WATER DEMAND MANAGEMENT AND THE ATHENS WATER SUPPLY

D. Xenos [(1)], I. Passios [(1)], S. Georgiades [(1)], E. Parlis [(1)] and D. Koutsoyiannis [(2)]
[(1)] EYDAP - Athens Water Supply & Sewerage Company
[(2)] Department of Water Resources, National Technical University of Athens

Abstract

Water demand management has acquired great importance in the framework of sustainable urban water management. Technological, economical, institutional and communicational means can be used to realise efficient water demand management. In this context, the general conditions and the potential for implementing water demand management in Athens is examined.

1. Introduction

1.1 The importance of demand management in the framework of sustainable urban water management

Historically, water resources management, especially in urban areas, has passed from several phases, driven by the population and water demand growth. These are schematically depicted on Figure 1 (due to Turton and Ohlsson, 1999; see also Ashton and Haasbroek, 2001). The initial phase, so called "water abundance", is characterised by low population numbers and thus low water demand relative to the quantity of water naturally available. As soon as the demographically induced water demand exceeds the naturally available water supply, the society enters a situation of "water scarcity" where the resource becomes increasingly inadequate (Turton and Ohlsson, 1999). Typically, in developed countries, this situation has been remedied by increasing water supply via engineering solutions such as construction of dams and transportation of water from other locations. This situation has been called the "supply phase" or even "hydraulic mission" and results in the so called "structurally-induced water abundance". From a political and social viewpoint the main characteristic of this situation is that the government takes over the role of water supplier, and the general public gradually loses perspective as to the real value of the water that is supplied to them (Ashton and Haasbroek, 2001). Where water demand continues to increase, the amount of water that can be obtained by conventional engineering solutions is soon exceeded; a situation of "water deficit" ensues and any further growth in water demand worsens the degree of water deficit. This point marks the onset of determined efforts to control and manage water demand through water conservation measures and strategies aimed at improving the efficiency of water use (Ashton and Haasbroek, 2001). From a social perspective, this transition is reflected in a change in the general social consciousness around water resources, and is often driven by a growing understanding of the issues of ecological or environmental sustainability. The management focus shifts from infrastructure management to water resource management, and from the elitist planning and management (based on groups of specialists) to full commitment and participation of the society (Vlachos and Braga, 2001). It is thus anticipated that with concerted and sustained effort the overall water demand will be maintained within the sustainable limits of water supply. This effort is mainly based on effective water demand management strategies and techniques.

Water Demand Management (WDM) can be defined as those activities, which aim to provide the greatest possible amount of services using the least possible volume of water. In a more general perspective, WDM refers to the activities that aim to reduce water demand, improve water use efficiency and avoid the deterioration of water resources. Some consider reducing water use through effective demand management equivalent to increasing supplies. They also consider WDM an obligatory solution in cases where the best supply opportunities have been exploited, and the marginal opportunities are much more expensive economically and environmentally. More than this however, WDM marks the implementation of a paradigm shift from the traditional orientation of increasing supply towards sustainability of water resources and the environment, as well as economic efficiency and social development.

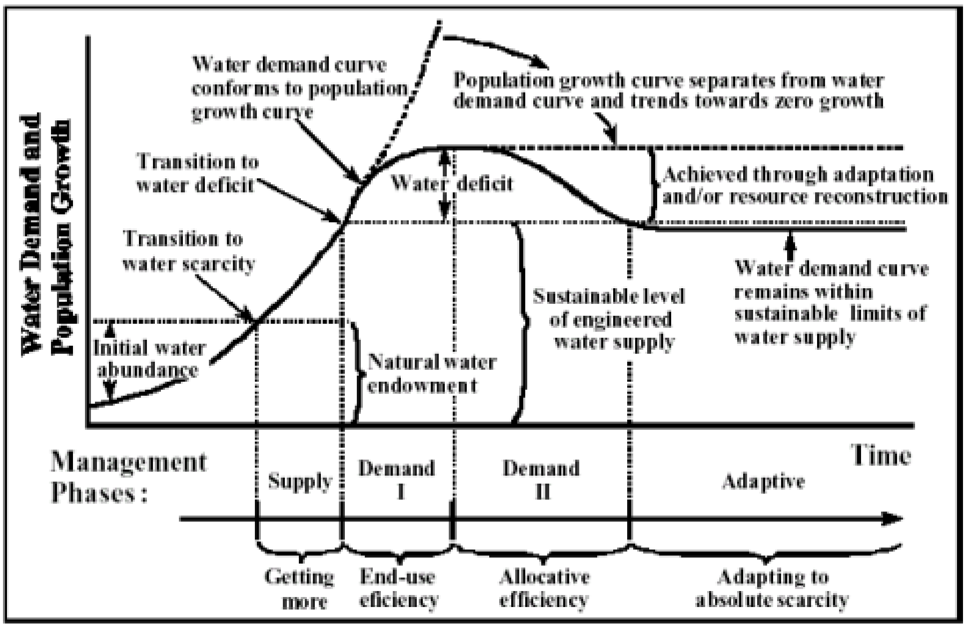

Figure 1 Schematic representation of historical phases of growth of water demand and supply (Diagram from Ashton and Haasbroek, 2001).

At the 1992 UNCED Earth Summit in Rio, Agenda 21 stated, “By the year 2000 all states should have national action programmes for water management, based on catchment basins or sub-basins, and efficient water use programmes. These could include integration of water use and other resource planning development and conservation, demand management through pricing, regulation, conservation, re-use and recycling of water.” Thus, WDM is a key component of integrated water resources planning, which is in turn the prerequisite for sustainable water management. Therefore, it has been proposed (Tate, 2001) that, unless water demand management is effectively implemented throughout the world, there cannot be sustainable development of water resources.

This, however, does not mean that engineering solutions in developing unexploited water resources have to be abandoned. Rather, it recognizes the need for balanced development between water supply augmentation measures and water demand management measures. The two must work synergistically, but all efforts should be made to manage demand in the most effective way before the consideration is given to augmenting water supplies in any significant way (Tate, 2001).

1.2 Demand management activities and tools

What makes WDM a feasible and efficient solution is the elasticity of water consumption, which is witnessed by the significant variability of urban water requirements over history, as well as at present throughout the world. Characteristically, at present in many countries in Sub-Saharan Africa the average per capita use rates are of the order of 10 litres per person per day (World Water Commission’s Staff Report, 1999), whereas in some European countries water consumption becomes of the order of 100 litres per person per day and in some areas in the USA exceeds 1000 litres per person per day (Hanemann, 2000). At a single place, the elasticity of water consumption becomes obvious especially during persistent drought periods, as it has been often decreased by a significant percentage.

It has been well understood that in places with high water consumption, the contribution of outdoor water use (landscape irrigation, gardening, car wash, swimming pools) is very high and can account for over 50% of the total urban use (Hanemann, 2000). Therefore, water-saving landscaping and gardening is an important topic in the framework of WDM. Landscapes can be designed to hold rainfall onsite, reduce runoff, and reduce the need for irrigation. The concept of xeriscaping in combination with appropriate irrigation systems, use of mulches, and appropriate choice and placing of plants can decrease water consumption and improve water use efficiency.

Other technological means closely related to WDM that aim at more efficient water use are the repairing of leakage from water supply systems, the adoption of systematic metering of all water facilities, the control of distribution networks operation (e.g. to avoid high pressures which increase water consumption and leakage) and the technical modifications of installations with the use of better hydraulic and sanitary equipment (low-flow plumbing devices).

Apart from technological means, economical means are also very important for the implementation of WDM. Appropriate pricing of water (i.e., implementing an increasing block rate pricing structure) has proven to be a very effective measure in changing the public behaviour towards water conservation and promoting economic efficiency and investment in new installations (Hanemann, 2000). Loans and subsidies for certain private activities such as retrofitting of homes with low-flow plumbing devices and practices for water saving in outdoor use can also be beneficial. This can be combined with legislation that enforces appropriate arrangements (e.g. tightened plumbing codes) for new buildings.

Last but not least, communicative strategies are vital prerequisite for WDM. These include raising the awareness of water resources specialists towards WDM policies, extensive public information campaigns (e.g., via press, TV and WWW), and school education programs that range between high school and university programs. This implies preparation and dissemination of a wide variety of materials aimed at various segments of the population as well as demonstrating tools and methodologies.

We must note that sustainable urban water management includes a variety of other options, in addition to WDM; for example, water recycling and reuse, particularly in outdoor water uses. This is a feasible and attractive option for regions where supply is limited or is of poor quality, or where it is expensive to develop. Wastewater can be treated and reused for agricultural production of nonfood-chain crops, for industrial use, and for irrigation of country areas, recreation areas, parklands, cemeteries, and university campuses. In the future, treated effluent may be blended with local raw water to produce potable water. Apart from wastewater recycling and reuse, another beneficial substitution option is the use of raw water of lower quality, such as harvested rainwater and abstraction from local aquifers for outdoor water uses.

2. The Athens water supply

2.1 A historical overview

Athens lies on a dry area characterised by annual rainfall around 400 mm. The end of the "water abundance" phase is lost in the depths of prehistory. Ancient Athens, with a population well exceeding 200 000 in the "golden" classical period (5th century BC) had developed an advanced, for that time, technological system of water supply consisting of an interconnected network of public and private wells, fountains and springs, aqueducts that carried water from long distances from the mountains around Athens and rainwater collection cisterns (Kallis and Coccossis, 2000). The water use was ruled by detailed regulations most of which were legislated by Solon around 594 BC. According to these regulations, all people had the right to take water from public supplies if they lived within a certain distance around them; citizens living outside the limits of public sources had to develop their own wells; if they failed to find water after drilling a well about 20 m deep in their own property, they had the right to take a pre-defined quantity of water from a neighbour twice a day (MacDowell, 1978) As the city's public system grew and aqueducts transferred water to public and individual fountains, private wells and cisterns tended to be abandoned. As these would be necessary in emergency situations (e.g, in times of war), the owners were forced by regulation to maintain their private facilities at a good condition and ready to use (Kores, 2000). Other regulations protected surface waters from pollution (MacDowell, 1978). Distinguished public administrators, called officers of fountains, were appointed to monitor enforcement of the regulation and to ensure the fair distribution of the water sources. This regulatory and management system must have worked exceptionally well and approached what today we call sustainable water management.

During the Roman period, the most important water supply work for the city of Athens was the 25 km long Hadrian aqueduct (commenced in the times of emperor Hadrian, 117 –138 AD) carrying water from the mountain Parnes. This was also a long lasting work, as it provided water to Athens until the beginning of 20th century (with periods of deterioration and abandonment through the centuries).

During the 20th century, the water consumption in Athens displayed an explosive increase as depicted in Figure 2. From 5 hm^3 in 1927 (population 800 000), the annual water consumption reached 400 hm^3 in 2000 (population 3 200 0000). To provide this amount of water, the Greek state had to develop an extensive and complex water resource system comprising four major works that were built at the times depicted in Figure 2. The current percentage breakdown of water consumption is shown in Figure 3.

2.2 Description of the current water resource system

The current Athens water resource system shown in Figure 4 is an extensive and complex system that extends over an area of around 4000 km^2 and includes surface water and groundwater resources. It incorporates four reservoirs, 350 km of main aqueducts, 15 pumping stations, more than 100 boreholes and four water treatment plants. The system is run by the Athens Water Supply and Sewerage Company (EYDAP). Two of the reservoirs, the Mornos reservoir and the natural lake Yliki, hold 88,5% of the overall storage capacity, which approaches 1400 hm^3. Although the storage capacity of the newly constructed Evinos reservoir is quite small in comparison, inflows to this reservoir are the largest. Therefore, water from the Evinos reservoir is diverted through a tunnel to the neighbouring Mornos reservoir, which stands as the main storage project for the Evinos River flow as well. The smallest reservoir, Marathon, is the oldest and the nearest to the city of Athens. Today the Marathon reservoir is kept at a high water level and it is used only as a backup for emergency situations and as a complement for the peak water demand during the summer season. The water of some aquifers, lying mainly in the northern part of the hydrosystem, is used as a backup resource.

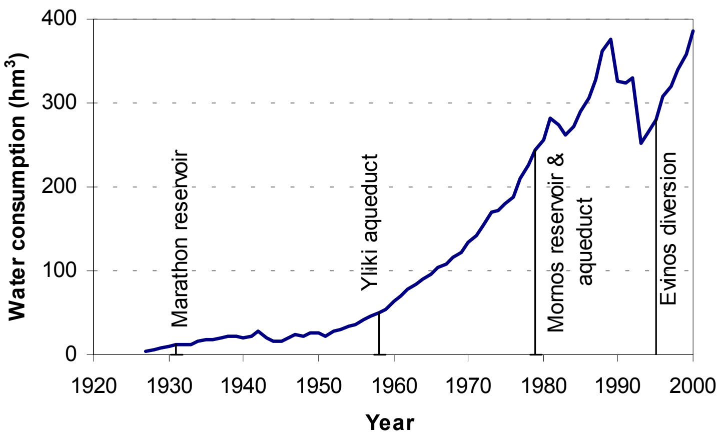

Figure 2 Evolution of water consumption in Athens and years marking commence of the different water supply projects.

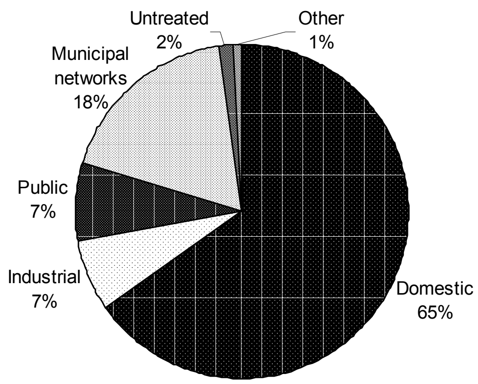

Figure 3 Percentage breakdown of water use in Athens (year 2000).

Two main aqueducts transfer water from the lake Yliki and from the Mornos reservoir. Interconnections of these allow alternative routes of water to the treatment plants. Although the Mornos aqueduct carries water via gravity, water is carried through the Yliki aqueduct only via pumping with considerable cost. Another characteristic of lake Yliki is the significant leakage due to its karstic underground. Due to the several losses, less than 500 hm^3 per annum can be available to the water supply of Athens, although the mean natural inflows are about 840 hm^3 per annum and the groundwater resources in theory can contribute another 90 hm^3.

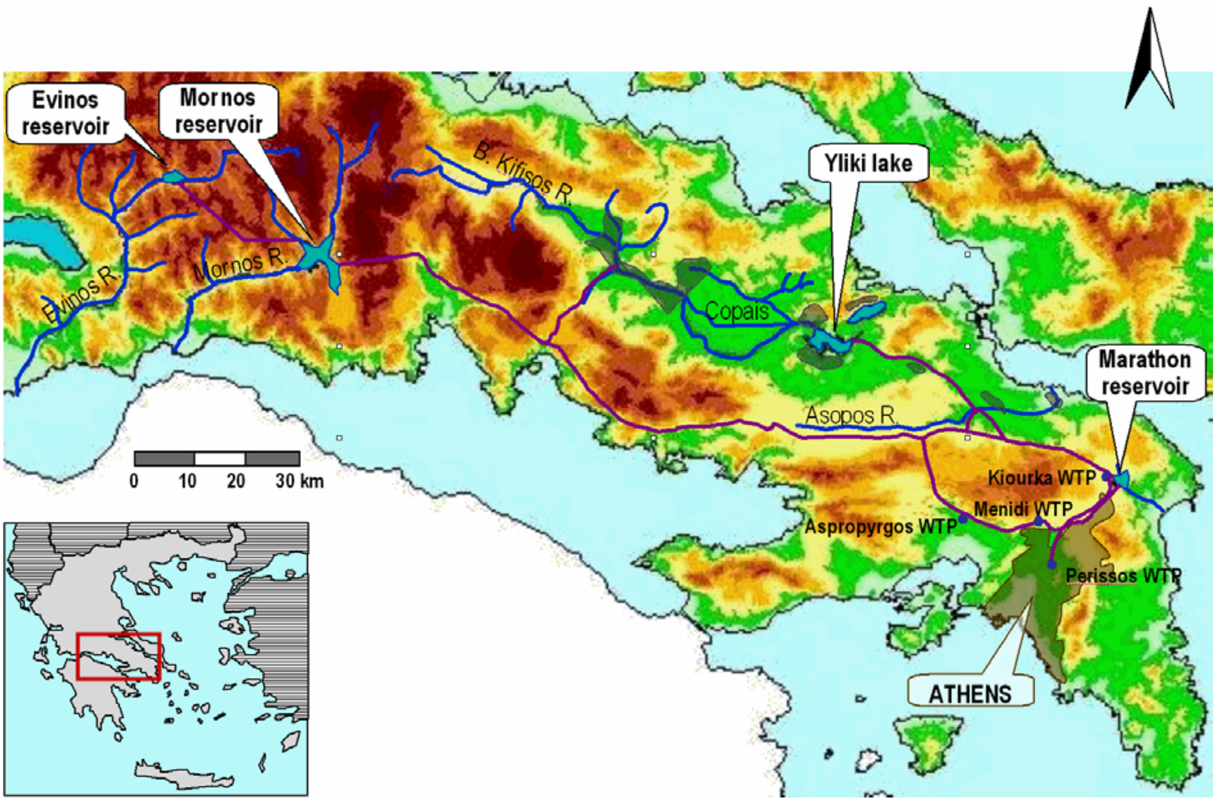

Figure 4 Schematic representation of the Athens water supply system.

2.3 The initiation of demand management

As clearly indicated in Figure 2, the urban water development of the 20th century, apart from the last decade, was supply oriented, aiming at providing structurally-induced water abundance to Athens. The early 1990s is a transition period where both supply and demand are taken into consideration. A persistent drought started in the late 1980s almost vanished every surface water resource available. At that time, the new Evinos project was studied and its construction began. Simultaneously, severe water conservation measures were studied and implemented. These included two drastic increases in water price, with simultaneous discount for significant water conservation. The pricing measures were accompanied by a massive water saving information campaign. At a later stage, severe restrictive regulations were also introduced, which (a) prohibited and fined the use of treated water for irrigation, car and road wash, and swimming pools, and (b) restricted the private consumption to an upper limit, which was 70-100% of the consumption of the previous year, and fined heavily the exceedance of this limit (Christoulas, 1994).

The results of these measures were impressive as water consumption was reduced by a third (Figure 2). At the same time, individuals and municipalities searched for alternative local water sources, mostly groundwater from lower quality local aquifers to irrigate private and public gardens, to wash roads and cars and to use in industry. The entire experience shows the significant elasticity of water demand and its clear relation to water pricing (Figure 5).

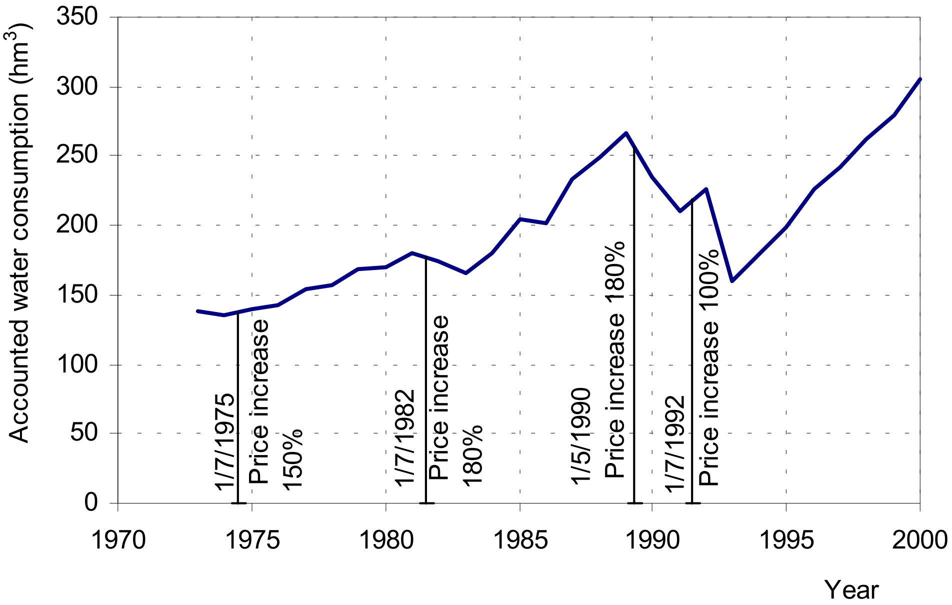

Figure 5 Schematic representation of the effect of price increase to water consumption.

2.4 Current situation and perspectives for the future

Today, seven years after the end of the drought period, the construction of the Evinos reservoir has been completed and put into operation, the restrictive regulations have been abandoned, and the annual water demand of Greater Athens exceeds the pre-drought period level (Figure 2). The rate of demand increase has become too high, exceeding 6% annually, although in 2001 as a result of a water conservation campaign it became 3%. A significant part of the rising trend is explained by the expansion of the supplied area and the trend of people to move from apartment buildings to houses with gardens at longer distances from Athens. This marks an improvement of living standard, but simultaneously is a threat for the water supply system.

Detailed studies (Koutsoyiannis et al., 2001) show that if this increase continues, the system will run out its capability in a few years. The potential for augmenting the water supply system by building new water resource projects is limited and extremely expensive. Therefore, demand management appears to be the only viable solution for Athens for the years to come. The experience from the water conservation campaign in the 1990s as well as the international experience in terms of the paradigm shift to sustainable water management show the feasibility and realism of this solution. In this respect, a comprehensive study is about to commence, which will analyse water use in depth and design demand management programs in a sustainability framework.

3 Conclusions

The last decade is marked by a paradigm shift in urban water context towards implementing sustainable urban water management, with demand management being a vital component. In Athens, a city with a dry climate and a long history that achieved sustainable water supply in ancient times, an explosive increase of water demand emerged during the 20th century, which forced the government to build an extensive water resource system conveying water from surface and ground reservoirs from long distances. However, in the last decade, a persistent drought forced the implementation of severe water conservation measures. This is regarded as a first step to modern water demand management; the next steps are now sought in order for the water resource system to become adequate on the long-term thus avoiding new structural solutions whose economical, environmental and social cost would be too high if not prohibitive.

References

Ashton, P.J., and B. Haasbroek, Water demand management and social adaptive capacity: A South African case study, in *Hydropolitics in the Developing World: A Southern African Perspective* edited by A.R. Turton and R. Henwood, 21 pp., African Water Issues Research Unit (AWIRU) and International Water Management Institute (IWMI), Pretoria, 2001.

Christoulas, D., Feasibility and potential for conservation of potable water, in *Proceedings of the Workshop The water supply problem of Athens*, 46-60, Department of Water Resources, Hydraulic and Maritime Engineering, Athens, 1994.

Hanemann, M., Pricing as a tool for demand management, Workshop *Water for the city: Strategic planning, demand management and network losses control*, National Technical University of Athens, University of the Aegean, Water Supply and Sewerage Company of Athens, Athens, 2000.

Kallis, G., and H. Coccossis, Metropolitan areas and sustainable use of water, The Case of Athens, Report, METRON project, University of Aegean, 2000.

Kores M., Water Supply in Ancient Athens, Workshop *Water and Environment*, EYDAP, Athens, 2000.

Koutsoyiannis, D., A. Efstratiadis, G. Karavokiros, A. Koukouvinos, N. Mamassis, I. Nalbantis, E. Rozos, A. Christofidis, A. Xanthakis, N. Damianoglou, C. Karopoulos, S. Nalpantidou, A. Nasikas, D. Nikolopoulos and K. Ripis, Master plan of the Athens water resource system - Year 2001-2002, *Modernisation of the supervision and management of the water resource system of Athens*, Department of Water Resources, Hydraulic and Maritime Engineering - National Technical University of Athens, 200 pp, Athens, 2001.

MacDowell, D.M., *The Law in the Classical Athens*, Thames and Hudson, London, 1978.

Turton, A.R. and L. Ohlsson, Water scarcity and social stability: towards a deeper understanding of the key concepts needed to manage water scarcity in developing countries, in *Proceedings of the Ninth Stockholm Water Conference*, 24 pp., Stockholm, Sweden, 1999.

Tate, D., An Overview of Water Demand Management and Conservation, Vision 21 synthesis paper, Water Supply and Sanitation Collaborative Council, 2001 (www.wsscc.org/vision21/docs/doc26.html).

Vlachos, E., and B. Braga, The challenge of urban water management, in *Frontiers of Urban Water Management*, edited by C. Macsimovic and J. A. Tejada-Guibert, pp. 1-36, IWA Publishing, London, 2001.

World Water Commission's Staff Report, World Water Vision, edited by W.J. Cosgrove and F.R. Rijsberman, 1999. (available at: http://www.oieau.fr/riob/forum2/visionreport171299.htm).