# The Hidden Costs of Resorting To Intermittent Supplies

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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, increase in number of bursts and leakage, 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.

**Keywords**

Water shortage; intermittent supply; leakage

## 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 inter alia, 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, normally during the summer period.

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.

Intermittent water supply may be defined as a piped water supply service that delivers water to users for less than 24 hours in one 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 roof tanks, where water is stored during the length of time that the supply is provided.

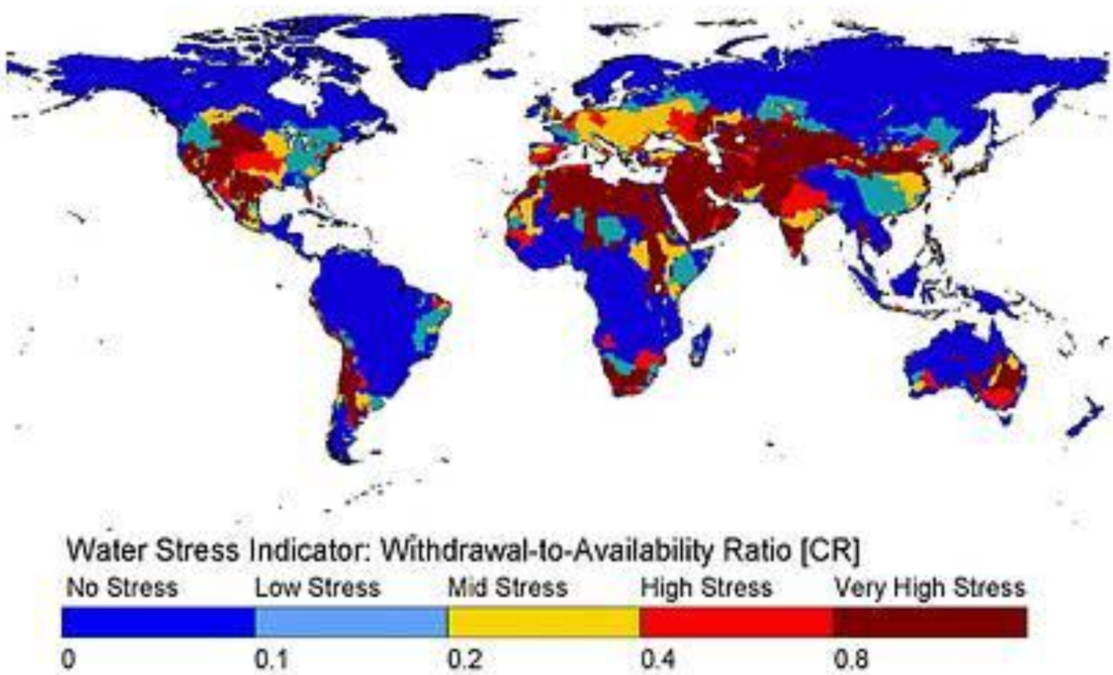
It is worth noting that intermittent water supply is enforced not only in cases where there is water shortage but also where the hydraulic capacity of a network is such that can not satisfy demand as well as in cases where the network is severely deteriorated.

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 and leakage reduction 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 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.

The pressures that exist on water resources are highlighted by the water stress indicator which measures the proportion of water withdrawal in relation to total renewable resources. As it can be seen from the map in Figure 1 a large proportion of the densely populated part of the planet has a high to very high water stress indicator. It is therefore imperative to develop appropriate water management approaches in order to manage our water resources efficiently and effectively.




Source: Water GAP 2.0 - December 1999

**Figure 1. Water Stress Indicator**

Climate change adds to these concerns. It has been affecting the average weather patterns that we were all used to and engineers and scientists have to take this into consideration in present and future planning. As an example, in Cyprus, the largest island in the eastern Mediterranean, the precipitation records of the last 100 years indicate an overall decrease in 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. This pattern is very similar across the Mediterranean basin and there are cases in recent years where cities were even forced to ship water from other countries in order to combat the crisis. For instance, the town of Lemesos in Cyprus was supplied daily by tankers with water from Athens in Greece for an eight month period in 2008/2009 to overcome a serious water shortage problem caused by prolonged drought. During the same period Barcelona in Spain was also being supplied water via tankers in order to relieve a similar water crisis. This phenomenon seems to be growing to global dimensions.

Faced with such pressures, there is the prospect that water authorities will increasingly wish to resort to delivering intermittent supplies. Usually during drought periods water authorities impose water restrictions to both domestic and agricultural supplies. At the same time they move forward with the construction of treatment units to treat domestic effluent for agriculture, and if this measure is not sufficient they resort to the construction of desalination plants to produce potable water for satisfying domestic needs, thus adding to the water balance and reducing deficit. However, in most cases water authorities seem to overlook the obvious, which is to manage the water networks in the most efficient and effective way in order to minimise losses.

## WATER LOSS MINIMISATION

Reducing losses from distribution networks is of the utmost importance and water utilities must recognise this and respond positively. Efficient and effective water loss control should be recognised as a first priority for improving potable water supply.

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.

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. A successful strategy is one that maintains the distribution network in a proper working order, reducing and maintaining leakage at an economic level, and of course providing the required level of service to all consumers

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## THE WATER BOARD OF LEMESOS CASE STUDY

### The 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 took 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 Group. 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. 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 the fact remains that the Water Board of Lemesos even though it has improved its network to such an extent that it is consider 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**

Analysis of case study data showed 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. The results are shown in Table 1 covering both mains and service connections.

**Table 1. Effect of intermittent supply on reported pipe bursts**

| Description | Number of Reported Breaks | | |
|---|---|---|---|
| | Before | After | % Increase |
| Mains | 1 in 7,14 km | 1 in 2,38 km | 300 |
| Service Connections | 15,5 in 1000 | 29,7 in 1000 | 200 |

This comparison showed that the number of breaks on mains increased from an average of 1 in 7,14 km of mains to 1 in 2,38 km of mains, an increase of 300%. Similarly the number of reported service connection breaks increased from an average of 15,5 in 1000 connections to an average of 29,7 in 1000 connections an increase of approximately 200%.

Of course, in addition to the reported breaks, there is a significant number of breaks, caused by the frequent emptying and refilling of the network, which do not come to the surface since the network is 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.

The Minimum Night Flow has increased in all District Metered Areas, a typical example being District Metered Area (DMA) 129. Figure 2 shows the Minimum Night Flow before and after intermittent supply for this DMA. From the graph it is evident that leakage in this DMA increased from 10 $m^3$/hr to 20 m3/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.

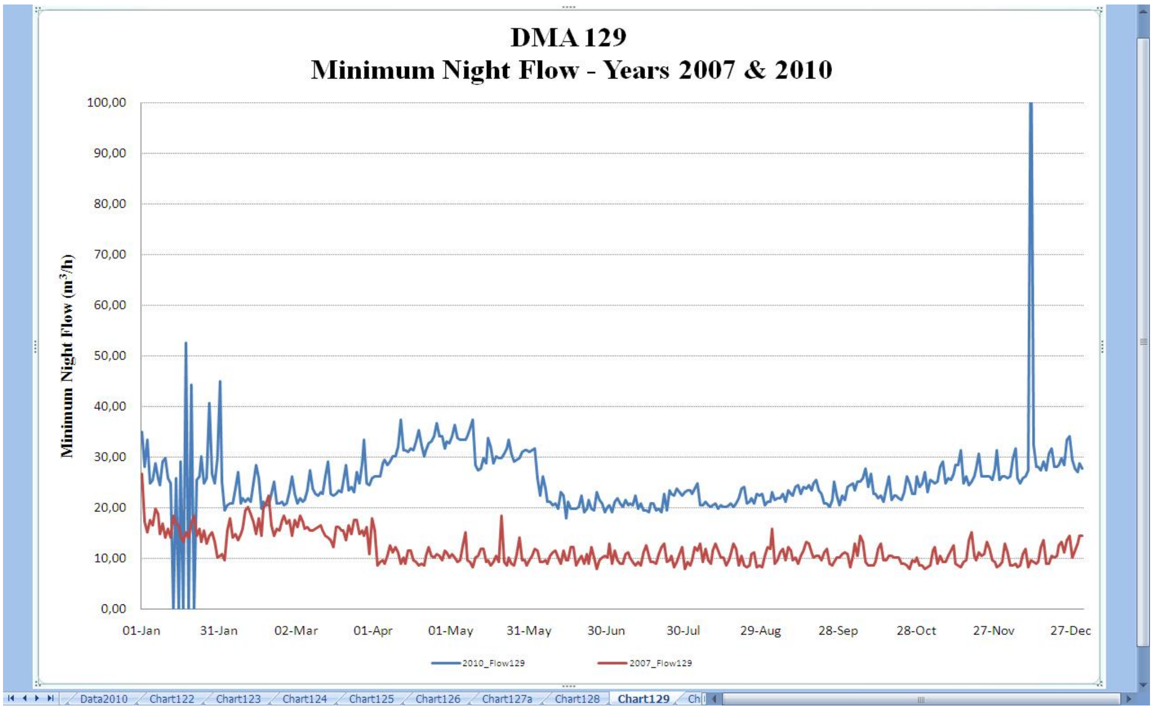


**Figure2. Minimum Night Flow Graph for DMA 129**

Calculations have shown that the overall 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.

Figure 3 shows the total Minimum Night Flow before (blue colour) and after (red colour) the intermittent supply. It is obvious that there has been a significant increase in the Minimum Night Flow which could only be attributed to the additional breaks which the network suffered during the intermittent supply period. These non reported breaks will have to be located through active leakage control activities and repaired in order to reduce the level of leakage to the level prior to the application of intermittent supply measures.

| 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 | |
| **Total ($m^3$)** | **11,701,571** | **12,801,990** | **1,100,419** | **9.40%** |
| | | | | |
| MNF (aver.) | 385 | 549 | 164 | $m^3$/h (period) |
| Consumers | 60,730 | 66,684 | 5,954 | |
| Night use | 103 | 113 | 10 | $m^3$/h |
| | 392,419 | 430,892 | 38,473 | $m^3$ (period) |
| Background losses & Bursts | 5,914 | 9,149 | 3,235 | $m^3$ (per day) |
| | 1,969,454 | 3,046,663 | 1,077,210 | $m^3$ (period) |
| | 16.83% | 23.80% | 6.97% | |
| Night use + Background losses & Bursts | 2,361,873 | 3,477,555 | 1,115,683 | $m^3$ (period) |

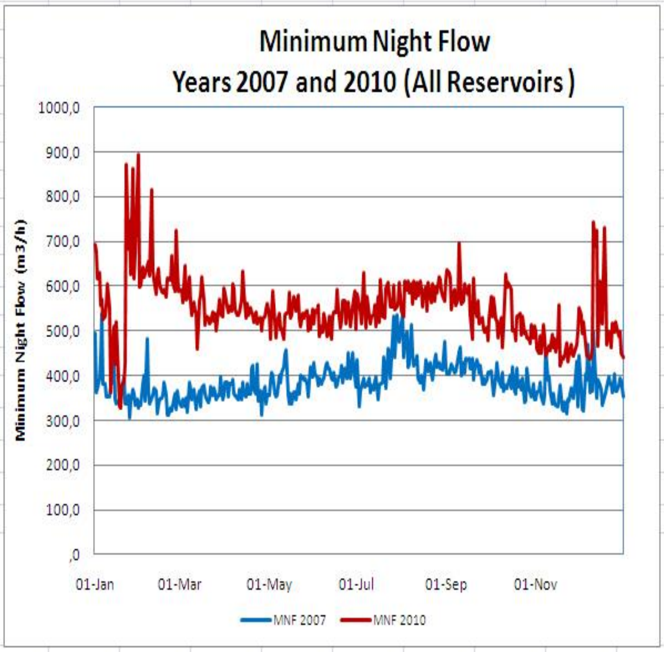


**Figure3. Minimum Night Flow Graph for all reservoirs**

From the graph in Figure 3 it can clearly be seen that the difference in the Minimum Night Flow between 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 $m^3$ / year which is slightly greater than the average annual volume of water saved (1.607.000 $m^3$) due to the intermittent supply measures during the 2 year period of the intermittent supply.

Further evidence from the case study to substantiate the increase in leakage due to the intermittent supply measures is given in Table 2 which shows an increase of 12,8% in the System Input Volume after intermittent supply compared with before without a corresponding increase in customer consumption. In fact the customer consumption was slightly less (1,2%) than that of the year before the intermittent supply measures were applied. It is also evident from Table 2 that the System Input Volume in the first year of Intermittent supply decreased by 17,5% whereas in the second year by 9,1% indicating that the breaks in the network were increasing in number. This is substantiated by the fact that the reduction in the customer consumption remained effectively the same for both years of intermittent supply.

**Table2. System Input Volume vs Customer Consumption**

| Year | System Input Volume | Customer Consumption |
|---|---|---|
| 2007<br>Before Intermittent Supply | Base line<br>0% | Base line<br>0% |
| 2008<br>Intermittent Supply | -17,5% | -9,2% |
| 2009<br>Intermittent Supply | -9,1% | -8,9% |
| 2010<br>After Intermittent Supply | +12,8% | -1,2% |

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 has a direct financial cost to the water utility in addition to the loss of revenue due to the decrease in the sales of water.

The loss of revenue to the utility is a direct result of the conservation of water by the customers. Of course, the corresponding system volume is also less which means that overall financial loss will be the difference between the selling and buying / producing the water. The cost of water which is lost through the additional leakage caused by the intermittent supply operation depends on the running time of each leak and the cost of water. It is however a major cost to the utility and one which will continue to burden the utility until the additional leaks are found and successfully repaired.

The direct costs include, amongst other additional operational costs for opening and closing sluice valves to implement water rationing the cost for repairing reported breaks caused to the network due to the frequent emptying and filling of the pipes.

A major financial burden t o the utility will be the cost of locating and repairing unreported breaks through an intensive and concentrated effort in order to minimise the running time of the additional leaks.

The Board estimated that the overall average loss of revenue due to the reduction in water sales was of the order of €300.000 for the 2 years of intermittent supply. The additional expenses paid in overtime to staff for the same period of the 2 years was estimated at €365.000 where as the cost of repairing the additional reported breaks was of the order of €325000.

It is also estimated that the volume of water which is lost due to the increase in leakage when continuous supply was established was estimated to be approximately 1.655.000 $m^3$ per year which is equivalent to €1.325.000.

## 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, which in fact places an added financial burden on the utility.

It is therefore evident that no matter how good a network is, intermittent supply operation has definitely a detrimental effect on its integrity and in addition the amount of water ‘saved’ is later ‘lost’ and in greater quantities through increased levels of leakage. Such operational conditions should be avoided especially in pipeline networks that have been designed for continuous supply.

In addition it has been shown that the domestic demand is in effect inelastic and in fact the quantities of water saved by the customers were very small. It is the authors opinion that perhaps better results could be achieved through a structured conservation programme rather than intermittent supply. Of course such programmes are to be introduced as part of an overall strategy for water conservation both on the supply and demand side.

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