

EU LIFE PALM PROJECT - DEFINING THE OPTIMUM LEVEL OF LEAKAGE

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ABSTRACT

Water is probably the world's most precious natural resource. Without it, there would be no life. Yet it is often managed in a haphazard and inefficient way. As a result, water networks variably leak as much as they deliver. In extreme cases, it is even necessary to interrupt the service at night, because the supply is insufficient to satisfy the demand. Technology has been available now for many years to reduce and control leakage which has yielded impressive results. Even so, water utilities seem reluctant to apply it, preferring instead to blame the climate or the illegal consumption of the customers, for the shortage. In addition to the huge environmental and social impact, a high leakage level also represents a significant economic loss. This is because of the need to treat and pump the water to the customers. However, locating and repairing the breakages also has a cost. The key then is to find, for every network, the optimum balance between the degree of intervention and the value of the recovery. This is the objective of the PALM project, co-financed by the EU's LIFE Programme, which involves leading international experts in the field of leakage management. The work is based in Perugia in central Italy, which represents an ideal test bench due to the complexity of its network and the extensive experience of controlling leakage with DMAs acquired over the last 15 years. It's hoped that the development of the freely available software called Efficiency Calculator, will stimulate many water utilities to achieve the economic benefits of reducing leakage whilst at the same time improve the quality of service to the customers.

1 INTRODUCTION

Water is probably the world's most important natural resource. Without it, there would be no life. It is a sad reality then, that over 5 billion, or around two-thirds of the world's projected 2025 population, will live without an adequate supply. As the UN Secretary-General highlighted in his 2011 World Water Day declaration, the reasons are many: "I urge Governments to recognise the urban water crisis for what it is – a crisis of governance, weak policies and poor management rather than one of scarcity".

An important cause of this crises is the high level of leakage found in many water networks all over the world and in particular the lack of importance and resources given to it by the water utilities. This stems largely from the misguided idea that all leaks are visible on the surface. Experience shows convincingly however, that this is not the case,

as soil conditions and the location of other underground services, including sewers, can easily drain away the leaking water.

Acoustic technology has been developed over the years to assist in locating invisible leaks. This is based on the principle that a leak in a pressure systems generates a noise. Eliminating all the breakages is unlikely to be sufficient to maintain a low leakage level, over time. This is because the repair of one leak will invariably cause another one to break out. It is therefore essential to create a control system, which allows the leakage level to be assessed at a regular intervals, preferably daily, and maintain the optimum pressure in the network at all times. This requires the division of the network into sectors, usually referred to as District Meter Areas (DMAs), supplied by a single pipe in which is installed a flow meter and a pressure reducing valve. In this way, it is possible not only to identify immediately the presence of a new leak, but to direct the detection exercise to the part of the network where it is located.

In addition to the social and environmental damage, a leak also has an important economic impact (Pearson, Trow). This derives in part from the investment required to eliminate it, which can vary from a simple spot repair, to the replacement of the whole pipe, but which is compensated for by the significant savings in production costs. It follows therefore, that there is economic level of leakage (Lambert, Lalonde), which maximises the return on the investment. Defining this point for all networks irrespective of their specific characteristics is the objective of the innovative PALM project (Pump And Leakage Management) co-financed by the EU LIFE programme, and which involves a number of leading international experts in the field of leakage management.

2 LEAKAGE REDUCTION AND CONTROL

Water Loss is the difference between the quantity supplied and that which is consumed. It is composed of two components: commercial and physical losses. The former includes inaccuracies in the measurement and illegal use and typically represents less than 20% of the total losses by volume of which only a small proportion can realistically be recovered. Physical Losses are due to breakages of the pipes and experience in many parts of the world has shown that this is by far the most significant component both in terms of volume and value. As only a change in Physical Losses will significantly affect the quantity of water produced, it is the only component which will be considered in this paper.

Finding an invisible leak a few millimetres in diameter in hundreds of kilometres of network is literally a 'needle in a haystack' type problem. The solution is to divide the network into a number of sectors, referred to as DMAs, containing around 10 km of pipework, each supplied by a single pipe on which is installed a flow meter. In this way, by regularly monitoring the flow, particularly at night when the customer consumption is a minimum, it is possible to accurately identify the presence of new leak and know in which part of the network it is located.

Permanently dividing a complex and interconnected network into sectors is a delicate operation, which could lead to serious supply problems if not undertaken with great care. The solution is to apply a well calibrated hydraulic model which simulates the operation of the real network in all of its key characteristics. In this way, by highlighting those pipes which have little or no hydraulic importance, it is possible to determine the optimum configuration of the DMAs which can be created in the field

without any supply problems.

One consequence of a leak in a pressurised system is the generation of a noise. This is the operating basis of instruments such as correlators and ground microphones which have been specially developed to locate hidden leaks in water networks with remarkable accuracy. By listening to the same noise from two microphones positioned a measured distance apart, and knowing its velocity of propagation in the pipe, it is possible to determine the exact position of the leak.

The amount of water leaking from a breakage in the pipe is dependent on the operating pressures, which in turn is a function of the flow. This means that when a leak is repaired, it could have the effect of increasing the network pressures, causing other existing leaks to grow or, when the structural integrity of the pipe is poor, for new leaks to form. The answer is to control the pressure (Farley, Trow). This can be done by installing a pressure reducing valve (PRV) on the DMA inlet which will not only maintain the original operating pressures after the leaks have been eliminated, but can also be programmed to reduce the pressure at night to reduce the residual leakage. It should be noted that such a configuration ideally requires a single supply pipe, which is usually possible only when a hydraulic model has been applied to design the DMA boundary.

Although controlling pressure will lower the leakage level, it is unlikely that it will be enough to significantly reduce the leakage level without also eliminating the breakages either by repairing or, when the condition is poor, replacing the pipe. It follows therefore that the more leakage is recovered, the more the cost will increase. If the network is completely renewed, even zero leakage is theoretically possible. Although such an intervention is highly unlikely in reality, it should not be discounted as the decision is entirely dependent on the value of the water and the cost of the intervention.

3 BENEFITS FROM REDUCED LEAKAGE

A water network typically evolves in response to the growing needs of the population that it serves. Surface sources are often the first to be exploited. Then as the demand exceeds supply, new and more expensive resource has to be developed, usually by exploiting underground aquifers. As more and more water is extracted, the available resource risks becoming depleted and contaminated, leading to even more expensive treatment and pumping. In extreme cases, particularly when the existing sources are unable to satisfy demand, desalination has to be introduced, which is very expensive and environmentally unfriendly due to the huge amount of pumping required in the process.

It follows therefore that as the production increases, so will the cost. On the other hand, if the leakage is recovered, production will decrease as will the production cost. This decrease is not linear, as a lower production requirement allows not just the elimination of the most inefficient sources, but also the exploitation of the cheaper electricity tariffs for the more efficient plants. In fact, when demand is high, it is usually necessary to maximise production just to keep the reservoirs full. Recovering the leakage reduces the drawdown of the reservoir allowing them to be filled mainly at night.

The PALM project will take into account the potential to improve efficiency by reducing production. In this way, it is hoped to stimulate not just the water utilities to drastically lower leakage levels, but also for regulating authorities to apply easily determined economically levels, instead of relying on arbitrary percentage value as is often the case today.

4 PALM PROJECT

It is clear therefore that reducing leakage allows potentially a significant economic return, which will offset the cost of intervention. The objective of the PALM project is to find for every network this optimum level. The project, which is based in Perugia, Italy, is co-financed by the EU's LIFE Programme and involves expert staff from three international companies some of which having a long and distinguished experience in leakage management,. The water network of Perugia, which dates back to the 14th century, is currently managed by Umbra Acqua SpA. which is part of the ACEA group in Rome.

The definition of the optimum level of leakage will be achieved by the creation of the "Efficiency Calculator". This will be a feely available software, where the main characteristics of the network will be inserted and an assessment made of the scope for reducing leakage. The key data required will include the following:

- Current production volume;
- Customer consumption volume;
- Characteristics of the sources,
- Characteristics of the pumps;
- Capacity of the reservoirs;
- Length of main;
- Energy costs;
- Treatment costs;
- Intervention costs;
- Cost / m³ of developing new sources in the case of intermittent supply or insufficient current production.

It is recognised that the information available within the water utilities is often incomplete and not always updated. One example is for the pumps. Even if the characteristic curve is available, it invariably refers to the operation of the pump when it was new and not to its current efficiency which has reduced with wear. Consequently a typical factor will be applied which will be derived from the testing in Perugia. In addition, the delivery resulting from a combination of pumps is invariably lower than the sum of the single units. Again, a typical factor will be derived from the project. Very few water utilities have detailed information about the cost of creating a permanent leakage control system and locating and eliminating the leaks. The Perugia network will be used to collect this information, supplemented by data derived from other projects undertaken by the partners.

Perugia is situated at the foot of the Apennine mountains where two of the spring sources that supply the city, are located. These spring sources alone are not enough to satisfy the demand even with the activation of a large booster at the Nocera spring. The production is therefore augmented by three large ground water sources down in the Valley in the vicinity of Assisi. In addition to the pumping from the numerous wells,

this water has to be boosted to the city, which makes it a vastly more expensive. Furthermore, the Petrigiano source has a high nitrate concentration which has to be eliminated by a costly biological treatment plant and dilution from the nearby Cannara source. The city is supplied by a series of reservoirs which are situated at different ground levels and which, in addition to providing storage, break the pressure down the hill as illustrated in Figure 4.1. The current leakage level is in excess of 30%.

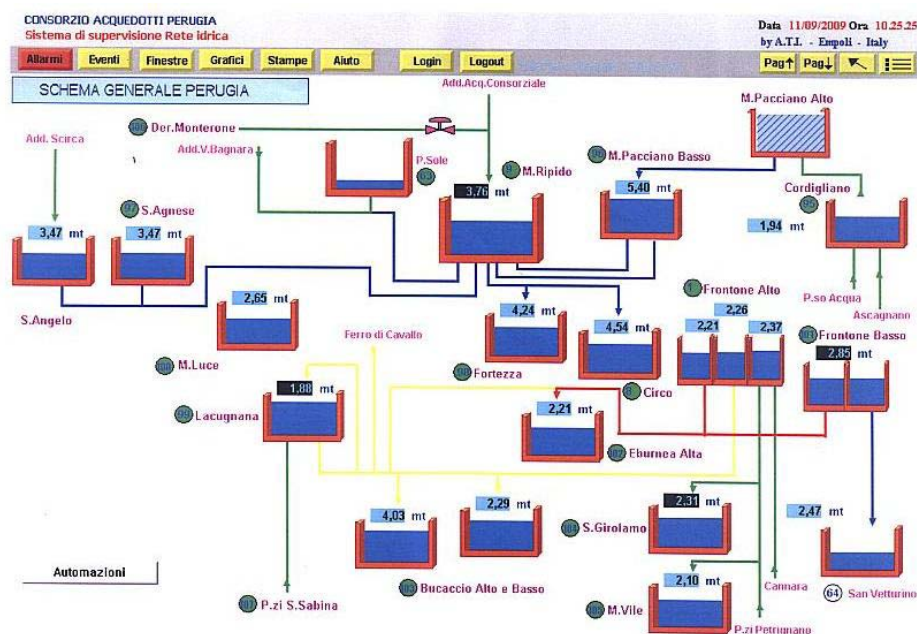


Figure 4.1. Configuration of the Perugia network

The Perugia network was chosen for the following two main reasons:

- Its complexity with 2 spring and 3 ground water sources, over 80 pumps and around 20 reservoirs;
- It represents one of the first cities in Italy to apply DMA technology to control leakage around 15 years ago.

The Perugia application will serve not only to collect the information required to create the Efficiency Calculator, but also to verify its overall accuracy. In particular, all pumps will be tested, together with the potential combinations so that realistic efficiency values can be derived. All of the service reservoirs will be surveyed to determine the typical accuracy of the historical plans. A hydraulic model will be constructed for two pilot distribution areas in which at least 5 DMAs will be created. One pilot area will be in the urban network and the other in the rural area. The model will be fully calibrated by comparing the calculated pressures and flows with those recorded during a field test. Any difference will indicate an incomplete historical knowledge of the network, which must be resolved. In fact, without the calibration activity, the model cannot be considered reliable enough to be applied to the design of the DMAs. All the leaks will be located and repaired so that the typical cost / recovery

curve can be determined.

In addition to the distribution models for designing the DMAs, a strategic model of the network will be constructed and calibrated. This will be a simplified model containing all the key elements of the supply network including the pumps, reservoirs, trunk mains and demand which will be divided between customer consumption and leakage. Once confirmed to be an accurate representation of the reality, it will then be used to determine the optimum production configuration at different leakage levels and compared with the Efficiency Calculator prediction. It is considered unlikely that the Efficiency Calculator will be perfectly accurate, particularly in view of the approximations that it contains. However, it will still be an extremely valid tool for determining the scope for optimisation of any network. In fact, the Perugia application, particularly considering its complexity, will however provide an useful guide to its effective validity.

5 EFFICIENCY CALCULATOR

The Efficiency calculator is a DSS which compares the cost of reducing leakage with the economic benefit obtained from improving the efficiency of production. It works by comparing the network's cost / recovery curve for reducing leakage, with the system production curve.

The major cost in recovering leakage occurs when pipes need to be replaced. Interventions such as pressure control and leakage repair, cost comparatively little and are sufficient to allow a 40 - 50% reduction in leakage. However, to then reduce further, requires the smaller leaks which might not necessary be detectable using acoustic methods, to be eliminated which usually means replacing the pipes. Zero leakage could theoretically be achieved if the entire network was replaced. A typical curve is shown in Figure 5.1 (Rogers, Bettin) to which will be applied the specific leakage value and replacement cost.

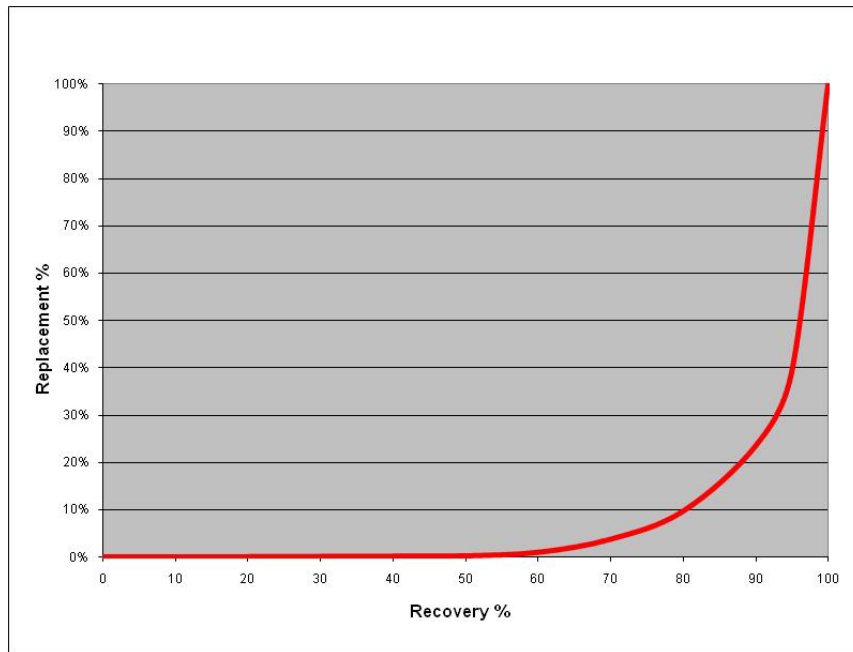


Figure 5.1. Typical Replacement / Recovery relationship

The saving that can be generated from recovering the leakage will be derived from the production curve of the network, similar to the one illustrated in Figure 5.2.

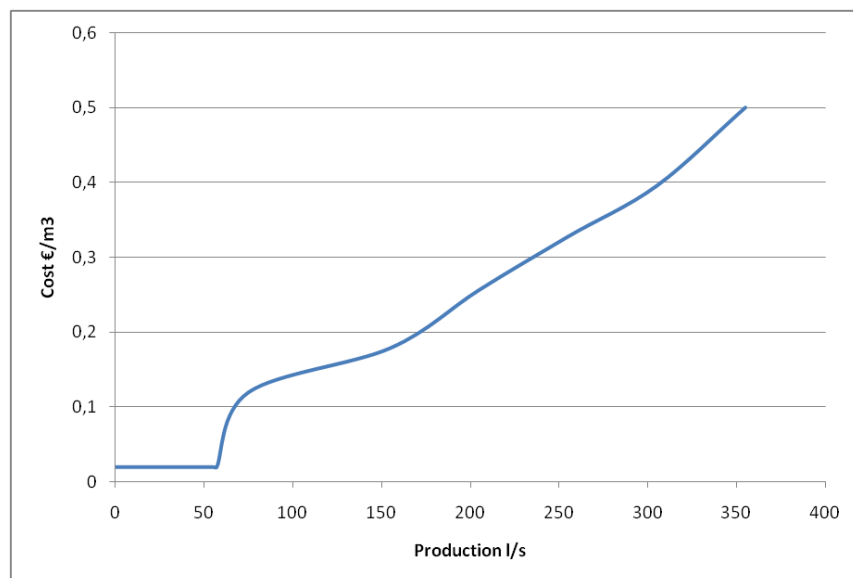


Figure 5.2. Typical Production / Cost curve

This shows how, for low production volumes, the costs are minimal, presumably due to the use of spring sources which require little treatment and no pumping. Then as the ground water sources are brought on line and the need for expensive treatment increases, so do the costs. The two network specific curves will be integrated and the optimum solution defined which will correspond to the shortest payback period.

Although the input data will be kept to a minimum to take account of the limited information typically available in water utilities, it will still be sufficient to provide a realistic representation of the situation, particularly with the application of the factors derived from the Perugia application. Where even this minimum level of information is not available, it is likely that the network is being poorly managed and a major data collection exercise is urgently required.

Having identified the optimum operating point and defined the target leakage level, it will be possible to determine which pumps and sources should be operated. In this way, the Efficiency Calculator will show clearly whether it is worthwhile undertaking such a detailed study in the first place and the benefits that can be derived.

6 CONCLUSIONS

Leakage is a problem which afflicts most water networks all over the world to varying degrees. In many extreme cases, high leakage is significantly reducing the quality of service to the customers and unnecessarily increasing the operational costs. The question is: if the situation is so bad, why aren't the water utilities intervening? The answer is complex, but lies in the lack of understanding of the network and the misguided belief that unless a leak is visible on the surface, it does not exist. In the meantime, the world continues to suffer the consequences of shortages believing that it is due to an insufficient availability and illegal or wasteful use, rather than any mismanagement.

An excessive leakage level represents a considerable economic loss. This is because of the high energy and treatment costs of operating the existing plants and developing new ones in an attempt to satisfy the demand. Recovering the leakage will therefore equate to a considerable saving. On the other hand, the recovery of leakage has a cost, not only in setting up DMAs to permanently control the level, but also to eliminate the breakages, whether by repairing or replacing the pipes. Whilst the economic return of eliminating leaks will increase the greater the quantity of leakage recovered, so will the cost of intervention. The key then is to find the optimum balance point. This is what the PALM project, co-financed by the EU LIFE Programme will define.

The project, which involves many leading international experts in the field of leakage management, is based in Perugia in central Italy. This network was chosen because of its complexity, as it is supplied by a combination of two spring and three large ground water sources, delivered through a total of over 80 pumps and around 20 reservoirs. In addition, Umbra Acque SpA, which is responsible for managing the water system, was one of the first Italian utilities to apply DMA technology almost 15 years ago and so has much historical data to assist in the evaluation. The work in Perugia will involve comparing the real performance with the information typically available in the utility database to define specific parameters which can then be applied to determine unique cost / recovery and cost / production curves for any water network. In this way,

it will be possible not only estimate the optimum leakage level, but the likely payback period. It is not intended that the Efficiency Calculator will replace a highly sophisticated hydraulic assessments; rather that it will be a starting point for deciding if such a detailed study is worthwhile and what are the likely benefits.

It is hoped that once the project is completed in 2013, the freely available PALM software will revolutionise the way the efficiency of a water network is assessed. By moving the question from a technical to an economic basis, where the full benefits of lower leakage rates are compared directly to the economic return, it will be possible to quantify the investment, justify the intervention, define the optimum operation of the sources and determine the return period for the benefit of the utility, the customers and the environment alike.

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