WATER LOSS DETECTIVES

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EDITORIAL

COMPETITION AND PROGRESS

Competition leads to progress. Any challenge, in sports or in other domains gives the participants the opportunity to assess and develop their abilities and competencies. In addition, a challenge designed for members of a particular profession creates connections among competitors, building an extended family, part of the larger professional group, which resembles a modern guild.

The water loss detectives gathered together again in May, in Constanta, for the 5th edition of the Leak Detection Challenge that reunited 19 Romanian regional water companies. The contest, organized by the Romanian Water Association, aimed to develop skills, transfer know-how and assess the operational performance of the dedicated leak detection teams. The event also brought to the attention of the general public the leak detection, a rather less known activity of the water companies, carried out in order to improve efficiency. As previously mentioned, perhaps the most important benefit for the competitors was that teams with similar responsibilites coming from various domestic and international water companies had the chance to get together, know each other and eventually build a support network.

At the current edition, the organisers asked the participants to look beyond the immediate goal which was to win the race and try to see that they all belong to the same family. Eventually, everyone has something to learn from such a competition, either from their own experience or from others.

Another competition for water companies professionals took place in Munich, in May. This time, the challenge was addressed to the sewage maintenance and inspection staff, but the purpose remained the same, performance evaluation and professional development.

Every profession should have its own guild and preserve a good tradition. In Timisoara, an old "nail tree", a replica of the more famous tree trunk in Vienna reminds us of the medieval guilds, while in Sibiu each guild used to have its own tower. In the past, the mayor, who had to be, first of all, a good professional, was elected from the candidates appointed by the guilds. Competitions such as the Leak Detection Challenge are an inspiration for professional development and provide a collaborative climate for all participants.

eng. **Alin ANCHIDIN**

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WATER LOSS DETECTION CONTEST ROMANIA 2012

THE GUILD OF HIDDEN WATER LOSSES DETECTORS

In human society evolution an extremely important role was played by the division of labor. Since the beginning of human organized life, they have tried to practice activities that they can support both physically and with the skills, with which they were endowed by nature, skills that once observed had to be supported by theoretical knowledge and especially practical made with tireless passion and especially love for the chosen profession.

If in the primitive commune there were quite a few common primitive occupations (farmers, hunters, fishermen, blacksmiths, carpenters, etc...), over the centuries the range of services has greatly diversified bringing in dozens of professions, which in turn contain dozens of trades for each category separately.

Thus, with the advent of the first water supply systems, water losses occurred by default and need their timely detection to avoid wastage. Due to changes produced in planetary ecosystem, and in parallel with increasing water needs, water has become a precious commodity that requires judicious management.

Romania, unlike other countries, still has significant resources available, but even so, the first condition in capitalizing as much as possible sources of water is to eliminate losses in the network, both in the transport and distribution.

Therefore, if at the beginning, the small number of losses and large quantities of water available afforded certain lightness for suppliers in addressing water losses, as the water has become increasingly more valuable, it increased the involvement of suppliers in determining and eliminating water losses. If a significant part is the visible loss, the other part is the hidden loss, sleeping, water making her way under the principle of communicating vessels and flooding ducts all kinds of basements, buildings, etc.

Over the years an industry has developed with the main activity production of machines and equipment for detecting this type of loss, all equipment with high technology which includes, people increasingly better trained to use them more effectively.

And just like that, slowly, step by stepa new profession has been shaped, that of hidden losses of water detector, craft that is as tough as it is pretty obvious when practiced by dedicated people, people who feel the joy of success, but also the bitter taste of unresolved loss. This trade is global, with the practitioners both men (mostly) and women in Prague, for example, Veolia's crew is formed in the vast majority from women. In Romania, the practitioners of the craft, being relatively small in number were able to know each other, and make countless exchanges. For example through the annual contest of hidden loss detection for pipelines organized

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NOTES CONCERNING THE WATER LOSS AND THE WASTED WATER

Key words: water loss, commercial water loss, physical water loss, apparent water loss, wasted water.

Water loss is a very complex notion that includes among other things the water that is wasted. As defined by IWA, the water loss is in fact the water that does not bring profit because it does not get to be sold (IWA named this water Non Revenue Water - NRW). In fact, this problem is more complex and the following will describe some of the other aspects that contribute to this problem. It is important to account for these additional issues since minimizing the water loss as well as the wasted water results in a more rational water use, hence the possibility of storing some water for the benefit of others who currently don't have any. Another factor that will not be discussed here is the currently observed climate change who also points to the fact that the unsalted clean reserves of water existent on Earth should not be wasted.

Water loss (the way we measure it) has two main components: one is the physical water loss and one is the apparent water loss (this is the water that is recorded as lost due to the errors in the water meter's readings or due to the incorrect use of the collected data from the meters). In both cases there is a part that represents the wasted water. Considering these, we could say that the water loss represents the quantity of water that was collected but due to several factors it didn't get to be used for its designated purpose (water for cooking, washing, drinking etc). This problem is more complicated than it sounds in theory. For example: Is the water that is used for testing and washing the water supply system (so called technological water loss) really a water loss? From the financial point of view it looks like it is but in reality it is not. This water should not be accounted as lost because if the filters and the settling tanks from the water treatment process are not washed properly, then there will be no water available to be sold to begin with, hence there will be no business. So the water is actually used not wasted. However, the washing should be done following the specified parameters for this operation. Otherwise, some water loss could occur such as:

- if a filter that can be washed with 4l/s*m2 was washed using 6l/s*m2,
- if instead of washing the filter for the recommended amount of time (example 10 minutes) the washing last for double or triple that time etc. in
- if instead of stopping the washing when the water obtained has the same turbidity as the settled water (the water that is going to be filtered) the washing continues until at the surface the water looks clean.

As a conclusion, the water loss is represented by the amount of water that was not rationally/ wisely used in the technological process.

The water lost in the distribution system (due to the pipe leakage, hydrants leakage, overflow, valve leakage etc.) can be divided into 2 main groups: (1) technically admitted loss (this value cannot be technically reduced because it would cost too much) which should not be considered as lost water and, (2) the detected water loss that is not stopped in time due to several reasons, which represents in fact a water loss. In this process the cost of water plays an important role. If the cost of water is high (probably because of the intricate design, a large amount of energy required, low water resources etc) then it is more likely that the repairing works will be regarded as a priority and will be done in due time. If however the price of water is low (water resources are generous) the water is not so highly regarded and preserved, hence an important water loss could occur in the case of a leakage left unattended (is easier to pay for the lost water instead of repairing the faulty pipes).

The water loss occurring inside the households is also an issue that is worth mentioned. Even though it is monitored twice within the block of flats (once on the main meter – on the branch - and once at the individual meters located in each unit) and sometimes it is paid twice (once as hot water and once as cold water), practically, from a commercial point of view, this is considered as Revenue Water. The truth is that a apart of this water is in fact lost water. There are an elevated number of discussions and calculations conducted in order to find a solution for the quantity of lost water resulting from the difference between the consumer's individual readings at their in-house meters and the group reading conducted at the main meter.

There is another important water loss that occurs when the water is used for other purposes that it was originally designated for (watering the garden, washing the car, sprinkling the pavement etc) or is wasted during in-house activities (keeping the water running while brushing your teeth, washing the dishes under a constant water flow, taking long showers, not closing the tap completely after use etc). Commercially this water loss represents a profitable business since the people are charged for this lost water. There is another factor to be accounted for and that is the water pressure. A tap located in a unit on the first floor is working at a pressure of 4-5 bar (1 bar = 105 Pa) so when it is opened, the quantity of water is way higher than the same type of tap located in a unit on the 10th floor of the same building, possibly having a pressure of 2-3 m water column. Therefore it is very important that the water pressure is regulated using a tap existing at the entrance point of the unit.

Some solutions to all the above issues have been identified: install different diameter taps, toilets with "two speeds", vacuum sewage systems (therefore reducing the washing basin capacity), precision water meters etc.

Energy loss represents a complementary (but important) component to the water loss. The quantity of energy required to deliver the water to different components of the system is around 1,0 kWh/m3. It is important to remember that the water lost from the system could be recovered (through the natural hydrological cycle, in the sewage, in the building's basement etc) but the energy used for delivering the water cannot. Since non-renewable sources such as coal, gas or oil are generally used in Romania to produce energy a thorough investigation on the energy levels should be conducted and energy loss kept to a minimum level. Also, the process of producing energy using the above mentioned resources is generating great quantities of CO_2 that have a direct negative impact on the surrounding environment.

Two main conclusions are:

- Water should be used wisely since the available resources of clean unsalted water are small;
- Keeping the consumer informed and educated is very important.

October 1st, 2012

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by ARA reached this year 5th edition held in Constanta by impeccable support provided by RAJA Constanta, through courses organized by the foundation Aquademica Timisoara, foundation that supports the journal of "Water Loss Detectives". As part of this "guilds" group event I mention Summer School, organized by ARA, with substantial support of the German company SEBA KMT, during which there was a very helpful and pleasant exchange with similar water company in Hungary and Austria, but also a major seminar at SEBA KMT headquarters.

The result was that most practitioners of the craft of Romania had known each other, communicated, shared each other both issues, special situations faced in everyday activities and not least became friends. Let's try in the future to come together and make the necessary arrangements to include this job in the official nomenclature of occupations in Romania and to make this a real" caste" of water leaks detectors an elite one!

As I said at the seminar organized by "Aquademica": "It's an exciting area, captivating, in my opinion and I invite all those who deal with this issue to deal with all the responsibility." Each loss is an experience gained resolved and a new lesson learned. You also learn both from your own experiences and the experiences of others, is an area where you always learn something. Fairness determining losses is our business card, it is true that there are many factors that contribute to it, but you know what they say, "Man sanctifies the place". Putting the results of the work of each of us to increase the prestige of this new and beautiful crafts!

Viorel Simionescu,
Product Manager
SEBA representative Dynatronic GmbH in

WATER LOSS REDUCTION IN RAZGRAD DEMONSTRATIVE PROJECT THROUGH ACTIVE LEAKAGE CONTROL, PRESSURE MANAGEMENT AND THE RELATIONSHIP BETWEEN PRESSURE MANAGEMENT AND LEAKAGE THE CASE OF KOOPERATIVE PAZAR DMA

Abstract: This demonstrative project comprises four of the 24 districted metered areas (DMA) of the town of Razgrad connected to SCADA system - Kooperativen Pazar, Largo 1, Largo 2 and Parkova zones respectively. The first phase of the project was implemented for three months. This was possible not only because of the high level of completeness of the SCADA system but also due to the realized in the period between September 2006 and September 2007 project under a Dutch governmental initiative managed by Aquapartner Ltd, Bulgaria and Aquanet Ltd, the Netherlands. The aim then was a twinning project between Water Company PWN, the Netherlands and Vodosnabdyavane Dunav, Razgrad for improvement of the water supply management in Water Company Razgrad, Bulgaria. The project was financed under programme LOGO East of the Association of Netherlands Municipalities (VNG) for strengthening of the regional and local government through partnership and by PWN, the Netherlands.

The report gives a summary of the Demonstrative project. The project observes the water supply network of the four zones by using the IWA approach and the achieved savings for this short period are demonstrated – for Kooperativen Pazar zone– 3.8 l/s, Largo 1 zone – 1.1 l/s, Largo 2 zone – 1.0 l/s and Parkova zone – 0.8 l/s.

Key words: Water loss, DMA, SCADA system, leakage

1. INTRODUCTION

This project has been implemented by the Aquapartner Ltd team and the team of Vodosnabdyavane EOOD, Razgrad, the water company, headed by the main engineer Stoyan Ivanov. The projects demonstrates the possibilities for delivering real and positive results in water loss reduction by water companies in Bulgaria with relatively few resources and the professionalism of the operating team.

The report addresses the various stages of analysis, preparation and application of an appropriate water loss reduction programme in 4 purposely pre-selected districted metered areas (DMA) and, in particular, the application of Active Leakage Control (ALC) and Pressure Management (PM) in DMA Kooperativen Pazar.

A prerequisite for the outcome obtained was the implementation of a joint project, which took place between September 2006 and September 2007, between two water companies - PWN, the Netherlands and „Vodosnabdyavane Dunav", Razgrad, aiming to improve the water supply management of the water company of Razgrad, Bulgaria. The project was initiated by Aquapartner Ltd, Bulgaria, and Aquanet Ltd, the Netherlands, and funded under the LOGO East Programme of the Association of Netherlands Municipalities (VNG) with the purpose of strengthening regional and local governments through partnership with PWN, the Netherlands. Under this joint project, the water supply system was surveyed throughout the town, a model of the water supply network was made and a pilot zone was selected to analyze water losses in it and prepare an investment programme.

2. OVERVIEW

The town of Razgrad is situated in the north-eastern part of Bulgaria (Figure 1) in an area with specific land relief and hydro-geological characteristics and ground level variations up to 110 m.

The town's population counts 38,725 residents. It is supplied with water mainly by means of pumps. The water supply network is 251 km long, of which: 135 km transmission and 116 km – distribution mains. There are five pressure tanks of a total volume of 45,740 m3; 5,251 service connections of a total length of 47 km.

Figure 1 Location of Razgrad

The quantity of water supplied is 7.1 million m^3, of which around 2.8 million m^3 comes from the Dunav water supply system.

The town of Razgrad receives water from five water supply sources:

- Pumping station „Vodna Tsentrala", operates 24 hours a day with a max capacity of 25 l/s.
- Water supply system „Getsovo" - operates 24 hours a day with a max capacity of 88 l/s.
- Pumping station „Yuri Gagarin", operates 24 hours a day with a max capacity of 38 l/s.
- Pumping station „Cherkovna", operates 24 hours a day with a max capacity of 28 l/s.
- Water supply system „Dunav". The system operates nights only supplying an average of 7,500 m^3 per night, i.e. an hourly average of 86 l/s over a 24-hour period. The operating time of the system „Dunav" is set according to the levels of the pressure tanks, which feed water to the town.

The street water-mains in Razgrad are made of asbestos cement and steel pipes, water-supply service pipes – of zinc galvanized steel pipes. All these were built in the 1935-1980 period. A small portion (less than 1%) of the street water-mains and service pipes have been replaced with PEHD pipes. The old and worn-out water transmission network, the characteristics of the relief and the lack of booster sets in the high-rise buildings contribute directly for the high rate of real water losses.

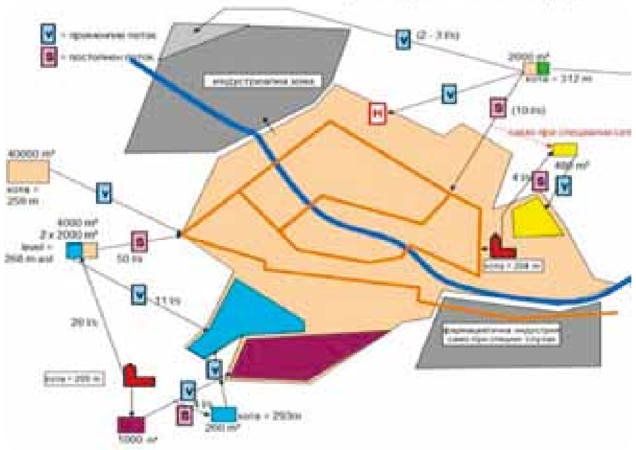


Figure 2 Diagram of Water Supply in Razgrad

All pumping stations, pressure tanks and part of the district areas chambers are under the control of an automated water supply management system – SCADA. This system allows a certain operating independence of the facilities following a certain algorithm. The SCADA operator on duty gets visual information for the current state of the facilities and the relevant sound alarm signals in case of departure from the pre-set parameters.

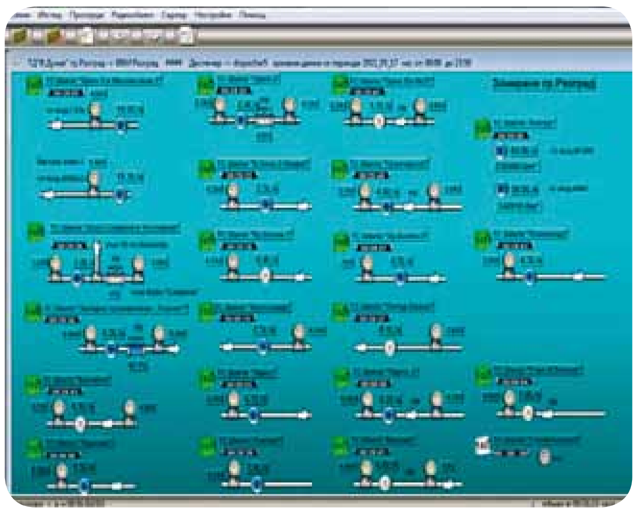


Figure 3 SCADA management of DMA's

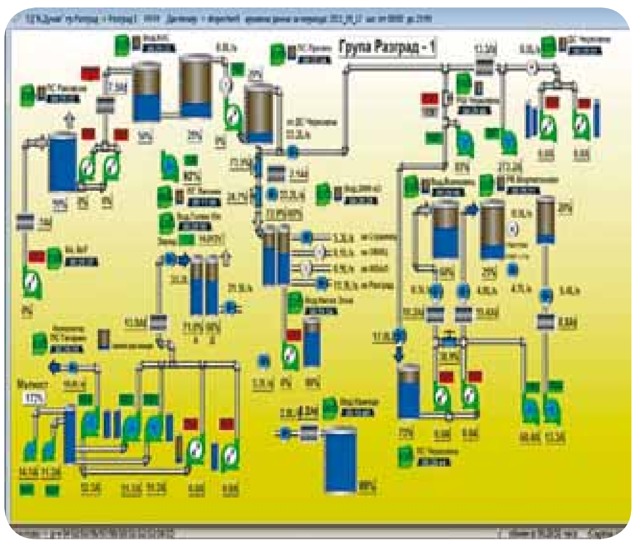
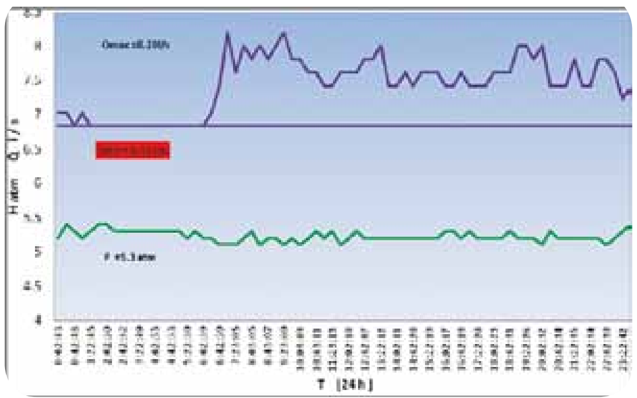


Figure 4 SCADA management of pressure tanks and PS's

3. WATER LOSS REDUCTION IN RAZGRAD DEMONSTRATIVE PROJECT

The project comprises four DMA's of the water-supply system (marked in red in Figure 5) – Kooperativen Pazar area, Largo 1 area, Largo 2 area and Parkova area with a total minimum night flow of 32.4 l/s in the small hours of the night, when water consumption is supposed to be at its minimum. The areas are concentrated in the central parts of the town with a total length of the water supply pipes of around 13 km and serviced population of 5 928 people. A great deal of the required data – 24-hour data on water input volumes, pressures downstream and upstream of the DMA chambers – were obtained through SCADA



Graph 1 Minimum night flow and pressures in aDMA chamber

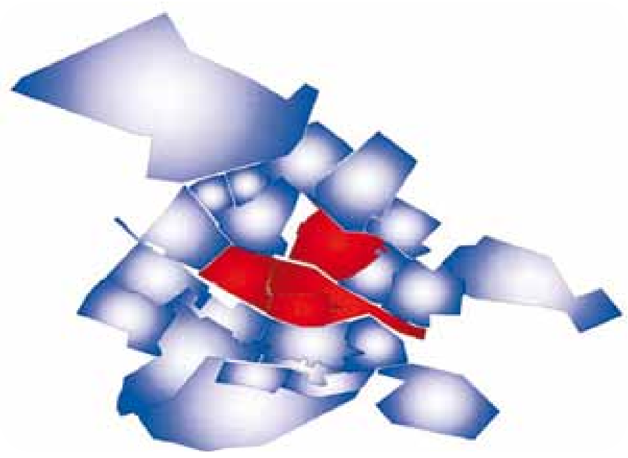


Figure 5 DMA's in Razgrad Graph 1 Minimum night flow and pressures in a DMA chamber

The methods of the International Water Association (IWA) were applied, to a great degree, in the respective areas for a period of 3 months:

- DMA monitoring;
- Preparing a water balance and calculating ILI;
- Applying Active Leakage Control (ALC);
- Pressure Management (PM).

3.1 DMA monitoring

Together with qualified specialists of the water operator, the Aquapartner's team surveyed the water supply network and its accessories: state of network, working stop valves, location of water pipelines, number of service connections, fire hydrants and other accessories. MNF (minimum night flow) and network pressure data was obtained by means of SCADA.

In order to rule out an error in the readings of bulk meters, those were tested in a licensed metrological laboratory.

The DMA's monitoring included 24-hour monitoring of the amount of water input into the DMA areas and pressures downstream and upstream of DMA's chambers.

Critical points were set for each DMA (Figure 6), where measurements were made (Graph 2) of pressures before and after each significant project step.

Graph 2 Control points

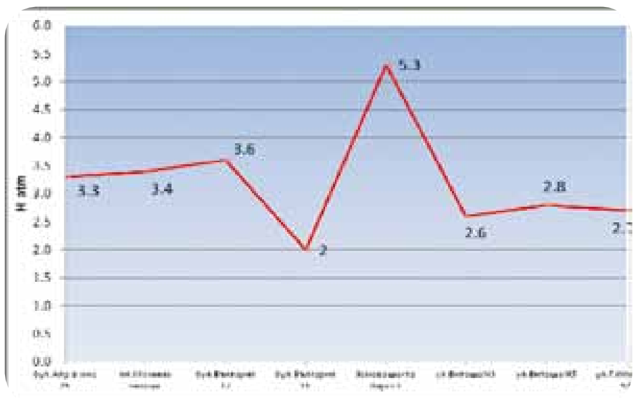


Figure 6 Control points where pressure is measured

3.2 Preparing a water balance and calculating ILI

Based on data provided by the water operator for the past reporting period 03.2010 - 03.2011 regarding the amounts of water input into the DMA and the volumes of water billed, we prepared a water balance for each DMA observing the rules and steps described in the Bulgarian Regulation 06/1 of 5 May 2006 on the Methodology for setting acceptable water losses from the water supply systems. We also calculated ILI (the Infrastructure Leakage Index), analyzed the data from the water balance data the ILI and undertook the necessary steps to reduce water losses. (Tables 1 and 2)

3.3 Conduction of Active Leakage Control (ALC)

Within the scope of the performed Active Leakage Control, we conducted a zero test, a step test, searching with specialized equipment for detecting hidden leaks and their timely and quality repair. Graph 3 Zero Test Graph Graph 4 Step Test Graph

As a first step we conducted a Zero Test (Graph 3), whereby, stopping the water supply into the area and monitoring the pressure in the critical point in the basement, we checked the isolation of the area, i.e. if there were any hidden connections with other areas. The tests carried

№	DMA	Period of Monitoring and measurement: one year
1	Determining the amount of water input into the respective DMA during the period	Q4 = 7 114 193 m^3/yr.
2	Determining the quantity of water supplied and billed during the period	Q3 = 1 781 684 m^3/yr.
3	Determining the quantity of water supplied but not billed	Q3A = 0 m^3/yr.
4	Determining the total authorized consumption	Q5 = 1 781 684 m^3/yr.
5	Water losses	Q6 = 5 332 509 m^3/yr.
6	Apparent losses 10%	Q8 = 711 419.3 m^3/yr.
7	Real losses	Q7 = 4 621 089.7 m^3/yr.
8	Specific real water losses	q = 4.54 m^3/h x km
9	Water supply network length	L = 116 km

Table 1 Water Balance – town of Razgrad

Determining the percentage of water losses:

Q loss = ((Q4 – Q3)/Q4) x 100 = ((7 114 193 – 1 781 684) / 7 114 193) x 100 = 74.95% (1)

74.95 % - high level of total water losses.

<table>
<tr><td colspan="7">'LEAKS' Suite of LEAKAGE EVALUATION and ASSESSMENT KNOW-HOW SOFTWARE CheckCalcs - a free software for identifying Leakage and Pressure Management Opportunities</td></tr>
<tr><td>CheckCalcs</td><td>Developing countries</td><td>Version 1a</td><td>16/08/2009</td><td>Bulgaria</td><td>BUL.001</td><td>© ILMSS Ltd</td></tr>
<tr><td colspan="7">THIS WORKSHEET SHOWS IWA BEST PRACTICE PERFORMANCE INDICATORS (PI) FOR TREATED NRW AND ITS COMPONENTS</td></tr>
<tr><td></td><td>Data entry</td><td colspan="2">Calculated Values</td><td>Default Values</td><td colspan="2">Data from another worksheet</td></tr>
<tr><td>Vod. Dunav</td><td>Town of Razgrad</td><td colspan="2">45 conn./km</td><td>01/01/2010</td><td>Up to</td><td>31/12/2010</td></tr>
<tr><td>Type of PI</td><td>Purpose of Performance Indicator</td><td colspan="2">Comments</td><td>NRW and its components</td><td>PI</td><td>Unit</td></tr>
<tr><td rowspan="5">Operational management of NRW (Treated water)</td><td>Metric: comparison between water companies</td><td colspan="2">Infrastructure Leakage Index ILI = CARL/UARL</td><td>Real losses</td><td>41.5</td><td>Non-dimensional</td></tr>
<tr><td rowspan="4">Process: monitoring the progress towards targets for the water operator</td><td colspan="2" rowspan="4">Use m3/km of mains/ day, if connection density is less than 20/km; for 20/km or more, use liters/service connection/day</td><td>Non Revenue Water (NRW)</td><td>2782</td><td>litres/service conn./day</td></tr>
<tr><td>Unbilled authorized consumption</td><td>0</td><td>litres/service conn./day</td></tr>
<tr><td>Apparent losses</td><td>311</td><td>litres/service conn./day</td></tr>
<tr><td>Real losses</td><td>2471</td><td>litres/service conn./day</td></tr>
<tr><td rowspan="3">Financial management of NRW (Treated water)</td><td rowspan="2">Traditional: with significant interpretation problems</td><td colspan="2">% of System Input Volume</td><td rowspan="2">Non Revenue Water (NRW)</td><td>75.0%</td><td>%</td></tr>
<tr><td colspan="2">% by volume of water supplied</td><td>75.0%</td><td>%</td></tr>
<tr><td>Metric: comparisons between water companies</td><td colspan="2">% of billed metered consumption (except for exported water)</td><td>Apparent losses</td><td>33.5%</td><td>%</td></tr>
</table>

Table 2 ILI – Town of Razgrad

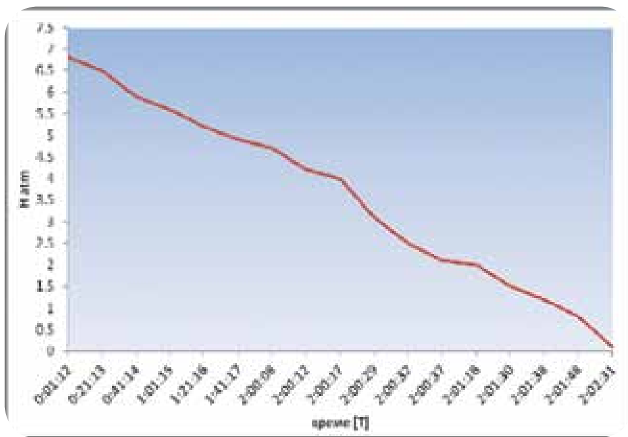


Figure 2 Diagram of Water Supply in Razgrad

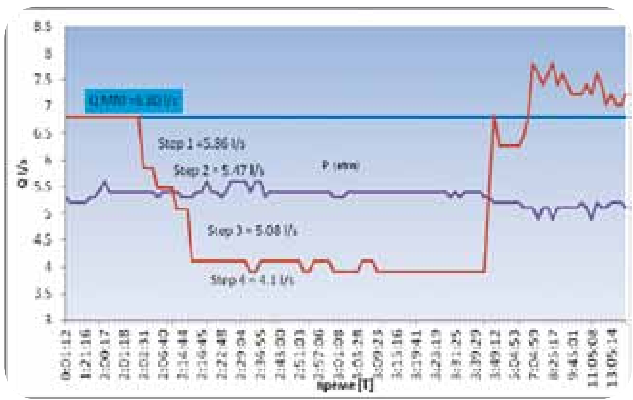


Figure 2 Diagram of Water Supply in Razgrad

out showed that the DMA's are accurately and well isolated from each other and there was no water flowing from one area into another.

We established the working stop valves for each area and with the help of those and additionally installed ones, we were able to isolate sub-areas to be monitored. A step test was carried out in those sub-areas (Graph 4). By means of SCADA we managed to establish the sub-areas with the biggest losses of l/s in the small hours of the night.

Together with teams trained to search the water supply network for hidden leaks, we localized 6 leaks (Picture 1 and 2) in four areas, the repair of which led to reduction of the minimum night flow in the areas with a total of 5,9 l/s.

Picture 1

Picture 2

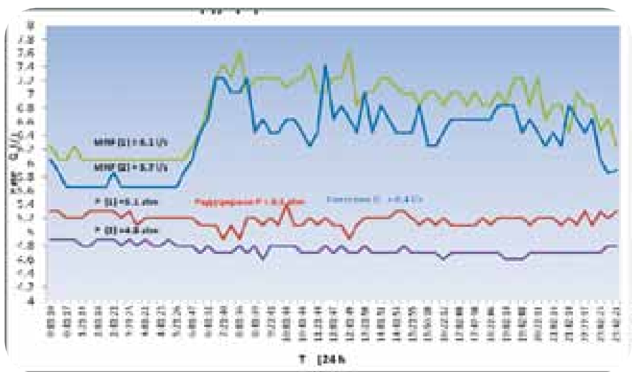
The repair of the leaks (Picture 3 and 4) in the DMA's was reflected in the increase of the minimum free pressure in the critical points. Another very common water loss reduction approach was put in place – Pressure Management (Graph 5).

Picture 3

Picture 4

3.4 Pressure Management (PM)

Analyzing the rise in the free pressure, which we had monitored systematically before and after the leaks repair, we resorted to reducing the free downstream pressure of the DMA's chambers of Kooperativen Pazar DMA with 0.5 atm and Largo DMA 1 with 0.3 atm. Controlling pressure down to the minimum acceptable for the DMA's resulted in further decrease in the night flow of the DMA's with 0.8 l/s.



Graph 5 Pressure reduction

4. THE CASE OF THE KOOPERATIVEN PAZAR DMA

The Kooperative Pazar DMA is situated in the central part of the town of Razgrad (Figure 7), isolated from the adjacent areas be means of boundary valves. The population serviced by the DMA is 1 105 people, the total length of the distribution mains being 3 076 m. 16% the water supply mains in the area are made of modern materials (PEHD), and the rest 84 % - of steel, eternit and zinc galvanized pipes. The average DMA's water supply rate is 98 l/resident/day.

The DMA is supplied by a single point from the main branches. A DMA chamber (Picture 5 and 6) houses a downstream pressure regulator regulating pressure to 5,1 atm and a digital night flow water meter - MNF = 10,6 l/s, which could be monitored in real time through SCADA. The

Figure 7 The water-supply mains of Kooperativen Pazar DMA

variation in the DMA levels is small, within 5.0 m, the average buildings height is around 6 floors. The average network pressure was maintained between 3.5 atm and 4,8 atm due to the existence of a 9-floor block of flats (the critical point) in the middle of the DMA, setting the downstream pressure of the pressure regulating valve (PRV).

Picture 5 The Kooperativen Pazar DMA's chamber – Water meter

Picture 6 The Kooperativen Pazar DMA's chamber – PRV

The high pressure and the old infrastructure predetermined the high level of losses - 88% in the DMA, which clearly indicated a high level of real losses, which in turn lent the possibility of applying the methods and principles of the International Water Association (IWA) and the preparation of water loss reduction programme.

4.1 Water loss reduction strategy in Kooperativen Pazar DMA

A water loss reduction programme undertaken in the project entails applying internationally practiced methods: monitoring, active leakage control and pressure regulation.

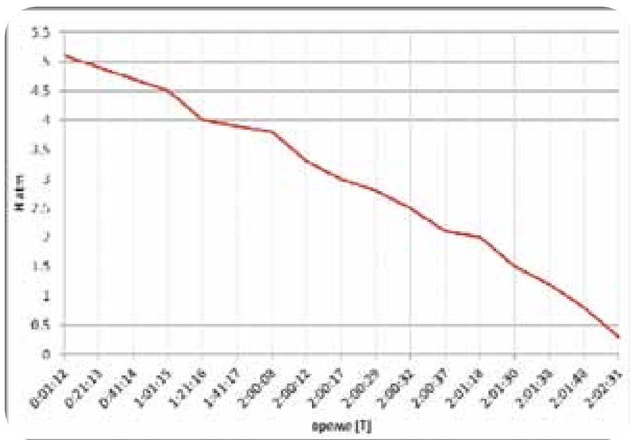
4.1.1 STEP 1 Detailed survey and collection of information

1) To start with, we dismantled the DMA's water meter DN 100 for a metrological inspection and sent it to a licensed laboratory to make sure that it metered the volumes of water supplied to the area within the acceptable measurement error.

The inspection showed that the water meter was in good repair.

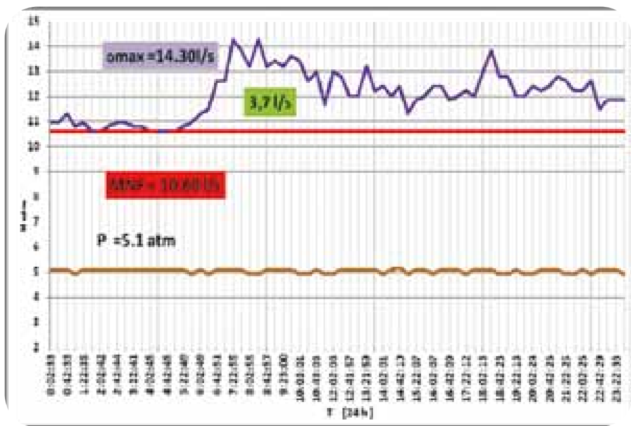
2) Together with teams of the water company, we went around the DMA and checked if the existing stop valves were in good condition, we also checked the location of the service connections. Based on historical data and field inspections, we established the diameters and the materials, of which the distribution mains and the service connections were made. The data was copied to a digital media to facilitate its analysis.

3) We conducted a ZERO TEST, to establish if the DMA was isolated from the other areas, through stopping the supply of the DMA and monitoring pressure the DMA's lowest point (Graph 6). The results in the above graph showed that the Kooperativen Pazar DMA was isolated from the other areas and water was not flowing from one area into another.



Graph 6 Zero Test Underway

4) Through SCADA we obtained the necessary information from the 24-hour DMA monitoring, namely data about the water volumes supplied to the DMA and the pressure downstream of the DMA's regulating valve, both as graphs and tables. (Graph 7).



Graph 7 SCADA graph of MNF = 10,6 l/s and pressure in DMA's chamber

The above graph illustrates that the maximum DMA's consumption was 14.26 l/s, and the minimum night flow in the small hours of the night was 10.6 l/s (the water losses). The difference between these, namely 3.7 l/s, was the real consumption. The DMA pressure was almost constant and was dictated by the DMA's critical point, namely the 9-floor block of flats in Maritsa St.

5) Using the annual reports provided to us on the DMA's input volumes and billed water volumes, we developed a balance of the water flows in compliance with Regulation 06/1 of 5 May 2006 on the Methodology for setting acceptable water losses from the water supply systems for the 2010 report year. (Table 3).

№	Kooperativen Pazar DMA	Monitoring period
1	Determining the amount of water input into the DMA at issue during the period.	Q4 = 357 824 m³ annually
2	Determining the amount of water supplied and billed during the period	Q3 = 44 667 m³ annually
3	Determining the amount of water supplied but not billed	Q3A = 0 m³ annually
4	Determining the total authorized consumption	Q5 = 44 667 m³ annually
5	Water losses	Q6 = 313 157 m³ annually
6	Apparent losses 10%	Q8 = 35 782,4 m³ annually
7	Real losses	Q7 = 277 374,6 m³ annually
8	Specific real water losses	q = 10.28 m³/h x km
9	Water supply network length	L = 3,08 km

Table 3 2010 Water balance table of Kooperativen Pazar DMA.

The water balance shows a high level of total water losses from the DMA.

4.1.2 STEP 2 Active Leakage Control

1) The active control for the DMA meant a periodical and regular reporting of the values of the minimum night flow (MNF), as well as the pressure in the distribution network. To monitor pressure, we determined beforehand the location of 12 control points, predetermined by means of EPANET (Figure 8), (Figure 9). For each point, manual pressure measurements were made and the values were recorded both in a table and a graphical format, before and after each significant event. (Graph 11) (Table 5)

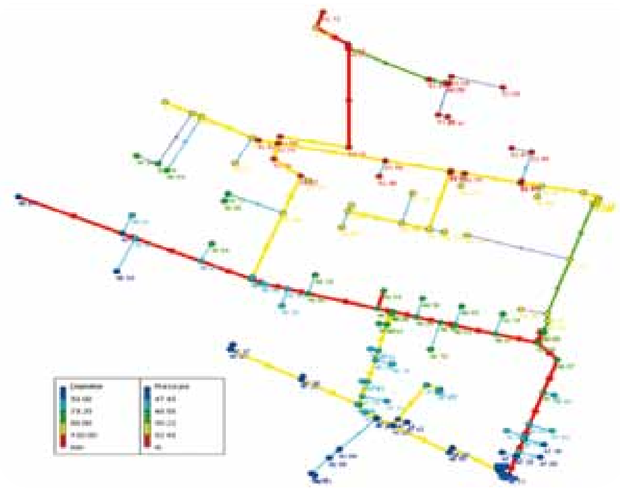


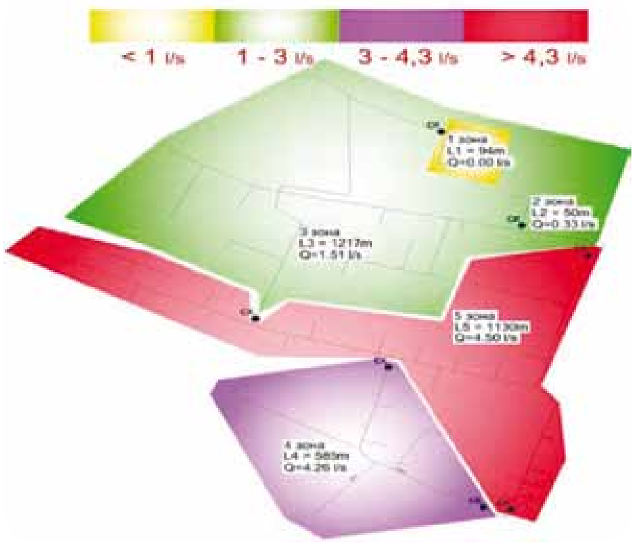
Figure 8 Kooperativen Pazar DMA - EPANET

Figure 9 Control points for Kooperativen Pazar DMA

2) The conduction of a STEP TEST aimed the localization of possible failures (leaks). Using the existing working stop valves, we subdivided the DMA into 5 sub-DMA's for the purpose of monitoring. We determined in advance for each area the length and the materials, of which the water-supply mains were made. The test revealed, through the step-by-step shutting-off of the sub-DMA's during the small hours of the night 1:00 – 4:00h (Pictures 7 and 8) and SCADA monitoring, how many l/s from the minimum night flow were owning to failures in each sub-DMA.

Picture 7 Step test in Kooperativen Pazar DMA

Picture 8 Step test in Kooperativen Pazar DMA



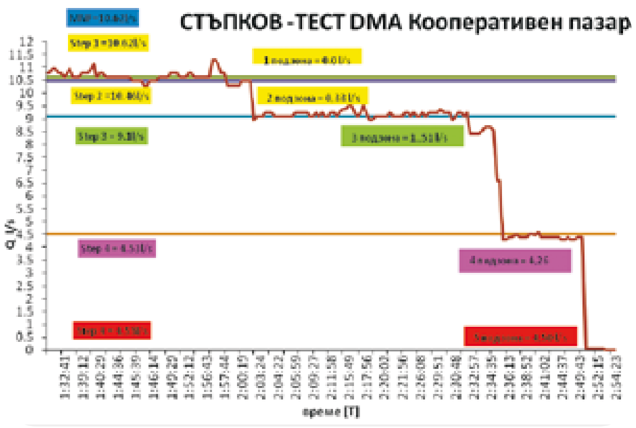
SUB-AREAS
Area 1 - 0,00 l/s - L1=94m
Area 2 - 0,33 l/s - L2=50m
Area 3 - 1,51 l/s - L3=1217m
Area 4 - 4,26 l/s - L4=1130m
Area 5 - 4,50 l/s - L5=585m

Figure 10 Step test in Kooperativen Pazar DMA

The test carried out, it was established that there were 2 sub-areas with high water losses. Table 4 exemplifies the allocation of losses in %.

Sub-area	Water losses (l/s)	L of sub-area (m)	Losses (%)
1	0.00	94	0
2	0.33	50	3
3	1.51	1217	14
4	4.26	585	40
5	4.50	1130	42
Σ	10.60	3076	100

Table 4 Water losses by sub-areas – Zero test results



Graph 8 Step test in Kooperativen Pazar DMA

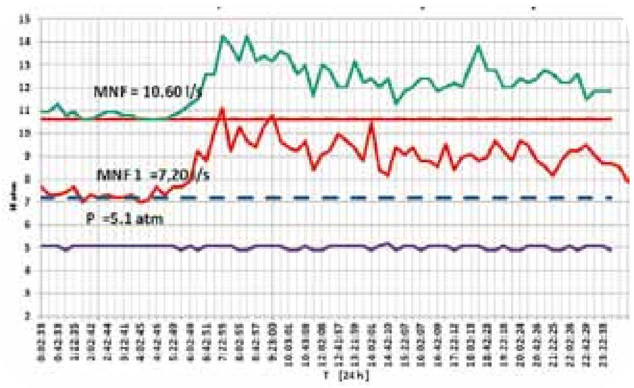
Based on the step test data, it was found out that 4.26 l/s were being lost in sub-area 4, in only 585 m, which indicated there was a huge leak (pipe failure). During the preparation ahead of the above mentioned test, we determined the pipe materials, which also provided a clue in finding possible failures. The water supply mains is mainly built of steel, zinc galvanized and asbestos cement pipes.

3) The next step in applying the water loss reduction programme was searching the area for hidden leaks with an electrical acoustic listening stick and a correlator. Together with a team of the Razgrad water company, specially trained and equipped for the purpose, we searched sub-areas 4 and 5, making our way along the water main branches made of steel and their associated service connections.

Picture 9 Searching in sub-areas 4 and 5 of Kooperativen Pazar DMA

Picture 10 Searching in sub-areas 4 and 5 of Kooperativen Pazar DMA

4) Following the interventions in the two areas, we discovered 1 significant leak in sub-area 5. The leak from the steel pipe was due to massive corrosion on the external side. We replaced a 3.0 m long pipe section with a PEHD Φ 90 PN 10. The effect of the repair of the leak was significant. The minimum night flow fell with 3.40 l/s – down to MNF 1 = 7.20 l/s, which in terms of percentages makes 32 % of MNF (Graph 9).



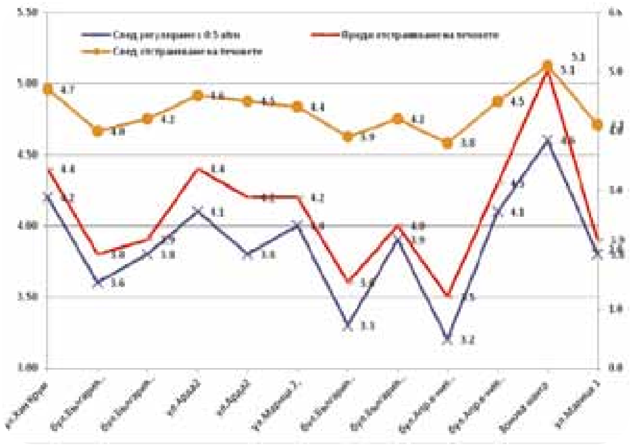
Graph 9 Kooperativen Pazar DMA MNF 1 = 7,20 l/s (SCADA)

Picture 11 Kooperativen Pazar DMA – Repair of a leak in a sub-area - 3,4 l/s

4.1.3 STEP 3 Pressure management

After the repair of the leak was done (Picture 11), network pressure was expected to rise and therefore we conducted a second pressure measurement in the above mentioned control points (Table 5), (Graph 11). It showed a rise in the free pressure in the critical point with 0.20 atm, which meant that pressure management could be applied (PM). Pressure management is widely used in international practice as a means for reducing mains leakage. It is a quick and effective method, which allows – through minimal interventions in the distribution mains (pressure regulation) – the achievement of relatively good results.

Graph 10 Pressure reduction with 0,50 atm in the DMA's chamber



Graph 11 Pressure monitoring graph in Kooperativen Pazar DMA

In this respect, we undertook Pressure Management in the Kooperativen Pazar DMA, where the pressure was reduced in the DMA's chamber with 0.5 atm, which was the maximum reduction possible in order to maintain the required pressure in the critical point. The supposed pressure, which we may maintain in the critical point in the basement of 2 Arda St, was 4,1 atm. (Graph 11).

Following the reduction of pressure, as expected, we achieved reduction of the night flow, too, with 0.4 l/s or, in other words, the minimum night flow fell to MNF 2 = 6.80 l/s (Graph 10).

As we have already mentioned earlier, the monitoring we did before and after each significant event, along with the information gathered, helped us make a table and a graph showing the variation

Number	Location where data was obtained	P at DMA's chamber	MNF	Pressure Readings, atm	P at DMA's chamber	MNF 1	Pressure Readings, atm	P at DMA's chamber	MNF 2	Pressure Readings, atm
	As shown in Figure 5			Before leaks repair			After leaks repair			After regulation of 0,5 atm
1	Han Krum St.			4.4			4.7			4.2
2	54 Bulgaria Blvd.			3.8			4.0			3.6
3	52 Bulgaria Blvd.			3.9			4.2			3.8
4	2 Arda St			4.4			4.6			4.1
5	2 Arda St			4.2			4.5			3.8
6	7 Maritsa St,	5.1 atm	10.6 l/s	4.2	5.1 atm	7.2 l/s	4.4	4.6 atm	6.8 l/s	4.0
7	27 Bulgaria Blvd.			3.6			3.9			3.3
8	25 Bulgaria Blvd.			4.0			4.2			3.9
9	62 Aprilsko Vastanie Blvd, Entrance A			3.5			3.8			3.2
10	23 Aprilsko Vastanie Blvd			4.3			4.5			4.1
11	DMA chamber			5.1			5.1			4.6
12	1 Maritsa St			3.9			4.1			3.8

Table 5– Pressure monitoring table in Kooperativen Pazar DMA

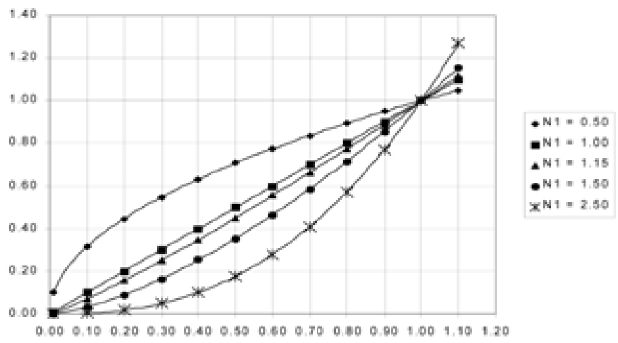
of the DMA pressure curve. It was monitoring that allowed us to analyze and start the current pressure management programme (PM)

4.1.4 Analysis of results

The water loss reduction programme implemented in the DMA with its 3 steps resulted in decrease of MNF with 3.8 l/s.

Allan Lambert and Julian Thornton, in their article on pressure management "The relationship between pressure and bursts – 'a state-of-the-art' update" in the April 2011 issue of Water 21, speak of a graphical and analytical relationship between pressure and leakage (Graph 12). In practice, for the purpose of forecasting the pressure-leakage ratio, they offer the best equation available in practice, which is based not on the difference but on the ratio of the pressure values (P1/P2).

$L_1 / L_0 = (P_1 / P_0)$ N (2)
N_1 – depends on pipe material and type of leak
L_0 – initial leakage rate, l/s
L_1 – leakage rate after pressure reduction, l/s
P_0 – pressure at initial leakage rate, atm
P_1 – pressure after pressure reduction, atm



Graph 12 Ratio of pressure to leakage rate

The above graph clearly shows that the average pressure/leakage ratio in heterogeneous systems made of mixed pipe material usually tends to (N1 = 1,0), but in case of huge leaks from metal pipes pressure/leakage ratio is (N1 = 0,5).

Based on the above relationship, we performed an analytical calculation of the amount, by which leakage rate could be reduced if pressure was reduced with 0.5 atm in the Kooperativen Pazar DMA with the assumption that N = 0.5 bearing in mind that the leak discovered was huge and was localized at a steel pipe.

5. EXAMPLE PROVING THE RELATIONSHIP BETWEEN PRESSURE AND LEAKAGE FROM THE KOOPERATIVEN PAZAR DMA:

$$P_2 / P_1 = \sqrt{(MNF_2 / MNF_1)} \rightarrow$$

$$MNF_2 = MNF_1 \sqrt{\frac{P_2}{P_1}} = 7,2x\sqrt{\frac{4,6}{5,1}} =$$

$$MNF_2 = 6,8l/s$$

Values from Graph 10:

P_1 – pressure before reduction – (5,1 atm)

P_2 – pressure after reduction c 0,5 atm – (4,6 atm)

MNF_1 – minimum night flow before reduction – (7,2 l/s)

MNF_2 – expected minimum night flow after reduction with 0,5 atm

The expected rate of the minimum night flow after pressure reduction (MNF 2) was 6.8 l/s, analytically calculated, and was a 99 % approximation of the graphical value in Error! Reference source not found., which visualizes the SCADA data.

The example showed a confirmation of the pressure/leakage relationship (N1 = 0,5) in Kooperativen Pazar DMA, which Lambert and Thornton discussed in Water 21 of April 2011.

The measures put in place for reduction of water losses in Kooperativen Pazar DMA, such as approaches developed by the International Water Association, brought about significant results – savings of 9 850 m3/month or, in financial terms – 4 925 BGN (≈ 2 462 €) per month, with the cost of water being around 0.5 BGN/m3 (0.25 €/m3). The initial investment of 6 200 BGN (3 100 €) will be paid back by the revenues from the savings for just over a month. We demonstrated that the analytical relationship between pressure and leakage held true for the DMA in our experiment and this is likely to be so for the water-supply networks in Bulgaria.

6. CONCLUSION

The Active Leakage Control and the Pressure Management applied in the four DMA's ultimately resulted in savings of 6.7 l/s, or the total minimum night flow fell to 25.7 l/s, which is a 5% decrease in the amount of water input into the DMA's.

Environmentally, following the interventions performed, a total of 579 m3 of water per day is being saved, which is reflected in saving 286 BGN/day. The costs incurred for the whole project (27 200 BGN) are expected to be returned in 95 days from the moment of bringing the real losses down with 6.7 l/s and maintaining this level. In other words, as of now, the initial investment has been returned.

References:

Lambert, A. and Thornton, J., The relationship between pressure and bursts – 'a state-of-the-art' update, Water21, April 2011

MONITORING WATER NETWORKS USING EXISTING METER DATA

A growing number of water utilities worldwide are taking a data-driven approach to managing and controlling their networks. Flow and pressure meters are being deployed, telemetry and SCADA enable the data to be collected in increased frequency, and the analysis of data by experts is now more commonplace than ever before.

But this trend gives rise to new challenges faced by the data-rich utility. Growing quantities of data have to be handled, analysed and correlated; the requirements from data analysts are increasing (but not all utilities can maintain a sufficient number of experienced analysts), and 'shortcuts' such as night-flow analysis or fixed-bound alerts bring with them the need to deal with numerous alerts, false alarms, and data-gaps caused by meter faults, transmission errors, GIS mismatches etc.

Several companies with data analysis expertise have attempted to address these challenges. TaKaDu, a young company specializing in automated algorithm-based analysis of data, has developed a web-based service turning utilities' data into real-time alerts on water loss, network inefficiencies and faults. The company's claim to fame – owing to specially developed algorithms leveraging mathematics, statistics and high-performance computing, it is able to provide accurate alerts without requiring a human analyst to look at the raw data. Utilities already using this Water Network Monitoring service report high geographical accuracy, a significantly reduced number of false alarms while never missing an event detected by other methods, and most importantly: days, sometimes weeks of early alert as compared with the utility's best practices.

How does the solution work?

Data from the utility's existing flow and pressure meters, including historical data, is sent to the TaKaDu servers and processed together with GIS records and repair records. The system also takes into account external information such as calendar events (holidays and special events) and weather data. Based on this information and the ongoing data transmission from available meters in the network, the TaKaDu system establishes the 'norm' – the predicted behavior in a particular area or DMA – considering not only the historical patterns but also spatial comparisons and correlations between different parts of the network. If a deviation from the norm is detected, the system looks for benign explanations for this change, and only if no such explanation is found, the system classifies the event (over 30 different event types can be alerted upon), indicates its magnitude and location, and assigns it to the relevant person in the utility.

TaKaDu alerts are delivered through a web interface and over email, to the user's PC or mobile device. In addition to the alerts, TaKaDu allows managing the event lifecycle, changing statuses, assigning to other people in the utility, and managerial dashboards enabling utility executives to get a bird's-view picture of the events in the network, and to easily drill down from the big picture into a specific DMA or event.

The service is used by water utilities across the globe, from Australia to Chile. In addition to water savings resulting from early detection, utilities using TaKaDu report operational efficiency gains both in the back-office (making data analysts more efficient) and in the field operations (sending detection and repair crews earlier, to the right place, with complete information about the event they are looking for), quick resolution of network inefficiencies (Breaches, valves opened or shut by mistake), increased visibility owing to fast detection of meter faults, and more benefits depending on the utility's specific needs.

The company has adopted a Software-as-a-Service model. The light footprint (no hardware and no software to install, everything done over a secure internet connection and the computer's web browser) makes a TaKaDu deployment much quicker and easier to compete than any system in the utility.

TaKaDu allows water utilities to make the most out of meter and sensor data already collected by the utility, but it can also provide recommendations as to the optimal location of additional sensors that will further increase the detection resolution.

More information can be found online: www.takadu.com or by contacting the company via email (info@takadu.com).

WATER BALANCE – FROM THE DESK TOP TO THE FIELD

Summary: Have you ever wondered what you do with the water balance after the various components have been calculated? Or how you can use the numbers to work out an investment strategy and an action plan and how to prioritise your actions in order to get the best return on your investment? This paper shows how the water balance can be used to derive an action plan for reducing non-revenue water as well as the relevant returns on investment for each action. Also it gives a full working model of how the Water Balance is taken to the next stage.

Furthermore it details the actions that are appropriate to be taken for each one of the above main components of the water balance in order to reduce non-revenue water and provides justification for each action proposed. It also expands on current thinking and knowledge in the planning and prioritisation of non- revenue water reduction options that are available to water utilities and recommends a basic action plan matrix.

Keywords: Water Audit, NRW reduction strategies, NRW action plan matrix

Introduction

Most water utilities use the water balance to calculate non-revenue water and to find the amount of water being lost. It is obvious that this is extremely useful and must be worked out in order to have a clear picture and to account for each constituent component of the water balance.

The planning of non-revenue reduction activities to be carried out and ultimately the compilation of an action plan are based on the findings of the water balance and in particular on the main components, namely, Authorised Billed Consumption, Unbilled Authorised Consumption, Apparent Losses and Real Losses. Depending on the amount of water which is being lost in each one of the above components which comprise the Non- Revenue Water, the action plan is targeted in order to provide the best return with the minimum of investment in the shortest time possible.

Accountability of water is extremely important in this process. This is achieved through a validated Water Audit which could be carried out internally by experience water utility personnel or by external auditor.

Water Audit

A water audit is a thorough accounting of all water into and out of a utility as well as an in-depth record and field examination of the distribution system that carries the water, with the intend to determine the operational efficiency of the system and to identify sources of water loss and revenue loss. It should include but not limited the following (Manual 2, Water Audits p9):

- A thorough accounting of all water into and out of a distribution system.
- A Water Balance calculation including inspection of system records and data verification.
- A meter testing and calibration program.

A water audit is a critical first step in the establishment of an effective water loss management program. With the successful completion of a system water audit, the utility gains a quantified understanding of the integrity of the distribution system and begin to formulate an economically sound plan to address losses. Water loss in a public water system can be a major operational issue. Non-revenue water components can significantly affect the financial stability of the utility. Addressing the issues associated with the non-revenue components will certainly entail a significant cost for the utility. The economic trade-offs between value of lost water given it generates no revenue and the investment to reduce this loss requires careful planning and economic judgment. The utility needs to clearly understand the type of loss as well as its magnitude. Water resource, financial and operational consequences must be weighed when considering these issues and the decision taken is unique to every system.

A brief summary of the main steps to perform an initial water audit is given below for ease of reference:

1. The amount of water put into the distribution system is determined.
2. The authorised consumption (billed + unbilled) is obtained from records.
3. Water losses are calculated (water losses = system input – authorised consumption).
4. Apparent losses are estimated (theft + meter error + billing errors and adjustments).
5. Real losses are calculated (real losses = water losses – apparent losses).

The above steps are an example of a **top down** audit, which starts at the "top" with existing information and records. It may also be known as a desktop audit or paper audit since no additional field work is required. Distribution systems are dynamic. The audit process and water balance has to be periodically performed to be meaningful to a utility's water loss management program.

After performing an initial top down audit it may become evident that some of the numbers are approximate estimates and inspire little confidence in their accuracy. The next action in the audit process is to refine the quantities that may have been initially estimated and begin reducing non-revenue water losses. A **bottom up** approach is often implemented after top down audit has been completed which can help in identifying the real losses component more accurately thus adjusting the initial Apparent losses estimate. A bottom up approach will help with finding real losses and begins by looking at components or discrete areas in the distribution system. It also assesses and verifies the accuracy of the water loss data associated with individual components of the distribution system.

It is important to stress that although utility personnel are well experienced and are familiar with the operational characteristics of the network it may be worth while having an external or independent audit carried out. External audits are usually an excellent way of helping water utilities to analyse and improve their data. It must stressed the external audits are an independent process, ensure accurate reporting, improve data collection and accuracy by identifying statistical and reporting errors and is an excellent method of helping utilities to improve their performance.

There are many types of audits that will analyse water use, from distribution system balances to household reviews. The accuracy of results depends on the methods used to generate the data. Audits have an important part to play in the development of strategic action plans for water efficiencies and financial savings as well as short and long term management. Therefore it is vital they are undertaken in ways which ensure that the most accurate data possible is generated (Queensland Environmental Protection Agency / Wide Bay Water, Manual 2, Water Audits p43).

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorised Consumption</td><td rowspan="2">Billed Authorised Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Metering Inaccuracies and Data Handling Errors</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakae and Overflows at Utility's Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to Point of Customer Metering</td></tr>
</table>

Figure 1, IWA Water Balance

Assessing Losses – IWA Water Balance

A significant contribution to reaching the point of water accountability was the establishment of the IWA Water Balance (Figure 1) which is a useful tool in analysing the various components of water production, storage and distribution. Through this analysis the utility will gain an understanding of the magnitude of the water loss problem and will set priorities for rectifying the situation based on the component analysis of the Revenue and Non-Revenue Water elements.

The findings from the water balance and in particular its main components should:

- Assist in estimating the best return with the minimum of investment in the shortest time possible
- Form the basis for planning NRW reduction activities
- Provide sufficient information for an effective action plan

It is strange however, that for a number of reasons instead of following the above desired results a different approach is adopted which follows the steps below:

- Limited and / or unreliable data is used
- Calculate non-revenue water
- Find the amount of water lost
- Do not like the outcome
- Change assumptions made to suit
- Management 'blaming' staff for not doing their job
- Employees pointing out lack of funding, commitment and support by management
- Finally, work out figures to suit management and employees

Obviously the above approach will result in serious problems for the utility and it must be avoided at any cost. The Water Balance is a useful tool which if used correctly it will certainly point the way to the actions and measures that need to be taken to reduce NRW. Answers to the questions below will take you to the next stage from the desk top to the field environment.

- Have you ever wondered what you do with the water balance after the various components have been calculated?
- Or how you can use the numbers to work out an investment strategy and an action plan?
- Or how to prioritise your actions in order to get the best return on your investment?

Answers to the above questions and what could be done with the water balance will be demonstrated using examples from case studies.

Case Study Examples

Top Down Approach

In this example the constituent components of the water balance are entered into the water balance using absolute volume figures and working out the corresponding percentage figures. It is this percentage figures which are usually quoted and has to be stressed that they could be misleading as a performance indicator since they are strongly influenced by consumption as well as changes in consumption.

The Non Revenue Water is often expressed as a percentage of the System Input Volume. However, a true financial performance indicator needs to reflect costs as well as volumes. An improved financial indicator can be used by converting the Non Revenue Water Volume to values. An example is shown in Table 1 below where the NRW volumes in the above Water Balance were converted to values using the corresponding unit value for water. The unit value for Unbilled Authorised Consumption and Apparent Losses is usually the average sale price of water to customers. The unit value for Real Losses is usually taken as the marginal cost of water that is the unit cost of producing and distributing water into the network or bulk charge whichever is the higher.

	Components of Non- Revenue Water	Assessed unit value of NRW component	Assessed total value of NRW component	
Non-Revenue Water 1 768 862 m³	Unbilled Authorised Consumption 59 928m³	1,2 € / m³	€ 71 914	Assessed total value of Non-Revenue Water € 1 127 436
	Apparent Losses 299 639m³	1,2 € / m³	€ 359 567	
	Real Losses 1 409 295m³	0,8 € / m³	€ 1 127 436	

Table 1: Converting NRW Volume Components to Values

From Table 1 it can be seen that the Real Losses have the biggest financial loss for the utility and it is evident that this area is critical and should be examined further. This examination should provide proof that repairing the leaks and savings this amount of water which is being lost makes financial sense for the utility. In order to arrive at this result the following methodology needs to be followed.

From the top down analysis in Figure 1 the amount of detectable losses are 1047938 m³. This figure is equivalent to a Night Line reduction of 1047938 m³ / 365 days / 20 hrs= 144 m³/hr. Assuming an average leak of the order of 1.6 m³/hr then the number of equivalent leaks that should be located and repaired is 90. Given that the network length is 345 km it works out that there is on average 1 leak every 3.83 km. Assume a leakage detection team comprises 2 technicians with an average output of 2.5 km per day, 5 day working week and a weekly charge of €5000/week. The average number of leaks found by the team per week is 5 x 2.5 /3.83= 3.26, say 3 leaks found per week. The total time required to find all leaks will be 90 leaks / 3= 30 weeks. Based on the above the following financial calculations can be made

- Total Cost for locating leaks= 30 x €5000 = €150000
- Total Cost for repairing leaks= 90 x €1500= €135000
- Water Saving = 1047938 m3 x €0.8/m3= €838350
- NET SAVING = € 838350 - € 150000 - €135000 = €553350

It obvious from the above calculation that the utility will have a considerable saving by moving forward with repairing the leaks first and an action plan to this effect should be work out.

In order to highlight a different approach to the above the apparent losses in Table 1 are increased with the corresponding reduction in the real losses. The revised figures are shown in Table 2 below.

	Components of Non- Revenue Water	Assessed unit value of NRW component	Assessed total value of NRW component	
Non Revenue Water 1 768 862 m	Unbilled Authorised Consumption 59 928m³ (0,50%)	1,2 € / m³	€ 71 914	Assessed total value of Non-Revenue Water € 1 678 917
	Apparent Losses 599 639m³ (5,00%)	1,2 € / m³	€719 567	
	Real Losses 1 109 295m³ (9,26%)	0,8 € / m³	€ 887 436	

Table 2: Converting NRW Volume Components to Values (Revised)

- In this instance the action plan needs to be different to the above for the following reasons:

System Input Volume 11.985.560 100,00%	Authorised Consumption 10.276.626 85,74%	Billed Authorised Consumption 10.216.698 85,24%	Billed metered consumption (including water exported) 10.216.698 (85,24%)	Revenue water 10.216.698 85,24%
			Billed unmetered consumption Zero	
		Unbilled Authorised Consumption 59.928 0,50%	Unbilled metered consumption Zero	Non-revenue water 1.768.862 14,76%
			Unbilled unmetered consumption 59.928 (0,50%)	
	Water Losses 1.708.934 14,26%	Apparent Losses 299.639 2,50%	Unauthorised use 59.928 (0,50%)	
			Metering inaccuracies 239.711 (2,00%)	
		Real Losses 1.409.295 11,76%	Real losses on raw water mains and at the treatment works Zero	
			Leakage on transmission and/or distribution mains 80.458 (0,67%)	
			Leakage and overflows at storage tanks 11.986 (0,10%)	
			Leakage on service connections up to the metering point 268.913 (2,24%)	
			Detectable Losses 1.047.938 (8,74%)	

Figure 2, Top down approach using the IWA Water Balance

- The Apparent Losses are almost equal to Real Losses in terms of revenue loss
- Need to deploy a strategy that will maximise benefits
- Tackle apparent losses with the minimum expenditure; reduce unauthorised consumption, meter reading and accounting errors at the first instance which will increase revenue.
- Simultaneously reduce leakage in order to save money in producing / buying less water.
- Invest savings in further reducing Apparent and Real Losses.

Bottom Up Audit – Case study to show bottom up and top down comparisons

It this example it is explained how the bottom up audit is extremely useful in complementing the top down approach. The case study data used are of the area of 'Sky' in Piraeus, Greece (Kanellopoulou, S., 2011). The main characteristics of the area are as follows:

- Length of network= 56km
- Number of consumers= 16840
- Service connections= 4000

A top down approach is carried out and the result is given in the table below. It should be noted that under the Real Losses the two main constituent components are included:

- Background Leakage on mains and service connections, and
- Detactable Losses

Description	M³ / year	Average Daily Volume (m³)
Input volume	2 898 100	7940
Construction	1 881 575	5155
Non-revenue water	1 016 525	2785
Unbilled Authorised Consumption (measured)		26
Apparent Losses (assumed 2.5% of consumption)		129
Real Losses		2630

Table 3: Top down approach for the area of Sky, Piraeus, Greece

In order to verify the assumption made for the Apparent Losses a bottom up audit will be carried out based on measured values. The Minimum Night Flow (MNF) as measured is shown in Figure 3. The Minimum Night Flow is 55 lit/sec (198 m³/hr). Based on this measured figure a bottom up audit is carried out of the constituent components of the MNF in order to arrive at the amount of potentially detectable losses as shown in Table 4.

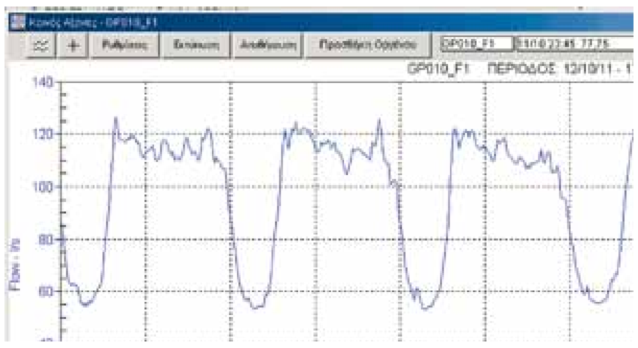


Figure 3, Minimum Night Flow Diagram for the area of Sky, Piraeus, Greece

As it can be seen from Table 4 below the potentially Detectable Losses are 2352 m³ per day compared to the overall figure of 2631 m³ per day estimated for all Real Losses in the system using the Top Down approach (Table 3).

This exercise shows that the initial assumption for Apparent Losses is reasonable and the NRW reduction plan should concentrate on reducing the Real Losses particularly in locating and repairing the leaks in the distribution network. The potentially detectable losses comprise 89% of the overall Real Losses which is of the right order considering that apart from a small percentage of Background Losses and Customer Night Use the remainder is attributed to losses in the distribution network which could potentially be located and repaired. Of course the Economic Level of Leakage must be taken into consideration in deciding how much of the amount of potentially detectable losses is financially worthwhile recovering.

Description	m³ / hr	Daily (m³)
Minimum Night Flow (measured)	198	198 x 20hr=3960
Background Losses (calculated)	21	21 x 24= 504
Customer Night Use	46	46 x 24= 1104
Potentially Detectable Losses	3960-504-1104	2352

Table 4: Bottom up audit for the area of Sky, Piraeus, Greece

Benchmarking of Non-Revenue Water

It is extremely useful to have a matrix which could be used to benchmark the performance of a utility based on the NRW figures.

The authors have developed and are proposing for use an action plan matrix which is based on the percentage of System Input Volume for each constituent component of the Non Revenue Water. The action plan matrix which is shown in Table 5 provides guidance as to the general actions that could be taken depending on the percentage figure in order to reduce the NRW in each component.

Of course the proposed matrix is only a guideline and much more investigation and development of this Matrix is required. The intention is to provide a guideline as to the general actions required which could be carried out by the utility whilst collecting and validating further data and information for more detailed analysis which will result in specific water loss management strategies.

Conclusions

It could not be stressed enough that utilities must target their actions and investments in order to get the maximum benefit. To achieve this it is important to have the necessary knowhow either internally or externally in order to be in a position to justify a proposed NRW reduction action plan which above all should be financially viable and sustainable. Needles to say in order to carry out such a plan the right level of knowledge and experience are required.

So, tackle first whatever gives you the quickest revenue return which will provide money for the longer term savings – think of the returns and not get caught up in the expensive solutions because it may be more attractive.

It is important to be understood that the Water Balance is the starting point for any NRW work. This paper aims to show that this could be done at the very early stages without having to wait until DMAs, pressure management, etc. are set up and data collected and analysed.

The Water Balance provides sufficient information to assist in the drafting of a NRW master plan in order to move ahead with water loss reduction and in parallel to make strategic improvements to the network. In the past it was thought necessary, mostly in developing countries, to develop DMAs in order to drive a NRW reduction master plan. The authors are suggesting that this could be done in parallel and that in the initial stages the Water Balance is the vehicle for driving a NRW Master Plan.

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Water Balance Component	% of System Input Volume	Suggested Action
Unbilled Authorised Consumption	Up to 1%	Considered within acceptable limits
	1% to 5%	Introduce new tariffs
	5% and above	Review overall billing policy
Apparent Losses	Up to 2%	Considered within acceptable limits
	2% to 5%	Reduce unauthorised consumption, meter reading and accounting errors
	5% and above	Review metering accuracy / policy
Real Losses	Up to 5%	Considered acceptable, may be uneconomic to reduce
	5% to 10%	Reduce visual leakages and overflows at storages and fix visual network leaks
	10% and above	Improve active leakage control, effective maintenance, pressure management

Table 5: Proposed Action Plan Matrix for NRW

FIFTH INTERNATIONAL CONFERENCE ON WATER LOSS REDUCTION IN WATER SUPPLY SYSTEMS

Water loss in water supply systems is a serious problem for all urban areas around the world and it can be even worse in areas with scarcity of water. This problem deserves immediate attention and appropriate action to reduce avoidable stress on scarce and valuable water resources. Several big cities have already started programmes geared towards the step-by-step reduction of the losses and it is well known that many institutions and water and sanitation utilities have developed and implemented strategies and technologies to control leakage and water loss. These strategies have proven highly efficient and received worldwide recognition.

The conference will be held for fifth consecutive year and is considered to be the major annual water loss event in the Balkan region. This year's conference will document available know-how and best practices and will recommend new approaches for more efficient management in the field of water with a focus on water loss reduction.

The conference is supported by the European Water Resources Association (**EWRA**). EWRA is a leading European non-profit organisation aiming at the enhancement of cooperation and the exchanges in application and research on all aspects of water resources. EWRA's activities include organisation of conferences, symposia and training courses, publication of journals, bulletins, conference proceedings and newsletters, as well as expert knowledge networks. Further information regarding EWRA can be found at www.ewra.net. **The conference** will be held on **19th November and 20th November** (morning**)**. It is aimed at decision-makers, experts in the water supply sector and water supply operators as well as at companies – producers or distributors of the respective equipment.

The Editorial Board of the Water Utility Journal published by EWRA will select a certain number of papers from those which will be accepted for oral presentation at the conference to be published in the first issue of the Journal in 2013. The papers to be published will be chosen based on originality, clarity, relevance, contribution to knowledge and which will present interesting solutions to water utility problems, technological innovations, practical guidelines for enhancing the efficiency of water systems as well as good practices and success stories.

OBJECTIVES OF THE CONFERENCE

To encourage the exchange of experience and information on successful examples within the different national/local programmes in improving leakage control and water losses reduction in water supply systems;

To concentrate on the most promising approaches, highlighting especially the need in institutional capacity development and the establishment of cooperation in order to apply the best available technical and managerial solutions;

To collect facts and figures and successful case stories to increase awareness and attention to the issue of water loss reduction by decision-makers and water managers;

CONFERENCE TOPICS

1. Innovative solutions to physical water loss reduction
2. Problems with apparent water losses reduction
3. Tangible target setting – how to maintain results
4. Problems related to Economic Level of Leakage

ORGANISING COMMITTEE:
Dr. Atanas Paskalev, Aquapartner Ltd., BG-chairman
Ani Sargavakian, BWA
Boycho Boychev, BWA
Pravda Mihaylova, BWA

RESULTS OF THE CONFERENCE

The 4th international conference "Water Loss Reduction in the Water Supply Systems" was held on 14-15 November 2011 in Sofia. Nearly 150 participants were registered, of them 42 international participants from 19 countries. As many as 34 presentations were delivered. Ten companies had their stands in the parallel exhibition.

The conference was opened by Dr. Atanas Paskalev, Vice President of BWA, who set out data for water losses in Bulgaria and Europe. Prof. Roumen Arsov, President of BWA, addressed the audience and underlined the importance of such events targeted at exchange of ideas and experience and contributing to the solution of challenges.

The participants were addressed also by Mr. Dobromir Simidchiev, Vice Minister of Regional Development and Public Works. "As a water engineer, I sincerely support such conferences which will bring about solutions of problems in the water sector. We all have to unite our efforts in order to reach better results", he said.

The address of Ms. Nona Karadzhova, Minister of Environment and Water, was read by Ms. Klimentina Deneva, Secretary General of the Ministry of Environment and Water. Mr. Bambos Charalambous greeted the audience on behalf of the European Water Resources Association (EWRA), which is a co-organizer of the conference.

The first session "Modern Technologies and Economic Aspects of Water Losses" included 4 presentations. The paper of Mr. Slavco Velickov of Bentley Systems International Ltd. (*Improving Efficiency of Water Distribution Systems*) was of special interest. The company has developed various software products concerning almost all activities in a water utility, like invoicing system, customer information system, GIS, water demand management and many others.

Prof. Matteo Nicolini of the University of Udine, Italy presented a holistic approach to leakage detection through a water supply system model calibration.

Prof. Gancho Dimitrov from UACEG, Sofia presented a paper concerning the pressure management in the water supply system of residential areas in the town of Burgas.

The second and third sessions were dedicated to water loss reduction (WLR) management. Nine papers were presented, concerning mainly the WLR management through pressure management. Three Greek papers summarised the results of a water loss project being developed by several Mediterranean countries.

Various papers for pilot projects and case studies were presented in the 4th, 5th and 6th sessions. Here could be mentioned the papers of Tomas Metelka, DHI, Czech Republic (*Conceptual Strategy for Minimizing Leakages in Water Supply Systems),* Bambos Charalambous, Cyprus *(Water Balance – The Next Stage)*, and Emad Masri, Palestine who explained how the Nablus municipality reduces the water losses. In the 4th session the Bulgarian expert Yavor Dimitrov reported his experience in several Bulgarian water utilities about NRW reduction and the problems related to non-accurate water metering. Several papers concerning case studies in Romania, Serbia and Bulgaria were presented as well.

Two presentations *(Ian Fitzerald, Bolton College, UK and Lutz Happich /VAG/, Andre Lammerdink / GIZ/-Germany)* stressed on the importance of training in the WLR field, while the presentation of Aleksandar Krstic, Serbia was devoted to the water operators' partnership. This topic was the subject of the WOP-SEE Steering Committee meeting on 15th November in the afternoon.

The 4th WLR conference left its mark as a truly international event attracting more and more participants each year. It was largely reflected in the Bulgarian media. Various WLR issues were debated – leakage management through pressure management, active leakage control, asset management-rehabilitation or replacement, concurrent comparisons between water utilities etc.