

# The Effects of Intermittent Supply on Water Distribution Networks

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## ABSTRACT

The world's population is increasing at a tremendous rate, the world's renewable water resources are reducing rapidly, the gap between supply and demand is widening with urbanisation and climate change making it even wider. This paper reviews how the Water Board of Lemesos, Cyprus, a water utility with a proven history of managing extremely well its distribution network, was forced due to water shortage conditions to have intermittent supply, providing water 3 times a week for about 12 hours each time. Although intermittent supply is perhaps the last measure to be taken in conditions of water shortage, it is however a situation worthwhile avoiding through proactive planning and timely response to critical conditions. The adverse effects of intermittent supply on customer service and on the integrity of the distribution network as well as the financial repercussions to the utility are also discussed based on the experiences gained from the intermittent supply measures taken during the water shortage periods faced by the Water Board in the last twenty years.

## Introduction

A drought can be defined as a prolonged period of unusually dry weather in an area where some rain might normally be expected. Droughts involve water shortages, crop damage, stream flow reduction and depletion of groundwater and soil moisture. A drought happens when a period of low rainfall leads to a shortage of water. It is

starting when total rainfall is well below average for several months. A balance must be maintained between the water taken out for supply and that being replaced by surface run-off. Normally the surface run-off during the winter far exceeds demand for supply, so that the excess water can be stored and used when surface run-off is less than demand from consumers.

Intermittent water supply may be defined as a piped water supply service that delivers water to users for less than 24 hours in 1 day. It is a type of service that, although little found in developed countries, is very common in developing countries. In an intermittent supply situation the consumers secure their water supply through the use of ground or tanks, where water is stored during the time that the supply is provided. Intermittent water supply is enforced not only in cases where there is water shortage but also where the hydraulic capacity of network is such that can not satisfy demand as well as in cases where the networks are badly deteriorated.

Usually water shortage is declared when the water supplies fall short of meeting water demands. This situation usually prevails in arid and semi-arid areas of our planet where precipitation has been steadily declining or where management of limited water resources has been wasteful and unwise.

In many instances there is no indication how long intermittent supply measures will be in place. The hydrological conditions in each case could impact adversely on water supply for years in

which case conserving as much as possible the limited water resources may not be the long term solutions but it may be necessary to add to the water balance new non conventional water resources. In many countries water shortage problems were overcome through the desalination of brackish or saline water. Of course exploring every potential water source available may be the only solution in many instances, but conservation is always one of the least expensive and quickest solutions to ensuring that water will be available when needed.

### **Water Resources at Great Risk**

The scarcity of water resources in the Mediterranean islands is one of the most pervasive natural resource allocation problems facing water users and policy makers. This problem is faced each day in the many conflicts that surround the use of this limited resource and the provision of water to the many user groups is determined based on the specific condition pertaining at any point in time.

Cyprus is the largest island in the Eastern Mediterranean with hot dry summers and rainy, rather changeable winters. The mean annual precipitation is about 500mm with substantial variation from 300mm in the plains to over 1000mm on the mountainous regions. The precipitation records of the last 100 years indicate an overall decrease of the mean annual precipitation of about 15%, but annual variation in precipitation varies considerably from the mean with long periods below average, affecting significantly the annual water resources of the island.

For the last fifty years the annual water demand in Cyprus was mostly satisfied by groundwater. However, over-pumping caused depletion of the island's aquifers. Intensive irrigated

agriculture and over-fertilisation increased nitrate content particularly in the coastal areas. To increase the water resources of Cyprus the Government embarked in an ambitious programme of tapping the surface water, which was lost to the sea through surface runoff. To increase further the water resources and especially to relieve the domestic water supply from the vagaries of the weather the Cyprus Government proceeded with the construction of desalination plants to produce potable water and with the construction of sewage treatment plants to treat domestic effluent for use mainly in agriculture.

### **A Sustainable Approach**

In Cyprus the growing imbalance between supply and demand in the last few decades reached a critical stage with the most recent drought periods in 1989-1991, 1997-2000 and 2007-2009 with concurrent dramatic decrease of the supply and considerable increase in demand.

During the above drought periods the government imposed water restrictions to both domestic and agricultural supplies. At the same time it has moved forward with the construction of treatment units to treat domestic sewage water for agriculture and of desalination plants to produce potable water for domestic needs thus adding to the water balance and reducing the deficit.

Despite the fact that the management of water, for both domestic and irrigation purposes, has improved tremendously in recent years by reducing losses from supply networks and adding recycled and desalinated water to the national water balance there is still an imbalance between water use and renewable water resources. The last drought period of 2007-2009 left the town of Lemesos with very limited water quantities and in order

to get over the crisis the Government of Cyprus in cooperation with the Water and Sewerage Company of Athens transported potable water with tankers from Athens, Greece to Lemesos, Cyprus on a daily basis from August 2008 to April 2009 to cover the domestic needs of the town.

## **Improving the Situation**

Reducing losses from distribution networks is of the utmost importance and water utilities must recognise this and respond positively. In addition water must be used wisely and wastage avoided. Unfortunately, water is wasted and as long as people are not facing water scarcity, they believe access to water is an obvious and natural thing. Efficient and effective water loss control should be recognised as a first priority for improving potable water supply. Decision makers at all levels in water utilities must understand that any water loss control strategy in order to be effective must be a continuous activity based on a long term strategy and should form an integral part of the utility's vision. The success of the strategy will inevitably depend on the commitment and dedication at all levels within the utility and of course on the adoption of appropriate strategies and techniques.

Accounting for water is the first step that must be made by any utility. It is imperative that an accurate and comprehensive metering system is in place for registering all water along the chain from production to the consumer, including measurement of the water produced and/or imported, water flow in and out of treatment plants and storage reservoirs and into the zones and district metered areas. It is imperative to eliminate or minimise Authorised Un-Metered Consumption thus achieving the highest possible accuracy in accounting for all water produced. Apparent and Real losses must be

analysed and action taken as necessary to reduce the Apparent Loss component thus increasing the utility revenues as well as applying the most cost effective leakage programme which reduces leakage to an economically, environmentally and socially acceptable level.

## **Water Board of Lemesos**

### **Distribution Network**

The Water Board of Lemesos is a non-profit, semi-government organisation charged with the responsibility of supplying potable water to the town and environs of Lemesos. The main activities of the Water Board are: planning and execution of technical projects, operation and maintenance of the water production and water supply systems and all associated financial services including collection of water revenues and determination of water tariffs.

The development of the distribution network takes place in an organised fashion with new areas of supply being incorporated into their respective pressure zones, strictly governed by the areas ground contours. Each pressure zone is subdivided into DMA's, a total of 60 are currently operating, which have a single metered source with physical discontinuity of pipe work at boundaries.

In late 1980 the Water Board embarked on a detailed programme of leakage management. Since 2002 the Water Board has adopted the practices and methodologies advocated by the IWA Water Loss Task Force. The efforts made and importance placed by the Water Board for proper leakage management is reflected in the reduction of the non-revenue water over the years and in the improved operational performance of its network. In 2007 the Board had an ILI below 2

and real losses under 100 litres/connection/day.

### **Water Supply Conditions**

The Water Board realised that water conservation is not to be equated with temporary restrictions on customer water use. Although water restrictions can be a useful emergency tool for drought management or water shortage situation, water conservation programs concentrate on continuous improvements in water use efficiency. To this end the Water Board embarked on a promotional campaign through television, radio and leaflets to increase public awareness for water conservation.

In 1991, the government legislated against the use of hosepipe for washing cars and pavements at all times, a law, which the Water Board enforces during drought periods only. During the drought period of 1997-2000 the government was forced to announce in early 1997 a reduction of 20% for potable water and 40% for irrigation water supplies. In 1998 the water situation became worse and the restriction measures became more stringent as the available quantities of water were diminishing and the government, much to the discontent of the public, went ahead with further measures, enforcing greater restrictions to the water supplies with targeted figures of 28% for potable water and 56% for irrigation use.

The Water Board of Lemesos always responded promptly to the government's declared drought measures and imposed each time restrictions to the continuous supply. In February 1997 restricted supply to consumers to four days a week. In 1998 due to limited water reserves the Water Board was forced to decrease further the availability of water reducing the time of the water being available to the consumers to 12 hours every 48 hours.

These measures were in force until the end of 2000. In 2008 and 2009 similar restrictions were applied providing water 3 times a week for about 12 hours each time. These actions resulted in an overall reduction in the use of domestic water of approximately 15% per annum which proved that the domestic demand is near enough inelastic.

It was thought that after the above 4 year period of intermittent supply, measures would have been taken so that there will be sufficiency of water quantities for at least the domestic needs. However, this was not the case and 8 years later, in 2008, water cuts for domestic use were imposed once again. Water was brought with tanker boats from Athens, Greece. For many this dire situation is blamed on the politicians for not taking the right decision at the right time. For others there is the argument that there has been mismanagement of the water reserves prior to the drought period and not sufficient forethought has gone into the planning of such a severe drought taking place so soon after the last one. In any case fact remains that the Water Board of Lemesos even though it has improved its network to such an extent that it is considered amongst the world's best with losses from the network being extremely low, it was faced with a situation beyond its control. Of course the situation would have been a lot worse if the Board did not continuously improve its network in order to minimise losses thus saving valuable quantities of water.

Intermittent supply therefore, may have seemed to be the short term answer to the water shortage situations faced in the last 20 years, however in the following sections the adverse effects on the integrity of the distribution network of such actions are discussed and quantified based on the experiences gained.

### **Effects of Intermittent Supply**

It was evident that there was a large increase in the number of reported pipe breaks during the period of intermittent supply. In order to quantify these a comparison was made for a large number of District Metered Areas, 20 in total, between the breaks reported in 2007, before the intermittent supply was applied, and those reported in 2010, the first year immediately after the measures were lifted. This comparison showed that the number of breaks on mains increased from an average of 1 per 7,14 km of mains to 1 per 2,38 km of mains, an increase of 300%.

Similarly, the number of reported service connection breaks increased from an average 15,5 per 1000 connection in 2007 to an average of 29,7 per 1000 connections in 2010, an increase of approximately 200%.

Of course, in addition to the reported breaks, there were a significant number of breaks, caused by the frequent emptying and refilling of the network, which did not come to the surface since the network was not pressurised for any significant length of time to force the water to come to the surface or to have the opportunity to locate these through active leakage control.

Calculations have shown that the increase in leakage due to the intermittent supply measures was of the order of 9%. This figure was substantiated in an analysis using a 'top down' and 'bottom up' approach for 2007, before the intermittent supply was applied, and for 2010, the first year immediately after the measures were lifted. This result is shown graphically in Figure 1 where it can clearly be seen that the difference in the Minimum Night Flow in 2010 and 2007 is the additional volume of water being lost due to new breaks caused by the intermittent supply operation. It is calculated that this additional volume is approximately

1.655.000 m<sup>3</sup> which is slightly greater than the average annual volume of water saved (1.607.000 m<sup>3</sup>) due to the intermittent supply measures during the 2 year period of the intermittent supply.

It is therefore evident that no matter how good the distribution network is, intermittent supply operation has definitely a detrimental effect on its integrity. In addition the amount of water saved is later lost again through increased levels of leakage.

Figure 2 shows the Minimum Night Flow for District Metered Area (DMA) 129 before and after intermittent supply. From the graph it is evident that leakage in this DMA increased from 10 m<sup>3</sup>/hr to 20 m<sup>3</sup>/hr. This situation is typical of all DMAs with relatively old, about 40 years, network. In order to reduce leakage the Water Board applied a program of Active Leakage Control commencing with Districts with the highest increase in the equivalent number of pipe bursts.

Furthermore numerous complaints were received from disgruntled consumers regarding quality problems and of course lack of pressure during intermittent supply. Needless to say that intermittent supply caused serious disruption and upheaval to the daily activities of people whether these were at home or at work.

### **Cost of Intermittent Supply**

The implementation of intermittent supply had a direct financial cost to the Water Board. On the one hand the Water Board suffered loss of revenue due to the decrease in the sales of water. On the other hand there were additional expenses paid to staff in overtime for opening and closing the sluice valves to implement water rationing and to repair breaks caused to the pipe work due to the frequent emptying and filling of the pipes.

The Board estimated that the average loss of revenue per annum due to the reduction in water sales was of the order of €300.000 and the additional expenses paid as overtime to staff and the cost of pipe work repairs was of the order of €100.000.

## **Conclusions**

It is evident from the results presented in this paper that although intermittent water supply may seem to be a solution to a water shortage situation in overall terms the water balance is adversely affected. Supplying less quantity in an intermittent manner causes such deterioration to the network that when continuous supply is re-established additional quantities are lost through increased leakage.

It is therefore prudent to avoid such operational conditions for the pipeline networks especially for networks that have been designed for continuous supply.

## **Acknowledgment**

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## **References**

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1 January to 30 December				
	2007	2010	Difference	
Zone 1	5,185,434	5,808,271	622,837	
Zone 2	5,150,320	5,497,431	347,111	
Zone 3	939,659	1,073,681	134,022	
Z4 Ag.Phila	180,690	152,175	-28,515	
Zone 5	141,591	114,837	-26,754	
Zone 6	83,118	134,086	50,968	
Zone 7	20,759	21,509	750	
<b>Total (m<sup>3</sup>)</b>	<b>11,701,571</b>	<b>12,801,990</b>	<b>1,100,419</b>	<b>9.40%</b>
MNF (aver.)	385	549	164	m <sup>3</sup> /h (period)
Consumers	60,730	66,684	5,954	
Night use	103	113	10	m <sup>3</sup> /h
	392,419	430,892	38,473	m <sup>3</sup> (period)
Background losses & Bursts	5,914	9,149	3,235	m <sup>3</sup> (per day)
	1,969,454	3,046,663	1,077,210	m <sup>3</sup> (period)
	16.83%	23.80%	6.97%	
<b>Night use + Background losses &amp; Bursts</b>	<b>2,361,873</b>	<b>3,477,555</b>	<b>1,115,683</b>	<b>m<sup>3</sup> (period)</b>

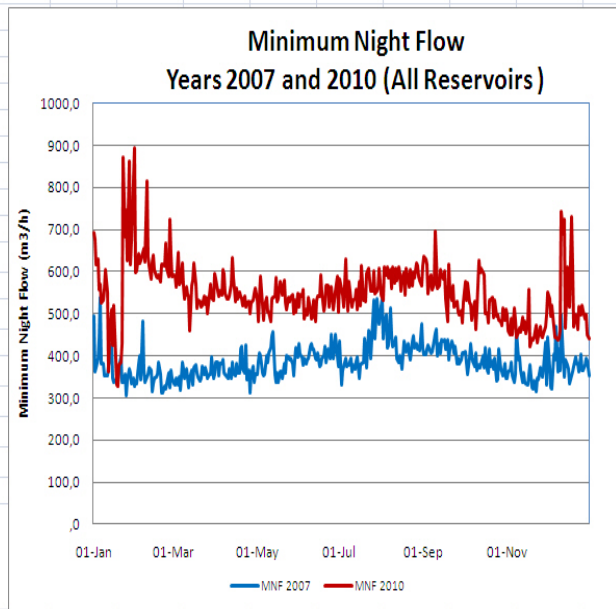


Figure1. Minimum Night Flow Graph for all reservoirs

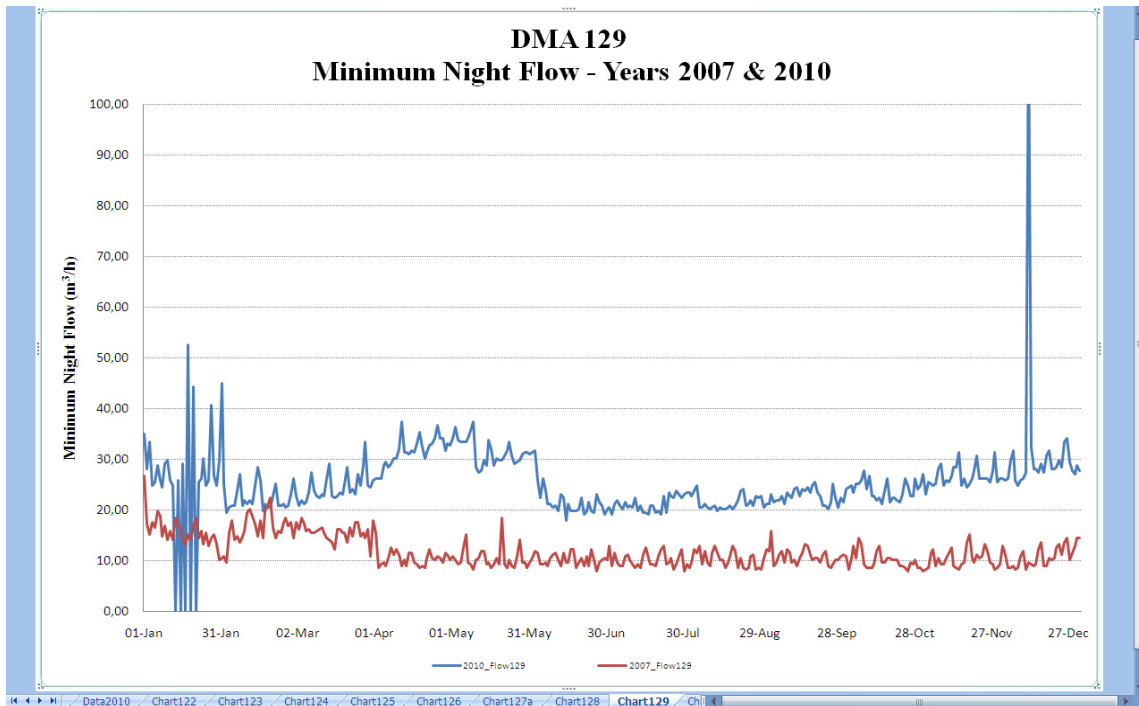


Figure2. Minimum Night Flow Graph for DMA 129