)	Daily inflow (m³/day)	Water savings for a 24-hour period (m³/h)	Water savings for 24-hour period (%)
Before installation of PRV	44.65	160.8			4899.3		
After installation of PRV	36.62	127.0	33.74	21	4029.4	820	17

Table 6.3: Water savings during minimum night consumption, for a 24-hour period in DMA Aerodorm-High Pressure Zone, expressed in m³ and in %.

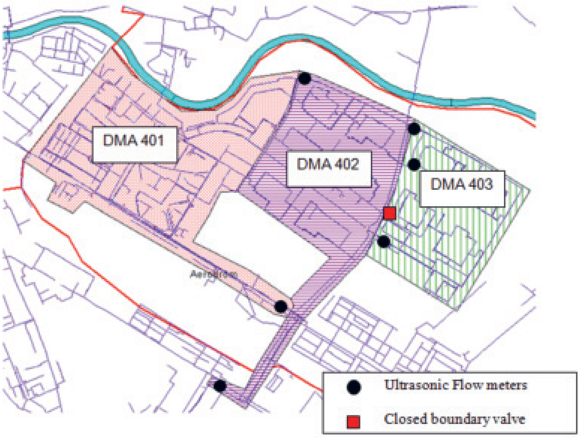


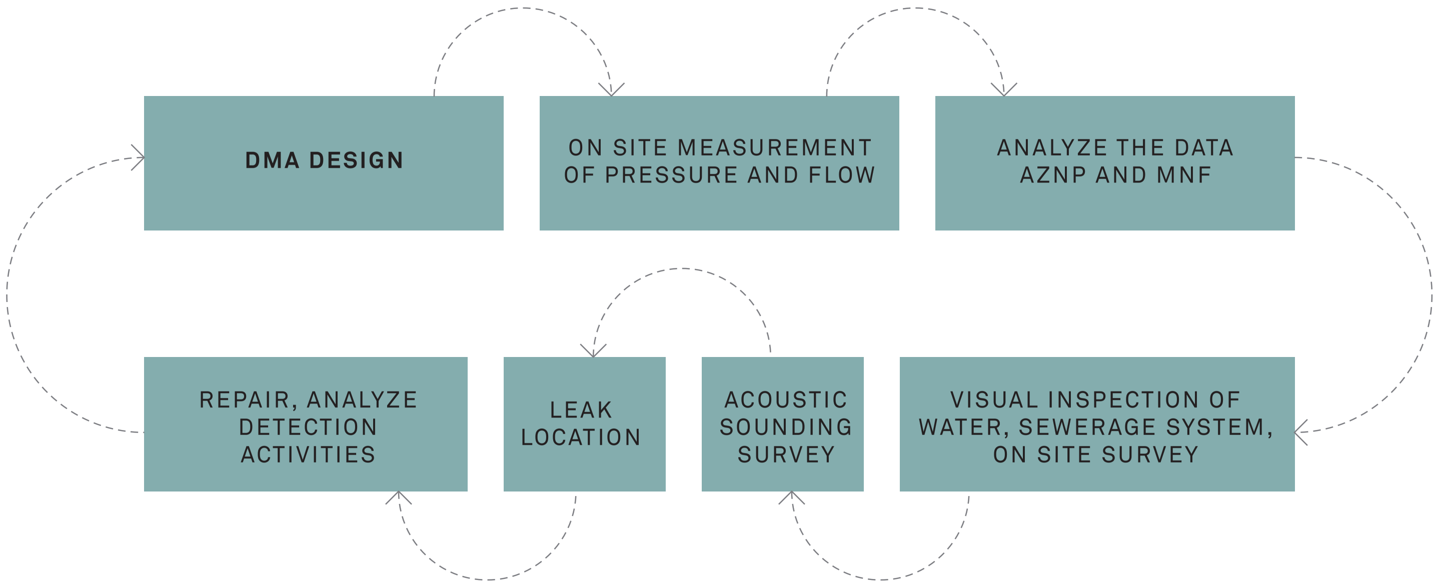
Figure 6.5: Overview of the three sub-DMAs, which are divided between themselves with clearly defined boundaries

ate inlets and outlets was monitored with portable ultrasound flow meters. It was required to close only one of the boundary valves, as shown in > Figure 6.5.

6.2.1 Methodology for leakage reduction applied in the study

The water loss methodology used in this project is shown in > Figure 6.6. Water loss in DMAs and appropriate sub-DMAs within the project was cal-

Figure 6.6


DMA DESIGN
ON SITE MEASUREMENT OF PRESSURE AND FLOW
ANALYZE THE DATA AZNP AND MNF
VISUAL INSPECTION OF WATER, SEWERAGE SYSTEM, ON SITE SURVEY
ACOUSTIC SOUNDING SURVEY
LEAK LOCATION
REPAIR, ANALYZE DETECTION ACTIVITIES

culated with the night flow analysis (method of minimum night flow). The measurement data can be seen in > Table 6.4.

6.2.2 Systematic activity for the reduction of real water loss

The systematic reduction activity used in this project contained visual inspection of the water and sewerage network, acoustic methods with

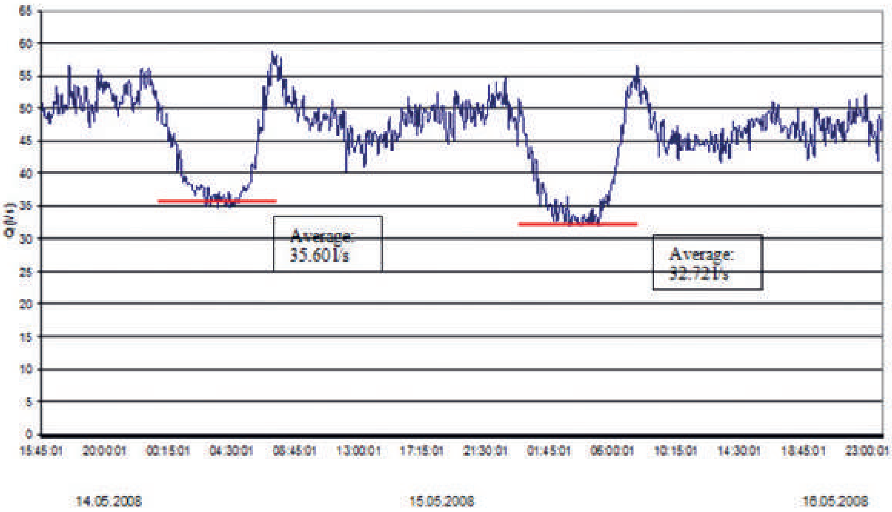


Figure 6.7: Overview of a daily consumption diagram at the inflow after repair work of some of the previously located leaks

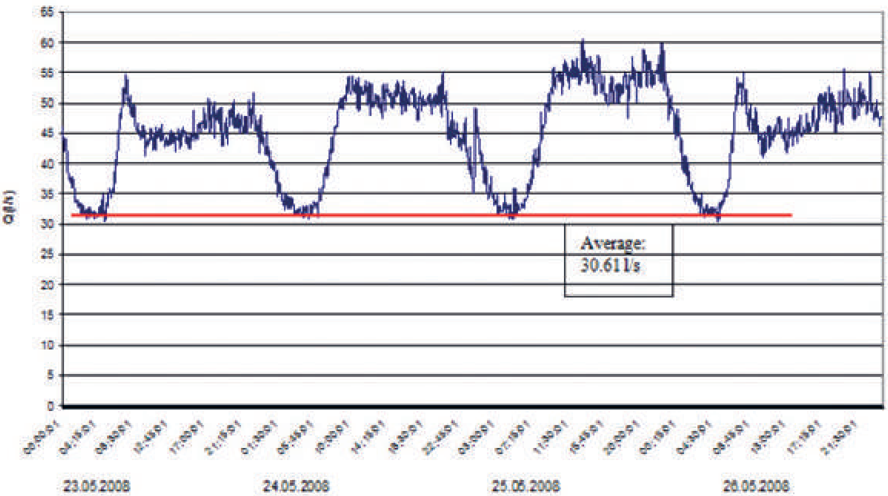


Figure 6.8: Overview of daily consumption patterns at the inflow after implementation of ALC

Sub-DMA	Min (l/s)	Max (l/s)	Average (l/s)	$Q_{min/h}$ / $Q_{av/h}$	Daily consumption (m³/day)	Minimum night consumption (m³/h)
Sub-DMA 401	2.73	13.11	7.76	0.35	670.15	12.85
Sub-DMA 402	9.24	22.28	16.22	0.57	2072.78	72.06
Sub-DMA 403	16.11	33.65	23.99	0.67	1401.61	32.54
DMA 400	32.62	69.97	47.97	0.48	4144.53	117.45

Table 6.4: Calculated leakage according to the method of minimum night flow for a 24-hour period (14.05.2008)

Water input in the system:	Daily consumption (m³)	Minimum night flow (m³/h)
Before project implementation	4899.29	160.75
After completion of Stage I - Pressure reduction	4029.44	127.01
After completion of Phase II - Active leakage control	3888.23	110.22

Average: 30.61 i/s

Table 6.5: Overview of daily consumption and minimum night flow, related to the different stages implemented in this project

contact microphones and noise loggers and pinpointing with ground microphones and digital correlators.

During the systematic examination of the water supply network, performed by the Leakage Detection Department, practically on all sub-DMAs, a significant number of various types of leaks was registered, contributing to such high night consumption.

Taking into consideration the existence of high and low zones in the examined area, which, by rule, have to be separated, it was found that they are connected in two places, resulting in water overflow from the upper into the lower zone as well as in increased water loss in the examined area. Certainly, immediately upon their detection, these links were disconnected.

Upon elimination of all visible and detected leaks, additional measurements of flow in the entire DMA were conducted.

6.2.3 Final results, achieved with the implementation of PRM and ALC

With the implementation of the two stages in this project (installation of a PRV (1st stage) as well as monitoring, analysis, location and repair of the leaks (2nd stage), significant water savings were achieved. The final results are shown in > Figure 6.7/6.8 and > Table 6.5.

CONCLUSIONS

With the installation of the pressure reduction valve (1st phase), the registered minimum night flow was reduced by 33.73 m^3/h or 21% of inflow, which means a saving of 840 m^3/day or 17%.

The implementation of active leakage control (2nd phase) has resulted in additional minimum night flow reduction of 16.80 m^3/h or 13%, which means a savings of 141.21 m^3/day or 4%, related to the 1st phase.

After the implementation of two phases, water losses were reduced by 50.53 m^3/h or 31%, which means a savings of 1,011 m^3/day or 26%.

Water savings of more than 1,000 m^3/day ensure a decreased number of a pump's working hours, decreased electricity consumption of the pump as well as economical savings.

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7 Innovative Technologies for Pipe Rehabilitation to Mitigate Water Losses

Stefan Zhelyazkov
Kazanlak, Bulgaria
[szhelyazkov@cm-bg.eu]

Bulgaria possesses a well developed water supply network, based on a core of main water lines. The majority of them were built during the 60s and 70s of the previous century, and there are pressure water lines in use that are 80 or more years old. Their life-time is at its end or already has expired long ago, therefore, a considerable number of them are in bad condition and need repair or replacement.

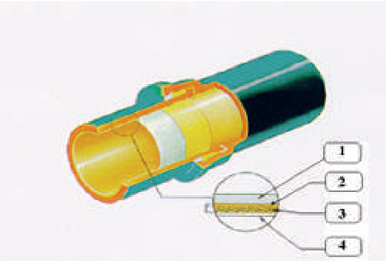
The most common problems are leakages caused by corrosion or joint dislocation, as well as decrease of their cross section, due to accumulation of sediments and formation of incrustations.

Besides the direct financial losses for the water supply companies, massive leakages are most dangerous because they can cause collapses and accidents. Therefore there is a pressing necessity of replacement or at least repair of a considerable number of main pressure lines. The standard digging technology offers a well known and safe but expensive, time-consuming and ineffective solution. As a result of the rapid growth of cities during the last decades, many main pressure lines turned out positioned in highly urbanized areas, where the tearing up of whole principal thoroughfares would cause great difficulties (and respectively – financial losses) for the local inhabitants and business activities.

There are alternative trenchless technologies that would allow the existing pipelines to be replaced or repaired, avoiding the shortcomings of the standard digging technologies.

One of the best suited and most wide spread trenchless technologies for main pressure water lines rehabilitation in the world is the “Phoenix” (also called “Cured In Place Pipe – CIPP“). It is used for rehabilitation of damaged, leaking due to corrosion, deteriorated or with dislocated joint seals, cracked or crushed pipelines, built with different pipe types – steel, asbestos-cement, cast iron, reinforced concrete, etc. The technology guarantees a 100% leakage elimination and improvement of the pipe hydraulic properties.

This particular trenchless technology until recently has had no application in Bulgaria despite its indisputable advantages. Its first application for the Lovech Water Supply Company is already a fact.



Position 1 is the wall of the existing pipe.
Position 2 is the epoxy resin, which glues the liner to the existing pipe.
Position 3 is reinforcing fabric, made of polyester fibres, which provides the structural strength of the liner and resistance to inside and outside loads.
Position 4 is a HDPE layer (1–2 mm thick), which provides smooth inside surface of the liner and compliance with sanitary and hygienic regulations.

Figure 7.1

Figure 7.2

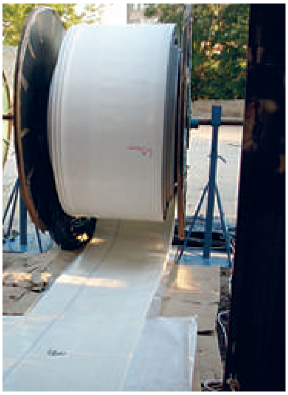


Figure 7.3

During the last two decades, a replacement of the old asbestos-cement pipes with new HDPE pipes is going on, and now the reconstruction has covered about 40% of the pipe network that needs repair. The water main pipeline, built with steel pipes at the beginning of the 80's to serve the needs of approximately 70% of the citizens of Lovech, was not included in the scope of these activities. Its operation life is already finished and it had broken down repeatedly due to corrosion leakages.

The replacement of this pipeline with a new one, with the traditional digging technology, would be expensive, extremely time-consuming, cause great difficulties to the traffic, and ultimately – big collateral losses to the society.

Because of this, the above mentioned "Phoenix" technology, or the "Cured in Place Pipe" technology, was used for rehabilitation of a part of this pipeline. This technology offers additional advantages, such as:

- Increased (if necessary) pipeline working pressure up to 13–15 bar
- Increased chemical resistance of the pipeline
- Applicable even in extremely confined and difficult surrounding
- Capability of crossing single knees up to 900 (R = 3 OD) or 4 consecutive knees of 450 each (when rehabilitating siphons)

The rehabilitation was done in eight segments with a total length of 950 m. The diameter of the pipeline is variable from 600 mm to 400 mm through the different segments.

First, it is important to provide some information about the "Phoenix" technology and its application in the city of Lovech.

The rehabilitation is performed when a hermetically sealing liner is installed on the inner surface of the old pipe. The material used to line the damaged pipeline is a flexible double layer pipe. After installation, it is tightly glued to the existing pipe, as shown in cross-section > Figure 7.1.

The repair sequence of a single section of about 190 m length steel pipeline with diameter 600 mm is as follows:

1. Preparation includes digging technological pits and delivery of the necessary materials; inspection of the pipe section with a special CCTV camera for assessment of the pipe condition; cleaning of the inside surface of the pipe from incrustations, rust, deposits, etc., with high pressure (750–1200 bar) water jet; repeated inspection of the cleaned pipe > Figure 7.2.
2. Liner installation: The liner is supplied in inverted shape, i.e. at the outside is the HDPE layer, on the inside – the reinforcing polyester fibre layer. Because the liner is flexible it is transported rolled up on reels with minimum size – below is shown a reel with liner for the rehabilitation of a water pipe with a total length of 450 m and diameter of 600 mm > Figure 7.3.

The installation starts with the preparation of the liner and the epoxy resin; pouring in and distribution of the resin along the liner; rolling up the liner into the inversion drum and fixing to the inversion head > Figure 7.4.

The liner is rolled up inside the inversion drum, the reinforcing fabric is uniformly impregnated with the epoxy (or polyester) resin. One end of the liner is fixed to the inversion head, the other to a rope with length, equal to the liner length.

The other end of the rope is fixed to an axle in the centre of the inversion drum. When the axle is rotating, first the rope and then the liner are winded inside the drum until the inversion head is positioned at the inversion drum flange. The flange (and the whole inversion drum) are hermetically sealed.

Figure 7.4

Compressed air is fed inside the drum, the air pressure starts to push out the liner through the opening in the inversion head, simultaneously inverting the liner (inside out).

After the inversion, the epoxy resin impregnated reinforced fabric is at the outer side of the liner and the isolating HDPE layer – at the inside.

The continuously expanding liner “hose” is directed to the end of the rehabilitated pie and starts to fill it in > **Figure 7.5**.

The process continues until the “hose” reaches the technological pit at the end of the rehabilitated section. The air pressure pushes the liner towards the pipe walls. The curing of the pipe is accelerated by high temperature steam, produced by a steam generator > **Figure 7.6**.

When the resin cures, the excess material is cut out at both ends of the rehabilitated section and repeated CCTV camera inspection is done; with this the installation is complete > **Figure 7.7**.

Finishing operations: The last step of the process is the connection of the rehabilitated sections, filling up of the technological pits and pavement reconstruction.

Due to the elasticity of the liner before the resin is cured, the air pressure pushes the liner out at the T-junctions (if such exist). Thus they are easy to find during the CCTV inspection and then can be cut open with a remotely controlled manipulator.

This technology allows the contractor to achieve several effects simultaneously:

Figure 7.5

Figure 7.6

Figure 7.7

- Complete elimination of leakages through joist, corrosion, cracks, displacements
- Improvement of the hydraulic properties of the pipe due to the smooth inside HDPE layer and the marginal decrease of the inside cross section of the pipe – a total diameter decrease of 8 mm
- Complete stop of the internal corrosion
- Elimination of incrustations
- Increase of the pipe lifespan
- Increase of pipeline resistance to vibrations and earth movements

With this technology, it is possible to repair pipelines with a diameter ranging from 150 mm to 1200 mm, at sections of up to 400–600 m.

As a conclusion, I would like to say that owing to the development of the trenchless technologies and their expanding rate of application in Bulgaria, now we have at our disposal various opportunities for a fast and effective rehabilitation of the water supply network without adverse effects to the environment and disruption of the routine way of life.

The trenchless technologies are the best solution for a successful decrease and minimization of losses of potable water – a precious natural resource.

8 Monitoring and Management of Water Distribution Network in Antalya City, Turkey using SCADA System

Ismail Demirel, Tuba Özden, Ibrahim Palancı,
I. Ethem Karadirek and Habib Muhammetoglu
Antalya, Turkey
[askiscada@hotmail.com]

8.1 INTRODUCTION

Antalya City is one of the most important tourist cities in Turkey and lies along the Mediterranean coast. Antalya Water and Wastewater Administration (ASAT) of Antalya Metropolitan Municipality is responsible for providing water and wastewater services to an area of 141,719 ha, inhabited by more than 700,000 people with more than 300,000 subscribers.

Groundwater wells and springs are the main water resources in Antalya City. The abstracted water has high water quality except for relatively high hardness levels (Çelik, E. & Muhammetoglu, H., 2008). The water is distributed to the city without applying any treatment. However, liquid chlorine in the form of sodium hypochlorite is added to the water to maintain certain concentrations of residual chlorine all over the water distribution network. Consequently, risk of pollution during distribution of potable water is reduced (Tiryakioglu, O. et al., 2005).

The inhabited areas of Antalya City are located at different levels, ranging from sea level up to 250 m above sea level. Therefore, the Antalya water distribution system is complex and consists of six main independent pressure zones (ASAT – Akdeniz U., 2008).

8.2 DESCRIPTION OF THE ANTALYA SCADA SYSTEM

ASAT SCADA stations are categorized as deep wells, pumping stations, distribution reservoirs and pipe network stations. The system includes 9 pumping stations, 17 reservoirs, many deep wells and about 60 pipe network stations located on drinking water network. SCADA system also monitors water level in the reservoirs, operation of pumps in the pumping stations, pressure and flow rates in pipe network stations, positions of valves (open, closed, partially open), in addition to energy and water consumption. Additionally, the system includes security alarms in reservoirs, pumping stations and measurement stations. Many water quality parameters such as temperature, pH, conductivity, turbidity and residual free chlorine are also controlled at many locations along the water distri-

Figure 8.1: SCADA Control Center

bution network. SCADA system was completed in 2007 with a cost over four million Euros. SCADA system proved to be very efficient in reducing water losses, controlling water quality, reducing energy consumption and improving water services to the customers.

All the monitoring results are displayed online and also stored in the SCADA control center shown in > Figure 8.1. Results of the measured and analyzed parameters are evaluated by SCADA engineers, who work at the ASAT control center. A SCADA screenshot, which shows the water levels in the reservoirs in addition to the conditions of the pumping stations, is given in > Figure 8.2.

8.3 BENEFITS OF THE SCADA SYSTEM

The SCADA system has helped in the quick detection and good repair of frequent bursts in the water distribution network. > Figure 8.3 depicts the flow rate and pressure due to pipe breakdown in the middle of August 2009. No water flow was noticed on the ground surface due to the karstic characteristics of the area (Kaçaroglu, F., 1999). Additionally, no complaints were received from the customers regarding any water breakdown or shortage of supply. The data sets obtained from the SCADA system informed about the event by giving warning alarms. Also, the SCADA data sets assisted in detecting the location of the pipe burst by giving the amount of flow rate increase.

Monitoring the water input to the reservoirs beside the water level, prevented the overflow from reservoirs and helped in detecting leakages. For example, the data sets supplied by the SCADA station at Çaglayan water distribution reservoir (15,000 m^3 storage capacity) showed that there is a water leakage of 100 m^3/hour, originated from a serious crack in the inlet pipe of the reservoir, as shown in > Figure 8.4.

In a similar way, SCADA station showed that the pumped water flow rate from Bogaçay station was less than expected. In this time, the reason was a rubber ring that was sucked from the water network as shown in

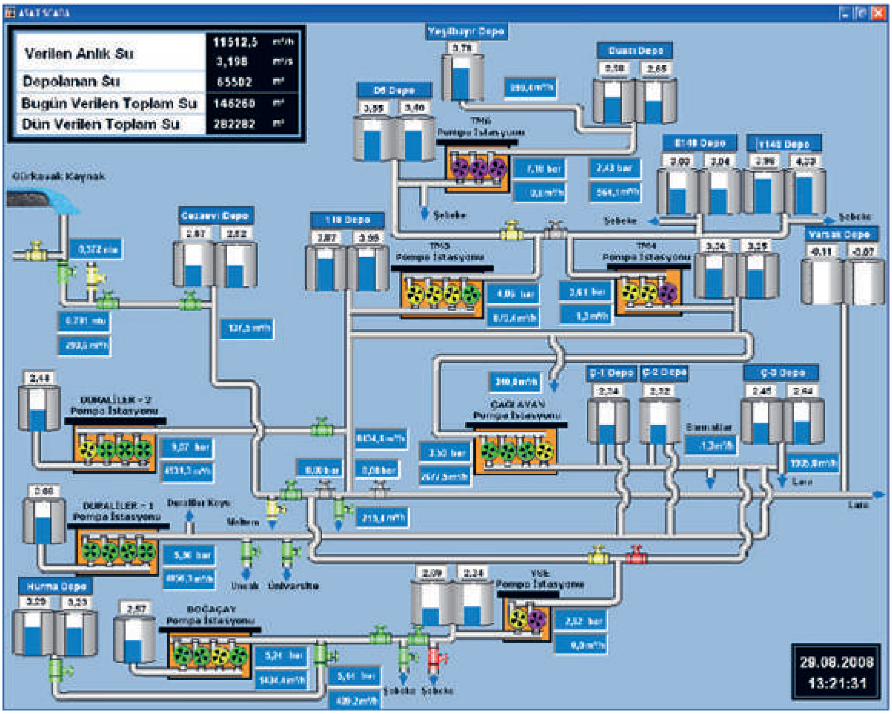


Figure 8.2: 36 SCADA screen shot showing pumping stations (PM) and Distribution Reservoirs (DR)

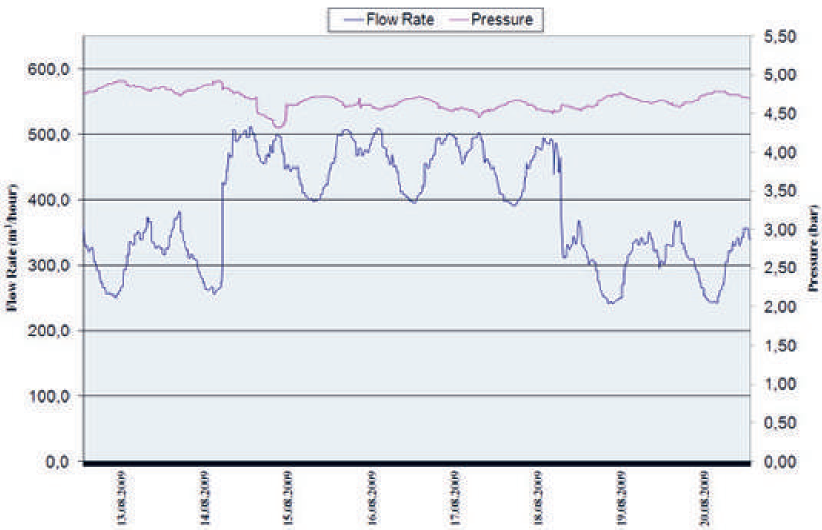


Figure 8.3: SCADA screen shot, which shows the profiles of pressure (upper curve) and flow rate (lower curve) after a breakdown in one of the water distribution pipes

Figure 8.4: Crack in the inlet pipe to *Çaglayan* water distribution reservoir

> **Figure 8.5**. Solving this problem led to increase the flow rate from 1,180 m^3/hour to 1,480 m^3/hour without increasing energy consumption.

The water quality of the Antalya drinking water is also controlled and managed by the SCADA system. According to the Turkish-related standards, free residual chlorine should be within certain limits usually taken as 0.1 to 0.5 mg/l as residual free chlorine (TS266, 2005). Real time measurements of residual free chlorine are accomplished at many points along the water distribution network. Warning alarms are given by the SCADA system if any of the measured levels exceed predetermined limits.

"Gürkavak" is an important water spring that supplies Antalya with around 440 m^3/hour of drinking water. The capacity of this spring water increases considerably after rainful events because of the karstic feature of Antalya groundwater. Additionally, heavy rains increase the turbidity levels of this water resource to limits that exceed the allowable ones for drinking purposes. At that time, SCADA system plays its role by automatically closing certain valves which stop the supply of water from this water resource to Antalya city. At the same time, SCADA system gives warning alarms to inform the water operators at ASAT about the situation.

8.4 CONCLUSIONS

The SCADA system of water distribution network is very useful. In Antalya, the drinking water distribution system is monitored, controlled and managed by the system. This has led to an increase in the reliability of the system, in addition to reducing the water losses and improving the water services to the customs in a cost-effective manner. Using the capabilities of the SCADA system, the followings was achieved in Antalya (ASAT, 2009):

- Average water production from the different sources was reduced from 260,000 m^3/day to 230,000 m^3/day (reduction of 11.54%)
- Total water losses were reduced from 169,000 m^3/day to 120,750 m^3/day (reduction of 28.55%)
- Total water losses were reduced from 65% to 42.50%


Figure 8.5: Rubber ring, reducing the capacity of *Bogaçay* pumping station

- Daily energy consumption was reduced from 208,000 kW to 138,000 kW (reduction of 33.65%)
- Energy consumption for water production, pumping and distribution was reduced from 0.8 kW/m^3 to 0.6 kW/m^3 (reduction of 25%)
- Energy consumed for lost water is reduced from 135,200 kW/day to 72,450 kW/day (reduction of 46.41%)

ACKNOWLEDGEMENTS

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43 B.

Chapter III –

Economics and Finance

MAIN CHAPTER MESSAGES

1 The value of water is higher than the costs of water services, unless water management and use are not carried out efficiently.

2 Although water is a human right, it is necessary and helpful to calculate the value of water to provide a rational basis to decide between competing forms of water usage, consumer groups, management strategies and investments.

3 Economic analyses of cost and benefits in water loss reduction must include direct as well as indirect effects, and evaluation methods and parameters must fit the country-specific conditions.

4 Donor grants and subsidised soft loans are necessary for initial development, but in the long term, the principles of charity must be replaced by bankable investments and operations to achieve a self-sustaining level of water efficiency.

5 Investments in technologies and facilities will not pay out unless accompanied by measures securing efficient operations and maintenance, with successful capacity development as a pre-condition.

9 Water Loss Reduction – Economic Gains

Karl-Ulrich Rudolph, Günter Klein
Bonn, Germany
[mail@uni-wh-utm.de]

9.1 THE VALUE OF WATER AND WATER UTILIZATION

Economists tend to value the utilization of water, rather than the water resource itself. For decades, they have been criticised for this attitude by ecologists, who usually attach greater value to water resources, flora, fauna and habitats. Taking a holistic long-term view, there is not much difference between these approaches and controversial opinions. In a long-term view, any advantage from the use of water is based on the availability of water resources, in quantity and quality. On the other hand, the word “utilization” is not limited to water consumption by industry or human beings, which may be quantified in monetary terms. Of course, the necessity to have and use “ecological waters” (e.g. a minimum outflow from a river dam to prevent the river bodies downstream from becoming parched during the dry season) is necessary and can be (even though sometimes very difficult) quantified in comparable terms, not always in euros or dollars.

Basically, within human societies and settlements, water is used by households, by industry, for agriculture (mainly irrigation), for power plants (as a specific branch of industry, often considered in a separate chapter), for shipment, and as a transport medium for liquid and even for the disposal of solid waste (in most cases illegally).

9.2 CAN AND SHOULD WE CALCULATE A VALUE FOR WATER?

The calculation of a value of water by economists does not always make sense, even if the best appropriate method and reasonable data are used. In an emergency, or in the case of severe water shortage, it does not matter what efforts are required to get water: you have to have it. An economist would say, “the willingness to pay is equal to the ability to pay”. In this context, if you have no money, you will pay in the sense that you will make all possible efforts, even start a war, to get water from your neighbours. Therefore, for good reason, in many countries, the basic

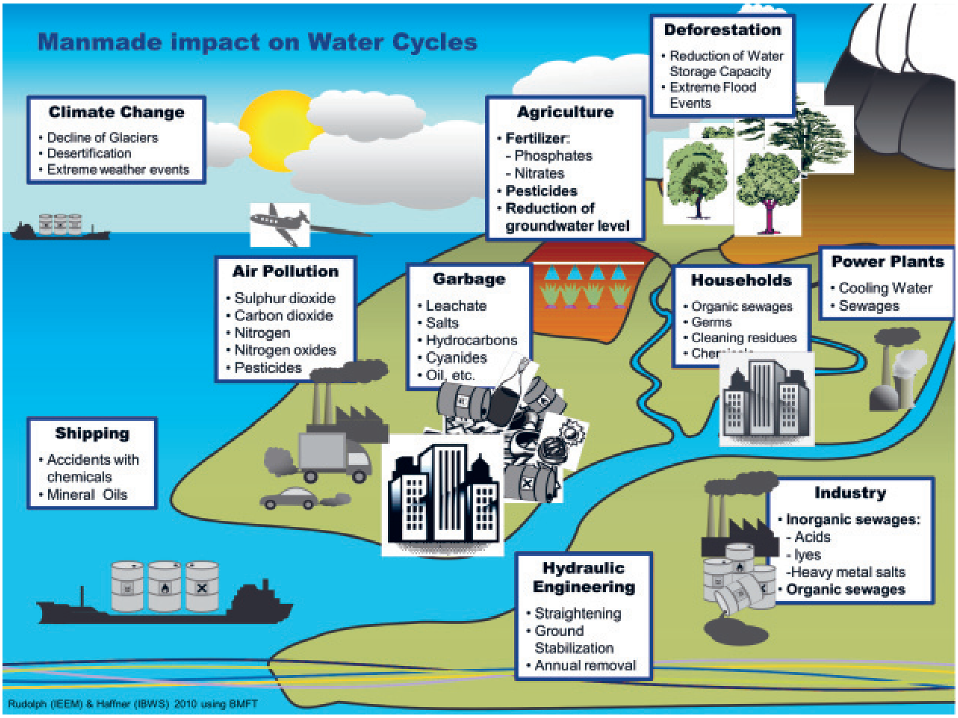


Figure 9.1: Use and man-made impact on water cycle (adapted from BMFT, 1989)

water supply is not a matter of sophisticated economic consideration but rather a matter of engineering, how to deliver water – no matter what effort or costs are required. For example, in South Africa there is free basic water by law. In Germany, people with low income are subsidised to get basic goods, including (among others of lower priority) water and sanitation.

However, once this basic supply is served, there is the need to balance between different options, to decide who should get water, and for what purpose. In this context, the term “who” is definitely not limited to human consumers, but would include flora, fauna, and habitats – the so-called “ecological waters”.

To decide between alternative options, nobody can escape the need to evaluate, quantify, and measure the costs of water and the benefits of water utilisation. An honest discussion about that can only question the method, parameters or figures, or the sensitivity of results. Whether or not economic efforts are necessary cannot be questioned. Economic, financial considerations are NOT misplaced in the water sector, by the principle of sustainability.

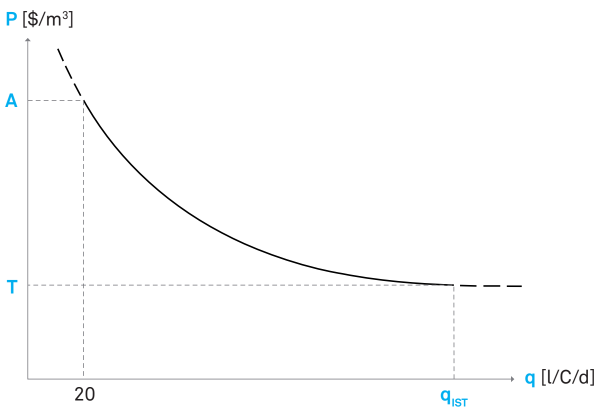
9.3 THE GENERAL APPROACH TO CALCULATING WATER VALUES

For this chapter, and in the context of water loss reduction, the different values of water of different qualities will be neglected (although it is clear that leaking networks may have a severe effect on water quality and cause serious extra costs, e.g. whenever a disease is caused by the inflow of faecal coli forms into water pipes, as happens every day somewhere in fast growing regions, like developing and transforming countries).

A focus on the value of water, measured in quantity (assuming appropriate water quality, see above), depends on the specific use. For household consumption, a small part of the public supply might be used for drinking and nutrition. This is the most valuable portion. Other valuable uses are sanitation and cleaning, whereas irrigation, car washing or wellness applications and swimming pools certainly have a lower value per cubic meter. For excessive consumption and water waste, the value of water will fall even further.

Therefore, the understanding that the value for very little water available (low specific consumption) is extremely high, whereas the value for the last cubic meters of water consumption at a very high specific figure is extremely low.

This understanding and philosophy is visualised and calculated in > Figure 9.2.



$$P = A \times \left(\frac{20}{q}\right) \text{Exp} \left(\frac{\ln(A/T)}{\ln(q_{IST}/20)}\right)$$

Valid between 30 l/C/d ≤ q_{IST} ≥ 280 l/C/d: $P = A - \sqrt{\frac{q' \times \triangle^2}{q'_{IST}}}$

P	=	shadow price [$/m³]
q	=	specific consumption $q' = q - 20$ [l/C/d]
q_{IST}	=	current specific consumption $q_{IST} = q_{IST} - 20$ [l/C/d]
A	=	alternative water procurement cost at 20 l/C/d [$/m³]
T	=	representative tariff price [$/m³]
$\triangle$	=	A – T [$/m³]

Figure 9.2: General formula for the valuation of supply water

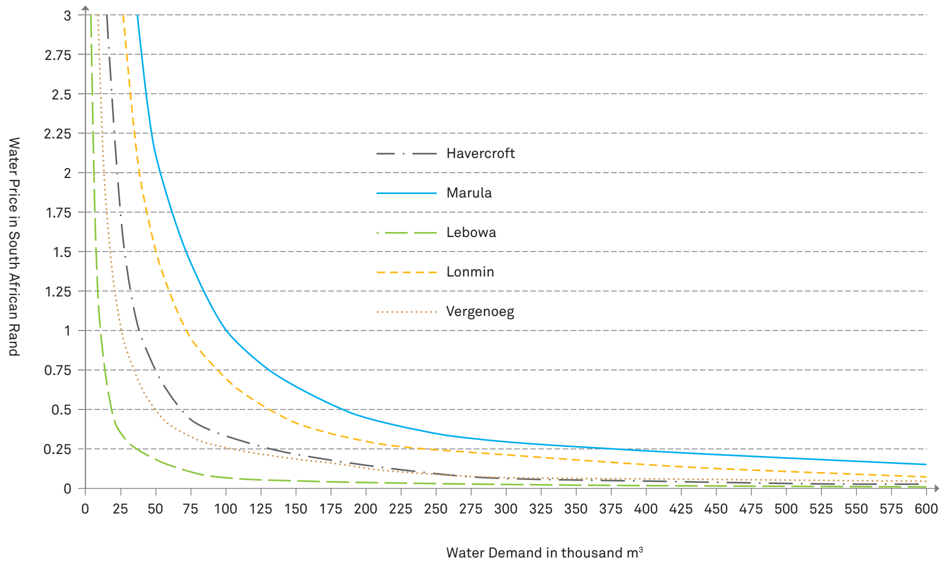


Figure 9.3: Industrial water demand curves for mining in the middle Olifants, RSA (BMBF/IEEM/ZEF 2009)

The formula is based on (at least one) representative point, for which a certain value (e.g. in euros or dollars per m³) can be fixed at a certain specific consumption rate (in litres per capita and day, or similar). The value is a so-called “shadow price”, to be estimated like an “as-if”-market price, marking the equilibrium between average customer consumption and payment in the service area under discussion.

Note: To meet legal, social and environmental standards, the formula must only be applied within certain restrictions. For instance, it would not make sense to weigh the profit of water from a river dam that was driving a hydropower station, against the water discharged from the dam into a receiving river to maintain the minimum flow. In this case, the so called “ecological water” is excluded from any consideration, and its benefit would be equal to the minimum costs (“opportunity costs”) of providing it.

Similar functions as those shown in > Figure 9.2 can be elaborated for other than domestic water consumption, e.g. for different branches of industry, etc. The more costly water is, the more the consumer (if charged for water consumption properly!) will start to save water, even installing recycling systems, etc.

9.4 THE COST HIERARCHY OF WATER PRODUCTION

For water uses with low value (such as excessive irrigation of grassland) it would probably not be economically reasonable to consume water produced at high cost, such as desalinated seawater. Water-demanding agriculture, industry, and settlements should (preferably) be located wherever cheaper water resources are available.

The higher the costs of water production are, the more water conservation measures are adopted. Moreover, water loss reduction improves, and sophisticated water recycling technologies become more profitable.

In some regions, the water production depends on easy and less costly technologies than in others. WLR-measures may make less sense – and vice versa. This is explained with the graph below.

Taking the effort and status of WLR in many countries world-wide, one could say that the real value of water and water utility is not appropriately reflected in day-to-day water operations, and that there seems to be much room for profitable WLR measures in many places.

9.5 COSTS AND BENEFITS OF WATER LOSS REDUCTION

9.5.1 The objective of cost-benefit analyses in water loss reduction

A cost-benefit analysis (CBA) for water loss reduction can help to answer the following questions:

- Do we need to (or: to what extent should we) carry out WLR measures? Is it really "cheaper" to produce more water instead of

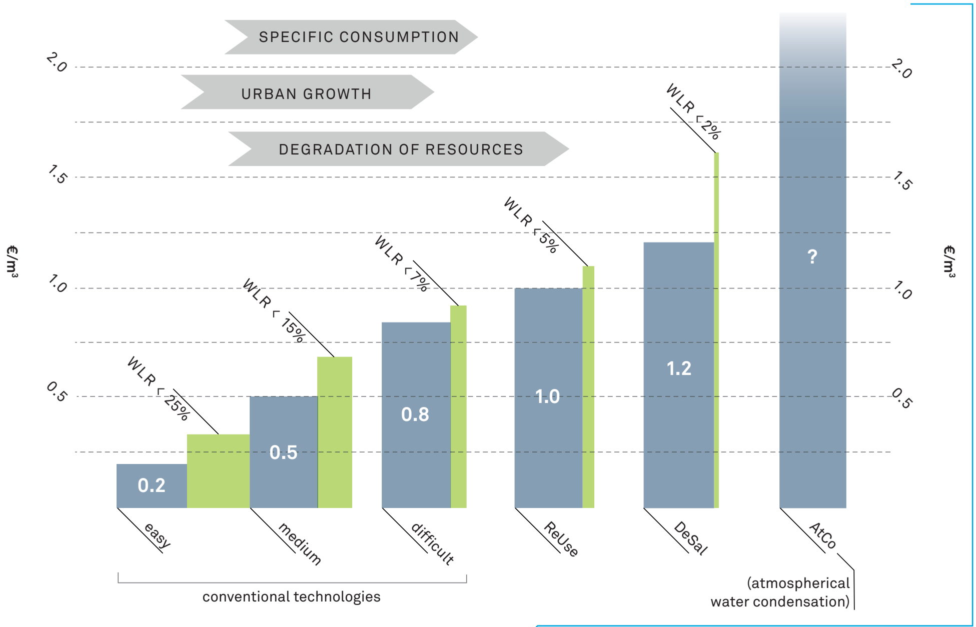


Figure 9.4: The cost hierarchy of water production

starting the continuous and long-term business of water loss control? What would be an appropriate, economical, ecological, and/or social balance between different water users and different forms of water utilisation (e.g. water for agriculture versus water for mining industry; or water restrictions to prevent excessive water consumption, for example for pools, green park irrigation, periods of water shortage, etc.)

- Who will benefit and who will bear the disadvantages from WLR programmes (e.g. disturbance of urban traffic through construction works)?
- How can we prevent the disadvantages of WLR; what additional costs do we have to expect (e.g. for trenchless technologies of pipe renewal)?
- What is the optimum rate of a Non-Revenue Water (NRW) under what conditions, taking into account the costs and the benefits of a given WLR activity, compared to the case of zero-activity in WLR or compared to excellent NRW?
- What is the best technical alternative to WLR, once we have decided to do it (e.g. low-cost repairs with short lifetime expectation versus durable re-investment for renewal of components, parts of pipe systems, networks)?
- What is the best alternate option, in whatever context, for the long-term (e.g. the construction of a new river dam with significant additional increase of raw water resources, or the stringent prevention of leakage and water theft within an urban utility)? Are there real alternatives?
- What is the appropriate organizational, managerial approach (single projects, bundled projects, programmes, holistic strategy)?
- How can financing and successful performance be realised? – Innovative and sustainable investment.
- And many other questions.

9.5.2 A standard approach of cost-benefit analyses

The CBA method of “first choice” is usually a comparison of WLR costs with WLR benefits, measured as reduced costs for water production, according to reduced leakages. > **Figure 9.5** visualizes the results of a CBA for a city that could avoid water desalination if the water losses were reduced below 30%. At this level, the cheaper water from a river dam in the mountains would be sufficient to meet the demand.

Another CBA approach is to compare the specific supply costs for different levels of water loss reduction, which usually goes along with equal levels of technical failure. > **Figure 9.4** shows a calculation of specific supply costs in two different networks, (a) the current situation for a large Asian city, and (b) a calculation for the technical stages equal to

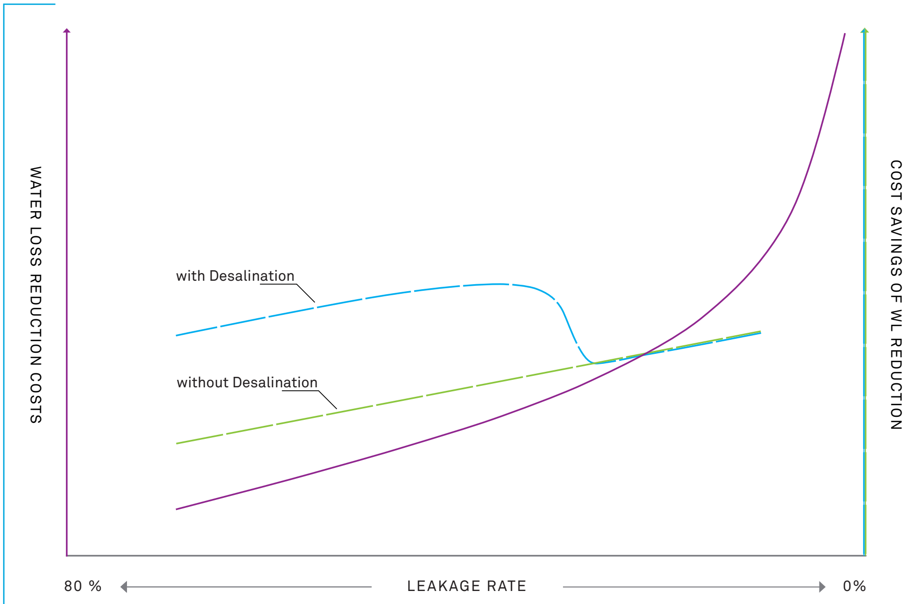


Figure 9.5: CBA (Cost-benefit analysis) for WLR-P (Rudolph 2009)

a)	Theoretical CAPEX	=	1€/m³	≙	1 €/1 000 l
	Leakage rate 45%	≙	450 l lost		
	Technical failure 30%	≙	300 l lost / 750 l lost		
	Real CAPEX	≙	1 € per 250 l **4 €/m³**		

b)	Theoretical CAPEX	=	1.15 €/m³	≙	1.15 €/1 000 l
	Leakage rate 8%	≙	80 l lost		
	Technical failure 6%	≙	60 l lost / 140 l lost		
	Real CAPEX	≙	1.15 € per 860 l **1.33 €/m³**		

Figure 9.6: WL and cheap technologies cause surplus costs (UNW-DPW 2009)

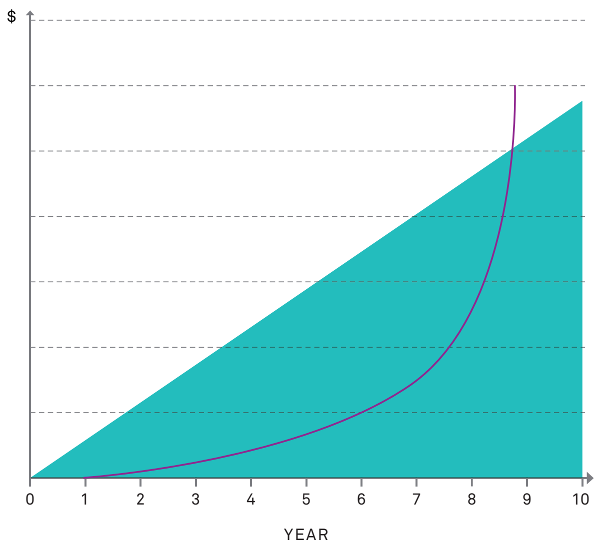
costs of high quality equipment and maintenance, as often achieved by water companies and water utilities in Germany (like Gelsenwasser, Huber, Remondis, Siemens, GWFA), Europe and other countries.

It can well be understood that leakage and technical failure increases the specific cost per water unit delivered enormously. Although higher costs for equipment might lead to a 15% higher overall CAPEX (note: civil constructions unchanged), the resulting costs per cubic meter are much lower (€/m³ 1.33 for high quality water compared to €/m³ 4 for poor quality).

Furthermore, a CBA should not be limited to public expenditures. Whenever water supply services are not reliable in continuity and pressure, the private customers bear significant surplus expenses, e.g. for booster pumps, roof storage tanks, etc. These surplus expenses (in one case: $/m³ 0.50 water sold) are often much higher than those which the (usually public) utility would have incurred for appropriate water loss reduction programmes, structural maintenance and network rehabilitation.

9.5.3 Specific requirements for cost-benefit analyses in dry and developing countries

For developing and transforming countries, especially ones that are dry and have scarce water resources, the definition of major cost components should reflect the specific situation onsite. This applies to labour costs (maybe near to zero for low-skilled labour in national economies with high unemployment), to electric power (in various countries, power is still subsidized and does not reflect the real values, which should be considered



Normal Curve for regular rehabilitation and structural maintenance according to technical lifetime of pipe network

ACD Curve for ERO strategy (no structural maintenance or preventive rehabilitations) in the first years, less expenses and little damage cost; i.e. cost advantage compared to normal curve. On the long run (by latest after ten years of operation) much higher

Figure 9.7: Damages through technical losses (Rudolph 2004, updated)

in a CBA), to imports and foreign currency exchange rates (local products may be advantageous under certain national/economic conditions), to natural resources (such as land used for plants to substitute for water loss reduction) and to the calculation focus (any CBA should clearly indicate what is considered to be OPEX and CAPEX, especially regarding the difference between operational and structural maintenance, and whether the focus is on micro-economic or macro-economic issues).

Revising about two dozen cost-benefit analyses (most of them donor-funded) in the frame of research projects funded by the World Bank, the EU and the German Federal Ministry of Education and Research, IEEM (the Institute of Environmental Engineering and Management, headed by the author) found that 17 were not appropriate in terms of economics and methodology and/or regarding the input data. This may have led to unfair decisions regarding:

- Wastewater pond systems versus activated sludge technology
- Decentralised versus centralised systems
- Water loss reduction versus desalination plants

9.5.4 Surplus damages through technical losses

> Figure 9.7 shows that the costs of failures from leaking or even collapsing pipe networks exceed the savings in expenses for structural maintenance and rehabilitation. In addition, emergency repair after failures have happened will generate significant surplus costs, especially for accidents, through destabilization of foundations, road collapse, wetting of buildings, electric appliances, damage to trees and green lands, flooding, hygienic risks or even diseases, odour nuisance, clean-up costs of flooded areas and emergency surplus costs, etc.

9.5.5 Surplus damage through administrative losses

The administrative losses, e.g. through water theft or non-payment of supplied water, according to the valid tariffs, are in no way limited to the loss of revenues on behalf of the water utility. The surplus effects are much more severe, such as:

- *Excessive consumption*
  Those who do not have to pay will not save water, and this will finally lead to water shortages, usually hitting the poor and suburban population.
- *Illegal water trafficking*
  In many cases, it was found that illegal water trafficking was likely to happen in those supply areas where administrative losses were not dealt with. If the water utility does not demand proper payment from the water customers, somebody else will step in – leading to the emergence of organizations often described as “local water mafia”.

- *Unwillingness to pay/to charge*
  Wherever there is little revenue, the incentive on behalf of decision makers and managers to decide on appropriate water tariffs and search for appropriate billing and collection is reduced.
- Finally, administrative water losses above a certain level will lead to financial destabilisation of the water utilities and prevent the development of sustainable water services.

This may result in a situation which can be called "the vicious circle in water and sanitation" > Figure 9.8.

In many developing and transforming countries, water tariffs do not match costs. The utilities have to work with insufficient budgets. However, with an insufficient budget, investments and operations are below the needs, which lead to poor water services, poor customer satisfaction and negative public opinion. As a result, the political support ("willingness to charge") to decide on cost-covering water tariffs cannot be expected. This vicious circle could be broken if all water produced reached the paying customer.

In other words, a proper water loss reduction programme is an essential pre-condition for attaining sustainable water services.

9.5.6 Cost-benefit analyses under budget restrictions

Why is water efficiency, and especially water loss reduction, neglected so widely, even though this means significant economic advantages are lost? In many cases, decision makers and managers from public water utilities complain about budget restraints, which "just do not allow capital or maintenance expenditures at a sufficient level". When trying to explore the background and the reasons why such budget restraints have been imposed, one might often find the mechanism of the "Vicious Circle" described in > Figure 9.8.

The lack of awareness among politicians and their voters, as well as the lack of water management capacities, knowledge and experience are the reasons for such budget limitations, which lead to surplus costs instead of savings. Cost-benefit calculations for WLR may well improve this, and convince treasurers, lenders and donors to sharpen their focus of financial priorities and decisions about WLR programmes.

At any rate, wherever budget restrictions exist, any pragmatic CBA to deliver results ready to use under today's working conditions must:

- Either exclude all measures generating expenditures above the budget limits (whether these are for WLR installations or WLR maintenance) and detect the most suitable option within the budget limits, even though this option may well be beyond the economic optimum;
- or include the so-called PSP option, which can be the delegation of investment in profitable WSP installations or contracting out WSP management (operations and maintenance), which can be realised out of public budgets and management.

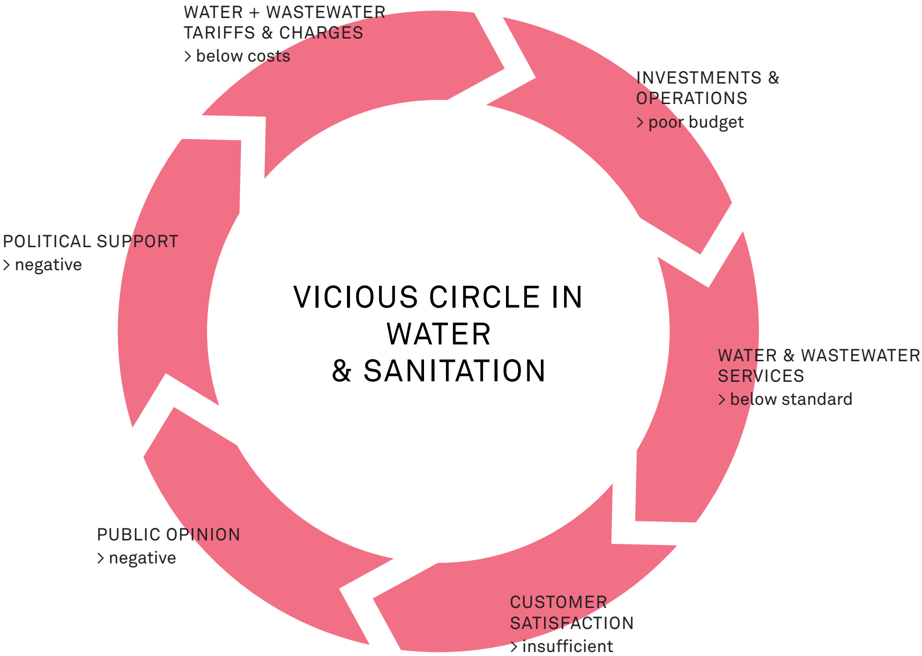


Figure 9.8: The vicious circle in water and sanitation (Rudolph 2007, modified)

9.6 FROM CHARITY TO INVESTMENT

9.6.1 Investing in competence for health and wealth through integrated capacity development on water and sanitation

Comprehensive understanding of the water system is an essential element in building health competence and combating poverty on the basis of safe water for all.

The recently passed UN resolution following the long debate on a 'human right to water' has now been launched with the comprehensive title "The human right to water and sanitation" (UN-GA 2010). This notion will be essential for understanding how to make effective investment in the water supply infrastructure. While there is still an ongoing debate about the moral aspects of ownership and trading of water, since it is essential for human life (esp. water for human consumption), there is no doubt that sanitation services are products and activities that have a price and deserve to be paid for.

This highlights some very clear facts:

1. WWDR 3003 summarized the widely accepted knowledge that efficiently operated water supply services at community level are by far

the most cost effective, and for customers by far the cheapest way of getting access to safe drinking water.

2. All communities or member states, which provide a reliable and safe water supply to all their citizens (all, without exception for commercial or other reasons), do this at almost negligible cost to the consumer. For example, the average financial burden for a reliable supply of safe water, 24 hours a day, 365 days a year, in Germany amounts to less than 1% of the average income.
3. The efficient water supply in several cities across Europe is the result of long-term and stable investment in building and maintenance of the water supply infrastructure, coupled with training of professional staff. This investment in hardware and software, including the protection of water resources and treatment, is all included in the above mentioned percentage. Therefore, the efficiency in water loss control we have seen in several case studies is not some kind of luxury “golden standard” but the result of efficient investment and appropriate allocation of financial resources to obtain a fair and low price.
4. It has been demonstrated in several of the case studies at the UNW-DPC workshops, and in those described in this book, that appropriate investment will lead to almost immediate returns. Within less than a decade, rotten networks and neglected infrastructure have been reconstructed, repaired and modernized. This has resulted in reduction of water loss figures from some 50–70% down to figures closer to 10%. Examples from the European countries in transition following the breakdown of the “Iron Curtain” are very convincing in this respect.

These “success stories” combine the commitment of the state or community with private companies, and in most cases private investment. Facing pressure to adapt to new legislation, or being confronted with reasonable data about efficient financing, managers and policy makers have been convinced to go for the approach that is both water-efficient and cost-efficient.

9.6.2 Private investment for sustainable development

This work to improve the public infrastructure needs to be done during a period when the “drain of resources” from public budgets is putting states and community financing under threat. This has opened wide perspectives for investors, who increasingly want their investment to be directed towards products of high respect, and that fulfil moral requirements. The number of investment funds of this type has increased since the mid 90s.

Most of these funds opened up, or even started with a dedicated water fund. They invest specifically in a wide range of companies, most of them listed on the stock exchange, who provide:

- Construction and management of water supply (water works, networks, sewage treatment)
- Filtration and pumping equipment
- Technical equipment for water and sanitation installations (such as water meters, toilet flushing devices, etc.)
- Desalination technologies using solar energy
- Solar energy equipment, e.g. for pumping or disinfection of water
- Electronic equipment for monitoring and controlling

Another group of investment providers initiates and supports the flow of investment capital into micro-finance programs. Small scale investment in decentralized infrastructure is increasingly supported by these tools.

Progress in combining public and private financing powers is driven through the co-operative policy of various multi-lateral donor banks, establishing financing programmes and funds, where private co-finance or equity finance is the pre-condition for receiving donors' loans. The ideas are:

- that the donors' credits can generate higher investment volumes if counter-financed through external sources ("leverage effect");
- that private lenders will be eager to secure their loans, and make sure that the investments lead to successful water service improvements, and (consequently) the payback of the loans, whereas donor banks may be entangled in political structures ("motivation effect regarding financial risk control").

Another option is to feed financing funds with donor sources, but to delegate fund administration and arrangement of counter-finance to private banks, like the GCPF (the Global Climate Partnership Fund, established by EBRD, IFC, KfW and administered by Deutsche Bank AG) or the EEEF (the European Energy Efficiency Fund, established by EIB, also administered by Deutsche Bank AG). Both funds are eligible for water efficiency investments, provided these are also accompanied by a gain in energy efficiency.

9.6.3 Global markets – local markets – long-term investment perspective

However, there is a market with some three billion new customers waiting urgently for provision of safe water and sanitation services. The UN resolution on the human right to water and sanitation services will provide an entry point for new legal commitments. This will never be delivered by charitable institutions, but only via a wide range of investment strategies. The market development has shown stable, but not exorbitantly high returns. The financial crisis of the last two years has of course had some impact, but on a much smaller scale than with other fields of investment. Almost stable returns of between 6 and 8% were demonstrated by one of the oldest water funds throughout the last decade – almost unaffected by the "financial crisis".

Long-term and stable investment in water infrastructure has been, and will be the basis for any stable and human society. Less than 1% of the investment in safe water can secure the other 99% of social and economic deliverables. Where this investment fails, all the other activities are at risk.

This investment will have to be comprehensive in the light of population and labour market development. The increasing number of young people in upcoming generations must not be subject to ongoing job-killing strategies of global business, nor can societies afford to ignore their potential for improving the livelihood of all. Recent studies show a trend in education and political support for professional areas, which governments want, but which they do not need. Engineers and plumbers, as well as good bookkeeping staff, cannot be replaced by the armies of IT-specialists that some countries are encouraging in an effort to be competitive in the exploding IT-market.

Export-oriented production and capacity development is of course essential for global collaboration. However, the non-delivery of sanitation services to half of the world's population shows the need and the enormous potential for investing in developing professional skills, which will allow these services to be delivered to some 8–10 billion people by the middle of this century.

From the point of investors or project developers, the essential precondition for any activity is that they can expect a repayment of the money, know-how and work injected to enhance water efficiency.

In donor-dominated markets (DDM), the decision makers and public utility managers may be used to receiving grants or soft loans. This will make them reluctant to pay interest and re-pay debt at commercial market conditions. In those cases, the shift from charity (= donor grants) to self-sustaining investment (= private loans) needs transparency in costs, tariffs and benefits. If (for instance) a water loss reduction programme is tendered through a service contract (preferably a performance-driven service contract, wherein the investing and operating company would receive a bonus for good performance and a deduction for bad performance), it might be necessary that the contractor's fee be paid or supported through donor aid.

In customer-driven markets (CDM), the water tariffs would be cost-covering and high enough. The customers and decision makers are aware that water loss reduction programmes are profitable. Service contracts, BOT-tenders or others can be launched in a "self-financing" way. At any rate, it might still be necessary for the public sector to cover certain political and country risks (namely in economies in transition, where water tariffs in megacities for industrial customers are already high enough to re-pay for enhancing water efficiency – but where the political stability or other country risks do not allow for private lenders to enter).

For this book, there is not much room to address the specifics of water finance, which are well-described in the literature provided for interested readers (see below).

Whether private sector participation (PSP) is considered when financing investments, as a stand-alone-activity or in combination with rehabilitation and operational services, combining management powers and technological innovations from the private sector with the capacities of the responsible public utilities is essential – all parties involved are recommended to use guidelines and toolkits for these specific issues (http://rru.worldbank.org/TOOLKITS/INFRASTRUCTURECONCESSIONS/ and http://rru.worldbank.org/TOOLKITS/WATERSANITATION/), and consider long-term experiences and lessons learned from different countries (Rudolph 2001).

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10 Cost Efficient Leakage Management in Water Supply Systems

Max Hammerer
Klagenfurt, Austria
[max@hammerer.cc]

10.1 INTRODUCTION

Companies for public water supply must manage two basic tasks:

> Fulfilment of the public mandate (customer satisfaction, availability, corporate image, and reducing and keeping the pipeline network losses low and having low risks from external influences)

> Efficient business management (cost of supply, corporate success and a long-term cost and rate structure)

The extent to which the company succeeds in striking a balance between these two tasks and successfully manages them is determined by the quality of the management and the long-term value of the supply systems.

The condition of the pipeline system is determined by the level of annual pipeline network losses and the amount of damage or alternatively repairs. For the definition of the amount of damage, it is important for leak testing to be performed continuously so that these figures refer to existing and not to (coincidentally) discovered damage.

10.2 RECORDING THE CONDITION OF THE PIPELINE SYSTEMS

Pipeline systems consist of pipelines (feed lines, main lines, supply lines and connecting lines), internal parts (valves, etc.) and fittings. Within the scope of modern company management, the pipeline system is managed in a Geographic Information System (GIS). For the individual objects, there are defined procedures for inspecting or alternatively defining the condition and the functional performance.

10.2.1 Goal-orientated maintenance

Within the scope of goal-orientated maintenance, the operating condition of drinking water pipeline networks must be monitored regularly, and their internal parts must be monitored in addition due to special circumstances to make sure that they can be found, that they have no leaks and that they work.

Inspections of the system components must be documented in suitable lists and statistics, containing the day, systems used and the respective results. The results of the inspections must be managed in damage statistics. Furthermore, a variety of information regarding events, maintenance work, costs and assessments of the inspected items must be documented.

10.2.2 Inspection of leaks in the lines (pipelines)

The type, extent and time intervals of line inspections is mainly determined by the level of water loss according to the creation of the annual balance, according to deviation between the registered feed quantity and comparative values, according to the frequency of damage, and according to the local conditions (subsoil, pipeline material, supply pressure, and so on).

The foundation for preparing the annual loss balance requires the maintenance and analysis of all feed and delivery quantities by means of suitable measuring equipment. So-called “internal consumption” and other water deliveries that are not billed must be recorded exactly and documented.

DVGW has developed key figures that provide an approximate value for the level of pipeline losses. However, it has been established that key values for the level of water losses can only be related to local conditions, which are affected by many factors.

Each company must form its own key values and derive conclusions from them for technical and economical measures.

10.3 WATER LOSSES IN DRINKING WATER PIPELINE NETWORKS

The water losses are reduced for hygienic, supply-related, ecological, and economical reasons. Low water losses are an important indicator of good pipeline network condition and lead to availability and reduced costs for maintenance. The most accurate and comprehensive measurement possible for the water volumes fed into the pipeline network and discharged from it is an important element of determining water loss. Here, the model, the installation, and the size of the water meters must be selected according to the technical standard.

10.3.1 Early detection of pipeline network losses

Early detection of water losses involves the use of permanently installed water meters that delimit the entire supply zone or sub-zone (pressure or supply zones), as well as the feed lines. These quantity values must be documented carefully and can provide a clear indication of the development and existence of water losses based on their levels. On one hand, this could be weekly quantities, daily quantities, or night time minimum values, which must be processed based on the consumption structure. Here, it is practically impossible to derive any general key values. The consumption trend can also be read from the long-term comparison of inflow quantities.

10.3.2 Factors influencing the level of water losses

The level of water losses is influenced by many factors, which in part can't be influenced. Here, we are mainly referring to the installed pipeline system and its installation quality, which was selected and installed many years ago according to the standard at that time (pipeline materials, installed parts, connection systems, installation technology, etc.).

Therefore, it is particularly important to find out those factors that permit an economically and technically feasible procedure to effectively reduce the pipeline network losses. Extensive knowledge of the supply system on the whole is necessary for this decision, as well as specific knowledge of the pipeline system and all internal parts and their condition. The Geographic Information System (GIS) as graphical and alphanumerical pipeline documentation, the results of a GIS-conforming damages file, and the results of a GIS-conforming pipeline network analysis are instrumental for this.

Naturally, the results of the damages analysis must be input from a systematic and regular pipeline network inspection so that influences on the pipeline components and weaknesses are not shown based on dominant events and situations.

A differentiation of the influence factors on the level of pipeline network losses is required so that the local problems can be dealt with selectively and the desired success of lowering the pipeline network losses can be achieved. The individual influencing factors must be identified and evaluated from the existing, long-term analysis of the operating data.

Besides selective influences affecting the level of pipeline network losses, the causes of the damages must be dealt with, which are also influenced by local conditions. Here as well, one must take into consideration that we are dealing with existing situations, which we can no longer influence afterwards for 30, 50 and more years.

Therefore, identify and act!

10.3.3 Procedure to record and reduce water losses

Looking for leaks (method of determining and localising leakage points) is broken down into 2 procedural steps:

- Prelocation (procedure of narrowing down likely leakage points to the smallest possible area or network section with inflow measurement or acoustic system)
- Localisation (acoustic procedure to localise the leakage points down to the point as a basis for excavation and repair)

The reasons for initiating a search for leaks could be:

- Routing or regular inspection of the pipeline system at the recommendation of rule groups or operational guidelines
- Other causes

10.4 DAMAGE STATISTICS

Damage statistics are entered in the PC program for all repairs made to the water supply system. The repairs are entered on a pre-made damage form with clearly defined names and terms so that all criteria are available to be analysed.

It appears that to assess the condition of the supply system and to make other statements for future measures, damage data is necessary over an extended period of time so that damage trends can be recognised and evaluated.

The establishment of damage statistics is an indispensable requirement of operators of pipeline systems for the documentation and assessment of the condition of the system.

The following data are necessary for defining and analysing the failures:

- Place of the failure
- Defect on
- Type of defect
- Date of repair

The content of the damages file covers all the built-in components of the supply system.

The analyses and evaluations require experience and knowledge of the assessment of weak points because, besides generating the statistics, these results are used to assess future investments and strategies to reduce water losses. Data from more than 10 years is necessary for a careful assessment of the pipeline condition. Identical to the damage data, the pipeline inventory data should be managed synchronously to determine annual key values for changes to the damage dynamics. A modern GIS maintains an archive for the system inventory and the damage data. That way, the damage dynamics can be assigned to the respective current pipeline inventory of the past.

10.4.1 Analysis of the damage data

It is important to know where the weak points in the network are located:

- In what system components

- In what streets or zones
- Type of damage and cause of damage
- Reason for repair (leak localisation or self evident)
- When did the damage occur or alternatively when was it repaired
- Additional information about the pipeline, bedding and measures

With this information, it is possible to conduct the necessary analysis to assess the condition of the system.

Note: The failures in a supply system are not uniformly distributed in their position!

10.4.2 Key values for damage rates in supply networks

For orientation purposes, DVGW reports guide values for damage rates. They are reported in worksheets and in the annual statistics as operating key values. The data in the following table are average values within one year.

Each supply company should maintain equivalent statistics and use them to establish a trend of a time period of at least five years to assess the condition of the pipeline system.

Every company must establish its own key values, taking into consideration the local conditions, and develop a strategy for operation management based on them.

10.4.3 Connection between loss trends and damage trends

The loss trends and the damage trends aren't necessarily connected. The results of many analyses of pipeline networks have shown that a reduction of the amount of damage is essentially dependent on a renewal of the pipeline components.

On the other hand, a reduction of the pipeline network losses is essentially dependent on a reduction of the elapsed time for the individual damage.

Therefore, identify losses as quickly as possible and then localise and repair them immediately.

This refers to the substance and the availability, because an old pipeline network with very dynamic damage can't be kept functional in the long term through repairs. Therefore, systematic renewals are absolutely necessary.

10.5 MAINTAINING THE SUBSTANCE OF PIPELINE SYSTEMS

The pipeline systems and facilities are constantly ageing and therefore are also more susceptible to damage and water losses. The availability becomes less certain and the costs for inspections and maintenance increase. As with all system components in our lives, which are in permanent use and subject to a great variety of loads, there is always wear and tear. Here, we are talking about the service life of the lines and facilities. This is the service life after which the pipelines and system components have to be renewed in order to ensure the reliability and efficiency of the supply.

The substance of the pipe system is influenced by the level of water losses and the numbers of the failures on the pipelines. Both factors are to reduce in practise.

- Reduce of water losses by monitoring, leak detection and repairs
- Reduce of the numbers of failures by replacement of pipelines on basis of the failure statistic and rehabilitation strategy

10.6 ROAD MAP FOR REDUCING WATER LOSSES

Long-term monitoring

- Inflow quantity into the supply sector and determination of key parameters
- Documentation of the failure repairs in a failure statistic

Organization of leak detection works

- Implementation of the right methods and instruments
- Staff training
- Determination of performance indicators of the inflow and repair concentration

Implementation of a future orientated inspection and rehabilitation strategy

- Cost- and benefit calculation for deciding on repairing and rehabilitation
- Selection of the right pipe materials for local situations
- Training programme and guidelines for qualified construction work

10.7 EFFICIENT WATER LOSS REDUCTION

The necessity of reducing and keeping the pipeline network losses low is justified as follows:

- Ecological aspects
- Legal liability aspects
- Supply-related aspects
- Preservation of systems and substance aspects
- Image-orientated aspects of the water supplier
- Financial aspects

The efficiency and effectiveness of water loss reduction requires that the pipeline systems be systematically or permanently monitored, inspections be carried out regularly, that there be an immediate response to possible water leaks, and that a repair be made immediately after the site of the leak is determined.

All measures and results must be systematically documented so that comparative analyses are possible over longer time periods (development of the damage dynamics and loss dynamics with the dedicated costs).

The operating goal of these organizational measures is to keep the duration of the water discharge from the leak site short.

The work involved in finding leak sites is dependent on the following factors:

- Amount of damage
- Existing waste volumes
- Operating pressure (sound energy)
- Pipeline materials (sound propagation)
- Number of contact points (acoustic leak position location)
- Structure of the supply network (size of the grid regions to be monitored)
- Objective of a requested possible water loss volume in the pipeline network

The efficiency of a reduction of the pipeline network losses is explained based on a monogram and result examples.

10.8 CONCLUSIONS

Inventory control and recording the condition of supply systems is indispensable. The guidelines for the scope of the inspections and the inspection cycles are recorded in the relevant guidelines of the trade associations.

Each company must establish its own key values so that local conditions are taken into consideration. Based on these key values, each operator of supply systems must develop its own strategy for maintaining the supply and, above all, for maintaining the substance of the asset value so that operation is guaranteed in the long term, both technically and economically. With the described procedure, ways have been shown with which optimum operations management can be achieved for an efficient reduction of the pipeline losses in harmony with the philosophy of the company, the local influences, the current condition of the systems and the economic possibilities.

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11 Application of a Financial Model for Determining Optimal Management of Non-Revenue Water in Developing Countries

Alan S. Wyatt, Kyle J. Romeo
North Carolina, USA
[asw@rti.org]

ABSTRACT

Non-Revenue Water (NRW) includes 1) physical losses (pipe bursts and leaks) and 2) commercial losses (illegal connections, un-metered public use, meter error and data recording errors). NRW levels are high in many developing countries, and can be expensive to reduce. Various authors (Lambert, Farley, McKenzie, Trow and others in the International Water Association (IWA)) developed a framework – the Economic Level of Leakage (ELL) – which outlines the optimum level of physical losses based on the costs of water production, physical loss control costs, and other engineering inputs. However, the ELL approach is less useful in developing countries, as it ignores 1) commercial losses, 2) the annualized cost of water supply capacity expansion, and 3) situations where production capacity does not meet demand. Also, the computerized ELL requires data which are not readily available in many countries. A new model, which addresses these issues, would allow individual, regional or national utility managers and regulators to establish NRW targets and to optimally allocate resources to NRW management.

This paper presents a financial model, which addresses the limitations noted above and provides acceptably accurate values of optimal steady-state NRW. The model uses an NRW framework, consistent with the IWA water balance, and solves the algebraic optimality conditions for commercial and physical losses. The spreadsheet form of the model computes optimal NRW from a modest, commonly known set of inputs. The paper examines the sensitivity of the model to the accuracy of input data. Next, the paper presents both generic results for optimal NRW and specific results for ten countries in Asia, Africa and Latin America. Input data come mostly from secondary sources. Key results and their implications are reviewed. The paper closes with conclusions and recommendations for further research and model application.

11.1 BACKGROUND

NRW is a very large issue in developing countries. The World Bank estimates that developing countries lose about $5.8 billion USD per year. Whether measured as a percentage of production, per length of distribution line, by connection, or using the infrastructure leakage index (ILI), the losses are generally high, compared to many other parts of the world. But reducing leakage and commercial losses costs money, especially if large sections of piping need replacement. Nevertheless, studies have shown that efforts on conservation and NRW reduction cost about one third of water production from new plants. The fact that NRW reduction costs increase as losses are reduced more and more is of critical importance. Depending on site conditions, any location has an "optimal" point where cost and benefits are equal.

Many policymakers tackling this problem have adopted very simplistic targets for multiple utilities, such as "cut the losses (% of production) in half", or "< 20 % = Good, 20–25% = Acceptable, and > 25% = Unaccept-

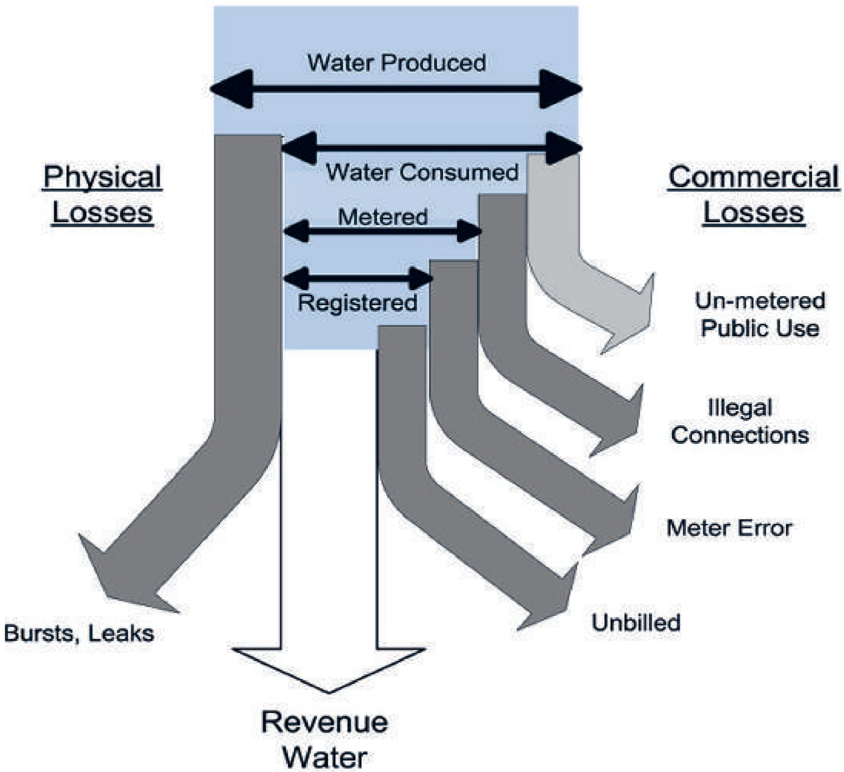


Figure 11.1

able". These targets do not use the correct indicator, nor are they based on local costs and conditions. Most importantly, the best target depends on the location, taking into account the influence of local costs, benefits, engineering parameters, etc.

A number of authors, including Lambert, Farley, McKenzie, Trow and others, have developed a conceptual framework known as the Economic Level of Leakage (ELL), which outlines the economically optimum level of physical losses based on pressure/burst relationships, marginal cost of water production, the cost of physical loss control programs, engineering parameters and other inputs.

However, the ELL approach is somewhat inappropriate for many developing countries, for a variety of reasons. First of all, ELL ignores the financial optimality of commercial losses, which can be a very large part of NRW in developing countries. Second, the ELL model does not account for the annualized cost of future water production capacity expansions (which is affected by loss reduction policies). This consideration is commonly used in other economic analyses. Third, the ELL approach does not address situations where water production capacity does not meet water demand. These considerations are of high importance in developing countries. In addition, detailed computation of the full ELL model requires data which are not readily available in many developing countries. A new model, which addresses these issues, would be a step forward. A revised model would allow managers of municipal, regional or national utilities to assess their performance in relation to optimum and to allocate resources optimally.

11.2 CONCEPTUAL FRAMEWORK

Terms and Definitions. The model depends on a clear set of terms and definitions, which are outlined in the water flow diagram in > Figure 11.1. This layout is fully consistent with the IWA water balance.

Another critical point, which > Figure 11.1 illustrates, is that representing the losses in terms of percentage of production can be misleading. Imagine a situation where the volume of the losses (shaded in gray) are constant over time. If consumption rises, production will also rise. Therefore, the ratio of losses to production will decrease, even though the actual amount of losses has not changed. IWA has abandoned the indicator of NRW as a percentage of production in favour of representing NRW in terms of litres/connection per hour (or per day).

Key Concepts. First, the model must show the distinction between transition situations and steady-state situations, as shown in > Figure 11.2. This model does not focus on the transition from a high level of losses to a lower level or how to achieve such a transition. Instead, it focuses on what the target for steady-state losses should be after transition. As illustrated in > Figure 11.3, a low, steady-state level of losses will require aggressive

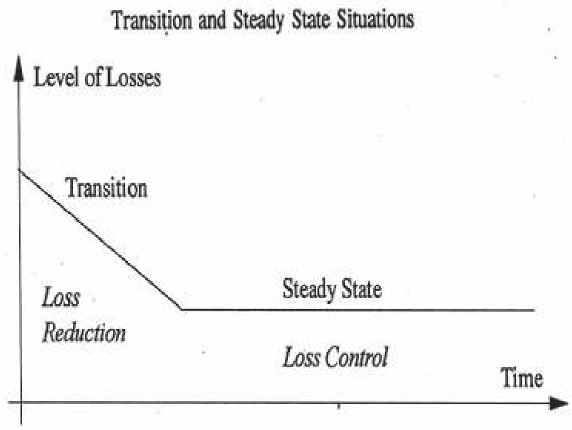


Figure 11.2

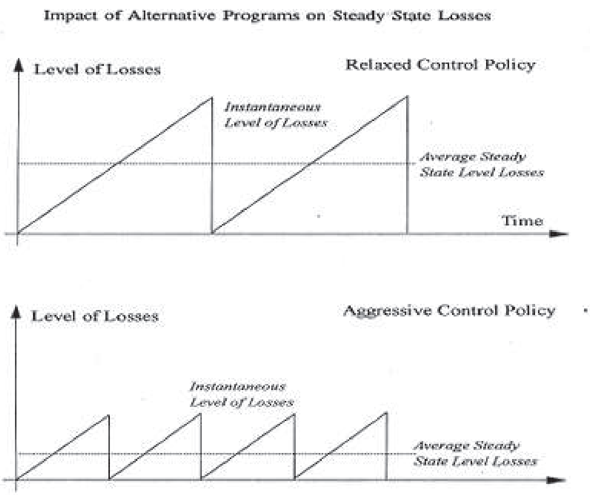


Figure 11.3

pressure management and a rapid Active Leak Control Program. A relaxed approach will yield a higher steady-state level of losses. An aggressive program will cost more than a relaxed one, so a trade-off is established between the cost of the losses and the cost of loss control.

Second, the model has to distinguish between situations where 1) water production capacity is ample (capacity surplus), or 2) where serviceable demand exceeds water supply production capacity (capacity deficit). In the first case, the benefit of reducing leakage will mainly be savings of

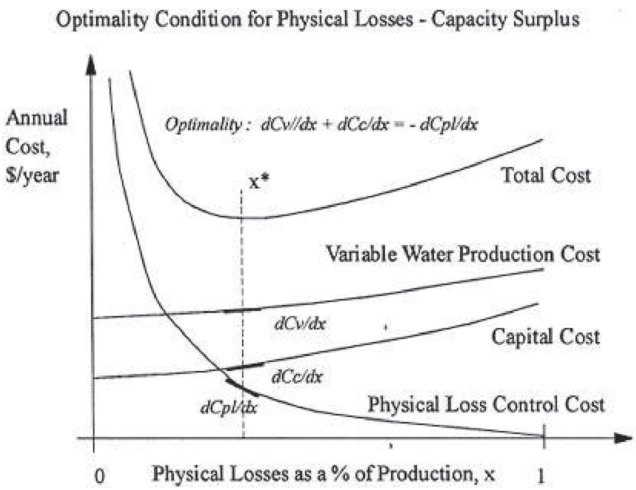


Figure 11.4

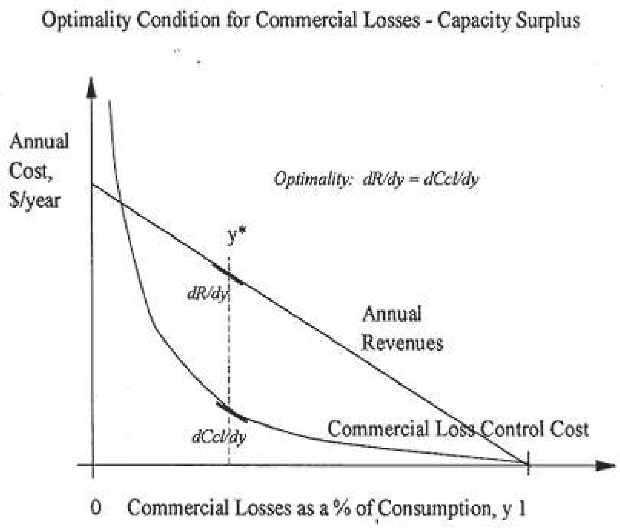


Figure 11.5

variable water production costs (electricity and chemicals). In the second case, the benefit will be the revenue that can be collected from the sale of the recovered water. In this second case, if the tariff or collection rate is low, as is common in developing countries, the benefits will be low.

Third, the model must take into account the diminishing return from an increasingly stringent loss-control policy. As shown in > **Figure 11.4**, the proportion of steady-state losses (x) increases, the cost of loss control falls, but other factors increase: the cost of water production and the cost of future capacity expansion (because expansion must happen sooner). Adding the costs will yield a total cost, which will have a minimum. Simple calculus shows that the optimum physical loss is reached when the marginal cost of physical loss control has the same magnitude as the sum of the marginal cost of water production and the marginal cost of future capital expansion.

The optimal commercial loss is reached when the marginal cost of commercial loss control is the same as the marginal revenue, as illustrated in > **Figure 11.5**.

Note: The diagrams shown here are only the optimality conditions, which apply to the Capacity Surplus conditions. This paper only deals with the Capacity Surplus scenario, but the model has been fully developed for Capacity Deficit conditions.

11.3 MODEL DEVELOPMENT

Next, algebraic expressions were developed for the costs and revenues associated with both commercial and physical losses. The brevity of this paper does not allow a full elaboration of all the formulae, but a detailed write-up is available from the authors. This paper will present a few of the highlights.

Note: Only those cost elements which are affected by the degree of "stringency" of the steady-state loss control program are considered. Thus the cost of excavating and repairing a leak is not included, because that cost will be incurred at one time or another whether the control policy is relaxed or stringent. It is possible that the excavation cost would grow over time, but this consideration has been ignored for now.

Commercial losses. Based on the optimality conditions in > **Figure 11.5**, we derived formulae for the cost of a commercial loss control program by extrapolating from the costs of a meter replacement program. The result was a formula of the following form:

Cc = M N s /2 y. where:
M = unit cost of a meter replacement program inflated to account for activities associated with other commercial losses
N = the number of connections
s = the slope of the meter accuracy line (accuracy decline/year)

This algebraic expression is consistent with the cost curve in > **Figure 11.5**. Next, we developed an expression for the revenues based on the collected tariff, number of connections, consumption per connection and the specific commercial losses (y). By taking the derivatives of each expression

Parameter	Default Value	Notes
Capital Cost of Water Production Facility	C = $3000 * Capacity^0.7	The exponent of 0.7 often reported
Capacity Utilization	67%	Often reported
Estimated Commercial Losses / Total Losses	40%	Sometimes reported
Active Leakage Control Costs	$200 / km of line	Needs local research
Commercial Loss Control Cost Parameter	$150 / connection	Needs local research
Burst Flow Rate	20 / (leaks / km / year)	More literature review needed

Table 11.1: Input Parameter Assumptions for Less Commonly Reported Parameters

Input Parameter	% change in Input	% change in NRW
1) Consumption	-20% to + 20%	+15.4% to -11.3%
2) Distribution Length	-20% to + 20%	-8.6% to + 7.5%
3) Average Tariff	-20% to + 20%	+5.8% to -4.3%
4) Production Capacity	-20% to + 20%	-5.4% to +3.8%
5) ALC Program Unit Cost	-20% to + 20%	-4.3% to +4.7%
6) Leak / Burst rates	-20% to + 20%	-4.3% to – 3.8%
7) Variable Operating Cost	-20% to + 20%	+2.7% to – 2.7%

Table 11.2: Model Sensitivity

with respect to (y) and equating them, we arrived at a simple formula for the optimal commercial losses:

NRWc = (M s q / K T) ^½. where:
q = consumption per connection, m^3/yr
K = a constant for conversion of units for algebraic consistency
T = collected tariff, \$/m^3

Note: This formula for optimal commercial loss does depend on the costs of the loss control program, the consumption, meter accuracy and tariff, but it does not depend on the number of connections, the population of the city, the length of distribution line, variable water production cost or any other factors. Also note that the formula includes a square root, so the optimal commercial loss is not highly sensitive to the inputs.

Physical losses. The derivation of optimal physical losses is much more complex than commercial losses, due to the multiple costs, illustrated in > Figure 11.4. However, the basic process is the same. We derived

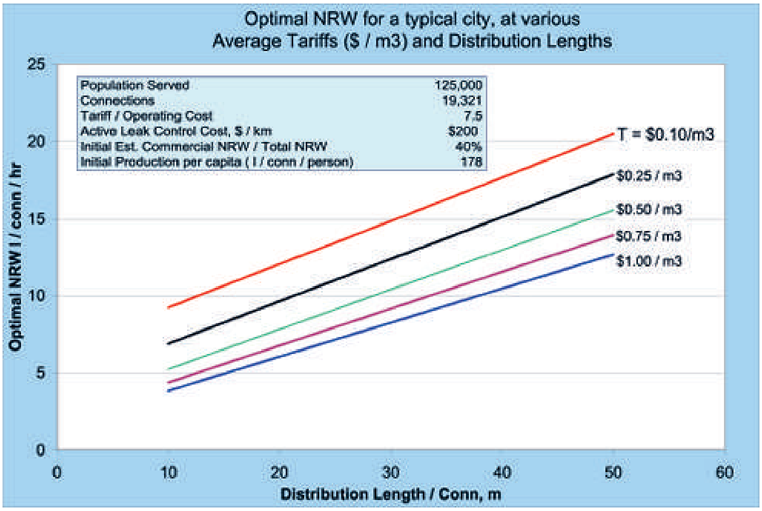


Figure 11.6

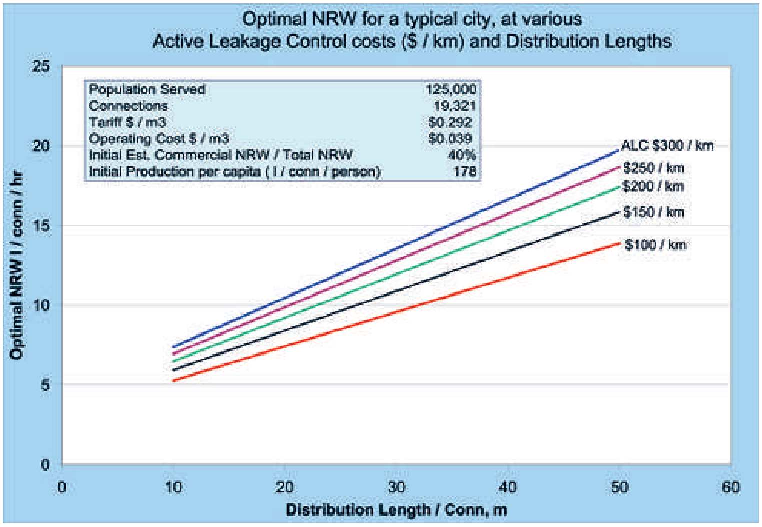


Figure 11.7: Shows the impact of a range of costs for Active Leakage Control

formulas for each cost element, found the derivatives with respect to x, and using numerical methods in a spreadsheet, solved for the optimum point. Key factors are the cost of the Active Leakage Control Program, the distribution line per connection, leak flow, and the variable cost of water production. The formula includes a square root, so the results are not very sensitive to inputs.

HIGH OPTIMAL LOSSES OCCUR WHEN:

1) Water consumption is *low*, and not rising quickly
2) Distribution length per connection is *high* (sparse population)
3) Average tariff is *low*
4) Active Leakage Control Program costs are *high*
5) Water production capacity is *ample*
6) Number of leaks or pipe breaks is *high*
7) Variable water production costs (electricity & chemicals) are *low*

The conditions above are mostly true in developing countries indicating that losses can be expected to be higher in LDCs.

Figure 11.8

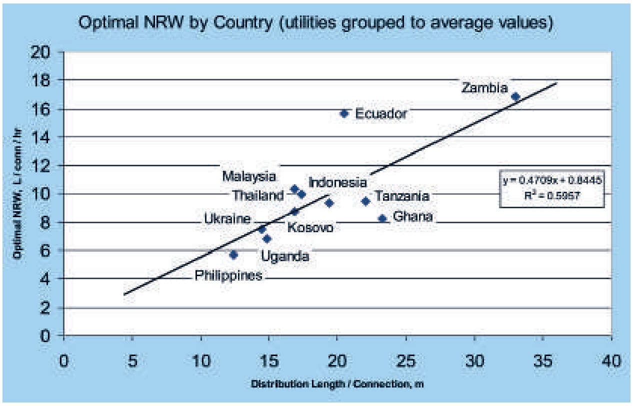


Figure 11.9: Shows similar results for commercial losses. (> also Annex 1)

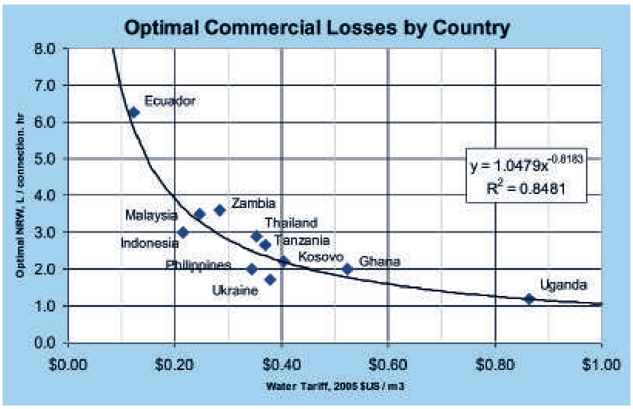


Figure 11.10: As with the total optimal NRW, the utility-level information is more informative than the aggregated country-level information. Note that the shape of the curve, both here and in the Annex, is consistent with the square root relationship in the formula for optimal commercial losses.

Parameter estimation. In applying the model, values for all the input parameters are needed. Some parameters are frequently reported, such as water production, number of connections, tariff, etc. However, some other parameters are not commonly found. In order to proceed on testing and evaluating the model, we derived default values for those parameters, based on reviewing dozens of documents from many countries. > Table 11.1 shows important variables and our current default values. These parameters should be the subject of more detailed research and estimation on a country-level basis if the model is going to be used regularly for planning purposes.

Sensitivity analysis. Next we performed a sensitivity analysis, with results shown in > Table 11.2. For a typical, hypothetical situation, we systematically varied input parameters and noted variations in results. > Table 11.2 shows that the model is not sensitive to any important variables. However, there could be more sensitivity if there were considerable uncertainty in multiple inputs.

11.4 MODEL APPLICATION

Generic results. The model can be used to generate expected results for a hypothetical, typical city in a lesser-developed country (LDC). Such calculations illustrate fundamental relationships coming from the model

Parameter	Minimum	Average	Std Dev	Maximum
Population Served (1000)	42	329	351	1,042
Connections (1000)	6	24	23	75
Production (1000 m^3/day)	7	87	103	311
Distribution (length/conn, m)	12.6	33.0	14.9	51.5
Average Tariff (\$/m^3)	0.164	0.295	0.142	0.578
Variable Production Cost (\$/m^3)	0.005	0.018	0.006	0.024
Reported Leaks / km / yr	1.3	3.8	1.3	5.2
Estim. Consumption (m^3/conn/day)	1.0	1.8	0.8	3.0
Actual NRW (L/conn/day)	380	1430	860	3100
Optimal NRW (L/conn/day)	225	400	130	645

Table 11.3

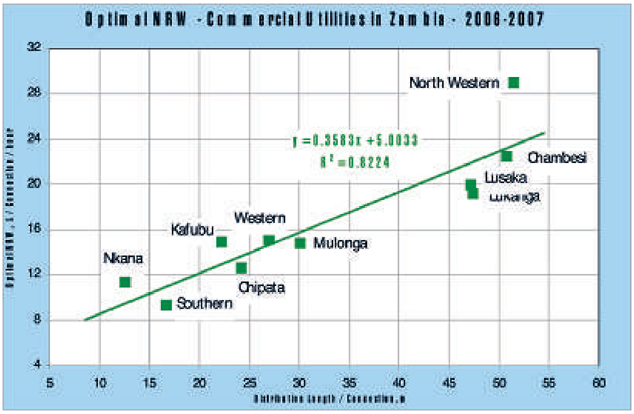


Figure 11.11

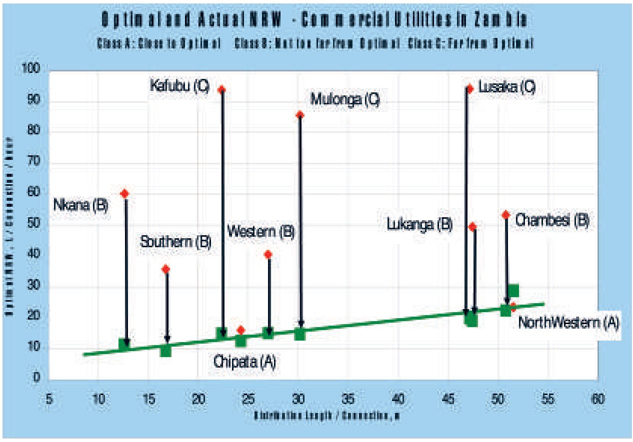


Figure 11.12

Lukanga (B)	61%	Lusaka (C)	94.2	19.9	Lusaka (C)	$5.04m	Lusaka (C)	3.4
Kafubu (C)	58%	Kafubu (C)	93.9	14.9	Kafubu (C)	$2.96m	Kafubu (C)	4.5
Mulonga (C)	56%	Mulonga (C)	85.6	14.8	Nkana (C)	$2.09m	Southern (B)	4.5
Chambesi (B)	54%	Nkana (C)	60.2	11.3	Mulonga (C)	$0.75m	Mulonga (C)	4.8
Lusaka (C)	51%	Chambesi (B)	53.2	22.4	Southern (B)	$0.69m	Nkana (C)	8.5
Western (B)	47%	Lukanga (B)	49.4	19.1	Lukanga (B)	$0.14m	Lukanga (B)	11
Southern (B)	43%	Western (B)	40.6	15.1	Western (B)	$0.08m	Western (B)	22
NorthWestern (A)	36%	Southern (B)	35.7	9.3	Chambesi (B)	$0.02m	Chambesi (B)	77
Nkana (C)	35%	NorthWestern (A)	23.5		NorthWestern (A)	$0	NorthWestern (A)	
Chipata (A)	31%	Chipata (A)	16.0	12.6	Chipata (A)	$0	Chipata (A)	

Table 11.4

optimality conditions. For example, > Figure 11.8 shows that as the distribution length per connection increases, the value of optimal NRW also increases linearly. In other words, as the population is less dense, the greater distance between connections requires more effort and cost for loss control, raising the optimal NRW. > Figure 11.6 also shows that lower tariffs will lead to higher optimal NRWs and vice versa. In other words, if the tariff is low, there is little reason to spend too much money to reduce losses.

Similar "monographs" can be produced for different sized cities, different levels of water consumption, etc. These charts can be handy to get a quick estimate of optimal NRW.

> Figure 11.8 presents some basic conclusions from generic use of the model. It explains the conditions that would lead to high optimal losses and, by implication, those that would lead to low optimal losses.

Model application in ten countries. We applied the model to 74 municipal, regional, and national utilities in Africa, Asia and Latin America, mostly using basic data from secondary sources. In several cases, we used correspondence with local officials to fill gaps in the data. In most cases, we used the default parameters noted above, due to a lack of such data. We recognized that these results would be preliminary but would 1) provide a "reality check" on the model; 2) give approximate results which could be useful; and 3) would indicate if the model could provide information useful to local planners or regulators. If the third outcome proves to be true, more investigation could be carried out to estimate the default parameters more precisely and to produce more precise overall results.

The results, detailed in > Annex 1, are summarized below, > Figure 11.9 shows the overall optimal NRW (in L/connection/hr) for the ten countries, based on the average inputs and results in each country. This graph shows the expected linear trend with optimal NRW rising as the distribution length per connection rises. Ecuador has higher optimal values due to low tariffs. However, grouping all utilities in a country is not the best way to analyze the results. > Annex 1 has a similar chart with all 74 utilities included. This full-page utility-level graph in the Annex is more accurate and useful.

One last note before turning to a detailed case study of Zambia. All the results reported so far have been optimal values of NRW; no actual values of existing NRW have been reviewed so far. The Zambia cases will explore this subject.

An extended analysis of Zambian commercial utilities > Figure 11.12. We applied the model to ten commercial utilities, each associated with a province in Zambia. These regional utilities typically serve one or two large towns and a modest number of smaller towns in the same province. Some are highly urbanized, such as Lusaka and utilities in the Copperbelt region, while others serve more dispersed populations. They are regulated by and report performance data to the National Water Supply and Sanitation Council (NWASCO), which does an excellent job of analyzing and disseminating information. Annual reports from 2000–2008, covering all the commercial utilities, can be found on their web site. Supplemental information was obtained from the World Bank's International Benchmarking Network Program, and from the dataset recently published by Water and Sanitation Program (WSP) and the Africa Water Operators Partnership (WOP).

> Table 11.3 and > Figures 11.11 & 11.12 present analyses of the data. The optimal NRW values follow the familiar linear pattern, with a good fit. Using the guidance in > Figure 11.8, we can explain North Western's high optimum NRW by low water consumption, infrequent pipe breaks, ample water production capacity and low variable water production costs.

We can now compare the actual NRW to the optimal to see how the utilities are actually doing. The results in > Table 11.4 show that there are two utilities operating close to the optimal NRW (Class A), five that are operating not too far from the optimal NRW (Class B), and three that are operating quite far from the optimal NRW (Class C). Clearly, the Class C utilities merit more careful examination and effort on NRW reduction.

> Table 11.4 examines the ten commercial utilities, using a variety of indicators. Considering NRW in terms of percentage of production, the utilities range from Lukanga at 61 % down to Chipata at 31 %. These are high values, even if this indicator is flawed. However, if we rank the utilities by actual NRW, the ranking changes drastically. Lusaka, a Class C utility, rises to the top, and Lukanga falls far down the list. Next, > Table 11.4 shows the potential net annual savings from a transition from actual to optimal NRW and the "payback period", assuming a cost of $200 per m^3/day reduction. In simple terms, it is the Class C utilities that have attractive payback periods for NRW reduction. Overall, we can see that the actual NRW in L/connection/hr and the "distance" to the optimal NRW are the key parameters in allocating resources to NRW reduction in Zambia (and elsewhere).

11.5 DISCUSSION

Before turning to areas of further research and model development, we cover a few key perspectives and observations about the information presented so far and about the model itself.

1. The optimal NRW depends on the tariff, operations and maintenance (O&M) costs, number of connections, and other factors that change over the years – so the optimal values will shift somewhat from year to year. Optimality calculations should be recalculated accordingly.
2. There is no way to scientifically prove that the model accurately predicts the optimal NRW. There is no other method or benchmark to compare to. We can only see if more elaborate models, with higher data requirements, lead to more plausible results.
3. The current model is a financial one. The O&M costs or tariffs do not necessarily reflect "economic" values of water, energy, labour,

commodities, or even political contexts. Adjustments may be needed in some cases, such as cases of severe water scarcity or drought. The model could be adjusted using “shadow” prices to define an economically optimal NRW rather than a financial one.

4. The model makes assumptions for default parameters where data is not available. This is a potential criticism of the current state of the model. However, if more research suggests a change in the default values, all is not lost. First, the model is relatively insensitive, and second, the basic concepts and relationships will not change. Lines may shift a little, but the key lessons of the model – that a site-specific optimal NRW can be derived (even if approximate) – will still be true.

11.6 AREAS FOR ADDITIONAL RESEARCH AND MODEL APPLICATION

Our team and developing country collaborators have identified several areas for continued application, research and improvement of the model. Those work areas include the following:

1. Application of the model in additional countries based on secondary data. More than 12 additional countries have already been identified with viable existing secondary data sets. It is likely that more countries, including those in the Arab world, would be able to provide secondary data and work with the model.
2. Refinement of the model based on additional literature review, especially the latest research on the effectiveness and costs of different control strategies.
3. Additional research on specific model parameters, especially the default parameters listed in > Figure 11.6. These studies will have to be detailed programs in specific countries where interest in using the model is high.
4. Development of protocols for country-level parameter estimation and development of a handbook for model use.
5. Development and implementation of training programs on model use, where relevant.

11.7 CONCLUSIONS

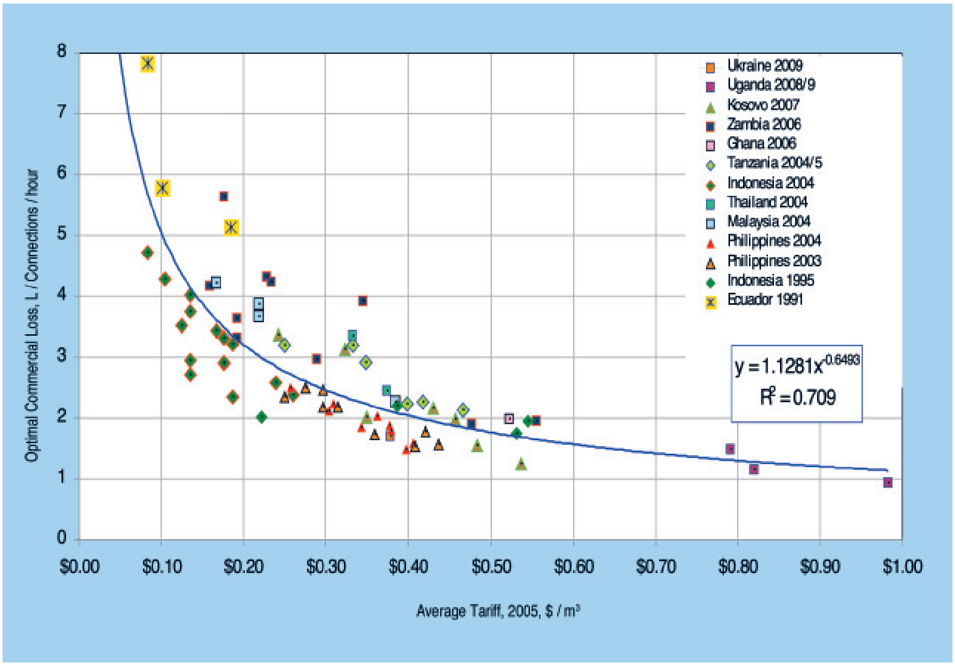
This paper indicates that a model can be developed which will allow utility managers or regulators to identify a good approximation of the financially optimal level of NRW in a given location. The field results to data show clear trend lines that are consistent with the model framework and theory.

An Analysis of a typical developing country case shows rather low model sensitivity to input parameters and also indicates that optimal NRW levels in developing countries will tend to be higher than in developed ones.

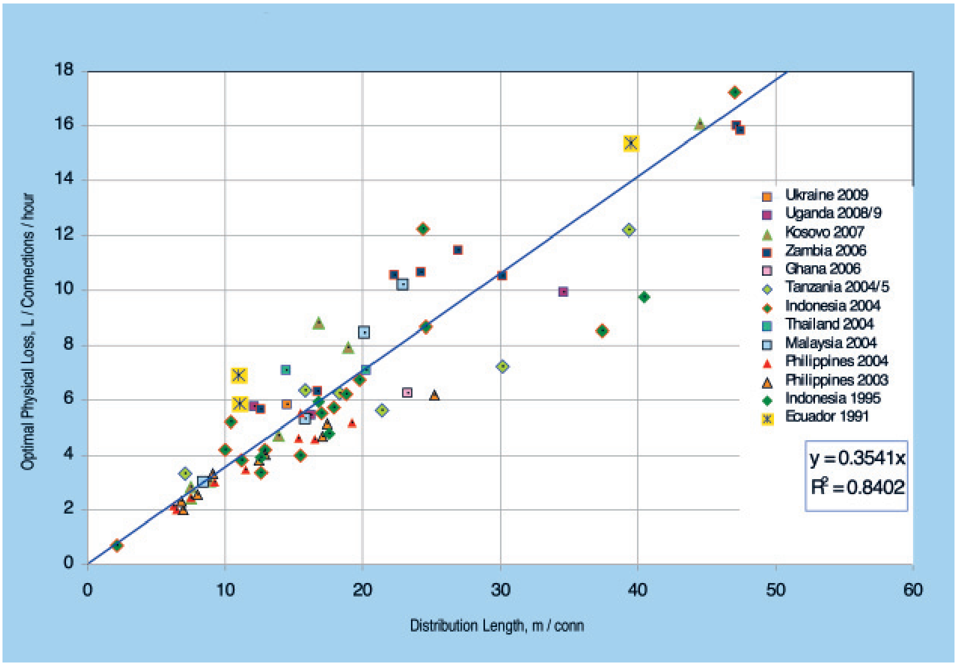
The Zambia case study illustrates how actual and optimal NRW values in L/connection/hr can allow managers or regulators to prioritize among different locations for investment in NRW reduction and steady-state maintenance.

Additional work on the model would be advantageous and is ongoing. Plans include the refinement of the model based on additional literature review, development of protocols for country-level parameter estimation, and application of the model to more countries.

Annex 1.1: Optimal NRW – Multiple Developing Countries



Annex 1.2: Optimal Commercial Loss –
Multiple Developing Countries



Annex 1.3: Optimal Physical Loss –
Multiple Developing Countries

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Chapter IV –

Capacity Development

MAIN CHAPTER MESSAGES

1 A series of UNW-DPC regional workshops on capacity development for improving water efficiency contributed to the identification of challenges and chances of capacity development in water loss reduction (WLR)

2 Social learning could be the new trend in WLR

3 The learning process should take place in networks or "communities of practice" that are influenced by the governance structure in which they are embedded

12 Capacity Development for Water Loss Reduction

Hani Sewilam
Bonn, Germany
[sewilam@unwater.unu.edu]

The problems with capacity to manage water and reduce its losses are different not only from region to region but also from one management level to the other. To address the capacity development challenges in different regions and at different levels, UNW-DPC organized in cooperation with UN-HABITAT and other partners a series of regional workshops on capacity development for improving water efficiency: "Water Loss Reduction in Water & Sanitation Utilities" in Latin America and the Caribbean (November 2009), the South East European region (November 2009) and the Arab region (January 2010). The total number of participants was 429, from over 60 different countries.

These workshops documented available know-how, good practices and recommended new approaches for more efficient management in the field of water and sanitation, with a focus on water loss reduction (WLR). The workshops also focused on the economic and political conditions for success in WLR in countries with economies in transition. This chapter aims to provide the reader with the most significant results of this series of workshops. In addition, the reader will be also introduced to some important trends in the field of capacity development (CD).

12.1 CHALLENGES OF CAPACITY DEVELOPMENT IN WATER LOSS REDUCTION

Inadequate capacity in dealing with Non-Revenue Water leads to huge water losses in most countries. The workshops of UNW-DPC enabled the identification of the challenges facing capacity development in different regions and countries. Some of these challenges are:

- In most countries where water loss reduction is an issue, water networks and utilities are in place. A certain level of know-how and certain capacities already exist. Therefore, UNW talks about "Capacity Development", instead of "Capacity Building" (which would normally start from near to zero).
- Assessing the needs as well as the impacts is very difficult due to

capacity constraints, particularly in the areas of training activities that don't have any direct tangible impacts. There are tools available, such as the World Bank Country Diagnostic, but they still need to be evaluated and made available in a simple way for implementation.

> Evaluating the impacts of capacity development costs a lot of money and time which may not be available. Therefore, it is important to find a balance between the best you can realistically do with the available resources.
> Capacity gaps should be identified within the sector at the global level and training programmes organized, which draw on appropriate participants from different countries. There is a need for sharing knowledge and introducing adaptive and learning mechanisms within the water sector and to change the idea of importing experts and trainers from outside.
> Deficits in the skills of individuals in many areas such as leak detection and repair, quality studies and analysis of water losses, meter management, and effective technical approaches to managing water losses.

12.2 NECESSARY CAPACITIES FOR WATER LOSS REDUCTION

In general, capacity building can address the shortcomings that are found with national and local governments, formal and informal service providers, NGOs, and communities, in helping them and their staff to deal with issues of governance, management and technology. Capacity is an attribute of individuals and organisations and other forms of institutions. Capacity is not something external to these institutions; it should be dealt with as internal. Thus, as an individual or institution seeks to improve its performance, CD is the change process internal to organizations and people. The OECD defines capacity as the "ability of people, organisations, and society as a whole to manage their affairs successfully". CD furnishes the frameworks, approaches and tools to carry out Institutional development; by its very nature CD is relevant only in the context of change, and it is part and parcel of change management (Alaerts et al. 1999, EuropeAid 2007).

As mentioned in Chapter II – Actions and Solutions, developing capacity is a cross cutting issue across water sector and can be carried out at different levels including:

> Analytical capacity is essential to carry out the first main step for governments and decision-makers to assess the performance of its sector, as well as of its components such as the water utilities, the hydrometeorology services, the training system, etc. This analysis may have a wide scope or more confined one, for example, with special emphasis on the water utilities.

- Technical capacity includes mainly technical skills and knowledge to ensure effective performance of water management such as data acquisition for estimating losses, ability to identify their locations and taking necessary measures. Necessary competences are skills of network operation, customer management, maintenance and repair, hydraulic modelling including GIS, quality control, leakage control.
- Managerial and administrative capacity is needed for every decision maker and institution, in order to play an efficient role in the water sector. The necessary skills can include vision creation, policy and strategy formulation, budgeting, monitoring and evaluation, management structures, processes and procedures, management of relationships between different organizations and sectors (public, private and community).
- Capacity to share knowledge among different stakeholders and organizations is a key issue to develop the capacities of both individuals and institutions. This can be achieved through enhancing the capacity to engage in multi-stakeholder dialogue, communication skills, introducing communication techniques, raising awareness about the value of sharing knowledge, and introducing knowledge management tools.

Research and Development (R&D) is the driving force for production of new knowledge such as leak detection optimization, efficient use of different equipment, more precise and more selective campaigns, etc. Diffusion of such new knowledge needs to be integrated in the process of developing the existing capacities. Therefore, building the R&D capacity should be also seriously considered to produce new knowledge.

12.3 CAPACITY NEEDS ASSESSMENT

UNDP (2007) has compiled experiences with capacity assessments and offers a framework for capacity assessment. Core issues to be assessed are institutional development, leadership, knowledge, and mutual accountability. Critical functional capacities include, e.g., capacity to engage in multi-stakeholder dialogue, situational analysis, vision creation, policy and strategy formulation, budgeting, and monitoring and evaluation. Institutional reform requires both time and the right conditions. In the industrialised countries it has taken a long time for the existing regulatory frameworks and institutions to emerge and take root. The assessment can cover a larger or smaller part of the sector (e.g., the management department, the maintenance department, etc.), or focus on a part of the overall institutional architecture and capacity (e.g., the training system, community management, or the legal framework). The SWOT (Strengths-Weaknesses-Opportunities-Threats) and similar analytical techniques can be very useful to conduct the assessment (Alearts 2009).

12.4 CAPACITY DEVELOPMENT THROUGH SOCIAL LEARNING

Participatory action and the involvement of all the stakeholders in the management of drinking water is the key towards water use efficiency. In order to involve more stakeholders in the process of water management to address the water loss and increase its use efficiency, new methods to structure participation must be introduced, capacities must be developed and knowledge must be shared. Therefore, social learning should be a mechanism integrated in the framework of water institutions at the core of adaptive management to provide an assessment and learning cycle (Pahl-Wostl et al. 2010).

In the literature, social learning has been described as an alternative to transmissive expert-based teaching, and is instead a form of community-based learning (Capra 2007) in which learning takes place in networks or "communities of practice" and is influenced by the governance structure in which they are embedded. Social learning requires institutional settings which have some stability and certainty but are not rigid or inflexible. Such conditions are developed through continued processes of social learning in which multi-level stakeholders are connected in networks which allow them to develop the capacity and trust necessary to collaborate in a variety of relationships both formal and informal (Pahl-Wostl, et.al. 2007).

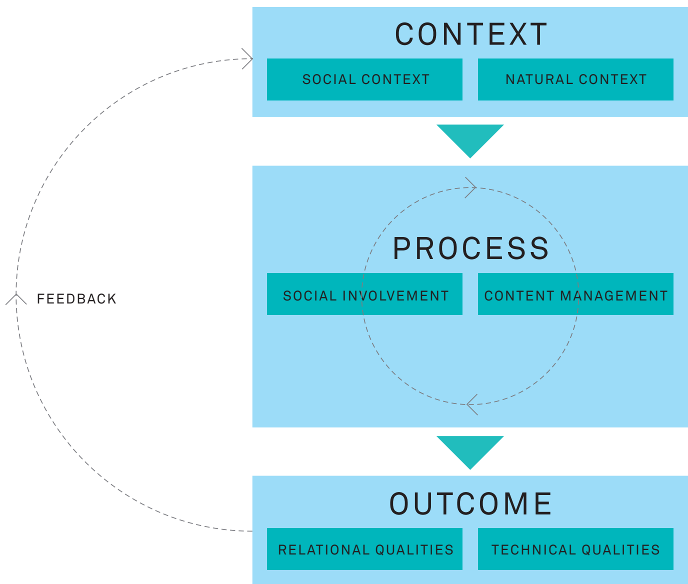

Figure 12.1: Outline of Social Learning Process (Pahl-Wostl et.al, 2008)

Successful social learning, that is, learning in and with social groups through interaction, leads to new knowledge, shared understanding, trust and, ultimately, collective action. Learning may take place at different levels from incremental improvements (single-loop) through to reframing where assumptions are revisited (double-loop) and transforming where underlying values and worldviews may be changed (triple-loop) (Pahl-Wostl 2007).

As shown in > **Figure 12.1**, the process of social learning is provided by multiparty collaboration embedded in a specific context and leading to specific outcomes. A feedback loop between outcomes and context takes into account structural changes in a cyclic and iterative fashion (Pahl-Wostl et al. 2008). As described in (Mostert et al. 2008), the social context includes the governance system, economy and culture, while the natural context includes the hydrological and geographical conditions. Together, they determine who the main stakeholders are and what they see as the main management issues. The stakeholders learn to solve management problems which are called management content.

Social involvement is the interaction between the stakeholders to reach the required management solutions. Stakeholders must reach a shared understanding of the problems at stake and the system to be managed, agree on a solution and ensure that the solution is implemented. The outcome of social learning is water management that better serves the interests of the different stakeholders (technical qualities). Moreover, stakeholders may feel more engaged, new skills may be acquired, new knowledge and insights may be obtained, trust may develop, relations may improve and institutions may change (relational qualities). This, in turn, changes the natural context and may improve management capacity (feedback).

12.5 E-LEARNING FOR DEVELOPING CAPACITY AND KNOWLEDGE TRANSFER

Time and cost limitations for organizing traditional training courses are significant factors that restrict the implementation of capacity development actions. The continuing rapid advance of ICT has made access to knowledge through eLearning easier and much more readily available and cheaper to the wider population around the world. eLearning is about "learning with fun", not to entertain people, like so many people do believe.

Courses and learning materials (either traditional instructor-led courses or pure eLearning courses) in WLR as well as all other fields should follow certain standards, for example the Selection-Organization-Integration theory (also called SOI theory). The fundamentals of the theoretical SOI model are (Sweller & Chandler 1991, and Paas et al. 2003):

- Human knowledge processing strictly separates between aural and visual inputs (two separate channels for information entrance)

- The processing capacity of those two input channels and the short-term memory is limited (the magic seven)
- Learning is always an active process; a coherent mental model (or reproduction) of the learning objects should be developed

Capacity development cannot be restricted to only eLearning, it is much more than only that. Therefore, it is always recommended to follow blended learning techniques, as a blend of traditional instructor-led courses plus additional pure self-directed eLearning courses > **Figure 12.2**. To make this happen, there is definitely a condition needed where the content designers fulfil the requirements of existing eLearning standards. These standards are still to evolve, but it would be a benefit for the eLearning community, if just only SCORM would be supplied by all content designers to exchange and blend eLearning modules between different learning management systems.

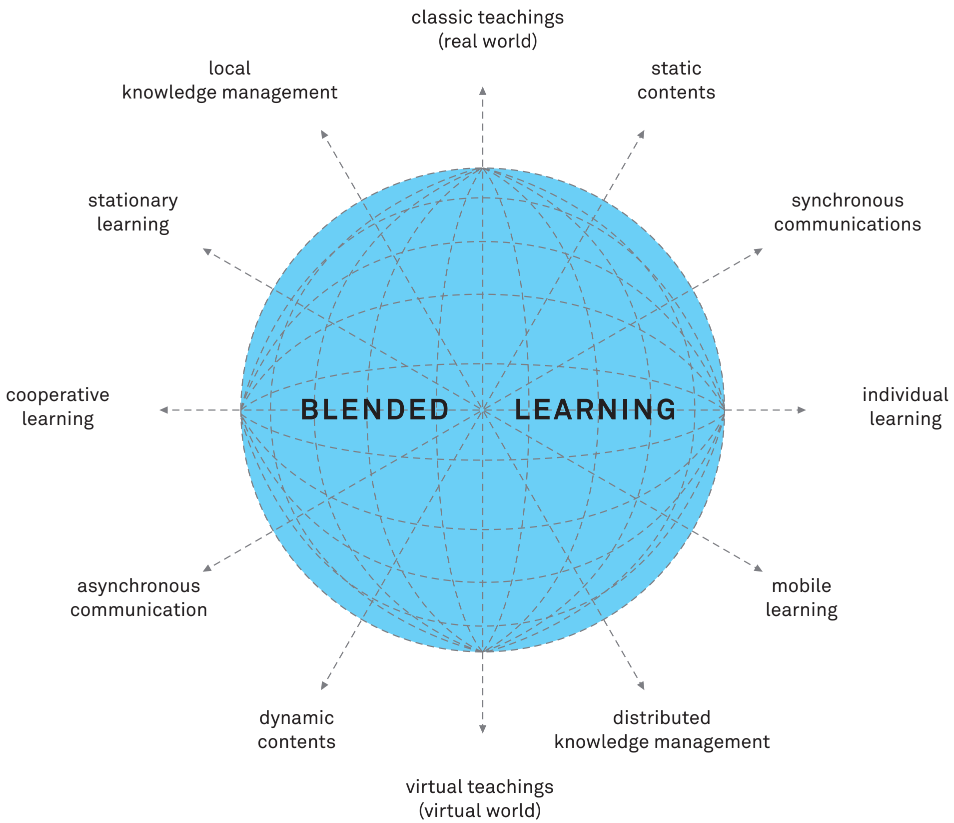

Figure 12.2: Blended Learning = traditional face to face teaching + eLearning

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13 Non-Revenue Water Management in the Arab Region: Solutions for Drinking Water Loss Reduction – Capacity Building Approach

Mostafa Biad
Rabat, Morocco
[abiad@onep.org.ma]

13.1 BACKGROUND

Water resources must be protected, conserved, developed, managed, used, and controlled in way that ensures efficient, sustainable and beneficial use in the public interest. In this context, "water demand management within the framework of integrated water resources management" is a key to securing and safeguarding water supplies for sustainable development.

Indeed, utilities pay particular interest to NRW and to performance improvement with a double objective: (1) to improve their financial situation by reducing costs and increasing revenues, postponing investments (avoiding early water resources saturation), and (2) to improve water service delivery mainly in areas experiencing shortages.

It is commonly recognized in the water sector that capacity development activities are one of the most important elements of a comprehensive and integrated water loss control programme. These activities are both intra-utility and inter-utility, with the involvement of private sector.

13.2 WHAT IS CAPACITY DEVELOPMENT?

In literature and within specialized agencies, it is generally recognized that capacity development involves three different levels:

1. Human resource development: skills, knowledge and training to ensure effective performance
2. Organizational development: management structures, processes and procedures, management of relationships between different organizations and sectors (public, private and community)
3. Institutional development and legal framework: enhancing capacities at legal and regulatory level, and helping institutions and agencies at all levels in the sectors

13.3 CAPACITY DEVELOPMENT APPROACHES FOR NRW

Capacity development in companies and institutions in charge of water production/distribution should be multi dimensional and articulated primarily according to different axes, i.e.

1. Axis: Institutional and Organizational
2. Axis: Exchange and Networking
3. Axis: Training, Competences and Communication
4. Axis: Private Sector Participation
5. Axis: R&D.

13.4 AXIS: INSTITUTIONAL AND ORGANIZATIONAL DEVELOPMENT

Institutional aspect:
NRW strategy should be on the agenda of the topmost institutions in the water sector, and translated into real measures among the utilities. This involves the establishment of law texts and bylaws, special programmes, incentives (targeted subsidies), etc.

Figure 13.1: Capacity development approaches for NRW

Organizational aspect:

- Coaching for identification and implementation of NRW integrated global action plan (supporting utilities in leading NRW diagnosis, identifying all forms of losses and then designing a logical and prioritized modus operandi to redress the situation in a sustainable manner)
- Choosing the best structure for "NRW function" and organization development (job descriptions, procedures, etc.)
- Setting up performance indicators, measurement systems, monitoring and reporting systems (both within the utility and within the sector, sector newsletter)
- Best management practices (incentives, management by results, etc.).

Axis: Training

Identifying needs in terms of capacity development, setting up and implementing training and multi-year action plans involving all NRW competences.

- Package of training modules (certification modules)
- Training plan for different levels of staff (top and middle management, technical, commercial and financial staff, etc.)
- Permanent modules
- Training of Trainers programme.

Axis: Exchange and Networking

The challenge is to identify partners among (1) local or regional institutions, (2) NGOs and (3) business associations (local/regional/international) with an interest in water issues, performance improvement, and in human, organizational and institutional development in the water sector. The objectives can be summarized as follows:

- Promoting experience exchange between institutions/regions, sharing difficulties
- Encouraging networking and creating a platform for exchange and dissemination of good practices (capitalizing on others' experiences, knowledge society)
- Sectorial and regional reporting for performance indicators, benchmarking among utilities, countries, regions (regional, sectorial newsletter), competition climate.

Axis: Private sector participation

Decisions on private sector involvement depend on numerous considerations relating to the utility environment such as technical needs, economic motivation, managerial aspects, and sometimes political orientations.

The combination of these considerations will help in deciding on the level of private sector participation in NRW activities.

From the point of view of a capacity development approach, concrete actions are multiple and more or less complementary, and include mainly:

- Information and awareness raising among leaders and decision makers about the importance of involving the private sector
- Supporting utilities in conducting analysis and diagnosis (SWOT) for private sector participation. Specific cases of successful experiences and examples of failure can be used as a guide to good practices to follow and mistakes to avoid
- Accompanying the modus operandi for PPP (drawing up specifications, possible arrangements, results-based contacts, etc.
- Supporting the private sector in meeting the utilities' expectations.

Axis: R&D

Promoting R&D in the field of NRW involves promoting technical solutions (processes, equipment, etc.) and methodologies (procedures, modus operandi, organization) that have a positive impact on the efficient use of water resources.

Examples include the following:

- Strategic watch for methodologies and best practices related to loss reduction
- Technological watch for equipment, software, hardware, etc. to improve performance (efficiency) in reducing NRW
- Research for leak detection optimization, efficient use of different equipment, more precise and more selective campaigns
- Technological-industrial watch for metrological equipment, software, hardware (metering, recording, etc.) to improve billing accuracy (increasing revenue) and management (decision support for optimization of equipment and facilities, etc.).

In terms of capacity development, R&D actions required are the following:

- Skills development
- Contribution to capacity development in utilities
- Setting up networks of internal and external experts, researchers, etc.
- Partnership with research centres, laboratories, universities, etc.

14 Development and Delivery of a Water Loss Control Training Course

Elisabeta Poçi, Enkelejda Gjinali
Tirana, Albania

14.1 GENERAL INFORMATION ABOUT THE WATER SUPPLY AND SEWERAGE ASSOCIATION OF ALBANIA

The Water Supply and Sewerage Association of Albania is a professional, not-for-profit association of water supply and sewerage professionals, who wish to improve the management of the Water Supply and Sewerage Sector, making it efficient, sustainable, and effective in accordance with the current Laws and Regulations in Albania. The Association is legally registered in the Court of Tirana.

The Association was formed in the Spring of 2000 by a group of representatives from eight water supply and sewerage enterprises in Albania. These individuals saw a need for a professional association to represent the interests of the operating enterprises in the water sector, and to raise the level of professionalism in the sector.

The Association's Mission Statement consists of two objectives:

- To improve the capacity of the people, who work to deliver water supply and sewerage services in Albania, so that they can perform their duties in a professional, reliable and cost-effective manner.
- To represent the interests of water supply and sewerage utilities and other professional in the water sector in Albania regarding laws, decrees, and regulations that may be proposed for action by the parliament or by the government.

The Association has a voting membership of water supply and sewerage utilities totalling 30, plus a number of members in its other membership categories, which include private company members, institutional members, individual members, and faculty members.

The Water Supply and Sewerage Association of Albania has been a member of the European Water Association (EWA) since November of 2006. The Albania Association was the first of the Western Balkans countries to become an official member.

Some of the Association's programs and projects include:

- Annual National Conferences and Exhibition of the Water Sector in Albania;
- Association newsletter "Burimi" published in English and Albanian;

- Polytechnic University Student Summer Internship Program;
- Association website;
- Children's Water Awareness Program;
- Training courses.

14.2 ALBANIAN WATER UTILITY SECTOR CHARACTERISTICS

Based on the data provided by the Monitoring and Benchmarking Unit at the General Directorate of Water Supply and Sewerage, some the performance indicators for the water sector in Albania are as following:

Service Coverage

The data provided by the utilities in the Program estimate a service coverage factor for water supply services of 76.4%, while that for sewerage services is 44.7%.

Metered Consumption

Water sold and metered at customer connections in all 54 participating utilities included in the Program represents only 42% of the total water supplied to the distribution systems of these 54 participating utilities.

Water Production and Water Sales (liters per capita per day)

Based on 2007 data, it can be stated that the average per capita production is 306 litres/capita/day, or at least twice higher than the suggested demand norm, and the average per capita sales is 105 liters/capita/day, i.e. two-thirds of the norm in effect.

> Figure 14.1 shows average values of production and sales in litres per capita per day (l/c/d) calculated for groups of utilities created on the basis of the type of production system (gravity-based, mixed and pump-based).

The data for 2007 show the overall bill collection rate for the 54 utilities in the Program as 74%. The collection rate for household customers is lower than collections from private entities and institutions. Specifically, the average collection rates for households, private entities, institutions and wholesale are, respectively, 69.0%, 74.6%, 93.0% and 15.0%.

Non-Revenue Water

The data for 2007 show that Non-Revenue Water represents 69% of the total water produced and/or purchased, based on the data reported by the 54 water utilities participating in the Program.

This compares very poorly with the suggested Non-Revenue Water or loss norm of 15–25%. When Non-Revenue Water is such a high percentage, it has a very dramatic impact on the financial performance of a utility in terms of pumping costs or in lost revenues due to non-billed, unregistered customers.

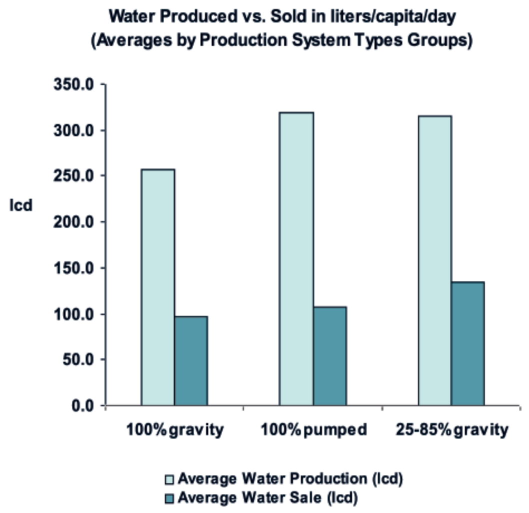

Figure 14.1: Bill Collection Rate

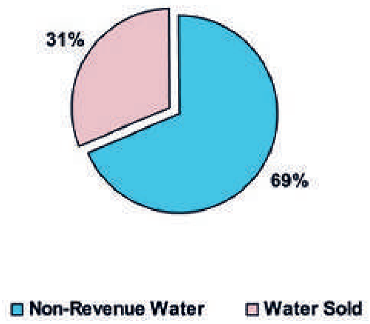

Figure 14.2

14.3 WHY ORGANIZE A WATER LOSS TRAINING COURSE?

The annual volume of water lost (Non-Revenue Water), across a water supply system, is an important indicator of both water distribution efficiency, as well as administrative procedures that do not properly account for water. Controlling water loss is one of the main challenges for all water companies striving to become financially self-sustaining.

Moreover, considering these figures of water loss the Water Supply and Sewerage Association of Albania identified Water Loss Control as one of the highest priorities for its members and therefore made it the first course to be developed and scheduled into its routine training program.

The course has been delivered several times to date and continues to attract large applications for registration. This course provides the participants with the full knowledge needed to begin to conduct a water loss control program for a water utility. The course is delivered by actual water utility personnel, who have had practical experience in the theory and procedures presented.

14.4 THE ASSOCIATION'S APPROACH IN DEVELOPING THE COURSE

The Association prepared a Training Manual on Water Loss Control, which was developed by combining the best practice experience of other countries concerning water loss control, together with the Albanian water utilities specific technical and managerial conditions. The manual was revised several times by different professionals in the water sector mainly engineers from the Association's Technical Committee, in order that it might better fit the Albanian reality of the water sector.

Considering the best experience on water loss detection and reduction of one of our members, the Korca Water Supply and Sewerage utility, two engineers from this utility were chosen to deliver the training. Based on the manual, the trainees developed a series of Power Point presentations, which are used to support the training delivery. The theoretical knowledge found in the manual has been combined with practical examples mainly from the Korca water utility, which is a step ahead in controlling and managing water loss.

The training lasts for two days, and during the second day, the participants are involved in a field exercise where the use of water loss detection equipment is demonstrated in a "hands-on" environment. In this way, the course participants can appreciate the relative simplicity and ease of using the equipment, while also developing an immediate appreciation of the value of the technology to locate unseen leaks under the ground.

In support of the training course, a questionnaire was developed by the trainees with different questions related to the water loss. Each participant from each of the water utilities in the course is required to fill in this questionnaire, which gets collected afterwards by the trainees. After making a first interpretation of the data and answers given by the participants, the trainees invite the audience to be involved in discussions while considering different topics of the questionnaire.

The course has been conducted for three years so far and around 70 people from the staff of the water utilities all over Albania have been trained.

A good partner to the Association in addressing the water Loss control has been as well the General Directorate of the Water Supply and Sewerage Utilities of Albania which has supported the development and organization of the Water Loss Control Training Course by the Association.

14.5 COURSE CONTENT

The course provides a common basis for defining the components of water loss so that professionals in the water sector may speak with a common language when addressing this important management issue. The training modules in the course include the following:

> Role of Metering and Water Demand Management
> Understanding Water Balance
> Performance Indicators
> Pressure Management
> Use of Water Audits and Leak Detection
> Conduct of a Water Audit

All participants in the course receive the Association's official Water Loss Control Manual of Practice with guidelines and forms for conducting water audits and water balances. In addition, each participant receives a Certificate of Completion as evidence of having attended the training.

14.6 TARGET AUDIENCE

This course is particularly valuable and has been attended by Water Utility Directors, Chief Engineers, Directors of Customer Service, and Consulting Engineers. It has raised the awareness of practitioners in the water utility field and has established a common understanding of the terminology in the field and how to begin to analyze water loss and Non-Revenue Water by breaking the problem down into more discrete elements that can each be addressed in a unique, solution oriented way.

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Glossary & Acronyms

AMR	Automatic Meter Reading
AquaFed	The International Federation of Private Water Operators
BWA	Bulgarian Water Association
CAAL	Current Annual Apparent Losses
CARL	Current Annual Real Losses
CBD	Secretariat of the Convention on Biological Diversity
CD	Capacity Development
CDIS	Capacity Development Information System
CEB	Chief Executive Board
CIS	Commonwealth of Independent States – Official members: Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Uzbekistan, Unofficial associate member: Turkmenistan; participating but no official member: Ukraine; Withdrawn since 2008: Georgia
CSD	Commission on Sustainable Development
CTA	Chief Technical Advisor
DESD	Decade of Education for Sustainable Development
DMA	District Metered Area
ECOSOC	Economic and Social Council
EEA	European Environment Agency
ESD	UN-Decade Education for Sustainable Development 2005–2014 (http://www.unesco.org/en/esd/)
FAO	Food and Agriculture Organization of the United Nations
GF4A	Global Framework for Action
GLAAS	Global Annual Assessment on Sanitation and Drinking-Water

GWA	Gender and Water Alliance
GWP	Global Water Partnership
HLCP	High Level Committee on Programmes
HLM	High Level Meeting (of the Global Framework for Action)
HNEE	University of Applied Sciences in Eberswalde / Germany (Hochschule für Nachhaltige Entwicklung Eberswalde)
IAEA	International Atomic Energy Agency
IAH	International Association of Hydrogeologists
IAHS	International Association of Hydrological Sciences
IBWS	former Water Strategy Initiative Office / Germany (Initiativbüro Wasserstrategie im PT-DLR)
ICID	International Commission on Irrigation and Drainage
IEEM	Institute of Environmental Engineering & Management (Private University of Witten Herdecke gGmbH)
IFAD	International Fund for Agricultural Development
IFAT	Trade Fair for WATER, SEWAGE, WASTE AND RAW MATERIALS MANAGEMENT
IHA	International Hydropower Association
ILI	Infrastructure Leakage Index
ILO	International Labour Organization
IRC	International Water and Sanitation Centre (http://www.irc.nl/)
IUCN	The World Conservation Union
IWA	International Water Association (http://www.iwahq.org)
IWMI	International Water Management Institute
IWRA	International Water Resources Association
IWRM	Integrated Water Resources Management
IZNE	Internationales Zentrum für Nachhaltige Entwicklung (Hochschule Bonn/Rhein-Sieg/Germany) International Centre for Sustainable Development
JMP	WHO/UNICEF Joint Monitoring Programme on Water Supply and Sanitation
JPOI	Johannesburg Plan of Implementation of the Agenda 21
MDG	Millennium Development Goal
NRW	Non-Revenue Water
NWSC	National Water & Sewerage Corp. (Uganda)

PSI	Public Services International
R&D	Research and Development
Ramsar	Convention on Wetlands (Ramsar, Iran, 1971)
SCADA	Supervisory Control and Data Acquisition
SIWI	Stockholm International Water Institute (http://www.siwi.org/)
SWA-GFA	Sanitation and Water for All: A Global Framework for Action
TEEB	The Economics of Ecosystems and Biodiversity
UAAL	Unavoidable Annual Apparent Losses
UARL	Unavoidable Annual Real Losses
UBA	Umweltbundesamt
UFW	Unaccounted for water, Federal Environmental Office of Germany
UN	United Nations
UN DESA	United Nations Department of Economic and Social Affairs
UN ECA	United Nations Economic Commission for Africa
UN ECE	United Nations Economic Commission for Europe
UN ECLAC	United Nations Economic Commission for Latin America and the Caribbean
UN ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UN ESCWA	United Nations Economic and Social Commission for Western Asia
UNCBD	United Nations Convention on Biological Diversity
UNCCD	United Nations Convention to Combat Desertification
UNCED	United Nations Conference on Environment and Development (1992), the "Rio Declaration""
UNCTAD	United Nations Conference on Trade and Development
UNDESA	United Nations Department of Economic and Social Affairs
UNDG	United Nations Development Group
UNDP	United Nations Development Programme
UNECA	United Nations Economic Commission for Africa
UNECE	United Nations Economic Commission for Europe
UNECLAC	United Nations Economic Commission for Latin America and the Caribbean
UNEMG	United Nations Environment Management Group
UNEP	United Nations Environment Programme

UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNESCWA	United Nations Economic and Social Commission for Western Asia
UNFCCC	United Nations Framework Convention on Climate Change
UNGC	United Nations Global Compact
UN-Habitat	United Nations Human Settlements Programme
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children's Fund
UNIDO	United Nations Industrial Development Organization
UNISDR	United Nations International Strategy for Disaster Reduction
UNSGAB	United Nations Secretary General's Advisory Board on Water & Sanitation
UNU	United Nations University
UNU-EHS	United Nations University – Institute for Environment and Human Security
UNW-DPAC	UN-Water Decade Programme on Advocacy and Communication
UNW-DPC	UN-Water Decade Programme on Capacity Development
UNWTO	United Nations World Tourism Organization
VAG	Vereinigte Armaturen Gesellschaft mbH / Germany (http://www.vag-armaturen.com/en/)
WASAZA	Water and Aanitation Association Zambia
Water For Life	The United Nations Decade "Water for Life" from 2005–2015 (http://www.un.org/waterforlifedecade/)
WB	The World Bank Group
WBCSD	World Business Council for Sustainable Development
WE	Water Efficiency
WEI	Water Exploitation Index
WfWP	Women for Water Partnership
WHO	World Health Organization
WLM	Water Loss Management
WLR	Water Loss Reduction
WMO	World Meteorological Organization
World Water Day	An annual event organized by UN-Water which was happened since 1992.

WRM	Water Resources Management
WSS	Water Supply and Sanitation
WSSCC	Water Supply and Sanitation Collaborative Council
WSSD	World Summit on Sustainable Development (2002)
WWAP	World Water Assessment Programme
WWC	World Water Council
WWDR	World Water Development Report
WWF	World Wide Fund for Nature