Southeast Europe Regional Conference

Water Loss 2019

Sep 22-24, 2019 Bucharest, Romania

Conference Proceedings

a regional event of the

IWA WATER LOSS SPECIALIST GROUP

the international water association

hosted by

ARA

Asociația Română a Apei

GOLD SPONSOR

sebaKMT

A member of Megger Group

BRONZE SPONSOR

xylem

www.waterloss2019.org

www.sebakmt.com

sebaKMT
A member of Megger Group

Intelligent systems for locating leaks and monitoring water pipe networks

- **Zone measuring / monitoring**

  Data loggers for pressure, flow and noise Level
  Ultrasonic and electromagnetic flow meters

- **Pre-location and pinpoint location**

  Correlators
  Noise level loggers
  Electro-acoustic listening equipment

- **Line and object location**

- **Completely equipped testvans**

Southeast Europe Regional Conference

Water Loss 2019

Sep 22-24, 2019 **Bucharest, Romania**

Conference Proceedings

ARA Publishing

ORGANIZER

ROMANIAN WATER ASSOCIATION

No. 202H Splaiul Independentei, Bl. 2, Section 1, Sc. A, Ground Floor, Ap. 2,

S. 6, Bucharest, România, Phone: +4 021 316 27 87/68, Fax: +4 021 316 27 88/68

E-mail: cts@ara.ro, secretariat@ara.ro

Website: www.ara.ro, www.araexpoapa.ro, waterloss2019.org

Water Loss 2019 Team:

TEHNOREDACTOR

Mihai Necșoiu

CONTENT

CHAPTER I
REGIONAL ACTIVITIES IN THE CONTEXT OF NRW

CHAPTER II
NETWORK ZONING AND DMA DESIGN

CHAPTER III
CUSTOMER METERING

CHAPTER IV

NRW ASSESSMENT AND STRATEGY DESIGN

CHAPTER V

LEAK DETECTION

CHAPTER VI
INSTITUTIONAL ISSUES

CHAPTER VII
NON REVENUE WATER MANAGEMENT

Southeast Europe Regional Conference
Water Loss 2019
Sep 22-24, 2019 Bucharest, Romania

Key Speakers

Stuart Hamilton is a qualified Civil Engineer, a Chartered Environmentalist, Chartered Manager, Fellow of the Chartered Institution of Water and Environmental Management, Fellow of the Chartered Institute of Management and a Fellow of the Chartered Plumbing and Heating Engineers. Stuart started working in the water sector in 1982 before leaving Anglian Water in 1994 to start his own Specialist Leak Detection / NRW company building this to be one of the largest privately owned company in the world prior to selling to a UK water company. Stuart continued his role is business and in 2011 purchased a technology company completing internal pressurized CCTV inspections for condition assessment and leakage control. Based on this Stuart is very hands on in the water distribution system and has completed projects throughout Africa, Asia, USA, Caribbean, Australia, Middle East and Europe. Stuart is a Fellow of the International Water Association and currently Chair of the IWA Water Loss Specialist Group having previously served as secretary and leader of the ALC initiatives group.

Bambos Charalambous is a Chartered Civil Engineer, a Chartered Environmentalist and a Fellow of the Chartered Institution of Water and Environmental Management. His experience in water related fields spans over 40 years and has worked on several projects in Europe, Africa, Asia and the Middle East. He has wide experience in urban water distribution network management, including Intermittent Water Supply, Non-Revenue Water and Water Loss Management. From 1995 to 2012 he was heading the Technical Services of the Water Board of Lemesos, a public water utility in Cyprus, with responsibilities over all technical and managerial matters, including planning, operation and maintenance of the water supply and distribution systems. Since 2012 he is a NRW and Water Utility Governance consultant and has served internationally on senior consultancy assignments with Water Utilities, IFIs and Water Associations. He is a Fellow of the International Water Association, a former chair of the IWA Water Loss Specialist Group, current Chair of the IWA Intermittent Water Supply Specialist Group and the current President of the Cyprus Water Association.

Southeast Europe Regional Conference

Water Loss 2019

Sep 22-24, 2019 **Bucharest, Romania**

Key Speakers

Roland Liemberger from Vienna, Austria, has worked on water distribution network efficiency, in particular water loss management, for the last 30 years. He has worked in more than 40 different countries, primarily in developing world. He has helped to improve water utility efficiency in cities as different as Dushanbe (Tajikistan) and Geneva (Switzerland). No water loss assessment is too small for him – and no project too large, as he has demonstrated when he designed and managed the world's largest water loss reduction project in Manila (Philippines). Roland is NRW advisor at Miya, a global water efficiency solution provider. He is a Fellow of the International Water Association where he held different positions. His main interests are water audits and the development of water loss reduction strategies.

Professor Ioan Bica is a civil engineer with 40 years professional experience. He is professor at the Technical University of Civil Engineering Bucharest, Department of Hydraulic and Environmental Protection. He has a wide range of experience in water resources management, environment politics, environment impact assessment, environment protection. He is also specialized in the area of urban water infrastructure, water distribution and waste water collection. Author and co-author of 3 patents in the field of Hydraulics and Groundwater Protection. He is author and co-author of many original projects for water infrastructure, environmental impact and risk assessment, strategic environment assessment (more than 70 studies), most of them related to water and waste water infrastructure development and rehabilitation under European Union financial support. Author and co-author of training and scientific manual related to Hydraulics and Environment Protection. He is high level researcher in Water Management, Applied Hydraulics and Groundwater management and quality protection. He is Director for UTCB of the Research projects financed under Horizon 2020 program of EU - BRIGAID - Bridging the gap for innovation in disaster resilience (2016 – 2020). He is Vice-president of the Romanian Water Association (ARA), and President of Muntenia Branch of the Romanian Environment Association (ARM).

CHAPTER I

REGIONAL ACTIVITIES IN THE CONTEXT OF NRW

EXPERIENCES IN REAL LOSS ASSESSMENT 10-YEARS AFTER IMPLEMENTING THE ILI AS DECISIVE KEY-PI IN AUSTRIA

Joerg Koelbl*, Allan Lambert**

*Blue Networks e.U., Roemerstrasse 18, A-8430 Leibnitz/Kaindorf, Austria, koelbl@bluenetworks.at
**Water Loss Research and Analysis Ltd (WLRandA Ltd), 3 Hillview Close, Hillview Road, Llanrhos, Llandudno, LL30 1SL, UK, wlranda@live.co.uk

Abstract
In 2009 the Austrian Association for Gas and Water (OVGW) published its updated water loss guideline OVGW W 63 (2009). At this time the guideline was one of the first to implement the Infrastructure Leakage Index (ILI) in Europe as the decisive key- performance indicator for real losses. Eight years later the German Association also implemented the ILI in its DVGW W 392 guideline (2017).
In the meantime, since 2009, several publications on suitable as well as on inappropriate performance indicators were published. An important publication, especially for the European water sector, is the EU Reference document Good Practices on Leakage Management WFD CIS WG PoM (2015), which promotes the ILI as the most appropriate performance indicator for real losses and explains why percentages are not suitable as technical indicator. Besides that, many other publications in the last decade focused on not using percentages as technical key performance indicator, e.g. Lambert (2015), Mercs et al. (2017).
With the experience as a consultant working with different structured water utilities of different sizes in Austria, other European countries and in countries outside Europe during the past 10 years, this paper should give an overview of successful and less successful examples of using different performance indicators for real loss assessment. Challenges of tackling persistence in using percentages will be discussed as well as needs for future improvements in real loss assessment methodologies for utilities with specific frame conditions, such as very small utilities.
Taking under consideration the utility structure for example in Austria, with a high number of small and medium sized water utilities, a key issue for the acceptance of innovative real loss assessment methodologies is seen in tailored assessment schemes reflecting the real loss situation in such small sized utilities. Therefore, it might be necessary to develop specific classification schemes for small systems. The full paper will describe current developments in customising Unavoidable Annual Real Losses (UARL) calculations for small systems, and provide a suggestion for a Real Loss classification scheme specifically for small systems.

Experiences of Austria

Austria has more than 5500 water utilities. Approximately more than 5000 of these utilities have less than 3000 service connections and can be considered as ‘small utilities’. A significant number of utilities serve less than 100 service connections. These small structures are common in most parts of Austria, especially in the Alpine regions and also in other rural regions.

The situation identified by the Austrian OVGW, during their water supply benchmarking studies (2003-ongoing) on utility and process level with more than 100 Utilities, which resulted in adoption of the ILI and litres/connection/day as the most appropriate leakage KPIs in Austria (OVGW W 63 guideline, 2009), shows, that many (small) utilities achieve low or even very low levels of leakage (ILI significantly less than 1.0). While a significant number of small systems achieve low losses, there are of course also situations where losses are high, and no proper water loss management is implemented.

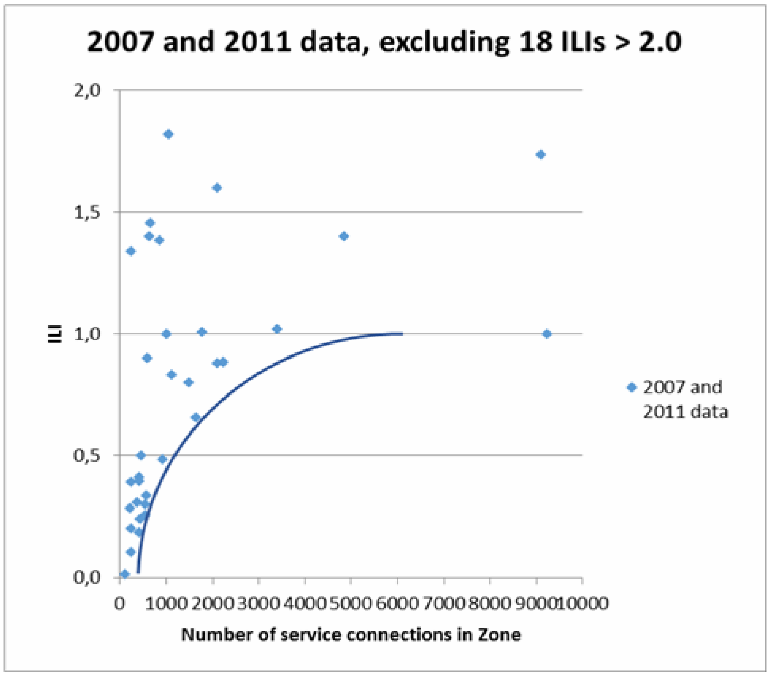


Fig. 1. Selected small system ILIs (data source: OVGW benchmarking)
Source: Austrian Small Systems Case Study, (Koelbl and Lambert, 2014, in EC Report

Anyway, the results shown in Figure 1 make clear that the widely used Leakage Performance Categories (LPCs) shown in Figure 2 are not class-divided accordingly to be sufficiently sensitive for small systems. In this discussion it has to be taken into account, that the ILI originally was designed for systems with more than 5000 service connections (compare Lambert et al., 1999).

High Income Countries ILI range	BAND	General description of Real Loss Management Performance Categories (WBI Band limits for ILI for Low and Middle Income Countries are double those for High Income Countries)
< 1.5	A1	Further loss reduction may be uneconomic unless there are shortages; careful analysis needed to identify cost-effective improvement
1.5 to < 2	A2	
2 to < 3	B1	Potential for marked improvements; consider pressure management, better active leakage control practices, and better network maintenance
3 to < 4	B2	
4 to < 6	C1	Poor leakage record; tolerable only if water is plentiful and cheap; even then, analyze level and nature of leakage and intensify leakage reduction efforts
6 to < 8	C2	
8 to <12	D1	Very inefficient use of resources; leakage reduction programs imperative and high priority
12 or more	D2	

Fig. 2. Leakage Performance Categories, (Lambert et al., 2014)

References

[1]. DVGW - Guideline W 392 (2017) Water losses in distribution networks – Assessment, monitoring, classification, water balance, performance indicators. DVGW, Bonn, Germany.
[2]. European Commission (2015): EU Reference document Good Practices on Leakage Management WFD CIS WG PoM – Main Report.- European Commission, ISBN 978-92-79-45069-3.

[3]. Koelbl, J. (2014): Learnings from implementing the IWA Methodology to National Water Loss Guidelines.- Conference Proceedings IWA Water Ideas Conference, Bologna, Italy, October 2014.
[4]. Koelbl, J. & A. Lambert (2015): Austrian Case Study: Small Utilities.- in EU Reference document Good Practices on Leakage Management WFD CIS WG PoM - Case Study document, European Union, Brussels, ISBN 978-92-79-45070-9.
[5]. Lambert, A. (2009): Ten Years Experience in using the UARL Formula to calculate Infrastructure Leakage Index.- IWA Specialist Conference 'Waterloss 2009',Cape Town, South Africa.
[6]. Lambert, A. (2015): Article 'Leakage Indicators fit for purpose' for Special Report on Water Losses (Dossiê especial Perdas de Água). March 5th 2015 edition of Água&Ambiente" (Water&Environment) Magazine, Portugal.
[7]. Lambert A; Brown T G; Takizawa M; Weimer D (1999). A Review of Performance Indicators for Real Losses from Water Supply Systems. AQUA, Dec 1999. ISSN 0003-7214
[8]. Lambert, A., B. Charalambous, M. Fantozzi, J. Kovač, A. Rizzo and S. Galea St John (March 2014): 14 Years' Experience of using IWA Best Practice Water Balance and Water Loss Performance Indicators in Europe. Vienna, Austria, 1st April 2014, IWA Water Loss 2014.
[9]. Lambert, A., Koelbl J. & D. Fuchs-Hanusch (2014): Interpreting ILIs in Small Systems.- Conference Paper at Water IDEAS 2014 Conference, Bologna 22-24 October, 2014.
[10]. Merks C., Shepherd M., Fantozzi M. and A. Lambert (2017): NRW as a % of System Input Volume just doesn't work!.- PI 2017 Conference of the IWA benchmarking and performance assessment group in Vienna, Austria, May 15-17 2017, Presentation.
[11]. OVGW Benchmarking reports, OVGW, Austria, www.trinkwasserbenchmarking.at
[12]. OVGW W 63 (2009): Water Losses in Water Supply Systems: Assessment, Evaluation and Measures for Water Loss Reduction. - OVGW Directive, OVGW, Vienna, Austria.
[13]. Professionals abandon %s of System Input Volume. (2015) http://www.leakssuite.com/kpis-fit-for-purpose/pros-abandon-percents-of-siv/

Keywords
Real Loss Assessment, Infrastructure Leakage Index (ILI), Small Systems.

TOWARDS REDUCTION OF NRW IN ALBANIA

Enkelejda Gjinali*, Bambos Charalambous**

*Polytechnic University of Tirana, Albania, enkelejda.gjinali@gmail.com
**Hydrocontrol Ltd, Limassol, Cyprus, email: bcharalambous@cytanet.com.cy

Abstract
The issue of IWS, when viewed as non-revenue water (NRW), and further considered from the perspective of hydraulic management of a water supply system, is one of the major problems when it comes to continuity of service and the unit cost of water supply in many developing countries. Continuous water supply concept is unknown, has no tradition, there is no legislation for mandatory supply on a 24x7 basis etc. in many countries practicing IWS. In many cases getting through the management hierarchy the message for integrated actions to achieve 24x7 is nearly impossible in our reality.

Keywords
IWS, Non-Revenue Water; metering system; illegal connection, energy costs.

Summary

Data collected from several utilities suggests that in a many cases poor management practices are employed, there is lack of lack of regulation and inconsistent water utility practices. This paper is based on the above perspective and viewed it more specifically through the lens of the situation in Albania where the authors have particular experience. Based on data provided by countries that contribute voluntarily to the World Bank's IBNET program, a number of countries in the Greater Balkans, such as Albania, Kosovo, Montenegro, Bosnia-Herzegovina, Macedonia, and Moldova have NRW values, in recent years, in the range of 45% to 70% of and the continuity of service ranges from 2 up to 18 hours/day.

The authors seek to emphasize that from their experience, IWS in Albania would require a long term strategic planning in order to transition to 24x7 and initially it would be beneficial to focus on improving bulk and customer metering in order to reduce commercial losses, and to gradually improve the hydraulic management of the water supply schemes. A survey is prepared by the authors to start creating a baseline on the Intermittent Water Supply (IWS) in Albania. The Survey is populated with data from 50 hydraulic systems and a report will be prepared followed data analysis.

The benefit, initially, of aggressively pursuing IWS as a hydraulic management of water supply system issue, is that it has the highly leveraged potential to reduce energy costs in largely pumped systems, as well as increase revenues, where unregistered customer connections are known to be common practice. In addition, the authors will stress the importance of training water utility staff in the use of relatively simple, but effective hydraulic management of water supply system. The findings, interpretations, and conclusions expressed in this paper are entirely those of the authors.

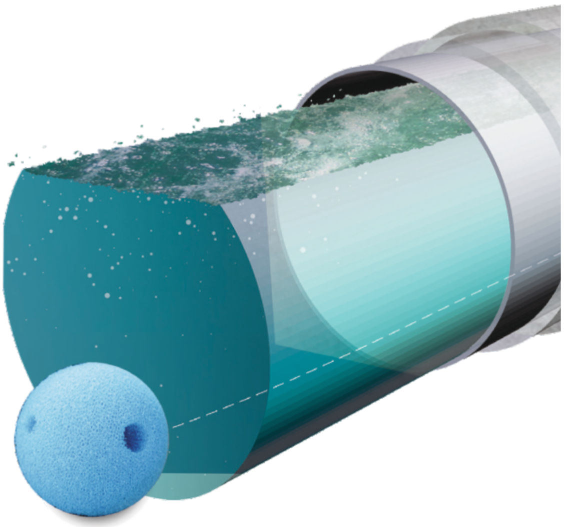
CHAPTER II

NETWORK ZONING AND DMA DESIGN

xylem
Let's Solve Water

SmartBall® Technology

A FREE-SWIMMING TOOL FOR LONG DISTANCE WATER AND WASTEWATER INSPECTIONS



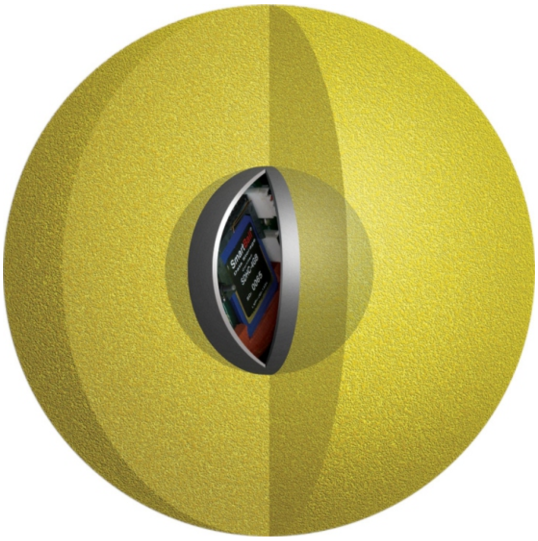
How SmartBall works?

The SmartBall® platform is a free-flowing tool for the assessment of pressurized water and wastewater pipelines 8 inches and larger. It can complete long assessments in a single deployment without disruption to regular pipeline service.

The tool is inserted into a live pipeline and travels with the product flow for up to 21 hours while collecting pipeline condition information. It requires only two access points for insertion and extraction, and is tracked throughout the inspection at predetermined fixed locations on the pipeline.

Applications

Owners of water and wastewater pipelines deal with a variety of infrastructure challenges; the SmartBall platform can collect a variety of pipeline condition information in a single deployment that helps owners manage their assets more effectively.



Leak Detection

The tool is equipped with a highly sensitive acoustic sensor that can detect pinhole-sized leaks on pressurized pipelines. The SmartBall platform has been able to identify leaks as small as 0.028 gal/min (0.11 liters) and has a typical location accuracy of within 6 feet (1.8 meters).

Gas Pocket Detection

The acoustic sensor is also able to identify the sound of trapped gas within pressurized mains. The presence of trapped gas can adversely affect pipeline flow or lead to degradation of the pipe wall in sewer force mains.

Inspection Benefits

- Easy to deploy through existing pipeline features
- No disruption to regular pipeline service
- Can complete long inspections in a single deployment
- Highly sensitive acoustic sensor that can locate very small leaks
- Can identify features relevant to the operation and mapping of the pipeline
- Indicates the position of leaks, and gas pockets relative to known points

xylem
Let's Solve Water

Pure Technologies, a Xylem Brand
EN 247, Edifício Jonobras, Sala 3, Piso 2
2670-027- Santo Isidoro, PORTUGAL
Tel +351 261 863 159
www.puretechltd.com

CEFAIN
Partener Service Autorizat FLYGT
www.cefain.ro

pure TECHNOLOGIES

DMA ZONING AT REGIONAL WATER COMPANY PRISHTINA-PRISHTINA DISTRIBUTION NETWORK

Ilir Abdullahu*

*RWC Prishtina, CEO, ilir.abdullahu@kru-prishtina.com

Abstract
Many water utilities operate their pipe networks as an open system where water is fed from more than one Water Treatment Plant (WTP) into an inter-connected pipe network.
Generally, NRW management in an open system is undertaken in a passive manner where NRW reduction activities are initiated only when the loss becomes visible or is reported. A more effective approach is to move towards Active NRW Management where dedicated teams are established and sent out to look for water losses or other causes of NRW such as reservoir overflows, in main pipes, distribution networks up to the customer, inaccurate meter reading, and illegal connections.
Active NRW Management is more cost effective when using zones to measure the NRW, where the system as a whole is divided into a series of smaller sub-systems for which NRW can be calculated individually. These smaller sub-systems, often referred to as District Meter Areas (DMAs) should be hydraulically isolated so that dedicated team would be able to calculate the volume of water lost within the DMA. When a supply system is divided into smaller more manageable areas, the utility can better target NRW reduction activities, isolate water quality problems, and better manage overall system pressure to allow for 24/7 water supply throughout the network. These include the analysis of minimum night time flows (MNFs) into District Metered Areas (DMAs), as well as the results of active leakage control surveys carried out in District Metered Areas.
The author seek to emphasize that from his professional experience at Prishtina Regional Water Utility, the issue regarding NWR, in most of the Water companies in Kosovo and or in Albania, should focus on one of aggressive, system-wide metering from sources, to production and storage reservoir meters, through district metering areas, and finally to customer meters.
Therefore, this paper will contain network zoning and design of DMA, active control of leakages, and achieved results in water loss reduction in metered areas. The findings, and interpretations, expressed in this paper are entirely those of the author.

Keywords
Water Losses, DMA (District Metres Areas), Leak Detection, NRW.

ESTABLISHING DMAs AND MANAGING PRESSURES IN OVERPRESSURED SYSTEMS. CASE STUDY IN THE CITY OF ONESTI

Alexandru Aldea*, Marius Andrei**

* Department of Hydraulics and Environmental Protection, Technical University of Civil Engineering Bucharest, 122-124 Lacul tei Blv, Bucharest, Romania
(E-mail: aldea@hidraulica.utcb.ro)
** Head of GIS Office, SC RAJA Constanta S.A., Romania
(E-mail: marius_andr@yahoo.com)

Abstract
The City of Onesti represents a particular case in terms of water loss management and pressure management. The water network was acquired by RAJA Constanta back in 2015 in a very poor state; with operating pressure that on average yields around 7.5 bar and consequently with a high level of NRW. Taking into consideration the fact that the vast majority of the network can operate safely at a 3.5 bar average pressure, the task ahead was to find a technical solution for reducing the pressure at the desired value and at the same time to establish DMAs in order to implement a proper active leakage control.
The final solution consisted of the following measures:
• Establishing DMAs in the water networks;
• Installing up to 10 PRVs (3 of them already installed by the water company);
• Installing up to 11 small booster stations for 8 and 10 story buildings.
As a result of the proposed solution, the average pressure was estimated to drop around the desired value as can be seen in the hydraulic simulation below. One preliminary conclusion is that 75% of the water loss reduction is a direct consequence of pressure reduction while the rest of 25% represents the effect of rehabilitation works.
The additional challenges that had to be overcome were dealing with the fact that the distribution network also needs to be supply alternatively from a new treatment station. This led to the fact that main pipes of the network were not part of any DMAs, but instead they were treated as transportation pipes. This approach proved to be beneficially especially when dealing with situations where some of the PRVs needed a by-pass pipe when switching from one supply solution to the other.
Finally, the paper presents some considerations regarding de performance indicators before and after the project with emphasis on ILI (which will vary from 32 to 21 and there is perfectly good reason for this) and other water loss PIs that indicate a much greater variation.

Keywords
Water losses, DMA, pressure management.

1. INTRODUCTION

The City of Onesti was taken under S.C. RAJA Constanta S.A. management back in 2016 in a very poor state regarding water losses and general management of the network. As a result, the water company was very interested in a solution that can greatly reduce the water losses on a short term but also to provide the bases for good active leakage control and pressure management in the future. This paper presents the challenges and the results of this activity.

Several common abbreviations will be used in this paper concerning both the components of the water balance and the performance indicators, as follows:

- SIV will designate the System Input Volume that is the water volume injected into the supply system for a period of one year. The value of SIV depends on what the actual system is defined: it could represent the volume of water directly entering the distribution network or it may represent the volume of raw water that will be treated and distributed;

- NRW will designate the Non-Revenue Water for the same period. The NRW contains both the water losses and the unbilled consumption and represents the difference between the SIV and billed consumption;
- LKN indicator designates the real losses per network length (excluding connection length). Different sources refer to this indicator by different denominations and measuring units. While the *National Manual* (3) prefers LKN in cm/km/year, in *Performance Indicators for Water Supply Services* (1) this indicator is identified as Op28 and expressed in l/km/day (when the system is pressurized);
- ILI designates the Infrastructure Leakage Index and is calculated as the ration between the Current Annual Real Losses (CARL) and the Unavoidable Annual Real Losses (UARL), both expressed in l/connection/day. ILI takes into account several factors: the network length, the number of connections and the average pressure in the network according to the following formula:

$$ILI = \frac{CARL}{UARL} \quad (1)$$

$$UARL = \left(\frac{18xLm}{Nc} + 0.8 + 0.025 * Lp\right) * P \quad (2)$$

The UARL formula may seem slightly different depending on the source material, but the constants are actually depending on the measuring units for length and pressure. The Eq. (2) is using the following variables and measuring units: *Lm* represents the length of mains in km, *Nc* represents the number of connections, *Lp* represents the average length of service connection in m and *P* represents the average pressure in mWC

2. HYDRAULIC MEASUREMENTS AND WATER BALANCE

The first approach in order to quantify / estimate the physical losses in the distribution network was to compare the nigh flows values with the diurnal flow values. Also, taking into consideration the fact that the system was over-pressurized, a separate campaign was conducted at the same time for pressure measurements. The utilized equipment were ultrasonic flow meters and pressure data loggers.

Concerning the flow measurements, five simultaneous measurements were conducted as follows:

- 3 measurements on the exit pipes of Reservoir A towards the water distribution network;
- 2 measurements on the exit pipes of 10,000 cm reservoirs on the Scutarului Street (in the main manhole).

Figure 1 illustrates the flow variations for each of the five pipes:

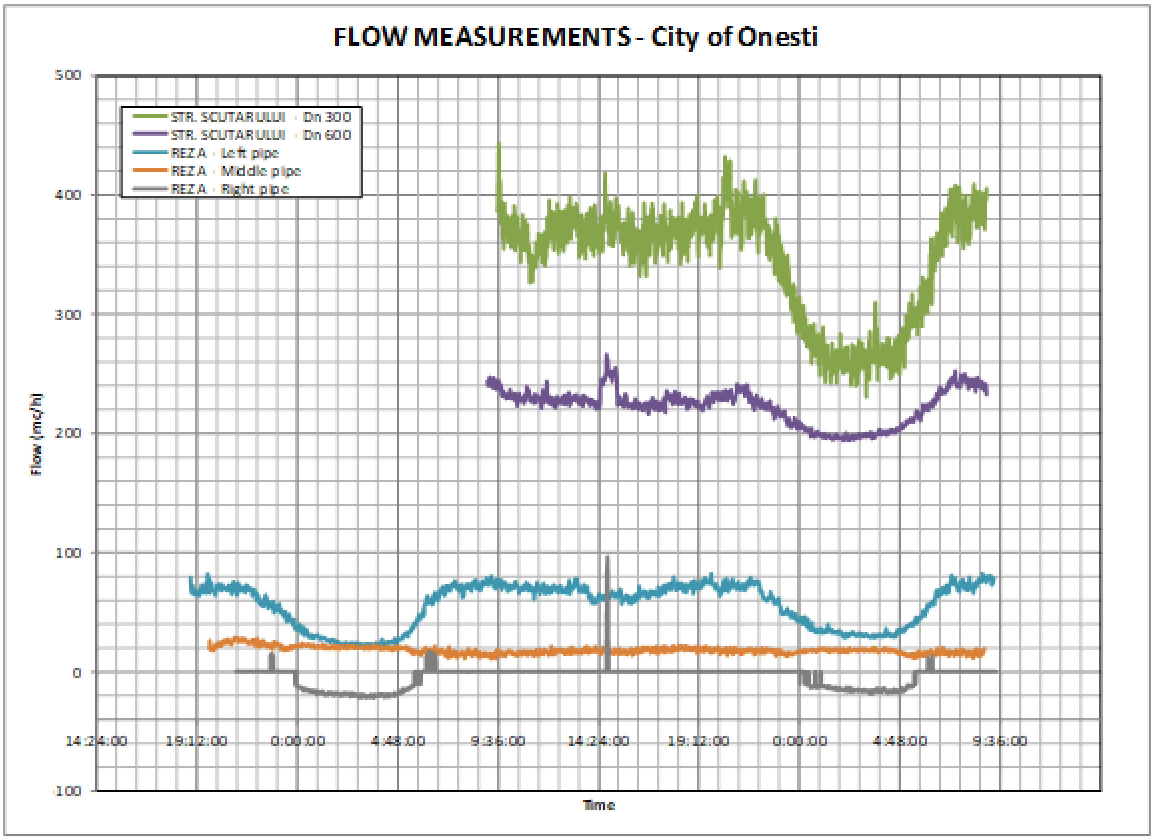


Fig. 1. Simultaneous entry points flow measurements for water distribution network of Onesti City (about 90% of the city is supplied by two pipes of DN 300 and DN 600 respectively)

For each of the five measurements a daily average and a nigh flow were calculated in order to assess the physical losses and to verify the SIV figure taken from the water company. One particular situation is represented by flow measurements from the right pipe of the reservoir, where the diurnal flow is null and the night flow is negative. For this pipe only the average daily flow was calculated. A brief analysis of the flow measurements yields some conclusions and remarks:

- The City of Onesti is supplied over 90% from only the two pipes located on street Scutarului;
- The night flows indicated and confirm a high level of physical losses;
- A possible explanation for the abnormal variation of the right pipe flow is that this pipe is normally closed by a valve that leaks during the high pressure at nighttime, which cause the reservoir to be supplied by the network instead of supplying the network. This hypothesis is supported also by the flow pattern of the middle pipe, which presents higher values in the night flow suggesting a loop between these two pipes.

The pressure measurements confirmed the high values indicated by the water company with figures as high as 7.3 bars. Since the average pressure needed for the supply network (with the exception of 30 apartment blocks) is around 3.5 bars it became clear that a pressure management is needed.

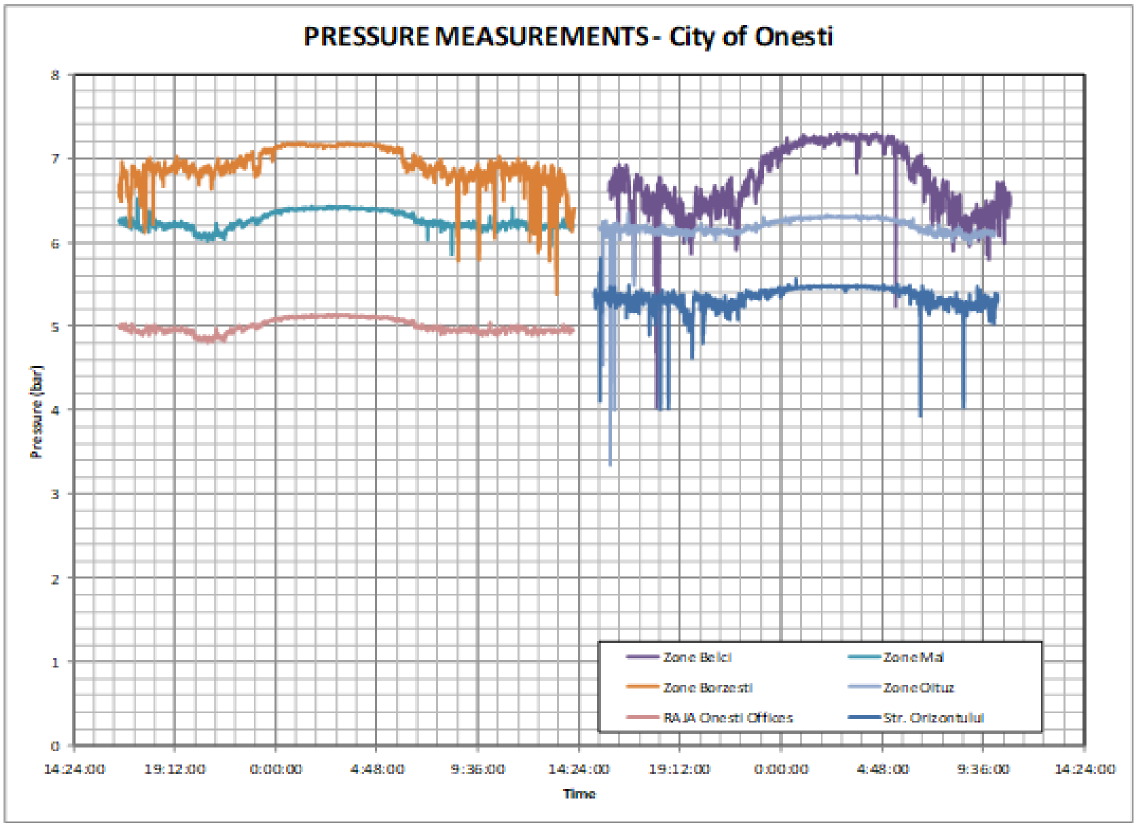


Fig. 2. Simultaneous pressure measurements for water distribution network of Onesti City (confirmation of high pressures)

3. ESTABLISHING THE DMAs

In order to ensure a good pressure management and a reliable active leaks control the water supply networks needed to be split into several DMAs. This task proved to be more challenging than initially expect due to some specific factors. One of these factors was the pressure management, which implied the solution for the DMA configuration would also have to work with the localization and settings of the future pressure reduction valves. The other crucial factor refers to the possibility of alternatively supplying this network from a new additional water source.

Finding a solution that works with these constraints took several iterations that needed to be confirmed with a hydraulic simulation.

Over the course of this activity, some general rules came into place regarding the DMA configuration and they are enumerated as follows:

- Perseveration of the main networks loops as much as possible. In this regard, the main transport pipes of the network will not be part of any DMA;
- The DMAs should follow as much as possible the existing networks configuration. In this regard the process of establishing the DMAs started with the peripheral zones of the supply network.

The zone supplied from the left pipe of the reservoir A was split into two DMAs and was not linked with the main supply network. However a new transport pipe was designed in such a way that this particular area could be supplied from either water source (the existing one and the newly proposed) irrespectively of the source supplying the main network.

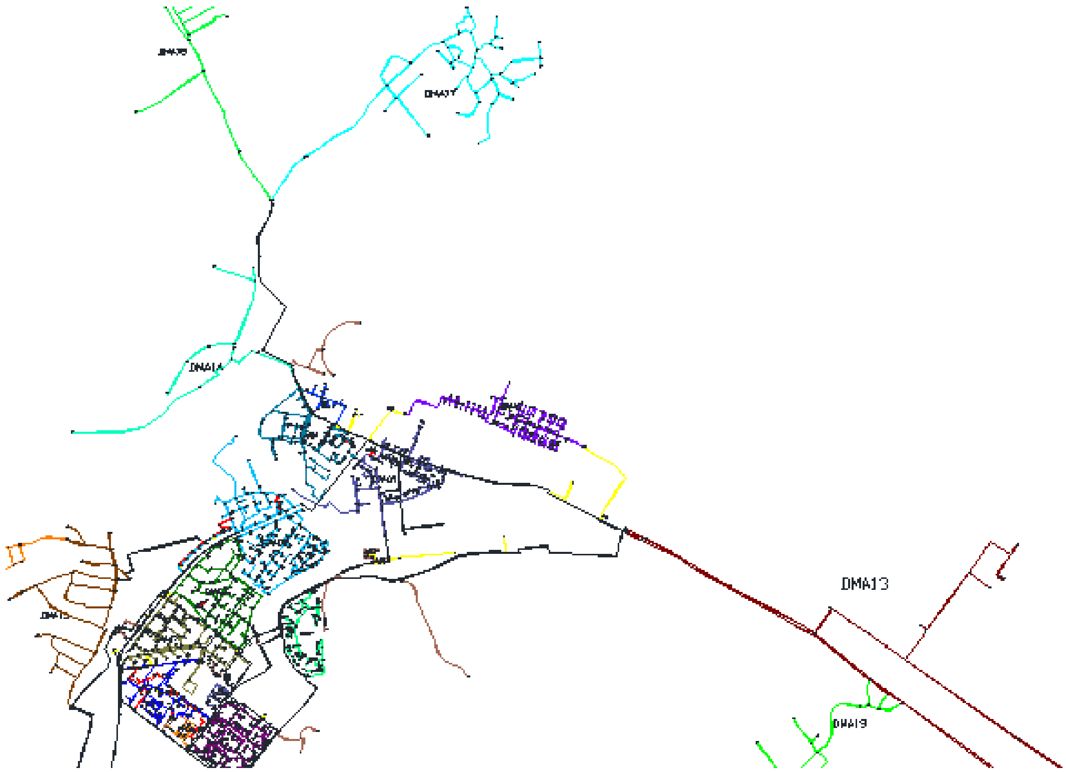


Fig. 3. Final solution for DMA configuration

The most difficult part to manage proved to be the center of the city, which presents lot of interconnecting pipes. Finding the solution for this area also required several trial and errors due the fact that the original layout of some of the existing pipes will suffer modification in the future rehabilitation process.

In other instances, in order to allocate as much as possible of the existing consumers to one DMA or another, the final solution proposed reconnecting these consumers to other main pipes. There were some situations where this idea could not be applied and in those cases the consumers were allocated to smaller areas (with up to 15 consumers) that would act in a similar fashion to a DMA. The final solution presented in figure 3 consisted of 19 DMAs and 15 small metering zones.

4. HYDRAULIC SIMULATIONS

The hydraulic simulations were a key part in the process of establishing the DMA configuration and the position of the pressure reduction valves. For the purpose of this project all of the hydraulic simulation were done with the help of Epanet for running the steady state models, but other software packages were used in order to build the model based on the DWG files.

Since there was no Customer Information System available, the demand allocation was realized based on the flow measurements but with 2 component for each node: one component for the actual demand and the other component for NRW estimation.

The hydraulic simulation of the initial situations refers to the existing situation at the time when the measuring campaign took place. Figure 4 shows the results of the numerical simulation in terms of pressure nodes. This simulation in particular was very useful because it showed a very good consistency with the measurements taken in the field.

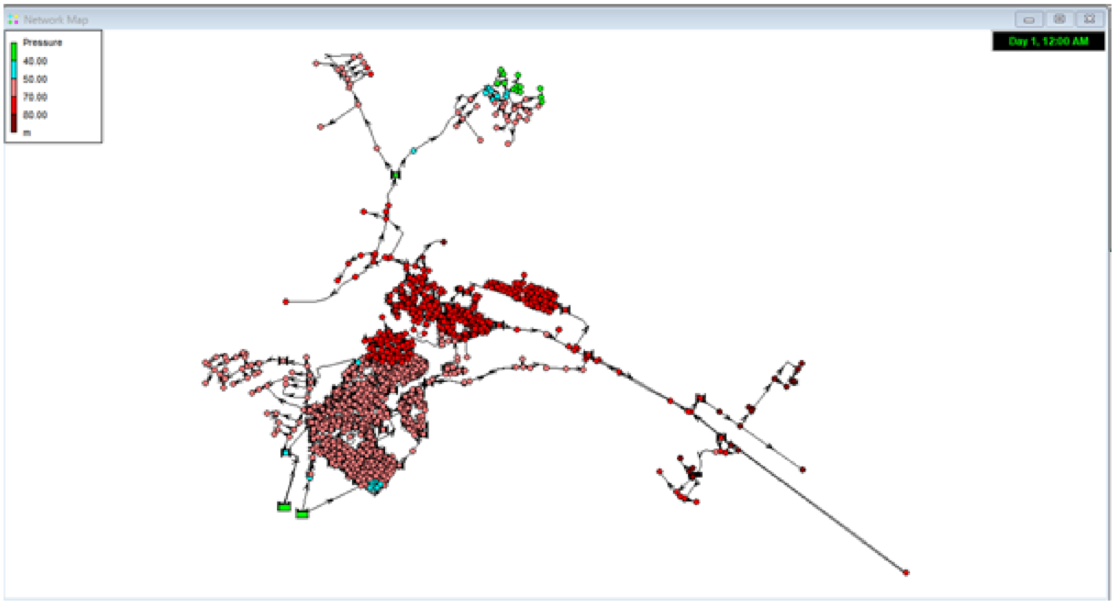


Fig. 4. Hydraulic simulation of the initial situation (very high pressures in the supply network)

Regarding the hydraulic simulation of the proposed solution, it is worth to mention that several numerical models were developed during the course of the project, but there are some share features between all of them. Firstly, the small booster stations separately commissioned by the water utility were considered as part of the final configuration. Secondly pressure reduction valves installed at different stages by the water utility were also part of the hydraulic simulation. Figure 5 shows the results of the final accepted solution in terms of pressure nodes with a much improved average network pressure.

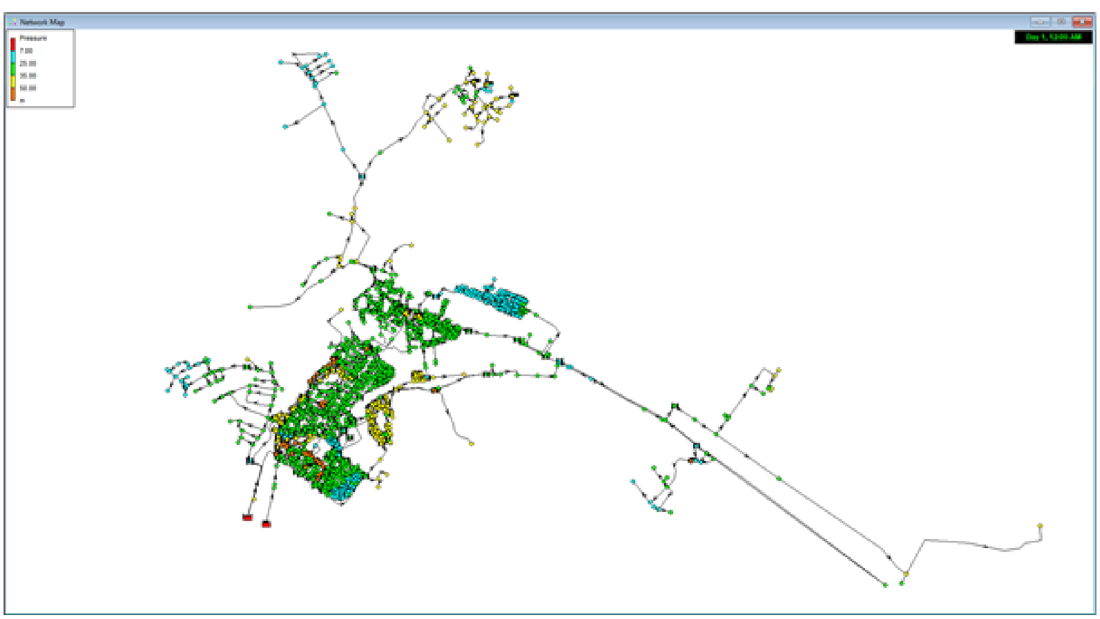


Fig. 5. Hydraulic simulation of the proposed solution with PRVs and DMAs (normal operating pressure)

5. FORECAST AND CONCLUSIONS

In terms of forecast of the total water demand and consequently the non-revenue water for the next 30 years several assumption were made in conjunction with the proposed rehabilitation solution ant pressure management.

In Table 1 are illustrated the relevant performance indicators calculated for 2017 (beginning of the project), 2021 (implementation of the project) and 2048 (30 year period). The inclusion of NRW indicator as percentage of SIV was done part as one of the project requirements but most importantly to compare it with the ILI.

Judging solely from NRW as percentage of SIV it appears that only minor water losses reduction measures have to be taken, but the ILI implies much more drastic approach. The relatively high ILI at the end of the project is a normal figure because it is a pressure dependent indicator. However, the biggest impact of the project is illustrated by the LKN indicator. It is worth mentioning that 75% of the total water loss reduction is a direct results of the pressure reduction in the network.

Table 1: Performance indicators

IWA	*Indicator*	*Units*	*2017*	*2021*	*2048*
A3	Total input volume	c.m./day	14.597	8.056	7.183
A21	Total non-revenue water	c.m./day	9.980	3.631	2.247
Fi46	Non-revenue water	%	68,37%	45,07%	31,29%
A19	**Real losses in the network**	**c.m./day**	**9.427**	**3.188**	**1.754**
Op27	Real losses per connection	l/conn/day	2.683	908	499
Op29	ILI	-	31	21	12
Op27	Real losses per km of pipes (LKN)	c.m./km/day	114	39	21

(c.m. – cubic meter)

BIBLIOGRAPHY

[1]. Alegre, H., Baptista, J. M., Cabrera E. Jr. et al: Performance Indicators for Water Supply Services – 2nd edition, IWA Publishing, ISBN 1843390515, 2007;

[2]. Liemberger, R., Brothers, K., Lambert, A., McKenzie, R., Rizzo, A., Waldron, T.: Water Loss Performance Indicators, IWA Water Loss, Bucharest, 1, 148-160 (2007);

[3]. ***: Normativ privind proiectarea, execuția și exploatarea sistemelor de alimentare cu apă și canalizare a localităților. Indicativ NP 133-2013;

[4]. ***: EU Reference document Good practices on Leakage Management, 2015;

[5]. Aldea, A.: Pierderi de apă - Estimarea indicatorilor de performanță în rețele de mici dimensiuni, Conferința tehnico-stiintifica Performanta in serviciile de apa-canal, vol. 2: Infrastructura urbana, rețele urbane, management, 29-34, ISBN 978-606-93752-2-8, 2014;

[6]. Aldea, A., Anton A.: O analiză critică a sistemelor de evaluare a pierderilor de apă utilizate în Romania, Conferința tehnico-stiintifica Efficient Use and Management of Water, 2018, Bucharest, Romania.

PARTIALLY CORRUGATED STAINLESS STEEL SERVICE PIPE REDUCES WATER LOSS

Benoît Van Hecke*, Gary Coates**, Nicole Kinsman***

* bvanhecke@nickelinstitute.org, Market Development Manager for Europe, Nickel Institute, Belliardstraat 12, 3rd floor, B-1040 Brussels-Belgium, Mobile: +32 495 58 91 77
** gcoates@nickelinstitute.org, Manager Market Development & Technical for North America, Nickel Institute - Toronto Office, Brookfield Place, 161 Bay Street, Suite 2700, Toronto, ON Canada M5J 2S1, Phone: +1 416 294 5415
*** nkinsman@imoa.info, Technical Director, International Molybdenum Association, 454-458 Chiswick High Road, London, W4 5TT, United Kingdom, Mobile: +41 79 362 1397

Abstract

Non-revenue water (NRW) is a significant problem in the majority of the world's metropoles. The total cost of NRW to water utilities is an estimated $39 billion per year (1). Water scarcity, high water cost, increase in population, droughts and climate change are key drivers for change in many of the world's areas. The losses, which for many cities are around 20 to 35%, contribute to the depletion of precious water resources. The losses are also costly to the consumer due to intensive water leak detection efforts, required repairs, lost process and pumping energy, wasted water treatment and follow-on cost such as road cave-ins and traffic disruptions. Because of leakage, the whole water infrastructure footprint of a city from intake to storage, pumping and treatment has to be larger (by more than the percentage lost), than what would be necessary to simply fulfil the water demand. Cost-effective, innovative and sustainable solutions are being called for by the global drinking water sector.

Partially corrugated Type 316L stainless steel service pipe was first developed as a solution for leakage in Japan. It is helping large cities to significantly reduce NRW and annual maintenance cost. Tokyo, Taipei and Seoul have replaced their service pipes on a large scale and some 35+ other Asian cities are following their lead. Tokyo, for example, reduced its water loss from 15% to under 3% after it replaced nearly all its service pipes over a twenty-year period. While Tokyo has also taken other measures to reduce water loss including replacement of water mains, improved detection techniques and speedy repairs, the utility credits the switch to stainless steel service pipe for most of the water and cost savings.

Details of the partially corrugated Type 316L stainless steel service line product and case studies for the Asian experience will be presented. Key requirements for successful stainless steel service pipe installation with and by local water utilities will be explained.

Keywords
Water loss, stainless steel, service pipe.

1. INTRODUCTION

Water availability and quality in cities is strongly influenced by effects of population growth, urbanization and climate change. Cities will see their share of the world's population grow up to 70% in 2050. By that time, water demand will increase by 55% compared to the year 2000, while four billion people will be living in water-stressed areas (2).

Referring to water scarcity, the World Economic Forum Global Risks Report found that the "water crisis", in terms of impact, ranked fifth in 2018 and fourth in 2019 (3). At the same time, many water utilities lose an estimated 20 to 35% of the fresh, treated drinking water they distribute on the way to the customer's tap. In Europe, the average water loss is 26% but some major cities there and in North America have reported leakage rates of 30% and more. Utilities in some of the lower GDP countries suffer water loss of 60% and even 70%. Over 40 cities were surveyed in a 2016 OECD study (4), with leakage rates ranging from 4% in Amsterdam to 65% in Tuxtla Gutiérrez, Mexico.

Many utilities try to secure additional water sources and invest in water treatment and desalination plants, when a more cost-effective solution would be reducing the water loss in their systems. Often, especially in low GDP countries, there is simply no money for infrastructure improvements, even if those improvements would help cut operating cost and recover income from water sales. However, as sustainability is becoming more important in the world, governments will be more reluctant to issue additional water rights for new water sources without proof that the waterworks have made every effort to eliminate waste in their existing systems.

Looking at the situation in the United Kingdom, the combined activity of reducing potential leakage (using pressure management), identifying leaks and subsequent repair, replacement or renovation of assets costs the water sector many millions of pounds per year. There recently have been developed a number of meaningful initiatives about reducing leakages, such as e.g. UKWIR's (UK Water Industry Research Limited) "Big Questions" which aims at achieving Zero Leakage by 2050 (5). Also, a Public Interest Commitment document was issued by Water UK during April 2019. As an indication of the investment commitment, this report reports companies' plans proposing increasing investment to over £50 billion over the next 2020-2025 asset management plan period – committing them to the most ambitious program to fix leaks in 20 years. The first commitment is about tripling the rate of sector-wide leakage reduction by 2030. As part of a wider long-term strategy to reduce per capita consumption of water and invest in more water transfer and storage, this goal represents an unprecedented rate of improvement to help meet the challenges posed to water supplies by climate change and population growth (6).

2. WATER LOSS RELATED PROBLEMS

Water losses are not just a waste of a precious resource in a sustainability context. It also means -economically - that a significant amount of water that has been collected, cleaned and disinfected, stored and distributed does not get used by the consumer and thus is not invoiced in the end. If a city grows or the traditional wells and rivers carry less water than previously, new water sources must be found, tapped, treated and stored at a cost which is, proportionally to the leakage rate, larger than necessary to simply fill the need of the population.

Other problems related to water loss can be detailed as follows (7):

- Droughts can have an enormous impact. Firstly, there is the risk of interruption of continuous water supply. According to a 2017 UK report (8), a three-month drought in 2050 (lasting 3 months) could result in the loss of 354,000 jobs and cost the economy about £35 billion if reserves of water continued to be depleted. A second drought related risk concerns ingress of bacteria and soil impurities – through the leaking system - into the clean drinking water in the pipe, thus contaminating the whole system. Systems with low leakage rates therefore are much more resilient in case of drought.
- Utilities need to have an infrastructure matching the amount of water needed to satisfy demand plus the water that disappears in the system. A large city with a leakage rate of 30%, for example, would have to build and operate ten water treatment plants, even though only seven would be sufficient to meet the needs of its citizens.
- The same applies to storage, dams and reservoirs; electricity for water transport, pressurization pumps and plant operations (water distribution uses 4% of all electricity worldwide and up to 40% of an utilities' operating cost is electricity); treatment chemicals; staff; everything must be bigger than needed.

- The same calculations also apply to the environmental impact of operating a utility, CO_2 emissions, effluents, and solid waste generated.
- In systems with high leakage rates, the maintenance cost is significantly higher, as the maintenance teams must tend to many more repair cases than in a utility with low leakage rates. That means a need for additional crews and materials and machinery for repairs. Moreover, maintenance contractors face the burden of penalties if not meeting contractually agreed execution times.
- Secondary problems caused by high leakage rates include difficulties to maintain pressure in the system, poor water flow, road cave-ins and road collapses, flooding of basements and streets and damage to building structures.
- Citizens have difficulties understanding the need for saving water in households and gardens, if the utilities lose a significant percentage of the water through their pipes.

3. WATER LOSS REDUCTION

Reducing water loss requires several measures. They include (i) the division of an area into district metering areas (DMAs) to measure and locate water loss, (ii) the vigilant search for and effective location of leaks and (iii) their repair and finally (iv) reducing water pressure, especially at night when demand is lower. The latter two turned out to be the most meaningful operational contributions to water loss reduction in the case-studies that will be presented. To really solve the problem in the long term it is necessary to replace old and leaking pipes and connections with more durable pipes, which is what this paper focuses on.

3.1. Location and origin of leaks

Utilities who have analyzed the location of leaks in their system found that over 90% of them occur in the service pipes which connect the water main to the water meter at the customer's house. These service pipes are historically made of lead, galvanized steel or various types of plastic. Newer lines are often in plastic or copper.

The origin of leaks in service pipe depends on the age and the type of pipe material, the connections, the soil and location. They include corrosion in metal pipes, cracking in plastic pipes, failure of joints, shut-off valves or ferrules, disconnection of tubes and excavation damage.

The underlying cause of many failures is mechanical impact through settling of the soil, seismic activity or vibrations from heavy vehicles passing on the street above. This can lead to loosening and even disconnection of joints, bending of metal pipes and to cracking in plastics, particularly in aged tubes and fittings. Corrosion can be caused by the soil in which the pipe is buried as well as the water inside the tube. Soil corrosiveness depends on the type and composition of the soil, its moisture and chloride contents, any dissolved chemicals, aeration, its conductivity and the location.

To reduce water loss, preventing leaks in service pipes is particularly effective, because the vast majority occur there. Service pipes therefore have to be resistant to mechanical damage and corrosion to have good longevity.

3.2. Leak detection time

Water main breaks are what comes to mind when water loss is evoked. These are the occasions where service interruption, apparently massive water loss, road digging and repair crew presence are obvious and most likely to hit the media. However, the most significant water losses come from service pipe leaks, because they typically have significantly longer running times. The International Water Association reports (9) that while a one day water main break may lose 75 m^3, an unreported service connection break may lose more than 4,500 m^3 over the six months which it takes on average for a utility to become aware of the leak. Consequently, a six-month unreported service connection break could result in forty times the water loss of a one day main break. Unreported service connection leaks, which are below the leakage detection limit of 10 to 20 liters per hour, may lose as much as 88 to 176 m^3 over a year's time. While they are not recorded (or even known), each one may silently lose more water than a main break each year it is not detected and repaired.

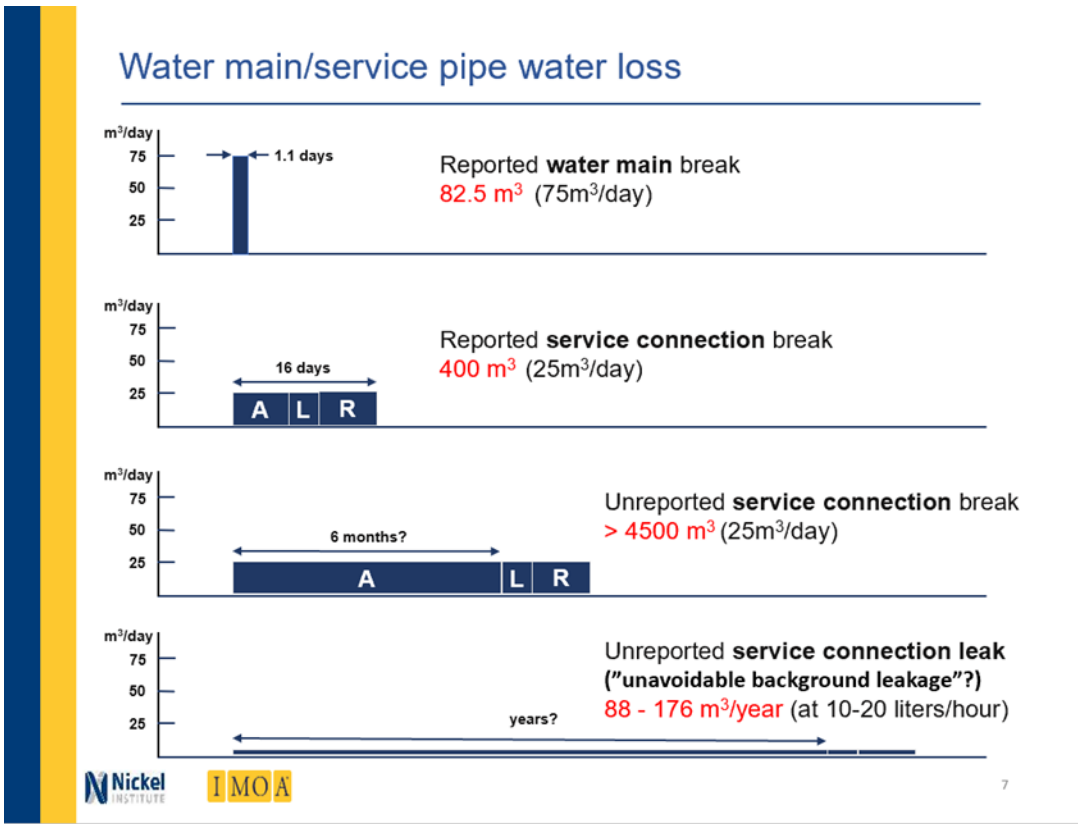


Fig. 1. Different leakage / bursting scenarios in terms of flow rate and time (adapted from IWA)

3.3. Partially corrugated service water pipes

Failing service lines and connections were thoroughly reviewed in Japan almost forty years ago. Considering various materials (such as stainless steel 304 and 316, carbon steel, lead and copper) as well as soil types, 316L came out of the comparison as the best material in terms of both corrosion resistance and mechanical properties. Initially 304L was considered but the greater corrosion-resistant properties of 316L made it the more suitable material. The first service line tubes were a straight length (not corrugated) version but there continued to be some leakages at the joints, the weakest link of the service tube. Partially corrugated stainless steel tube, developed in the 1990s, addressed this problem, for its easier installation and ground movement resistance (due to e.g. earthquakes, traffic vibrations).

Fig. 2. Service pipe made of partially corrugated stainless steel (ISSF, Philippe De Putter)

Since then thousands of kilometers of stainless steel service pipes have replaced other materials in both replacement and new construction projects. With the success of the program in Tokyo other cities like Seoul, South Korea and Taipei, Taiwan began their own projects to solve their water loss issues by replacing tubes rather than just repairing leaks. Now there are more than thirty five cities in Asia with stainless steel service pipes programs.

Seismic resistant fittings have been developed alongside. They have three times the pull-out strength of typical press fit-type fittings which makes them also extremely resistant to mechanical impact. Additionally, stainless steel is hygienic, does not affect water quality and is 100% recyclable, featuring real value at the end-of-life stage of the components.

When it comes to corrosion of stainless steels in soils (10), the process is more complex than in waters, often because of the natural heterogeneity of soils. A large amount of scientific work has taken place since the 1960s to determine the general suitability of stainless and the correct grade to be used. In general, for Grade 316L stainless steel the following conditions are suitable for direct burial in soils: (i) pH > 4, (ii) resistivity above 2000 ohm.cm and (iii) chlorides < 1,000 mg/L. In practice, the vast majority of natural soils fall within these parameters and are suitable for Grade 316L stainless steel. Disturbed, i.e. dug up or otherwise mechanically moved soils have different physical characteristics to undisturbed soils, in that the simple process of digging up a soil can cause oxidation, change redox potentials and alter chemical reaction rate. Only disturbed, aggressive acid sulphate soils and high chloride coastal soils are unsuitable, as they are for all metallic pipe systems, unless protected by wrapping or coating. Further, it is essential practice for all buried pipe and tube systems, including partially corrugated 316 stainless steel pipe, to be buried in a granular inert back fill such as clean sand.

4. CASE STUDIES

Tokyo, Taipei and Seoul are among the most well - documented examples involving nearly complete replacement by stainless steel service pipe. This has brought about a significant reduction in water loss as well as massive cost savings linked to both water and repairs.

4.1. Tokyo example

Tokyo has about 2.2 million connections, distributing 1.53 billion m^3 of water in 2016. It was determined that 97% of their repair cases were service piping related. Since the early 1980s, Tokyo has started a program using stainless steel service pipe (which was changed to partially corrugated tubes in 1998) and seismic resistant ductile iron mains while improving leak detection to reduce their water loss rate. The program resulted in a reduction from 260 million m^3 (15.4%) in 1980 to 48 million m^3 (3.1%) of water loss in 2016. At the same time repair cases were reduced from 69.000 per year to 8.600 per year. The total savings result corresponds to almost 500 million USD per year, based on the following assumptions that 212 million m^3 water saved x USD 1.70/m^3 = USD 360 million / year plus 60.400 fewer repair cases x USD 1.800 / case means USD 109 million / year.

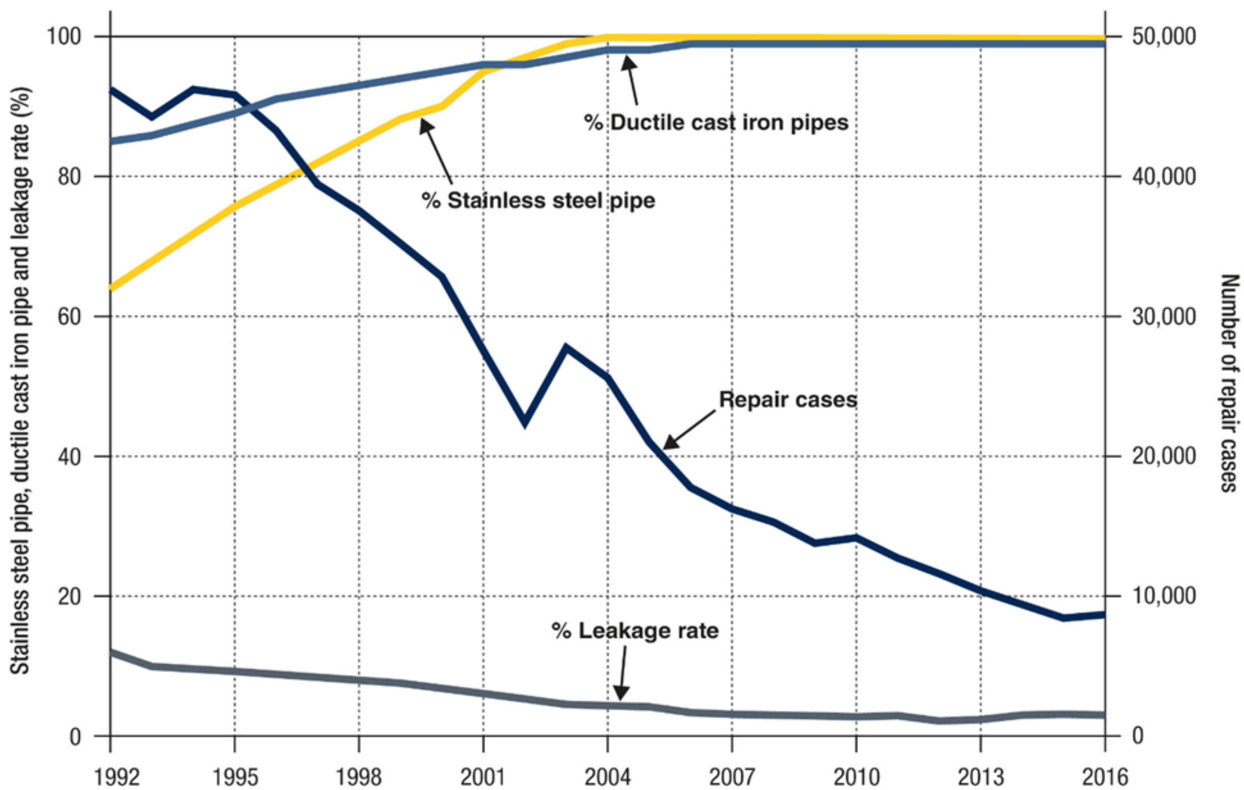


Fig. 3. Tokyo's leakage reduction efforts over time (Bureau of Waterworks/Tokyo Metropolitan Government)

4.2. Taipei example

Following a drought causing severe water shortages with intermittent water supply for 49 days, Taipei began evaluating their program in 2002. They started their 20-year 316L partially corrugated 316L stainless steel service pipe installation program in 2005. Taipei has 310.000 connections distributing 825 million m^3 of water. 95.7% of their repair cases were service piping related. The program resulted in a reduction from 365 million m^3 (27%) in 2005 to 183 million m^3 (14.2%) of water loss in 2017, 12 years into the program. At the same time repair cases were reduced from 11.300 per year to 3.000 per year in 2017. When even more severe drought conditions returned in 2014, Taipei had no service disruption, in fact it was able to maintain a surplus which was distributed to storage reservoirs and other utilities.

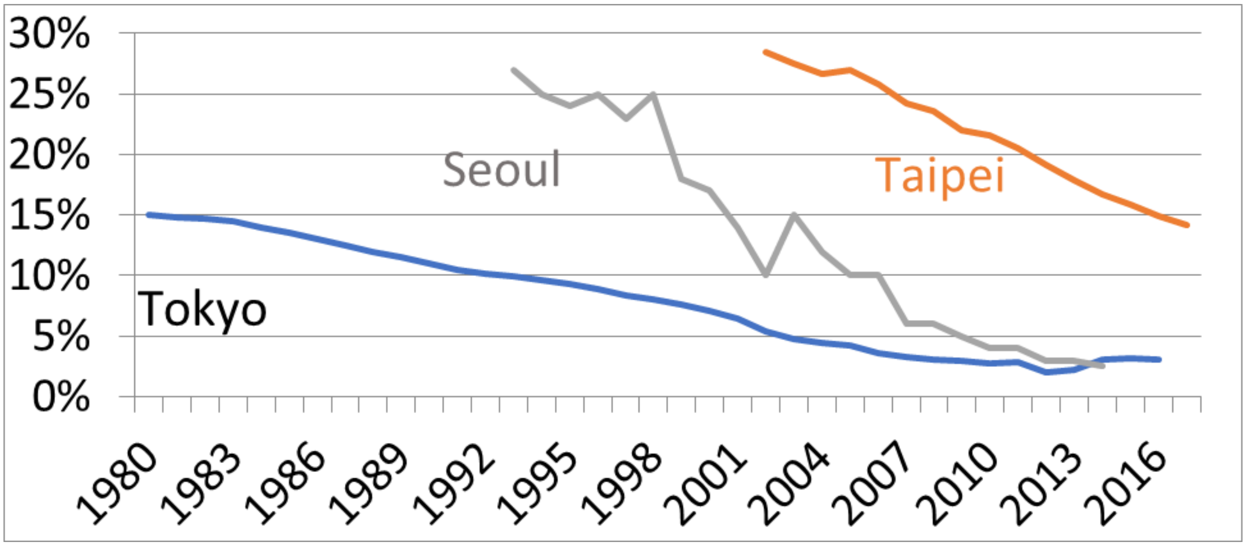


Fig. 4. Summary of leakage rates over time (Tokyo: Tokyo Waterworks Bureau; Seoul: Ministry of environment, Republic of Korea; Taipei: Taipei Water Department)

5. DIMENSIONS, STANDARD, TESTING and PILOT INSTALLATION

The most commonly used partially corrugated stainless steel service pipes are 22.2mm OD x 1mm wall x 4m long. Up to 50 mm outside diameter can be produced in Japan. The product complies with the Japanese standard JWWA G119 and has previously passed test procedures according to NSF standards 61 and 372. Longer lengths can be obtained by orbital welding techniques. Connections can be made using press-fit fittings in 316L, although the Tokyo, Taipei and Seoul experiences rely on sleeve-in anti-seismic fittings. North American standards (ASTM and AWWA) are being developed.

Recent trial site feedback from Australia learns that – provided that correct tools are applied – the installation is not very different from working with copper and brass fittings, certainly when it comes to the tools and fitting techniques used.

6. CONCLUSIONS

Against the background of water scarcity and population growth, water loss is definitely a major problem around the world and the vast majority of leakage cases are found in service pipes. Partially corrugated 316L stainless steel service pipe brings answers to several material related challenges, such as:

- Hygienic;
- Strong and tough, therefore resistant to mechanical damage;
- Corrosion-resistant;
- Non-reactive with water;
- No bursting in cold temperatures;
- Seismic-resistant;
- Fire-resistant.

These advantages offer unique possibilities to reduce non-revenue water loss and operating costs and environmental footprint. Also, by having to pump significantly less water, great contributions can be made to bringing down energy consumption. Finally, from a societal point of view, the long-lasting reliable character of the solution makes cities more resilient, causing less discomfort to citizens, through improved service and less mobility disruptions.

Not-for-profit global associations such as the Nickel Institute, the International Molybdenum Association and the International Stainless Steel Forum can be consulted for information (11) (12).

REFERENCES

[1]. Quantifying the global non-revenue water problem. *Liemberger, R.* and *Wyatt, A.* Cape Town: International Water Association, 2018;

[2]. *Romano, O.* and *Akhmouch, A.* Water Governance in Cities: Current Trends and Future Challenges. Basle: MDPI, 2019;

[3]. World Economic Forum: Global Risks 2018 and 2019: 13th and 14th Edition. . Geneva: World Economic Forum, 2018-2019;

[4]. OECD: Water Governance in Cities, p. 36. s.l: OECD Publishing Paris, 2016;

[5]. Achieving Zero Leakage by 2050: Water Accounting and Quantification Methods. London: UK Water Industry Research Limited, 2017;

[6]. Public Interest Commitment. London: Water UK, 2019;

[7[. Reducing water loss with corrugated stainless steel service pipe. *Kinsman, N.*, *Matheson, R.*, *Coates, G.*, *Esaki, S.* Kobe: 1st International Conference on Energy and Material Efficiency and CO_2 Reduction in the Steel Industry, page 424, 2017;

[8]. *White, C., Thoung, C., Rowcroft, P., Heaver, M., Lewney, R. & Smith, S.* Developing and piloting a UK Natural Capital Stress Test: Final Report, prepared by AECOM and Cambridge Econometrics for WWF-UK. 2017;

[9]. *Pilcher R., Hamilton S., Chapman H., Field D., Ristovski B., Stapely S.* Leak location & repair guidance notes. London: International Water Association, 2007;

[10]. Corrosion Resistance of Stainless Steels in Soils and Concrete - Plenary Days of the Committee on the Study of Pipe Corrossion. Cunat, P.J. Biarritz: CeoCorr, 2001;

[11]. Stainless steel service pipes: a proven solution to water loss and water quality everywhere. s.l.: Nickel Institute, Toronto and International Molybdenum Association, London, 2018;

[12]. A workable, lasting solution for water losses through leaking water pipes. Brussels: International Stainless Steel Forum, 2017.

COMPREHENSIVE MODEL ANALYSIS FOR HIGH WATER DISTRIBUTION NETWORKS PERFORMANCE

David Duccini*

*Suez/ Division Manager, CTD, 38 Rue Du Président Wilson, Le Pecq, France, david.duccini@suez.com

Abstract
In the light of the current climatic and demographic conjecture, and in order to limit the loss of an alarmingly depleting resource, improving the performance of water networks is a major concern for most public services around the world. Many international organizations have developed standardized indicators and methods that can be used to calculate different types of losses in the water supply system. Within this framework, SUEZ has developed the "Aquacircle™" tool and methodology, which is based on the definition of a baseline from which actions can be carried out in order to obtain performance improvement results. This analysis is done in 3 phases: an initial diagnosis of the network, multiple simulations projected over the coming years, and the proposition of an action plan which is consistent with the performance targets. The following paper aims to present, through 3 practical cases, the advantages and limits of this approach, and suggest for the latter aspect appropriate perspectives of adaptation, in accordance with the new analysis and data management technologies.

Keywords
Water Distribution REx, Network Performance, Water Losses, Causal-Consequential Pathways.

1. INTRODUCTION

SUEZ has been working as a water network operator for more than 150 years. Day-to-day, SUEZ has to ensure operational performance of 300 000 km pipelines for the security, the comfort and the requirements of 60M people from more than 70 countries around the world. Facing this huge challenge, SUEZ has been always innovative for pursuing the best way to manage water networks as per the client's needs and consequently many solutions were developed to improve the performance of the network. Based on those solutions, SUEZ later developed AquaCircle™ to target the performance management issue for medium to long term. It helps operators select the actions to achieve the required performance targets related to water volume balance and assets, based on the evaluation of actions, and its impacts on performance. With its 10-year deployment, SUEZ has gained rich experiences from more than 200 studies about the issues from water balance diagnosis to contractual commitments with an action plan.

2. METHODS

We present thereafter three practical cases as illustrations for the deployment of this solution in order to draw a critical analysis of the model assuming established links between the baseline and the results to be achieved, and derive the implementation conditions which are inherently critical to it, and propose surpassing technological prospects, through the existing partnerships between Suez and high-tech entities. The three case studies are the Parisian region, followed with Bordeaux's and Casablanca's networks.

2.1. Ile de France Ouest, a success story

The Ile de France Ouest Regional Company has been present in the Yvelines since 1924, managing a network of 1960 km. The objectives at the regional company level are set by SUEZ's Technical Department in terms of the linear loss index. For 2013, the target was 8 $m^3/km/d$.

An Aquacircle™ study was carried out in 2010 and made it possible to define an action plan leading to a predicted Linear Loss Index of 7.8m^3/km/d that was effectively achieved in 2012. As for reaching the 2013 objective, and with the change in the scope of the contract, this action plan was adapted and actions of renewal and pressure management were recommended following a new Aquacircle™ study that also yielded satisfactory results.

2.2. Bordeaux, on the model's application

The Aquacircle™ approach makes it possible to highlight the measures to effectively improve the network's performance, as was also the case in Bordeaux, where the recommendation was that of active pressure management to expand the lifespan of. The study consisted in identifying the sources of transient pressure phenomena in the network, and evaluating and orienting mitigation actions for confirmed sources. This has made it possible to accurately establish the level of protection of the network and to schedule operations in high-risk areas, which resulted in the restoration of the network's lifespan.

The two examples above were characterized by an availability of data that could adequately feed the model, through the effective deployment of sensors in the network, and the obtainability of necessary databases.

2.3. Lydec, illustration of the model limits

On the other hand, for Lydec, the operator managing the drinking water network in Casablanca, Morocco, the network was first diagnosed in 2010, and despite the many actions implemented since then, the network performance rate was stagnating at 73% since 2013, and the 80% targets set for 2015 were not achieved that year. These results put forward the fact that the performance rate, although being a very useful indicator for positioning a contract in comparison with similar contracts, is however very sensitive to variations in consumption, and thus not the most appropriate to monitor the evolution of the adequacy of performance over the years, particularly in the case of Lydec, which is a network with very high consumption. Indeed, as a network's linear grows with a consumption that does not follow the same evolution, the linear loss index can express in a more relevant way the evolution of the network's performance. Therefore, the straightforward implementation of the model can at this level display results that do not reveal accurately the evolution of the network's performance if the appropriate indicators are not identified prior to that.

3. CONCLUSIONS

The following insights can be drawn from the previous analyses:

1. **The reliability of the evaluation model is closely linked to its utilization by network experts as well as the exhaustiveness of the original data, and to the conditions for implementing the action plan**. Nonetheless, even if other exogenous factors may play a role in the effectiveness of the causal links between the baseline and the results, the diversity of case studies, and **the field and operational expertise acquired by SUEZ experts makes it possible to ensure this exhaustiveness** in view of the many contracts managed by Suez, which offer a very broad spectrum for implementation conditions.

2. The swiftness of the decision-making process is crucial in performance evaluation situations, and **the ability to formulate rapid guidance even from incomplete data is very valuable**, provided that the evaluation systems chosen are adequate.

3. **This limit on data reliability can be overcome by using machine learning techniques to fill the gap and increase the model robustness**, by evaluating the uncertainty of the proposed solutions, and allowing for complex decision-making strategies to be carried out thanks to the possibility of generating multiple combinations of actions with their correlated impacts.

Solvers like Optimatics' Optimizer™, allow to calculate the area according to the expressed limitations, either in terms of data or other factors, and select the optimal solution within a field of alternatives, and if this solver is currently used by Suez Utilities for asset management optimization, one could imagine its coupling with Aquacircle™ in the very near future, for results combining precision, speed and comprehensiveness.

REFERENCES

[1]. Bhave, P.R. Calibrating Water Distribution Network Models, Journal of Environmental Engineering, Vol. 114, Issue 1, (1988).
[2]. Seifollahi-Aghmiuni, S. Haddad, O. Omid, M., Marino, M. Effects of pipe roughness uncertainty on water distribution network performance during its operational period, Water Resources Management, vol. 27(5), pages 1581-1599 (2013).
[3]. Engerati Water utilities, never too much data, available on: https://www.engerati.com/article/water-utilities-never-too-much-data (2017).
[4]. SUEZ, Etude Organisationnelle et de Performance réseau - Entreprise Régionale, Ile de France Ouest Val de Seine (2014).
[5]. SUEZ, Eau France – Bordeaux Métropole: Calm Network (2018).
[6]. SUEZ, Mise à jour Aquacircle™ Lydec (2015).

TRADITION OF IGNORING CONTINUOUS NON-REVENUE WATER MANAGEMENT IN WATER UTILITIES IN SOUTH-EAST EUROPE

*Dijana Draganovic and Sead Badnjevic**

*MSc. Civil Engineer (draganovic_dijana@hotmail.com)
**MSc. Civil Engineer (sbadnjevic@gmail.com)

Abstract

One of the major issues affecting water utilities in the South East Europe (SEE) is the considerable difference between the amount of water put into the distribution system and the amount of water billed to consumers. It seriously affects the financial viability of water utilities through lost revenues and increased operational costs. These water utilities often operate under weak governance and financial framework, strong political and economic constraints and with lack of the technical and managerial skills necessary to provide reliable service to their population. Establishing and maintaining an effective NRW program is ultimately a managerial problem.

Twenty years ago, leakage management was more based on estimation than on precise science. In the last decade a comprehensive set of analytical tools, water loss reduction strategies and specialised equipment has been developed. All of them were followed with development of capacity building strategies, so today a lot of water utility staff is trained and still there is plenty of training courses available. In the past 10 years, more than numerous projects related to reduction of NRW in SEE were implemented. Despite some encouraging success stories, most water supply systems in SEE still have high levels of water losses. Current data form IBNET database[1] are showing 57,91% of NRW as average in SEE. It is evident that the technical and organizational difficulties and complexities of NRW management are underestimated. Often, projects are designed on short basis for 1-2 years which is not sufficient to adopt a new way of working. Due to weak coordination between donor's agencies, different approaches to NRW projects are designed for the same water utility and in most cases the end results often fail to match expectations.

For successful NRW reduction not only new technical approaches have to be adopted, but effective arrangements must be established in the managerial and institutional environment—often requiring attention to some fundamental challenges in the utility. Although an intense and comprehensive NRW reduction program is suitable to reduce the backlog of required NRW reduction measures, it will not lead to a sustainable low level of NRW, unless NRW management becomes part of the normal day-to- day activities of the water utility. Addressing this issue will require both, an acceptance of the widespread challenges and consequences associated with NRW, and then the development of appropriate training materials, methods, and institutions. Once when utility staff starts with trainings, certain work procedures in utility must be adopted and traditional behaviour "we had training and there is nothing to implement in my utility" should turned in "we have to adjust our systematization in utility, organize leak detection team and work procedure should look like this we learned in training". Although the topic of how to make a public utility, more efficient is beyond the scope of this paper, improving NRW management is a major outcome that would be desired from such initiative.

The designer of any NRW program needs to look carefully at the incentives for the managers and staff of the program, as well as all the parties involved (municipalities, customers). Any program should ensure, as far as possible, that the incentives are properly aligned with the objective of developing an efficient and effective utility that meets the needs of its consumers. It is noteworthy that even though many utilities in the SEE have implemented NRW reduction programs with donor funding, it is rare that after project any of mechanisms are in place to monitor and evaluate results and to adjust and improve next projects.

Reducing the NRW is not only a technical problem. However, the right incentives can be put in place in a public utility within a broader framework of encouraging autonomy, accountability, performance and customer orientation. One of the solutions can be performance-based service contract by the management of a public utility to carry out a comprehensive NRW reduction program, with sufficient incentives and flexibility to ensure accountability for performance and with payment linked to actual results achieved in NRW reduction. Such an approach could be especially attractive in situations where there is not enough skilled technical persons and where it would take a lot of time to hire and train them for the complex

[1]Based on data for Albania, Bosnia, Bulgaria, Kosovo, Macedonia, Montenegro, Romania and Serbia

program. This is a way where government still keeps the water utility under public management, but it is looking for ways to capitalize on the technical expertise and potential efficiency of the private sector. Practice showed that one sustainable way could be technical assistance contract where regular support will be provided to management on accomplishing NRW action plan, to keep motivation of the staff and to objectively monitor improvement in NRW reduction. Increased awareness and involvement of all interested parties to reduce the NRW will provide long-term benefits and sustainability of the funds invested.

Keywords
NRW management, capacity building, awareness.

WATER LOSS MANAGEMENT IN CALARASI WATER UTILITY

Petronel Birjaru*

*Ecoaqua Calarasi, FDP Chief, birjaru.petronel@outlook.com

Abstract

Ecoaqua SA Calarasi has been created in 2004 as a water and sewer operator for Calarasi County. It is a shareholder company, owned by the local authorities. Currently its operating area covers most of Calarasi County and almost half of the neighbouring county Ialomita (Urziceni and its surroundings). The company has been divided in three branches, Calarasi, Oltenita and Urziceni. Ecoaqua Calarasi water distribution system is comprised of over 580 km of water main and services over 30000 connections.

Traditionally, water loss levels have been tracked via a rudimentary Unaccounted-for Water (UFW) analysis which compares the volume of water supplied into the distribution system to the volume of water sold to customers. Historically, this value has varied between 45 to 50%.

In 2018 an water audit and a water balance completed as part of an internal study established the current level of Non-Revenue Water (NRW) for Ecoaqua – Calarasi Branch at 3.582.074 m^3 or 49,73% of the total system supply. From this, the system leakage or real losses were calculated at 2.989.940 m^3, or 41,53%. This volume of real losses is equivalent to supplying the daily demand of a system servicing a population of approximately 50000 people and in real money 8.969.819 lei (1.908.472 €).

Prior to 2017 when the current CL8 modernization program ended, Ecoaqua had no active leak detection program. However, post 2018 our company has created a dedicated team for detection and management of the water losses, implemented an active control program and focused their leak detection efforts more on a reactive program of dealing with reported water main breaks (due to the aging infrastructure).

Our team has three major goals:

- Active Leakage Control involves identifying and quantifying existing leakage losses on a continuous basis, typically by performing acoustic leak detection surveys at regular intervals.
- Speed and Quality of Repairs aims to ensure timely and lasting repairs and is regarded as critical to the success of the overall Real Loss Control program. The length of time a leak is allowed to run affects the volume of real losses, so repairs should be completed as soon as possible once a leak is detected.
- Pressure Management aims at minimising excess (unnecessary) pressures in the water distribution system as well as removing transients. It can be implemented through suitable pressure zoning and DMA management, which is to be implemented next.

We have started by implementing a night flow and pressure measurement program aimed to determine the minimum night flow, using the existing SCADA system. Typically it had occurred between 00:00 and 05:00 AM when customer demand was at its minimum and therefore the leakage component was at its largest percentage of the flow. The next step was the closure of certain areas (mostly industrial sites) while measuring the flow leaving the pumping station. By doing so we determined the percentage of leakage in the monitored areas and the physical condition of the network in those industrial sites.

Then we focused on the distribution network pressure management using the existing 23 monitoring points in Calarasi. Each point is fitted with an Intellisonde 2000 multipara meter probe, able to monitor physical, chemical and water quality parameters and to transmit real-time readings in SCADA. Although readings were not always compliant, the probe requiring frequent calibration, we could get an idea of “pressure map” of the city.

The next steps in this process is the development and implementation of three pilot DMAs (District Metered Area) in Calarasi, completely measured and monitored. Their role is to divide the distribution network into manageable areas or sectors into which the flow can be measured to determine whether bursts are present or not.

We also have a program of active listening using sound loggers mounted on the distribution network. Basically, each week we identify a network sector to be monitored and according with the obtained readings we use the other equipment that we have (Corelux, Hydolux etc) in order to determine the exact point of the burst and to fix that loss.

Keywords

Leakage control, pressure management, DMAs, sound loggers.

CHAPTER III

CUSTOMER METERING

APPARENT LOSSES CONTROL – CUSTOMER METERS RENEWAL POLICY OPTIMIZATION

A. Santos*, A. Ganhão*, S. Graça*, P. Ramalho*, J. Feliciano*

*AGS – Administração e Gestão de Sistemas de Salubridade, S.A,, Lagoas Park, Edifício 6, Piso 0-A, 2740-244 Porto Salvo, Portugal, asantos@ags.pt, aganhao@ags.pt, sgraca@ags.pt, pramalho@ags.pt, jfeliciano@ags.pt

Abstract

Introduction

Utilities have focused a strong effort on minimizing real losses, nevertheless important work is still to be developed on apparent losses, namely in the component related with metering inaccuracies. Metering accuracy is affected by factors such as design, water quality, and installation conditions, among others. The water utilities knowledge regarding these factors influence on meters' degradation rate still insufficient leading to replacement policies sustained only on meters' age.

AGS is a Portuguese multi-operator owned by both Marubeni and Innovation Network Corporation of Japan (INCJ) that manages 13 urban water utilities in Portugal and Brazil under long term concession agreements. For this reason, an optimized management of customer meters is of most importance for AGS to improve the economical sustainability of each utility.

Based on this concern and following the participation on the R&D project iPerdas, developed and coordinated by the Portuguese National Laboratory for Civil (Loureiro et al., 2015), AGS developed a collaborative project for its utilities having has main goal the development of water-energy reduction plans and where the apparent losses reduction played an important role (Almeida et al., 2017).

The paper will present the work developed under "efficient control of water-energy losses program" (PGPE) coordinated by AGS, regarding the implementation an integrated water meter management approach in its companies. The case study presents the methodology for estimating metering errors and the benefits of renewal policies based on the meters' lifespan and the estimation of optimal renewal frequencies instead of applying traditional policies based on the meters' age. Results regarding the implementation of this methodology in two Chilean utilities will also be showed.

Methodology

Through the PGPE implementation, AGS was able to test and implement a new approach for analysing customer meters lifespan. This approach follows principles presented by Arregui (2010), which considers the balance between the cost of meter replacement and the gains obtained from the reduction of sub measurements.

The error associated to each meter is not constant nor independent from consumption (Arregui et al., 2014): low flows correspond to higher errors; medium and high flows correspond to lower error variations. Thus, the weighted error, i.e., difference between the registered water volume and the real consumed volume, is a function of two parameters: a) the pattern of the client's consumption (histogram) and b) the meter's characteristic error curve. Variables such as meter error degradation rate, replacement costs, volume consumed per client and the costs for sub measuring associated to the water utilities' tariff, allow to determine the optimized lifespan of a meter.

Keywords

Apparent losses; integrated meter management; optimum life cycle.

CONCLUSION

It is essential that utilities adopt optimized investment solutions for an efficient use of resources. The approach used for estimating metering errors based on the meters' lifespan rather than basing decision solely on the meters' age can help utilities decrease non-revenue water whilst decreasing costs which can be allocated to other aspects of combating water losses.

The work developed promoted the review of water utilities internal processes to guarantee higher metrological control and allowed AGS to develop a tool that supports customer meters management.

REFERENCES

[1]. Almeida R., Santos A. R., Soares M., Ferreira A., Ramalho P., Ganhão A., Loureiro D., Feliciano J. (2017). Aplicação do conceito nexus água e energia a entidades gestoras do grupo AGS (Aplication of the water-energy nexus in water utilities). In ENEG 2017. Évora, Portugal.
[2]. Arregui F. J., Cabrera Jr. E., Cobacho R. (2010). Integrated Water Meter Management. London, IWA Publishing. ISBN: 9781843390343.
[3]. Arregui F. J., Gavara F. J., Soriano J., Cobacho R. (2014). Analysis of domestic water meters field performance. In Water Loss 2014. Vienna, Aústria.
[4]. Loureiro D., Alegre H., Mamade A., Ribeiro R., Vieira P., Coelho S.T. (2015). Implementing water-energy loss management in water supply systems through a collaborative project: the Portuguese national initiative. In WDCE 2015 (Water and Development Congress & Exhibition 2015), Dead Sea, Jordan.
[5]. Taborda, C. (1998). Melhorar a Qualidade da Medição (Improving metering accuracy). In 4. Congresso da Água. Lisboa, Portugal.

SMART METER PARK OPERATION: LESSONS LEARNED

Adrian Rubio*, Manuel Roldan*

*Go-Aigua, Alvaro de Bazan, 10 (Pasaje Luz) 46010 VALENCIA (Spain)
adrian.rubio@go-aiugua.com, manuel.roldan@go-aigua.com

Abstract

Definition of Service

The advances on smart metering technology as well as loT communication networks have laid the path for the creation of Big Data platforms that integrate, operate and monitor the real-time consumption of customers at a household level. This article outlines the lessons learnt and solutions developed while operating one of the largest smart metering parks in Europe with more than 700.000 devices, focusing on how to handle such databases, optimize its processing and exploiting its insights.

Such amount of operating smart devices, which account for more than 180 million yearly consumption data points, have allowed an in-house developed algorithmic solution, which makes use of that data to develop the one of the most advanced operational hubs for client consumption monitoring in Europe. Such a system allows, among many other added value features, the detection of over 2.500 monthly internal leaks, thereby driving consumption optimization to an all-time high while reducing the aggregate water expenditure that the clients face every month.

Technology

As we have indicated in the previous section, the architecture of the Tiresias Solution operates in two differentiated strata, first as integration hub for the smart meters recording of consumption data points, and second, as an algorithmic engine focused on consumption pattern recognition.

The integrator hub, dubbed Nexus lntegra, aggregates the consumption parameters of the clients, both the real-time hourly consumption as well as the historical values of such figures. Such structure of data indexing allows for a comparison of current consumption to historical records, thereby estimating some standard consumption patterns associated to each client.

An important added feature to this process of integration is the data filter which ensures the quality of the data by checking its proceeding hardware as well as the entire communication protocol use to communicate the reading data point.

The second level takes the integrated patterns of historical consumption and makes use of them in two paramount ways:

• The first one involves the definition of event alarms, which involve a system if trigger warnings when the current consumption data deviates from stablished patterns which might mean everything from an internal undetected leak, to perhaps an empty house occupation among many other things.

• The second usage made of the historical data revolves around the development of consumption forecasts. At a household or block level this allows the utility to deliver water more efficiently, but it is at a larger, aggregated level where this feature can achieve the greatest improvement in efficiency.

Regardless of how large a network of operating smart devices, there will always be areas less well supplied of them, or perhaps faulty units that don't display the information correctly; however the aggregated calculation of historical consumption patterns allows to effectively overcome those shortages and develop consumption forecasts for entire sectors, information which itself, allows further efficiency gains down the service line (such as optimizing water pumping from wells, or ensuring sufficient supply at water deposits).

Added Value offers

Beyond the efficiency and managerial gains to be derived from such a comprehensive and integrated view of the entire client consumption, the Tiresias System offers further value to both final clients and users.

To the final client the benefits of consumption monitoring are manifold, chief among them is a real-time hourly information about a household consumption, as well as the aforementioned internal leakage detection, both important in ensuring a transparent and consumer-centric service.

Beyond those, the uses for the alarm system to warn about anomalous consumption can be many; currently Global Omnium informs health and governmental bodies about sharp decreases in consumption on houses with elderly or sick people, which might have suffered a sort of accident. Conversely, households that are expected to be unoccupied (perhaps because the inhabitants are on vacation) but start exhibiting water consumption are also reported.

For the users of the Tiresias system further added features can be mentioned: the system incorporates a pattern profiler, which enables an identification of the type of installation whose consumption is recording. With a high degree of accuracy the system can therefore tell based on historical figures weather it's an industrial facility, a household or perhaps a bar that's monitoring.
Beyond that, potential fraudulent situations can be monitored by representing a sharp decline on recorded consumption and compare it with the actual water usage in an area, as well as the median consumption on a sector.

Keywords
Telemetry, Big Data, Algorithms.

ASHEVILLE NRW PROGRAM TAKES COMMERCIAL METER TESTING TO THE NEXT LEVEL FOR REAL PAYBACK

Steve Cavanaugh*, Will Jernigan** and Brandon Buckner***

*Steve Cavanaugh, P.E., Cavanaugh & Associates, PO Box 11197, Winston Salem 27116; Steve.cavanaugh@cavanaughsolutions.com
**Will Jernigan, P.E., Cavanaugh & Associates, 76 Blue Ridge Ave., Asheville, NC 28806; Will.jernigan@cavanaughsolutions.com
***Brandon Buckner, City of Asheville Water Resources, Dept., 200 Bingham Rd., Asheville, NC 28806; bbuckner@ashevillenc.gov

Abstract
The City of Asheville's Non-Revenue Water (NRW) Program has received national attention, most recently having been featured in the US Environmental Protection Agency's published conservation reference guide as a prominent case study for smart conservation (US EPA, 2016). In December 2017, the City's NRW program was highlighted as a featured case study at the North American Water Loss Conference (NAWL, 2017). The results for this North Carolina, USA city to date have been a win for both the environment and the rate payer alike – as avoided costs correlate to an offset of where water rates would have been, had those costs been incurred. Asheville's NRW comprehensive program is built from the AWWA M36 Methodology (AWWA, 2016) and includes annual AWWA auditing & data validation, full time leak detection crews, DMAs and night-flow analysis, a formal commercial meter testing program, billing system audits, and pressure management.
The full NRW program has already been presented at IWA and AWWA in the past, so this presentation is intended to provide a deeper dive into Asheville's formal commercial meter testing (CMT) program. The Asheville CMT efforts have been refined from 2012 to present, and now include annual test planning based on a benefit-cost model to ensure they are only testing the amount and selection of meters that are likely to yield a net payback. Asheville has also developed an online portal, so its meter testing crews can easily plan their work, record results, and see a dashboard of outcomes.
The CMT efforts have yielded discoveries from some of the system's largest customer meters, which to date are providing over $100,000 annually in revenue recovery. The presentation will feature the utility's experience in getting the program off the ground, keeping the momentum, and a review of the online portal that serves as its hub for operations.

Keywords
Non-Revenue Water Management, Leak Detection, Pressure Management, Meter Testing, NRW Strategy, Water Auditing.

REFERENCES

[1]. US Environmental Protection Agency (2016). Best Practices to Consider When Evaluating Conservation and Efficiency as an Alternative for Water Supply Expansion. EPA-810-B-16-005.
[2]. Buckner, B. (2017) City of Asheville 10-Year Non-Revenue Water Program. North American Water Loss 2017. San Diego, CA, USA.
[3]. American Water Works Association (2016). Manual M36, 4th Edition. Water Audits and Loss Control Programs. ISBN 9781625761002. © AWWA 4th Edition.

AQUAWAN - INTELLIGENT SYSTEM FOR REMOTE READING SMART WATER METERS, USING THE LORAWAN COMMUNICATION PROTOCOL

Simó Attila*, Ilie Vlaicu**, Katalin Bodor**, Cristian Florian**, Cristina Borca**, Alin Anchidin**

* ETA2U, HUB 700, Str. Gh. Dima no. 1, Timisoara, Romania, asimo@eta2u.ro
** AQUATIM SA, Str. Gh. Lazar, no. 11A, Timisoara, Romania, alin.anchidin@gmail.com

Abstract
In the current context of existing technologies, the virtual digitization of any information around us, implicitly of water consumption, is a desire of modern society. It is mandatory to integrate the information in order to analyse the parameters for each consumer, from the perspective of the rational use of this essential resource, water. In this paper, a pilot project, called AQUAWAN is presented. Developed by ETA2U in partnership with AQUATIM this project aims firstly to validate the implementation of the remote reading of smart water meters, using the LoRaWAN communication protocol, in real field conditions.

Keywords
Smart metering; AQUAWAN; LoRaWAN.

1. INTRODUCTION

Water is an essential resource for life, and the trend is to reduce its availability for both the current generation and future generations. In the current context of technologies, scaling up a system at an urban level for automated collection of individual water consumption parameters is essential. Using existing modern technologies for virtual digitization of any information around us, implicitly of water consumption, is a desire of modern society. It is essential to integrate the information in order to analyze the data for each consumer, from the perspective of the rational use of this essential resource, water. This allows consumers to adapt their operating parameters more easily to their needs. Postponing the implementation of these modern technologies can accentuate the gap between the availability of the water resource and the needs of society.

The goal of this paper is to present a pilot project, implemented by ETA2U in partnership with AQUATIM. This project, called AQUAWAN, deals with smart water meters reading, using the LoRaWAN communication protocol.

One of the current technologies that can provide viable solutions for such projects, as remote reading smart water meters located on a large geographical area is the Low Power Wide Area (LPWA) technology.

LPWA represent a new communication paradigm, which will complement traditional cellular and short-range wireless technologies in addressing diverse requirements of Internet of Things (IoT) applications. These technologies offer unique sets of features, including large geographical area connectivity for low power devices and low data rates, which are not provided by legacy wireless technologies. The low power wide area networks are special because they make different tradeoffs than the traditional ones, such as short-range wireless networks (Bluetooth, Zig-Bee, Infrared transmission), legacy wireless networks (WI-FI), and cellular networks (GSM, LTE, CDMA) etc.

The legacy non-cellular wireless technologies are not suitable to operate low power devices distributed over large geographical areas because the range of these technologies is limited to a few hundred meters, in the best case scenario. For this reason, the devices cannot be randomly deployed or moved anywhere, which can be a requirement for many applications for smart city, tracking, smart metering etc.

Obviously, this field is addressed for the mobile industry, and initiatives have been ongoing for several years in an attempt to deliver standards that will enable mobile operators to offer LPWA-like connectivity. Due to a range of a few to tens of kilometers and battery life of ten years and beyond, low power wide area technologies are promising for the Internet of low-power, low-cost, and low throughput "things". IoT become even more interesting due to the existence of Low Power Wide Area (LPWA) networks. IoT promise to change the way we live. To achieve visions like energy crisis, resource depletion, environmental pollution, etc. things need to "feel" their environment, part this information among them as well as with peoples to offer intelligent decision-making.

Due to the features of this technology devices "are able" to spread and move over large geographical areas, thus IoT and M2M tools connected by low power wide area networks can be turned on anywhere and anytime to sense and interact with their environment [1].

LPWA technologies are not designed to address each and every IoT use case. Although these technologies achieve as advantages long range and low power operation, also presents disadvantages as low data rate (in orders of tens of kilobits per seconds) and higher latency (in orders of seconds or minutes). In conclusion LPWA technologies are addressed for those use cases that are delay tolerant, do not need high data rates, require low power consumption and low cost.

LoRa (long range) is a proprietary physical layer used for low power wide area connectivity, which modulates the signals in SUB-GHz ISM band using a proprietary spread spectrum technique developed and commercialized by Semtech Corporation. Using a special chip spread spectrum technique they resolved a bidirectional communication, which spreads a narrow band input signal over a wider channel bandwidth. LoRaWAN (long range wide area network) is an open standard defining architecture and layers above the LoRa physical layer (Fig. 1), which was proposed by a group of several commercial and industrial participants, named as LoRa™ Alliance. The multiple devices communication at the same time, using different channels and/or orthogonal codes (spreading factors) is solved with a simple ALOHA scheme at the MAC layer level. End-devices can hop on to any base-station without extra signaling over-head. As next step, these base-stations connect end devices via a backhaul to network server, these representing the central unit of the LaRaWAN system that suppresses duplicate receptions, adapts radio access links, and forwards data to suitable application servers. The received data is processed by the application servers, also performing user-defined tasks (Fig. 2) [3, 4].

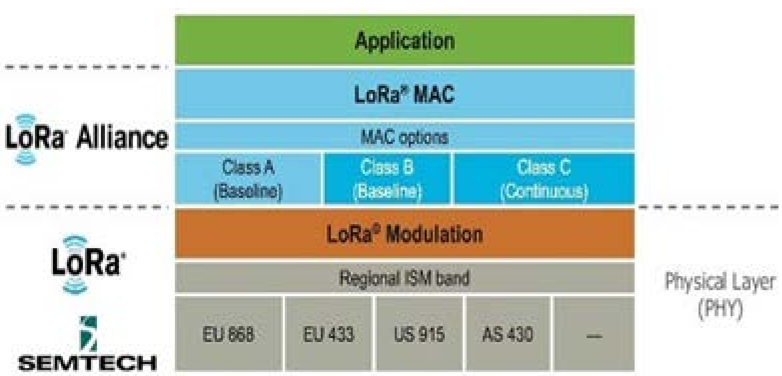


Fig. 1. LoRa Technology architecture

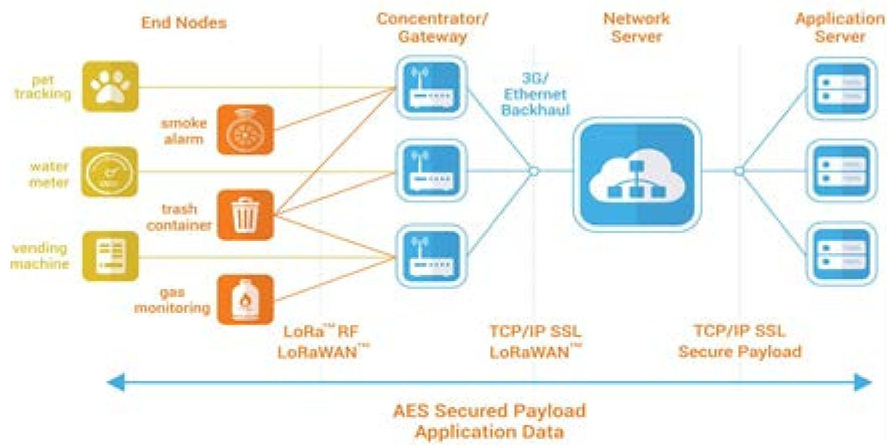


Fig. 2. Generic architecture of a LoRa type network

Because the end-devices have different capabilities as per application requirements LoRaWAN defines 3 different classes of end-devices. All classes support bidirectional communication but with different downlink latency and power requirements. These classes are the following:

- Class A - device achieves the longest lifetime but with the highest latency. It listens for a downlink communication only shortly after its uplink transmission;
- Class B - device, in addition, can schedule downlink receptions from base station at certain time intervals. Thus, only at these agreed-on epochs, applications can send control messages to the end devices (for possibly performing an actuation function);
- Class C - device is typically mains-powered, having capability to continuously listen and receive downlink transmissions with the shortest possible latency at any time.

For device authentication with the network LoRaWAN standard is using symmetric-key cryptography, and preserve the privacy of application data [2].

In the literature few papers discuss about smart water meters management. In [5] the authors present a pilot project, about a LoRa based smart water grid management system in Mori, a village in the eastern Godavari district in Andhra Pradesh situated near to Bay of Bengal. The water grid management system proposed in this paper involves different sensors deployed at various strategically chosen locations to measure the quality of water by generating real time data. The system also provides an alert mechanism which notifies the different level of authorities through email and SMS in case of any issues.

The study in [6] introduces a schematic methodology for smart water grids for use in water management platforms, which integrates information and communication technology into a single water management scheme. The authors do not remember with what technology they bring data into the database.

The 1st section provides an introduction into the low power wide area technologies world. In this sections the LoRaWAN communication protocol is also presented briefly. The 2rd part of this paper shows the use case about creating a smart water grid based on the LoRaWAN communication protocol. Finally, conclusions are synthesized within the 3rd section.

2. RESULTS AND DISCUSSIONS

The pilot project, called AQUAWAN, developed by ETA2U in partnership with AQUATIM aims firstly to validate the implementation of the remote reading of smart water meters concept in field conditions, so it can study and analyze the difficulties that may arise both in the implementation phase and in the exploitation phase. Another important aspect is the analysis of the social and economic impact. The social impact takes into account both from the perspective of accepting the change in the methodology of collecting information at consumer points and in terms of minimizing consumer interaction with representatives of utility providers.

The proposed specific objectives of the project are as follows:

• remote reading of smart water meters without human intervention;

• ensure flexibility on data reading frequency, depending on the different parameters set by the operator, based on operational needs;

• creating a web based platform which allows access to all parameters of the water management system, regardless of its degree of automation and localization;

• ensure a connected infrastructure that can provide data for increasing the system efficiency based on daily consumption information, correlated with environmental conditions and seasonality.

The pilot project was implemented in Timisoara (Romania), in the area called "Neptun".

In this project, 167 meters were installed in different locations of the Neptun area, their positioning on the map can be seen in fig. 3. Zenner counters (Figure 4) were used, which are dry dial counters with an attachable "Electronic Data Capture" (EDC) module. This EDC module enables electronic pulse detection, remote data reading and water meter integration in intelligent measuring systems.

The 167 counters are of different diameters being divided as follows:

• 25 pieces DN15 (R160) C class;
• 100 pieces DN20 (R160) C class;
• 40 pieces DN32 (R160) C class;
• 2 pieces DN50 (R100) B+ class.

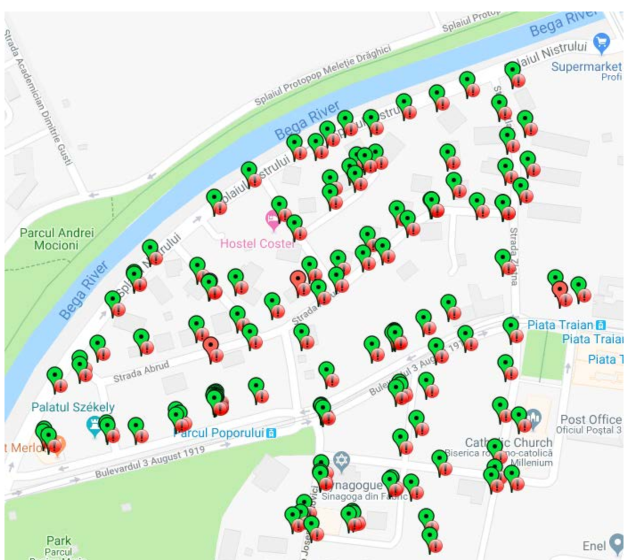


Fig. 3. Location of water meters - Neptun area

For proper operation of the meters it was necessary to go through some stages listed below:

- Integration of the water meters into the Network Server (Actility);
- Optical activation of water meters;
- Testing the LoRaWAN Communication between water meters and Network Server.

Fig. 4. Zenner smart water meter

Data transmission is done at night, once every 24 hours. For data transmission ETA2U has used the LoRaWAN communication protocol.

The measuring devices are sending data via the LORTIM network and the EDC module attached to the Zenner counter.

All EDC modules are locked on the SF12 (transmission at 1.2 s) by the Zenner water meter manufacturer. Adaptive Data Rate (ADR) is disabled. The reason for blocking devices on SF12 and deactivating ADR is the desire to increase the success rate of the communication. If we have many devices, as is our case, if they all transmit at the same time with ADR enabled, the risk is to "jam" the communication between the devices and the base stations. To maximize the rate of success, we prefer to send with maximum power (SF12) and request a response from the base stations (acknowledge). If the EDC does not receive a response from the gateway on the first attempt that packets have been received, it tries to send the data two more times, and if neither the second nor the third transmission is successful, then the packet is considered lost.

LORATIM is a wireless communications network developed by ETA2U in Timisoara, based on the LoRaWAN communications protocol with 868 MHz operating frequency. The network is made up of 9 gateways in key locations in the city. Due to their positioning, Timisoara has a very good coverage (Figure 5).

The problems encountered in this project were multiple, either problems due to atmospheric conditions, installation conditions of the meters (reinforced concrete man hole, basement, car parked over the man hole). There are many reasons that can jam the radio signal.

Out of the total of 167 installed water meters, there were several meters that suffered package losses. In the first phase the water meters with problems were identified and the problems were studied for each separate meter. At the location of these counters various investigations were made, finding that the main causes of packet loss are caused by the flooding of the concrete man hole and the position of the EDC module towards the gateway (Figure 6). These problems have been solved by removing the water from the man hole or by modifying the position of the EDC module, in some cases also having to bring the meter closer to the lid of the man hole. (Figure 7).

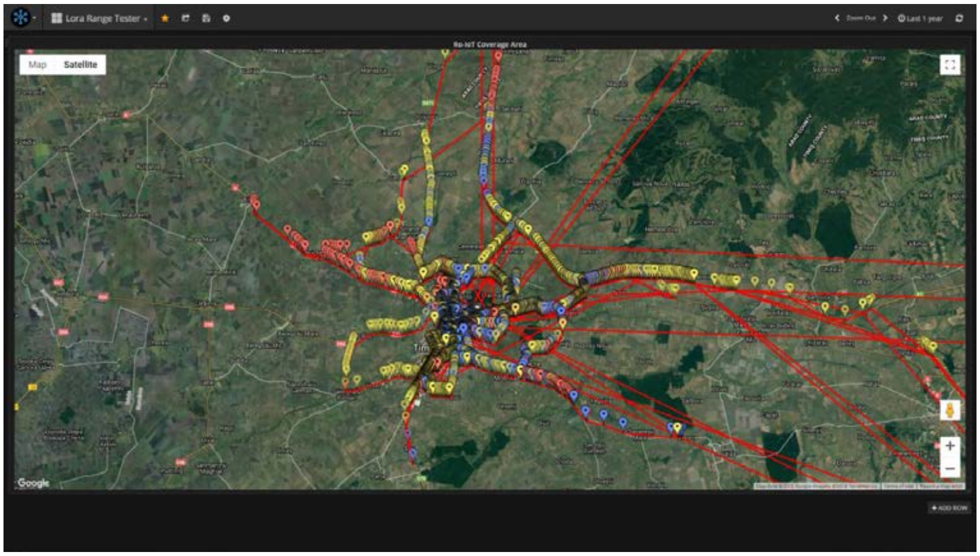


Fig. 5. LORATIM coverage

Fig. 6. The initial position of the meter

Fig. 7. The final position of the meter

Other causes that may influence the quality of the signal could be unfavorable weather conditions, a car parking over the man hole causing partial or total jam of the radio signal, but these are short-term causes without affecting the long term data reading.

In order to monitor the system in general and the meters in particular and for analyzing the data read by these water meters, a web application was made. Access to the web application is based on a username and password.

The data can be displayed directly on a map (Figure 8) or in a table (Figure 10). With the help of the map you can precisely locate the mounted water meters and you can find a multitude of data about these meters and the data recorded by them (fig.9). Water meter data can be interrogated using multiple filters (date of interest, gateway to which a meter is connected, consumer type etc.).

The platform offers two ways of searching in the total number of mounted meters:

- after the last transmission date:

  - ✔ ● symbolizes the meters that last transmitted at the date selected by the user;
  - ✔ ▲ symbolizes the meters that last transmitted one day before the date selected by the user;

- ✔ ■ symbolizes the meters that have not transmitted for at least two consecutive days prior to the date selected by the user.

- by the type of consumer to which the meter is mounted:
  - PF: refers to meters that are mounted at home owners;
  - AE: refers to meters that are mounted at economic agents;
  - I: refers to meters that are mounted at institutions.

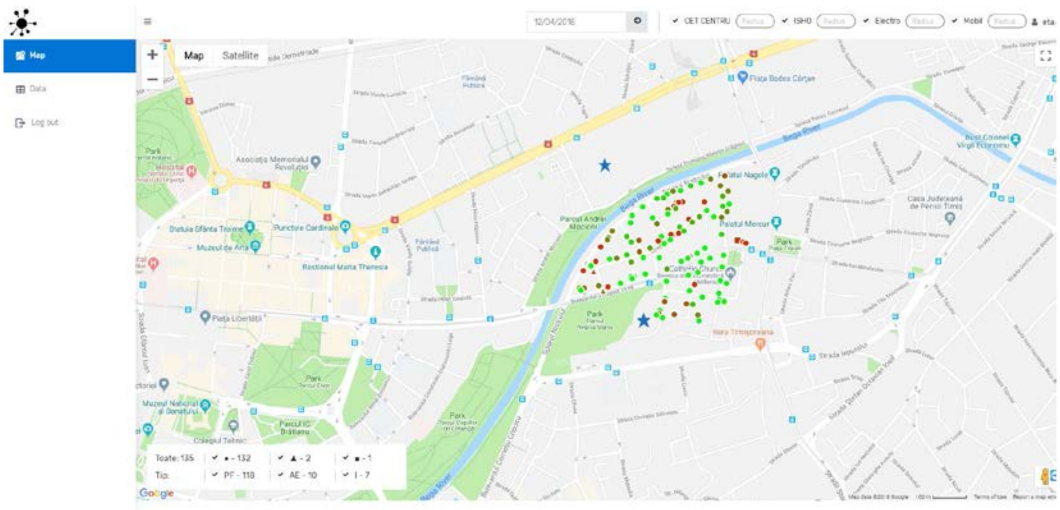


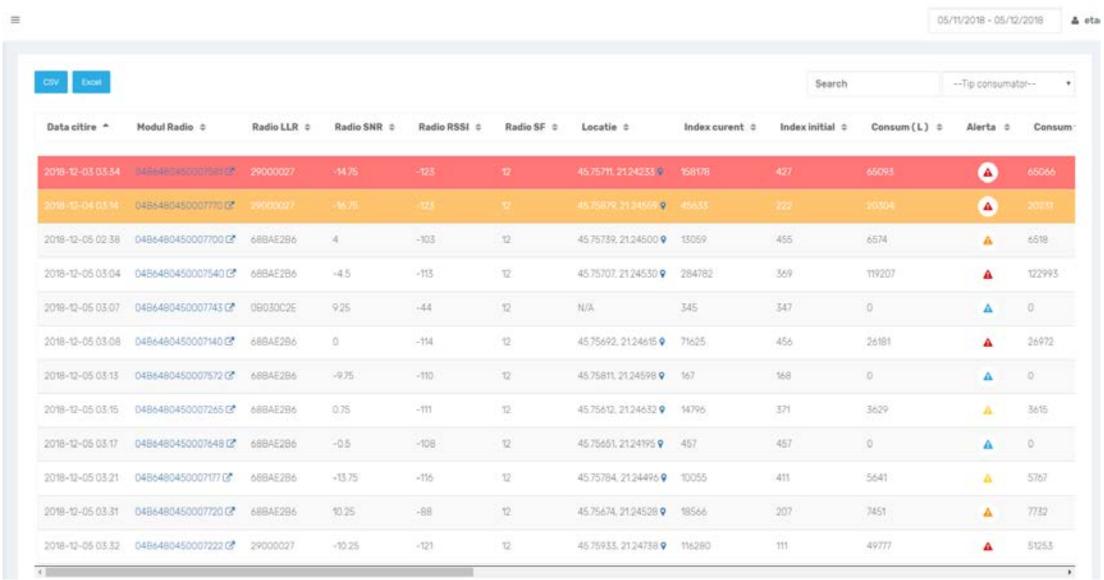
Fig. 8. Map with the position of the water meters

By selecting a meter on the map the application will display a new window (Figure 9), which contains data about both the network parameters for the selected equipment and the meter data. Also in this section are information about the consumer: name, address, subscriber code.

Fig. 9. The information displayed when selecting a meter

The application offers two ways of exporting data:

- CSV format: For this type of export, the information will be extracted in the form displayed on the screen, filtered or not, depending on the user's preferences;
- Excel format: in this case, the data in the table is extracted in a format imposed by Aquatim and does not take into account what is seen on the screen, i.e. the filters applied the user.



05/11/2018 - 05/12/2018

CSV Excel

Search --Tip consumator--

Data citire	Modul Radio	Radio LLR	Radio SNR	Radio RSSI	Radio SF	Locatie	Index curent	Index initial	Consum (L)	Alerta	Consum
2018-12-03 03:34	[illegible]	29000027	-14.75	-123	12	45.75711, 21.24233	158178	427	65093		65066
2018-12-04 03:14	04B6480450007770	29000027	-16.75	-123	12	45.75879, 21.24559	45633	222	20304		20231
2018-12-05 02:38	04B6480450007700	68BAE2B6	4	-103	12	45.75739, 21.24500	13059	455	6574		6518
2018-12-05 03:04	04B6480450007540	68BAE2B6	-4.5	-113	12	45.75707, 21.24530	284782	369	119207		122993
2018-12-05 03:07	04B6480450007743	0B030C2E	9.25	-44	12	N/A	345	347	0		0
2018-12-05 03:08	04B6480450007140	68BAE2B6	0	-114	12	45.75692, 21.24615	71625	456	26181		26972
2018-12-05 03:13	04B6480450007572	68BAE2B6	-9.75	-110	12	45.75811, 21.24598	167	168	0		0
2018-12-05 03:15	04B6480450007265	68BAE2B6	0.75	-111	12	45.75612, 21.24632	14796	371	3629		3615
2018-12-05 03:17	04B6480450007648	68BAE2B6	-0.5	-108	12	45.75651, 21.24195	457	457	0		0
2018-12-05 03:21	04B6480450007177	68BAE2B6	-13.75	-116	12	45.75784, 21.24496	10055	411	5641		5767
2018-12-05 03:31	04B6480450007720	68BAE2B6	10.25	-88	12	45.75674, 21.24528	18566	207	7451		7732
2018-12-05 03:32	04B6480450007222	29000027	-10.25	-121	12	45.75933, 21.24738	116280	111	49777		51253

Fig. 10. Table form for showing the meters

It is very important to note the contents of the "Alert" column, which refers to the supplier's limits of consumption, where the following situations may occur:

•  this symbol means that the value of that water meter is within the required limits, so there is no alert;

• this symbol means that the value from that water meter exceeded 1 day the limits, so one or more Type 1 alerts occurred;

•  this symbol indicates that the value from that water meter exceeded the limits for 2 consecutive days, so one or more Type 2 alerts occurred;

•  this symbol means that the value from that water meter has exceeded the limits regularly and has exceeded them even at the end of the period of interest.

In the table viewing mode, it is possible to analyze data recorded by the meters.

The data provided is divided into three categories:

• Consumption (figure 11) - here is the daily consumption on that meter for the selected period as a graph. Also, it is important to note that there are meters that cannot be read every day, and for the days that are missing the values are approximated. On each consumption graph there is also a consumption limit represented by a horizontal red line;

• Virtual meter consumption (Figure 12) - Virtual meter consumption 0000000000000000 is the cumulative consumption in the entire Neptun area, which contains monitored consumption in the SCADA system (readings once every 10 minutes);

• Counter Details - this section deals with the details of the selected counter: whether or not the counter is active (if the value of this field is 0 then the meter data is not displayed for the user only for the administrator if it is 1 then the meter data is displayed for the user and for the administrator) GPS position, set limits etc.;

• Virtual counter loss (Figure 13) - this section refers to the loss of the selected period. It is calculated by the difference between the past consumption through the virtual counter 0000000000000000 and the sum of the consumption recorded from the individual meters (with LoRaWAN transmission) attached to the monitored pipeline with the virtual counter.

Fig. 11. Consumption

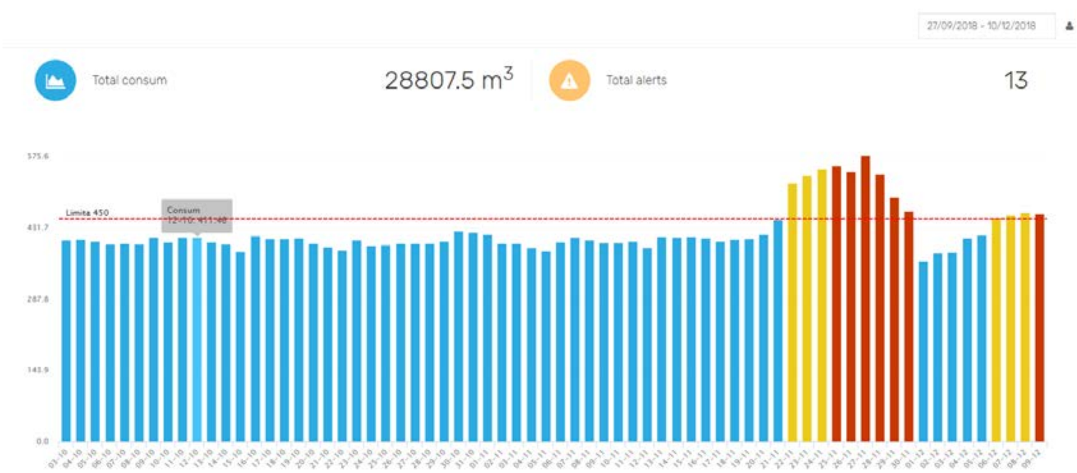


Fig. 12. Consumption for the entire Neptun area

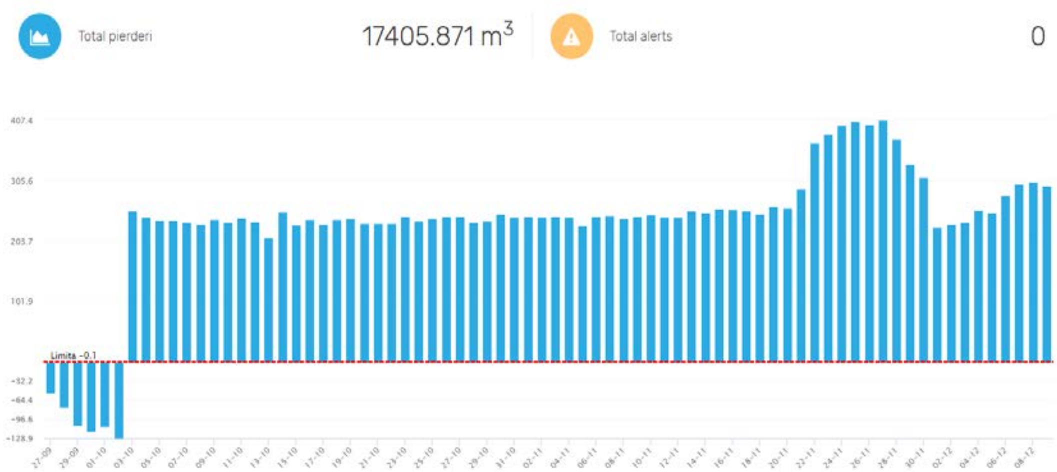


Fig. 13. Water losses in the area

3. CONCLUSIONS

Water is an essential resource for life, and the trend is to reduce its availability for both the current generation and future generations. In the current context of technologies, scaling up a system at an urban level for automated collection of individual water consumption parameters is essential. Using existing modern technologies for virtual digitization of any information around us, implicitly of water consumption, is a desire of modern society. It is essential to integrate the information in order to analyze the data for each consumer, from the perspective of the rational use of this essential resource, water.

This pilot project has demonstrated that the LoRa technology, more precisely the LoRaWAN communication protocol, is suitable for a smart water meter management system. Using the web based platform, it is possible to obtain valued information for the system operator and what is more important that the reaction time in case of any problems becomes very low.

Also such an approach allows consumers to adapt their operating parameters more easily to their needs.

Postponing the implementation of these modern technologies can accentuate the gap between the availability of the water resource and the needs of society.

REFERENCES

[1] *Augustin A., Yi J., Clausen T., Townsley W.M.* 2016 A Study of LoRa: Long Range & Low Power Networks for the Internet of Things, Journal of Sensor, vol. 1466, pp. 1-18;

[2] *Mekki K., Bajic E., Chaxel F., Meyer F.* 2017 A comparative study of LPWAN technologies for large-scale IoT deployment, Open Access funded by The Korean Institute of Communications Information Sciences, Volume 3, Issue 1, pp. 14-21;

[3] Lte evolution for iot connectivity, Nokia, Tech. Rep., 2016, Nokia White Paper;

[4] What is the LoRaWAN™ Specification?, https://lora-alliance.org, 2018;

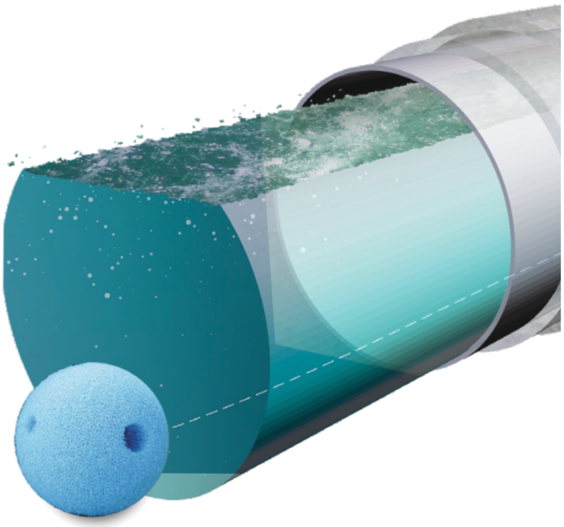
[5] *Saravanan M., Das A., Iyer V.* 2017 Smart water grid management using LPWAN IoT technology, Global Internet of Things Summit (GIoTS), pp. 1-6;

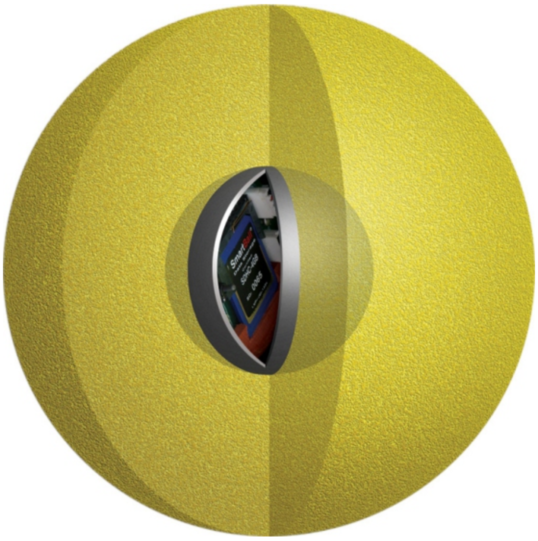
[6] *Seung W. L., Sarp S., Jeon D. J., Kim J. H.* 2014 Smart water grid: the future water management platform, Journal of Desalination and Water Treatment, pp. 339 - 346.

xylem
Let's Solve Water

SmartBall® Technology

A FREE-SWIMMING TOOL FOR LONG DISTANCE WATER AND WASTEWATER INSPECTIONS





How SmartBall works?

The SmartBall® platform is a free-flowing tool for the assessment of pressurized water and wastewater pipelines 8 inches and larger. It can complete long assessments in a single deployment without disruption to regular pipeline service.

The tool is inserted into a live pipeline and travels with the product flow for up to 21 hours while collecting pipeline condition information. It requires only two access points for insertion and extraction, and is tracked throughout the inspection at predetermined fixed locations on the pipeline.

Applications

Owners of water and wastewater pipelines deal with a variety of infrastructure challenges; the SmartBall platform can collect a variety of pipeline condition information in a single deployment that helps owners manage their assets more effectively.

Leak Detection

The tool is equipped with a highly sensitive acoustic sensor that can detect pinhole-sized leaks on pressurized pipelines. The SmartBall platform has been able to identify leaks as small as 0.028 gal/min (0.11 liters) and has a typical location accuracy of within 6 feet (1.8 meters).

Gas Pocket Detection

The acoustic sensor is also able to identify the sound of trapped gas within pressurized mains. The presence of trapped gas can adversely affect pipeline flow or lead to degradation of the pipe wall in sewer force mains.

Inspection Benefits

- Easy to deploy through existing pipeline features
- No disruption to regular pipeline service
- Can complete long inspections in a single deployment
- Highly sensitive acoustic sensor that can locate very small leaks
- Can identify features relevant to the operation and mapping of the pipeline
- Indicates the position of leaks, and gas pockets relative to known points

xylem
Let's Solve Water

Pure Technologies, a Xylem Brand
EN 247, Edifício Jonobras, Sala 3, Piso 2
2670-027- Santo Isidoro, PORTUGAL
Tel +351 261 863 159
www.puretechltd.com

pure TECHNOLOGIES

CHAPTER IV

NRW ASSESSMENT AND STRATEGY DESIGN

sebaKMT
A member of Megger Group

Reprezentanţa Seba Dynatronic
Str. Aviator Ştefan Protopopescu nr.1
Bl.C6, et.6, ap.25, sect.1, Bucureşti
Tel. 021 2309138 Fax 021 2039381
Internet: www.sebakmt.com
E-mail: seba.ro@sebakmt.com

Seba Dynatronic®, a member of the **Megger** Group, is a world leader in the production of individual equipment and fully-equipped test vans for locating losses in water distribution networks, cathodic protection pipelines and faults in power or telecommunication cables, with a field experience of over 65 years. The company also manufactures buried pipes and cables locators.

Headquartered in Baunach - Bavaria, the company has subsidiaries on all continents. "The key word of our philosophy is **TRAINING**." Seba Dynatronic® offers its clients every year a number of seminars organized at the seminar centre in Baunach - Germany, or at the beneficiaries' headquarters where more than 30,000 specialists from 120 countries, including Romania, have already participated.

All major water companies in Romania have purchased from our company portable equipment to locate network water losses, which have proven their robustness and efficiency in operation, with more than 75 test vans being delivered at the time.

As far as equipment for the energy sector, up to now, on the Romanian market, our company has put into operation a number of over 200 fully equipped test vans and mobile fault location systems.

It is a great pleasure to introduce our range of tools and equipment produced by our company and used in the field of operation / maintenance of water pipelines, district heating and sewerage:

- Fully equipped test vans - **"ECO" COREMOBIL**
- Flow meters and pressure gauges - **UDM 300-500, TDM 200**
- Pressure monitoring systems- **Seba Flow**
- Pressure and flow loggers - **SebaLog® D3, SebaLog® P-3, P-3mini**
- Leakage monitoring / network correlators - **SebaLog®N3**
- Correlators - **Correlux® C3, Correlux® C300, sebalog CORR**
- Trunk main monitors / Correlators - **Hydro Corr**
- Electroacoustic listening equipment - **Hydrolux HL7000, HL-H$_2$®, HL50BT**
- Pipe and cable locators - **vLocPRO3, Ferrolux®, easyloc**
- Manhole cap locators - **VM 880, FT 80**
- CCTV Systems - **vCam6**

All the instruments offered are extremely robust, easy to use, even in the toughest conditions, allowing you to successfully get out of the toughest situations by quickly performing the necessary tests and measurements. We are confident that SebaKMK offers you the **complete solution** to solve all your problems, and the choice and use of our tools will always make you a winner.

PRACTICAL ASPECTS FOR WATER LOSS PI'S TARGETS IN WATER DISTRIBUTION SYSTEMS

Alexandru Aldea*

* Department of Hydraulics and Environmental Protection, Technical University of Civil Engineering Bucharest, 122-124 Lacul tei Blv, Bucharest, Romania
(E-mail: aldea@hidraulica.utcb.ro)

Abstract
The key method for tracking the progress of reducing the non-revenue water and especially the physical losses in a supply network is trough-continuing evaluation of certain key performance indicators. Thus water loss management became a major priority for the water utilities worldwide in the past decades and at the same time it became obvious that one predominant aspect is to establish realistic targets for these particular indicators.
Earlier studies on the implementation and use of performance indicators across water utilities in general (6) concluded that the most common issues regarding the use or misuse of PIs are the following:
- the overconfidence in the available data can result in severe over- or underestimations of the variables needed to calculate de performance indicators;
- the NRW indicator proved to be inadequate as a target PI for real losses because doesn't offer detailed information on the real problems;
- the choice of different benchmarking matrix can yields different strategies, so it is recommended to carefully chose the benchmarking matrix and then restrain to change it;
- the choice of assessing the performance indicators should follow this simple rule: financial indicators when dealing with a water utility / subsidiary and operational indicators when dealing with the actual distribution network.

Keywords
Water losses, performance indicators, forecast.

1. INTRODUCTION

The International Water Association (IWA) has proposed over the years a best practice methodology and terminology regarding the water balance, which will be used in this paper. The basic concepts of this methodology include the calculation of the water balance for a period of one year (as seen in Figure 1), the calculation of key performance indicators and finally a benchmarking process directed either at the same water utility for different periods, or at several water utilities for the same period.

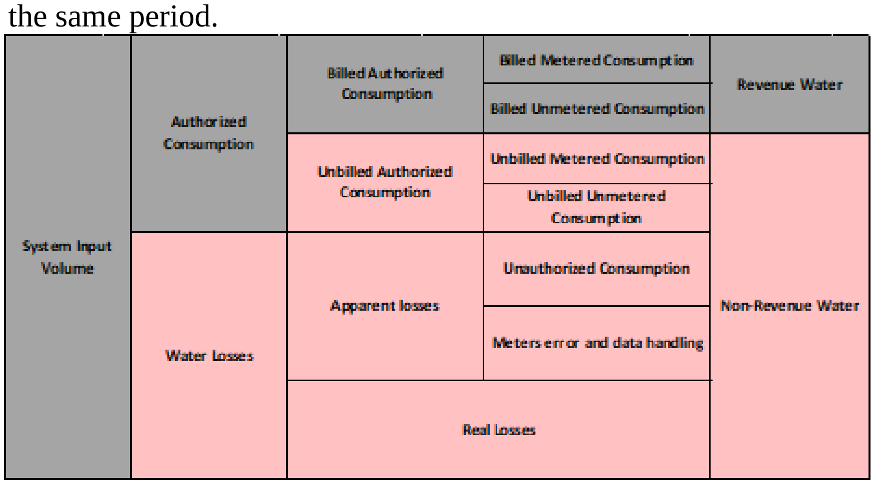


Fig. 1. The Water Balance according to IWA best practice methodology

Several common abbreviations will be used in this paper concerning both the components of the water balance and the performance indicators, as follows:

- SIV will designate the System Input Volume that is the water volume injected into the supply system for a period of one year. The value of SIV depends on what the actual system is defined: it could represent the volume of water directly entering the distribution network or it may represent the volume of raw water that will be treated and distributed;
- NRW will designate the Non-Revenue Water for the same period. The NRW contains both the water losses and the unbilled consumption and represents the difference between the SIV and billed consumption;
- LKN indicator designates the real losses per network length (excluding connection length). Different sources refer to this indicator by different denominations and measuring units. While the *National Manual* (3) prefers LKN in cm/km/year, in *Performance Indicators for Water Supply Services* (1) this indicator is identified as Op28 and expressed in l/km/day (when the system is pressurized).
- ILI designates the Infrastructure Leakage Index and is calculated as the ration between the Current Annual Real Losses (CARL) and the Unavoidable Annual Real Losses (UARL), both expressed in l/connection/day. ILI takes into account several factors: the network length, the number of connections and the average pressure in the network according to the following formula:

$$ILI = \frac{CARL}{UARL} \quad (1)$$

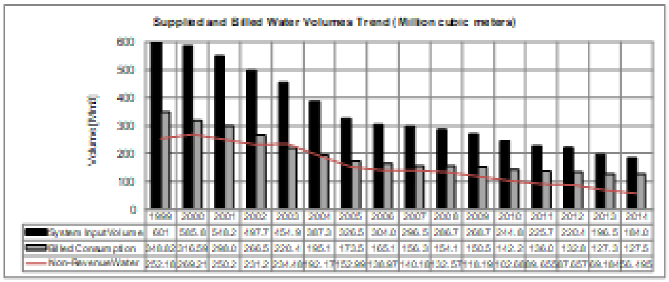
$$UARL = \left(\frac{18xLm}{Nc} + 0.8 + 0.025 * Lp\right) * P \quad (2)$$

The UARL formula may seem slightly different depending on the source material, but the constants are actually depending on the measuring units for length and pressure. The Eq. (2) is using the following variables and measuring units: *Lm* represents the length of mains in km, *Nc* represents the number of connections, *Lp* represents the average length of service connection in m and *P* represents the average pressure in mWC.

2. WATER SUPPLY PERFORMANCE INDICATORS

Despite the fact that the non-revenue water expressed as a percentage of the system input volume is a very popular choice for benchmarking, industry experts (most notable by Allan Lambert – “The Zero-Sum Leakage Performance Indicator”, www.leakssuite.com) have heavily criticized its usage (2).

Recent studies (8) concerning the trends for supplied water, billed water and non-revenue water in the Bucharest area illustrated in another way the non-correlation between NRW expressed as a function of billed volume and the system input volume, as seen in Figure 2.



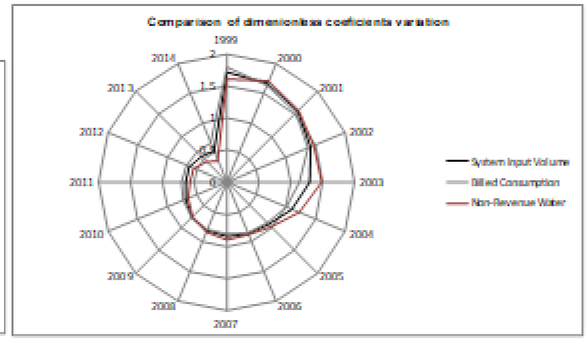


Fig. 2. (*left*) Trends for Supplied and Billed Water Volumes over a period of 15 years in millions cubic meters; (*right*) Comparison between dimensionless variation coefficients for the three trends

The Billed Water Volume shows a monotonically decreasing trend, almost logarithmical and it appears to be stabilized from 2011 onwards. This fact suggests that the consumption rate may have reached a normal figure for this particular water supply system. The System Input Volume also keeps a monotonically decreasing trend at different rates over the same period, but there is no evidence at this point to suggest that this trend is stabilized yet; on the contrary it may decrease in the near future. At first glance both trends suggest a better situation versus the precedent year; however when the Non-Revenue Water is calculated, this new trend doesn't keep the same monotonic characteristic. Although undoubtedly the NRW trend is decreasing over the entire 15 years period, there are occasionally situations when this value is higher that the precedent year. This fact is easily seen by calculating the dimensionless variation coefficients for all three trends as follows: for each trend an average value was calculated taken into consideration the entire period of 15 years and then each annually value was divided by the corresponding average. This is an important observation for the analyzed system, because traditionally the design standards for sizing a water treatment plan for a water supply network evaluate the design flow rate by adding a certain percentage of the supposed Billed consumption. As a result, this approach is commonly used also for forecasting the System Input Volume for certain time periods. Figure 2 illustrates why this type of approach presents certain risks and also why is advisable to consider a forecasting approach based on the water volumes instead.

Other studies on the implementation and use of performance indicators across water utilities in general (6) concluded that the most common issues regarding the use or misuse of PIs are the following:

- the overconfidence in the available data can result in severe over- or underestimations of the variables needed to calculate de performance indicators;
- the NRW indicator expressed as percentage of SIV proved to be inadequate as a target PI for water losses because doesn't offer detailed information on the real problems;
- the choice of different benchmarking matrix can yields different strategies, so it is recommended to carefully chose the benchmarking matrix and then restrain to change it;
- the choice of assessing the performance indicators should follow this simple rule: financial indicators when dealing with a water utility / subsidiary and operational indicators when dealing with the actual distribution network.

The introduction of the Infrastructure Leakage Index as a key performance indicator offered some objective comparison between different water utilities, as it takes into consideration important networks characteristic such as number of connections, network length and average pressure. Although currently the ILI is regarded as the most appropriate choice for this task, it presents some limitations when used for establishing a target performance indicator for a particular system or for drawing general conclusions from one or more systems. According to *A. Lambert*, the ILI should be used as a target KPI only when all the appropriate actions for the pressure reduction have been undertaken by the water utility.

General situation in Romania

At the moment, the performance indicators system used by water utilities in Romania is derived either from the IWA best practice manual *Performance Indicators for Water Supply Services – second edition* (Alegre *et al*., 2010) or the *National Manual for Water and Wastewater Operators* (2008, 2010) and compared with the World Bank Matrix or National Manual Matrix. The most common and popular indicators concerning water losses are the NRW as a percentage of SIV, LKN, ILI, and various percentages of SIV for the real or apparent losses.

The Romanian water utilities are designated as Regional Operators, that is every Regional Operator consists of several subsidiaries that manage 1 to 20 supply systems, depending on local conditions. This particularity quickly became an issue when comparing different entities for the following reasons:

- many subsidiaries manage independent systems and consequently any PI calculated for the whole subsidiary is of little use when trying to prioritize the investments an rehabilitations on independent system level;
- the regulator only asks for compliance to a certain percentage of NRW of SIV for the entire water utility, so most of the utilities tend to disregards other PIs and consequently they don’t have a tradition of keeping sound records of variables used to calculate these particular PIs.

A detailed analysis of various benchmarking and design documents utilized in Romania was presented in a 2018 paper (12) concluding that there are a great number of discrepancies between these documents and urging for a uniform approach regarding the water loss management.

3. COMPARISON CRITERIA

Consequently there is need for further context factors in order to make the comparison relevant, that is to determine which systems are “more similar” with another in terms of network characteristics and behavior. In this respect the following information was assessed for more than 30 water supply systems in Romania:

- the density of connections (connections/network length);
- the ratio between inactive and active connections;
- the ratio between mains length and distribution length;
- the annual authorized consumption profile (only were multi-annual data was available);
- the consumption per capita (in order to compensate for different connection diameters).

The supply systems vary in size, from small villages to medium size cities. Figure 3 offers an overview of all the various systems used in this study, emphasizing the network length, the number of connections and the resulting density of connections. Also this overview served as an initial grouping of the studied systems, that is one group consisting of medium to large size and the other consisting of smaller supply systems (usually under 10,000 inhabitants). The detailed representations of the smaller systems also illustrated a great diversity of the resulted density of connections, which implied that further grouping was necessary.

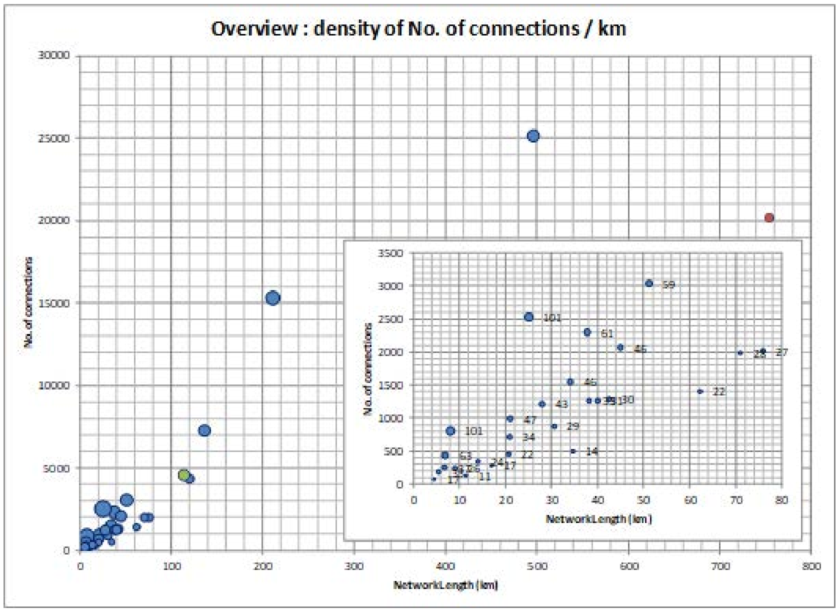


Fig. 3. Overview of the various supply systems used in this study: red and green dots represents systems where the transportation pipes were taken into account

This density of connections criterion was calculated using only the length of the distribution network, but in two cases it was not possible to separate the values for transportation and distribution lengths (these systems actually consist of more than one distribution network).

The obtained values actually served two purposes: one was to establish the smaller groups of systems better suited for PIs comparison and the other was to raise a “red flag” regarding the somewhat big differences of the resulted figure. Further investigations revealed that in some cases the record of existing connection only took into consideration the active connections and in other cases the length of transportation pipes was included in the utilities’ data as part of the distribution network.

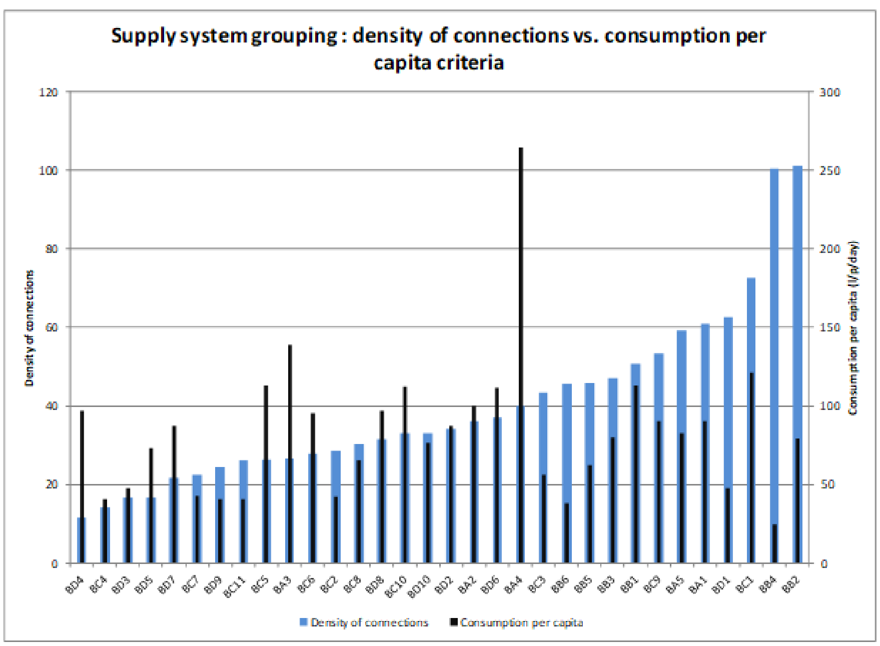


Fig. 4. Consumption per capita criterion suggests different comparison grouping

The next important comparison criterion turned out to be the consumption per capita (the measuring unit used was l/person/day). The problem regarding this criterion is not that the results suggested a different grouping of the studied systems than the density of connection criterion, but also managed to raise another set of “red flags” concerning some very low or very high values.As a thumb rule for Romania, for urban area consumption in the vicinity of 100 l/person/day is generally accepted while a for rural areas the accepted value is around 80 l/person/day. In this respect, any resulted value that differs greatly from these figures needs further investigations.

Generally speaking, the very low values (around 40 – 50 l/person/day) characterize the new small networks, where either not all citizens were connected to the water supply or they still had an alternative water source from private wells. This situation emphasizes the need to clearly estimate the ratio between inactive and active connections and to differentiate between an “urban” and a “rural” system.

The only case when the consumption per capita had a very large figure (about 264 l/person/day) proved in the end to be a poor billing system management, where the non-domestic consumption was part of the actual domestic consumption.

The detailed investigations also revealed a very low degree of accuracy of the billed consumption records, which had a direct impact on the water balance itself and consequently on the PIs.

However, when dealing with “similar” systems, one more comparison criterion was studied and it refers to the sheer size of the network (more precisely the network length). When this criterion was put against the daily consumption, again it suggested different grouping. Figure 5 illustrates this issue. Although it is clear that at first glance two groups can be formed (one group comprised of the three big supply systems and the second group comprised of the rest), when we try to discrete based on the daily consumption we obtain various figures especially in the second group. This could also be explained based on the fact that many of the small systems are very new and with various connection rates.

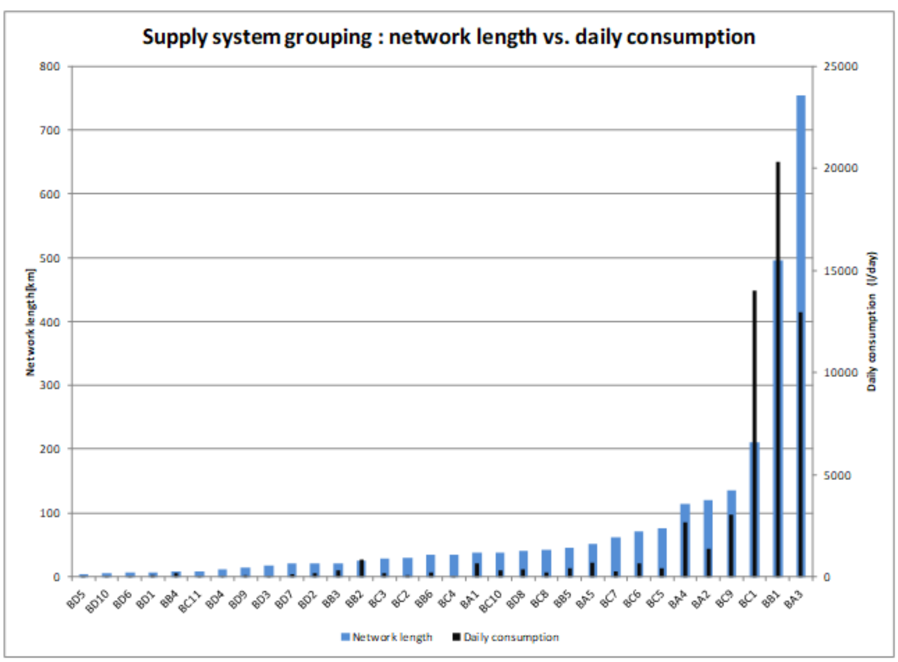


Fig. 5. Network length vs. daily consumption: each criterion suggest different system grouping

4. CONCLUSIONS

One important conclusion that resulted from applying this type of assessment is that it can be applied also for the same system over a period, in order to determine if the network characteristics and behavior changed significantly. This analysis proved to be very useful in the context of continuing water networks extension and rehabilitation programs currently undergoing in Romania.

This exercise suggests that the best approach to compare “similar” systems is to apply successively a number of criteria rather than randomly using different criteria for the same purpose.

All of the criteria served in the end two purposes: a primary purpose for objectively choosing the system to be compared and a secondary purpose of warning against corrupt or dubious data.

BIBLIOGRAPHY

[1]. Alegre, H., Baptista, J. M., Cabrera E. Jr. et al: Performance Indicators for Water Supply Services – 2nd edition, IWA Publishing, ISBN 1843390515, 2007;

[2]. Liemberger, R., Brothers, K., Lambert, A., McKenzie, R., Rizzo, A., Waldron, T.: Water Loss Performance Indicators, IWA WaterLoss, Bucharest, 1, 148-160 (2007);

[3]. ***: Manualul Național al Operatorilor de Apă și Canalizare;

[4]. ***: Normativ privind proiectarea, execuția și exploatarea sistemelor de alimentare cu apă și canalizare a localităților. Indicativ NP 133-2013;

[5]. ***: EU Reference document Good practices on Leakage Management, 2015;

[6]. Aldea, A., Anton, A: Operational vs. Financial Indicators in Water Losses Assessment, Water Loss Management: Conference Proceedings, 69–74, ISBN 978-606-93752-6-6, 2015;

[7]. Aldea, A., Stoica, N., Tudor, R.: Re-assessing Water Losses PIs in Small Distribution Networks, Water Loss Management: Conference Proceedings, 357–361, ISBN 978-606-93752-6-6, 2015;

[8]. Aldea, A., Aldea, M.: The inter-relationships between urban dynamics and water resource and supply based on multitemporal analysis, Proc. SPIE 9688, Fourth International Conference on Remote Sensing and Geoinformation of the Environment (RSCy2016), 96881B (August 12, 2016); doi:10.1117/12.2242021;

[9]. Aldea, A.: Key Mistakes for Establishing Water Loss PI's Targets in Small Networks, Efficient PI Conference Cincinnati, 2015;

[10]. Perju, S., Aldea, A., Mihailovici, M., Zaharia, V.: Challenges in the assessment of water loss KPIs in large distribution systems. Case study of Bucharest Water Supply System, SGEM 2016, Albena;

[11]. Aldea, A.: Pierderi de apă - Estimarea indicatorilor de performanță în rețele de mici dimensiuni, Conferința tehnico-stiintifica Performanta in serviciile de apa-canal, vol. 2: Infrastructura urbana, rețele urbane, management, 29-34, ISBN 978-606-93752-2-8, 2014;

[12]. Aldea, A., Anton A.: O analiză critică a sistemelor de evaluare a pierderilor de apă utilizate în Romania, Conferința tehnico-stiintifica Efficient Use and Management of Water, 2018, Bucharest, Romania.

THE STATE TO STATE DOMINO EFFECT - WORLD'S LARGEST LEVEL 1 VALIDATED WATER AUDIT DATA SET COMPELS US UTILITIES, REGULATORY AND EPA FINANCING PROGRAMS TO MANDATE IWA/AWWA WATER LOSS BEST PRACTICES

Steve Cavanaugh*

*Steve Cavanaugh, P.E., President/Chief Innovation Officer, Cavanaugh & Associates, P.A., PO Box 11197, Winston Salem, NC 27116, 1-877-557-8923, steve.cavanaugh@cavanaughsolutions.com

Abstract

The original state-wide Water Loss training program in the United States (Georgia) was presented at 2013 IWA Efficient (Paris)[1]. The program, which assisted utilities in the preparation, submission and validation of Water Audits on an annual basis was driven by the Water Stewardship Act[2] resulting from the 2008 drought. However, the continuation of programmatic state funding, and expansion to a validation certification program was certainly not expected once the drought pressure subsided.[3] forefront as they soon legislated a requirement - SB 555[4] - for all urban retail water providers to perform an annual AWWA M36 water audit and obtain a Level 1 Validation.[5]

Like Georgia, the critical need for progressive module learning with hands on implementation was understood by the State Water Resource Control Board. Modelled after Georgia, the water loss technical assistance program (TAP) was advanced in California to include detailed instruction on Level 1 Water Audit Validation as well as next steps for implementation – audit to action. This second successful state-wide program in support of legislative requirements, with over 400 utilities (representing direct training to 1,500 utility personnel[6]) has captured the attention of 30 additional US states who are considering implementation and regulatory change.

This technical paper and presentation will highlight how US states are navigating the political, regulatory, and funding landscape of water loss control to assure industry adoption and sustained increases in utility technical, financial, and managerial capacity. In addition to details about the specific steps taken by the states, attendees will learn from 338 California Water Loss TAP survey participants who offered their direct written responses including lessons learned and action steps taken following the education and submission of the Water Audit.[7] The survey participants also shared suggestions for improvements for follow on technical assistance programs in California which provides further insight to other states.

Insights from the California regulatory program will be presented, as well as states who are considering enacting water loss control reporting change, and participating utilities as they give perspective of what moved them from learning about the ideas to full scale implementation.

It is expected that the audience will draw a correlation to how they can translate these utility and governmental ideas and strategies to their own geographic region to advance water loss control as a sustained business practice.

Keywords

Water Loss Control; Technical, Managerial & Financial Capacity Development; Economic Level of Intervention; Water Audit; Audit to Action; Water Audit Submission Requirement; Level 1 Validation; Data Sets; Drinking Water SRF.

BIBLIOGRAPHY

[1]. Cavanaugh, Steve (2013) Widespread BMP Implementation: Innovative Teaching Model for Water Auditing & Efficiency Training in Georgia, USA Program Overview. 7th International Conference on the Efficient Use and Management of Urban Water. Paris, France.

[2]. The 2010 Georgia Water Stewardship Act (2010) http://extension.uga.edu/publications/detail.html?number=C995.

[3]. Georgia Environmental Finance Authority – Sustained Water Loss Technical Assistance website – (Active) https://gefa.georgia.gov/water-loss-technical-assistance.

[4]. California Senate Bill 555 (2015) - https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB555.
[5]. Water Research Foundation (2016) – Level 1 Water Audit Validation Guidance Manual – Project 4639A http://www.water.ca.gov/wateruseefficiency/docs/2017/Level%201%20Water%20Audit%20Validation%20%20Guidance%20Manual.pdf
[6]. CA-NV AWWA Water Loss Control Technical Assistance Program Training website – (Active) http://www.californiawaterloss.org/.
[7]. Mosburg, Sue (2017) - The largest Water Loss Technical assistance program in the Nation. Association of California Water Agencies – 2017 Regulatory Summit. Sacramento, California, USA https://www.acwa.com/wp-content/uploads/2017/10/08_Mosburg.1030am.pdf.

WATER LOSS REDUCTION USING DIGITAL SOLUTIONS FOR WORK FORCE MANAGEMENT

Mădălin Mihailovici*, Alexandru Moldovan* and Valentin Zaharia*

*Splaiul Independentei, no. 235, C2 Building, Floor 1, Bucharest, Section 6, Romania
(madalin.mihailovici@veolia.com)
(alexandru.moldovan@veolia.com)
(valentin.zaharia@veolia.com)

Abstract
The increase of the water demand in recent years, as consequence of population growth, urbanization and climate change, is stressing the water supply system to its limits [1]. Water loss represents in the same time an economic, environmental and social issue due to their connection with urban areas and human activities. Water loss management in terms of reduction and control is a critical factor in the 21st century and can be observed as a decrease in the costs associated with the water supply system (energy, production, operational costs) which contributes to a sustainable development. Furthermore a better management of the drinking water network will avoid unnecessary loss of water and generates a lower environmental footprint [2]. Nowadays the DWN companies need to embrace the digitization process which represents a key factor in the improvement in terms of services, water loss reduction and also cost of investment and maintenance.

Keywords
Water losses, leakage, work force management, digital, network efficiency.

1. INTRODUCTION

Bucharest's drinking water network has a total length of 2500 km and 990 km of service-pipes (approximately 130 000 pieces). The transport of drinking water from treatment plants is done through the aqueduct system (with a total length of 192 km) to 20 reservoirs with a total storage capacity of 359 000 cubic meters, where it is temporarily stored and pumped by 7 first stage pumping stations into the distribution network. In addition to the first stage pumping stations, the drinking water distribution system also has 40 re-pumping stations, currently 29 in operation (2^{nd} stage) and 200 booster stations, currently 108 in operation (2^{nd} and 3^{rd} pumping stage). The entire drinking water system, from the production stage to the consumer, is controlled and monitored in real time through the SCADA system and gives hydraulic parameters which offer essential data for water balance, hydraulic modelling, leakage detection and water losses management.

2. WATER LOSS REDUCTION METHODS

According to the *International Water Association (IWA)* the water losses can be either real or apparent losses. Real losses represent the physical ones, which appear mainly due to the leakage of the water pipes lines, service connections and pipe bursts. Apparent losses represent commercial losses which are the consequence of illegal water consumption and inaccurate customer metering. A total of 27 725 smart meters are currently installed in Bucharest's DWN in order to reduce the commercial losses from the large consumers.

Among the methods used to detect and reduce water losses are included:

- *District metering areas*

In order to increase the efficiency of the network (decrease of technical and commercial losses), the distribution network is divided in District Metering Areas (DMAs). For each area, the water balance is calculated using flow and pressure meters installed along the distribution network and connected to the SCADA system, allowing real time alerts for potential pipeline failures. In order to improve the network efficiency Bucharest's DWN has been divided over the last decade in 255 districts (111 low pressure zones and 144 high pressure zones).

- *Field monitoring*

The condition of the network and the actual level of leakage are continuously monitored through regular inspections performed by field teams which identify illegal consumptions and hidden water losses with the help of technical equipment (correlator).

- *Hydraulic Modelling*

Hydraulic modeling of drinking water network is used to predict the hydraulic parameters such us flow rate, velocity, pressure, quality etc. It is also used to predict the impact of different scenarios and events that can affect the water supply. The results of implementing hydraulic modelling: pressure distribution in whole network, adjust pressure at PS, velocity in pipes, analyze optimization and extension of network, water age, highlight leakage hotspots and build proper DMAs.

3. WATER LOSS REDUCTION USING WORK FORCE MANAGEMENT DIGITAL SOLUTIONS

SMART applications are used for processing and managing the events that occur in the drinking water network, in order to reduce the time of detection (for visible and hidden leaks) and, implicitly, to repair them. The speed and quality of the repairs is one of the four leakage control strategies of managing real water losses according to *IWA Water Loss Task Force* [3]. In this context an important fact is the integration of the digital solutions and operational work force.

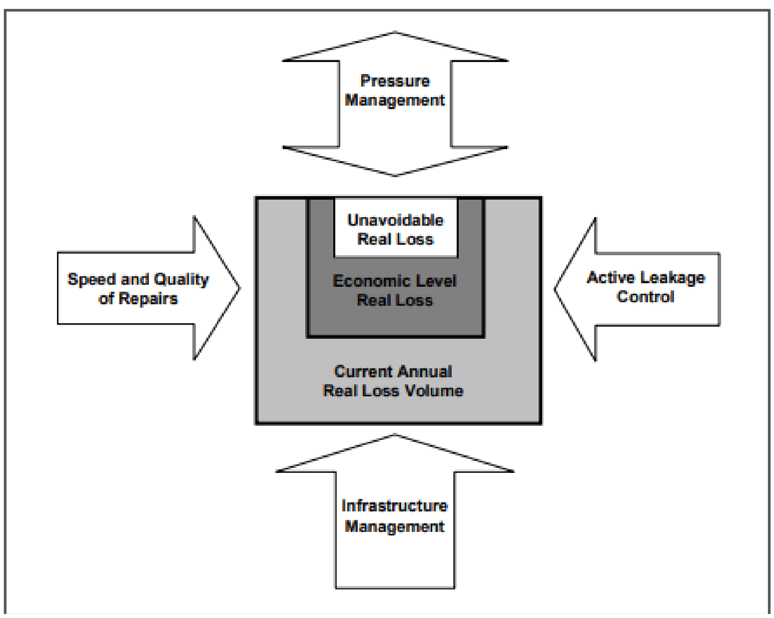


Fig. 1. IWA four leakage control strategies

Over the past years Bucharest has adopted a variety of digital solution among which an application that focuses on the work force management. The real time app receives notification from the back office and allows visualization and assigning on field work orders. Each intervention can be programmed and prioritized according to its magnitude. Also the application allows the user to browse the history (for a certain amount of time) and perform detailed reports for each intervention.

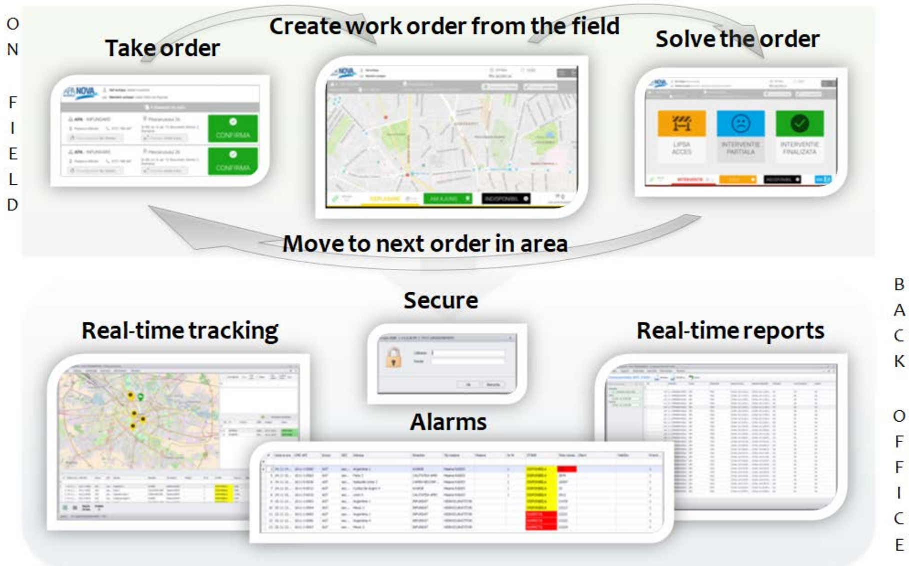


Fig. 2. Work force management application

4. RESULTS AND CONCLUSIONS

The efficiency of the drinking water network of Bucharest has reached 79%, from 51% in the year 2001. This significant increase is a result of many improvement methods adopted along the past years, but in order to maintain and further improve the efficiency digital solution are being implemented and are in a continuous development.

The implementation of the work force management application has achieved significant improvements to the efficiency of the DWN with some important results: fast response time and address identification, no downtime between orders, increased traceability and data analyze possibilities, less paperwork. The overall increase of the network efficiency has a positive impact on the quality of customer services, environmental protection (loss reduction), financial (lower costs) and operational activities (rate of damage occurring).

REFERENCES

[1]. M. Mihailovici, V. Zaharia (2013). Water loss reduction through hydraulic modelling, p.316-319, conference volume: Proceedings of IWA 5th Eastern European Young and Senior Water Professionals Conference, Kiev, Ukraine.
[2]. European Commission (2018). Safer drinking water for all Europeans, 1 February, Brussels.
[3]. Water Loss Task Force (2004). Draft IWA DMA Manual.

SUSTAINED LEAKAGE REDUCTION AT AN ILI OF 0.6 – LESSONS LEARNED FROM THE ONGOING WATER LOSS CONTROL PROGRAM OF WATERBEDRIJF GRONINGEN

Cor Merks*, Wout Kompagnie **

*Ramboll Netherlands B.V., Hooikade 13, 2627 AB Delft, the Netherlands, cwam@ramboll.com
**Waterbedrijf Groningen, P.O. Box 24, 9700 AA Groningen, the Netherlands, W.Kompagnie@waterbedrijfgroningen.nl

Abstract
Waterbedrijf Groningen supplies annually 45-46 million m^3 of reliable drinking water to about 580,000 customers in the province Groningen in northern part of the Netherlands. The average operating pressure is 33.0 metres, length of mains is 5,608 km, water is supplied to 230,189 connections, average length of customer service line is 12.7 metres, average customer retail unit cost is € 1.32 per m^3 and revenue water is 43-44 million m^3 per year (all data refer to year 2017). Waterbedrijf Groningen is operating their water supply system at Real Losses of 1 litre/connection/day/m pressure and an ILI of 0.6; quality assured values established with the AWWA Free Water Audit Software® of which parts have been translated in Dutch language.
Waterbedrijf Groningen has two main drivers to continue the ongoing water loss control program: i) the utility strives to excel on asset management, and ii) growth of the utility is limited by a lack of fresh groundwater resources. The strategic response has been to consider leakage management an essential long-term activity and to embed the leakage reduction methods and activities in both the ISO 9001 Quality Management scheme as well as in the ISO 55001 Asset Management scheme. Annual water audits are the basis for the short-term leakage reduction plan (or: improvement plan) that follows the Plan-Do-Check-Act cycle.
The aim of our presentation is to inform the participants about "how" Waterbedrijf Groningen has integrated the Good Practices on Leakage Management over the last decade to arrive at one of the world's lowest ILI in a specific geographic case with salt water intrusion and an increasing water demand. A secondary aim of the presentation is to provide the lessons learned from the ongoing water loss control program that ensures the utility of additional revenue water against limited additional cost. Waterbedrijf Groningen experiences that targeted investments in water loss control result in the cheapest, nearest source of new water.

Keywords
Asset management, good practices on leakage management, sustained leakage reduction.

About the authors

Cor Merks is a lead consultant on water supply and has acted as project manager for the EU Reference document Good Practices on Leakage Management WFD CIS WG PoM (© European Union, 2015). He has been working with Waterbedrijf Groningen from 2015 onwards. Wout Kompagnie is a senior consultant and project manager of Waterbedrijf Groningen. He leads the ongoing water loss control program of the utility. Furthermore, he acts on behalf of Waterbedrijf Groningen as senior consultant on NRW reduction in various projects in developing countries, thereby contributing to the Sustainable Development Goal 6: Clean water and sanitation.

IDENTIFYING OF WATER LOSS SECTORS BY MEANS OF FLOW MEASUREMENT

eng. Sorin A. Murariu*; dr. eng. Mihail Doruş**

* Chief Office Network Analysis, S.C. APAVITAL S.A., no. 6 Mihai Costăchescu Street, Iaşi, Romania (email: sorin.murariu@apavital.ro)
** Technical Manager, S.C. APAVITAL S.A., no. 6 Mihai Costăchescu Street, Iaşi, Romania (email: mihai.dorus@apavital.ro)

Abstract
The paper refers to the fast and accurate identification of defective pipe sections inside the water distribution network of a DMA by means of a portable flowmeter mounted on the DMA supply point. This method creates a subsector inside an existing DMA with which we intend to find out the distribution of flows recorded overnight during period 01-04 a.m. within this DMA. Subsequently, based on results obtained, the best water loss reduction strategy is to be applied. The main advantages of this method are that losses are precisely pre-located and good quantitative information related to them can be obtained, information that is important for making correct and effective decisions in order to eliminate such losses.

Keywords
DMA analysis; water loss evaluation; flow measurements with portable flowmeters.

1. STAGE 1 - SELECTING THE MICRO-SECTOR

The selected DMA for our example is “Platoul Aviatiei” area that belongs to the Iasi City metropolitan area. It was created in 2007 when the water distribution network rehabilitation works were completed. Initially, a mechanical flowmeter was mounted. This flowmeter was used to generate one week period reports on consumed water flows and volumes (this was made via a dedicated flow logger that was mounted two or three times per year). Since 2018, a technical solution has been found in order to transfer data from a pulse transmitter flowmeter towards SCADA, in real time, fact that enabled the monitoring of night water consumption and the quick identification of a failure occurrence.

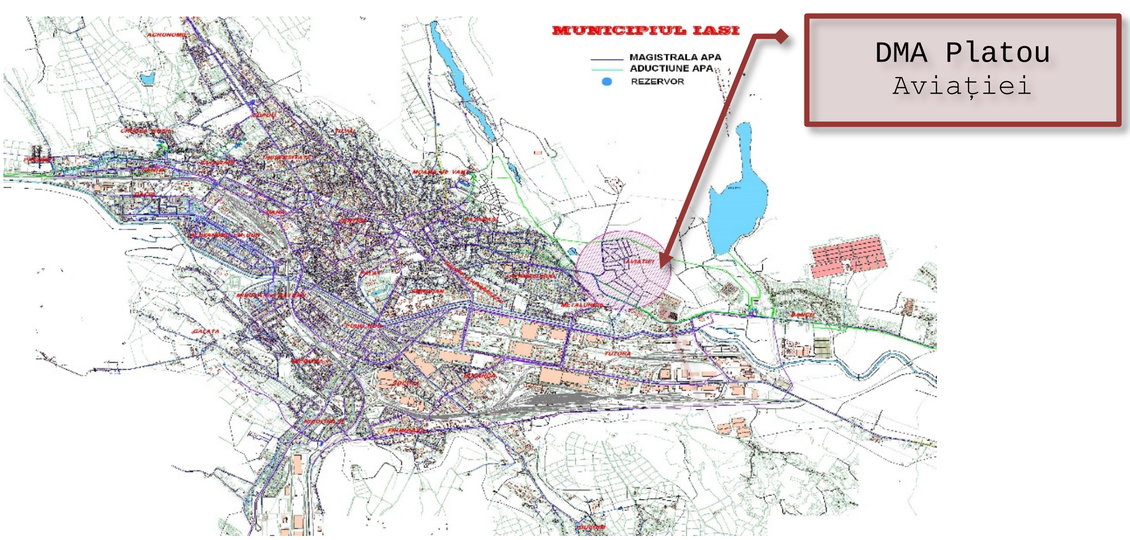


Fig. 1. DMA “Platou Aviatiei”

Where:
"Magistrala apa" = Main Water Pipeline;
"Aductiune apa" = Main Water Supply Pipeline;
"Rezervor" = Water Tank.

Technical data - The "Platou Aviației" DMA:
1. Area = approx. 526.000 m^2;
2. Pipe total length = 9,465 km;
   a. FP DN80 --- DN100 = 1.268 km (pressure cast iron);
   b. OL DN100 --- DN200 = 0.784 km (steel);
   c. HDPEDN32 --- DN160 = 7.413 km;
3. No. of connections = 560.

A section-by-section verification campaign of the entire distribution network in this DMA, by means of conventional methods (acoustic correlator, ground listening, noise loggers) would take months and eventually the obtained results may be relevant or not (in such case results ultimately depend on many external factors that can negative influence he fairness of measurement).

The proposed method in this paper significantly reduces the defect identification time, finally resulting in a map showing the subsector distribution of night consumption, recorded with an electronic measuring device mounted in the DMA general water meter manhole. Once these data are gathered, a real assessment of pre-localized defects can be carry out and, hence, the best remedies for them can be found.

2. STAGE 2 - UPDATING THE MICRO-SECTOR'S DISTRIBUTION NETWORK LAYOUT

Data related to the distribution network on which activities are to be carried out are extracted from the GIS, in order to update the boundaries of the micro-sector that is to be analyzed. Moreover, the status of the sector valves must be checked on field (valves must be properly closed). Then, within the micro-sector, all line valves will be identified, i.e. the valves which would help to create DMA sub-sectors (this action will be based on maps/layouts and discussions held with area operation personnel). More functional valves means a higher accuracy of final results. Afterwards, the existence of valves and their operational condition is to be checked on field (by closing-opening manoeuvers). Sometimes access to some valves or valves manholes/covers/street boxed may be hindered as a result of public road works. In such case the valves must be located and uncovered in order to ensure their functionality in good conditions.

In our situation, a number of 37 line valves have been identified, out of which:

- 1 micro-sector boundary valve, manhole mounted, functional and closed;
- 6 manhole mounted valves;
- 30 rod-operated valves encased in street boxes, out of which 11 required various operations as locating, digging, rising valve to proper elevation, mounting of new rods, various repairs.

Fig. 2. General Water Meter

Where: "Apometru general" = General Water Meter

In order to ease the sub-sectorization activity, a layout of distribution network was produced. The layout shows the streets with their valves positions, all valves and manholes being numbered (fact needed at a later stage).

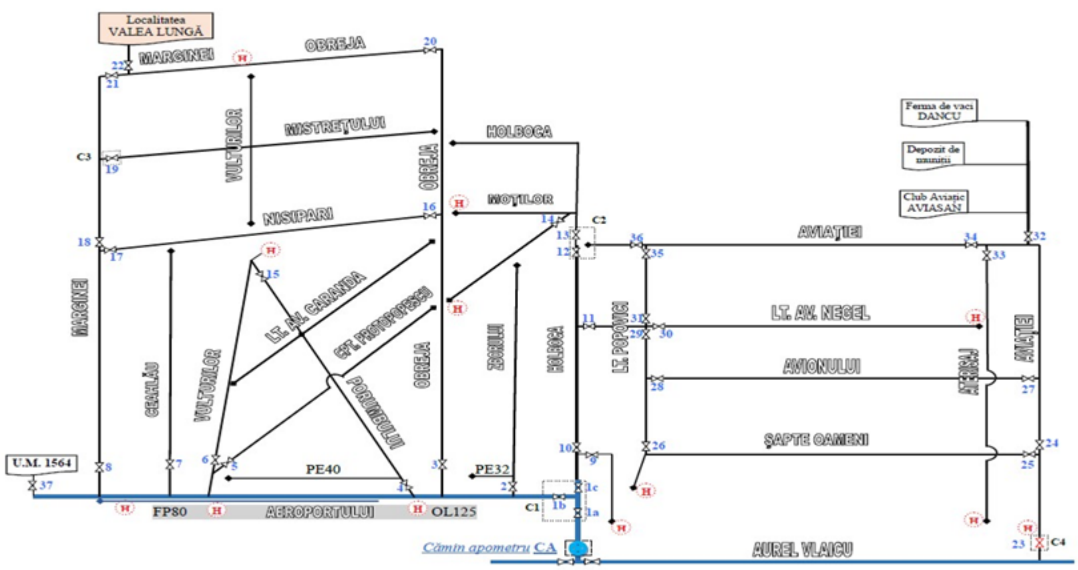


Fig. 3. Valves positions on the streets

3. STAGE 3 - THE FLOW METER

A flow measurement campaign needs an electronic flow meter which must be accurate as possible, being also able to save all flow/time data into an internal memory from which data must be afterwards downloaded to a computer. In this case, we have used a Flexim F-601 portable ultrasound meter, a device that performed very well under test conditions in the Apavital

Metrological Laboratory. Even so, the mounting conditions on field will always influence the measurement results. Therefore, it is crucial to choose an optimal and suitable place where to mount the flowmeter. For the analyzed micro-sector the only optimal measurement location, considering the possibilities offered on field, was a place upstream the general flowmeter manhole.

Fig. 4. US portable flowmeter

Once the measuring location has been set, the US portable flowmeter was installed. Afterwards, after a minimum 24 hours running time, a first comparison was made between the data transmitted to SCADA from the general (permanent) water meter and the data saved into the portable flowmeter's memory. The results obtained in our case were similar, this being proof that the negative influences due to the physical location of measurement are minimal and, hence, the obtained data could be trusted.

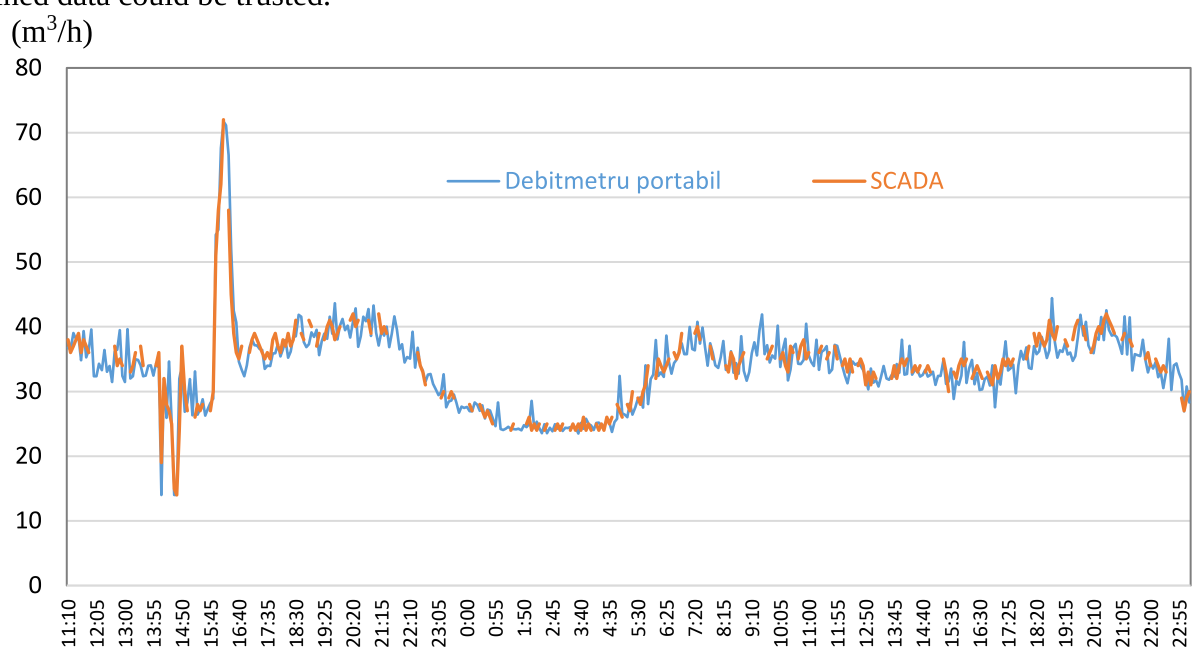


Fig. 5. Comparison - Data transmitted to Scada and data saved into portable flowmeter's memory

Where: “Debitmetru portabil” = Portable Flowmeter

The data obtained at this stage are to be used as benchmarking values for the end of the pre-localization and network defect repairs stages, when these data will be compared with the new obtained values.

4. STAGE 4 - PREPARING THE TERRAIN FOR NIGHT-TIME WORK

At this stage, the latest details are set to ensure the soundness and success of the campaign:

- the working team is established;
- media is notified about the measurement campaign (date, hourly interval and streets affected by water cut-offs);
- the valve closing planning is set;
- the settings of the portable flowmeter are verified, respectively the synchronization of its internal clock with the ground operator’s watch (crucial for an exact correlation of the moment when a valve closes and the effect of this closing on the flow rate variation recorded by flowmeter);
- other elements are verified and set: the internal memory capacity (must suffice for storing current data), the condition of flowmeter external battery (if flowmeter has been running continuously for several days), a convenient data storage interval (not too low, that would lead to a much to fast filling of memory, but not too large, situation when flow variations are lost - in our case data recording interval was set to 3 seconds, a number of 20 values saved per minute being considered a satisfactory amount);
- on the day before the measurement night, access to all valves is re-checked, and where necessary, special measures are taken: signposts installed in order to prevent car parking above valves, manholes filled with rain water are drained off etc.

Another important thing that must be set is the time interval at which the successive valve closing manoeuvers are to be carried out. It is usually considered that the nocturnal interval when only water losses are recordable is between 02-04 a.m. For the “Platou Aviatiei” micro-sector we have analyzed data recorded in SCADA during the last week before the night measurement campaign, and we have noticed that the smallest and steadier level showed by the consumption graph occurred between 01:30 hours and 04:00 hours.

Once the time interval and the number of closing manoeuvers (i.e. 20) were set, we have computed that in order to comply with the proposed time interval the time between 2 consecutive manoeuvers should not exceed a value of 10 minutes.

The planning involved the drafting of a table indicating the order in which the valve closing sequences are to be carried out. Thus, the table indicates the valve or the valves, based on numbering made in Stage 2, the exact time when the manoeuver was performed and the areas where water cutoff will occur (as accurately as possible).

Example:

The order of manoeuvers conducted on line valves during the night of 23 to 24 May 2019 in the „Platou Aviatiei” DMA.

Table 1: Order of manoeuvers conducted on line valves in the "Platou Aviatiei" DMA

No	Hour	Closed valves	Water cut-off affected streets
1.	01:15	22	Valea Lungă village
2.	01:25	32	Fp50 pipe towards the *DANCU CATTLE FARM*
3.	01:35	33	str. Aterisaj
4.	01:45	25 + 27 + 34	str. Aviației (partially between str. Aterisaj and str. Aurel Vlaicu)

The order of line valves closure is dictated by the following rule: the action must be commenced from the network's farthest point in reference to the general water meter and valves are successively closed until the last valve before the flowmeter is reached.

5. STAGE 5 - FIELDWORK AND DATA CORRELATION

This is the most interesting part of this method, when after several weeks of preparation the team is ready to enjoy the results, as a result of contribution from each team member.

On 24 May 2019 works were carried between 01:15 hours - 04:00 hours in the "Platou Aviatiei" micro-sector, and the working team included 2 people, the undersigned and one plumber. The results obtained are presented as a graph and a table.

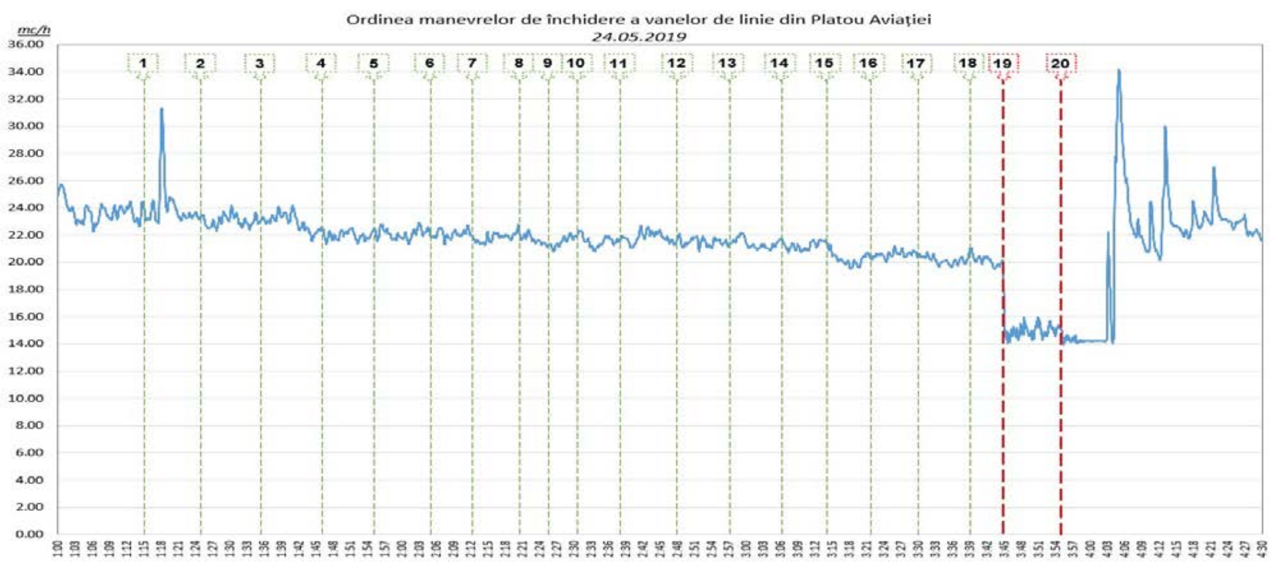


Fig. 6. Order of manoeuvers performed on line valves during the night of 23/24 May 2019 inside the „Platou Aviației" DMA

Table 2: Order of manoeuvers performed on line valves during the night of 23/24 May 2019 inside the „Platou Aviației" DMA

No	*Hour*	*Closed valves*	*Streets affected by closed valves*
1.	01:15	22	Valea Lungă village
2.	01:25	32	Fp50 pipe towards *DANCU farm*
3.	01:35	33	Aterisaj street
4.	01:45	25 + 27 + 34	Aviației street (partially between Aterisaj and Aurel Vlaicu)
5.	01:55	30	Lt. Negel street
6.	02:05	29	Lt. Popovici street (partially) + Avionului street + 7 Oameni street
7.	02:12	11	Lt. Popovici street + Aviației street (fully,both)
8.	02:20	14	Cpt. Protopopescu street (partially)
9.	02:25	16 + 21	For interruption of ring on Marginei street and Obreja street
10.	02:30	19	Vulturilor street (partially) + Mistrețului street
11.	02:38	17	Nisipari street
12.	02:48	8	Marginei street (partially up to valve 21)
13.	02:57	7	Ceahlău street
14.	03:05	5	Cpt. Protopopescu street (fully)
15.	03:14	4 + 6	Vulturilor street + Porumbului street + Lt. Av. Caranda street
16.	03:22	3	Obreja street + Marginei street (fully)
17.	03:30	2	Zborului street
18.	03:40	10	HDPE75 partially distribution Holboca street
19.	03:45	1b	Aeroportului street
20.	03:55	1a	Holboca street (minus the sector between Aurel Vlaicu, Aeroportului) + Moților street

6. STAGE 6 - DATA ANALYSIS AND MEASURES TAKEN

After correlation of information related to the effect produced by each manoeuver on the night flow variation and conducting their analysis, the following conclusions were drawn:

1) Manoeuvers 1-18 - about 85% of distribution network was closed, resulting in a flow decrease of about 4 m^3/h, these being possible inner losses at customers or consumptions.
2) Manoeuver 19 - Closing of OL125 + FP50 pipe section on Aeroportului Street has indicated a 6 m^3/h water loss, hence we were sure that it was a pipe defect, due to the sudden drop in instantaneous flow.
3) Manoeuver 20 - After closing valve 1a from the intersection Holboca Street-Aeroportului Street, the OL200 pipe section from the general water meter remained under pressure and valve 1a too, this indicating a water loss of 14 m^3/h.

The next action was to carry out the actual identification of the defect site or defects identified on the two pipe sections. Naturally, we started with the most important one, the one from Holboca Street. On Monday, May 27th, correlations were carried out with the special devices and the defect place was pre-located with the acoustic correlator. Then, by ground listening with the "electronic ear” the exact position of the damage was marked, after which diggings were performed and the pipe defect was repaired.

Fig. 7. Holboca Street

Once the defect was repaired on Holboca Street no. 1, the portable flow meter was re-installed in the general water meter manhole and valve 1a was closed during the day for a short time. Thus, the result obtained showed that the identified and repaired network defect was the only one on this sector.

As stated at the beginning of this paper, one of the advantages of this method is that it can quantitatively assess the value of a water loss. Plus, when several failures occur, we can use this criterion in order to prioritize them for future repairs or for even a more radical decision, such as the full replacement of a sector, or a sector decommissioning. In this case, a short calculation showed the amount water saved in one month: 14 m^3 x 24 h x 30 days = 10.080 m^3.

Fig. 8. Checking of DN200 section on Holboca Street up to the intersection with Obreja Street (29 May 2019)

Moreover, the data recorded in SCADA from the general water meter, recorded before and after the failure repair indicated a decreasing in night consumption from 23 m^3/h to 9 m^3/h.

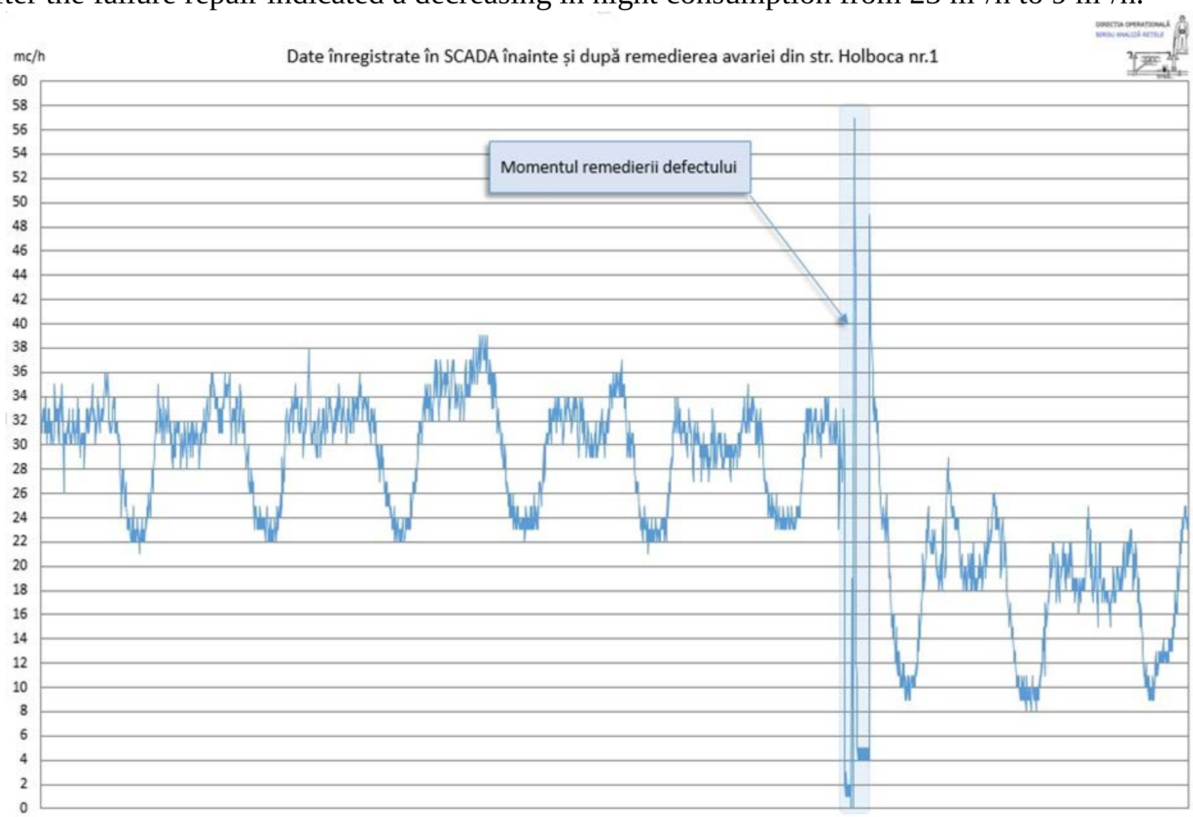


Fig. 9. SCADA recorded data, before and after the repair of defect located on Holboca Street No. 1 (Where: "Momentul remedierii defectului" = Moment when pipe defect was repaired)

Another negative aspect caused by this failure to customers in the „Platou Aviatiei" micro sector was the peak pressure fluctuation. We found this with a Sebalog D3 Pressure Data Logger mounted to a customer next to his complaints, as regards this unpleasant situation. The data logger was mounted on Thursday, May 23rd, and was removed on May 30th after the failure was repaired (the address of the consumer being on 9, Lt. Caranda Street).

The recorded graph is quite suggestive, under two aspects:

Before repairs, the pressure fluctuations were significant, this being visible from the graph's "thickness" and after repairs these fluctuations almost disappeared;

Before repairs, the minimum pressure was up to 1.2 bar, but after repairs it did not fall below 1.75 bar. The graph also shows an increasing of maximum pressure by about 0.2 bar.

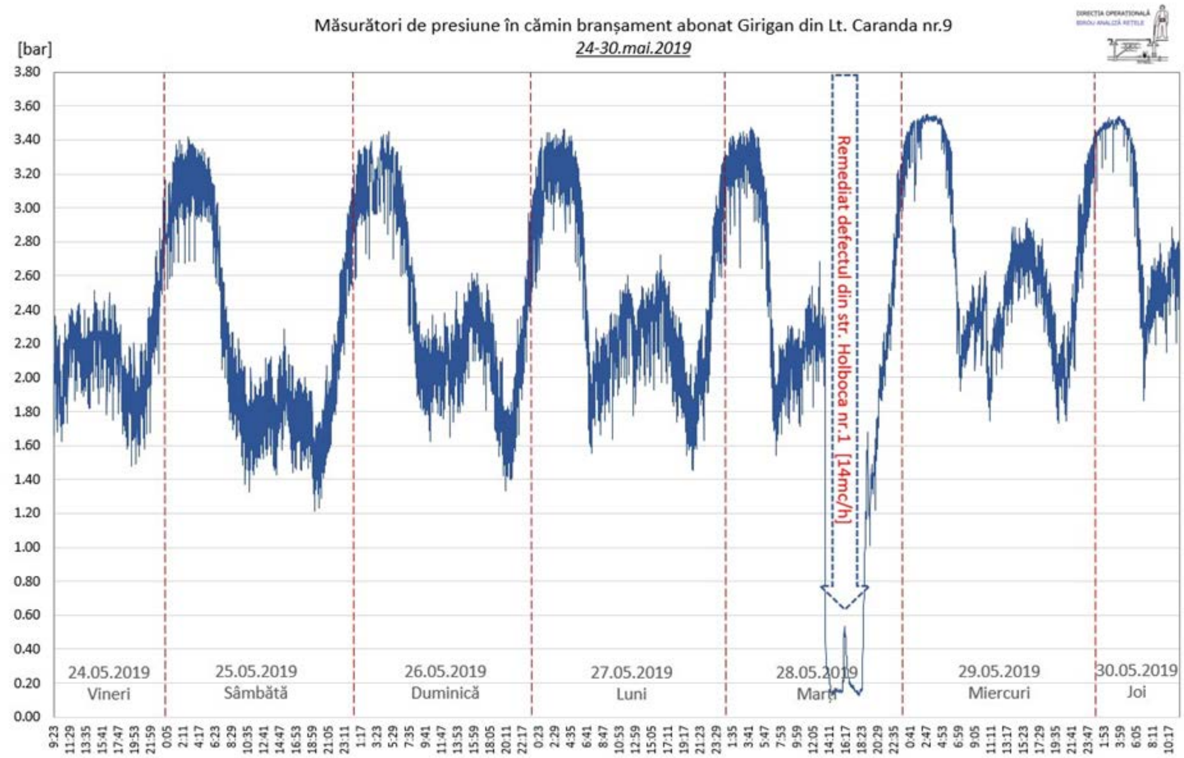


Fig. 10. Graph-pressure measurements in connection manhole, customer Girigan, 9, Lt. Caranda

It is to be said that all these negative effects were caused by a 2 cm hole in a OL200 pipe, with gravity supply and pressure of 4,5 bar in the failure area.

7. CONCLUSIONS

Two weeks and half of work were needed for identifying this water loss, during which the water distribution layout was updated, new customers were added, most of line valves were detected, repaired and operated, correlations and ground listening campaigns were carried out on a single pipeline sector, and most importantly, only one road drill survey was conducted.

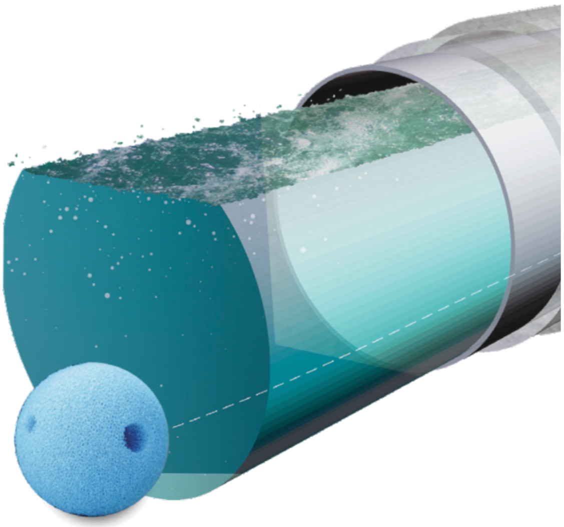
On the other hand, by means of this method of identifying water losses we managed to save 10,080 cubic meters/month of water and the water pressure at customers' taps has been significantly improved.

Considering that until the drafting of this paper measures could not be taken for solving the second water loss, this water loss will be identified and repaired as soon as possible.

xylem
Let's Solve Water

SmartBall® Technology

A FREE-SWIMMING TOOL FOR LONG DISTANCE WATER AND WASTEWATER INSPECTIONS



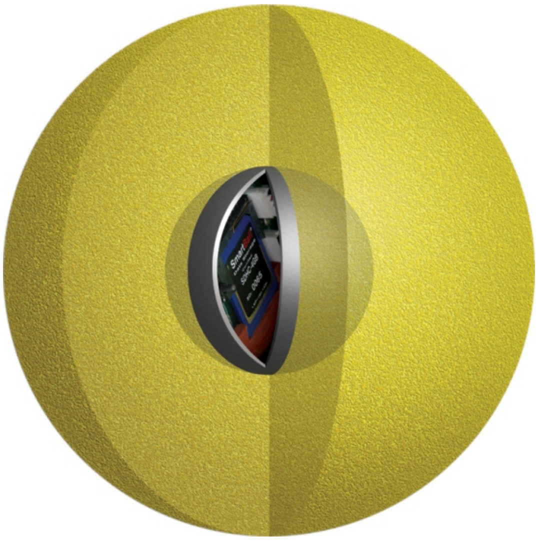
How SmartBall works?

The SmartBall® platform is a free-flowing tool for the assessment of pressurized water and wastewater pipelines 8 inches and larger. It can complete long assessments in a single deployment without disruption to regular pipeline service.

The tool is inserted into a live pipeline and travels with the product flow for up to 21 hours while collecting pipeline condition information. It requires only two access points for insertion and extraction, and is tracked throughout the inspection at predetermined fixed locations on the pipeline.

Applications

Owners of water and wastewater pipelines deal with a variety of infrastructure challenges; the SmartBall platform can collect a variety of pipeline condition information in a single deployment that helps owners manage their assets more effectively.



Leak Detection

The tool is equipped with a highly sensitive acoustic sensor that can detect pinhole-sized leaks on pressurized pipelines. The SmartBall platform has been able to identify leaks as small as 0.028 gal/min (0.11 liters) and has a typical location accuracy of within 6 feet (1.8 meters).

Gas Pocket Detection

The acoustic sensor is also able to identify the sound of trapped gas within pressurized mains. The presence of trapped gas can adversely affect pipeline flow or lead to degradation of the pipe wall in sewer force mains.

Inspection Benefits

- Easy to deploy through existing pipeline features
- No disruption to regular pipeline service
- Can complete long inspections in a single deployment
- Highly sensitive acoustic sensor that can locate very small leaks
- Can identify features relevant to the operation and mapping of the pipeline
- Indicates the position of leaks, and gas pockets relative to known points

xylem
Let's Solve Water

Pure Technologies, a Xylem Brand
EN 247, Edifício Jonobras, Sala 3, Piso 2
2670-027- Santo Isidoro, PORTUGAL
Tel +351 261 863 159
www.puretechltd.com

pure
TECHNOLOGIES

CHAPTER V

LEAK DETECTION

THE NEW TEHNOLOGYS IN WATER LOSS DETECTION

Ilie Ivan*, Alin Anchidin**

* SC APA CANAL 2000 SA Pitesti, ivan_ilie2000@yahoo.com
** SC AQUATIM Timisoara, alin.anchidin@gmail.com

Abstract
Finding and repairing leaks on our network quickly means that we can keep the amount of water wasted every year to a minimum which is good for our customers and the environment.

Keywords
Leakage, SAR, GPR.

Romania is one of the countries with the most drained water resources in Europe, which are relatively poor and unevenly distributed in time and space, and the usable resource is about 40 billion cubic meters, according to the World Water Day, the National Administration " Romanian Waters ". ANAR states that Romania depends to a large extent on water resources in different upstream countries, but these are not entirely usable. ANAR says that Romania's water resources amount theoretically to 134.6 billion meters (consisting of surface waters - rivers, lakes, the Danube river - and groundwater), of which the usable resource, according to the level of hydrographic basins, is about 40 billion cubic meters.

"The specific endogenous resources of Romania for the population are 1,894 m^3 / year / place, Romania being one of the countries with the lowest water resources in Europe, taking into account also the exogenous water resources (representing the contributions that are made on the territory of other countries and then enters the territory of the country) - in the case of Romania Danube and watercourses in the upper Siret basin - 170 km^3 / year, Romania's total water resources amount to 212 km^3 / year".

Considering these aspects, the importance of reducing water losses is high and the use of any new technology makes future resources better managed in the interests of future generations.

Classical water loss localization methods provide fairly good information regarding location of losses, but require high verification times for stretched networks and has large gaps where a well-established GIS system is not available to locate the correct of the verified routes.

These methods are:

- Dedication and monitoring through DMA interfaces;
- Monitoring the consumption and flows from the sewerage network at night in the suspect areas (use of the flowmeters at certain measuring points specially built for this purpose... advantages, disadvantages);
- The night monitoring technology of distribution networks (monitoring with logger in system push and lift, network with direct correlation etc.).

Traditionally water utilities designed their water networks as large interconnected and often looped systems. This design gave the system the greatest number of options for water flow and provided the utility with robust operational options.

Over time it was found that, with the flexibility of the interconnected system, there were issues in working out where the water was flowing in the network and this lead to challenges such as identifying which treatment plants were providing water to which customers and minimizing unaccounted for water.

It became important to begin to introduce some more pro-active non-revenue water (NRW) management techniques to complement the more reactionary passive NRW management techniques (such as repair following reporting of the leaks). Active NRW Management was introduced where staff were deployed to identify the sources of unaccounted for water such as leaks, water theft or errors in demand prediction.

To further help the utility understand where the water was flowing in the network and how to prioritize their active NRW management, DMAs were often introduced to the water networks. DMAs are discrete isolated parts of a water network with all of the inputs from mains, and optionally outputs to other parts of the system, measured using bulk meters. There are several common DMA topologies:

Single inlet DMA

Where there is only one inlet meter into a DMA. This is preferable where possible as it minimizes errors in metering and provides greatest clarity to the utility.

Multiple inlet DMA

Where for pressure or system redundancy purposes it is not possible to have single meters, multiple inlet meters may be used to feed a DMA.

Cascading DMA

Sometimes due to topology of the network a DMA or multiple DMAs may be fed by other DMAs through meters. In this situation the flow into the downstream DMA is subtracted from the flow into the upstream DMA for water balance purposes.

Pressure Reduced DMA

Where excessive pressures are present in a DMA a PRV can be introduced to reduce the pressure in the isolated DMA to reduce leaks and bursts.

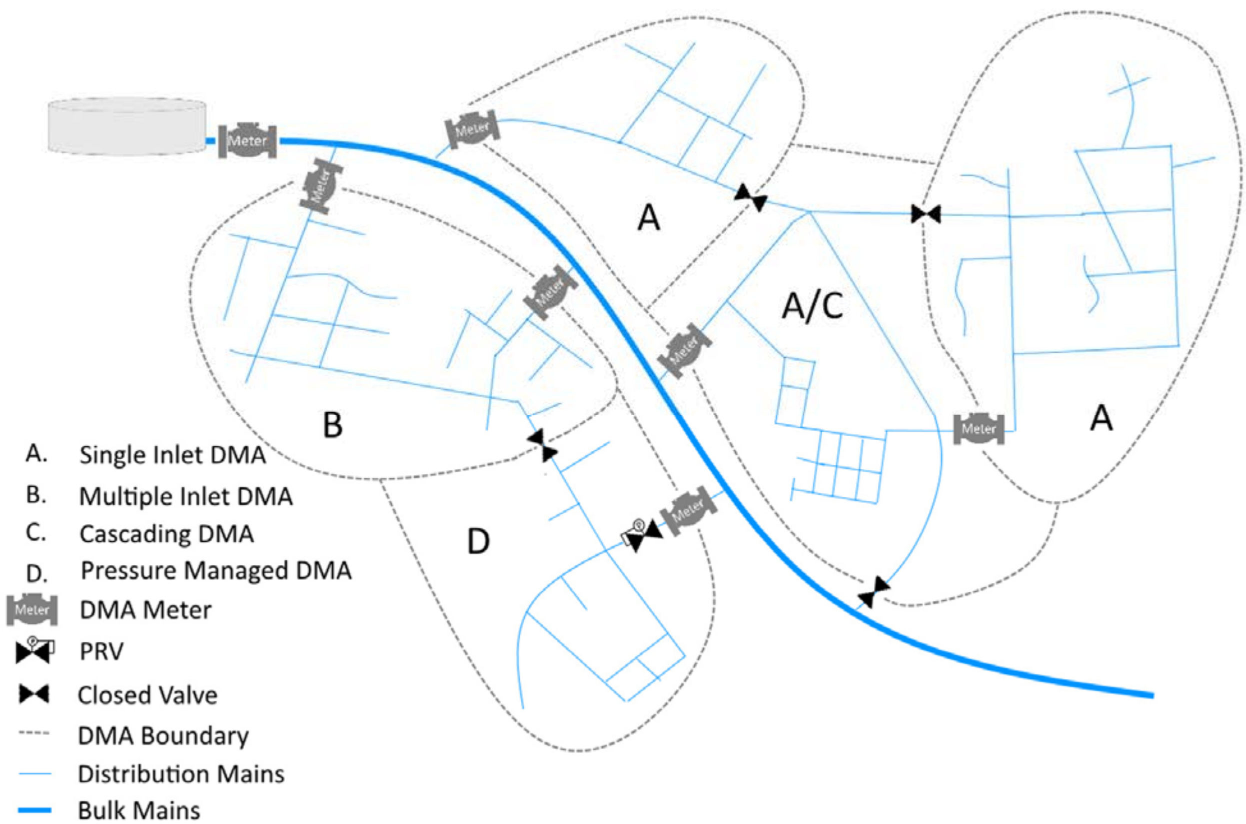


Fig. 1. Types of DMA

It is important to determine the objective of the creation of DMAs and ensure that everyone has the same expectations of the exercise. This is because the process necessarily includes making decisions that trade-off between, and prioritization of objectives.

DMAs are usually designed to take into account several objectives, but these objectives at times have to be traded off in a final design. Some example objectives are:

- Minimize new meter and augmentation costs;
- Minimize changes to current system operations;
- Optimize size of DMAs;
- Maximize system operation flexibility;
- Optimize pressure management;
- Minimize water quality issues;
- Minimize number of meters into DMAs;
- Minimize cascading DMAs.

A range of stakeholders typically have responsibility for these objectives and should be allowed an input into the decision making process. The stakeholders commonly include:

- Operators and Network Managers;
- Hydraulic Modelers;
- Capital maintenance and asset managers.

In order to get results, these methods need to be combined, which require human resources and quite high times.

NOISE LOGGER

The system consists of loggers equipped with highly sensitive piezo microphones, amplifier, digitizer, memory and battery, as well as a data acquisition and processing system. Each logger has a robust, waterproof housing. By recording night-time noise, it makes it possible to detect bursts in water networks without being assisted by the operator. The loggers record the noise produced by the loss through a sensitive microphone that is connected to the digitizer amplifier. The received sound signals are recorded in the memory of the neural adaptive software both in intensity and frequency. The loggers are equipped with accumulators that give the system a high degree of autonomy over time (over 5 years of continuous operation). They are designed to be installed on hydrants, valves or other direct contact points with the pipe. Each assigns a unique recognition number, which is required in the subsequent evaluation of the data, in order to coordinate the logging with the associated measurement locations. For a successful use of the system, at least 6 logging is required. The best results are still obtained by using 15 - 45 logging. Their number determines unbound and higher measurement accuracy. First, based on the overall plan (if possible on a scale of 1: 5000), an analysis point planning is performed. It is mainly used hydrants located in accessible and important places, ie at the intersection of the pipes. Each logger is installed on each measuring point. It is advisable to install them in the metallic networks at distances up to 200 m between them, and in non-metallic networks at max. 100 m.

The area where the loggers are located is scanned with a Commander, which receives by radio link from them all the data necessary to recognize the loss. The big advantage is that the data is interpreted on-the-spot without the need for processing on a computer or a go between the land and the company's office for processing. It is possible to immediately locate and confirm the losses in the field. The neural axis allows simultaneous analysis of both the frequencies and the level of noise that occurred during the measurements, unique in the sense that no other producer uses this technology and especially beneficial for the correctness of the determinations, the possibility of errors being substantially reduced.

Generally, after the evaluation is completed, measurements will be made with the correlator, both to confirm the results and to determine unequivocally the place of the break. Considering these aspects and the vital importance of water in the evolution of humanity, specialists in the field have tried to apply the latest loss detection technology.

THE NEW TECHNOLOGY

USE OF SAR SENSORS ON SATELLITES TO DETECT WATER LEAKAGES IN PIPELINES:

TECHNOLOGY DEVELOPED BY UTILIS

Here are the steps involved in a typical missile detection project:

Step 1: Obtaining and analyzing images

A typical project will focus on a defined area established by the water company where they know large leakage areas and night lines, or DMA with high percentages of plastic and CA pipes. The satellite will cover the specified area by acquiring raw images using synthetic radar sensors (SAR). These sensors send the electromagnetic waves that collect data from the surface of the Earth to send them back to the satellite.

Step 2: Radiometric corrections and algorithmic analysis

The raw data collected by the SAR sensor must be prepared by filtering unwanted satellite sounds from buildings, other man-made objects, vegetation, lakes, pools, drains and sewage resources and a whole range of other interferences.

Each pixel in the acquired image is passed through a unique algorithm that has been developed to look for the spectral signature of drinking water.

At this stage is added the utility pipe layer, which provides the leaks identified on a map along with the streets and pipeline locations, which display thousands of square kilometers.

Step 3: Leakage Report and Delivering Results

An entire network can be studied periodically, providing more sets of findings annually. Customers will receive data in the key markup language (KML) that can be added to their GIS systems and maps, web or mobile applications to produce a global leakage sheet.

Areas that have a low probability of leakage will be marked in blue, where areas marked with red mean a high probability of leakage. Drain technicians are then sent to areas to find the exact place.

Depending on customer preference, results can be provided in one of four ways:

- Web-based GIS;
- Leak sheets for field work;
- Application that allows remote access;
- GIS files.

Step 4: Confirm the results on the ground

There may be situations in which leakages have been reported or repaired after taking over the satellite image and their confirmation is done before the on-site check-up begins.

CASE STUDY - PITESTI SUMMER SCHOOL 2018

Starting from this aspect and encouraged by the results obtained by this method to other Romanian counterparts (RAJA Constanta, Apa Nova Bucharest, Aquaserv Targu Mures etc.), the loss detecting department together with SC APA CANAL 2000 SA decided to use this method and in its coverage area. We contacted the Romanian partners of UTILIS and SC BioTech SRL for setting the details and establishing the steps to follow. After that, the scanning area was established, the coordinates sent to the service provider, UTILIS, which performed the scanning of the required area, made the radiometric corrections and determined the possible leakage of water. Utilis has submitted the results both printed and electronically to the operator, and so at the end of June together with SC BioTech SRL we decided to organize a practical workshop in Pitesti to detect water leaks based on the results of UTILIS. In this respect, in collaboration with the Romanian-German Aquademica Foundation and SC BioTech SRL and UTILIS, it was established that on July 9-11 we will organize a meeting with the detection teams in the country and in the form of a contest and try to locate as much as possible many damages. Ten teams representing the water companies in Timis, Dolj, Prahova, Neamt, Maramures, Buzau, Covasna, Targoviste, Turda and Brasov to identify as many water losses as possible in the Pitesti municipality.

As a result of the water network scanning there were identified 83 areas with possible damage in Pitesti, which had to be localized by the participating teams by classical (acoustic) methods. From these areas, 5 areas / team were selected and teams could use any method to locate as many as possible damage. Each team was able to enter the UTILIS application where they could identify the area and contributed where the investigations had to be made. The team that located the first crash was the team in Buzau (about 20 minutes), the team that was awarded by BioTech. The weather was more of autumn than summer, the rain came and did not want to leave. However, all teams have shown involvement in locating water loss.

Weather conditions were tricky, plus traffic, environmental noise and other unexpected traps. Under the aforementioned conditions, 23 locations were identified with the damages, the damages to be dug up and repaired. There are dangers that have consistent flow rates (5 l / sec) and which have not been reported by anybody collect in time considerable amounts of water lost in the sewage system.

The mission of the detectors was to go...on the tracks of the satellites and narrow down the "suspect" area of defect, so that the maintenance teams could take over the part of the excavation, replacement and restoration, that is, the repair of the defect.

The team that first localized network failures was Buzau, in a record time of 20 minutes, the detectors being awarded by BioTech.

About the technology used to detect the loss of water in space, we spoke in advance of the practical test. Biotech presented the results to the participants, and the representative of the water company in Craiova, who carried out the network scan, shared the experience. Loss experts have agreed that the "satellites" method does not solve all the losses on the ground, but it helps field people with clues about where to look for defects.

As with any competition we have a winner. The winners of this edition are colleagues from Piatra Neamt: Alexandru Postăvaru and Costel Spiru.

USING GPR IN RAPIDLY LOCATING NETWORKS AND WATER LOSSES

Ground Penetrating Radar (GPR) is used to detect subsurface features and objects.

The machine rests on collapsible and highly portable three-wheel cart that is pushed over the surface. A radar signal from an antenna passes into the ground and reflects off objects under the ground. The information is displayed on a screen providing real-time views. Mapping subsurface utilities: GPR, sondes, cable/pipe locator and CCTV is used to create a “map” of underground services. One instrument on its own cannot provide the accuracy needed for such a survey.

POSSIBILITIES WITH GPR

- Environmental Impact Assessments: locate sub-surface objects, water table mapping;
- 2D & 3D imaging;
- Locate pipelines, cables, ground disturbance, tanks & voids.

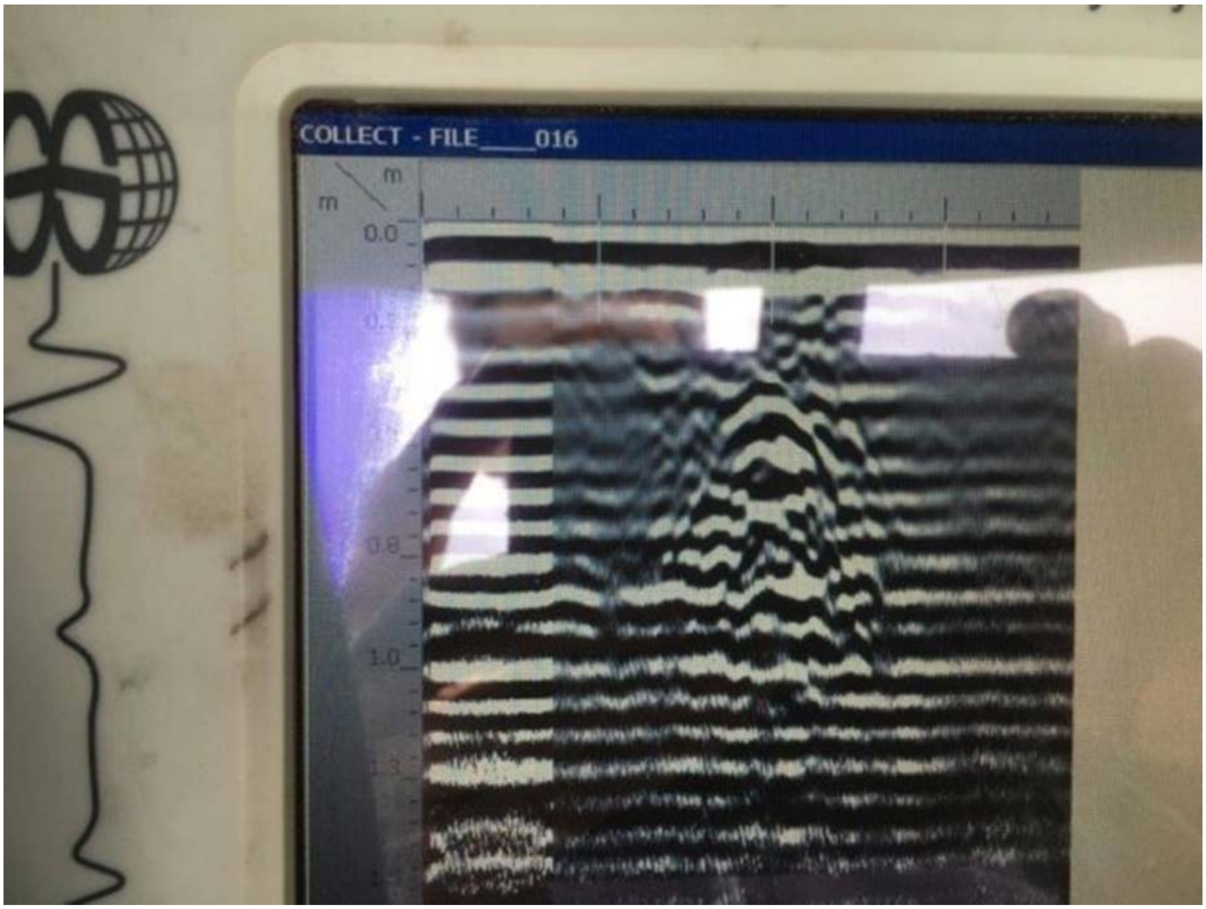


Fig. 2. GPR scan image

USING THE PERMANENT LOGGER CHAIRS FOR THE WATER FLOW RATE

The PermaNET+ system from HWM combines Permalog leak noise sensor and our versatile telemetry data technology to create a fixed network to monitor leakage. Once installed, leak data calculated using the proven Permalog algorithm, and secondary data, is transmitted via low cost GPRS or SMS telemetry. This removes the requirement for expensive site visits and “drive by” data retrieval.

PermaNET+ allows leakage teams to monitor the status of each logger deployed from map based host software. This can be viewed from any internet enabled device using PermaNETWeb. The system works in conjunction with Google Maps technology to provide a live on screen tracking, allowing leakage teams to respond quickly to problem areas and bring them under control efficiently.

Once the presence of a leak has been identified, secondary measures can be used to check and remove ‘false positives’ and also to localize the leak position.

Correlation - Audio files are used to correlate remotely to localize the leak position for follow up.

Aqualog - Remotely retrieving the Aqualog detailed noise graphic, clearly indicates the consistent presence of a leak.

Audio - For operators who prefer to “hear” their leaks audio files are transferred to the host.

PERMANET WEB

PermaNET Web is a secure, web based portal designed to enable the remote identification of network leakage.

Supporting acoustic correlation, leak detection and logger location, PermaNET Web can be used with multiple loggers and provides the user with numerous ways to view selected data.

KEY FEATURES AND BENEFITS

- **Two-way communication**: local and remote logger parameter settings;
- **Auto processing**: interference and external noise filtering;
- **Time synchronization**: automated synchronization from remote data server and network;
- **Data Security**: firewall - locked down to used ports only. Users have separate logins and locational access. Regular updates and penetration testing;
- **Compatible**: supported by all major web browsers;
- **Noise Filtering**: auto-processing for equalization, frequency correlation and coherence;
- **Cost and Time Efficient**: remote leak noise listening;
- **Alarm Profiles**: alarm available via e-mail;
- **Audio Data Recording**: audio data is sent to the server if a leak is present.

THERMAL CAMERA

The presence of leaks in hot water systems is often first indicated by low boiler pressure or a constant need to top up the boiler, meaning that there is very little clue as to the location of a leak before investigations begin. Identifying hot water pipes throughout a property and finding water leaks can be a time-consuming and labor intensive process when the system is hidden under tiled or concrete flooring. Conventional inspections lead to digging up floors which in turn results in great expenditure in terms of both materials and labor as flooring is lifted and restored. Thermal imaging provides a cost-effective, time-saving solution to these problems.

CHOOSING YOUR THERMAL CAMERA

With temperatures typically falling between 15˚C to 30˚C, leak location applications generally do not require extremely advanced or expensive thermal imaging equipment. We advise considering cameras with a resolution of no less than 120 x 90 pixels but ideally 160 x 120 and a thermal sensitivity of between 0.1˚C (100mK) and 0.06˚C (60mK). An easy-to-operate “point and shoot” camera such as the FLIR E5, FLIR E6 or Testo 868 would usually be suitable although more challenging leaks may require a more advanced camera. Information on our cameras for purchase can be found on the Thermal Imaging Camera page whilst a separate page provides information on Thermal Imaging Camera Hire which often proves a great option for one-off or occasional use.

HOW IT WORKS

Whilst floors typically remain at room temperature (18˚C to 21˚C), hot water pipes tend to raise the surface temperature of the floor by approximately 4-5˚C when in operation so it is important to turn the boiler on before carrying out an inspection. A thermal imaging camera will depict heat patterns with a color contrast which clearly shows the pipes under the floor. The majority of our cameras have an auto ranging function that can seamlessly adapt to the temperature differentials detected and display these clearly on screen for quick and simple scanning. Figure 3 is a typical thermograph showing hot pipework in a bathroom.

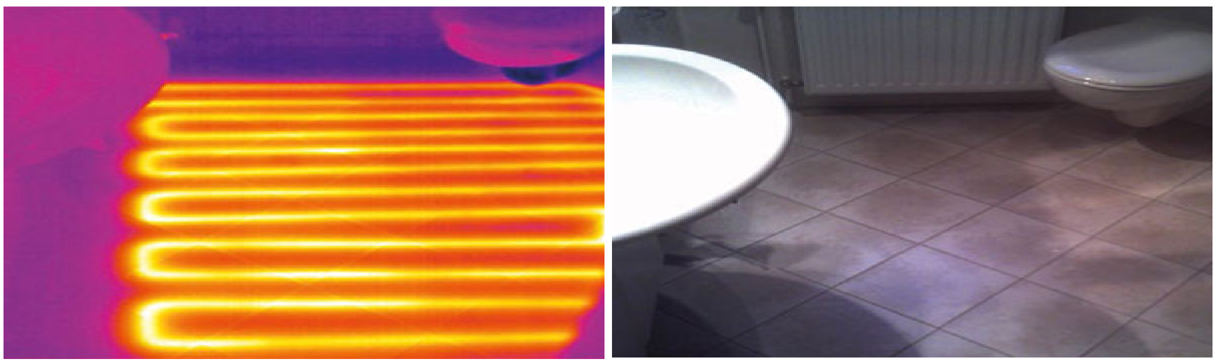


Fig. 3. Hot pipework in a bathroom

HOW TO LOCATE THE LEAK

Water leaking from hot water pipes will produce a distinctive thermal pattern on the surface of flooring. Whereas pipework produces a relatively sharp picture with clear differentiations between the hot pipes and cold surroundings, leaks appear as more of a splodge on the camera screen with a bright hot-spot center and gradual gradient to the cold floor. Figure 4 shows a leak under tiled flooring.

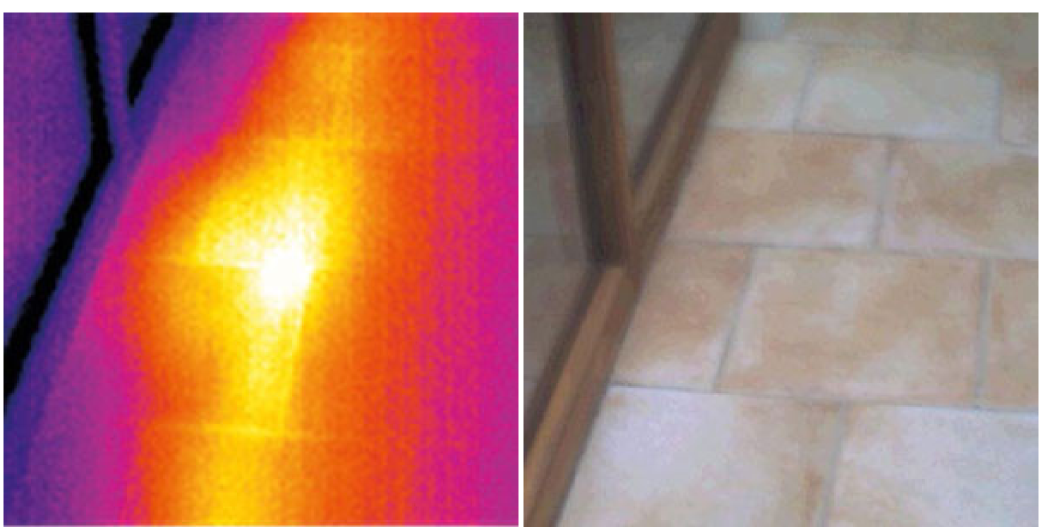


Fig. 4. Leak under tiled flooring

Where water leaks are hidden below multiple layers of flooring, a more powerful thermal imaging camera may be required. A higher 320 x 240 pixel resolution, such as the FLIR E8 or E75 will often be capable of showing heat patterns from pipework below carpet, rubberized underlay and up to 90 mm into concrete screed. Leaks can be marked with tape for later inspection so that the thermal inspection can be carried out in one session over the whole property. This allows multiple leaks to be located before digging up flooring in order to rectify issues.

The benefits of using thermal imaging to trace concealed pipes and find hidden water leaks are very clear. By depicting the heat patterns of a hot water system, the user can accurately target physical intervention so that fixing leaks causes as little disruption and damage as possible.

CONCLUSION

Finally, if we analyze, each method has its advantages and disadvantages. For a complete success in eliminating water loss, it is a good idea to combine the classic detection methods with the modern ones, depending on the specific situations of the individual networks. Combining these methods can lead to very good results. Using these combined methods we succeeded in SC APA CANAL 2000 SA Pitesti between 2016 and 2018 to reduce the distribution losses in the network by about 16 percent.

SATELLITE BASED LEAK DETECTION – CASE STUDIES IN MITROVICA (KOSOVO) AND SKOPJE (MACEDONIA)

Bojan Ristovski*

*Aquasave ltd, Owner/Managing Director, bojan@aquasave.mk, www.aquasave.mk

Abstract
The article is focused on using the modern technology (satellite radar technology) in finding leakages in water supply system of Mitrovica, Kosovo, financed by Lux Dev (Luxemburg Agency for Development Cooperation) and Skopje, Macedonia, financed by Public enterprise Water supply and sewerage-Skopje and implemented by Aquasave ltd Skopje, with cooperation of Israeli company Utilis. The Mitrovica project was the first project of this kind in the Balkan and wider region. The services under the project were set up to achieve the following objectives:

- Assessment of the network in whole and deliver locations of leaks displayed on several user-friendly GIS interfaces to Mitrovica Regional Water Company and PE Water supply and sewerage-Skopje.
- Check/confirm presence of leaks in some of the buffers defined by the particular leak Sheet in predefined period by means of different leak detection equipment.
- Improve i.e. enhance the capacity of two utilities in implementation of own leak detection activities and its capacity to continue with confirmation of leaks within the buffer defined in the Leak Sheets which have not yet been visited and checked by the Consultant.

The project has been divided in two tasks:
Task 1 - Leak detection by analysing spectral images from satellites.
Task 2 - Leak detection - verification of the leaks on the field, including training of the utilities NRW staff.

Keywords
Satellite, leak detection, NRW training.

CASE STUDIES ON USING UNMANNED AERIAL VEHICLE

Alexandru Postăvaru*

*C.J. Apaserv S.A. Neamt, Head Office NRW, alex.postavaru@apaserv.eu

Abstract
The current paper approaches the possibility of using the devices owned by the Company I work for, namely U.A.V, for the purpose of pre-identification of losses on pipelines and transportation of drinking water, identifying fraudulent consumers by determining possible unauthorized digging and monitoring the sewage and treatment plants.
The paper comprises a series of cases we actually encountered on site.
The cases are explained, illustrated with on-site images and have been confirmed by visual inspection in the respective areas and by other devices on Mobile Laboratory for Loss Detection.
The paper does not in any way advertise a type of product on the market or any type of experimental devices, it only shows a possible method of pre-identification of water losses with the help of the drones.
This method can be used in certain circumstances, in completing existing classical procedures.
In conclusion, the type of drones used by us in certain situations may be used as an unconventional method for the pre-identification of damage on large areas of network pipes, helping to locate the unauthorized digging of different fraudulent consumers.
The use of UAV systems is not be perceived as universal replacement of all the so far existing devices, either in terms of loss identification or in terms of by identifying fraudulent consumers, but as a complementary method to existing traditional methods or as a stand-alone.

Keywords
Alternative methods for water losses identification – drone surveillance.

TECHNOLOGY AND APPLICATION OF LEAK DETECTION METHODS FOR LARGE AND SMALL DIAMETER PIPES

Pedro Pina*; Michael Allen**

*Pedro.pina@xyleminc.com, Xylem, Edifício de escritórios Jonobras, EN247, Sala 1C, Ribamar, 2640-027 Santo Isidoro
**Michael.P.Allen@xyleminc.com, Xylem 106 Hawley Ln, Farnborough GU14 8JE, UK

Abstract
Methodologies for achieving the best results to reduce water losses are continuously evolving. This is leading to some innovative technologies and new product development to complement current methodologies.
The choice of a particular leak detection technique and technology depends on a number of factors namely: the operating conditions, construction material of the pipeline, diameter amongst others. For example, in large diameter pipes leaks below 40 l/min are hardly detectable by traditional methods such as bulk flow metering or external fixed acoustics. In small diameter pipes those traditional methods are effective but given the complexity of the networks and the fuzzy acoustic environment, false positives are traditionally frequent. Overall there are a vast number of techniques to detect where leakage is occurring in the network. Often a tool-box approach is used, where multiple technologies are deployed (Hamilton & Charalambous 2015). This paper will focus on two approaches: inline leak detection for large diameter pipes (transmission) and fixed monitoring based on multiple data streams for distribution networks and present successful examples of their application.

Keywords
Leak detection, toolbox approach, large and small diameter.

1. INTRODUCTION

Controlling water loss has become a priority for water utilities around the world. In order to improve their efficiencies, water utilities need to apply good practice in leak detection. To deal with losses in an effective manner water utility managers are increasingly turning to technology to reduce costs, increase efficiency and improve reliability. Companies that continuously invest in technology and innovation should see a positive return on investment in terms of improving daily operations and collection and analysis of network data for decision making and forward planning. Further to the direct impact of leaks (water loss) those can also be interpreted as a good indicator of the condition of the pipe and a warning signal for potential problems. Before a leak becomes prominent or eventually leads to a failure, which can be quite catastrophic especially in large diameter pipes, it will typically go through an escalating period.

2. INLINE LEAK DETECTION

Many of the technologies currently used for leak detection involve acoustics, the reason being a leak inside a pressurized pipeline produces a specific acoustic signal. This acoustic signal is created when the pressurized product inside the pipeline escapes into the lower pressure atmosphere outside the pipe.

Traditional acoustic detection equipment identifies the sound or vibration resulting from the acoustic signal emitted by a leak. While these devices have proven to be one of the most effective and reliable means of identifying water leaks in conduits, fixed sensors (noise correlators) have limited range due to the rapid attenuation of sound, making it a difficult task if the distance between the leak locations and the position of the equipment is significant.

This has led to the development of free swimming or tethered acoustic equipment for detection of in-line leakage, which is inserted into the pipelines while it remains in service. This type of technology is referenced by the IWA as one of the most effective for leak detection in large diameter conduits (Hamilton & Charalambous 2015).

Acoustic in-line leakage detection is a non-destructive technology, where the acoustic sensor passes through the pipeline while it remains in service. The technology detects the sound generated by the existing leaks with great sensitivity and accuracy as it passes in close proximity to the leak.

SmartBall™ is a commercial free swimming in line tool that traverses the pipeline, it continuously records all acoustic data in the pipeline, which is evaluated later to identify acoustic activity that may be associated with leaks along the pipeline. As the SmartBall tool rolls along the bottom of the pipeline, it will always pass within one (1) pipe diameter of a leak or pocket of trapped gas.

As the SmartBall tool approaches a leak, the acoustic signal detected by the SmartBall technology will increase. The acoustic signal will crescendo as the tool approaches the leak, peak at the point at which the SmartBall tool passes the point of the leak, and then diminish as the SmartBall tool continues away from the leak. This phenomenon is clearly evident in Figure 1.

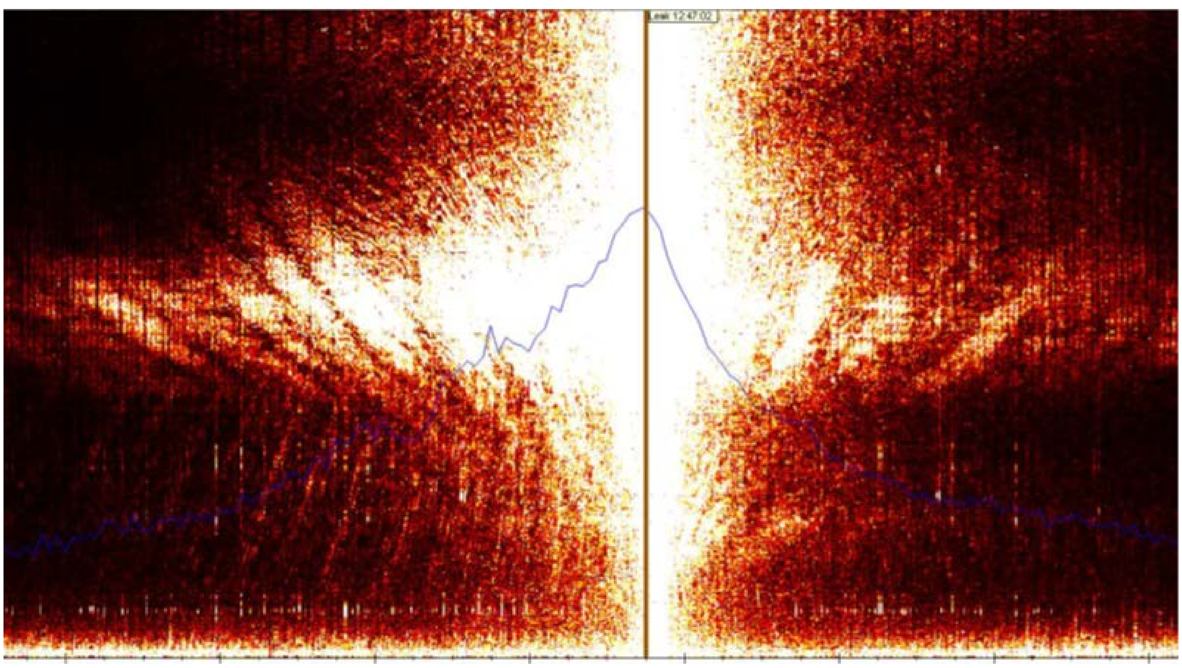


Fig. 1. Acoustic frequency spectrum of a lea event

In addition to detecting potential leaks and pockets of trapped gas, acoustic events are further evaluated to estimate the approximate magnitude of the leak. SmartBall is able to report leaks as being small, medium, or large. Small leaks are estimated to be in the range of 0 – 7 liter/per minute (l/pm). Medium leaks are estimated to be in the range of 7 - 37 l/pm and large leaks are estimated to be greater than 37 l/pm.

3. LEAK AND BURST DETECTION BASED ON FIXED MONITORING AND MULTIPLE DATA STREAMS

One of the well accepted strategies for dealing with pipe bursts and pervasive leakage problems is monitoring systems that can detect and localize underground burst events or sources of long-term water losses, enabling implementation of timely mitigation and repair. To date the most detailed data about the current state of the water network in terms of flow, pressure and water quality is gathered using Supervisory Control and Data Acquisition (SCADA) systems located at reservoirs or water tanks.

Although this is a growing area generally permanent systems comprising on-line monitoring and analysis capabilities deployed on the pipes and valves within water distribution networks are not so frequent. For example, pressure and water quality are spot-checked to comply with regulations or to deal with customer complaints, while background leakage surveys are performed periodically around the system (typically using mobile acoustic leak detection devices). Since the pipes in a water distribution network are pressurized, events such as pipe bursts, valve opening/closure can be detected remotely as pressure transients distinct from the background pressure signals.

Wireless sensing technology has advanced to the point that the deployment of dense networks of low-cost devices for real-time infrastructure monitoring is now feasible. When combined with appropriate data processing techniques, the increased density and availability of these measurements enables improved response, management and prediction of infrastructure failures.

The WaterWiSe (Water Wireless Sentinel) platform has three components: i) an online wireless sensor network, ii) the Integrated Data and Electronic Alerts System (IDEAS), and iii) the Decision Support Tools Module (DSTM). The WSN provides on-line streams of data or events; IDEAS processes raw data streams to detect and localize abnormal events (such as leaks or contamination events); and DSTM provides decision support tools based around a hydraulic model of the water distribution network that is periodically calibrated using data from the WSN. These components provide key services to help both water supply network planning and operations teams in the office and in the field. WaterWiSe can operate as a stand-alone system as well as a component in an integrated water management system. In stand-alone mode, a map-based web interface and dashboard is provided to both IDEAS and DSTM. This user interface is accessible through the web-browser on regular desktop PCs as well as tablet and smart phone, allowing for in-field analysis and validation by the field crew. WaterWiSe is either hosted locally within a water utility or over the internet via the cloud.

4. CASE STUDY 1: SINGAPORE

The WaterWise system has been deployed in Singapore since 2009, Singapore is one of the best examples in the world of NRW reduction, we like to think that we have made a strong contribution for that achievement. The system has scaled from a proof-of-concept 8-node network collecting only pressure data to 321 sensors installed nationwide across the potable water mains network for about 5400 km. These sensors continuously transmit pressure, water quality, flow and acoustic data in real-time to the WaterWiSe data management, modelling and analytics platform. Constantly monitoring and collecting of data from the network enables better situational awareness. Advance data analytics applications on WaterWiSe also provides early detection of poor pressure, pipe bursts and water quality events, identification of pipes at risk of failure, hydraulic simulations of operational scenarios, water demand analysis and prediction, as well as generating of virtual sub-zones for isolating water quality events. These are some examples of the way Singapore is using the system for leak detection:

1) Leak detection: IDEAS automatically detect transients at several sensor node data streams minutes after the data has been sampled. Several detections are grouped together and show a cluster of likely junctions that match the relative times of the detections. An alert is sent to all subscribed engineers about the possible burst and the estimated location.

2) Leak validation: The coordinating engineer sends a field crew to the estimated location to look for obvious signs of a leak. The field team remotely contact the DSTM network map on a tablet device to pinpoint the location of the junctions based on their names and locations, and find water above ground close to where IDEAS indicated. The leak-detection crew arrive to find the exact leak location.

3) Solution testing: The team of engineers in the supply network office determine the set of valves required to isolate the leaking pipe for repair. The engineer uses DSTM's operational simulator to find the relevant valves in the network model and run a 24 hour-ahead simulation to determine the expected impact on customers. Satisfied that the valve operations will not adversely affect customers, the engineer gives the go-ahead to the field crew to run the operation. The engineer shares the simulation results with the field crew via their tablet logged into DSTM, who begin looking for the correct valves within the area to close.

4) Execute repairs: Over the following hours, the ground around the leak is excavated and the pipe isolated. During this time, the engineers use the IDEAS interface to keep a close eye on the data streams of the sensor nodes that detected the burst and make sure the data match the expected behavior, paying close attention to any new alerts that arrive over email or SMS. The burst pipe is repaired, and the pipe is decommissioned. The field crew verify the pressure and flow data have returned to the expected values before the leak and report back to the engineers in the supply network office.

5) Validate repairs: Over the following hours and days, the sensor node streams are closely monitored on IDEAS to make sure the repairs have fixed the leak as expected.

5. CASE STUDY 2: LISBON

In the last 15 years, EPAL the water utility of Lisbon has successfully implemented a network monitoring project aimed at reducing water losses. The basis of this project has been the progressive implementation of more than 150 District Metered Areas (DMAs), along with associated flow and pressure monitoring equipment and telemetry systems, undertaken in parallel with the renewals and rehabilitation program (Dias et al., 2014). The success of this process was manifest: Between 2005 and 2014 EPAL reduced their real losses from 23.5% to 8.1% (corresponding to a saving of 26.93 M m^3/year to 8.18 M m^3/year) (Donnelly, 2019). In 2016, EPAL measured the first notable reverse in NRW trend since the implementation of the program. The issue was promptly identified in two supply zones, encompassing 150 km of mains, mainly composed of larger diameters pipes (>400 mm). Due to complexity of the system, the (expected) inaccuracy of bulk flow meters to detect very small flow variations and the limitations of the traditional leak detection methods (correlation, field hydrophones and others) EPAL decided to invest in specialized leak detection interventions using Sahara and SmartBall. The Sahara campaign included 11 surveys and identified 26 leaks on 10.5 km of DN800/1000 mains. The SmartBall trial consisted of 1 survey and identified 11 leaks on 1.6 km of DN500/600 mains.

One of the most notable results that might seem counter intuitive is the extremely high number of leaks for such short distances, especially considering the low NRW numbers of the system. In fact, after more than 8000 km of inspections with these technologies all around the world Pure, A Xylem brand reports an average of 3 leaks per 10 km for these types of pipes. We believe the reason for such high rate is the precision that supported the choice of pipes to be inspected. Based on their existing information system, EPAL knew quite well where the blind spots were located, e.g. areas where due to the reasons described above the existing solutions couldn't provide EPAL precise leak location results. EPAL focused their inline leak detection efforts precisely on those areas.

After inspections EPAL went on the excavate and repair the leaks. The overall results reported in 2018 are quite compelling: NRW in those two key supply zones was reduced by 17% and 36%, representing a trunk main NRW reduction of approx. 1.7 million m^3 corresponding to a saving of approx. 1 million euros.

6. CASE STUDY 3: AMSTERDAM

Leak detection technologies are typically used by utilities and pipeline owners to manage non-revenue water (NRW) levels. However, owners are increasingly looking to leak detection tools as a means for condition assessment and integrity management.

The WRK-1 and WRK -2 pipelines, 1500 mm and 1200 mm diameter concrete pipelines are the main arteries of Waternet serving Amsterdam in the Netherlands.

As a result of incidents with pressurized water pipelines in nearby dikes, the dikes authority required Waternet to prove the integrity of their pipelines assets. While both pipelines travel through rural farmland, some sections of the pipes run through dike systems. SmartBall has been used approx. every two years since 2013 to check for leaks along the lines (approx. 200 km) to provide the dike owner with confidence in the integrity of both the pipeline and the dike.

In this instance, independent research by the dike owner indicated that the dike systems could withstand pipeline leaks of up to 1 liter per minute without compromising the dike's integrity. In 2013 Waternet performed independent checks with SmartBall and during their evaluation they confirmed the repeatability of the technology and they were able determine a minimum leak detection limit below 1 l/min that was the requirement of the dike authority. Since 2013 multiple inspections have happened together in some occasions with high resolution condition assessment evaluations to determine the pipe health condition. Only a limited number of leaks have been found but in some cases, these are very high risk such one very small leak that was detected in the pipeline 24.6 kilometers from the insertion point. The position of the leak was located in a high-risk area upstream from a dike, and verified through repeat inspection runs. The size of the leak was classified as 'very small' and estimated to be less than two liters per minute.

Waternet subsequently performed an excavation at the reported location and found the leak in a seal of the pipeline.

7. CONCLUSIONS

One solution doesn't fit all, in leak detection such as in many other areas a tool box approach is recommend and in many occasions such like in the examples provided the best results comes from the right combination of data streams or technologies. Leak detection tools have been proven useful for pipeline condition assessment. Different deployment options provide utilities with a variety of ways to effectively gather information, taking into consideration operational constraints.

BIBLIOGRAPHY

[1]. Allen, M., Preis, A., Iqbal, M., Srirangarajan, S., Lim, H. B., Girod, L., Whittle, A.J. (2011) "Real-time in- network distribution system monitoring to improve operational efficiency," Journal American Water Works Association (JAWWA), 103(7), 63–75.
[2]. Dias, N., Ferreira, N. and Donnelly, A., 2014. Integration of modelling and monitoring to optimize network control: two case studies from Lisbon. Procedia Engineering, 70, pp.555-562.
[3]. Donnelly, A. 2019, ' Trunk Main Leakage and Optimal Customer Meter Replacement – Enhancing the Water Balance', paper presented to 10th Global Leakage Summit 2019, London UK, 25 to 26 June 2019. http://www.global-leakage-summit.com/.
[4]. Fick, Gregory, and Travis B. Wagner. "Leading the Way: The Washington Suburban Sanitary Commission's Comprehensive PCCP Management Program." Pipelines 2010: Climbing New Peaks to Infrastructure Reliability: Renew, Rehab, and Reinvest. 2010. 989-997.
[5]. Gaewski, Peter E., and Frank J. Blaha. "Analysis of total cost of large diameter pipe failures." Proc. AWWA Research Symposium Distribution Systems: The Next Frontier, Reno, Nev. 2007.
[6]. Hamilton, Stuart, and Bambos, Charalambous. Leak detection: Technology and implementation. IWA Publishing, 2015.
[7]. Rodriguez, Jorge A., et al. "Numbers Still Don't Lie—PCCP Performance Based on a Statistical Review of Fifteen Years of Inspection and Monitoring Data." Pipelines 2016. 506-514.
[8]. Romer, Andrew E., Graham EC Bell, and R. Dan Ellison. "Failure of prestressed concrete cylinder pipe." Pipelines 2007: Advances and Experiences with Trenchless Pipeline Projects. 2007. 1-17.
[9]. Whittle, A.J., Girod, L., Preis, A., Allen, M., Lim, H.B., Iqbal, M., Srirangarajan, S., Fu, C., Wong, K.J., Goldsmith, D. (2010) "WaterWiSe@sg: A testbed for continuous monitoring of the water distribution system in Singapore," Proc. ASCE 12th Water Distribution Systems Analysis Conference (WDSA'2010), Tucson, pp. 1362-1378.
[10]. Wrigglesworth, M., van Heck, G., Kinsbergen K., and Kler, J. T. L. Orr. "Using Leak Detection For Dike Integrity Management"Proceedings of 29th International NO-DIG Conference, Berlin, 2011.

POST METER WATER LEAKAGE DETECTION USING SMART METERING

Ayse MUHAMMETOGLU*, Yalcin ALBAYRAK**, Habib MUHAMMETOGLU***

*Akdeniz University, Department of Environmental Eng., Antalya, Turkey, aysemuh@akdeniz.edu.tr
**Akdeniz University, Department of Electrical and Electronic Eng., Antalya, Turkey, yalbayrak@akdeniz.edu.tr
***Akdeniz University, Department of Environmental Eng., Antalya, Turkey, muhammetoglu@usa.net

Abstract
Excess water losses in water distribution networks (WDNs) is a serious problem almost for all water authorities. In Turkey, total water losses in WDNs is estimated at around 40% on the average and therefore in 2014 a regulation was issued requiring the reduction of total water losses below 25%. However, unbilled authorized water consumption (UAWC) is not included in the water losses and this component is usually neglected and used unwisely. Religious places, parks, public toilets and graveyards are UAWC in Turkey where post meter water leakage is common. A research project has been recently initiated to detect such leakages using smart metering. A number of smart meters were installed at selected facilities of UAWC for online hourly monitoring of water consumptions and the monitored data sets are accessed by mobiles and computers. Most of the monitored facilities had continuous water flows because of unrepaired water taps, toilet flushing systems and semi-closed taps.

Keywords
Leakage detection; post meter; smart metering.

Water scarcity is recognized as a main threat mostly in the Mediterranean area. Therefore, water authorities are obliged to become very efficient to secure sufficient quantities of good quality water. Since water is one of the most valuable natural resources, water losses in urban water supply systems represent an urgent problem that needs to be managed (Kanakoudis & Muhammetoglu, 2014). Water balance calculation is basic for water losses determination and management and it is usually carried out in terms of volumes for one year. The Ministry of Forestry & Water Affairs in Turkey issued a regulation for water losses reduction in 2014 and a practical description of the technical procedures in 2015. The water balance required by the Turkish regulation is slightly modified from the IWA (International Water Association) and AWWA (American Water Works Association) where the leakage on transmission and distribution mains, and leakage on service connections components are combined in one component for simplicity, as given in Table 1.

The regulation aims to reduce total water losses in all water authorities below 25% within certain time periods. All the water authorities are required to carry out yearly water balance and report them to the Ministry together with forms to follow up the efforts towards water losses reduction. However, the "unbilled authorized consumption" component is not included in water losses and this component needs management. In this aspect, a research project has been recently initiated by the Faculty of Engineering at Akdeniz University in cooperation with the water authority in Antalya (ASAT) and a private water meter company, with a financial support from The Scientific and Technological Research Council of Turkey (TUBITAK). The project aims at identifying leakages by online monitoring of water consumptions at short intervals (one hour or 15 minutes) all over the day. Consequently, 25 smart water meters were installed at selected unbilled authorized facilities. The first collected data sets showed continuous leakage at most of the monitored facilities. Figure 1 depicts the monitored flow rates at three facilities in March 2019, as an example. The installed smart meters are capable of sending warning messages about leakages. These warning messages will be updated within the project based on the monitored flow rates for immediate and efficient leakage detection & determination. Moreover, the monitored flow rates will be used to assess the suitability of the sizes of water meters as water authorities install unsuitable sizes of water meters in many cases. This in turn affects the accuracy of consumption measurements.

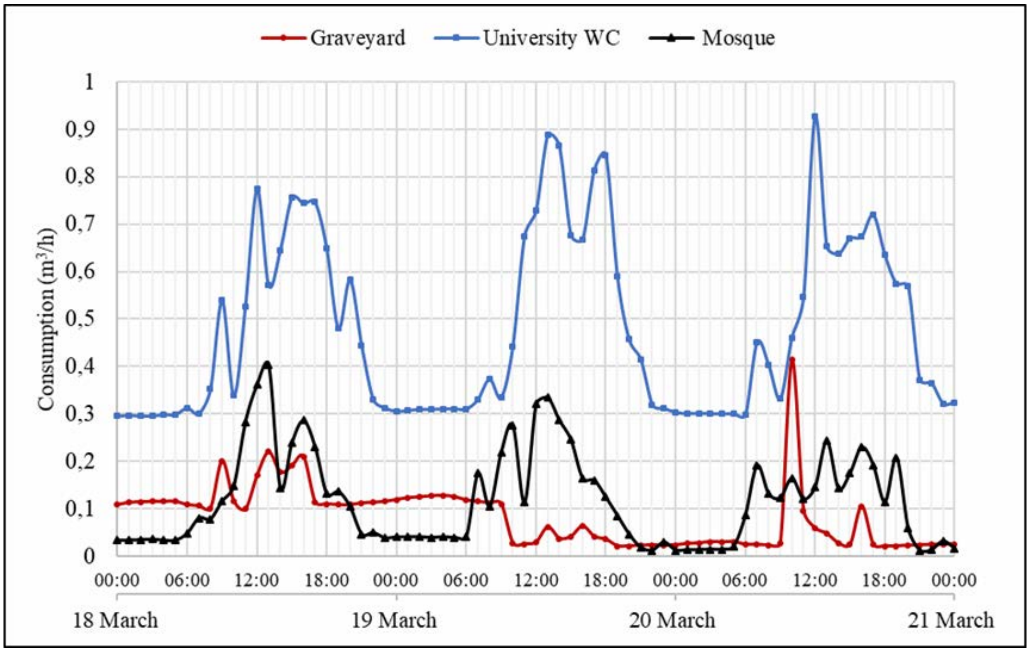


Fig. 1. Hourly water consumptions monitored at three facilities in March 2019

Table 1: Water balance showing water losses and Non-Revenue water components (OSIB, 2014)

<table>
<tr><td rowspan="8">System Input Volume</td><td rowspan="4">Authorized Consumption</td><td rowspan="2">Billed Authorized 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 Authorized Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="6">Non-Revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="4">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorized Consumption</td></tr>
<tr><td>Customer Meter Inaccuracies and Data Handling Errors</td></tr>
<tr><td rowspan="2">Physical Losses</td><td>Leakage on Transmission and Distribution Mains, and Service Connections</td></tr>
<tr><td>Leakage and Overflows from Storage Tanks</td></tr>
</table>

REFERENCES

[1]. Kanakoudis, V. & Muhammetoglu, H. 2014. Urban water pipe networks management towards non-revenue water reduction: Two case studies from Greece and Turkey, CLEAN-Soil, Air, Water. 42(7), 880-892.
[2]. OSIB. 2014. Ministry of Forestry and Water Affairs, Regulations on water losses control in drinking water supply and distribution system, 8 May 2014, Turkish Official Gazette No. 28994.

THE LEAK DETECTION PROJECT OF THE WALLOON WATER COMPANY

David Brunet*, Denis Devos*, Olivier Pinsar*

*Walloon Water Company (SWDE), Belgium
(david.brunet@swde.be)
(denis.devos@swde.be)
(olivier.pinsar@swde.be)

Abstract
The Walloon Water Company (SWDE) is one of the leading water companies in Belgium. It manages 27,000 km of pipelines and 1 million customer meters. It has embarked on a project to modernize leak detection that has reduced water losses by 5.5 million cubic meters per year. This project is based on an improvement of the knowledge of the DMA through the GIS, a daily and automatic calculation of a linear index of loss, and a new management of the teams of research of leaks.

Keywords
Leak detection, remote reading meters, GIS.

CONTEXT

SWDE is one of the largest public water companies in Belgium. It manages a network of 27,000 km of pipelines and serves 2.4 million customers through 1 million meters. Until 2014 the search for leaks was an activity practiced on the basis of manual index statements with as an indicator the yield. It suffered from a lack of overall strategy and was managed differently by SWDE's different operational centers with very different methods and results depending on the affinities of the local operators. There was no significant improvement.

In 2014, SWDE started a project to reduce water losses by 8 million m^3 by 2022. The project consisted of sectoring the network in DMA, and placing remote meters. From a performance-based leakage search, the goal was to move to a leakage search based on a linear loss index with a daily update of the information.

Another important part of the project was to review the management model by building a centralized leak detection team.

METHOD

The first step of this project was to determine the optimal number of meters to be metered. It is clear that putting a flow meter to monitor each street is unpayable and monitoring the entire network with a dozen meters is not effective! In other words, it is necessary to determine the optimum number of DMA and therefore their optimal size. This work was conducted taking into account the following elements:

- The density of the network;
- The number of m^3 that pass through the DMA (meter sizing);
- The price of produced water;
- The presence of sensitive customers;
- The pressure.

The economic model led to an optimum of 2,600 DMA and 3,000 remote reading meters.

The next step was to design the DMAs and encode them into the GIS. Previously, DMAs were often simply colored on plans and sometimes their knowledge was in the hands of one person. The structure of the DMA is now encoded in the GIS and includes, 3,000 input and output meters, and 6,000 closed valves between DMA. These DMAs are visible on the GIS by all. Being the gateway for any modification, the GIS also ensures the update for all.

It was then necessary to deploy the remote meters. Part already existed in the system of remote management of the water towers. However, 1,700 new meters had to be installed on the network. The solution chosen was to place a battery-powered flow meter with a data logger. A specific method was devised to industrialize the deployment process with only 2 full-time equivalents for 3 years. Important work has also been done to maximize feedback. Now, every day, 99.5% of data loggers communicate their data to the calculation software.

Software developed by SWDE synthesizes the meter data with the GIS information to compute the linear index of each DMA. This calculation is updated daily. A tool allows to automatically extract from the GIS the contribution of each counter in the calculation of the DMA, including the direction of their contribution, + or -. The tool also extracts from the GIS the linear and the number of connections of each DMA. Linking the GIS with the calculation software ensures consistency and up-to-date information.

RESULTS

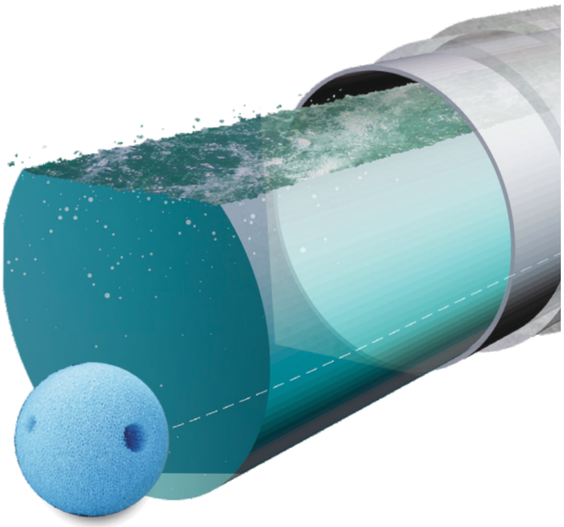
At the end of 2018, all the DMAs had been deployed with the new system. This project, representing an investment of € 7 million, was carried out over 5 years and is already generating results. Today, 5.5 million m^3 were recovered from the target of 8 million, and 6 full-time equivalents were saved on manual indexing. The 90-person leak detection team detects about 9,000 leaks a year.

This project also revealed a major difficulty in knowing the open or closed status of valves because they are manipulated by network operators but are not always restored to their original state. SWDE is conducting a research and development project for a solution at the valve or tool used to manipulate them to determine the status of the valve.

The project also leads to a new project that consists of automatically creating network diagrams from information encoded with DMA. These network diagrams currently require a long and tedious manual update work, so complicated that the schemas are never up to date. Linking these network diagrams with the data sent back by the meters will also make it possible to visualize the hydraulic operation.

SmartBall® Technology

A FREE-SWIMMING TOOL FOR LONG DISTANCE WATER AND WASTEWATER INSPECTIONS



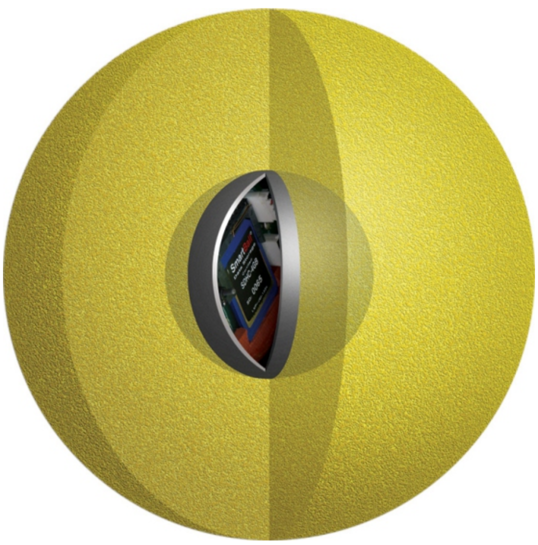
How SmartBall works?

The SmartBall® platform is a free-flowing tool for the assessment of pressurized water and wastewater pipelines 8 inches and larger. It can complete long assessments in a single deployment without disruption to regular pipeline service.

The tool is inserted into a live pipeline and travels with the product flow for up to 21 hours while collecting pipeline condition information. It requires only two access points for insertion and extraction, and is tracked throughout the inspection at predetermined fixed locations on the pipeline.

Applications

Owners of water and wastewater pipelines deal with a variety of infrastructure challenges; the SmartBall platform can collect a variety of pipeline condition information in a single deployment that helps owners manage their assets more effectively.



Leak Detection

The tool is equipped with a highly sensitive acoustic sensor that can detect pinhole-sized leaks on pressurized pipelines. The SmartBall platform has been able to identify leaks as small as 0.028 gal/min (0.11 liters) and has a typical location accuracy of within 6 feet (1.8 meters).

Gas Pocket Detection

The acoustic sensor is also able to identify the sound of trapped gas within pressurized mains. The presence of trapped gas can adversely affect pipeline flow or lead to degradation of the pipe wall in sewer force mains.

Inspection Benefits

- Easy to deploy through existing pipeline features
- No disruption to regular pipeline service
- Can complete long inspections in a single deployment
- Highly sensitive acoustic sensor that can locate very small leaks
- Can identify features relevant to the operation and mapping of the pipeline
- Indicates the position of leaks, and gas pockets relative to known points

xylem
Let's Solve Water

Pure Technologies, a Xylem Brand
EN 247, Edifício Jonobras, Sala 3, Piso 2
2670-027- Santo Isidoro, PORTUGAL
Tel +351 261 863 159
www.puretechltd.com

CHAPTER VI

INSTITUTIONAL ISSUES

www.sebakmt.com

sebaKMT
A member of Megger Group

Intelligent systems for locating leaks and monitoring water pipe networks

- **Zone measuring / monitoring**

  Data loggers for pressure, flow and noise Level
  Ultrasonic and electromagnetic flow meters

- **Pre-location and pinpoint location**

  Correlators
  Noise level loggers
  Electro-acoustic listening equipment

- **Line and object location**

- **Completely equipped testvans**

ADDRESSING FUTURE HUMAN RESOURCES CHALLENGES IN THE REGION OF SOUTHEAST EUROPE IN NRW CONTEXT

Jurica Kovac*

*Aqua Libera Ltd., Consultant in water loss management, Ribnica 146c, 10415 Novo Cice, Croatia, jurica.kovac@mail.com and jurica.kovac13@gmail.com

Abstract

Context

Water utilities in the region are facing serious challenges regarding available workforce in general and in particular considering growing needs in NRW control and reduction. In average NRW in the region is 50% and we already have established understanding that improvements are needed in all aspects, especially in networks renewals and wider use of proven methodologies like DMAs, pressure management, active leakage control and control of apparent losses due to meters inaccuracy and illegal water use, but all these changes can show progress only if we will have available human resources empowered with competences, skills and motivation.

Our region is witnessing serious “brain drain” and this is especially visible in water utilities due to numerous reasons:

- Economic situation and EU open border policy allows easier workforce mobility (young and competent people are looking for jobs in Western Europe);
- Weak financial capacities of water utility companies do not offer attractive employment of your people (low salaries and without motivational bonuses and rewards);
- Low interest of young generations for jobs in water sector (in particular in maintenance departments);
- Ageing workforce in water utilities is not followed with proactive policies (planned replacement with new generations) and this problem will only increase in the next 5-10 years;
- Lack of organised national programs for education and training;
- Water utilities are publicly owned companies with strong influence from politics and as an outcome with non-efficient governance and organisation.

Presented context requires our reaction and with my presentation I want to emphasise 3 opportunities (group of solutions) that can help in addressing presented challenges in the future:

Opportunities in Human Resources Management

- Identify potential experienced colleagues, who can act as “mentors/coaches” to YWP;
- Peer-exchange: employees are sent to learn from colleagues (on the spot learning/coaching). Advantage is that it is not costly and it creates a network of specialists;
- National/international experience exchange with other well-developed utilities will increase know how, e.g. Study tours;
- Identify knowledge gaps and needs;
- Management should be responsible for investing in professional development and should include in their business plan and allocate enough financial resources;
- Donor/IFIs community requires a minimum knowledge (managerial competences), e.g. investment projects, feasibility studies;
- Provide opportunity to legislate certification;
- Various capacity development programs already exist but not used enough;
- Make use of online webinars;
- Self-promote a quality standard that implies an accepted state-of-the-art procedure – prerequisite is a critical mass of utilities to enable certification;
- The big private operators who run concessions have training courses on a regular basis, these could be tapped on by public utilities. The same for university courses;
- Disseminating the knowledge gathered in the training course among other colleagues within the company or change participants who attend trainings to increase the reach of the activity;
- Create a reward system for employees who invest in increasing their capacity;
- Take advantage of a young and motivated workforce by providing them with opportunities of

professional development within the utility.

Opportunities from new technologies

- Proactive use of SMART systems (SCADA, remote monitoring, autonomous control systems etc.);
- Internet of things;
- Data collection digitalisation;
- Big Data IT solution implementation (use of Artificial Intelligence Algorithms);
- New technologies for leak detection (Satellite leak detection, Drones for leak detection etc.);
- Robotisation.

Opportunities in new management solutions

- Public-Private Partnerships;
- Performance based contracting;
- Outsourcing some activities;
- Utilities aggregation;
- Water pricing policies (better financial opportunities);
- Less political control of public utilities (reducing local politics influence);
- Innovations in management (key managers are professionals with bonuses if reaching KPIs, clear and transparent policy for rewards and promotion etc.).

Keywords
Human resources, mobile workforce, automatization, robotisation.

HOW TO DESIGN A PERFORMANCE BASED NON-REVENUE WATER MANAGEMENT CONTRACT

Roland Liemberger*

*Miya, Pfalzauerstrasse 72, 3021 Pressbaum, Austria, roland@liemberger.cc

Abstract
For decades performance based Non-Revenue Water Management Contracts (NRW PBCs) have been proved to be a most efficient solution for water utilities in need of reducing high levels of NRW. Development banks and funding institutions more and more see the benefits of the approach. But the design of (to be) successful NRW PBCs is not trivial. This paper will explain some basics, the lessons to be learned and mistakes to be avoided.

Keywords
Non-Revenue Water, Performance Based Contracts, NRW PBC.

1. INTRODUCTION

Outsourcing of certain water loss reduction activities is not a new practice. Many water utilities in Europe, the United States and even in low and middle income countries (for example, SABESP in Brazil) use private leak detection contractors to periodically survey their distribution network. This is usually done through the most basic form of outsourcing, where the contractor gets paid on a schedule of rates (e.g., per day or per km pipeline checked) regardless of the achievements made.

However, during the last 20 years, more utilities throughout the world are using contracts with performance related payments. These are commonly referred to as performance-based contracts (PBCs). Under a PBC, an NRW Management Firm (NRWMF) is contracted to implement a NRW reduction program, and payments are (to varying degrees) linked to performance achievements. Contract models and level of performance-based payments can vary widely from one utility to another.

This paper will summarize the necessary consideration for the design of successful NRW PBCs.

2. METHODOLOGY

Besides dealing with political and legal issues, which are different from county to country, the process of designing a successful NRW PBC needs always to include the following steps:

- Rapid NRW assessment, following the IWA method and resulting in NRW performance indicators (PIs).
- Determination of the project area (if not the entire system) and, if possible, calculation of water loss PIs for this area.
- Determination of the scope of work (NRW reduction? Physical loss reduction only? Commercial loss reduction only?
- Determination of the implementation model, e.g. turn-key NRW PBC, Co-management approach or basic advisory contract.
- Preparation of an NRW forecast – with and without project; volumetric quantification of realistic savings.

- Valuation of physical and commercial losses, e.g. can recovered leakage be sold to existing or new customers or will leakage reduction only lead to a reduction of variable water production and distribution cost?
- Preparation of a REALISTIC cost estimate (the contractor needs to make profits and the utility needs good quality and success!).
- Preparation of a cost/benefit analysis.
- Designing the contract model and determination of performance achievement measurement methods and performance indicators.
- Preparation of procurement documents, decision on bid evaluation method and criteria.

Results and conclusions

The paper will discuss the different approaches and give recommendations on how to best develop an NRW PBC.

CONSULTANCY IN THE CONCEPTUAL MANAGEMENT OF A WATER SUPPLY SYSTEM WITH THE LOWEST PRODUCTION PRICE

Tobolcea Cosmin*, Creţu Valentin**

* PhD.eng.ec. - General Manager S.C. PRO TOBY S.R.L. Iaşi, e-mail: cosmin.tobolcea@protoby.ro
** ”Gh. Asachi” Technical University Iași, Faculty of Hydrotechnics, Geodesy and Environmental Engineering, Department of Hydropower, e-mail: v_cretu_2002@yahoo.com

Abstract
This paper proposes the provision of technical consultancy in the conceptual management of water supply systems so that the cost price of drinking water is minimal. The variables are the transport, storage and distribution options, without commenting on the quality/treatability of the water delivered. It is interesting that the solutions can be altered in other unprivileged systems, irrigation systems and industrial water supply systems.
The paper also presents a series of examples made by authors for localities with a small, medium and large number of consumers (inhabitants and economic agents) in different geo / topographical areas in Romania. The realization of these systems was due to the high-performance computing programs, the performance of new hydraulic equipment, the automation / SCADA systems and the performance of materials for pipes and fittings.

Keywords
Water supply, conceptual management of water supply system.

1. INTRODUCTION

The cost of drinking water is the sum of direct investment costs plus production (exploitation and repair) and indirect costs (taxes, wages etc.). The investment costs are conditioned by the design of the supply system in direct correlation to the location and power of the pumping stations from the water supply transport, the location and the size of the compensating storage/reservoirs, and the design of the water distribution system to the consumers. It would be ideal for each consumer to have the same minimum pressure to ensure the optimal conditions of operation of the domestic equipment. By treating all types of water as a valuable resource, new approaches and opportunities arise; both directly in terms of preserving the freshwater resource and obtaining climate resilience, and indirectly in terms of creating more livable cities by linking the new water infrastructures to aesthetical and recreational benefits.

In classical water supply systems, drinking water is pumped to the maximum and then gravitationally discharged to consumers.

2. OVERVIEW OF THE WATER SUPPLY METHOD BY AUTOMATED PUMPING UNDER CONTROLLED PRESSURE REGIME

Given that in the field of pumps and automation there are currently large possibilities of applications for automatic / intelligent distribution of power systems, we propose by this work to cancel (exclude) the transport of the total flow from the collection plate to the pressure tank plate (clearing) and proceed as follows:

- treatment and offsetting of debts on the landing site shall be provided;
- eliminating of Drinking Water Pumping Station with constant flow, replaced by a variable flow pumping station controlled according to two decisions of the integrated SCADA system:

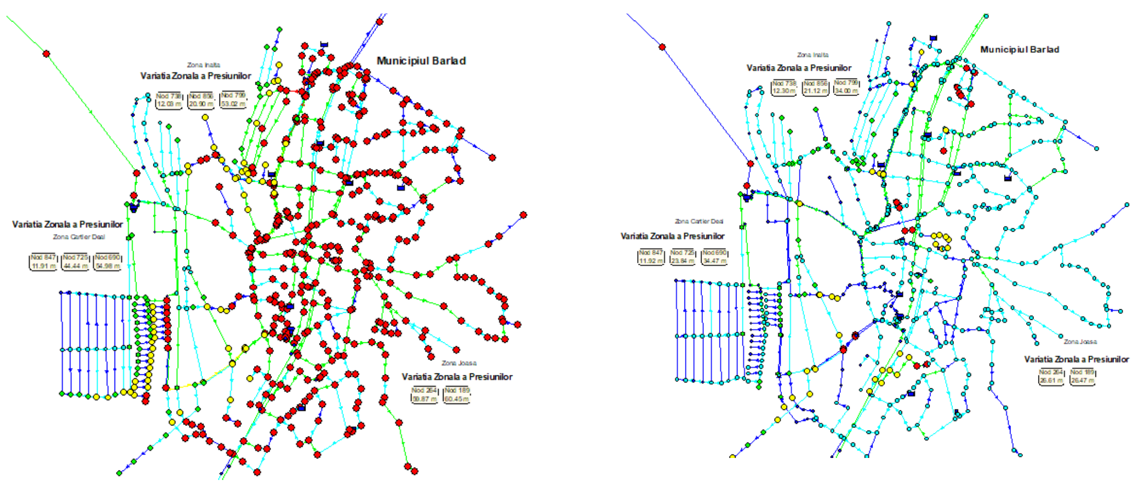
1. minimum pressure to the farthest consumer is constant;
2. minimum pressure constancy is ensured by the addition of flow from Drinking Water Pumping Station directly proportional to the flow of drinking water consumed in the system. Any consumption materializes under pressure, read on the manometer mounted to the farthest consumer transmitting the data to Drinking Water Pumping Station;

- Drinking water is injected from the bottom up into the distribution network (basically reversing the direction in the distribution network to the top-down classic supply solution). The maximum flow rate will be subject of piping dimensioning at the bottom of the settlement, and as the rate increases, the flow rate decreases depending on the consumption, so that the main feed pipes will carry the flow rate for the last consumers at the highest point of the settlement. From here and up to the location of the fire tank, the single connecting pipe will only carry the fire rate;
- the main pipeline conducting the distribution network will control pressure at different points by pressure regulators mounted on each secondary branch so that they are controlled minimum pressures. This will give you the minimum cost.

3. CASE STUDIES

Example 1 - Miroslovești, jud. Iași, less than 1.000 inhabitants, does not need compensation tanks because it uses the adduction pipe for Moţca-Pascani System (~20,000 inhabitants). The pumping station is fully automated and has a main pipe supplying the main column, trunk, secondary columns and branches. The main column feeds for Δh = 350mca and the secondary columns for pressures <6mca.

Example 2 – Bârlad, jud. Vaslui. The water supply is pumped from the bottom of the city and free fall from the treatment plant.



I - Current pressure regime – hydraulic modelling   II - The pressure regime proposed by intervention works

Fig. 1. Water supply of the municipality of Barlad - night pressure regimes

In the proposed situation of the hydraulic modelling, the losses have been modified by replacing some sections, the water supply system has been branched down, so that with minimal investment the losses in the distribution network have been considerably reduced.

Example 3 - Alexandria - pumped water supply system from two underground sources: capture field Peretu-Plosca and capture field Orbeasca-Lăceni.

The following operating regimes were designed on the distribution network:

- continuous pressure measurement on the common discharge line of pumps with pressure transducer;
- continuous pressure measurement on the common suction line of pumps with a pressure transducer transmitting a fault signal when the suction pressure value decreases;

- continuous measurement of pressure from the water network to consumers for monitoring purposes;

- local pressure measuring circuits with bourdon pressure gauges mounted on pump dispensing.

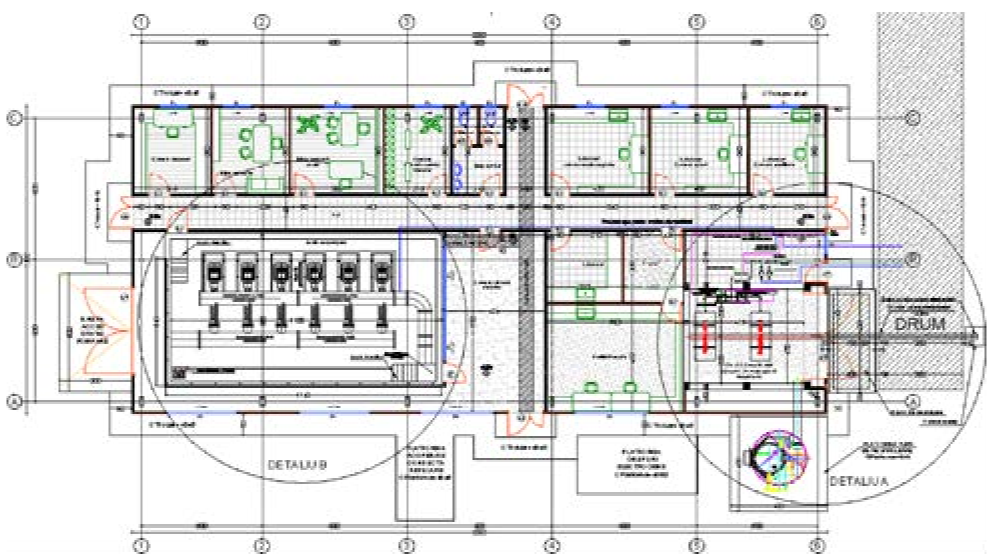


Fig. 2. Drinking Water Treatment Plant Vedea

Pressure optimization through computational software for water management adapted to the dynamic hydraulic modelling of complex systems allows, by controlling the minimum allowable Pressure (through distribution monitoring), a minimum cost price for water distribution and minimal operating and repair costs by reducing the losses in network. Overall objectives are to increase efficiency (in terms of cost, energy and resources) of process and information technologies applied in the priority areas.

The present plan for the future it to create a **Water Smart City** approach is to exploit these opportunities in a **smart way**.

A **sustainable water price** is a price that will **(1)** reflect true costs and thereby induce efficient water production and consumption, **(2)** promote optimization or the achievement of least-cost solutions to providing water service, **(3)** achieve equity in terms of incorporating cost-sharing practices as needed to enhance affordability, and **(4)** enhance the long-term viability of the water utility.

Innovative technologies have the potential to lower the costs of water-related investments. Innovative business models and policies can help monetize the benefits of improved water management and protection against water risks.

REFERENCES

[1]. *Gavrilaş, G*., 1991, „Remarks Concerning the optimization of the pumps energetic working conditions for the Systems of water distribution", bul. I.P. Iaşi, Vol. XXX VII (XLI), fasc. 1-4.
[2]. *Tobolcea, C., G., Gavrilaş*, 1995, "An artificial neural network approach to water pumping analysis" - 3rd International Symposion of Technic University Vinnita, Ukraine.
[3]. *Tobolcea, C., Creţu, V*., 2008, "Possibility of extension of water supply and sewerage network, residential district Gura Humorului", Scientific Research Contract.
[4]. *Mănescu, Al*., 1998, "Water Supply" Applications, H*G*A* Publishing House, Bucharest;
[5]. *Gavrilaş, G*., 1999, "Urban Hydraulics", „Gh. Asachi" Publishing House, Iaşi.
[6]. **NP 133-2013** "Normative regarding the design, construction and operation of the water supply and sewerage systems of the localities";
[7]. Water Infrastructure and Investment - World Bank (2016), High and Dry: Climate Change, Water and the Economy, World Bank, Washington, DC. License: Creative Commons Attribution CC BY 3.0 IGO, https://ec.europa.eu/eurostat/statistics-explained/pdfscache/1182.pdf;
[8]. SUSTAINABLE WATER PRICING, *Janice A. Beecher*, Principal Beecher Policy Research, Inc. and *Peter E. Shanaghan* Small Systems Coordinator U.S. Environmental Protection Agency.

DIGITAL WATER SYSTEM: THE CASE OF GANDIA

A. Rubio*, J. Barba* and M. Roldán*

*Go-Aigua, Álvaro de Bazán, 10, 46010 Valencia (Spain)
*Corresponding Author - Email: manuel.roldan@go-aigua.com

Abstract
New technologies such as IoT sensors, data loggers and big-data platforms have allowed for a qualitative shift in the nature of Water Networks. Nowadays they stand as one of the most fundamental data-generating assets, and therefore a source of efficiency insights. This article will outline how a successful digital transformation towards smart networks making use of these advancements can be achieved. Taking as a blueprint for success the case of the city of Gandía, focusing on the steps followed, the technologies involved and the direct and indirect gains derived from it.

Keywords
Water Efficiency, Smart Metering, Digital transformation.

From Traditional to Smart Networks

The process of digitalization currently reforming the water industry has fundamentally transformed the nature of water networks, in the past these were regarded as merely the transport mechanism employed to supply water to municipalities, cities, and ultimately, through internal pipes, deliver it to the final consumer. Nonetheless, the advent of the data-gathering and communication technologies in recent years has brought a qualitative shift regarding the value that these networks have for the Water Utilities.

Modern technological advances have converted Smart Networks from exclusively a physical asset owned, employed, payed, and taken care of by the Water Utilities, to a much more complex and potentially economically profitable source of crucial efficiency and consumer insights.

A successful and carefully designed sensitization environment deployed over the different points in the networks will generate information regarding the overall performance of the system which could be used to improve several points where inefficiencies are spotted. These could range from the detection to sudden drops in pressure in steep areas of the network, to potential leakages; to something more complex such as client consumption patterns.

Those operational insights (and many more that could be obtained) will be of great value to a water utility seeking to reduce costs by improving efficiency, reduce water wastage or improve client satisfaction. Then it becomes self-evident how these technologies, and the big data algorithms that treat, structure and ultimately generate the operational insights from that data, have enhanced the value water Networks bring to the company.

The technologies involved

This qualitative shift from traditional to smart networks has been brought by the technological advances at a hardware, software and telecom levels of the recent decade. This article will now outline the key technologies that take part in the digitalization process.

The main information-recording unit is the sensor, which is able to capture consistent data of a given variable (KPI) such as flow, pressure, conductivity etc. and transmit it to physically separated databases.

The Smart Meters, of more recent development, are essentially sensors which record household consumption endowed with IoT capabilities, which allows them to, once again, transmit data.

The communication protocols through which the data is shared in IoT environments, are crucial to improve or deteriorate the transmission and aggregation of data proceeding from sensorized environments. The Narrowband IoT network was used in this case to ensure better data distribution of smart meters in isolated areas, or areas with poor communication.

Finally, once that has been captured and transmitted it must be integrated in a versatile database that can structure very different types of data, and allow for algorithmic applications to run over it, extracting operational insights.

Case Study: Gandía

Having outlined the disruption occurring at the Water Industries we will now focus on a particular example of a successful complete digitalization of water networks, particularly on the city of Gandía.

On November of 2018 the City of Gandía in partnership with Global Omnium (the operating water utility in the region) and Vodafone (a telecom provider) started a six-month process of smart metering deployment, which would provide hourly consumption data for its more than 74 thousand inhabitants, becoming Europe’s first municipality to fully digitalize its networks and integrate consumption data.

The city council of Gandía, has for many years undertaken a complete digital transformation and sensorization of different levels of its water network prior to the recent deployment of smart meters. This article will now look at the steps through which this success has been achieved.

The pathway from traditional to smart water networks can be traced in Gandía’s process of digitalization:

About 20 years ago Gandía, had a traditional distribution network, however, both the city council and the operating water utility reached an agreement of investing in the network: two efforts were considered paramount at such an early stage: the sensorization of some of its largest infrastructures (storage systems, wells, large valves, treatment plants etc.) so that fundamental information could be gathered about its operations; and a process of sectorization of the network, which would divide the network into smaller sections, where the water input on each sector’s network will be recorded by smart caudal meters and data loggers.

Once both processes where successfully conducted, the city council and the water utility had a much clearer picture of their operating reality at the city, which enabled them to deploy (second step) leakage detection algorithms (using information from pressure and caudal meters per sectors) and predictive maintenance algorithms in the sensorized infrastructures to ensure full supervision.

The third, and final step, involved the deployment of smart meters at the consumer’s end of the pipe network. These devices would, as stated above, record hourly consumption data at household level of every client in a sector. Two fundamental insights were derived from this: the first one allowed for accurate demand forecast and client consumption profiles to be generated from the gathered data; the second one, allowed for an improvement in the efficiency of sector leak detection since reliable aggregated consumption data could be added to the algorithm which would compare it to input water and look for any remarkable asymmetries.

CATAWBA-WATEREE: NORTH AMERICAS FIRST RIVER BASIN WATER LOSS REGIONAL STRATEGY

Steve Cavanaugh*

*Steve Cavanaugh, P.E. President/Chief Innovation Officer
Cavanaugh & Associates, P.A., PO Box 11197, Winston Salem, NC 27116 1-877-557-8923
steve.cavanaugh@cavanaughsolutions.com

Abstract
Water supply challenges and the need for robust conservation planning are driven by increasing customer demand, declining supplies, and aging utility infrastructure. Water Loss Control is an important part of water resource management for water utilities. States are taking note of the importance of Water Loss Programs as well as 13 state programs across the country to date and even more on the horizon. This topic will provide an overview of these programs and highlight a unique program currently underway in North Carolina.

The Catawba-Wateree Water Management Group (CWWMG) has embarked on a Water Loss program to develop meaningful basin-wide targets for water loss. In November 2014, the CWWMG conducted a training workshop for its members to introduce the basic concepts of the AWWA M36 Methodology of Water Loss Control Management. This workshop introduced the backbone of the methodology, the Water Balance and provided guidance for moving away from the outdated terminology of Unaccounted for Water and outdated practice of using water loss as a percentage of total water supplied as a performance indicator. There are 19 total systems that participate as members in CWWMG representing approximately 550,000 total service connections. There is one large system (Charlotte Water –280,000 service connections) and ten medium sized systems (between 10,000 and 50,000 service connections). The other eight systems are less than 10,000 service connections and categorized as small systems. Most systems are interconnected with other utilities, either buying/selling water or for emergency back-up supplies.

Most recently, CWWMG and Cavanaugh developed a Basin-wide Water Loss Program (BWLP) that would provide the members with a multi-phase water loss training & technical assistance program. This program would be accommodating for the members at varied levels of water loss management knowledge and experience with the overall goal of the program to result in long-term reductions in water loss for the basin.

In February 2017, CWWMG members took the next step in understanding and addressing Basin challenges with water loss through a water auditing refresher workshop before engaging in the Level I Validation with their Water Audits later in the Summer/Fall. After these calls, the utilities will have a Level 1 Validated audit for use in the basin-wide analysis. Now that the audits have been completed, they will be consolidated to develop the current baseline for the basin. These metrics are reviewed with specific statistical confidence limits to establish a high and low band for the existing data. One of the metrics from the validated water audits is the quantified real losses, or physical leakage.

In 2018, the program moved in to the next and most recent phase of real loss component analysis to further evaluate these real losses, by performing a bottom-up quantification of the volumes through a real loss "component analysis". The central aspect in the component analysis, is understanding there are three types of real losses and each has specific suite of tools to consider for intervention strategies. This step helps determine the types of leakage and appropriate tools for addressing leakage in effort to find the economic optimum level of intervention. In order to maintain consistent tracking and progress toward the goals of the BWLP, annual auditing will be required of all members and basin-wide progress will be reviewed and reported to the larger group on a routine, systematic basis. This presentation will provide an overview of the multi-phase Catawba-Wateree Basin-Wide Water Loss Program and discuss results of the first round of validated water audits, and non-revenue component analysis to help establish meaningful basin-wide targets for water loss, and look ahead to the development of water loss programs for each member. This program has also generated state wide interest in North Carolina and a brief introduction and update to the North Carolina Pilot Water Loss Program including 10 utilities will be provided.

Keywords
Basin-wide Water Loss Program, Validated Water Audits, Performance indicators, Conservation Planning, Basin-wide analysis, Quantifying Real Water Loss.

COMMERCIAL LOSSES – THE LOW HANGING FRUIT

Bambos Charalambous*

*Hydrocontrol Ltd, Limassol, Cyprus, email: bcharalambous@cytanet.com.cy

Abstract
Control and efficiency of a distribution network is imperative in today's changing world climate. Following the initial major investments in the construction of a distribution network, successful management of this high cost infrastructure is required in order to operate and to deliver the required service as efficiently and cost effectively as possible. The management of the commercial activities of a utility is an integral part in achieving this goal.

Keywords
Non-Revenue Water, financial efficiency, commercial cycle, commercial losses.

INTRODUCTION

Expanding water networks without addressing commercial efficiency improvement through proper business planning will only lead to a cycle of waste and inefficiency. The level of commercial efficiency in water utilities varies from country to country, region to region, utility to utility and will be affected by a number of factors, such as, metering, operational practices, level of technology and expertise applied in controlling customer billing and other local factors. This paper reflects international best practice relating to Commercial Efficiency performance measures and reduction of commercial losses.

METHODOLOGY

Commercial and financial management are integral utility functions and top management priority areas on a daily basis. Commercial Efficiency is most efficiently and effectively addressed on the basis of the following two key elements:

• The Commercial Cycle, which is the hard element of commercial management (meters, readings, billing and collection);

• The "soft" customer service element (call centers, complaints-handling units, websites etc.).

It has been recognized internationally that a self-sustaining utility should focus on the "Commercial Cycle", which is a chain of 4 sub-processes, and failure in one of these results in poor performance overall.

The logic that a commercially-efficient water utility shall have its commercial activities organized around a seamless commercial cycle that includes the following distinct stages is crucial:

• Meter Management: the meter itself, its accuracy, the activities of meter installation, maintenance, calibration etc.

• Meter Reading: access to the meter, reliability of the reading, registration practices of the meter reading.

• Customer Billing: data entry of readings, data management (including assumptions, distributing common needs etc.) and producing and sending the bill tom the customer.

• Unauthorized use: that is water used illegally without providing income to the utility.

Failure to control one of the above stages may result in a non-efficient process irrespective of efficient and effective set-up of the others.

RESULTS AND CONCLUSIONS

The paper will discuss the different approaches and give recommendations on how to best pick "the low hanging fruit" in order to reduce commercial losses and thus Non-Revenue Water.

IMPLEMENTATION STRATEGY FOR "REGIONAL PROJECT FOR THE DEVELOPMENT OF THE WATER AND WASTEWATER INFRASTRUCTURE IN IASI COUNTY, DURING 2014-2020 PERIOD", IN ORDER TO LIMIT THE NRW VALUES IN THE OPERATION OF DRINKING WATER SUPPLY SYSTEMS

dr. eng. Mihail Doruş*, eng. Ciprian Savastru**, eng. Ioan-Vladut Apetroi***, eng. Stefania Chirica***

* Technical Manager, S.C. APAVITAL S.A., no. 6 Mihai Costăchescu Street, Iaşi, Romania (Email: mihai.dorus@apavital.ro)
** Head of Investment & Development Department (Email: ciprian.savastru@apavital.ro)
*** Investment & Development Department (Email: vlad.apetroi@apavital.ro, stefania.chirica@apavital.ro)

Abstract
At present, the existing strategies aimed to reduce water losses are limited to optimizing, rehabilitation and control of existing water systems. In contrast, for new systems, there are very few measures able to limit and control water losses, starting from the premise that a new system is functional and highly efficient. In order to ensure a sustainable development of water supply systems, there is a need to identify the causes which are leading to major deficiencies in operating systems and, hence, to take appropriate measures. An example of good practice in this area is represented by projects developed under SOP Environment Program. The continuation of this type of investments, but also the implementation of additional projects across the entire operating area of Apavital Company via the LIOP program will lead to a decrease in NRW values and water supply systems efficiency. The implementation strategy highlights the practice conducted during the design phase, the execution phase and the operating phase. These are aimed to increase the performance level of new water networks and facilitate the gathering of data used to assess the water supply systems efficiency.

Keywords
NRW, optimization, Smart Water Networks, Strategy.

1. INTRODUCTION

As regards the investments carried out for the extension of water supply systems, a key issue is the development of a unitary strategy at regional level. This strategy must correlate water sources (in terms of quality, available flows, zonal distribution) with the consumers' requirements [1]. The lack of such a strategy leads to inappropriate sizing of water supply systems that feature pipe diameters and storage capacities not adequate for the real water demand [2].

Inappropriate sizing of water supply systems leads to big NRW values either from network stress and frequent leakage, either from water aging in the network, thus the need to evacuate and replace it, leading to authorized non-billed water volumes, components of the NRW factor.

2. THE EXISTING SITUATION AND THE NEED FOR IMPLEMENTING A NRW RELATED STRATEGY

Considering the regional nature of Apavital S.A. Company, which operates systems of various nature, operating parameters and distinct performance indicators, there is need to implement a company-wide strategy in order to limit the NRW amounts across the entire operating area.

The expanding of Apavital operating area is achieved by three different methods, which are leading to operation of systems featuring various technical capabilities and performance. These include:

a - taking over of water systems that are already operational, but featuring advanced degrees of deterioration (e.g. the Town of Paşcani);

b – taking over new systems or network extensions from local government investments;

c - managing new systems, which were completed by investments from Apavital funds or non-reimbursable funds, carried out by means of Apavital design department or via third-party designers.

In order to ensure the sustainable development of new water systems, there was need to identify the causes that are leading to major deficiencies in systems currently operated, some of which are listed below:

- inappropriate sizing of water systems, this generating either high water velocities or prolonged water stagnation inside pipelines and the need for periodic pipe flushing;
- difficult defining of pipeline routes in relation to operational capacity (difficult accessible areas, large number of under-crossings and direction changes etc.);
- lack of correlation or incorrect correlation between materials used and the nature of terrain/network site (heavy traffic areas, areas prone to landslides etc.);
- deficiencies in the operation of water tanks and pumping stations;
- sectors with illegal consumers;
- problems with monitoring and controlling water losses inside under-crossing systems;
- changes in network operational pressures according to the increasing/decreasing of estimated consumed flows.

3. CASE STUDY REGARDING THE NRW AMOUNTS AFTER THE IMPLEMENTATION OF THE ENVIRONMENTAL SOP PROGRAM IN THE TÂRGU FRUMOS OPERATIONAL AREA

One of the major projects completed under SOP Environment Program was the investment named "Upgrading of water and sewerage systems in the Town of Târgu Frumos" (Works Contract 11).

The works execution started in June 2013, and were finalized in July 2016, with a defect notification period that lasted until July 2017. The implementation of the project was aimed at the partial replacement of the water supply infrastructure, by considering the needs identified during operation until year 2012, these being:

- the need to replace asbestos-cement pipes;
- the need to correlate the transportation network diameters with the real consumption requirements;
- the need to reconfigure certain routes in relation to the updated legal situation of terrain and land implied;
- the need to extend the system in order to take over new consumers.

The project was aimed at replacing the aging infrastructure, replacing connections made with compression pipe joints with connections made with electro-fusion joints, local reconfiguration of pipeline routes and expanding the network in order to make it able to accept new consumers. The network, at key locations, was equipped with measurement and control devices integrated with both local and central dispatch and control departments.

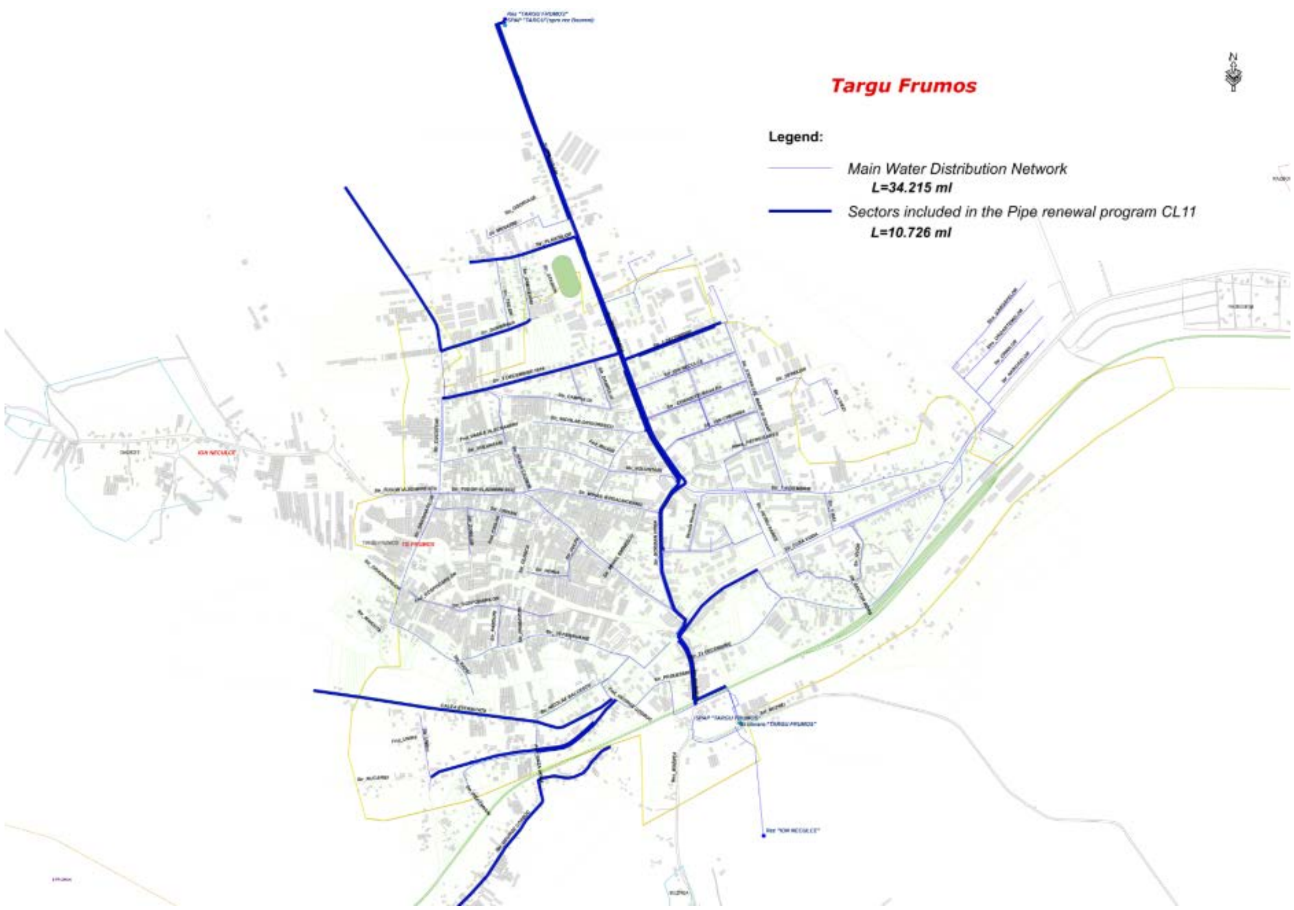


Fig. 1. Graphic view of Targu Frumos Water Supply System

Under the project, rehabilitation works were foreseen for approximately 19% of the existing pipeline network length, and extension works for approximately 15.5%. The target technical indicators of the project are shown in Table 1.

The case study of Târgu Frumos operating area included data sets recorded during the pre-accession phase of the SOP Environment program, during the project implementation phase and after works completion. The data analysis presented in Figure 2 shows the annual variation of water volumes supplied to the Târgu Frumos system during period 2011 - 2017 gradually decreased between 2011 and 2016, with a subsequent slight increase in 2017. Data obtained, referring to the tendency of a water consumption increasing, per household, and the continuous increasing of consumers numbers throughout the research period (in the context of a decreasing of the water volumes injected into the system), illustrates the final effectiveness of this investment (Works Contract 11) as regards the reducing of NRW amounts in the Târgu Frumos operational area.

In 2011, before the upgrading of water supply systems, the volumes of water entering the system reached an amount of 679,233 m^3. In 2017, after the completion of modernization works carried out under the SOP Environment program, the volumes of input water decreased by about 20.42%, down to 540,536 m^3. At the same time, the number of connections increased by 14.77%, from 1767 in 2011 up to 2028 in 2017.

Table 1. Technical indicators achieved under SOP Environment program in the Târgu Frumos operational area

No	Activity	Length [m]
1.	Upgrading of main water pipelines	913
2.	New main water pipelines	3,012
3.	Hydraulic upgrading of existing distribution networks	597
4.	Replacement of asbestos-cement sectors	1,253
5.	Extension of water supply network	4,951
	Total	10,726

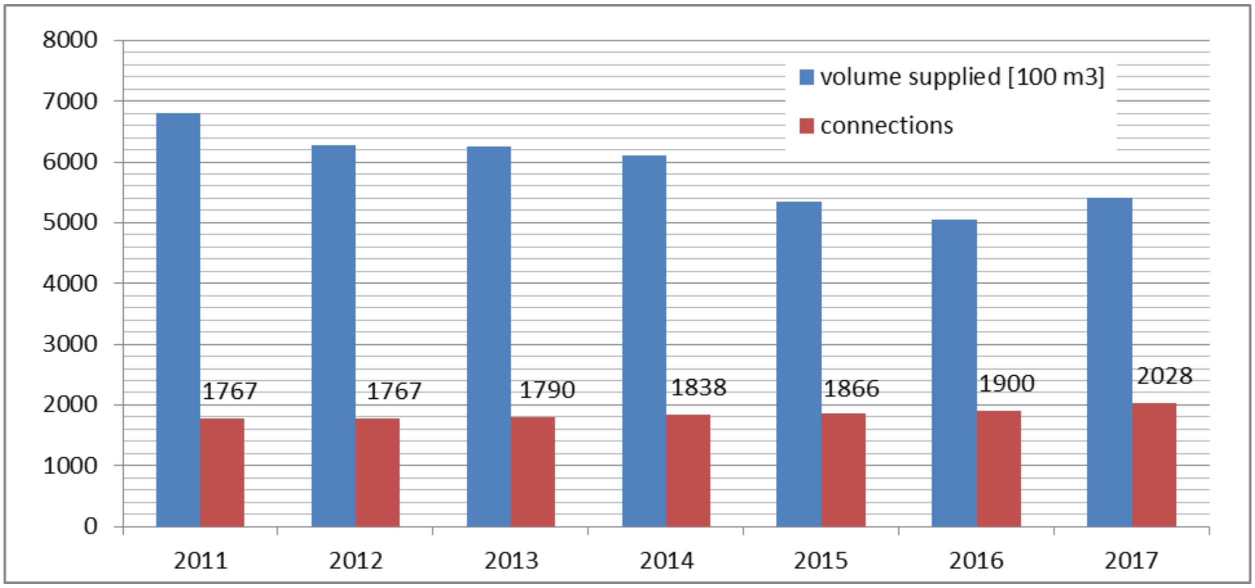


Fig. 2. Annual Supply/ number of connections within Târgu Frumos water distribution network

The analysis of billed water volumes shows a variation for period 2011 - 2013, followed by an upward trend in the following period, namely the 2014 - 2017 period. The billed water volumes were steadily increasing since 2014, a situation justified by the increasing in the number of consumers, together with the increasing of metering level, metering also achieved under SOP Environment investments.

The analyzed period 2011 - 2017 is characterized by three stages of evolution for the Târgu Frumos water supply system (Figure 3):

a) Rehabilitation and upgrading stage through investments implemented with Apavital funds was carried out until 2013. The completed investments had low values and capacities. As shown in Figure 3, the pipe replacement during the 2010 - 2011 period decreased the amount of water losses down to 156,507 m^3 in 2012. The subsequent increase in water loss in 2013 indicated that, in order to continue the downward trend for the NRW amounts, it was necessary to continue investments in the water supply system;

b) The system upgrading stage through the completion of Works Contract 11 project during period 2013 - 2016 lead to an improvement of technical and financial indicators obtained before implementation. The network performance indicators obtained during the works implementation at this stage have shown a reduction in input water volumes pumped into the system, up to 504,324

m^3, an increase in the billed water volumes of up to 403,915 m^3 and a decrease in water losses, up to 89,522 m^3;

c) The system operation stage is represented by the values obtained in 2017. At this stage there was an increase of the input water volumes by about 7.18%, this meaning a volume of 540,536 m^3 and an increase of water losses up to 110,897 m^3. The operational period that follows the completion period is known as the system's "running-in" stage, stage during which water loss values can increase. This stage is also described by technical literature [3], [4] and lasts for about two years.

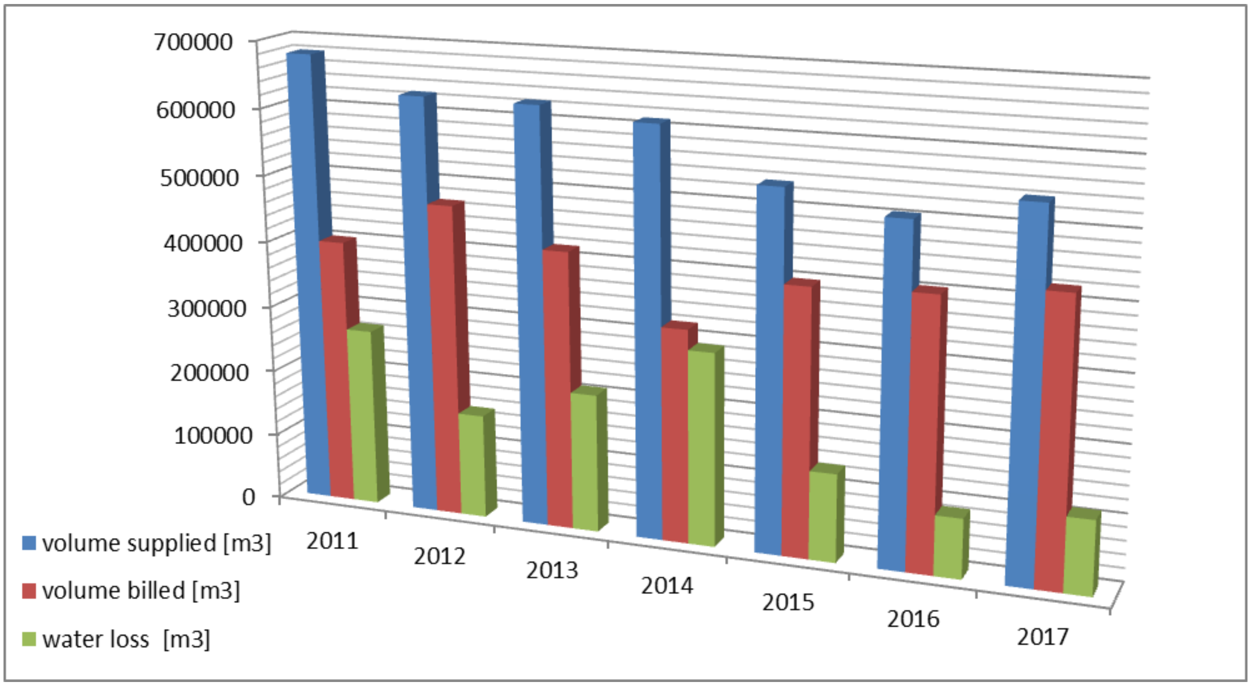


Fig. 3. Annual variations of water volumes within Târgu Frumos distribution network

The effectiveness of measures adopted under the projects is reflected in NRW values obtained after project implementation (Table 2). In the case of Târgu Frumos, where the water supply system has become a combination of old and new network sectors, the NRW amounts have fallen from 47.65%, the maximum value recorded during contract execution, down to 19.91% after works completion. After the end of completion period, the system went through a "running-in" period, when there was possible to identify and repair possible defects that generate water loss. In this case, it is worth to notice the NRW value obtained for 2017, which is with 9.79 % higher (as percentage) than in 2016, thus reaching a value of 21.86%.

Analysis of data in Table 2 shows how the volumes of water injected into system gradually decreased starting 2011 as a result of investments carried out with Apavital financing and continued to decrease as a result of the implementation of the project financed by European funds. The system's upgrading started in 2013 and the rapid progress of the work can be noticed by analyzing the subsequent monitoring intervals. Thus, the study period 2014 - 2015 is marked by a substantial increase in the performance indicators obtained in the Târgu Frumos system:

- water flows injected into system decreased from 610,887 m^3/year down to 535,149 m^3/year;
- billed consumption increased by 42.23% (as percentage), that is from 52.35% to 74.46%;

- water losses decreased by about 48.05% (as percentage), from 47.47% to 24.66%;
- NRW amounts dropped from 47.65% to 25.54%, this being a 46.40% decrease (as percentage).

Table 2. Water Supply distribution within Târgu Frumos system

Year	TWS	Percentage from the total water supply			
		BC	UMC	WL	NRW
	[m^3]	[%]	[%]	[%]	[%]
2011	679,233	59.01	1.48	39.51	40.99
2012	627,775	74.90	0.17	24.93	25.10
2013	626,174	66.62	0.18	33.20	33.38
2014	610,887	52.35	0.18	47.47	47.65
2015	535,149	74.46	0.89	24.66	25.54
2016	504,324	80.09	2.16	17.75	19.91
2017	540,536	78.14	1.34	20.52	21.86

Note: TWS – Total Water Supply; BC – Billed Consumption; UMC – Unbilled Metered Consumption; WL – Water Loss; NRW – Non-Revenue Water

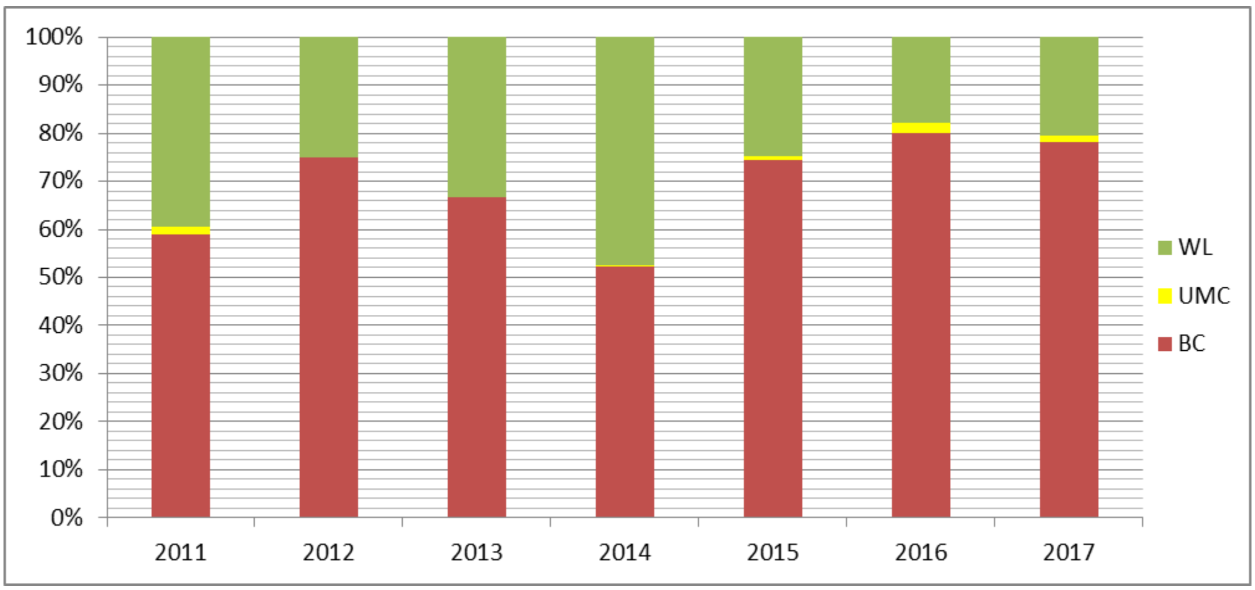


Fig. 4. Percentage distribution of revenue and non – revenue water

Starting with 2015, an increase has been noticed in the water volumes used for the system's own consumption (unbilled metered consumption). In addition to the expanding of operating area, as modernization works have been completed, more and more sectors have been tested and commissioned, fact that led to large volumes of water used for network flushing. These volumes are found in performance indicators, and are included in the NRW amounts.

Transposing the data from Table 2 in Figure 4 illustrates the distribution of water volumes injected into system between 2011 and 2017. The graph shows the fluctuation of billed and non-revenue water volumes in all three stages of system evolution: the domestic investments period 2011 - 2013, the SOP Environment investment period 2013 - 2016 and the operational period, 2017.

As results show, following up on such investment together with additional projects can lead to an important drop in NRW values and increased water supply efficiency over the entire operating area of S.C. Apavital S.A.

4. THE IMPLEMENTATION STRATEGY OF THE LIOP PROGRAM IN REFERENCE TO THE MINIMALIZATION OF NRW VALUES

Currently, S.C. Apavital S.A. Iasi operates approx. 4600 km of water supply network, managed through four operational sectors: Distribution-Sewerage ZMI (Iaşi Metropolitan Zone), Bahlui Operational Sector, Prut-Bârlad Operational Sector, Siret Operational Sector.

The investments carried out through LIOP program are aimed at the development of the regional water supply system, this meaning the construction, extension and rehabilitation of 331,484 m of distribution networks, and 284,303 m of main water pipelines. Through the implemented measures, 10 new water supply systems will be created, systems identified according to Figure 5.

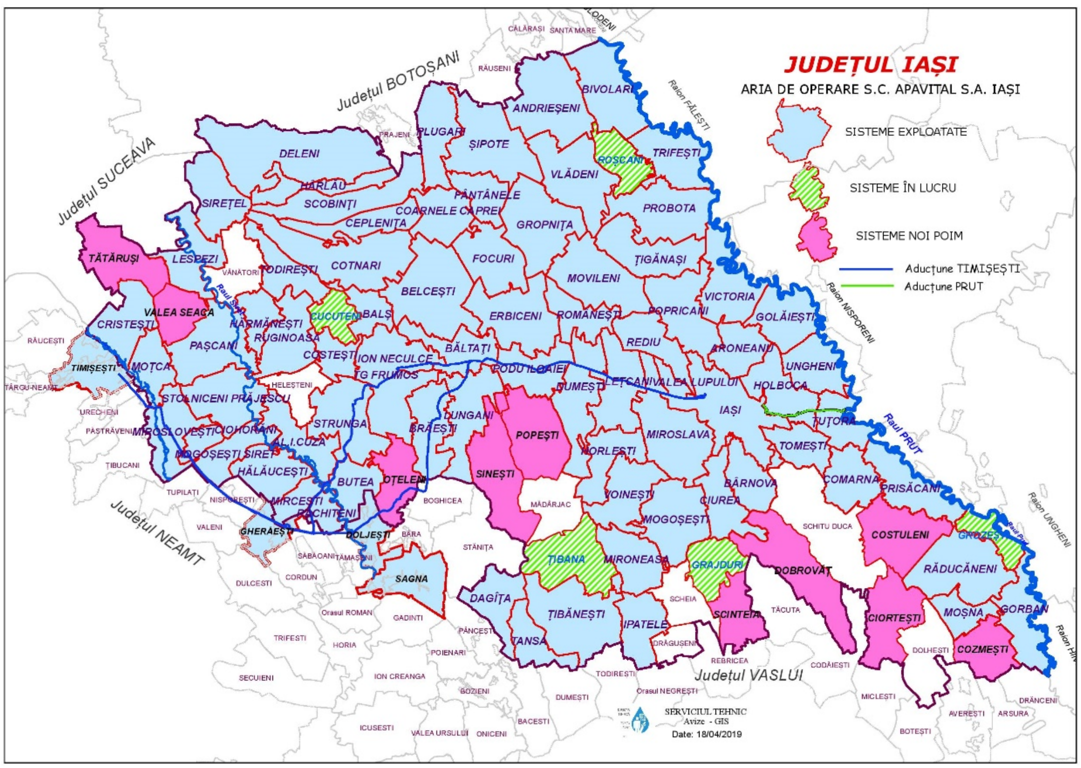


Fig. 5. S.C. Apavital S.A. coverage area and expansion policy (color legend: Blue – operated systems, Green – systems in work, Pink – LIOP Program systems)

Given that each operating area has its particularities, the directions required for the systems streamlining come from data collected on field. Each operational sector is proposing intervention plans for the annual investment program. These are grouped according to the importance of the operation, the necessary implementation time, the cost/benefit ratio and the budget value. S.C. Apavital S.A. is completing investment works from their own funds both in the “in-house” way via the Design Department and its own work teams, and, as well as by outsourcing the design/execution services.

The implementation strategy of the "Regional Project for Development of Water and Wastewater Infrastructure in Iasi County for period 2014-2020" represents a collection of good practices identified in operating process of water supply systems and in implementation of the infrastructure projects developed by S.C. Apavital S.A. both by company's own funds and by non-reimbursable financing. Measures taken by the operator in the design, execution and operation phases guarantee the sustainable development of the water supply systems in operation, having a major impact on the immediate reduction of NRW amounts in existing systems and the capacity to keep these amounts at low values in the newly commissioned systems.

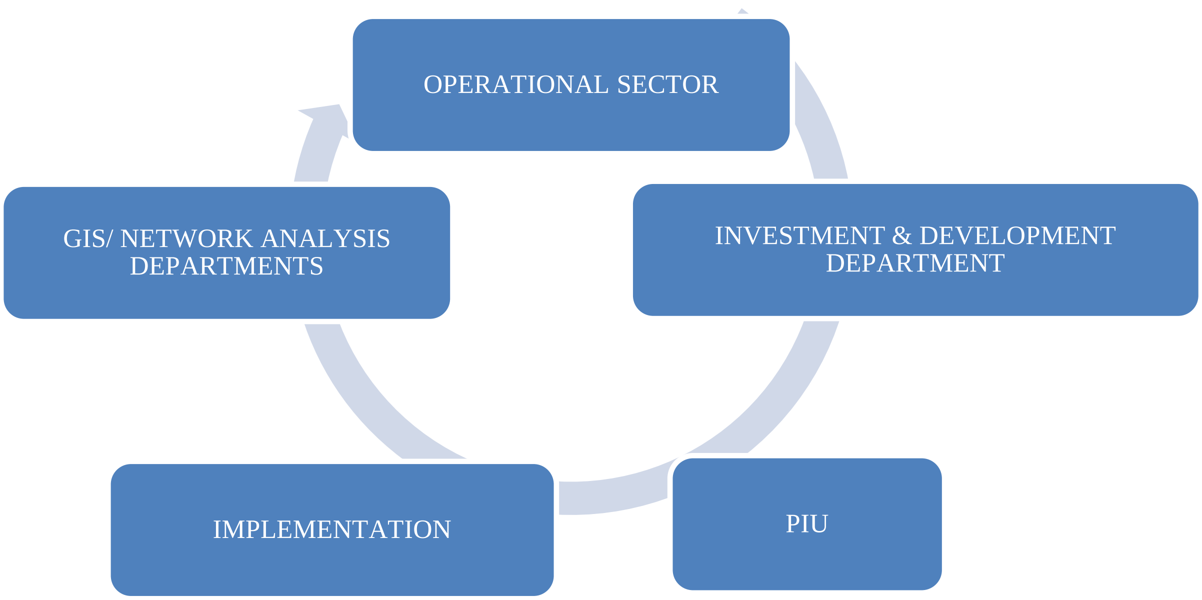


Fig. 6. Workflow summary – water network renewal process

a) The procedure during the design phase

The operational sector defines the system's need and notifies the PIU about the requests for rehabilitation, replacement or extension of network sections in the operating area (Figure 7).

The Project Implementation Unit (PIU), via the personnel in charge with the verification, the correlation of activities with the Master-plan, the Feasibility studies and other investments, establishes the design brief and submits for approval, towards the TEC (Technical-Economic Council), the investment's main indicators.

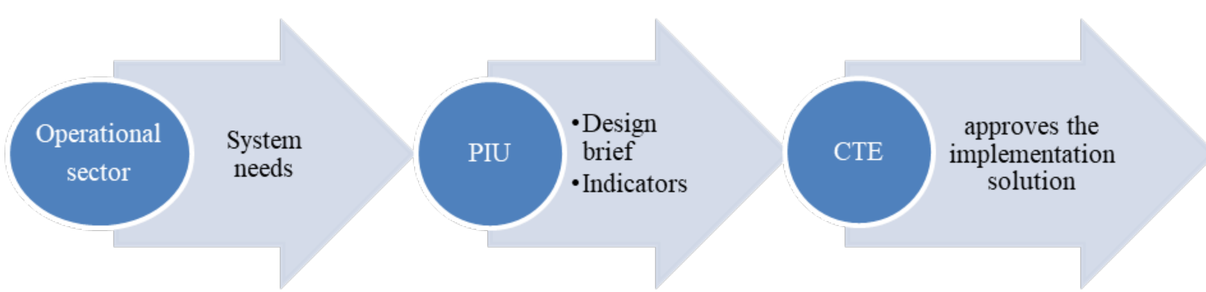


Fig. 7. Workflow summary during design stage

The main guiding lines in choosing the materials and execution technologies are as follows:

- the materials used are HDPE for distribution networks and cast iron for main water pipelines (this decisional step is based on annual statistics related to the occurrence of network failures);
- using pressure class immediately above the class resulting from sizing calculations; this measure is justified by the analysis section execution cost / intervention cost in case of system failures caused by high pressure fluctuations; an increase in costs with approx. 15% was noted when switching from PN6 pipes to PN10 tubes;
- a minimum 32 mm diameter is mandatory for public connections (manufactured by electro welding).; the result is a superior efficiency as regards the reduced number of pipe bursts and pipe leakages, compared to the previous over-use of 25 mm connections, (manufactured by compression joining);
- the use of "C" class water meters (fitted with remote data transfer units) is mandatory;
- the automation of pumping stations and storage tanks and their integration into the central dispatcher control room;
- placement of water leakage collecting manholes and observation manholes at under crossings;
- using pressure limitation equipment and additional network protection measures in case of technical failures in the system.

The design brief is submitted to the General Designer in order to compile the technical documentations. After their completion, the investment is taken over by PIU in order to correlate the design activity with the operation method (choice of materials, network route tracing, creation of DMAs and pressure zones, setting the measurement and control points, implementation of Smart Water Networks concept).

b) The procedure during execution phase

PIU ensures the project implementation through assigned project officers. These officers will supervise the contract physical and financial indicators and will ensure the relationship with the Consultant. No project officer will implement more than two contracts at the same time within the Program.

In addition, the project officers co-opted in the PIU structure will also have a Site Supervisor specialization in relevant areas. By implementing this measure from the SOP Environment program, an additional control measure is introduced as regards the Consultant supervision, which drastically reduces the number of reported defects during the notification period and implicitly the NRW value.

The procedure of on-site verification of As-built documents will be attended by the PIU, the Consultant and the Contractor, and also by the area manager from the Operational Sector that is assigned to take over the works.

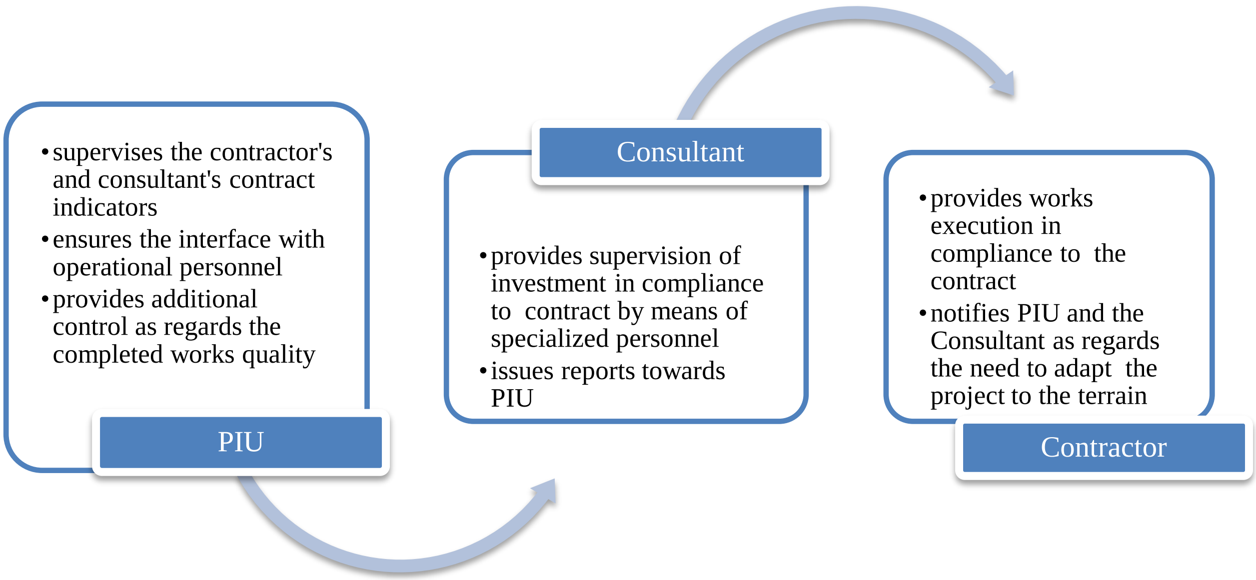


Fig. 8. Workflow summary during execution phase

c) The procedure during the defect notification period

During the defect notification period (1 year), the As-built documentation is submitted to GIS and Network Analysis Departments for digital mapping. After inputting the data in GIS, the Network Analysis Bureau builds the network hydraulic model with MikeUrban Software. In this way, during this period not only the obvious defects will be detected (failures, low pressures), but the model shall also highlight all major gaps between designed parameters and real network parameters.

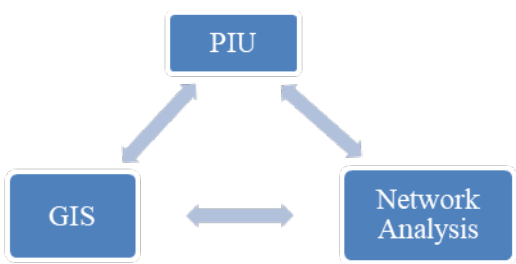


Fig. 9. Workflow summary during defect notification period

The measures listed above are focused on two issues that are crucial in limiting the NRW values in the forecasted period:

- increasing the quality of executed networks;
- gathering data for the first year of operation, which can be used as benchmark data in the annual network evolution analysis.

5. CONCLUSIONS

1. S.C. Apavital S.A. operates water systems that feature various technical specifications and performance indicators, fact which leads to the need to adopt optimization solutions that are to be tailored according to the specific features of each system.

2. The water loss management, in the company, is based on a thorough analysis of each operated water supply system, by identifying the existing deficiencies and defining optimal solutions needed to address risk situations.
3. The case study analyzed in the Targu Frumos operational area demonstrated the necessity to upgrade the water system, fact supported by performance indicators obtained before, during and after the implementation of investments financed under SOP Environment program.
4. During the implementation period the NRW amount decreased from 47.65% to 19.91% and one year after the completion of the upgrading works of the Târgu Frumos water supply system. Thus, out of the total injected water volume of 540,536 m^3, the billed consumption was 78.14% and the NRW amount was 21.86%.
5. The procedures adopted during the three phases are an integral part of the company-wide strategy to reduce the NRW value. Its effectiveness can be observed at local level, through the implementation of CL 11 works contract in Târgu Frumos city, as well as at the level of the entire operating area of S.C. Apavital S.A., by continuing the investment programs financed from own funds and non-reimbursable sources.
6. At each stage in the lifetime of a water supply system, from the conceptual stage to the operation phase, the measures implemented by S.C. Apavital S.A. aim to prevent, limit and control the value of water losses and NRW.

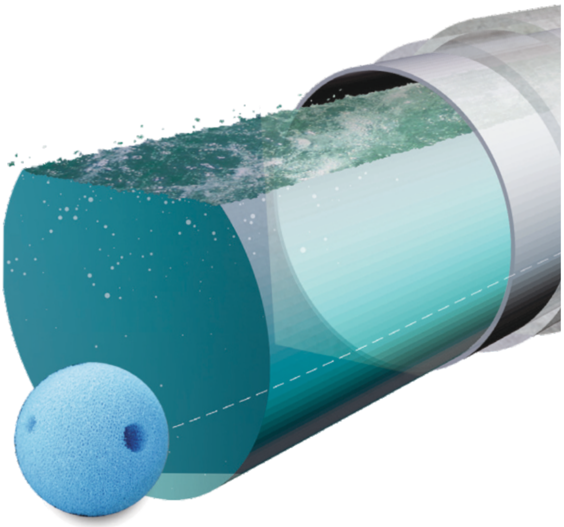
REFERENCES

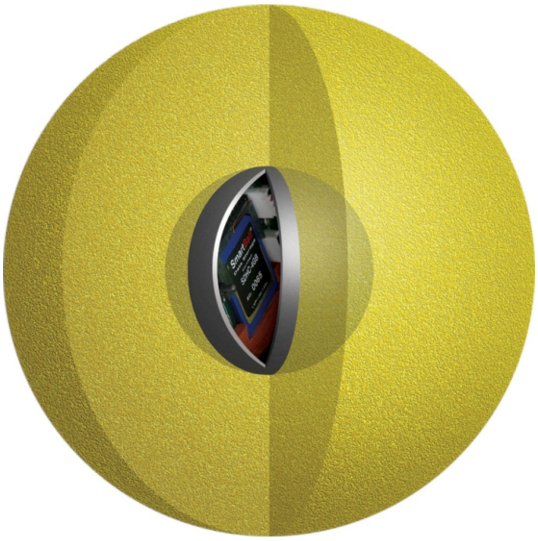
[1] *J. Thornton*, “Water loss control manual”, McGraw Hill Professional, 2002;
[2] *A. O. Lambert*, *W. Hirner*, “Losses from Water Supply Systems: Standard Terminology and Recommended Performance Measures”, International Water Association, 2000;
[3] *I. Kropp*, *R. Herz*, “Bewertung von Leitungsnetzen”, wwt wasserwirtschaft wassertechnik, No. 5, 2005;
[4] *Al. Mănescu*, “Manual pentru controlul pierderilor de apă din sistemele de alimentare cu apă”, Ed. EstFalia, Bucureşti, 2012.

xylem
Let's Solve Water

SmartBall® Technology

A FREE-SWIMMING TOOL FOR LONG DISTANCE WATER AND WASTEWATER INSPECTIONS





How SmartBall works?

The SmartBall® platform is a free-flowing tool for the assessment of pressurized water and wastewater pipelines 8 inches and larger. It can complete long assessments in a single deployment without disruption to regular pipeline service.

The tool is inserted into a live pipeline and travels with the product flow for up to 21 hours while collecting pipeline condition information. It requires only two access points for insertion and extraction, and is tracked throughout the inspection at predetermined fixed locations on the pipeline.

Applications

Owners of water and wastewater pipelines deal with a variety of infrastructure challenges; the SmartBall platform can collect a variety of pipeline condition information in a single deployment that helps owners manage their assets more effectively.

Leak Detection

The tool is equipped with a highly sensitive acoustic sensor that can detect pinhole-sized leaks on pressurized pipelines. The SmartBall platform has been able to identify leaks as small as 0.028 gal/min (0.11 liters) and has a typical location accuracy of within 6 feet (1.8 meters).

Gas Pocket Detection

The acoustic sensor is also able to identify the sound of trapped gas within pressurized mains. The presence of trapped gas can adversely affect pipeline flow or lead to degradation of the pipe wall in sewer force mains.

Inspection Benefits

- Easy to deploy through existing pipeline features
- No disruption to regular pipeline service
- Can complete long inspections in a single deployment
- Highly sensitive acoustic sensor that can locate very small leaks
- Can identify features relevant to the operation and mapping of the pipeline
- Indicates the position of leaks, and gas pockets relative to known points

xylem
Let's Solve Water

Pure Technologies, a Xylem Brand
EN 247, Edifício Jonobras, Sala 3, Piso 2
2670-027- Santo Isidoro, PORTUGAL
Tel +351 261 863 159
www.puretechltd.com

pure TECHNOLOGIES

CHAPTER VII

NON REVENUE WATER MANAGEMENT

Reprezentanţa Seba Dynatronic
Str. Aviator Ştefan Protopopescu nr.1
Bl.C6, et.6, ap.25, sect.1, Bucureşti
Tel. 021 2309138 Fax 021 2039381
Internet: www.sebakmt.com
E-mail: seba.ro@sebakmt.com

Seba Dynatronic®, a member of the **Megger** Group, is a world leader in the production of individual equipment and fully-equipped test vans for locating losses in water distribution networks, cathodic protection pipelines and faults in power or telecommunication cables, with a field experience of over 65 years. The company also manufactures buried pipes and cables locators.

Headquartered in Baunach - Bavaria, the company has subsidiaries on all continents. "The key word of our philosophy is **TRAINING**." Seba Dynatronic® offers its clients every year a number of seminars organized at the seminar centre in Baunach - Germany, or at the beneficiaries' headquarters where more than 30,000 specialists from 120 countries, including Romania, have already participated.

All major water companies in Romania have purchased from our company portable equipment to locate network water losses, which have proven their robustness and efficiency in operation, with more than 75 test vans being delivered at the time.

As far as equipment for the energy sector, up to now, on the Romanian market, our company has put into operation a number of over 200 fully equipped test vans and mobile fault location systems.

It is a great pleasure to introduce our range of tools and equipment produced by our company and used in the field of operation / maintenance of water pipelines, district heating and sewerage:

* Fully equipped test vans - **“ECO” COREMOBIL**
* Flow meters and pressure gauges - **UDM 300-500, TDM 200**
* Pressure monitoring systems- **Seba Flow**
* Pressure and flow loggers - **SebaLog® D3, SebaLog® P-3, P-3mini**
* Leakage monitoring / network correlators - **SebaLog®N3**
* Correlators - **Correlux® C3, Correlux® C300, sebalog CORR**
* Trunk main monitors / Correlators - **Hydro Corr**
* Electroacoustic listening equipment - **Hydrolux HL7000, HL-H$_2$®, HL50BT**
* Pipe and cable locators - **vLocPRO3, Ferrolux®, easyloc**
* Manhole cap locators - **VM 880, FT 80**
* CCTV Systems - **vCam6**

All the instruments offered are extremely robust, easy to use, even in the toughest conditions, allowing you to successfully get out of the toughest situations by quickly performing the necessary tests and measurements. We are confident that SebaKMK offers you the **complete solution** to solve all your problems, and the choice and use of our tools will always make you a winner.

BUDAPEST WATERWORKS EXPERIENCE IN MANAGEMENT OF WATER LOSSES

Evelin Madzin*, László Varga**

*Network Engineer, Network Operations Department, Budapest Waterworks Ltd., Váci út 182, H-1134 Budapest, Hungary (E-mail: Evelin.Madzin@vizmuvek.hu, tel: +36 (30) 229-8467)
**General Manager, Aquacust Water-loss Analysis Co. Ltd., Jobbágy út 37. H-1221 Budapest, Hungary (E-mail: LaszloVarga@vizmuvek.hu, tel: +36 (30) 222-4554)

Abstract

Objective of the presentation and its conclusion:
For supplying more than 2 million people on a 5,380 km long network on various pressure zones, one of the key figures is loss management. Managing water loss in water supply system of Budapest is a complex and determinative task for several department of the company. The problem of losses deserved attention and appropriate actions to have reduced avoidable stress on our valuable water resources.
We have applied well known and less known solutions and instruments, and we have developed and implemented several new solutions (technical, economic, service and administrative), in order to manage losses.
For assessing water losses, the standard terminology of the water balance according to the IWA is used by Budapest Waterworks. To reduce the value of NRW, we also deal with commercial losses parallel with the physical losses.
In our presentation we'll introduce our Active Leakage Control activities, especially District Metered Areas, furthermore will be presented the Pressure Management activities of Budapest Waterworks.

Active Leakage Control Activity
The Fig. 1. shows the Active Leakage Control (ALC) Activity of Budapest Waterworks.
During the leak detection process the first step is to monitor the network with minimum night-flow measuring and/or with DMA-s. Thus, the place of the leakage can be determined in advance. The second step is to pre-locate. Thereby the faulty line section will be highlighted. And finally the third and the last step is to pinpoint the location of the fault.

Fig. 1. Leak detection methods of Budapest Waterworks

District Metered Areas
In present there are 47 districts due to 154 metering points in Budapest Waterworks water supply system.
Measuring the water flowing into and out of the DMA, we get knowledge of how much is the district's minimum night flow. Based on the value of minimum night flow we can conclusion from size of the leakages.
The Diagram 1 shows an example of this method. This Diagram shows the daily and night average water

consumptions of district no. 14/1 among the given period. It can be seen that, the value of water consumptions started to increase. As a conclusion of the fact that the night consumption curve has also grown, it can be said that hidden leakage is the cause of this change. After the data analysis, the ALC team examined the area. During the examination a hidden leakage was detected in the pipeline. After the repair works the values decreased in the same level as the initial values as can be seen on the chart.

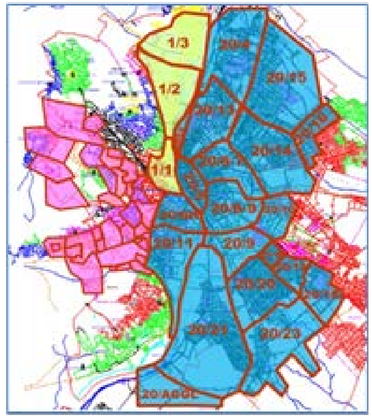


Fig. 2. District metered areas at Budapest Waterworks

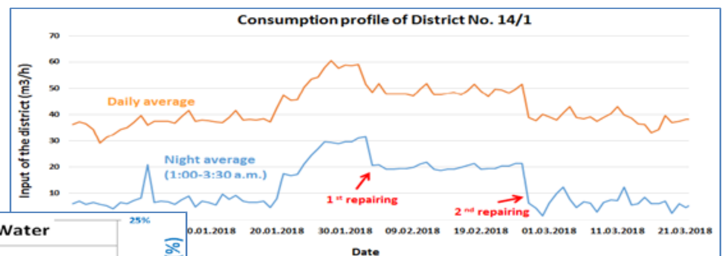


Diagram 1 - Consumption profile of District No. 14/1

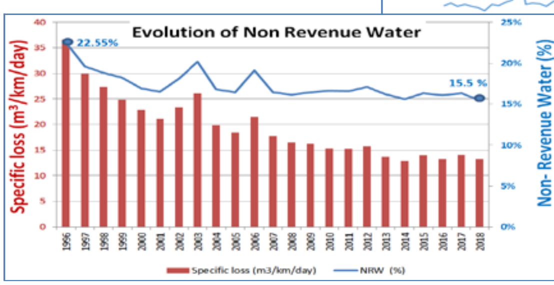


Diagram – Evolution of NRW at Budapest Waterworks

The rate of NRW has significantly decreased in the past years. This is illustrated in the following diagram. The value of NRW was 15,5 % in

CONCLUSIONS

The NRW consist of many components, so reduction of NRW is a complex task. Therefore there are many ways to decrease NRW. Budapest Waterworks has collected long-term experience concerning reduction of water losses. It means, that it is a not a plug & play method that can be applied to all kinds of circumstances. Thorough engineering, preparation, planning, and realization are needed to reach the most economical solution that can be executed in the given conditions.

Our strategies have driven to optimum efficiency achieved, decreased source extraction, optimised system operation and energy usage. After 25 years of hard work on the topic, Waterworks of Budapest collected wide scale of experience concerning the reduction of water losses.

The actions made to push the leakage level lower and lower will be in the focus of this presentation.

Keywords

Non-Revenue Water, Active Leakage Control activity, District Metered Areas.

CONSIDERATIONS ON WATER LOSSES FROM STORAGE TANKS

Stefania Chirica*, Mihail Luca**, Ilie Logigan*** and Alexandru Lucian Luca****

* Stud. Ph.D. Eng. Doctoral School, Faculty of Hydrotechnics, Geodesy and Environmental Engineering, Technical University “Gheorghe Asachi” of Iasi, 67 D. Mangeron str., Iasi, Romania
(E-mail: stefania.chirica@gmail.com)
** Prof. Ph.D. Eng., Dept. of Hydroamelioration and Environ. Prot., Technical University “Gheorghe Asachi” of Iasi, Romania
(E-mail: mluca2015@yahoo.com)
*** Lecturer Ph.D. Eng., Dept. of Hydroamelioration and Environ. Prot., Technical University “Gheorghe Asachi” of Iasi, Romania
(E-mail: ilie.logigan@yahoo.com)
**** Ph.D. Eng., Polias-Instal Company, 5A, Basarabi str. Iaşi, Romania
(E-mail: lucian.luca2015@gmail.com)

Abstract
Water storage tanks leak water due to constructive structure and hydraulic system degradation. The greatest water loss values are recorded for storage tanks made of stone / brick masonry and for reinforced concrete tanks. The storage tank constructions record leakage through the floor, tank and valve chamber walls, around the pipe wall pass through system etc. The water losses result from the micro-cracks and cracks in the tank walls and floor. Also, significant water losses are recorded around the pipe wall pass through system between the tank and the valve chamber. High value leakage is present around fitting joints and fixtures in the hydraulic installation. The studies and researches conducted have highlighted that the action of natural and anthropic factors present in the storage tank location have led to water loss. The research highlighted that background and visible water loss recorded for a reinforced concrete storage tank can reach up to 22-28% of the accumulated daily volume. Over the last period of time, anthropic actions have led to the increase of water losses from tanks with high service life.

Keywords
Cracks, filtration, flows, hydraulic system, tank, valve house.

1. INTRODUCTION

Storage tanks are an important objective in the water supply system structure. The first materials used to build storage tanks were stone and brick. Modern storage tanks are made of reinforced concrete, steel, composite plastics etc. Storage tanks with large potable water volumes are made of reinforced concrete and prestressed concrete [1]. Their volume varies from 100 …500 m^3 up to 2000…10,000 m^3. The water storage tank is equipped with hydraulic, electrical, ventilation, monitoring and automation systems etc. Over time, static and dynamic actions on site determine the storage tank supporting structure degradation. Hydrodynamic actions have an impact on the hydraulic system integrity. The storage tank construction and hydraulic system is degraded by the corrosive action of water loaded with chemical agents (the case of mixing storage tanks). The presence of chemicals in water (mainly chlorine) intensifies the corrosion phenomena of concrete and metal elements. Their structural and functional degradation requires the implementation of rehabilitation and modernization works [2].

The rapid development of technique in the hydraulic systems fields leads to premature aging phenomenon in some storage tank circuit components. The water presence in areas considered dry (eg: the valve chamber) causes a rapid degradation of the metallic components within the installations. The lack of maintenance works quickly contributes to the degradation of the storage tank structural components. The storage tanks rehabilitation is also required by the change of the design and operation standards in the water supply field [2], [3].

The aim of the paper is to analyze how water losses occur in the constructive structure of storage tanks made of reinforced and prestressed concrete.

2. ANALYSIS ELEMENTS ON THE INITIATION AND EVOLUTION OF WATER LOSSES

A water storage tank is made of two main building structures: a - the tank; b - the valve chamber. The storage tank can be built in relation to the ground elevation with an underground, partially buried, above ground and elevated position (Figure 1). The tank has a circular or rectangular shape. It has a water storage and water quality conservation role. The tank is made of the following components: foundation (annular foundation, continuous foundations), foundation frame, elevation, cover plate. Elevation consists of cast-in-place walls or precast elements assembled on the foundation. Water storage tanks can be made in the following alternatives: a – cast in place reinforced concrete; b - prestressed cast in place concrete; c - prestressed concrete elements [4]. Storage tanks for large water volumes use the circular shape and the elevation is made of prestressed reinforced concrete [5].

The second component consists of the valve chamber, which has the function of protecting and managing part of the storage tank hydraulic system. In certain situations, the valve chamber may also include hydro-mechanical equipment for water pumping. The valve chamber is made of brickwork or reinforced concrete. Between the tank and valve chamber there is a shared wall through which the hydraulic system components are passing [6].

a b

Fig. 1. Water storage tanks: a – above ground; b – underground [2]

The storage tank is equipped with a hydraulic system made of pipes, joint fittings, derivation and flow control fixtures etc. The hydraulic system differs in structure according to the role of the tank (storage, fire, mix etc.). The storage tank supply and water discharge is made through the valve chamber. The following pipes pass through the shared storage tank - valve chamber wall: supply, overflow, drain, distribution, fire etc.

Ensuring impermeability is a main condition in storage tank operation [6]. Waterproofing is achieved through a compact concrete and by using a special plaster on the inside. Water losses are the effect of natural and anthropic actions on the storage tank in various time periods. The natural actions on the storage tank are determined by the initial site conditions and those induced in time by a series of climatic, geotechnical, hydro-geological etc. changes. A load group consisting of own weight, water pressure, groundwater sub pressure, weight and earth load, seismic action, temperature variation etc. act on a storage tank. [5] During the operation period, a series of new or more intense actions can be induced, which influence the water losses.

The initiation and evolution of water losses in storage tanks are based on a chain of action generated by the following situations, respectively working stages [2]:

a – the design studies quality and elaboration process; the professional quality of the study specialists drawing up the studies;

b - the quality and the manner of drawing up the technical documentation of the storage tank at the design phases (feasibility study, technical project, execution details, documentation for building permission etc.); the professional quality of the design team for the specialties required by the technical documentation;

c – the quality of the materials used, the execution technologies and the way of turning to advantage the site conditions for the storage tank execution; the professional quality of the storage tank components contractors;

d – the management quality during storage tank operation for normal lifetime period; the professional quality of the technical personnel involved in the operation.

Water losses can be generated in each working phase through the construction process. During the storage tank operation phase there are also a number of anthropic factors. They depend very much on the professional quality of the operating staff.

Research has highlighted the areas and the water loss emergence process for a reinforced concrete storage tank. Water losses are of concentrated and diffuse type according to the evolution process, visible and invisible by the way of highlighting. The water losses are influenced by the position of the storage tank construction towards the ground: underground, partially buried and above ground [2], [7].

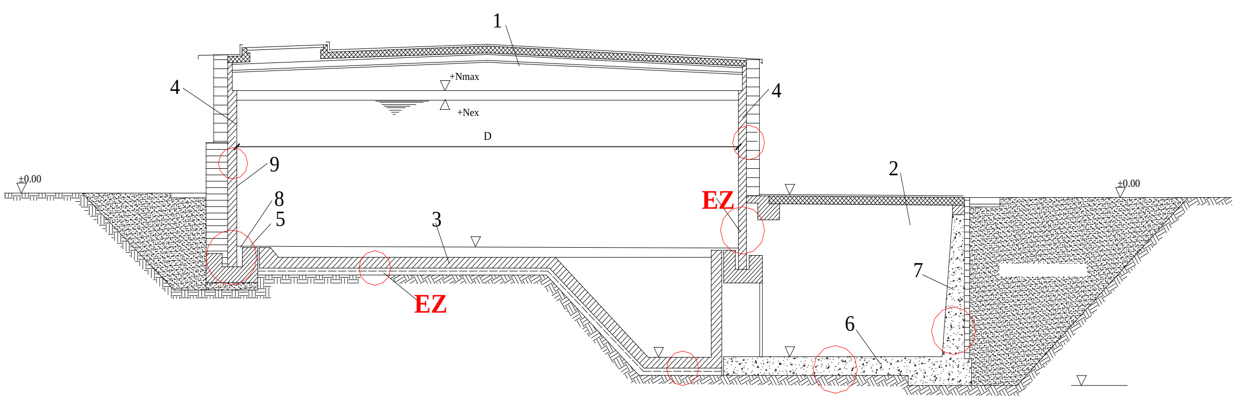


Fig. 2. Identification of water loss areas in the structure of a reinforced concrete storage tank: 1 – tank; 2 – valve chamber; 3 - tank foundation frame; 4 – tank wall; 5 – annular foundation; 6 – valve chamber foundation frame; 7 – valve chamber wall; 8 – sealing joint; 9 – waterproofing plaster; EZ – water emission zone [2]

Water losses through the storage tank structure emerge through the following areas (Figure 2) [8], [2]:

- the area formed by the joint between the foundation frame and the annular foundation; leakages are registered on the tank perimeter and the water infiltrates into the ground;
- areas on the tank foundation frame where micro-cracks and cracks appear in the reinforced concrete structure; the joint and foundation frame area always work under maximum and approximately constant hydraulic load;

- the tank wall area, where water emission zones result due to the degradation of the waterproofing plaster and the formation of cracks in the wall;
- the area formed by the wall separating the valve chamber, in which the pipe wall pass through elements of the tank hydraulic system are located; this is the most favorable area for the formation of water losses; water losses in this case are visible and of diffuse (through cracks) and concentrated (sealing of pipe wall pass through elements) type.

The valve chamber is a dry area in order not to damage the components of the hydraulic installation and the contact with the electrical system. The valve chamber is continuously under a maximum hydraulic load through the presence of the hydraulic system. However, in many storage tanks, the valve chamber has become a water loss producing area. The valve chamber constructive structure does not have a waterproofing plaster, and the walls do not have a composition meant to withstand water filtration over time. The water losses produced by the construction of the valve chamber take place through the following areas (Figure 2) [5], [2]:

- contact area between foundation frame and elevation, where leakage occur on chamber perimeter and water infiltrates the foundation ground; water losses are diffuse and concentrated;
- the perimeter wall area, where water losses occur through micro-cracks, cracks and even crevices; water infiltrates into the foundation ground; leakages are diffuse and concentrated;
- the area of the perimeter wall where the pipe wall pass through systems are located towards / from the storage tank, where the water losses result from the failure of the sealing system; leakages are diffused and concentrated.

Water losses emerge from the components of the hydraulic system located in the valve chamber and the storage tank chambers. Water losses are recorded through the joint fittings (flanges in particular), valves, pressure vents etc.

Water losses from storage tanks are determined by control and inspection procedures during the operation process [9]. In the case of obvious and high value water losses, a technical expertise is conducted which suggests rehabilitation works to limit and eliminate the phenomenon. Storage tanks water losses can be reduced through optimal operation process, which includes a concrete construction and hydraulic installation control program (Figure 3). Water loss control in storage tanks requires disconnection of water supply to consumers, a situation affecting the water supply system operation and the relationship between the water company and the consumer.

The methods for visualizing and detecting water losses are as follows [9], [7]:

- measuring the level decrease within a determined time interval; the storage tank must be completely sealed, filled with water and the measuring program in use;
- use of marking tracers in storage tank water with visualizations and measurements in observation drills;
- tank and valve chamber visual inspection on empty water storage tanks for a limited time (technical expertise case) or when the storage tank is decommissioned;
- tank walls and foundations uncovering to visualize emission zones (technical expertise);
- water filled storage tanks visual inspection using divers to verify emission areas;
- injecting compressed air into the hydraulic system components, at a low water height, for the purpose of viewing the emission zones.

The water loss methods for visualization and detection are used depending on the constructive and functional characteristics of the storage tank.

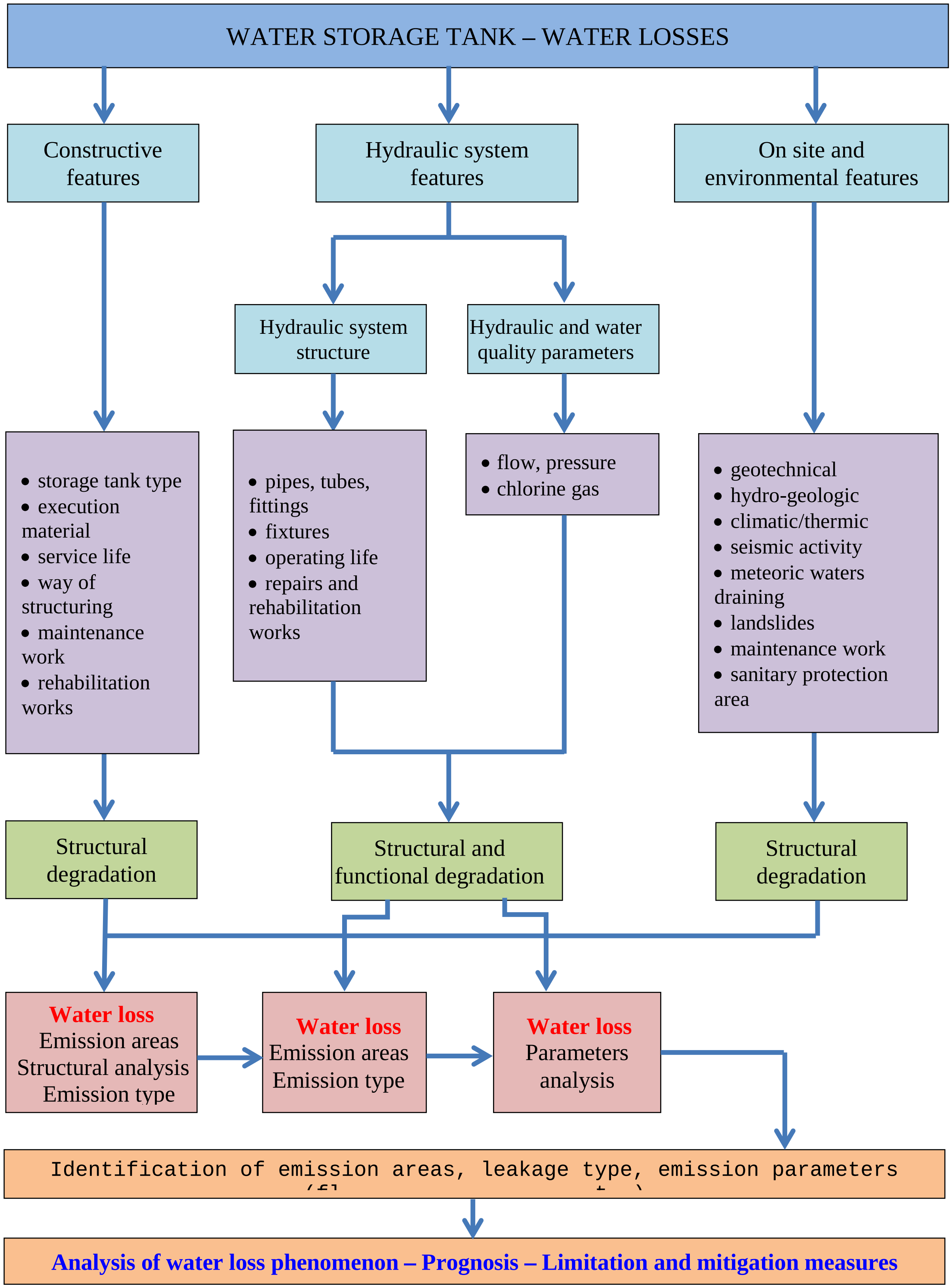


Fig. 3. Storage tanks water loss assessment plan [7]

3. CASE STUDIES. DISCUSSIONS AND RESULTS OBTAINED

***Case study I** - Water losses through the constructive structure of a reinforced concrete and prestressed concrete storage tank*. The research was carried out on the structure and functional installations of a storage tank with the volume of 10,000 m^3 [10]. The storage tank has an above ground position. The structural components of the storage tank are made of reinforced concrete and prestressed concrete elements (Figure 4). The drinking water storage tank draft, V = 10,000 m^3, was carried out according to 5376/17 I.P.C.T type project. The storage tank is located in the climatic zone II and is not equipped with external thermal insulation. The storage tank is placed in a layer of gravel with rocks and sand, brown, damp, thick. The underground water is at a depth of 2.60 m from the ground level. This situation influences the rapid discharge of storage tank leakages.

a **b**

Fig. 4. General view of the V = 10,000 m^3 storage tank: a - general view of the shared tank; b – view of the valve chamber [10]

From a structural point of view, according to the design documentation, the analyzed storage tank consists of the following subassemblies (details in [10]):

1. The elastic foundation plate is 12 cm thick and made of concrete with P8 degree of waterproofing. The foundation plate is separated by a compression joint both from the wall annular foundation and the central pillar.

2. The tank wall annular foundation is made of reinforced concrete and laid on a leveling concrete layer. After prestressing the component elements ribs, the joints between the cylindrical wall and the mortar annular foundation were cast in place on the outside and inside of the tank.

3. The tank wall was made of double-curved precast elements with a nominal width of 3.00 m (47 identical elements). After prestressing the upper tank, the joints between the wall precast elements were poured in place using M 100 mortar both on the exterior and inside of the tank.

4. The central (interior) bearing of the tank was made of eight pillars arranged in a circle, consisting of cast in place reinforced concrete. At the top, the inner pillars allow a precast reinforced concrete cap to rest upon.

5. The storage tank roof is of planar type, made of "T" type prestressed concrete elements with post-tensed rectilinear beams, having a variable width plate.

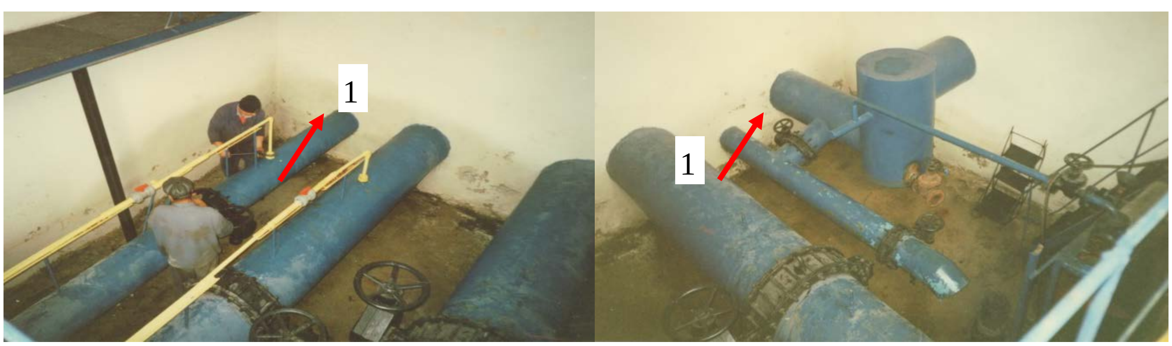
The field inspection was carried out in two stages: **a** - normal storage tank and pumping station operating conditions; **b** - empty storage tank for internal inspection and analysis of the foundation frame, joint, cylindrical wall intrados and roof structural condition. The field analysis revealed the presence of water losses through the wall, the wall - foundation frame joint and foundation frame. The storage tank inspection results have been in line with the initial data submitted by the beneficiary and which required conducting the technical expertise [10].

The water losses were emerging from a series of prestressed tank structure elements, being determined by the micro-cracks in the reinforced concrete layer (Figure 5.a); the salt layer presence in the water emission zone confirms the existence of the wall infiltration process (Figure 5.b). Major water losses occur through the cast in place prestressed elements joint, mainly at the bottom, where the hydraulic load is maximum (Figure 5.c). The presence of water in the valve chamber at a level superior to the hydraulic system pipes confirms the water infiltration from the tank into the valve chamber (Figure 6).

a b c

Fig. 5. Water emission areas through the 10,000 m^3 tank elevation: a - emission through the precast plate; b - plate vertical extended emission area; c - emission through the joint between plates: 1 - emission point [10]

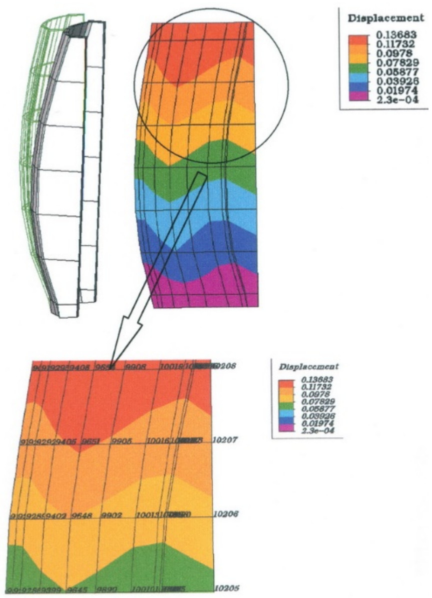
The presence of a gravel layer with sand and rocks on site influenced the collection and rapid discharge of water lost from the storage tank. A stream which drains the groundwater is located near the storage tank. The observation drills made after conducting the technical expertise confirmed the loss of water through the foundation frame and the joint between the annular foundation and foundation frame.

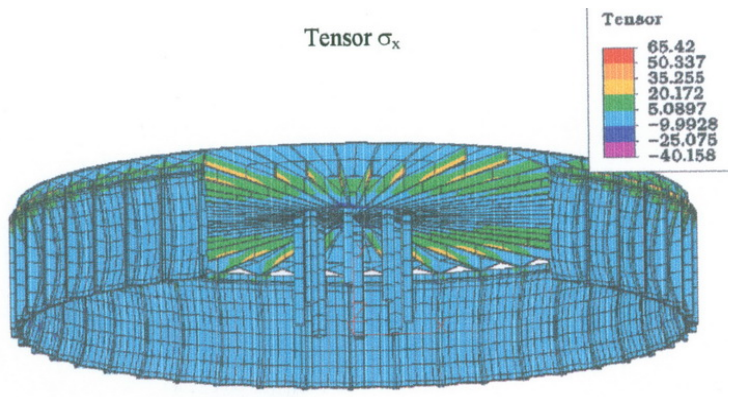


a b

Fig. 6. Water losses through the shared tank - valve chamber wall for the 10,000 m^3 storage tank with highlighting of the infiltration zones in the valve chamber: a – valve chamber left view; b – valve chamber right view: 1 – valve chamber water level [10]

The structural analysis used the finite elements computation method, which allows the complex geometry description both of the structural components (double curved elements and rigid ribs) as well as of the "cylindrical wall" shape structure coupled with the inner reticular system through the precast roof. The structural analysis focused on the behavior of the precast wall elements as well as the overall tank structure. The analysis outcomes are represented by stress fields and displacement under the action of forces resulted from site and operation processes (Figure 7). A special analysis was conducted on the tank wall behavior for temperature variation from the inside (the wall in contact with water temperature) and from the outside (the wall in contact with the air temperature) (Figure 8).





b

a

Fig. 7. Results on tank structural analysis: a - displacements in the precast reinforced concrete element; b – stress field σ_x [8], [10]

The numerical simulation results indicate the appearance of vertical cracks in the curvature area of the precast wall elements (double curved elements and rigid ribs) (Figure 7.a). Wall defects through which water losses occur are determined by a number of negative aspects of the execution process, but also by the poor quality of some materials used [10]. The simulation conducted by imposing boundary conditions in the finite element model highlighted and confirmed the situations that occurred in operation. It should be noted that the building solution adopted at that time was a technical novelty, and the results of the technical expertise and simulations conducted contributed to the improvement of the computation method and execution technology.

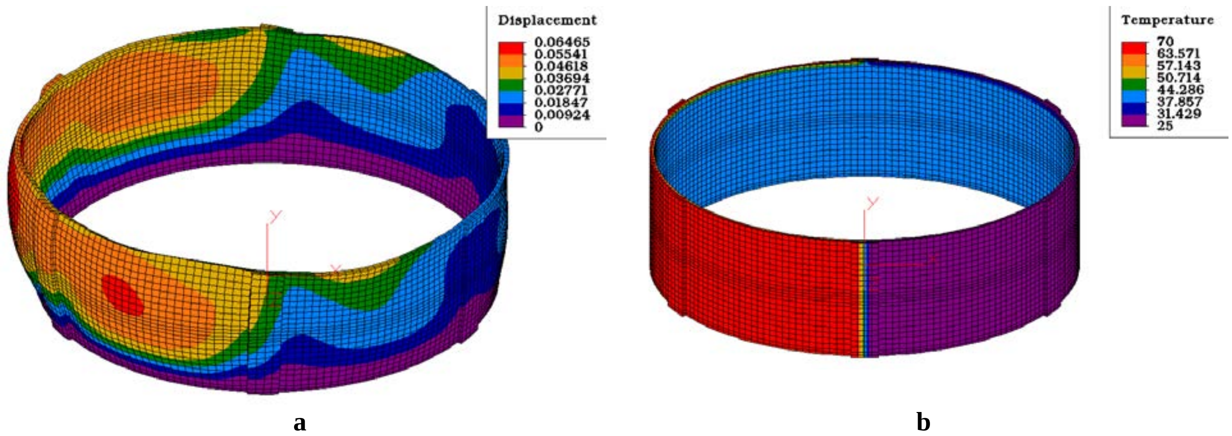


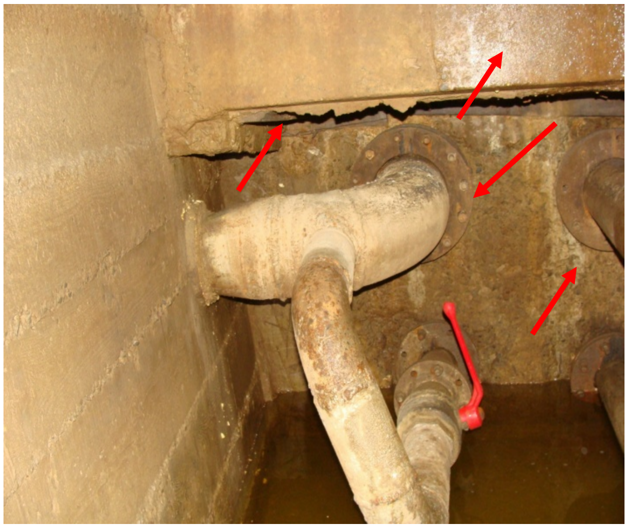
Fig. 8. Results on the tank structural analysis for the tank walls thermal action: a - displacements field; b - temperature distribution on the tank wall [8], [10]

The research conducted [10], [2] highlighted the areas where the most significant water losses occur: foundation frame, elevation (double curved elements and rigid ribs), valve chamber (Figure 5 and 7). The authors show that the leakages through cracks in the 10,000 m^3 volume storage tank foundation frame reach up to 40% of the water stored when no rehabilitation works are conducted.

Case study II - *Water losses determined by storage tanks execution technology and materials*. The research was carried out on the structure and hydraulic systems of a 200 m^3 volume storage tank [11]. The storage tank has a partially buried position. The tank and valve chamber were made of reinforced concrete (Figure 9.a). After about 14 years of operation, the storage tank shows water leaks from the tank and valve chamber [12]. The water tank structural state required a technical expertise to be conducted [5], [11]. The tank water losses are caused by deficiencies in the storage tank construction, together with the site environment actions. Water losses emerge through micro-cracks in the tank wall (the waterproofing plaster is partially degraded), through the foundation frame - elevation joint (the sealing mortar no longer insures the sealing function), through cracks and crevices in the shared tank - valve chamber wall - 9.b) [11].

Fig. 9. Tank with partially buried position made of cast in place reinforced concrete: a - general view, 1-tank, 2-valve chamber; b - degradation of foundation frame and elevation sealing, 1-foundation frame, 2-wall, 3-degraded sealing [11]

The structural degradation of the shared tank – valve chamber wall allowed the occurrence of an infiltration current in the pipe wall pass through area (Figure 10.a) and through cracks in the reinforced concrete wall structure (Figure 10.b). Infiltrated water flooded the valve chamber and damaged the hydraulic system by corrosion (Figure 11). Water accumulated in the valve chamber (Figure 11) is discharged on site through the foundation frame and wall cracks [11].

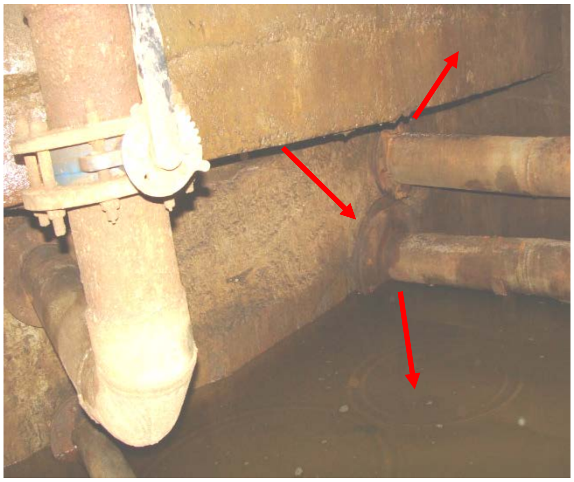


a

b

Fig. 10. Shared tank - valve chamber wall water losses identification for a full storage tank: a - general view of the pipe wall pass through; b - details on the water emission areas [11]

The research has highlighted a series of deficiencies in the storage tank execution, in particular of the reinforced cast in place concrete tank. The relatively rapid degradation of some structural components confirms the poor quality of some materials used in execution. The tank water losses are also due to the inefficient use of concreting and waterproofing technologies of the reinforced concrete tank [11].



a

b

Fig. 11. Functional state of the full water storage tank valve chamber: a - details of the water losses in the pipe wall pass through; b - details on the presence of water on the premises [11]

Water losses through the valve chamber hydraulic system are caused by degradations and damage to the components that supply and discharge stored water. The studies and researches carried out revealed the following groups of leakages [7], [2], [14]:

A - Leakages due to degradation of the tank hydraulic system components: valves (sealing wear), float valves (closure system wear and blocking). Blocking the float valves results in significant water loss, which is immediately discharged through the overflow pipe and cannot be viewed and controlled.

B - Leakages due to storage tank valve chamber hydraulic system components degradation: valves (sealing wear, blocking of the drive system), flange connection of the pipes (sealing and assemblage system wear), steel pipes corrosion. Water losses are visible and can be viewed.

C - Leakages resulting from the hydraulic system degradation due to lack of maintenance and rehabilitation works over time.

The research has revealed a series of deficiencies in the storage tanks execution, in particular for the reinforced cast in place concrete tank. The relatively rapid degradation of some structural components confirms the poor quality of materials used during execution.

4. CURRENT PROBLEMS REGARDING STORAGE TANKS REHABILITATION

Storage tanks currently in service in Romania's water supply systems have variable ages. Many storage tanks are in operation for about 30 ... 50 years. After the 90s, a large number of storage tanks with volumes of 100 ... 300 m^3 were executed in the water supply systems of rural localities. By reducing industrial activities, a number of water storage tanks have become available. They have a modified hydraulic system according to the function they serve (fire water, process water, drinking water etc.). The storage tanks hydraulic system was customized on diameters and materials according to the required function.

The rehabilitation of the constructive structure and hydraulic system to a tank in operation or conservation requires conducting a technical expertise. The technical expertise paper directs the storage tank rehabilitation and modernization project. The technical expertise analyses the structural and functional state of the storage tank in the following cases:

- after an operation period exceeding the normalized service life;
- after the supporting structure degradation caused by accidental actions on site or resulting from the operational process;
- after the hydraulic systems degradation due to accidental actions during the operational process;
- when the storage tank function changes in time;
- the rehabilitation of the storage tank constructive and functional elements;
- when design and operation parameters change over time etc.

The determination of the storage tank structural condition and future behavior is achieved through simulation programs. The group forces according to operational assumptions are considered the storage tank running scenarios. Some analysis scenarios consider accidental actions caused by on site environment (uneven foundation settlements, earthquakes, element displacements, high temperature variations etc.). The simulation program is solved by numerical and special methods (finite element method) [5].

The change of storage tank function within the water supply system requires the investigation of hydraulic systems for the new operating conditions. This situation requires changes in the hydraulic system structure regarding the technical plan, geometric parameters, hydraulic parameters etc. The hydraulic system is degraded in time by the stored water quality which contains excess chemicals (for example, the mixing tanks for chlorine gas disinfection). Preserving water quality in storage tanks is an operation condition [15], [16].

Static and dynamic actions on site and operation process parameters contribute to the storage tank's supporting structure degradation. Structural degradation occurs in the tank assembly: foundation, foundation frame, wall, roof plate and thermal protection system. The degradation of the supporting structure causes cracks in the wall and foundation frame [8]. The cracks enable the phenomena of infiltration and seepage of water from the storage tank, respectively from the outside. Water losses influence the foundation ground stability and, implicitly, of the storage tank. Significant degradation are registered over time in the hydraulic supply, derivation and storage tank protection system, which causes uncontrolled water losses. All these require the implementation of some storage tank rehabilitation and modernization works on the structural components assembly.

5. CONCLUSIONS

1. In the operation period, the structural and functional assembly of a storage tank is subjected to actions determined by the environment and operational process, which lead to degradation of the construction and result in water losses through the constructive elements.

2. The research has highlighted storage tank areas with a high degree of degradation over time, areas that become sources of water emission from the tank / valve chamber: the joint between the annular foundation and foundation frame of the tank, the shared tank - valve chamber wall, the tank waterproofing plaster etc.

3. The research highlighted a number of storage tank hydraulic system components which can become a source of water loss (valves, flanges joints, welding areas etc.) and can influence the storage tank stability on site.

4. The research has highlighted a high risk area of water loss that is the pipe wall pass through the shared tank - valve chamber wall, where both natural and anthropic actions allow the formation and maintenance of an important filtration current.

6. ACKNOWLEDGEMENTS

This paper was realized with the support of S.C. APAVITAL S.A. IASI in programs of research, technical expertise and technical projects.

REFERENCES

[1] *Mănescu Al., Sandu M., Ianculescu O.*, 1994, Alimentări cu apă, Edit. Didactică şi Pedagogică, Bucureşti;
[2] *Luca M.*, Reabilitarea şi modernizarea sistemelor hidroedilitare, Note de curs, Universitatea Tehnică „Gh. Asachi", Iaşi, 2017;
[3] *Mănescu A.*, [2002], *A general strategy to control water losses from water supply system is a necessity,* "Ovidius" University Anals, Constanța, year III-IV, Special Proceedings, Series-Constructions, p. 647…650, ISSN 12223-7221;
[4] Pestişanu C., *Construcţii*, Edit. Didactică şi Pedagogică, Bucureşti;
[5] *Hobjilă V., Luca M.*, 2000, Complemente privind proiectarea şi expertizarea unor tipuri de construcţii hidrotehnice, Editura Cermi, Iaşi;
[6] Pâslăraşu I., Teodorescu M., Rotaru C. - *Alimentări cu apă*. Editura Tehnică, Bucureşti, 1981;
[7] *Ştefania Chirica*, "Contribuţii la cercetarea fenomenului „pierderi de apă" din reţelele hidroedilitare (Research contributions on the "water loss" phenomenon in water utilities networks)". Proiect de cercetare ştiinţifică. Şcoala doctorală a Universităţii Tehnice "Gheorghe Asachi" din Iaşi, 2017;

[8] *Hobjilă V., Luca M., Mitroi A*., Rezervor circular din beton precomprimat cu fascicule postîntinse segmentate, vol. I, Elemente de calcul hidraulic şi static, Editura CERMI, Iaşi, 1999;
[9]*** Manualul naţional al operatorilor de apă şi canal, 2008;
[10] *Hobjilă V., Luca M*., Expertiză tehnică privind “Starea actuală a rezervorului de 10 000 m^3 de la S. P. Mărgineni, RAGC Bacău, judeţul Bacău şi posibilitatea reabilitării funcţionale”, S.C. POLIASCAS S.A. Iaşi, 2000;
[11] *Luca M*., Expertiză tehnică pentru rezervor 200 m^3 Satu Nou şi rezervor 500 m^3 la staţia de tratare Belceşti, jud. Iaşi. S.C. POLIAS-INSTAL S.R.L. Iaşi, 2013;
[12] *S.C. APAVITAL S.A*., “Raport tehnic 2016”, 2017;
[13] *** NP 036 Normativ de reabilitare a lucrărilor hidroedilitare din localităţile urbane, MLPAT, Bucureşti, 1999;
[14] STAS 4165/83. *Alimentări cu apă. Rezervoare din beton armat şi beton precomprimat. Prescripţii generale;*
[15] *M. Luca, Ştefania Chirica*, “Considerations regarding water loss from distribution network analysis” Bulletin of the Polytechnic Institute from Iaşi, Published by Technical University "Gheorghe Asachi" from Iasi, Tome 63 (67), No. 1-2, 2017, Section Hidrotehnica, Edit. Politehnium, p. 55-64 ISSN 1224-3892, 2017;
[16] *** NP 133/1-2013 Normativ privind proiectarea, execuţia şi exploatarea sistemelor de alimentare cu apă şi canalizare a localităţilor, Vol. 1, Ministerul Dezvoltării Regionale şi Administraţiei Publice, Edit. Matrix Rom, Bucureşti, 2013;
[17] *Hunter P.R., et. al, Water Supply and Health,* PLOS Medicine, Vol. 7, 2010.
.

WATERLOSS REDUCTION IN S.C. C.U.P. DUNAREA BRAILA S.A.

Stere Jiru*

*SC C.U.P. DUNAREA BRAILA SA (sjiru@apabraila.ro)

Abstract

In the municipality of Braila there are about 850 blocks with 55,000 apartments having a height regime of GF + 4 and GF + 10.

The main activities for reducing commercial and real losses are:

1. District of the water supply system of Braila Municipality;
2. Monitoring of the hydropower stations in Braila Municipality;
3. Mounting the radiometers to the consumers from Braila Municipality;
4. Tracking and managing the consumption recorded by the radiometers.

Activities for reducing water losses within SC DUNAREA Braila SA Public Utilities Company:

In 2015, at the company level, the “Waterloos reduction strategy for the period 2016-2020” was established.

All these works are included in the "Investments and endowments program for the period 2018 -2021 financed by the operator SC Dunarea Braila SA from the Development Fund - IID".

Given that in Braila the quantity of water distributed represents about 70% of the quantity of water distributed at the company level, we will present below the main activities that are implemented on the water networks in the Municipality.

Keywords

DMA, radiometers, consumption monitoring, reducing commercial and real losses.

1. DISTRICT OF THE WATER SUPPLY SYSTEM OF BRAILA MUNICIPALITY

In order to establish the quantity of water that supplies the consumers of Braila Municipality, due to the fact that the neighboring localities are supplied directly from the network, the following monitoring areas (DMAs) have been realized, according to the figure below.

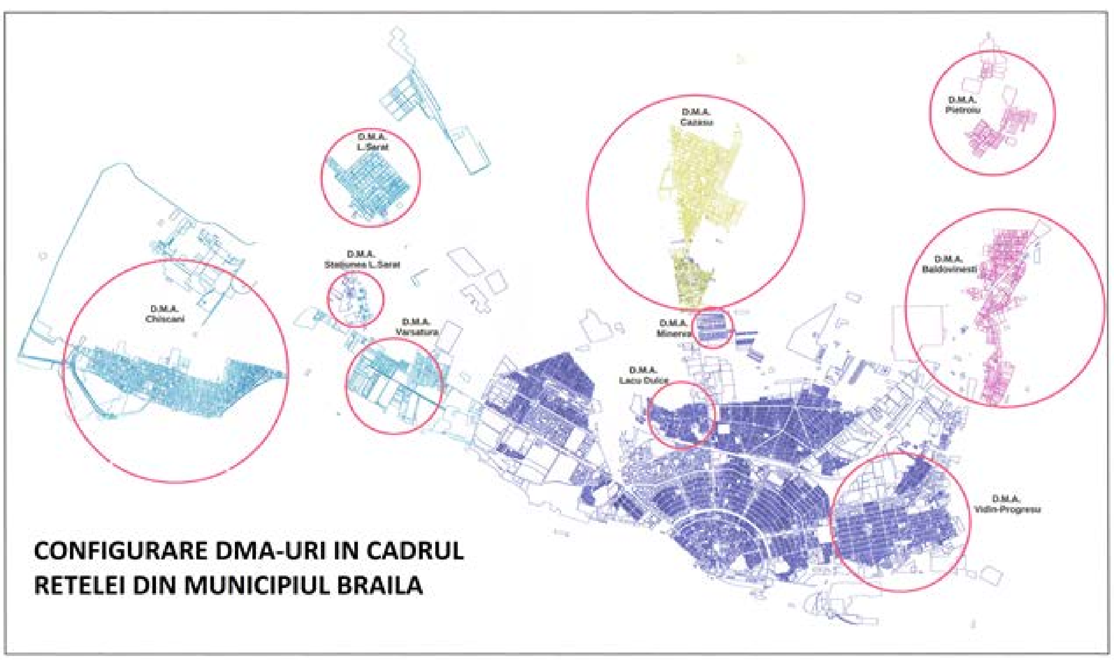


Fig.1. DMA monitoring areas Braila Municipality

In order to achieve them, the following data have been established:

- Water supply points;
- Identification of consumers and their water needs;
- Dimensioning of flow meters;
- Purchase of flowmeters and pressure sensors;
- Mounting the flowmeters in the connection chambers;
- Achieving the GSM connection and transmitting data in the SCADA system of the company;
- Monitoring and carrying out balance sheets regarding the water that is supplied and invoiced in each locality.

DMA's achieved:

1. Varsatura locality - 2 monitored inputs;
2. Chiscani locality - 2 monitored inputs;
3. Cazasu pumping station - 1 monitored input;
4. Baldovinesti and Pietroiu locality - 2 monitored inputs;
5. Lake Sarat resort and Lake Sarat locality -3 monitored inputs;
6. Chiscani Platform and Albina locality - 1 monitored input.

Within the dispatcher through the SCADA system, the quantities provided are permanently tracked and in the event of a loss, it is detected and resolved in the shortest possible time.

Monthly balances are carried out regarding the quantity distributed and invoiced.

In Braila, four DMAs were created, which are mounted in the SCADA system as follows:

- Lacu Dulce neighborhood - 5 inputs, 1294 connections, 12 Km network;
- Brailita neighborhood (Progresul - Vidin) 2 monitored inputs, 3864 branches, 47 Km network;
- Islaz neighborhood - 6 monitored inputs;
- Minerva neighborhood - 1 monitored input, and the neighborhoods of the blocks Viziru I, Viziru III, Calarasi IV and Hipodrom.

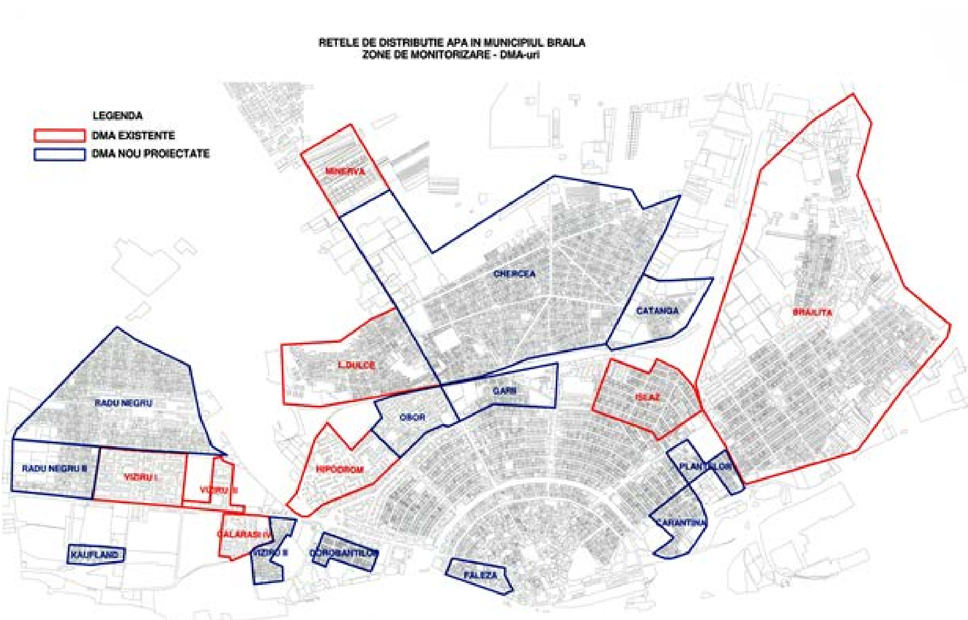


Fig. 2. Monitored and newly proposed areas

In 2019, the acquisition of 41 debitmeters and the accomplishment of 11 DMAs are envisaged, which will achieve the monitoring of over 60% of the distribution network. The value of this investment will be about 200,000 Euro. The figure below shows the monitored and newly proposed areas.

Hourly rates and pressures for water supply are monitored in the SCADA system of the unit and are also tracked within the company's Dispatch Office.

The figures below show the flow and pressure graphs for 2 DMAs between May 1 and 15, 2019:

Fig. 3. Pressure and flow graph – DMA Brailita

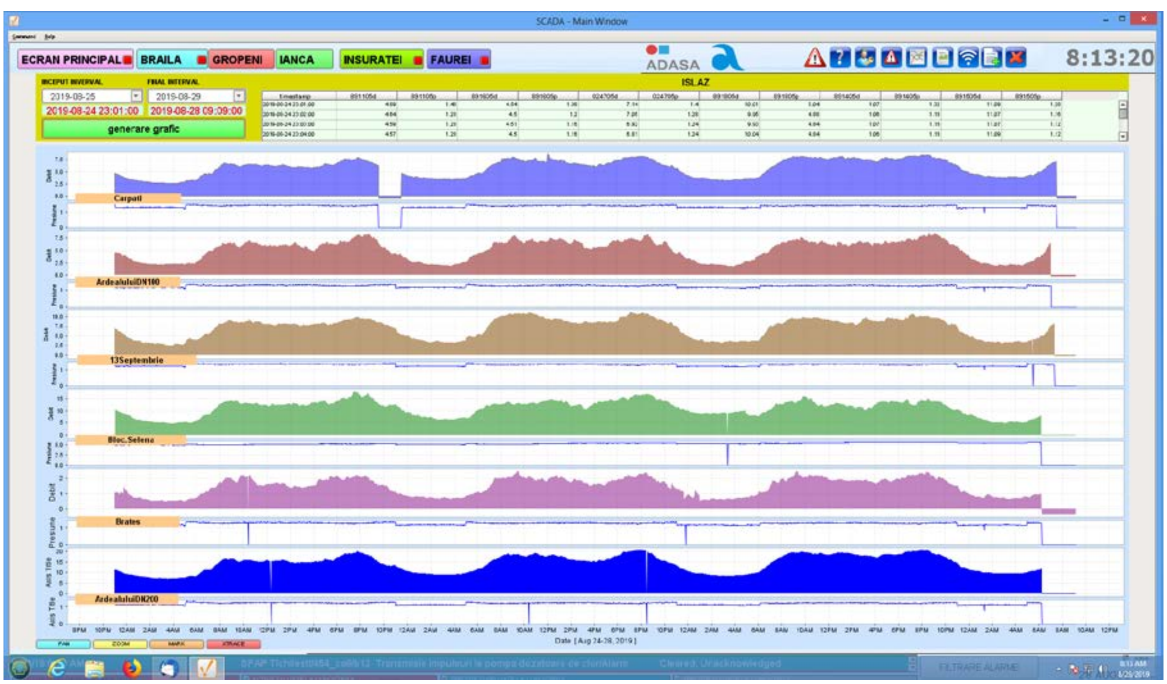


Fig. 4. Pressure and flow graph – DMA Islaz

Monthly the balance sheet with the supplied and invoiced flows is carried out.

2. MONITORING OF THE HYDROPHORE STATIONS IN BRAILA MUNICIPALITY

Within the Braila Municipality, two pressure zones are distinguished in the supply of consumers:

- **low pressure** area of consumers - 1.5 atm - domestic consumers, economic agents and budgetary;
- **high pressure** area (3 - 4.5 atm) of the housing blocks through the hydrophore stations.

Thus, at the level of Braila Municipality the company has in operation 61 hydrophore stations.

Through these hydrophore stations are provided to the associations of owners about 55% of the water billed to the entire Municipality.

In order to monitor their functioning and to determine the flow rates provided, the decision was made to create each hydrophore station in a DMA. Currently, the supply flows are monitored at a number of 42 hydrophore stations by mounting a meter on each distribution branch, and at a number of 28 hydrophore stations the exploitation and supply data are transmitted in the SCADA system of the company.

In the figure below is presented the picture of the operation of the hydrophore stations in which the following parameters are monitored:

- inlet pressure and outlet pressure;
- no pumps in operation;
- the flow rates provided on each branch of the hydrophore station;
- the amount of water supplied per day compared to the previous days.

Fig. 5. Table of operating parameters - Hydrophore stations

Daily reports are drawn up with the supplied rates and monthly the balance sheet is drawn up for each hydrophore regarding the water billed to consumers connected to a hydrophore.

Thus the losses on the high pressure networks are at a percentage of 5-10% of the distributed quantity. Continuous monitoring facilitates taking measures in the shortest possible time in the event of a loss of water on these networks.

3. MOUNTING THE RADIOMETERS TO THE CONSUMERS FROM BRAILA MUNICIPALITY

The Public Utilities Company Dunarea Braila based on the contract for the supply of smart meters for cold water purchased from SC ELSACO ELECTRONIC SRL a number of 30.175 meters with radio module of different sizes including software, communication equipment, software and hardware for reading their value of the contract being 13.076.395 lei.

So far, a number of 18.000 meters have been installed with the radio module, of which about 3.100 have been fitted to consumers in the neighboring localities Chiscani, Varsatura, Cazasu, Baldovinesti and Pietroiu, and the difference of 14.900 meters are installed in Braila.

In the Municipality of Braila radio meters have been fitted to all homeowners associations, to all budgetary consumers, to private consumers and to domestic consumers.

Once the meters are fitted with the module, they are also resized according to the consumption of each consumer. The diameter range of the fitted meters was at:

- domestic consumers - DN 15 - a nominal flow rate of 2.5 mc / h;
- the owners' associations - from DN 20 to DN 40;
- economic and budgetary agents - from DN 15 to DN100.
- In the strategy of mounting the meters, the following principles are considered:
- the installation of the meters is performed by our company;
- their sealing is performed only by the Mechanical-Energy Service of our company;
- the installation is made in the existing house located on the public domain or in the interior at maximum 2m from the property limit;
- construction of fireplaces if the conditions of distance from the property limit are not respected;
- verification of the contractual situation at the commercial service of each consumer identified in the field and the entry into legality of the unregistered consumers.
- Positioning the meter mounting chambers in the company's GIS system.

The activity of counting the domestic consumers in Braila Municipality has led to the following results (Table 1):

Table 1: Domestic consumers

Braila Municipality	Billed consumption domestic consumers (mc)	Number of domestic consumers	Invoiced volume (mc) / delivery
2016	1.631.431	22.172	73.58
2017	1.803.688	22.337	80.75
2018	1.890.604	22.550	83.84
2019 (jan-july)	953497	22688	Extrapolated year - 84.05

It can be observed that the volume invoiced / delivered increased from 73.58 cubic meters in 2016 to 83.84 cubic meters in 2018, and the number of consumers increased by 378 in 2018 compared to 2016.

Making a comparison between the consumption invoiced to the domestic consumers with a classic water meter, compared to the consumers to whom the radio mode meter was fitted, the situation is as follows (Table 2):

Table 2: Domestic consumers meter – without radio module / with radio module

Consumer category	Average consumption invoiced January-June 2019 (mc) / month
Domestic consumers meter without radio module	6.61
Domestic consumers meter with radio module	7.52

There is a 13% increase in consumption.

4. TRACKING AND MANAGING THE CONSUMPTION RECORDED BY THE RADIOMETERS

In order to monitor the consumption recorded by the radio module meters fitted to the consumers, our company purchased a computer program to verify them.

The program has several modules that facilitate the verification of the consumption recorded before issuing the consumer invoices.

The main modules of the program are:

- collection of meter data from consumers and district meters;
- data storage, user interface, alarm detection;
- reading analysis, data comparison, list of meters;
- groupings and balances;
- consumption reports by customer types, alarm report, index report;
- maintenance of meters;
- validation of consumption before being sent for billing;
- carrying out daily, weekly, monthly, annual balances on the DMAs carried out at the level of Braila Municipality;
- export of data to other systems.

The use of this program is allowed in several compartments, depending on the specificity of each compartment. This allows the possibility of viewing all modules and the activity of each compartment will be restricted only to the modules for which it has competence.

Below is a statistical situation of the readings made for a month in which the management of all existing alarms is presented.

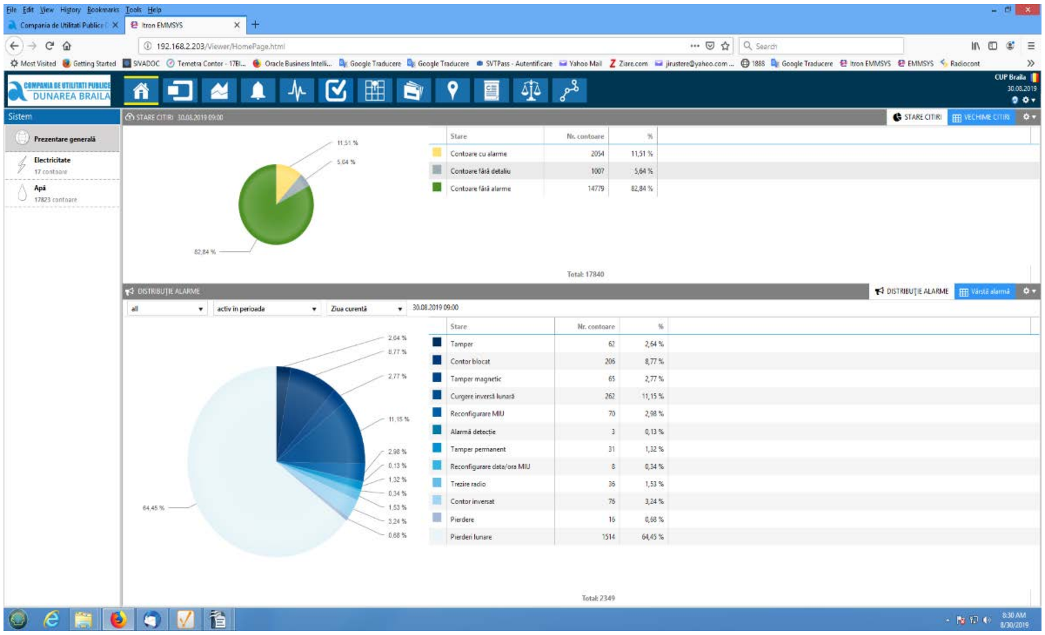


Fig. 6. Interface - Monthly readings statistics

For each type of alarm, separate reports are generated which are given for solving the mechanical energy compartment.

The figure below shows a consumption history for a consumer (owners association) where it is observed that for a certain period it had a higher consumption than the normal one.

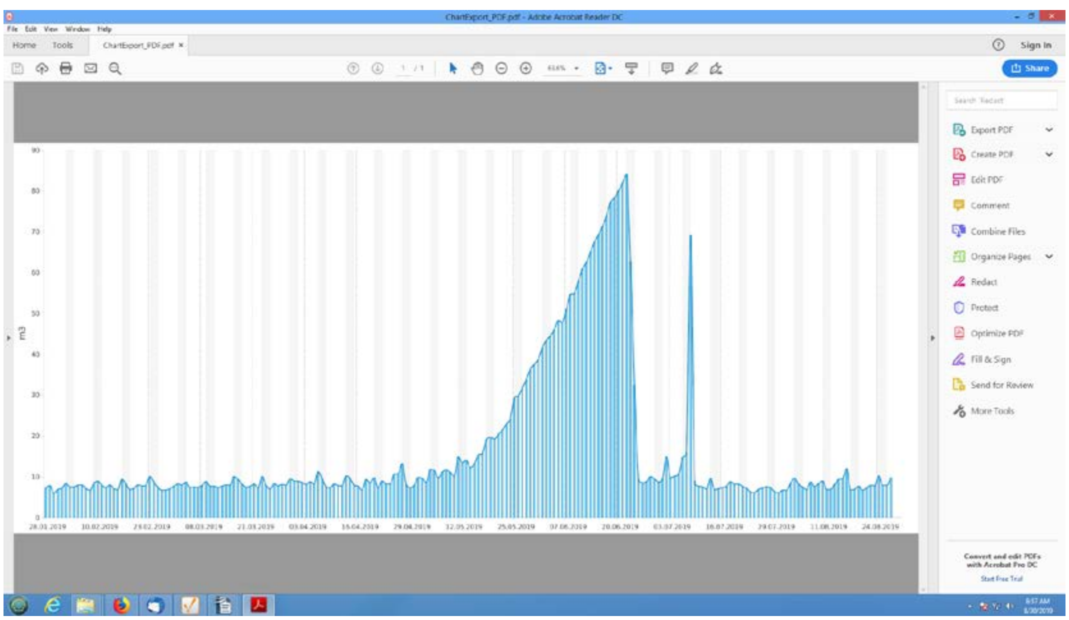


Fig. 7. Consumer History - Owners Association

Highlighting this abnormal consumption can be made known to the customer through the customer portal that is being implemented within our company.

During July, at the company level, a pilot project was started on installing counters with the LORA type radio module to a number of 23 consumers. The respective data including alarms are downloaded to the SCADA system of the unit, these being monitored daily by the dispatcher and the specialized departments within the company.

The data regarding the billing index at the end of each month is automatically downloaded from the SCADA system in the meter tracking program where they are examined, validated and exported in the billing program allowing this to be done automatically without the writing the billing index by hand by the operator. This eliminates the possibility of human error.

In the image below is the window of the SCADA system with a consumption history for a consumer who has mounted a meter with LORA mode.

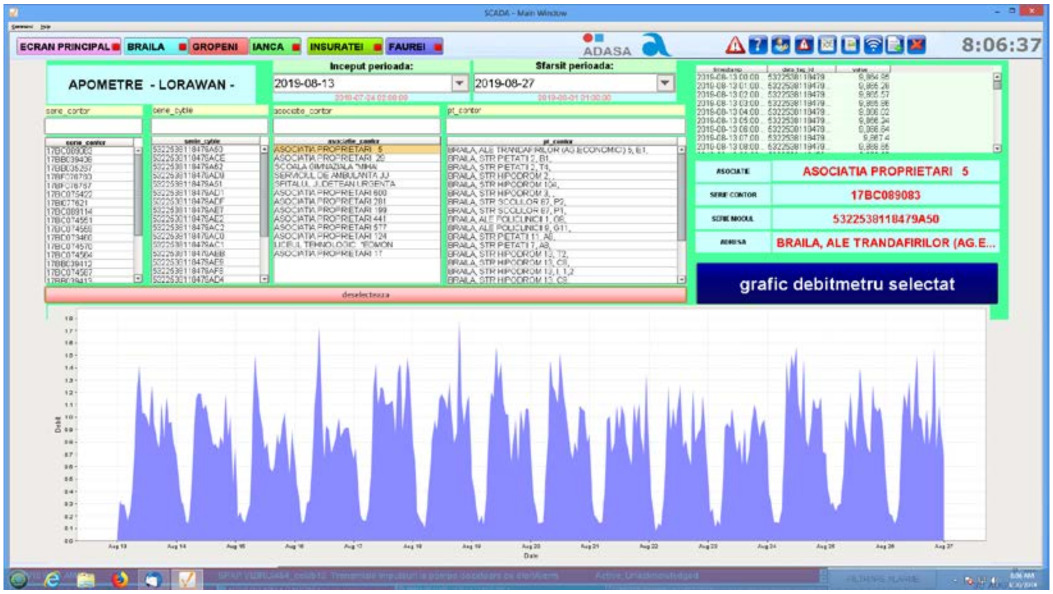


Fig. 8. Consumer history - Consumer with meter with LORA mode

Depending on the costs of implementing this system and the advantages it has, a comparative calculation will be made regarding the costs of implementation and operation of the new system compared to the existing system of meter reading, following the decision to extend this PILOT program for certain types of client categories (associations, economic agents and budgets).

At the level of Braila Municipality in the Table 3, the water losses data is presented in the distribution networks during the period 2014-2018.

Table 3: Water losses – 2014-2018

Luna	Nr. zile	Apa distribuita	Apa facturata	Pierderi distributie	Pierderi retele %	Nr. bransam.	Km retea	Pierderi	
								mc/brans.	l/km/h
2018	365	13,459,855	7,717,161	5,742,694	42.67%	25,561	496	224.7	1,323
2017	365	13,355,723	7,464,695	5,891,028	44.11%	25,345	496	232.4	1,357
2016	366	13,514,205	7,335,404	6,178,801	45.72%	25,199	496	245.2	1,419
2015	365	14,456,960	7,428,121	7,028,839	48.62%	25,156	496	279.4	1,619
2014	365	14,610,469	7,415,656	7,194,813	49%	25,133	496	286.3	1,657

It is observed that the losses in the distribution network the quantity of unregulated water decreased from 7.194.813 cubic meters in 2014 to 5.742.694 cubic meters in 2018 and the percentage of losses decreased from 49% to 42.67%, which leads us to the fact that the activities carried out have led to the reduction of water losses.

USING A HYDRAULIC MODEL FOR REDUCING THE NON-REVENUE WATER IN CASE OF A VILLAGE

Cristina Capotescu*, Ilie Vlaicu**, Cristina Borca***, Alin Anchidin****

* Aquatim S.A., Gheorghe Lazar 11A, 300081, Timisoara, România, cristina.capotescu@aquatim.ro
** Aquatim S.A., Gheorghe Lazar 11A, 300081, Timisoara, România, ilie.vlaicu@aquatim.ro
*** Aquatim S.A., Gheorghe Lazar 11A, 300081, Timisoara, România, cristina.borca@aquatim.ro
**** Aquatim S.A., Gheorghe Lazar 11A, 300081, Timisoara, România, alin.anchidin@aquatim.ro

Abstract
This paper presents an investigation and an assessment of the non-revenue water (NRW) in the case of a commune located in Timis County, in the western part of Romania. The main goal is to develop a non-revenue water reduction strategy in that particular case. Starting from the model elaborated by International Water Association, several steps are recommended to improve operational practices for implementing a NRW reduction strategy.
First of all it is necessary to clarify some aspects of the features of a network. The questions are: How much water is being lost? Where is it being lost from? Why is it lost? How to improve performance? In order to answer to this questions it is necessary to make some basic observations to identify the main causes of water loss. In this stage, the operator can observe whether there are unmeasured/unauthorized consumptions or water leaks. This is a diagnosis of the water network that consists in assessing how the network is operated and what are its limits. The next step is about to develop a hydraulic model that provides technical indications on how the system safely works and also what are the investments needed to improve the system.

Keywords
Non-Revenue Water; diagnosis, hydraulic model.

INTRODUCTION

One of the key aspects of a NRW reduction strategy is to accurately assess the volume of NRW as it is described in the book – “Losses in Water Distribution Networks – a Practitioner’s Guide to Assessment, Monitoring and Control” (Farley and Trow, 2003). The models developed by the International Water Association for understanding, measuring, monitoring and comparing losses, and the mechanisms for supporting it, can be applied to any water network, anywhere in the world.

1. GENERAL DESCRIPTION OF THE WATER SUPPLY SYSTEM

The village for which the study was conducted has a population of 986 inhabitants. The water supply network has a length of 11.6 km and the pipe diameter varies between 110 mm and 140 mm. The material is high density polyethylene. The village is supplied with water from two drillings. Each drill is equipped with a pneumatic tank and one of them also has a frequency converter to maintain constant pressure. The drillings are count and read monthly. Each costumer is also counted and the consumption is read quarterly.

2. DETERMINATION ABOUT HOW MUCH WATER IS BEING LOST

The comparisons between supplied and invoiced water volumes were observed quarterly as it is represented in Table 2.1 and, respectively, in Figure 2.1.

Table 2.1: The NRW during the research period

Duration	Supplied water (m³)	Billed water (m³)	NRW (m³)
2018 - Second quarter	26.599	13.056	13.543
2018 - Third quarter	24.101	14.370	9.731
2018 - Fourth quarter	22.352	13.832	8.520
2019 - First quarter	23.571	15.463	8.108

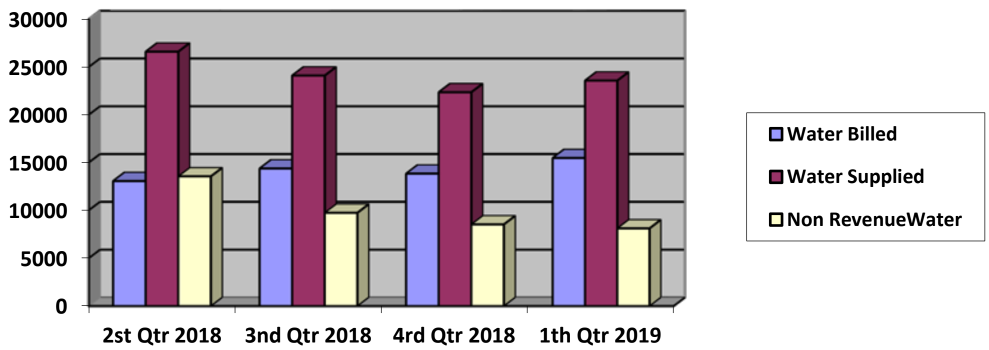


Fig. 2.1. Comparisons between supplied/invoiced/NRW

3. LEAK LOCALIZATION OR WHERE IS WATER BEING LOST FROM

Along with these measurements, the water operator identified two loss sources estimated at 2 m³/day, located on the map according to Figure 3.1.

Fig. 3.1. Leak localization

4. THE HYDRAULIC MODEL OF THE NETWORK - PRESSURE MANAGEMENT

Measurements are an essential feature of network management, especially to provide data for water balance calculation. The rate of leakage in water distribution networks is a function of the pressure applied by pumps (Farley, & Liemberger, 2005).

According to the measurements, the total volume of water supplied per one year (April 1, 2018 - March 31, 2019) was 96.623 m³ and the calculated average daily flow was 264.72 m³/day or 3.064 l/s. The measurements were made in a rainy time when the possibility of using water for irrigation or swimming pools is very low.

During specific period of night time, from 4 AM to 5 AM, measurements showed the supplied water flow was 3.172 m³/hour or 0.881 l/s. According to the Romanian standard regulations (SR 1343/1-2006), for this specific interval, in case of a rural locality, the consumption represents 0.5% of the average daily flow which in this case is 1.324 m³/hour (or 0.368 l/s for a daily average flow of 264.72 m³/day). The difference between the two values – 1.848 m³/hour (or 0.513 l/s) - represent water loss or non-revenue water.

Table 4.1: The flow rate variation

	The flow rate variation (m³/hour)
12:PM-01:AM	4
01:AM -02:AM	3.17
02:AM -03:AM	3.17
03:AM -04:AM	3.17
04:AM -05:AM	3.17
05:AM -06:AM	15.5
06:AM -7:AM	28.58
07:AM -8:AM	20.3
08:AM -9:AM	11.5
09:AM -10:AM	11.1
10:AM -11:AM	11.1
11:AM -12:AM	11.91
12:AM -01:PM	22.5
01:PM-02:PM	21.5
02:PM -03:PM	3.97
03:PM -04:PM	3.97
04:PM -05:PM	6.3
05:PM -06:PM	6.3
06:PM -07:PM	8.5
07:PM -08:PM	14
08:PM -09:PM	20
09:PM-10:PM	19
10:PM-11:PM	8
11:PM-12:PM	4

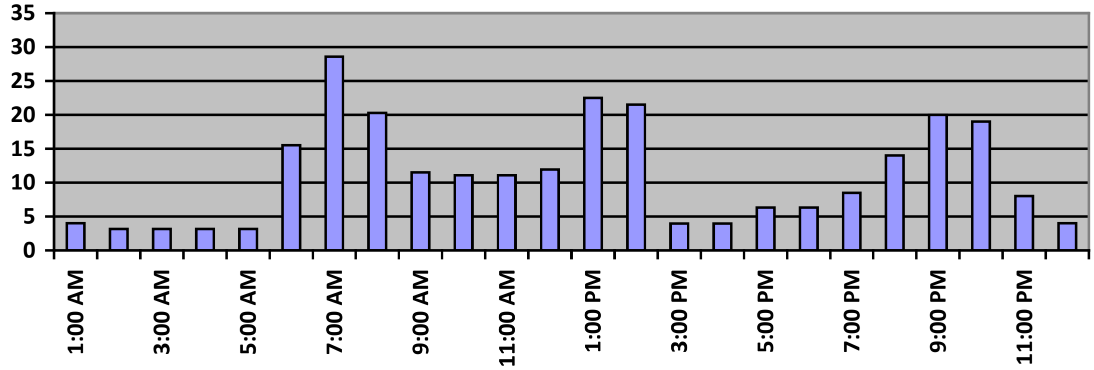


Fig. 4.1. The flow rate variation during 24 hours

With all data gathered from ground, a hydraulic model of the network was developed. According to this model, the pressure for an external hydrant in the most unfavorable node (J40) is 1.427 bar for next features:

- Q_{daily} = 5.94 l/s;
- External fire rate = 5 l/s.

The good news is in that node the pressure is higher than the minimum required value which consist to be 0.7 bar according to Florescu et al. (2015).

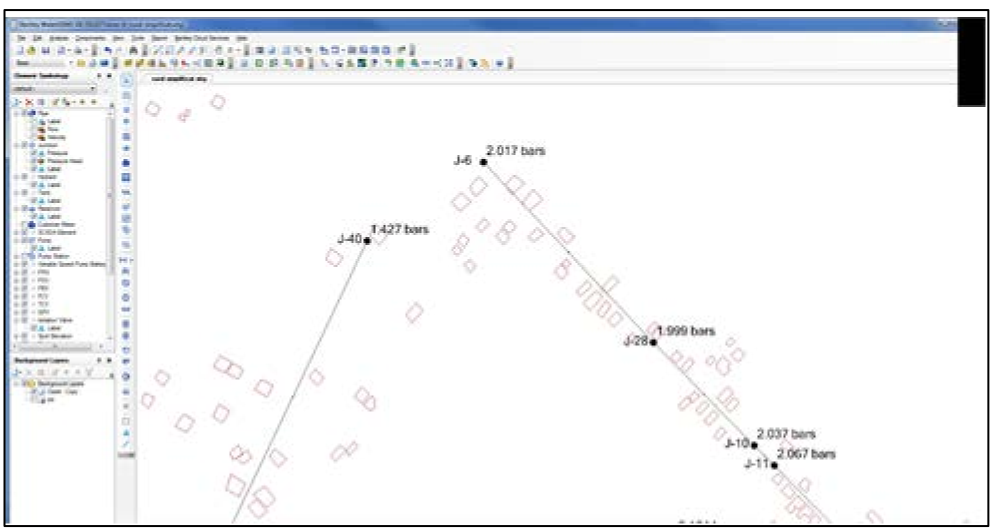


Fig. 4.2. The hydraulic model of the network

$$Q = K \cdot S \cdot R^{2/3} \cdot J^{1/2};\quad v = C \cdot \sqrt{R \cdot J};\quad C = K \cdot R^{1/6};\quad J = \frac{\Delta H}{L};$$

$$J = \frac{v^2}{K^2 \cdot R^{4/3}};\ J = s_o \cdot Q^2;\ h = J \cdot L;\ s_o = \frac{10{,}3}{K^2 \cdot D^{16/3}};\ D = \left(\frac{10{,}3 \cdot L \cdot Q^2}{K^2 \cdot h}\right)^{16/3}$$

Fig. 4.3. Calculation formulas of the hydraulic network

In the formulas developed by model, there are some variable:

- Q, the flow (m^3 /s);
- K=1/n, inversion of the roughness coefficient;
- S, the cross-sectional area (m^2);
- J, the hydraulic slope;
- ΔH, the difference between the piezo metric elevations in the extreme sections of the pipes (m);
- V, water pipeline speeds;
- s_0, the specific hydraulic resistance of the pipe (s^2/m^6);
- C, the Chezy's coefficient (m/s);
- H, the load losses in adduction (m);
- D, pipe diameter (m).

5. CONCLUSIONS

Operation and maintenance is essential for the successful management and sustainability of water supply networks, regardless of technology level or infrastructure development. As it can be seen in table 2.1, during the research period, the volume of non-revenue water dropped from 50.92% for the second quarter of 2018 to 34.4% in the first quarter of 2019. In this time, by monitoring the water balance between the supplied and consumed water flow, measures have been taken in order to identify water losses and repair the damages. But, the most important, there were a number of consumers identified who did not have counters. In the end, they have entered into legality and received bills for their consumption.

REFERENCES

[1] *Farley, M.* and *Trow, S.* (2003). Losses in Water Distribution Networks – A Practitioner's Guide to Assessment, Monitoring and Control. IWA Publishing, London available at http://www.iwapublishing.com/template.cfm?name=isbn1900222116;

[2] *Farley, M.*, & *Liemberger, R.* (2005). Developing a non-revenue water reduction strategy: planning and implementing the strategy. Water Science and Technology: Water Supply, 5(1), 41-50;

[3] *Florescu et al.* (2015) - Guide for the calculation of water supply constructions and installations available at: https://www.ct.upt.ro/studenti/cursuri/florescu/Indrumator_pentru_calculul_constructiilor.pdf;

[4] SR 1343/1-2006, Romanian Water Standard - Water supplies. Part 1: Determination of drinking water quantities for urban and rural localities.

ADAPTIVE ALGORITHM FOR WATER LOSS ESTIMATION IN NETWORKS BASED ON ADVANCED ANALYSIS OF MINIMUM NIGHT FLOW (MNF)

D. J. Vicente*, M. García**, F. Salazar***, J. Helmbrecht****

*International Centre for Numerical Methods in Engineering (CIMNE), djvicente@cimne.upc.edu
**WatEner - INCLAM Group, miguel.garcia@water-idea.com
***International Centre for Numerical Methods in Engineering (CIMNE), fsalazar@cimne.upc.edu
****WatEner - INCLAM Group, jh@watener.com

Abstract
The Minimum Night Flow (MNF) concept is one of the most widespread methods for estimating losses in water distribution systems. Its impact can be seen in its continued use over the last decades (UKWI 1994; Puust et al. 2010). However, there is no standard methodology on how it should be applied. Certain actions have been identified as main steps or stages of this method, since they are applied in most studies. Figure 1 shows these stages, in total four, showing their relationship, the main variables associated with them and some of the most common expressions used in this methodology.

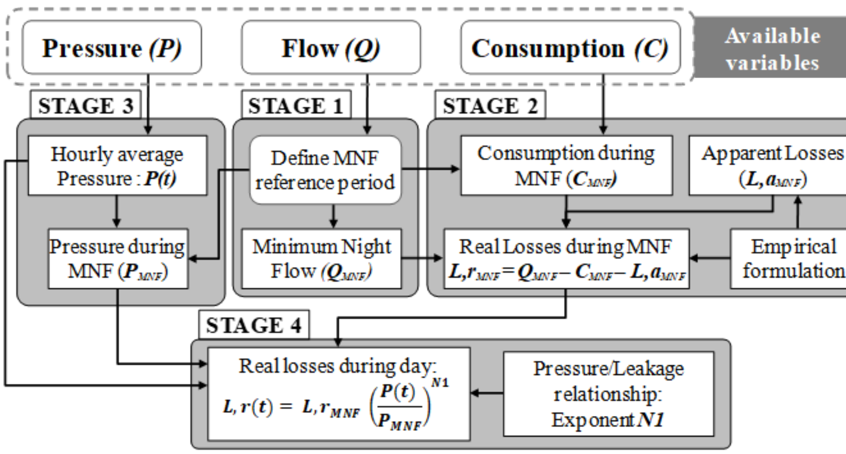


Fig. 1. Global scheme for leakage estimation using the MNF method and main stages

The stages are the following: (1) calculation of the reference MNF value, (2) estimation of real losses (through empirical formulation or disaggregating the QMNF into sub-components, (3) calculation of average pressure and (4) extrapolation of real losses during the MNF to the rest of the day. After an exhaustive review of case studies worldwide, a large number of criteria have been identified for each step, many of them based on approaches or empirical equations proposed in the specialized literature. This results in the existence of a wide range of sub-methods with different levels of detail, many of which introduce great uncertainty into the calculations. Therefore, most of the methods applied in a particular water distribution system are not applicable to other cases with different characteristics.
In this context, and in order to solve the problem linked to the lack of standardization detected when using this concept and the uncertainty associated with it, the objective of this study is the following: *to develop an algorithm for the estimation of water losses, based on the MNF concept and adaptive to each case study*. To achieve this goal, the following actions have been carried out:
(i) ***Exhaustive review of specialized literature and compilation of sub-methods*** - Information has been collected on 48 real projects from 25 countries, including 5 continents, where the MNF concept has been used. The most relevant aspects of each project have been identified and analysed, paying special attention to which techniques are more frequently used, which ones can introduce greater uncertainty in the calculation and also highlighting newer initiatives (Table 1).

Table 1: Most relevant aspects analysed of each project and classification according to main stages of the MNF

Main Stages (from Figure 1)	**Most relevant aspects analyzed**
Define MNF reference value: Q_{MNF}	▪ Data series features: length (window width), variability, existence of annual or weekly seasonality ▪ Reference time band: fixed or varying hours, instant vs. mean values ▪ Preprocess actions: outliers elimination, basic statistics actions
Real losses calculation: L,r_{MNF}	▪ Real losses calculation approach: direct (empirical estimation) or derived (disaggregation from Q_{MNF}) ▪ Disaggregation detail: number and type of sub-components considered ▪ Methods to obtain each sub-component: empirical formulas, monitoring, numerical models, surveys, etc.
Average Pressure calculation: $P(t)$ & P_{MNF}	▪ Number and location of pressure sensors: inputs, P_{ave} representative point, critical points, wide sensor network ▪ Topological characteristics of the network: district size, elevation range, mean diameters (oversized networks) ▪ Pressure head-loss consideration: with sensors or models
Extrapolation of real losses to rest of the day: $L,r(t)$	▪ Extrapolation methods: day-night factor, correction factor, application of equation at each hourly period ▪ Value assigned to exponent N1: based on literature, estimated on the basis of network characteristics, calculated by pressure variation (inverse method), calculated through numerical models

(ii) ***Elaboration of multi-criteria algorithm*** - The second step has consisted in the development of an algorithm which includes a wide variety of criteria and sub-methods. The algorithm suggests the most suitable approach for each case based on different factors: available data, topological characteristics of the sector, hydraulic series profile (flow, consumption and pressure series), whether numerical models are available or not etc. The structure of the algorithm has been programmed in a modular way with two levels: a first level that relates each main stage of the MNF method and another one of greater detail associated to each stage. Each module integrates both methods drawn from the literature and others originally proposed in this project.
(iii) ***Integration of the algorithm in a DSS platform*** - WatEner - WatEner is a fully functional software developed by the INCLAM group (http://www.watener.com). It is a web platform that improves efficiency in the daily operation and management of water supply networks through real-time event monitoring, decision support systems, numerical and statistical models and expert knowledge. The incorporation of the new algorithm in the platform will improve its capabilities, making the calculation options more flexible and allowing it to be applied to a greater number of case studies regardless of the available data and the characteristics of each network.

Keywords
MNF, Non-Revenue water management, Leakage estimation, Decision Support Systems.

REFERENCES

[1]. Puust, R., Kapelan, Z., Savic, D. A., Koppel, T. (2010). *A review of methods for leakage management in pipe networks*. Urban Water Journal, 7(1), 25-45.
[2]. U.K. Water Industry. (1994). *Managing leakage-Report F: Using Night Flow Data*. UKWI, Engineering and Operations Committee, WRc/WSA/WCA, London, UK.

DECREASING THE NON-REVENUE WATER VOLUME IN THE CHIRIȚA WATER TREATMENT PLANT - IAȘI CITY

Mihail Doruş*, Cristian Chirica**, Ioana Roman***, Dan Popovici****

* S.C. APAVITAL S.A., no. 6 Mihai Costăchescu Street, Iaşi, Romania, mihai.dorus@apavital.ro
** S.C. APAVITAL S.A., no. 6 Mihai Costăchescu Street, Iaşi, Romania, cristian.chirica@apavital.ro
*** S.C. APAVITAL S.A., no. 6 Mihai Costăchescu Street, Iaşi, Romania, ioana.roman@apavital.ro
**** S.C. APAVITAL S.A., no. 6 Mihai Costăchescu Street, Iaşi, Romania, dan.popovici@apavital.ro

Abstract
In conventional water treatment plants, which include clarifiers and sand / activated carbon filters, part of the produced drinking water is used as process water, i.e. for washing processes carried out according to process technology. At the same time, the storage tanks are also periodically washed and disinfected by means of this drinking water.
All this non-revenue water (NRW), used for process purpose, is finally evacuated down to drain. An efficient management of processes, equipment and machinery can result in a decreasing of NRW water volumes.
Depending on several factors, as the raw water quality, used technology and the state of equipment and construction, the amount of process water can vary between 5 ÷ 15% of the entire amount of produced drinking water.
Most washing technologies, especially in plants that lack SCADA system, are based on a washing sequence time limit (e.g. 20 minutes).

1. In the Chiriţa Water Treatment Plant, in order to decrease the water volumes used for the sand filter no. 1 backwash process a submerged turbidity meter (connected to a controller) was installed. The system has the function of stopping the backwash process when the pre-set turbidity (max. 5°NTU) in the washing water is reached. This way the backwashing sequences have a variable duration of between a few minutes and a maximum of 20 minutes.

Benefits:

- Significant reduction of the volume of backwash drinking water volume;
- Decreasing of equipment running time (turbofans, washing pumps, AUMA valves);
- Significant decreasing of power consumption, that means the lowering of specific costs per cubic meter of produced drinking water;
- Capacity to generate additional profits by lowering specific production costs and leading to a superior water quality;
- In case of failures of automation systems (a blocked process computer), the implemented system can be operated on manual mode, without affecting the filter backwash process;
- Due to the applied principle (that is, the optical measurement of water turbidity in the filtering tank) the technological, economic and qualitative efficiency for the entire drinking water production process is ensured.

2. In the Chiriţa Water Plant, on Clarifier no. 1 an ultrasonic device is installed, device that measures and determines the sludge level inside clarifier. The device is connected to a controller, and when the pre-set sludge layer thickness is reached, the sludge draining system is automatically started.

This way, the washings and sludge draining sequences are only executed when necessary, thus saving water and reducing the NRW volume.

Keywords
Backwash, savings, sludge.

1. INTRODUCTION

The Apavital's Chirita Water Treatment Plant in Iasi City has undergone a comprehensive modernization program aimed to ensure compliance to the EU 98/83 Directive on Life Quality and Drinking Water production at National Standards.

The water treatment sequence consists of two radial Cyclator clarifiers with a capacity of 10,000 m3 each. The installed drinking water flow rate is 1.15 m^3/s.

Two patented inventions have been developed and implemented in order to increase the drinking water quality and the efficiency of process activity.

2. THE PROCESS OF SLUDGE REMOVAL FROM THE DRINKING WATER PRODUCING CLARIFIERS

The sludge removal (sludge produced next to the coagulation-flocculation process) takes place via three draining sumps fitted with AUMA electro-valves. Their control is provided through a proximity contact located on the scraping bridge. The closing and their opening is conducted sequentially upon contact with the scraping bridge, fact that generates large losses of clarified water.

In order to decrease the amount of lost water and avoid the produced side effects, **an invention patent registered with OSIM no. A00633/04.07.2011** was developed and afterwards implemented in the Chirita water treatment plant, this being a sludge removal technique different than the one provided in the refurbishment design.

For this purpose, in the suspension clarifier no. 1 continuous measurements of sludge level were conducted, with a Sonatax SC 1000 type probe. The device used, the Sonatax Hach-Lange device, works on the principle of ultrasonic hydro location and is capable to vertically measure the sludge thickness.

The ultrasonic hydro location device was mounted on the clarifier's scraping bridge, vertically above the sludge collecting channel that holds the three sludge removal sumps. During the scraping bridge rotation cycle, the collecting channel is permanently swept by a one-way ultrasonic beam that is continually measuring the sludge level.

Fig. 1. Location of the ultrasonic scanner and the controller module of sludge measurement device

The information is shown on an LCD display device placed in a controller, located on the clarifier and integrated into the computer control loop with the SCADA application. The figure shows the image displayed by the controller set on the scan position. The graph shows the clarifier's bottom profile, the sludge layer height and the compaction level.

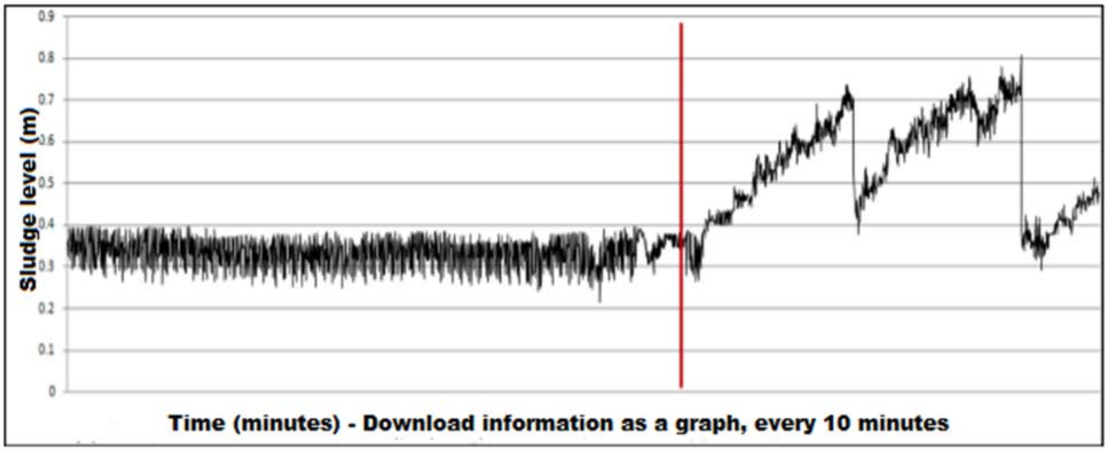


Fig. 2. Image displayed by the controller set on the scan position

The graph shows the operating mode under SCADA control, the sludge level ranging from 30 to 40 cm. After switching on manual mode (after the red marker), an increasing tendency of the sludge level can be noticed (in the clarifier's sump channel).

An increasing of sludge density is beneficial to the evacuation process because the concentration in dry matter gets higher, which reduces the water removal rate accordingly.

In the following period, a new sludge extraction graph was generated for the clarifier, adapting the machinery operation to the variations that take place in the "sludge level" parameter.

The sludge extraction was carried out at a six days interval, with a sump opening time of 30 minutes. The six-day time interval was considered optimal, being sufficient to reach the sludge height and density required to a maximum limitation of water losses.

Beyond the six-day period, during summertime, there is a risk of sludge anaerobic fermentation phenomenon inside the sump channel, this resulting in gas releasing (hydrogen sulfide, methane) and toxic metabolic products. Their presence in the water may lead to a deterioration of drinking water quality and the overloading of granular active carbon filters. The results of this process optimization are quantified in the table below:

Table 1: Results of process optimization

	System status	Effects of using the Sonatax device	Advantages of using the Sonatax device
1	Increasing of sludge level prior to extraction	Sludge extraction at a lower frequency	Decreasing of operation time for the sludge extraction electro-valves
			Adaptability to variable intake flows
2	Ensuring an uniform sludge level prior to extraction	Extraction of a sludge with higher dry matter content and a lower water content	Decreasing of water losses (water extracted together with sludge)
			Extracted sludge is free of excess ferric chloride and feeric hydroxide (reagents that may harm processes in the wastewater treatment plant where sludge is discharged)

The newly implemented techniques bring important benefits:

- reduction of water losses and an efficient use of treatment reagents;
- reducing of running time for sludge removal equipment (AUMA electro-valves, on-line densitometers) with immediate effect in decreasing of power consumption and increasing the equipment lifetime;
- reduction of turbo-mixer and flocculation mixer speeds by means of the frequency converter (from 8 Hz to 4.2 Hz) up to the optimal value needed to firmly keep the integrity the flocs formed inside the suspension cone.

The immediate effect was noticed as regards the reducing of power consumption and the process of obtaining large flocs, prone to fast sedimentation. It should also be mentioned that the proposed solution is applicable to any values for turbidity, the opening of valves depending on the sludge layer thickness, thus ensuring reproducible water quality irrespective of the load degree (turbidity) in raw water.

The table below shows the current operating mode implemented after plant's upgrading and the operating mode with the Sonatax device.

Table 2: Current operating mode implemented after plant's upgrading and the operating mode with the Sonatax device

Automatic operation	Sonatax device experimental operation
Valve opening - once at every 20 minutes Valve operating time - 180 secunde	Valve opening – once at each 6 days AUMA valves operating time: 30 minutes The water losses dercreasing (measured with flowmeters) is 10,000 m^3/month

Economic analysis:

The benefits of implementing this invention are:

- 240,000 m^3/year of filtered water are saved in the two clarifiers, the total production being of 15,918,839 m^3 this implicitly leading to an increase of the potentially produced drinking water;
- Power savings: 562 Kwh/year (due to the reducing of number of operating hours);
- Eliminates the premature wear of valves mechanical and electronic components by decreasing the number and frequency of „closing-opening" sequences;
- The needs for maintenance, overhauling and repair operations is decreasing, and therefore the involved personnel can be re-directed to other activities;
- The revenue/expenditure balance shows a benefit of 554,234 Ron/year, value resulting from the additional produced water, from power savings and, as well, from the lower maintenance needs (for the AUMA valves mechanical and electronic components).

3. THE PROCESS FOR CONTROLLING WATER USED FOR FILTERS BACKWASH IN DRINKING WATER TREATMENT PLANTS. NATIONAL OSIM REGISTRATION: NO. A00633/09.04.2019

The backwash of a filter is needed when the filter mass (sand or activated charcoal) gets clogged, and high hydraulic resistances occur, fact which significantly reduces the filters production capacity, and even leads to the full stopping of this process.

Depending on the level of automation implemented in water plants, the backwash is stopped by a timer set to about 20 minutes, or by the simple operator's appreciation. The initial control software, regardless of the situation, shall launch a filter backwash sequence once at each 24 hours.

The 20 minute backwash time may be too high, and may lead to unnecessary drinking water losses, or it may be inadequate, thus performing an inadequate washing of the filtering unit. This involves high power consumption, and premature wear of backwash pumps, and, as well, of all hydraulic and pneumatic equipment.

The technical problem that this invention resolves consists in optimizing the consumption of backwash water in water treatment plants.

The water flow control system for water used in fast filter backwash is based on optimal time control for backwash time and involves the use of an on-line turbidity probe able to communicate real-time data on turbidity of water inside filtering tank. The information is displayed on a screen placed inside the probe and in the central process computer via the SCADA application.

The turbidity probe is immersed in the filter in the opposite direction of the clarified water supply valve, and the information taken from the probe is processed by a controller that controls the stopping of the backwashing process by stopping the pumps. Depending on the preset turbidity value, the backwashing time can be reduced or extended.

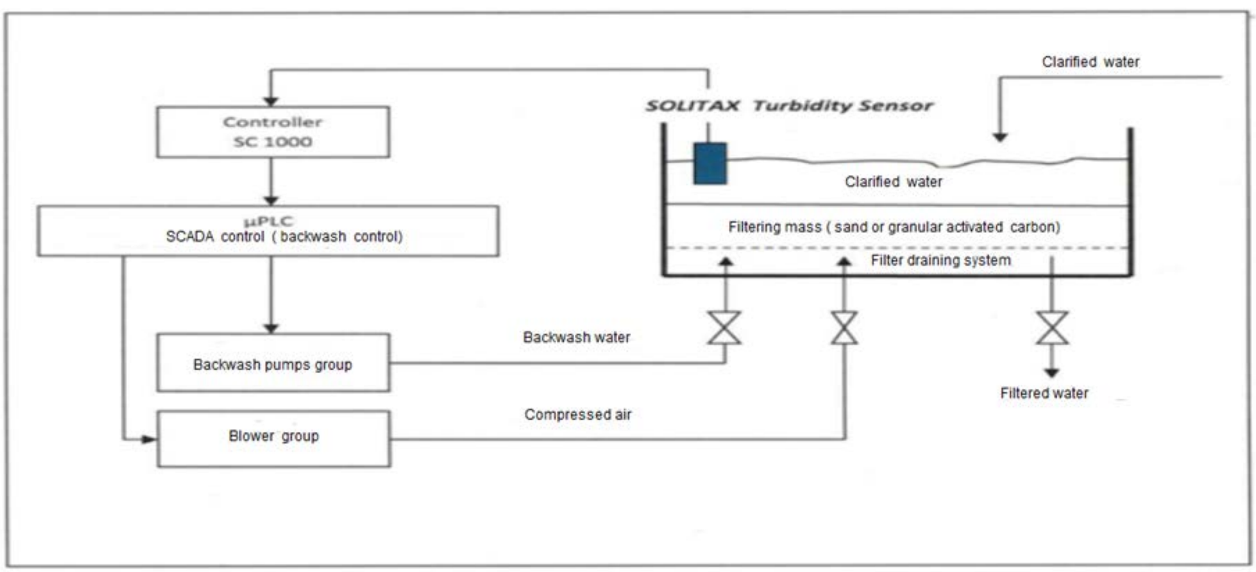


Fig. 3. Diagram of the system that features a turbidity probe for the backwash of a filter used for drinking water at the Chirița water treatment plant

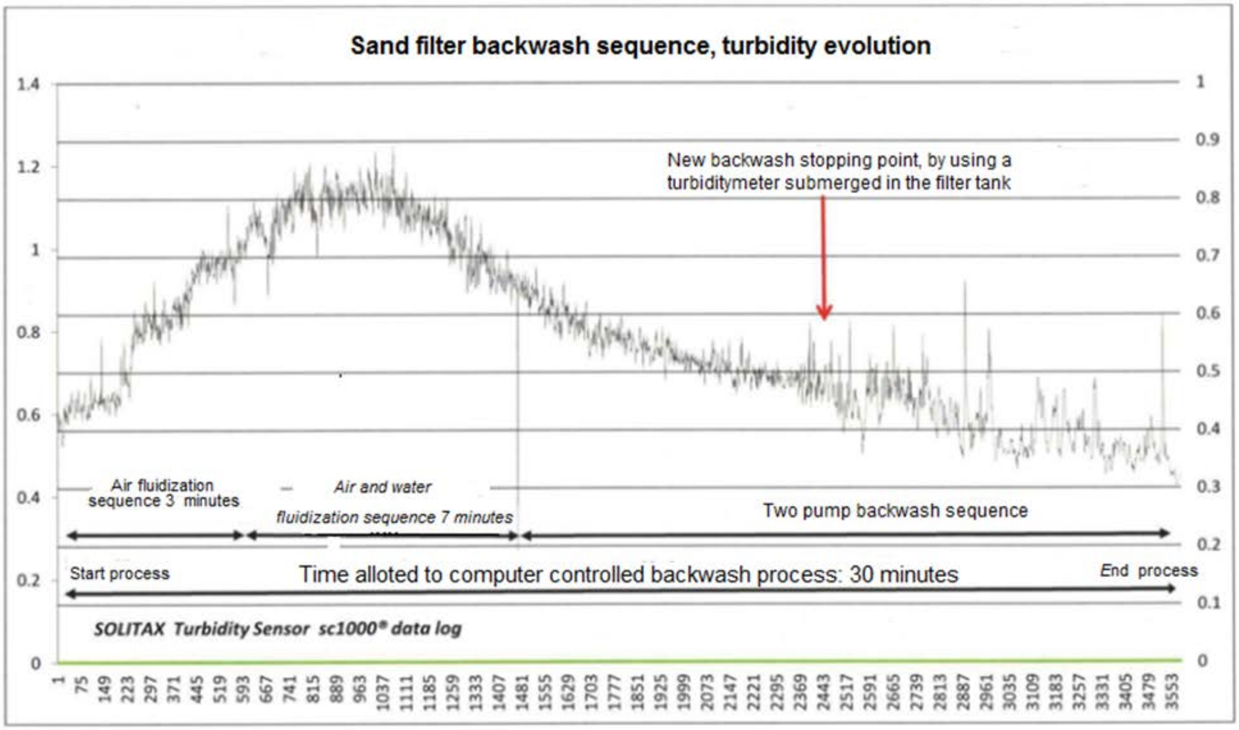


Fig. 4. Turbity evolution graph (control provided by the turbidity probe)

The stop command is given by the water quality obtained at the turbidity required by the operator. The diagram shows the advantages of using this invention in the process of filter backwash.

Economic analysis:

The benefits of implementing the invention are:

For a backwash cycle, the consumptions for a filter composed of two filtering tanks (according to data recorded on the backwash water flowmeter) are:

- 750 m^3 of drinking water;
- 42 kW power;

Considering that backwash time decreases from 20 minutes to 12 minutes (the lowest value obtained), the consumptions are:

- 450 m^3 of drinking water;
- 25 kW power;

At the Chirita water treatment plant, considering that 8 (eight) sand filters are operated and the average water flow is (2500 ÷ 3000) m^3, the savings in 24 hours are:

- 2400 m^3 of drinking water;
- 136 kW power.

The advantages of the present invention consist in:

- reducing the volume of water used for backwashing;
- reducing the operating time of hydraulic equipment;
- considerably reduces power consumption by decreasing the pumps and blowers running time;
- production of a superior quality water;
- in case of malfunctions of automation systems, the system can be manually operated.

The Water Loss Specialist Group is strongly focused on all treated water that is lost, which is mostly from underground leaks on water-mains and water service pipes, and also how to reduce those losses through leak detection and hydraulic control. However those losses include any water that has entered the networks following treatment, and fails to get through to consumers/customers. Identifying how much water is being lost is the recommended starting place for utilities and practioners. The group has developed a method of accounting for all water entering a water supply system, and this process has been accepted world –wide by everyone associated with managing water networks. The terminology then changed from "Unaccounted For Water"' to "Non Revenue Water", on the basis that all water can now be accounted for, albeit that the IWA process for accounting for water will highlight the strengths and weaknesses of data they have for measurement. This "top down" approach provides a strategic direction for utility managers to determine their best approach to reducing losses. The group has also identified four important actions that can be taken to reduce water losses, and subsequently this has been graphically shown as a strategic plan to reduce the overall volume of lost water.

A key message to the industry that is an outcome from this work, is that percentages are a poor method of measuring losses when used to measure progress, or as comparisons to other similar utilities. An emphasis has been placed on having accurate data regarding flow measurement into water distribution networks, and water pressure variance. These are key factors to be known in order to identify where most leakage is, and to understand where leaks can be found and how leaks can be stopped from.

More info at https://iwa-connect.org/group/water-loss/about

Romanian Water Association is at the heart of connecting the vast community of water professionals, at national and international levels, promoting the integration of cutting-edge ideas of professionals in the research and innovation fields.

As an ARA member, water professionals benefit from the resulting "know-how" from the collaboration of various professions and specialties at national and international level.

Thanks to its network of members, professionals in research, operation, regulation, consulting and design, ARA can address unique expressions of global challenges within communities in the country to create extensive knowledge and integrated and sustainable solutions. At the same time, ARA promotes solidarity among its members, initiates, develops and support sector development strategies and programs, and contributes to the promotion and improvement of modern and unitary forms of institutional organization and management in the water sector. It performs, in co-operation with the National Regulatory Authority for Community Utilities, the Annual Report on the state of water supply and sewerage services.

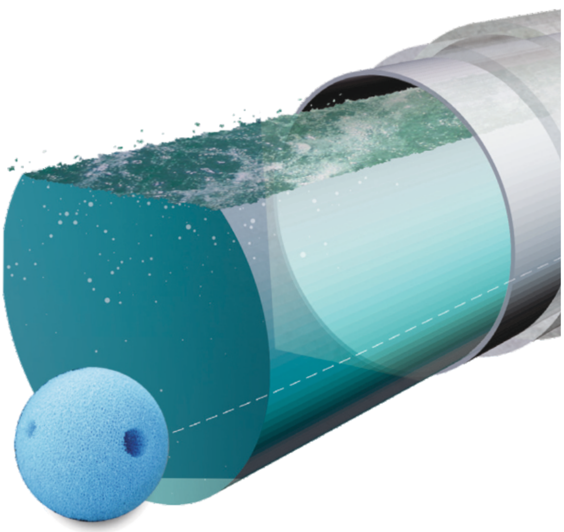
Through the Excellence Center for Benchmarking, ARA performs benchmarking exercises annually, aiming to promote best practices and to use it as a management tool.

More info at http://www.ara.ro/

xylem
Let's Solve Water

SmartBall® Technology

A FREE-SWIMMING TOOL FOR LONG DISTANCE WATER AND WASTEWATER INSPECTIONS

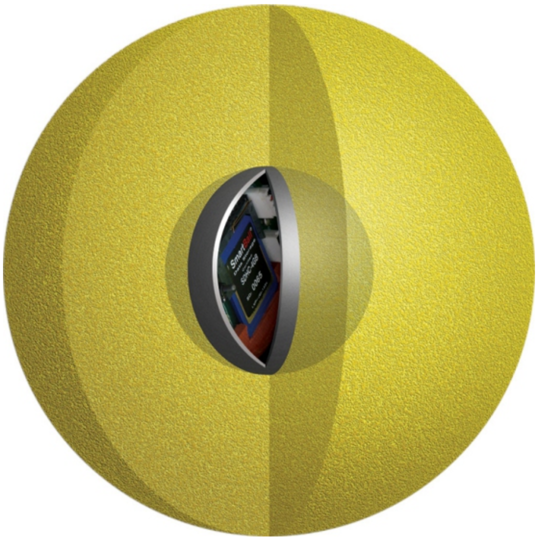


How SmartBall works?

The SmartBall® platform is a free-flowing tool for the assessment of pressurized water and wastewater pipelines 8 inches and larger. It can complete long assessments in a single deployment without disruption to regular pipeline service.
The tool is inserted into a live pipeline and travels with the product flow for up to 21 hours while collecting pipeline condition information. It requires only two access points for insertion and extraction, and is tracked throughout the inspection at predetermined fixed locations on the pipeline.

Applications

Owners of water and wastewater pipelines deal with a variety of infrastructure challenges; the SmartBall platform can collect a variety of pipeline condition information in a single deployment that helps owners manage their assets more effectively.



Leak Detection

The tool is equipped with a highly sensitive acoustic sensor that can detect pinhole-sized leaks on pressurized pipelines. The SmartBall platform has been able to identify leaks as small as 0.028 gal/min (0.11 liters) and has a typical location accuracy of within 6 feet (1.8 meters).

Gas Pocket Detection

The acoustic sensor is also able to identify the sound of trapped gas within pressurized mains. The presence of trapped gas can adversely affect pipeline flow or lead to degradation of the pipe wall in sewer force mains.

Inspection Benefits

- Easy to deploy through existing pipeline features
- No disruption to regular pipeline service
- Can complete long inspections in a single deployment
- Highly sensitive acoustic sensor that can locate very small leaks
- Can identify features relevant to the operation and mapping of the pipeline
- Indicates the position of leaks, and gas pockets relative to known points

xylem
Let's Solve Water

Pure Technologies, a Xylem Brand
EN 247, Edifício Jonobras, Sala 3, Piso 2
2670-027- Santo Isidoro, PORTUGAL
Tel +351 261 863 159
www.puretechltd.com

pure
TECHNOLOGIES

ISBN: 978 - 973 - 88245 - 5 - 3