Pressure management whitepaper

Save Water, Energy and Costs Using Pressure Management

Grundfos demand driven distribution reduces leakage losses, increases energy efficiency and saves operation and maintenance costs.

Average figures based on delivered projects since 2014

15% LEAKAGE REDUCTION

25% ENERGY SAVINGS

35% PIPE BURST REDUCTION

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PUMP CLOUD SERVICES

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Possibility in every drop

Table of content

Introduction

The introduction highlights the effectiveness of pressure management in addressing issues like reducing NonRevenue Water (NRW), improving energy efficiency, and cutting operation and maintenance costs. It emphasizes the significance of precise predictive models for burst frequency and suggests that extended asset life is expected to be a significant benefit of pressure management. The article discusses challenges faced by municipalities regarding high NRW levels and inefficient management of distribution system pressures, which lead to excess leakage and infrastructure damage. It also acknowledges emerging concerns regarding water scarcity, water quality, and energy costs. Despite these challenges, there's an expectation for the water market to grow rapidly, prompting the need for new and efficient water solutions. Pressure management is recognized as crucial for optimal water supply and distribution system management, with proven benefits including water conservation, reduced bursts and leaks, lower repair costs, and improved customer service. The article aims to explain these benefits using the latest research, best practices, and advanced tools, focusing on three main areas: Non-Revenue Water, energy efficiency, and operation and maintenance costs.

What Do We Mean by Pressure Management?

Pressure management can be defined as ***"the practice of managing system pressures to the optimum levels of service ensuring sufficient and efficient supply to legitimate uses and consumers, while reducing unnecessary or excess pressures, eliminating transients and faulty level controls, all of which cause the distribution system to leak unnecessarily"*** Definition by the Pressure Management Team of the Water Loss Specialist Group of the International Water Association (IWA)

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Recent Historical Perspective

In recent years, there has been a notable increase in focus on pressure management within potable water distribution systems, driven by the recognition of its numerous benefits. This surge of interest can be traced back to tests conducted on Japanese and UK distribution systems in the 1980s, which revealed a strong relationship between pressure and leak flow rate, contrary to the theoretical square root relationship between pressure and discharge velocity. Subsequently, in 2003, the Pressure Management Team of the IWA Water Loss Task Force began compiling research and advocating for pressure management practices, leading to the widespread adoption of FAVAD (Fixed and Variable Area Discharges) as a best practice concept for predicting pressure-leak flow relationships. Prior to this, the correlation between pressure management and burst frequency reduction was not widely recognized, and few practitioners believed in its efficacy beyond controlling pressure transients. However, Thornton and Lambert's publications in 2006 and 2007, which presented data from 10 countries demonstrating significant reductions in burst frequencies after implementing pressure management, along with explanatory concepts and practical methods for identifying zones with potential burst reduction, played a crucial role in shifting this perspective.

Fixed area orifice: Leakages in cast iron pipes are behaving as a fixed area orifice.
With such a leak the leakage flow depends on the pressure according to q=K p^n where n=0.5

Pressure dependent area orifice: With pressure dependent orifice areas the orifice in the pipe opens with the pressure. This means that the leakage flow increases faster with pressure than in the case with a fixed area orifice. With such a leak the leakage flow depends on the pressure according to q=K p^n where n>0.5. In a network with different types of pipes an n value around 1 is typically a good choice (A. Lambert, 2000)

The increased international interest in pressure management stems from its potential to reduce burst repair and associated costs, leading to improved asset management. Since 2007, numerous pressure management schemes have been implemented globally, with their benefits widely accepted, including reduced leak flow rates, possible reduction in burst frequency, and extension of asset life. To justify investments in pressure management, water utilities need to predict these benefits, with Lambert, Fantozzi, and Thornton's 2013 research providing insights into pressure-burst relationships. Other advantages include lower active leakage control costs and improved customer service due to fewer supply interruptions. Pressure management is now utilized not just for leakage control but also for demand management, water conservation, and asset management. A format introduced in recent Australian research project summaries various pressure management benefits, categorized into leakage, energy efficiency, and operation and maintenance costs, which are further discussed in the subsequent sections.

Pressure Management: Reduction Of Excess Average And Maximum Pressures								
Conservation Benefits			Water Utility Benefits			Customer Benefits		
Reduced Flow Rates			Reduced Frequency Of Bursts And Leakes					
Reduced excess or unwanted consumption	Reduced flow rates of leaks and bursts	Reduced and more efficient use of energy	Reduced repair and reinstatement costs, mains & services	Reduced liability costs and reduced bad publicity	Deferred renewals and extended asset life	Reduced cost of active leakage control	Fewer customer complaints	Fewer problems on customer plumbing & appliances

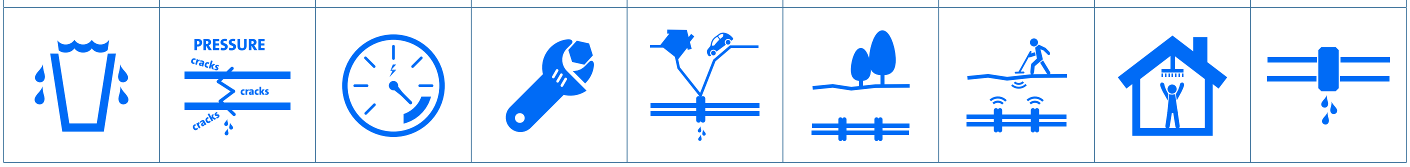

Figure 1: *Multiple benefits of pressure management*

Issue 1: Leakage Component of Non-Revenue Water

High levels of Non-Revenue Water (NRW), defined as the difference between water put into the distribution system and water billed to consumers, pose significant challenges to the financial viability of water utilities due to lost revenues and increased operational costs. The global cost of NRW is estimated at USD 14 billion annually, with a significant portion occurring in the developing world. NRW comprises unbilled authorized consumption and apparent losses, both minimally affected by pressure management, and leakage and overflows from water utility transmission and distribution systems, which can be substantially reduced through pressure management. The leakage component of NRW, varying from 95% to 50%, is influenced by apparent losses levels, with systems featuring customer storage tanks experiencing higher levels. Pressure management can effectively reduce both the frequency and flow rates of leaks, thereby cutting costs associated with water production, distribution, and energy consumption. Intelligent pumping solutions and advanced pressure reducing valves can contribute to these efforts, but careful identification of areas within the distribution system that will benefit most and selection of appropriate pressure management methods are crucial.

> The best long-term solution is to design systems to operate continuously at moderate pressures
> (Pearson and Lambert, 2013)

Issue 2: Energy Efficiency

Water supply systems consume vast amounts of energy throughout various stages including water abstraction, treatment, and distribution. Energy ranks as the highest operating cost item after manpower for most water companies, with significant annual spending by water and wastewater systems, projected to increase by over 20% in the next 15 years. Approximately 90% of energy in water distribution is consumed by pumping systems, representing a substantial portion of total life cycle costs for pumping stations. Energy efficiency presents a significant opportunity for cost reduction, particularly in anticipation of rising energy prices. Developing solutions to reduce energy usage and costs is crucial for efficient water distribution system management. Historically, control functions in water management systems prioritized operational constraints without adequately addressing the drawbacks of high pressure settings, primarily due to the lack of appropriate technologies and knowledge regarding the consequences and costs associated with excessive pressure.

Pressure Management Has Produced Measurable Benefits

Grundfos has built up considerable experience with pressure management using the company's Demand Driven Distribution solution. In the following three cases the potential for energy savings using pressure management is demonstrated by using the Demand Driven Distribution solution, showing the benefit of the control approach. In addition, experience has shown that additional savings of up to 50 % can be harvested by replacing existing pumps with the latest pump solutions.

Case 1: Bucharest, Romania
APA-NOVA Bucharest has recently implemented new Grundfos solution for pressure management in one pumping station in Bucharest. The primary purpose of the controller is to optimise the pump delivery pressure into the city to reduce leakage and energy use – and at the same time maintaining good customer service. Changing the pumps from running at constant pressure to proportional pressure with Grundfos Demand Driven Distribution has had the following effect:

- **Energy consumption reduced by around 15 %**

Case 2: Talca, Chile
Essbio in Chile had a challenge in delivering good customer service, as well as improving the efficiency at the Tejas Verde plant. Grundfos implemented a pressure management Demand Driven Distribution controller at the start of 2013, achieving the following:

- **Energy consumption reduced by around 28 %**

Case 3: Skagen, Denmark
Frederikshavn Forsyning, the water utility serving Frederikshavn municipality in Denmark, has a proven track record in successful pressure management implementation. An example is the Skagen district, where the installation of the Demand Driven Distribution controller allowed better protection of the system, achieving:

- **Energy consumption reduced by around 17 %**

Issue 3: Operation And Maintenance Costs

Europe has an extensive water distribution network spanning 3.5 million km, posing various challenges for water utilities. Over the next few decades, significant investments, estimated at EUR 20 billion annually, will be required for the rehabilitation of these networks. To optimize these investments, strategic prioritization and dynamic pressure management tools are crucial. By employing such tools, water utilities can save up to USD 2 billion annually. Recent studies have shown that reducing excess pressure in areas with high burst frequencies can substantially decrease bursts. By analyzing burst frequencies and pressure levels, utilities can effectively target zones for pressure management, resulting in faster payback and reduced infrastructure damage.

Recent research has provided improved predictions for a whole range of burst frequencies and how pressure management provides benefits (Lambert, Thornton & Fantozzi 2013). It is important to point out that big savings can be achieved in many cases by a quite small reduction in pressure, as shown in Figure 2.

Figure 3 shows actual and predicted changes in repair frequency on mains in the Durban Central Business District (CBD), South Africa, using both prediction methods, for mixed mains materials (AC, plastic, steel, cast iron). The seasonal variations in burst frequency were much reduced on both mains and services, with corresponding significant reductions in overall repair costs.

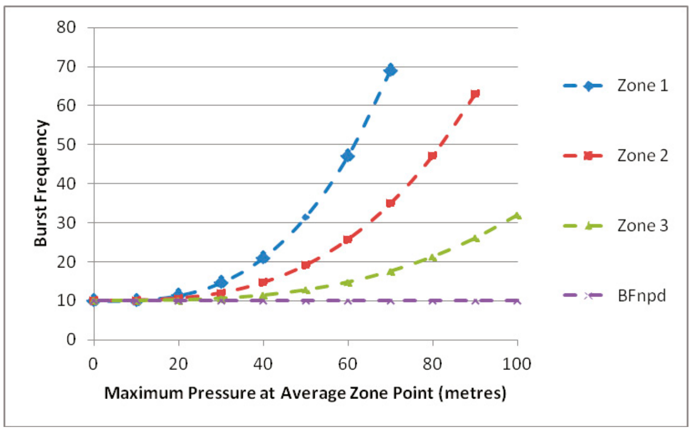

Figure 2: *Characteristic relationship between AZPmax and burst frequency for individual zones (reproduced with the permission of WLRand Ltd)*

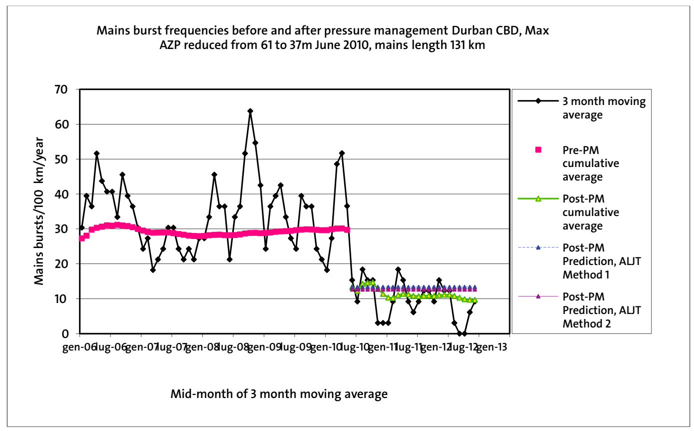

Figure 3: *Mains repair frequencies pre- and post-pressure management, Durban CBD showing more than 50% drop in burst frequency, and therefore similar savings in maintenance costs (reproduced with the permission of Ethekwini Municipality)*

Recent established relationships between pressure and burst frequency, as depicted in Figures 2 and 3, are now being utilized to predict changes in burst frequency in various countries and situations. However, the most significant financial benefits are likely to come from deferred pipe renewals and extension of asset life. Significant reductions in burst frequencies due to largescale pressure management are influencing decisions on which pipes to renew each year. Water utilities are beginning to retain some mains and services that would have been replaced otherwise, leading to substantial financial savings. Careful analysis is required to identify the parts of the distribution system that will benefit most from pressure management and to assess specific benefits accurately. Some utilities are concerned about potential revenue losses after pressure reduction, as changes in system pressure can affect metered consumption. Prediction models developed in Australia allow for estimating changes in consumption based on various factors. However, whether consumption reductions from pressure management are considered beneficial or costly, they typically represent a small portion compared to reductions in leak flow rates, burst frequency, and infrastructure life extension. Financial implications should be calculated to predict and identify the impact on the water utility's revenue.

Benefits For Resource Management, Customers and Communities

Additional benefits from pressure management include:

Water resource management: Pressure management allows utilities to adjust pressure based on demand cycles, ensuring minimum service standards at customers' premises. During droughts, pressure can be further reduced to conserve water, avoiding the need for intermittent supply, which can increase burst frequency and damage the distribution system. Some countries mandate reporting of average pressure along with water balance calculations and NRW indicators, promoting best practices.

Improved customer service: Regulators emphasize customer service metrics like interruption frequency and continuity of supply. Pressure management schemes are designed to comply with these criteria in a cost-effective manner, enhancing service quality.

Minimized community disruptions: Pressure management reduces disruptions caused by water main bursts and system failures, leading to fewer lost productivity hours and lower repair costs.

Protection of customers' plumbing: National plumbing standards specify maximum permitted pressure levels to extend the life of customers' appliances and reduce noise. Pressure management helps meet these standards, minimizing damages to customers' plumbing systems.

Reduced liability costs: Catastrophic water pipe failures result in water loss, expensive repairs, and disruptions to consumers' lives. Pressure monitoring and management can mitigate these failures, reducing their frequency and impact, saving costs for the utility, and improving customer satisfaction.

Opportunities and Solutions

Consistent with the latest research results and with achievements by advanced water utilities, pressure management represents one of the biggest opportunities to improve water utility performance. Figure 4 summarises the various benefits of improved pressure management related to problems facing water utilities.

Problems Facing Water Utilities, and Benefits with Different Modes of Operation			
	Intermittent Supply: (Not "24/7" Operation)	**Continuous Supply: (Excess Pressure)**	**Optimal Pressure Management: (Demand Driven Distribution)**
Nrw – High Leakage Component	Leakage flow rates reduction due to limited time of pressurisation. Very high burst frequencies on mains and services. Big risks of contamination when the pipes are not pressurised.	High burst frequencies due to higher than required maximum pressures for much of the time. High leak flow rates due to higher than required average pressures.	10% reduction of average pressure produces 10% to 20% reduction in annual leakage (depends on pipe materials and type of leaks). Experience from delivered projects of DDD since 2014 show that leakage is reduced by 15% on average, and pipe burst frequency by 35%.
Energy Efficiency	High energy costs for pumping as higher flow rates are imposed to move the same volume.	Excess energy costs due to excess pressurisation from pumping.	10% reduction of excess average pressure produces around 10% decrease in energy costs from pumping. Experience from real installations with DDD since 2014 show energy savings of 25% on average.
Operation and Maintenance	High manpower costs for valving operations. High repair costs.	High repair costs. High liability costs.	10% reduction of average pressure decreases economic intervention costs of active leakage control by 10%.
	Active leakage control is difficult due to insufficient pressure.	High active leakage control costs due to higher rate of rise of unreported leaks.	10% reduction of average pressure decreases economic intervention costs of active leakage control by 10%.
	Short asset life time due to poor operation and pressure transients.	Short asset life time due to excess pressure.	Deferred renewals, residual asset life extension. This benefit can be very substantial; prediction methodology for pressure reduction being developed.

Figure 4: *Three different control approaches evaluated against their effect on water leakage, energy efficiency, and operation and maintenance costs*

Pressure management entails identifying and minimizing pressure transients to mitigate adverse effects and transitioning from intermittent to continuous supply, even at lower pressures if necessary. By controlling pressure transients and maintaining lower continuous pressure, bursts can be reduced, leak flow rates minimized, and asset life extended, leading to significant budget savings for water utilities. Methodologies exist to calculate payback periods and financial benefits for different pressure management options. Leveraging smart pumping technologies and pressure-reducing valves can address water challenges effectively. However, there's a need for a robust business case for pressure management technologies to replace heavy capital expenditures, emphasizing potential annual savings. Widespread adoption of pressure management requires concerted efforts from stakeholders to overcome challenges like lack of awareness, funding, and political/regulatory support. Regulatory incentives can kick-start pressure management, especially in water-scarce areas where water efficiency is critical.

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Resolving Issues With Pressure Management

Pressure management is a vital technology for enhancing water distribution network operation. Grundfos offers a Demand Driven Distribution solution that efficiently manages network pressures. It utilizes battery-driven data loggers transmitting data to a controller via the GSM network, enabling smart adaptive control of pumping stations without extensive analysis or system reconfigurations. The controller employs pressure ramping to prevent pressure transients, reducing the risk of piping cracks. This system adapts pressure control based on operational conditions, optimizing service levels and generating savings from reduced non-revenue water, enhanced energy efficiency, and lowered operation and maintenance costs. It is effective in various scenarios, including continuous supply, drought, and intermittent supply management. Ongoing advancements in pressure management focus on intelligent technologies, pressure-burst relationships, validation of scheme results, transient analysis, and management in very lowpressure zones.

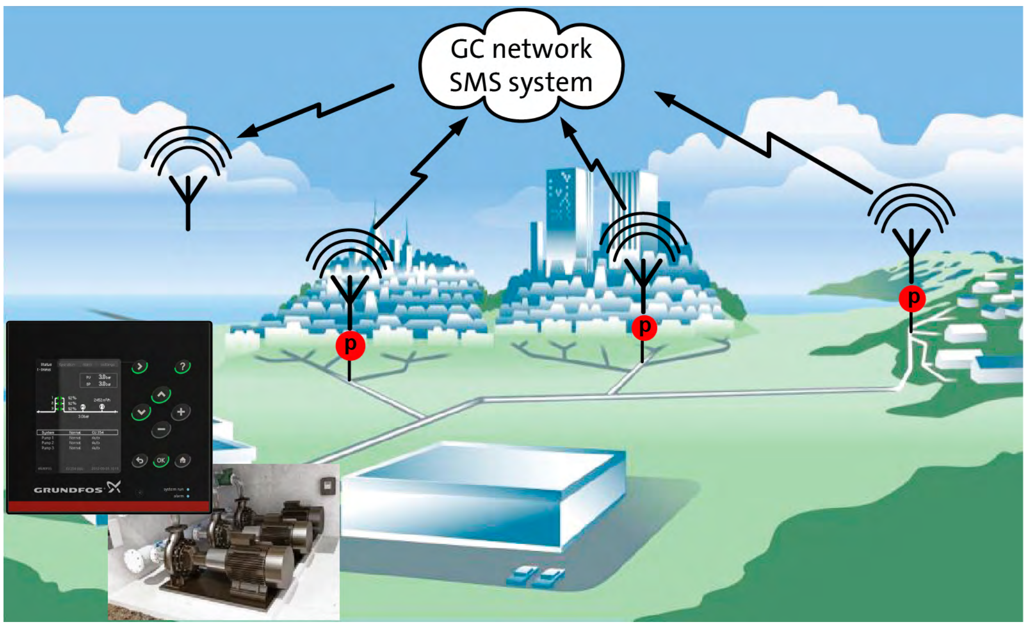

Figure 5: *The Demand Driven Distribution controller connected to network pressure sensors via the GSM network allows control of the pumps in accordance with the logger data via a smart adaptive control algorithm*

Conclusion

Pressure management offers significant financial savings for water utilities and is a timely opportunity to address challenges in water resource management. With ample knowledge about its benefits and success stories from various utilities, pressure management is now more achievable than ever. Demand Driven Distribution from Grundfos provides an effective solution for pump systems, addressing key issues and delivering substantial benefits for resource management, customers, and communities. It enables utilities to vary pressure based on demand cycles, improve customer service, minimize disruptions, protect plumbing, and reduce liability costs. Overall, pressure management is a valuable tool for utilities to enhance efficiency and service quality while addressing pressing water management challenges.

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List Of References

IWA Water Loss Specialist Group:
(http://www.iwahq.org/r8/networks/specialistgroups/list-of-groups/water-loss.html)

Lambert A, (2000):
What do we know about pressure: Leakage relationships in distribution systems? IWA Conference on System Approach to Leakage Control and Water Distribution Systems Management, Brno, Czech Republic, 2000.

Lambert A, (2002):
International Report on Water Losses Management and Techniques: Water Science and Technology: Water Supply Vol. 2, No. 4, August 2002

Thornton J and Lambert A (2006):
Managing Pressure to reduce new breaks. Water 21, Dec. 2006, 24-26

Thornton J and Lambert A (2007):
Pressure management extends infrastructure life and reduces unnecessary energy costs, Water Loss 2007: Conference Proceedings, Bucharest -Romania, 23-26 Sept. 2007.
(http://173.254.28.127/~leakssui/wp-content/uploads/2012/11/2007_ThorntonLambert-IWABucharest-2007P.pdf)

Lambert A, Thornton J, and Fantozzi M, (2013):
Practical approaches to modeling leakage and pressure management in distribution systems – progress since 2005. 12th International Conference on Computing and Control for the Water Industry, Perugia, September 2013 Leakssuite
(http://www.leakssuite.com/wp-content/uploads/2012/11/CCWI_Sep2013paper_PressureburstsALMFJT-1-2003-2013K1.pdf)

Pearson D and Lambert A (2013):
Accounting for Water Leakage and Managing Performance, 'Sustainable Cities, building for the future'; Climate Action, United Nations Environment Programme (UNEP), June 2013. ISBN: 978-0-9570432-8-2

DOE, HI, Europump (2001):
Pump Life-Cycle costs: A Guide to LCC analysis for pumping systems, US Department of Energy's Office of Industrial Technologies (OIT- DOE), Hydraulic Institute, Europump.

Abelin, S., Pritchard, M., Sanks, R. (2006):
Chapter 29 – Costs, in Jones, G, Bosserman, B., Sanks, R., Tchobanoglous, G. (eds), Pumping Station Design – Third Edition, Elsevier, EUA, 2006, ISBN 978-0-75067544-4.

Veness, J (2007):
Pump Energy Reduction - A Systems Approach, article presented in Institute of Mechanical Engineers, 2007, United Kingdom.

SENSUS (2012):
Water 20/20 Bringing Smart Water Networks into focus, 2012.

EUROSTAT (2009):
Panorama of Energy - Energy statistics to support EU policies and solutions, EUROSTAT statistical books, European Commission, ISBN 978-92-79-11151-8

Energy and Water Department (EWD) of the World Bank Group (2006):
Kingdom, B, Liemberger, R, Marin, P, The Challenge of Reducing Non-Revenue Water (NRW) in Developing Countries. How the Private Sector Can Help: A Look at Performance-Based Service Contracting

Lambert A and Fantozzi M (2010):
Recent Developments in Pressure Management. Proceedings of IWA Special Conference 'Water Loss 2010', Sao Paolo, Brazil, June 2010.
(http://173.254.28.127/~leakssui/wp-content/uploads/2012/11/2010_LambertFantozziSaoPaoloIWAl-2010H.pdf)

WSAA (2011):
Framework for Targeting Leakage and Pressure Management. Report for Water Services Association of Australia, by Wide Bay Water Corporation and Water Loss Research & Analysis Ltd, May 2011, as part of WSAA Asset Management Project PPS-3, Review of Leakage Reporting and Management Practices, Stage 3

Pearson D, Fantozzi M, Soares D, Waldron T (2005):
Searching for N2: How does pressure reduction reduce burst frequency? Leakage 2005: Conference Proceedings, Halifax, Canada, September 2005.

Lambert A and Thornton J (2011):
The relationships between pressure and bursts – a 'state-of-the-art update'. Water 21, April 2011, 37-38

LAPMET software (2011):
Leakage and Pressure Management Evaluation and Targeting software. Australian Version 1b , May 2011. ILMSS Ltd Leakssuite
(www.leakssuite.com)

Lambert A and Fantozzi M (2008):
Recent developments in predicting the benefits and payback periods of introducing different pressure management options into a zone or small distribution system, Second International Conference on Water Loss Management, Telemetry and SCADA in Water Distribution Systems, Ohrid, Macedonia, June 2008
(http://173.254.28.127/~leakssui/wp-content/uploads/2012/11/2008_FantozziLambertMacedoniaIWA-2008L.pdf)
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