From intermittent water supply to 24/7. Approach and methodology to face water crisis.

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Abstract

The combined effect of climate change and increasing water demand accelerates the depletion of water recourses. This “new” environment pushes water managers to face unprecedented emergency situations. Most of the time, they face this situation through the interruption of the water distribution for some hours per day in order to allow the reservoirs to be safely filled. Unfortunately, once implemented IWS, to bring back the network to continuous supply is really challenging. IWS, in fact, due to continuous and uncontrolled valves operation, determines the increasing of burst frequency and the rapid deterioration of the pipe integrity. The repetitive opening and closing of water distribution generates pressure transients and big volume of air in the pipeline that are extremely negative for asset duration and network efficiency. IWS can also bring to water quality problems caused by contamination when the network is not pressurised.

The objective of this paper is to demonstrate, through the implementation of a successful case study, the methodology applied to restore the continuity of water supply in a network that, due to a significant reduction of water availability from the main source, had been forced to operate under IWS conditions. The pilot network under study, managed by Valle Umbra Servizi S.p.A, is in the province of Perugia in Italy in a well-known touristic area. Hitachi Aulos, has been commissioned to prepare the action plan to bring back the water network to a suitable level of service.

The methodology to establish continuous water supply has been based on the following actions: water audit, DMA set-up, pressure management, pressure transient elimination, advanced air control, leaks detection and pinpointing. As a conclusion, it can be stated that the benefit from leaks repair can be maintained over time only after the permanent removal of the causes that generate leaks. Thanks to the step by step application of the afore mentioned methodology the continuity of supply has been achieved and permanently maintained.

INTRODUCTION

IWS is no longer a phenomenon limited to emerging countries, but, unfortunately, is increasingly affecting even developed countries. The main reason is the combined effects of climate change and increasing water demand that accelerate the depletion of water recourses. In fact, due to the changing in precipitation regimes caused by climate change, the periods of droughts are more and more frequent even in areas characterised by temperate climate. This “new” environment pushes water managers to face unprecedented emergency situations. Most of the time, they face this situation through the interruption of the water distribution for some hours per day in order to allow the reservoirs to be safely filled. At the beginning, IWS is seen as a temporary situation before the implementation of structural interventions that takes longer time and generally bigger investments. Unfortunately, once IWS is implemented, to bring back the network to continuous supply (24x7) is really challenging. IWS, in fact, due to repetitive valve operation, determines the increasing of burst frequency and the rapid deterioration of the pipe integrity. The fast opening and closing of section valves to charge and discharge the network generates pressure transient and big volume of air along the flow. Both these phenomena are extremely negative for asset duration and network efficiency.

The paradox of water leakage, that in many cases exceeds 50% of the inlet volume, is more and more evident because in order to face the increasing demand and water scarcity the traditional approach is directed to exploit new water provisions, new wells, new treatment plants without focusing on leakage reduction.

Valle Umbra Servizi SpA (VUS) is the water utility that manage water and wastewater services in several administrations in the area of Foligno, Spoleto and Valnerina in the Perugia province, in the center of Italy. VUS manages 2.910 Km of distribution network serving 152.300 inhabitants. Norcia Municipality has a resident population of around 5000 inhabitants, with a high number of tourists. The water is mainly supplied by the Capregna source located near the town. Due to modification of precipitation regimes and to the frequent occurrence of drought periods, the availability of fresh water from this source has significantly decreased, during the last years, mainly in the summer season. From an average annual flow of 45 l/s, the flow measured in 2012 was only 19 l/s. In order to meet the increasing demand above all during summer, VUS management decided to operate intermittently turning off the water overnight downstream the service reservoir.

VUS, in the context of the severe water crisis experienced in the early summer of 2012, identified the need to commission an urgent assignment for the hydraulic analysis of the water distribution system of Norcia (Perugia), in order to plan interventions aimed to guarantee an adequate level of service and to bring back the network to 24/7 supply. Hitachi Aulos has been awarded the assignment to carry out the study and to deliver a plan of interventions.

ACTIVITIES CARRIED OUT AND METHODS

Initial Audit

Following acquisition of the old non-updated network maps and meetings with local water operators, a clear picture of the situation has been established. In order to check the reliability of the existing map and to update the pipe database, a comprehensive survey of the network was carried out. As a result, a detailed hydraulic scheme of the network showing main connections, boundary valves, reservoirs, wells, sources and distribution area was produced. Once the hydraulic scheme was completed and the network operation understood, a water audit was performed. The inlet flow was measured and the water consumption estimated using the data from the billing department of VUS.

As can be seen from the hydraulic scheme (Figure 1), from the Capregna source an average flow of 21 l/s is delivered to a distribution tank. From the intermediate tank an average flow of 10 l/s is delivered to the Norcia Reservoir and 7 l/s to Monte Oro Reservoir. 4 l/s is distributed directly from the intermediate tank to a separated DMA with 75 users. The main reservoir is also fed by wells (Fontevena) with an average flow of 9 l/s. The total distributed flow is therefore 34 l/s (including 1.5 l/s from a well plus 1.5 l/s from another well for the industrial area district). The initial water balance highlighted that the NRW was around 22 l/s (64% of the System Input Volume).

In order to allow the Norcia Reservoir to be filled in the early morning before the peak consumption, 2 outlets pipes (DN150 and DN200) from the reservoir were usually closed overnight. This kind of operation was generating continuous complaints from customers dealing with “dirty water” due to pipe sediment removal and transport. In some cases the sediment was even generating clogging of meters. Many customers were also complaining for high quantity of pressurized air exiting from their taps and generating vibration to their plumbing system mainly during the morning after the opening of the distribution valves downstream of the storage reservoirs.

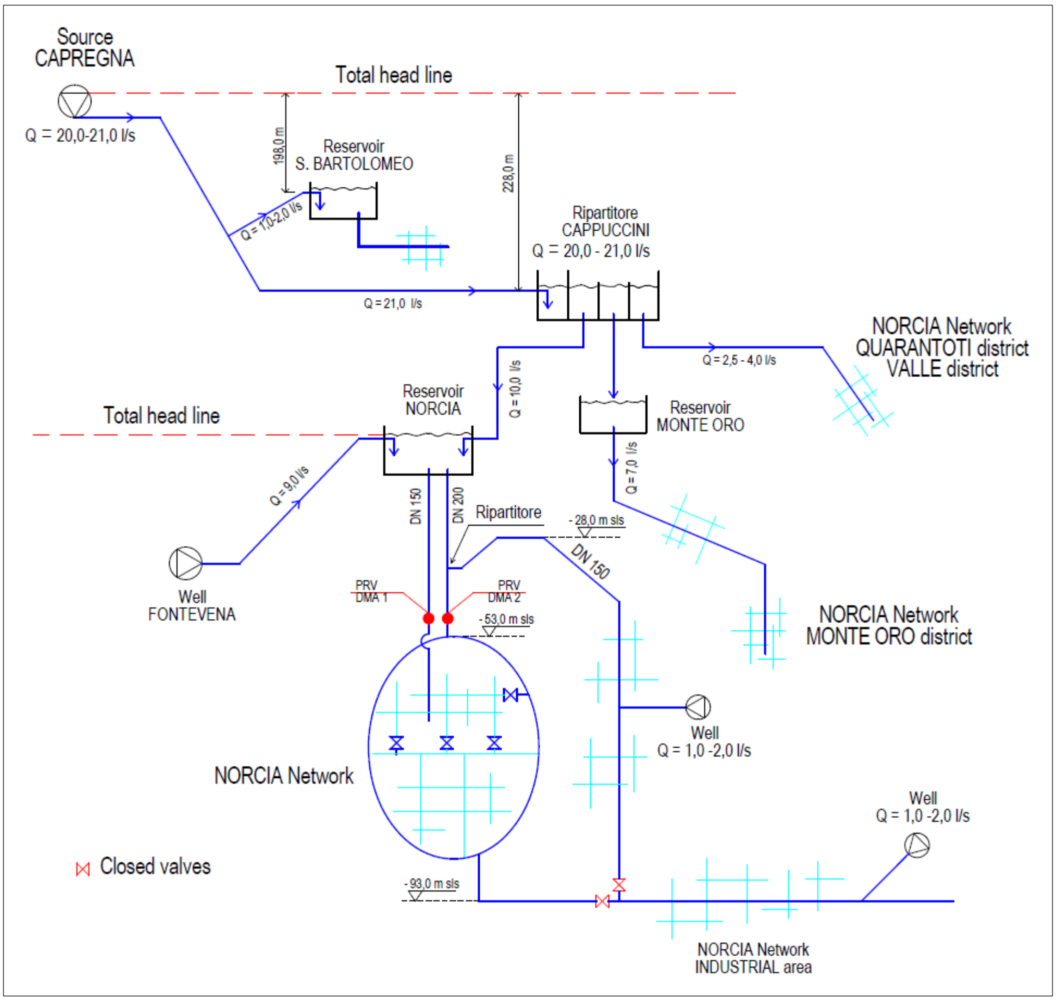

Figure 1 – The hydraulic scheme of Norcia water network. From source and wells to reservoirs and distribution. Highlighted in red the boundary valves that were closed to isolate 3 DMAs.

VUS reported frequent pipe bursts and a high level of water loss that was difficult to locate. The continuous operation of valves to open/close the water supply in a context characterized by uncontrolled pressure, is the best environment for the increase of pipe breaks and of the frequency of bursts. Moreover in such a contest the sole repair of leaks is not worthwhile. In fact, after the intervention, leakage generally returns back to the initial level in a short time due to the high leakage rate or rise typical of such cases.

The measurement of real losses has been obtained by analyzing the Minimum Night Flow (MNF) after assuring that the valves at the outlet of the reservoirs were open. Real losses, equal to 19 l/s, has been measures as the difference between MNF and legitimate night consumption.

Air and pressure transients control

Uncontrolled air in the network, typically present in conditions of IWS, determines several problems such as: high pressure surge, vacuum conditions, reduced cross flow, higher corrosion for metal pipes and parts, lower pumping efficiency, higher energy losses, inaccuracies in flow measurement, cavitation.

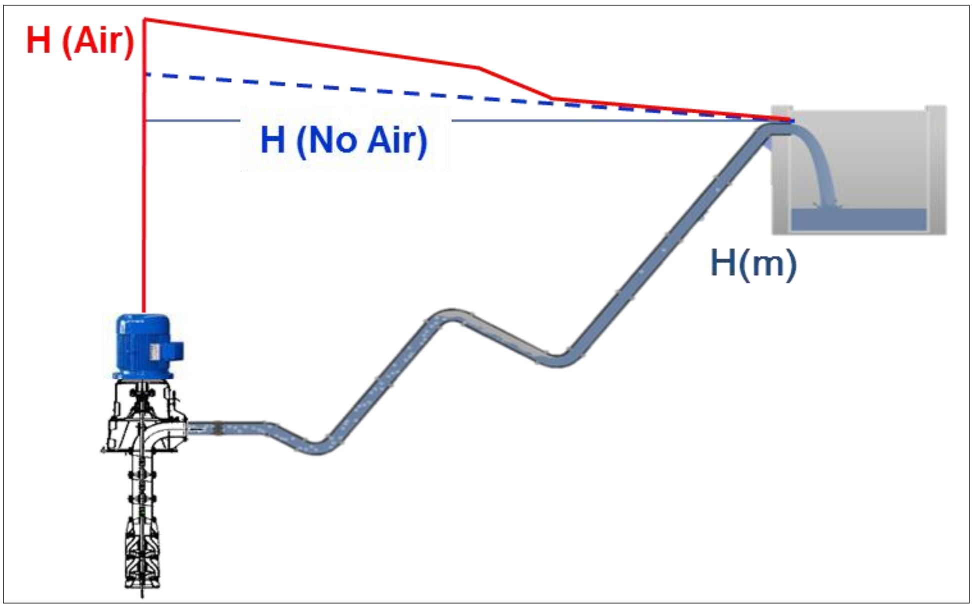

Figure 2 – Air pockets in piped systems reduces pump efficiency increasing energy consumption. As can be seen, pump head is higher with air inside the pipe (red line).

Due to the presence of air in the distribution pipes it was initially difficult to obtain a reliable measurement of the flow at the outlet of the reservoir. The measurement of pressure transient using special dataloggers with a recording time step of 5/100" highlighted the presence of pressure transients along the network. Negative pressure has been measured at one main hydraulic node, named "Ripartitore", located downstream the reservoir at -28 m from the static piezometric line, in the DN 200 feeding the lower area. As can be seen from the picture below, the negative pressure (related to atmospheric pressure) is equal to -7m. In parallel with negative pressure, due to pressure transient, negative flow was also recorded from the lower node (located at -93 m from the piezometric line) to the reservoir. This situation, probably exacerbated by the uncontrolled opening/closing of the reservoir outlet, was resulting in continuous water hammer highly detrimental to the integrity of the system and eventually responsible for the progressive increase of the number of bursts and pipe collapses.

In order to limit the detrimental effect due to the air in the pipe network and to reduce at the same time pressure transient an air control valve has been installed at the critical node named ("Ripartitore"). The valve has a threefold function: air venting, evacuation of large volumes of air and allowance of air into the pipe to avoid negative pressure.

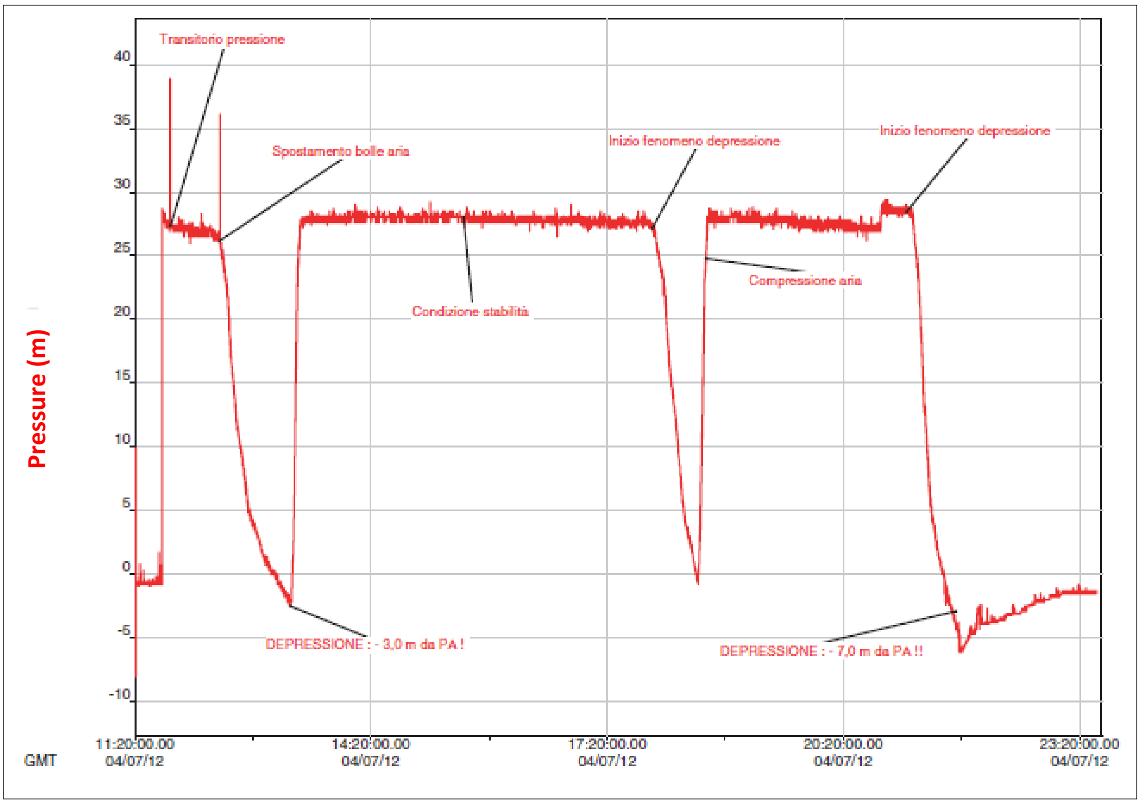

Figure 3 – Measurement of pressure transient at the node "Ripartitore". The negative pressure highlights the presence of an air pocket subject to compression decompression phenomena. Large quantities of air probably affect even the direction of flow that has been measured negative in the pipe exiting the reservoir, (i.e. flow from downstream to upstream).

DMA setup, pressure management and leakage detection

Once the initial audit was carried out, the main effort was directed to the optimization of the network in view of the permanent leakage reduction. To achieve this important result, a direct action aimed at the neutralization of the causes generating pipe burst has been implemented.

The first step was the design of 3 permanent DMA in order to allow optimal pressure management and leakage control. The design was initially carried out on the map and then verified in the field through the direct checking of boundary valves water tightness.

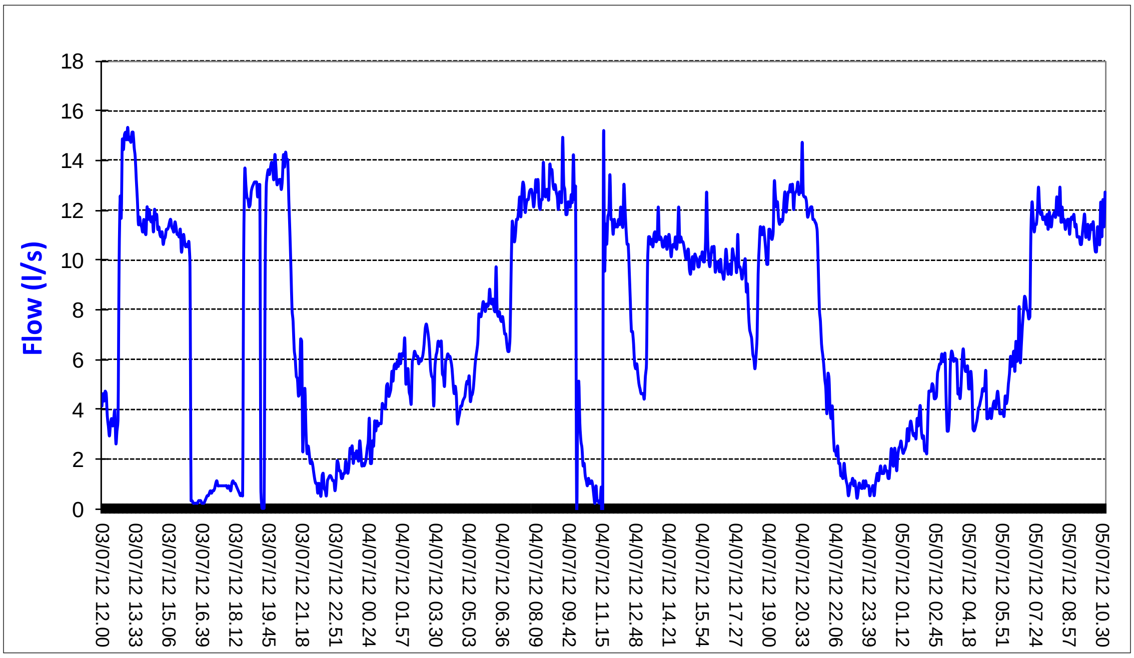

Figure 4 - Initial flow at the inlet of DMA 1 (DN 150) before intervention.

The second step was characterized by the detailed study of pressure control. Field measurements showed high and unnecessary pressure particularly overnight. It was therefore decided to installed 2 Pressure Reducing Valves (PRVs) at the inlet of each of the two DMAs fed by the Norcia Reservoir (see figure 1). The PRVs selected are equipped with double pilot in order to allow two different settings, day and night with the night pressure set-point lower than the daytime.

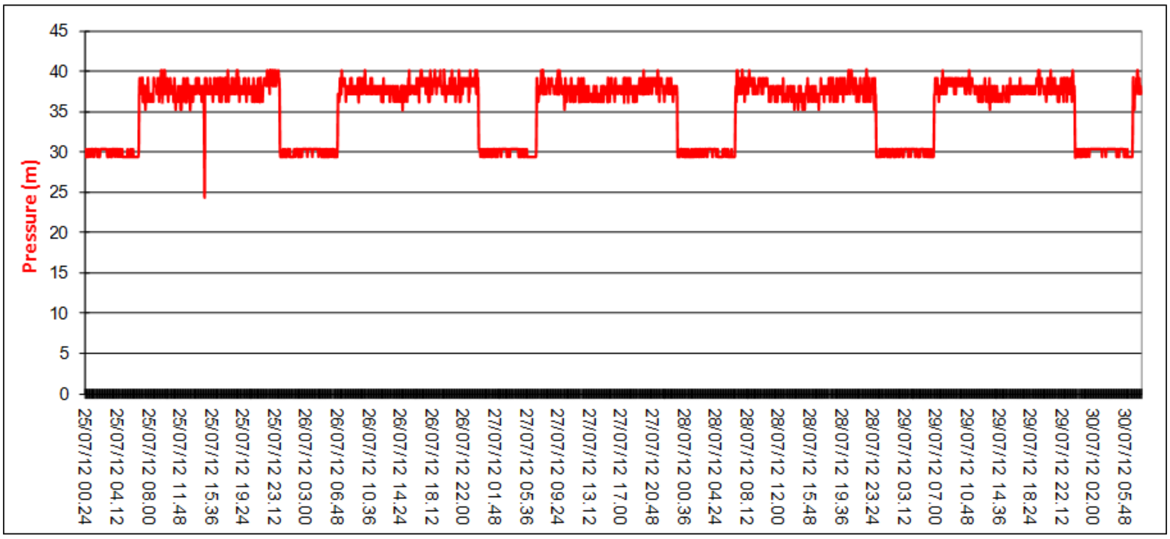

Figure 5 - Pressure available downstream the PRV installed at the inlet of DMA1 (ground elevation equal to -53 m from reservoir maximum water level).

Once the PRVs were installed, leakage detection was carried out starting with the execution of step test to identify most critical areas. Leaks were then been pinpointed using acoustic equipment such as ground microphones and correlators. A total of 20 leaks were located and fixed. In some challenging cases, mainly characterized by low pressure, leaks were pinpointed using tracer gas technology with a blend of Hydrogen and Nitrogen.

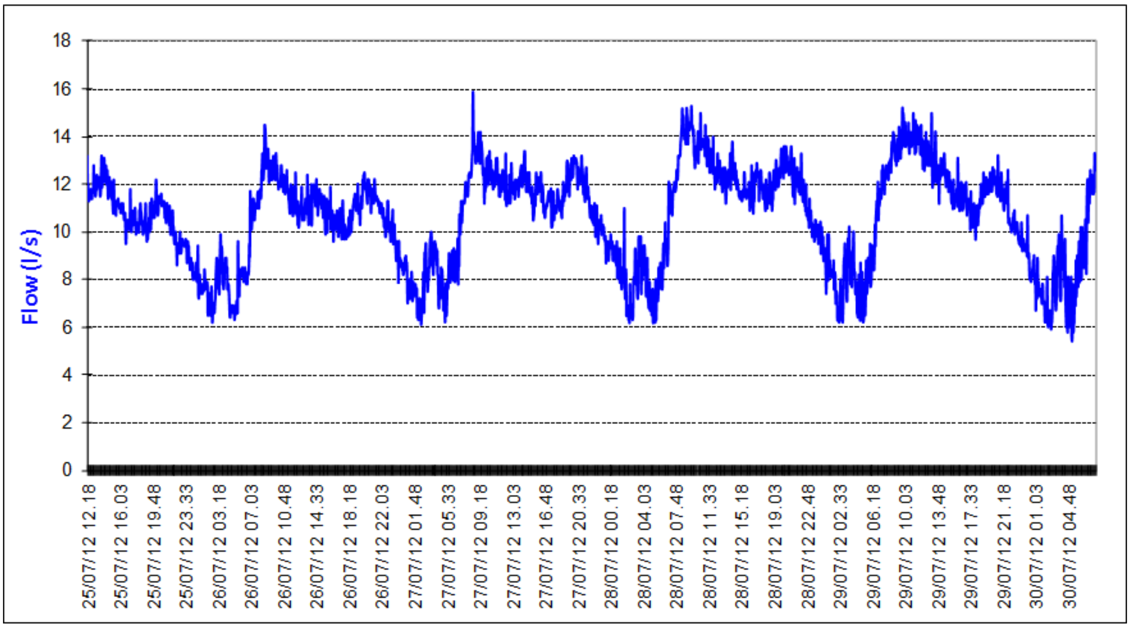

Figure 6 - Flow at the inlet of DMA 1 after installation of PRV. MNF has dropped to 6 l/s from 10 l/s.


Figure 7 – Typical installation of a PRV.

After installation of PRV, to further optimize network performance, a suitable number of air valves were installed in critical points of the network.

RESULTS - TRANSITIONING FROM IWS TO 24X7

The methodology followed to obtain the continuity of supply has been based on the following approach: measurement of initial hydraulic conditions, analysis, set-up of intervention, maintenance of achieved results.

The first step of the intervention has been directed to eliminate air pockets that were affecting the network performance. The installation of a suitable air valve in the right position downstream the reservoir near the "Partitore" has solved the big part of the problem. Secondly a good improvement was achieved from pressure management. To this end separate pressure areas were created and PRVs installed.

Once the network has been put under suitable operation conditions, leak detection has been carried out focusing on the most critical sub districts. Following this process, 24x7 was gradually achieved. At the end of operations and installation, the guideline for the telemetry system of pressure and flow integrated with reservoirs level has been provided to the water company. The operation procedures to maintain over time the achieved results have also been delivered. Thanks to the intervention carried out and the willingness of the water managers to follow these simple but effective rules, today the network is still delivering water 24x7 even during the summer peaks and drought periods.

CONCLUSIONS

The main effort in any NRW study should be focused on the permanent elimination of the causes that contribute to generate new leaks and pipe breaks. A network affected by intermittent supply is generally stressed by the repetitive and uncontrolled opening and closing of the section valves. Generally this action is done manually and too fast resulting in dangerous pressure transients.

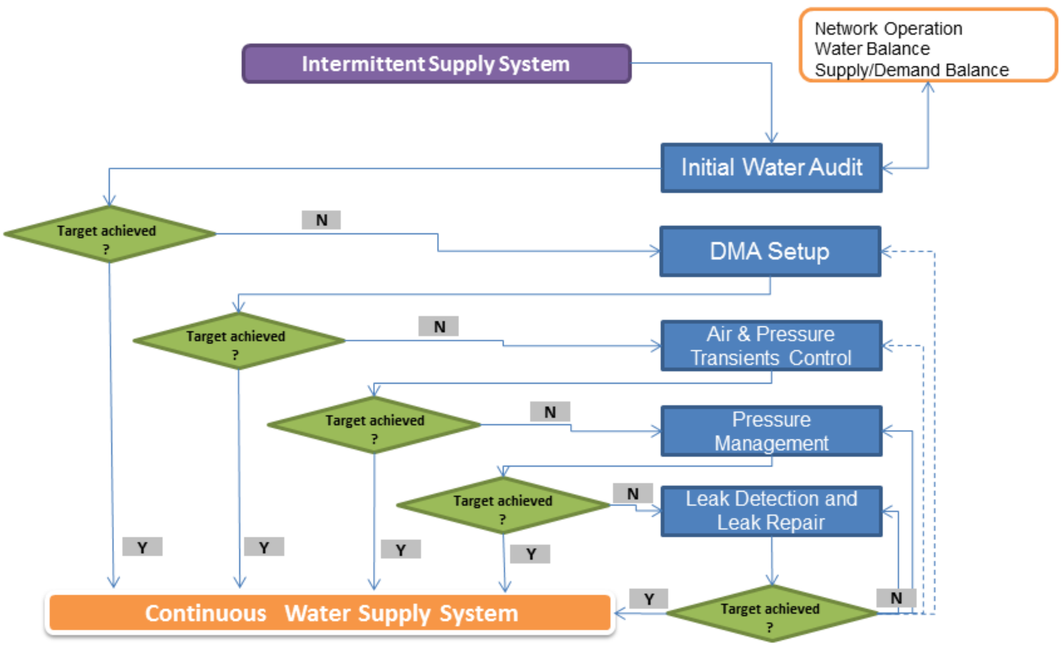

Figure 8 - Flow Chart to bring the network from Intermittent Water Supply (IWS) to continuous supply (24/7).

Based on the lesson learnt in the present case study and from the results obtained in other projects carried out by Hitachi Aulos, a methodology to bring the network from IWS to continuous supply has been achieved. As reported in Figure 8, first of all it's necessary to carry out a detailed water audit that should give precise information on the existing network situation including daily operations carried out to quit water supply. A detailed monitoring of the inlet flow will give data to carried out a Water Balance and hence calculate the level of NRW and physical losses. It's important at this stage to evaluate the current supply/demand balance that consist in the evaluation of the available water amount (reservoir storage or pump capacity) against expected water demand considering the new level of leakage after the intervention.

After the initial water audit, it's necessary to implement DMA in order to optimize water distribution, monitoring efficiency and leakage control. At his stage it is necessary to provide air control in order to reduce the negative effect of pressure transients and flow reduction. Afterwards the implementation of pressure management should be considered in order to obtain a more equitable water distribution between DMAs and to reduce real losses stabilizing at the same time pressure regimes. Eventually leaks detection will be carried out and leaks promptly repaired. Tracer gas will be selected to pinpoint leaks under conditions of low pressure. If, at this point, the continuous distribution is not achieved, the process restart with the further adjustment of PRVs to take into account the effect of leaks already repaired. Then a new leakage detection campaign has to be carried out to fix other leaks not found with the previous campaign. If necessary, and under certain conditions, it could be worthwhile to review the DMA configuration and the control of air and pressure transients. This procedure, described in figure 7 should be repeated unless the network is operated with continuous water supply.

As a conclusion the best approach is to establish the right operational conditions in the network through pressure management, pressure transient elimination and air control and then move on to reduce leakage. The benefit from leaks repair can be maintained only if the causes that generate leaks are removed. Otherwise, leaks continue to grow at a fast pace cancelling rapidly the achieved results.

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