Efficiency in water planning and management (an implementation experience)

F. Vojdani
Tehran Province Water and Sewage Company (T.W.W.C), Room # 309 Central Bldg, Hejab Ave., Tehran, Iran (E-mail: *fvojdani@hotmail.com*)

Abstract Water is a primary factor in sustainable development; it may also be considered the most important component of economic and political power in contemporary world. Countries like Iran, which are located in arid and semi-arid regions of the world, since they are in permanent water crisis condition, must react by concentrating on research, pure studies and striving as far as possible to utilize water as optimally and manage water consumption. Lack of precipitation, inadequate infrastructure for collection, storage and recycling of water and above all, lack of public awareness regarding such issues as standard consumption patterns, force all countries like Iran to adopt strategic management policies and techniques toward such issues as water resources, maintaining and upgrading water quality, recharging of water resources and also other concepts, such as, "defined consumption".

Although Tehran province enjoys having various surface and underground water resources, and also so-called scattered and undirected water resources such as Qanats, springs, treated waste water, etc., adding all these resources together, it still cannot quench its thirst. Average annual temperature and rainfall, and also explosive rate of population migration to the province, are main reasons of existing and widening gap between supply and demand. It seems the only alternative left is to capitalize and utilize various techniques to reduce consumption, otherwise Tehran will face a continuous and uninterrupted water crisis. Proposed strategic management viewpoint should also cover other areas such as supply, transfer, treatment, storage and also distribution and consumption. For each of above topics, special operational management should be considered and executed. Although, there were many reasons behind the recent water crisis, one of the main reasons was uncoordination among various management divisions which ended up in rationing. Tehran's water crisis was handled successfully by utilizing various strategic management techniques, but in order to prevent such crisis repeating itself, we must adopt long-term strategic policies and demand management, also various techniques of efficient use of water.
Keywords Demand management; efficient use; water crisis

Introduction

There is no more valuable component in nature than water; life can not continue without water. Although 70% of earth is covered with water, in practice, only a small percentage of it is useable. Various studies point out that 97% of available water is saline; only 3% is freshwater, and 79% of this 3% is in ice caps and glaciers. Only 1% of this 3% is easily accessible and is in various forms of surface water; the other 20% of this 3% is in the form of underground water. This surface and underground water is utilized for various human needs like agriculture, industry and urban use. Figure 1 shows the overall condition of water in the world (Lean and Hinrichsen, 1994, p.107).

Although the available volume of fresh water seems to be enough for present human needs, the problem is that the geographical distribution of freshwater sources is not even, and its volume is decreasing. Figure 2 compares distribution of per capita freshwater among various continents in 1950 and 2000 (Vojdani, 2001, p.4).

On the other hand, precipitation rate and continuous accessibility of fresh water is not in a proper equilibrium in the world. Figure 3 shows a comparison of precipitation rate among some continents, Iran, Tehran, and also the world average (Conference of Planning, 1999, p.43).

Water Science and Technology: Water Supply **Vol 4 No 3 pp 67–80** © IWA Publishing 2004

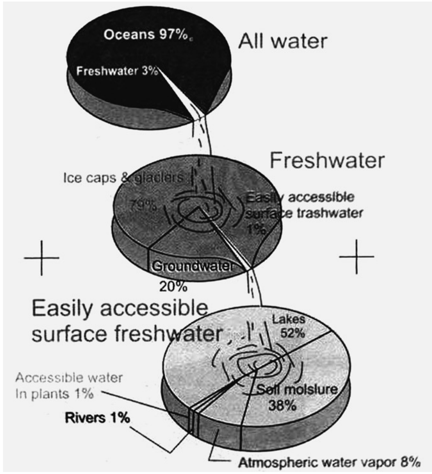

Figure 1 Distribution of the world's water

It is very clear that in the near future as the world population grows further and freshwater resources are inadequately protected, the whole world will face a water crisis. This situation could easily turn into political disputes and war. It is the duty of international organizations to exert strategic management over various sources of freshwater to ensure their protection and finally logical distribution. Although Iran is located between the Caspian Sea on the north and the Persian Gulf and Sea of Oman on the south, in its centre two vast deserts (Loot and Namak) exist; this condition has created an arid climate condition in central plateau of Iran. The capital city – Tehran – is on the fringe of these two deserts. Most megacities of the world are established close to a river, except Tehran. Historically, there was no intention to establish Tehran as the capital city of Iran, because there is no river in its vicinity.

Average annual rainfall in Iran as we have shown in previous diagram is about 250 mm which is 40% less than average annual rainfall of Asia and 29% less than average annual rainfall of the whole world. Also, average precipitation in Iran is not evenly distributed: at one extreme by the Caspian Sea rainfall is about 440 mm and at the other, around Hamoon lake it is about 110 mm. The figure for Tehran is about 231 mm, which indicate the situation can easily turn into water crisis at any moment.

Due to dispersion of population in Iran, the uneven distribution of precipitation in various parts of the country and also a lack of planning, most of the rainfall flows into the Caspian Sea, Persian Gulf and Sea of Oman, or goes into neighboring countries. For efficient use of water inside Iran, we have not yet defined a strategic management approach (T.W.W.C. Activities Report, 2001, p.19).

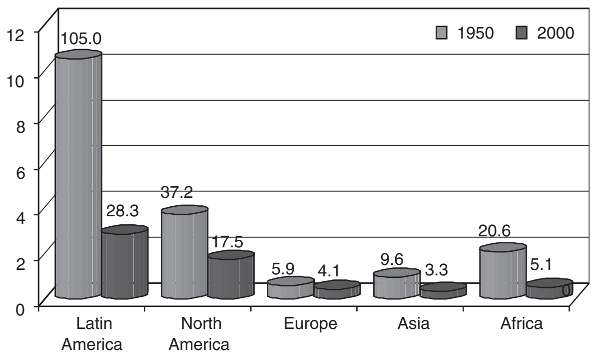

Figure 2 Accessible per capita drinking water resources in various continents (1950 and 2000)

Effective factors related to waterworks in Tehran

Factors related to special geography of Tehran

Geographical potential of Tehran. One of the most important factors is the geographical potential of Tehran. Tehran, now considered one of the megacities of the world, not long ago was a small village near Damavand mountain, located in the north of the city of Ray; Ray was the most prosperous city of the central plateau of Iran. There was no intention to turn this sleepy village into a city, and certainly no intention to turn it into the most important capital of Middle East. Mostly, it had mud housing, and because it had a very low population, despite lacking a modern water network, there was no problem at all related to supply of water for its residents. This is why this place slowly started to attract incomers and grew. Not having a problem with supply of water became a main attraction for new immigrants from all of Iran. As the population increased, and despite installation of a modern water network and expansion of waterworks facilities, consumption kept increasing. Finally it reached a point where, due to inadequate supply, problems started to occur. Water shortages were more and more felt. As a result, for the first time in 1963, it was decided to tap into the underground water resources during peak consumption time.

Owing to this unplanned fast expansion of Tehran and not having a proper model for managing the city, various city managers have never had an opportunity for proper planning and to exert long-term management. In this situation, the various authorities responsible for offering services related to water, power, gas, and the municipality have pulled in their own direction. This is one of the main reasons why Tehran has not been able to offer urban services that match modern standards for quality and quantity. Preventing further unplanned expansion of Tehran has become essential. Modern Tehran does not have any further capacity for expansion. The explosion of the population is forcing further extraction of underground water resources, which in turn causes extreme drops in underground water levels.

The rechargeable water resources volume of Iran is about 130 billion cubic metres a year. For the province of Tehran this figure stands at 6 billion cubic metres. The potential annual per capita resource for the whole country is around 2,030 m^3; for the province of Tehran this figure is about 1,000 m^3; for the city of Tehran this figure is about 600 m^3. When we compare this with world's Per Capita Index, which stipulates 1,000 m^3, we get a clear picture of where we are headed. If the per capita value reaches 500 m^3/year, we have a definite crisis. Tehran is very close to that value, and is always on the border of crisis.

As shown in Figure 4, annual per capita rechargeable volume of water for the whole country (based on 2001 statistics) was about 1,776 m^3. If we subtract about 600 m^3 from this figure, we will have last year's per capita value for the province of Tehran, which is an

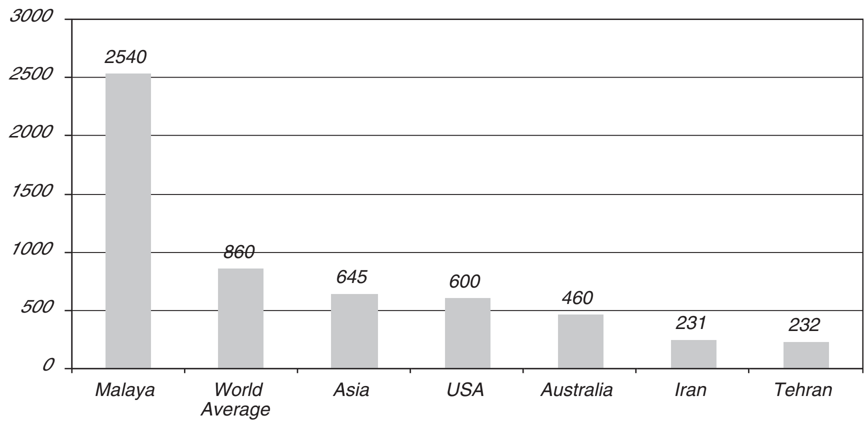

Figure 3 Comparison of average precipitation in different locations of the world

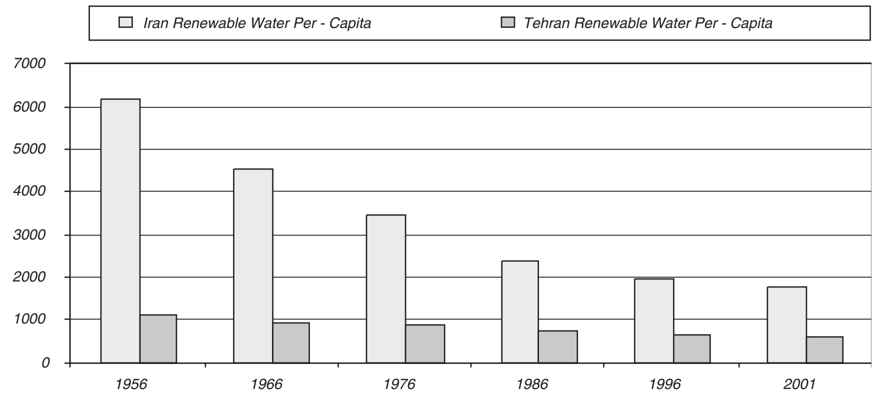

Figure 4 Comparison of national renewable water per – capita with that for Greater Tehran (1956–2001)

indicator of a supply crisis situation for Tehran area, and also indicates that there is an extreme need for the transfer of water from long distances. On the other hand, from consumption point of view, there is also an extreme need for better and more efficient distribution management and consumption (Vojdani , 2001, p.28).

Precipitation. As mentioned before, Tehran is located close to the central desert and far from a permanent river; its an annual precipitation rate of 231mm is less than national precipitation rate of 250 mm. The last 60 years of collected data also indicates that, every several years, we are faced with unusual climatic conditions which cyclically create dry and wet periods. One more point has to be emphasized: the durations of these dry and wet periods are uneven. Since 1998, a new round of "dry season" started; it lasted all the way till 2001. In Figure 5 the annual rainfall of Tehran is compared with average rainfall through the drought and wet periods of the last 60 years (Tehran water crisis, 2001, p.15).

During dry periods (like the recent one), problems related to all facets of waterworks usually become harder and more complicated. Meanwhile, Tehran's population keeps growing, and in turn consumption keeps increasing, the opportunity to replenish the dams does not exist and surface sources decline. This is clearly shown in Figure 6 which shows statistics for the last decade (Vojdani , 2001, p.10).

Explosion of population and unplanned immigration. The size of population with access to sanitized water network is directly affected by the rate of increase of population and rate of

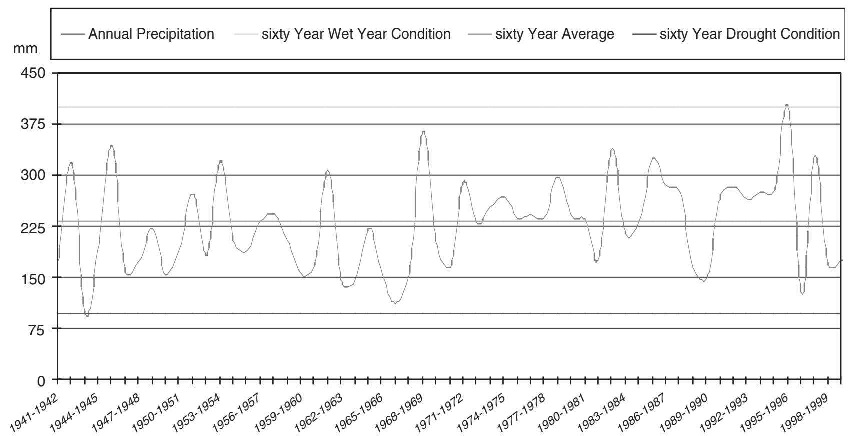

Figure 5 Comparison of Tehran annual precipitation trend with sixty year average precipitation, dry year and wet year conditions

immigration to this megacity. The influx of thousands of so-called guests (2 million non-residents) who for various reasons, including lack of proper planning at national, provincial and municipal level, have to travel to Tehran, creates many complex problems including those related to water. Relatively high living standards in Tehran attract immigrants. To the the south, the cities of Ray and Tehran are connected; to the north, we have already reached 2,000 m altitude. To east and west, Tehran has become connected to suburban towns. New high rises and apartment complexes go up constantly, adding to existing problems.

Figure 7 compares Tehran population during 1956–2001, and also shows consumption trends. It is very clear that as population grows, the consumption rate grows even faster (Strategic plan of T.W.W.C, 2001, p.17). Figure 8 indicates that per capita rechargeable water has an inverse relation to the rate of population growth. As population has grown, per capita rechargeable water has decreased from 675 m^3/year to its lowest level of 255 m^3/year. In 2001, Tehran population reached 7.2 millions (plus 2 million non-residents) and the number of people with sanitized water network access reached 7.06 millions (Tehran water crisis, 2001, p.11).

Factors related to water supply resources limitations

Potential surface water resources. The main surface water resources in Tehran area are Karaj river with a potential of providing 330 million m^3/year or 8.2 m^3/s and Jajrood river with a potential of providing 270 million m^3/year or 7.5 m^3/s or 4 m^3/s during dry periods. Lar river which is located above Jajrood river, and Taleghan river which runs above Karaj river, are considered next when it comes to surface water resources. In other words, all surface water potentials have been utilized. Figure 9 shows the maximum potential of

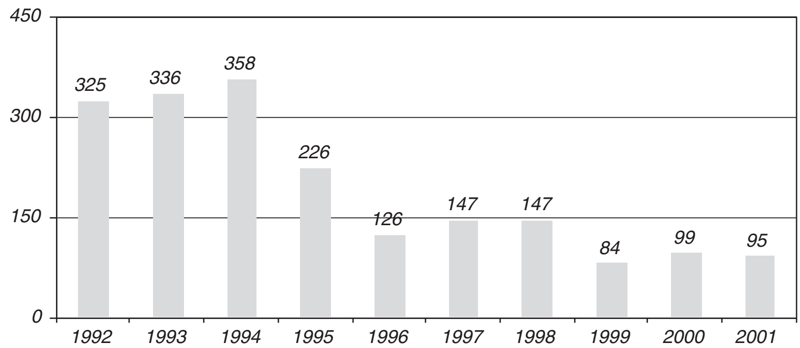

Figure 6 Comparison of total volumes of dams (Karaj, Latian and Lar) end of: 1992–2001

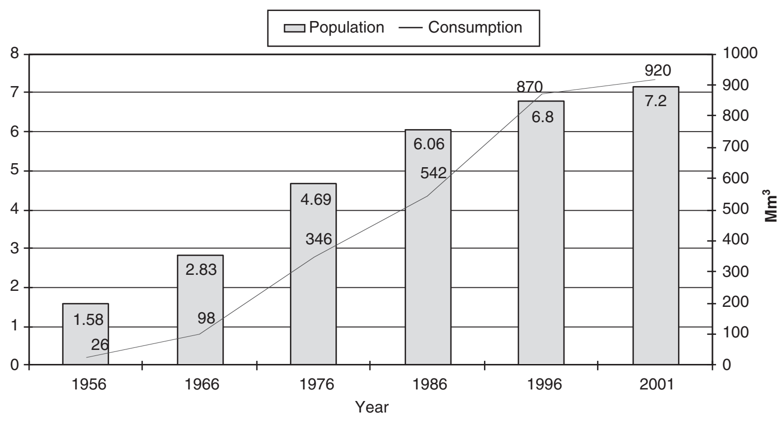

Figure 7 Comparison of Tehran population growth with consumption trend (1956–2001)

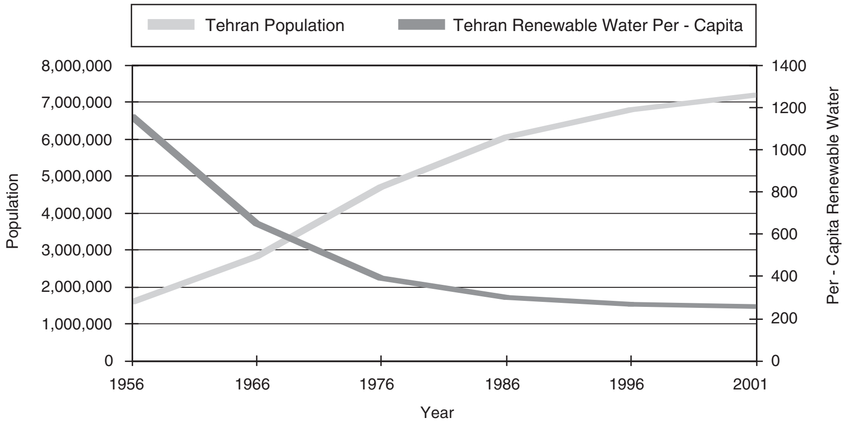

Figure 8 Comparison of trend of per capita renewable water with Tehran's population (1956–2001)

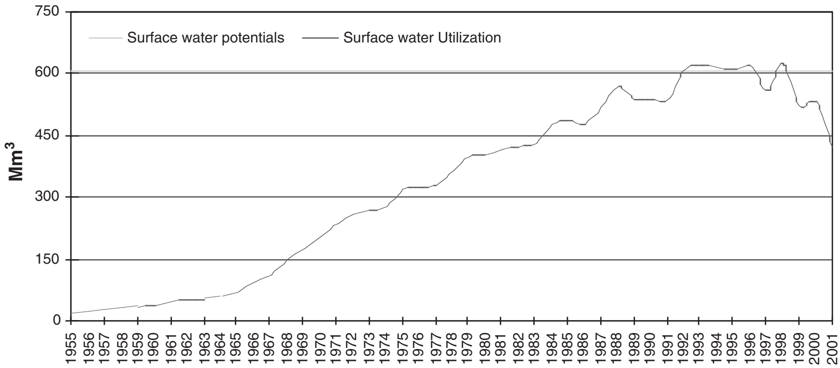

Figure 9 Comparison of surface water potentials and utilization rate of these resources (1955–2001)

surface water and also reflects the volume of water that has been taken from these resources(Vojdani , 2001, p.12).

Limitation of raw water dam storage. The total volume of water that can be stored behind Karaj dam is about 200 million m^3, for Latian dam this figure is about 90 million m^3 , and for Lar dam 900 million m^3. The total amount of raw water that can be stored behind these dams is thus about 1.190 million m^3 which cannot all be utilized. It is estimated that about 50 million m^3 of this total volume is sediment. Figure 10 compares the volumes of usable surface water during the period 1992–2001 (Tehran water crisis, 2001, p.15).

Potentials of underground resources. Based on the results of studies that were carried out by consultants, the overall annual potential of underground water that can be extracted is about 250 million m^3. During dry or drought seasons, owing to reduction of surface water volume, there is a tendency to extract more water from underground resources than the defined limits. This in turn reduces underground water levels.

Experience has shown that any extraction over this recommended level causes extreme damage to these fragile resources. Initially underground water resources were considered as reserved for only the peak hours of summer season (June–August), but gradually Tehran was left no option other than utilizing these underground resources on continuous basis. During recent years, the volume of water extracted from these resources has reached 150% of the recommended limit. Figure 11 is a comparison of water extraction from underground resources between 1992–2001 with the recommended allowable limits (Vojdani, 2001, p.14).

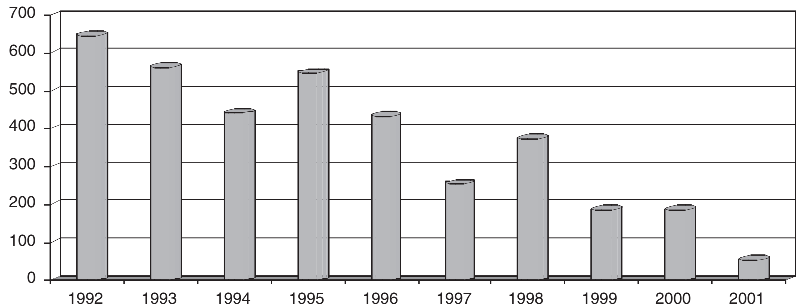

Figure 10 Comparison of utilization of surface water capacities (3 dams)

Adding the total annual potential of surface water (c. 600 million m^3) and the recommended annual extraction from underground (c. 250 Mm^3) gives 850 million m^3 water available to be utilized on annual basis. If we compare this total volume of resource with the 2001 consumption level (c. 920 Mm^3), we see a 70 Mm^3 shortage, which should be replaced either from underground resources or by various techniques of consumption management.

It should be noted that the consumption level of 920 Mm^3 is about 2% of total national resources, while, 20% of country's population live in Tehran. These figures very clearly show the lack of equilibrium between these two factors, population and water resources.

Factors related to limitation of waterworks facilities

Current facilities (pipelines). Limitation of transferring facilities of raw water from Kari and Latian dams to Tehran during good (wet) years sometimes has been the main problem with waterworks. Waterworks facilities and pipelines date from at least 20 years ago, and were tailored for the population of that time. These facilities have to be repaired, renewed and also expanded. The total length of raw water transfer facilities is close to 568 km, which could transfer about 12.5 m^3/s from Karaj dam, and 10 m^3/s from Latian dam, adding to about 22.5 m^3/s.

Treatment limitation. Currently, total treatment capacity at 4 treatment facilities is about 22.5 m^3/s or 547 million m^3/year. If a fifth facility becomes operational, total treatment capacity will increase to 37.5 m^3/s. Since 1987, these facilities have been utilized above their nominal capacities. Figure 12 compares the volume of treated water to the overall nominal capacity by treatment plants during 1984–2001. Practically, the available facilities are treating 15 m^3 less than the volume needed by Tehran citizens (Vojdani , 2001, p.22).

Pumping capabilities. With due attention to special topography of Tehran city, pumping stations and capabilities are extremely important factors. At present there are 35 pumping stations, pumping water to 6 higher levels, to altitudes of 2,000 m above the sea level.

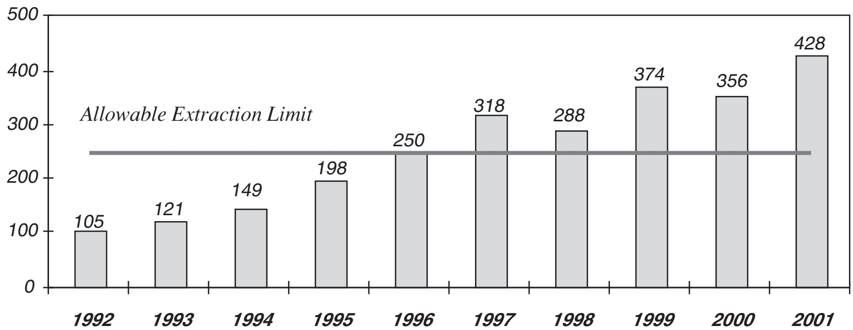

Figure 11 Comparison of deep well extraction (1992–2001)

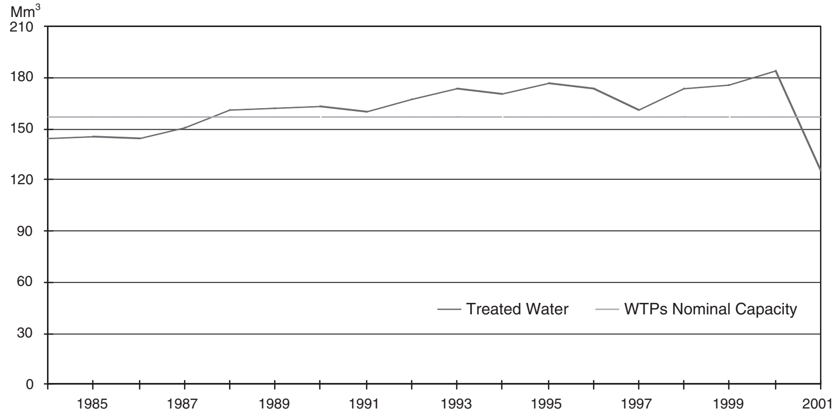

Figure 12 Comparison of treated water produced with WTPs nominal capacity in summer (1984–2001)

Tehran has an extreme difference between its lowest and highest point of around 800 m. This creates a special problem of providing proper pressure on the network on a continuous basis. This is why at present there are 530 water reducing valves being utilized; of course, aligning all these valves needs a specially high level of effort. The total volume of water being pumped to higher levels is about 1,750,000 m^3/day. Figure 13 compares the maximum volume of water that was pumped to higher points with the maximum potential of capability of pumping to higher points during 2001. We can easily conclude from these statistics that some of Tehran's waterworks facilities are right at a crisis point from operational point of view (Strategic plan of T.W.W.C., 2001, p.32).

Total capacity of water reservoirs. All together there are 55 distribution, pumping and reservoirs facilities in Tehran. Currently all major cities of the world have not only reservoirs for daily consumption, but also enough reserve capacity to provide water for at least 24 to 48 hours, as precautionary measures. From this point of view, Tehran has not reached an acceptable standard level. Also the total amount of water reserved for distribution is not in proper shape. Because the total capacity of reservoirs in operation now is about 1.7 million m^3, due to expertise and experience of waterworks personnel reserving and distribution of water has been down on time. Minimum volume of required treated water for Tehran on daily basis is 2.1 million m^3, average daily consumption volume is about 2.55 million m^3 and maximum daily consumption volume is about 3.1 million m^3. In other words, average need is about 21 m^3/s and in summer season, this figure easily reaches 33 m^3/s.

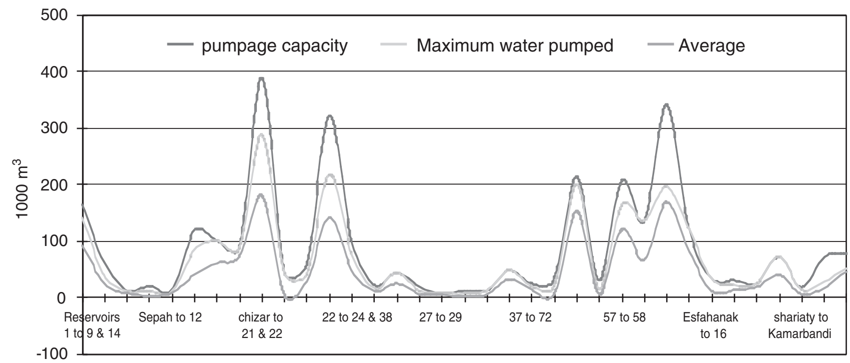

Figure 13 Comparison among maximum and average volume of water that was pumped to upper levels with maximum capacity during 2001

Distribution network. The distribution network of Tehran city is in worse condition than other facilities. Its total length is 9,200 km, servicing an area of 50,000 hectares. With the continuing addition of new buildings and the aging of large portions of the existing distribution network, complicated problems are emerging in distribution. Leakage is mainly due to the age of some parts of the network, and the lack of enforcement of engineering standards during installation of facilities is another big problem. The network also incorporates 100,000 main valves and 530 pressure reducing valves.

These complicated issues and problems facing effective waterworks and distribution, and also the disequilibrium in water supply and consumption since 1991, have forced senior management of Tehran Water and Wastewater Company (TWWC) to re-examine previous actions, to look at everything from an accountancy point of view and at the same time, start planning for repairs, reconstruction and renewal of the transfer line, waterworks facilities, distribution network and also leakage control. At the same time, effective measures were considered to promote more efficient operation when it comes to treated water. With the continuation of drought during 2001, the extreme shortage in water resources, and the increasing consumption rate, Tehran reached a water crisis and consequently water rationing was imposed (Vojdani, 2001, p.25).

What is water crisis?

Needed per capita water for every consumer is the sum of his/her drinking, sanitary, industrial and agricultural needs. These are embodied in the following equation:

per capita index = total available water/total population

Currently, from a per capita water point of view, countries in the world have been divided into three categories:

1. countries without water shortage, i.e. with an annual water per capita of above 2,500 m^3
2. countries with water shortage (stress), annual water per capita of 1,000 to 1,700 m^3
3. dry countries; those with annual water per capita less than 1,000 m^3.

An annual water supply per capita of 1,000 m^3 has been defined as an international index for water crisis (scarcity); the universal index for absolute water crisis is about 500 m^3/year. From this perspective Iran is in the second category. Figure 14 shows conditions of

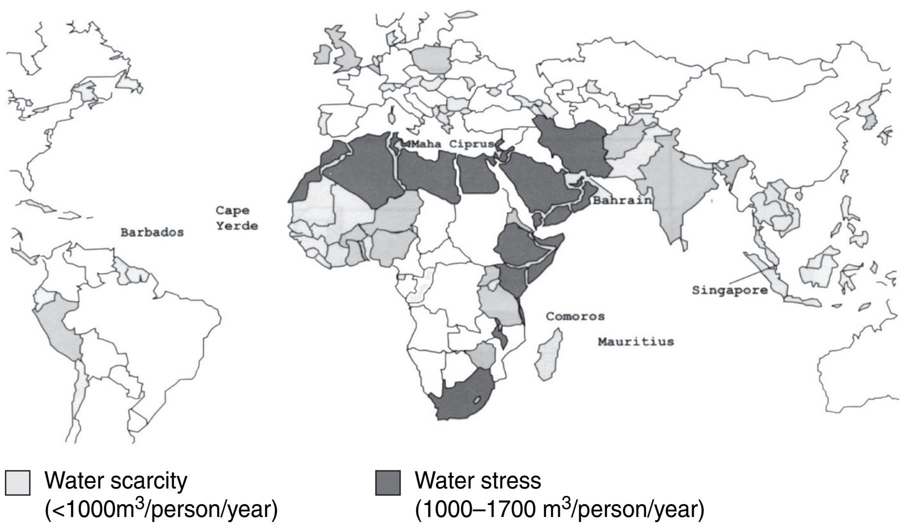

Figure 14 Conditions of various countries of the world from water shortages and water crisis point of view

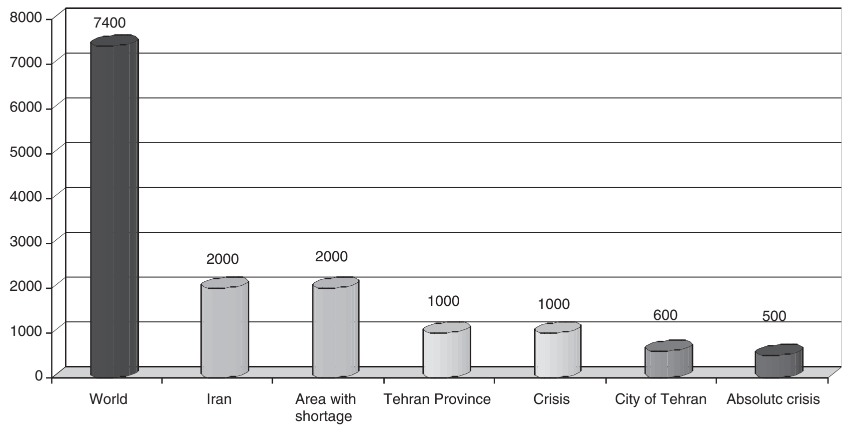

Figure 15 Comparison of potential per capita of Tehran with absolute crisis, crisis, area with shortage per capita with Iran and world

countries of the world from water shortages and water crisis point of view (Gardener-Outlaw and Engelman, 1997, p.69).

Iran's low average precipitation (less than 1/3 of the world average) places it among the arid and semi-arid countries of the world. The very uneven distribution of water resources (both surface and underground) and population across Iran aggravates matters. Dividing Tehran's water resources volume by its population gives about 600 m^3/person/year, which puts Tehran very close to absolute water crisis condition (500 m^3/person/year). Figure 15 compares Tehran per capita of water to absolute crisis volume, crisis, areas with shortages of water, Iran and the world (Vojdani, 2001, p.21). Either resources have to be increased, which is almost impossible if we consider potential precipitation and total volume of surface and underground resources, or the number of people in the area must be reduced by preventing further development and discouraging people from moving to Tehran.

Statistics indicate that national water per capita decreased from 7,000 m^3/person/year to 2,000 m^3 during last 40 years, and this trend still continues. Not increasing raw water reservation capacity will perpetuate and complicate this problem during dry and low precipitation periods. One important point is that national water conditions, especially in Tehran area, have been known for many years ago and from the available statistics the repetition of dry periods is nothing that could not be predicted. It thus becomes clear that the main reason of water shortage is unplanned population increase in the whole country, and especially in Tehran province. Tehran was also faced with unplanned and continuous increase of migration, which intensified the situation. These two factors, migration and uncontrolled population increase, should have been controlled and limited many years ago, and Tehran's dimensions should have been defined and restricted long ago.

Drought has a very important role in limiting surface water resources, but we should not forget that this phenomenon is periodical; if the water system has enough capacity, it can with proper maneouver and skills cope comfortably with drought. It is worth mentioning that if we did not have a water crisis in the recent drought it for sure would certainly occur in the next few years because of rapid increase of consumption. The water crisis since 1991, when supply and demand curves reached their break-even point, was to some extent predictable: we should never forget the fact that supply resources are limited.

Although reaching the optimum of consumption and production seems remote and not easily accessible, trying to reach these points can prevent future catastrophes. An effective strategy would be to concentrate on demand reduction and various known techniques of consumption management, giving optimum and proper exploitation of water resources.

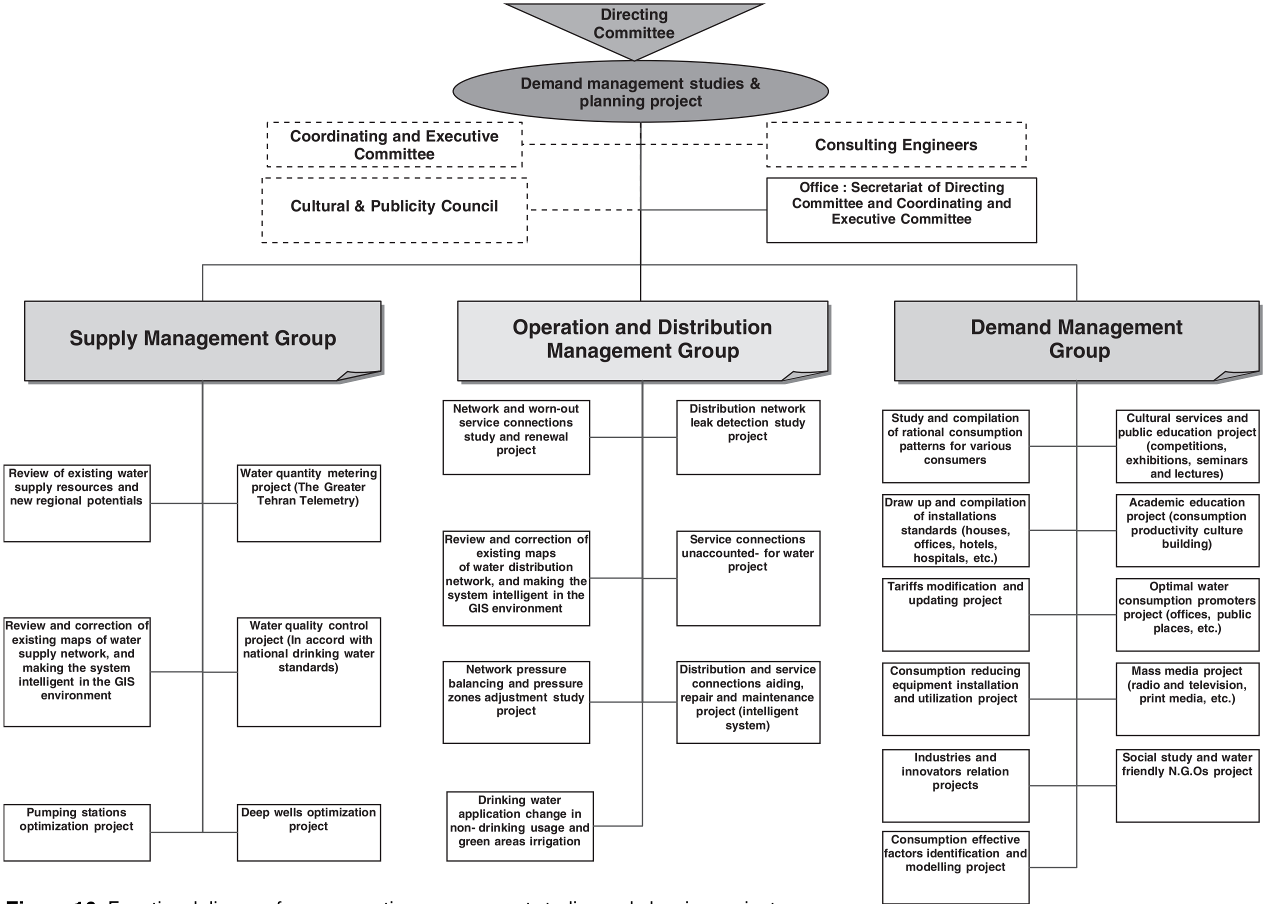

Figure 16 Functional diagram for consumption management studies and planning project

Demand reduction and consumption management

During the previous droughts, when annual precipitation was not at the usual level, in order to reduce its intensity, usually the only solution was to implement various new measures in the water network. These activities were the foundation of the water crisis committee of Tehran Water Organization (TWO).When Tehran Water and Wastewater Company (TWWC) was founded in 1991, the idea of holding such committee was adopted, and periodically the committee was active.

During winter 1995 we did not have enough precipitation, and it was predicted for 1995–96 that it would be a very dry season. Therefore, the importance of activating such a committee was once more noticed. This committee, with membership of general director's deputies, management staff, and various top experts of TWWC and TWO started regular weekly meetings; one of the main objectives was to find and define effective factors for reduction of consumption levels. The results were a sum of ideas of participants, identification and listing of various cultural and practical techniques, which when implemented had a great effect on supply side of the equation, and various aspects of consumption were better known and organized.

With the limited water resources and low precipitation, the increase of population with access to sanitized water and rapid increase in consumption, plus extremely high costs related to reclamation of household wastewater due to detergent contamination, the need to control demand and exert various techniques of consumption management became much more critical than before. However simply paying attention and concentrating on demand control and consumption management were not enough: some sort of rational and reasonable consumption management had to prevail. That these views were not prevalent among the public had been in the minds of senior officials for some time, and they were seeking solutions. In 2001, as pressure of drought was felt again, in order to review and lay the foundation for institutionalizing public opinion regarding demand management, (and organizing and directing public opinion within the framework of organized long-term plan, which was divisible in 5-year plans) it was decided a project should be defined. The title of this project was "Consumption Management Studies and Planning Project". The objective was that within its framework, all effective factors related to Tehran waterworks should be reviewed and organized in one structured project.

Consumption management studies and planning project

In order to recognize effective factors in planning and managing Tehran water, this project was started with the help of a group of experts and highly experienced personnel. Members of the group were divided into 3 sub-groups and were asked to concentrate on specific subjects as follows.

Supply management

This includes predictions and long-term policies regarding sustainable and sanitized supply of quality water for the city of Tehran. It is necessary that all water resources be audited one more time and all new potential resources be recognized. Also, all maps related to water network shall be audited and any necessary correction and amendment shall be executed in a GIS environment. Also effective solutions shall be considered to improve the operation of pump stations and deep water wells. One of the main programs in this section will be measurement and telemetering of supplied water in different stages of production so that we can determine the exact percentage of unaccounted for water. Another part of the program will concentrate on ensuring that necessary and proper quality control shall be observed following national and international drinking water standards.

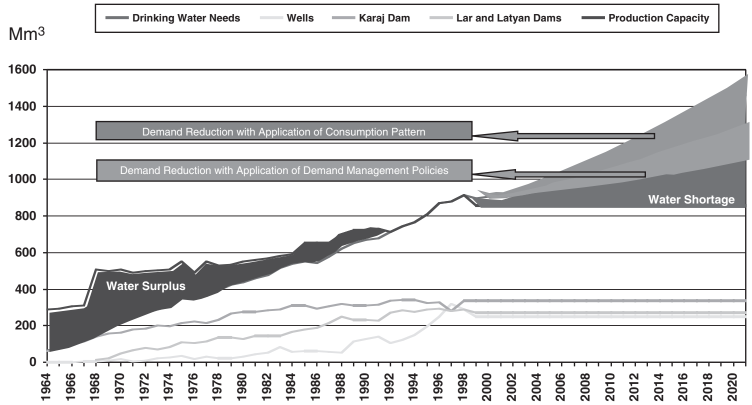

Figure 17 Trend of consumption growth rate and comparison between Tehran potable water supply and existing potentials by 2020 (TWWC Activities Report 2002, p34)

Operation and distribution management

In order to utilize the maximum potential of equipment and personnel in a framework of a dynamic and effective management system, it is necessary in operation and distribution area, that all distribution network maps be updated and corrected in the framework of an intelligent GIS environment. Old sections of networks and connections shall be repaired and reconstructed. Various pressure zones shall be introduced, in order to keep the whole network in a balanced and low-pressure situation. The whole network shall be controlled for leakage. By replacing old water meters, the percentage of unaccounted-for water should drop. Using sanitized drinking water to water greenery shall be stopped and unauthorized subscriptions shall be identified. Emergency repairs and distribution network maintenance shall all become part of an intelligent systems.

Consumption management and demand reduction

A logical pattern and a proper consumption culture, in effect a total new look at water as a valuable element of life must be fostered in new generations; this shall be done through proper policies and orderly reduction of demand and consumption control in consumption management area. Two types of activities related to subscribers' issues and to socio–cultural issues shall be addressed. Defining a logical pattern of consumption for all different kinds of subscribers, updating and correcting water tariffs, installing water reduction equipment, logical relation with manufacturers and inventors of water reduction equipments, recognizing and classifying various effective factors in consumption, all are various issues related to subscribers. Public education regarding water consumption via exhibits, shows, seminars, etc, fostering the culture of efficient water consumption in collaboration with ministry of education, fostering efficient water consumption in public and private organization, and defining the important place of water in human life (and in particular the importance of waterwork equipments in urban life), teaching the public about consumption patterns, utilizing NGOs, all can be issues related to cultural social activities. Figure 16 details the Consumption Management Studies and Planning Project (Vojdani, 2001, p.24).

Strategic solutions to water crisis

Given the lack of water resources, low potential of precipitation and underground resources, and Tehran's topography, distribution network age, increasing population accessing sanitized water, high rate of consumption (even more than international standards), the high cost of reclaiming industrial and household wastewater, and finally, lack of acceptable alternatives, the only option left would be to concentrate on bringing consumption level down from its current level and reach an equilibrium with potential water resources.

To reach this goal while trying to relieve some of the current deficiencies, TWWC has to concentrate on fundamental repairs to intake facilities, transfer network, water treatment centres, pump stations, distribution network and finally expand the sanitized water network to cover all of Tehran's city limits. This must be done within a long term framework, divided into several 5-year plans in such a way as to comply with national social and economic 5-year development plans.

For implementing such a plan, a very exact timetable is required and we have to accept that this project would be a costly one, and it may not be executable in such a fast pace that is expected. Because its initial groundwork will mostly be educational and cultural, it will be extremely time-consuming and like any other cultural phenomena it must involve all dimensions of society. If these ideas can be implemented, other cultural phenomena like efficient use of water will become possible. In short, to reach the goal of exiting current and future crises, various measures are needed; here we will only mention some of these targets and strategies.

- Reduction of unaccounted-for water from current 32% to 20%; this will be an acceptable international level.
- Changing consumption patterns in order to reduce consumption from 380 L/day per capita to 300 L/day by 2020.
- Utilization of various unaccounted resources like springs, quants, treated wastewater, deep wells with low quality water in order to dedicate them for other uses than drinking water.

Viewing the situation over a period of 60 years (see Figure 17), three distinct sub-periods can be identified.

- First period, from 1962–1992; in this period supply is greater than demand. There was no problem in various aspects of waterworks, and in fact, there was a surplus of water.
- Second period, from 1992–1999; supply and demand reached a break-even point and when there was any shortage, underground water resources were tapped to compensate.
- Third period, from 1992–2020; supply capacity is less than demand and shortage amount slowly completion and execution of logical water patterns, and implementation of proper consumption intensifies, the gap between supply and demand will reach 584 Mm^3/year on 2020. It is hoped that with management 271 Mm^3/year, we could reduce above mentioned gap. In this scenario, 306 Mm^3/year shortage will be a definite capacity for year 2020 which shall be transferred to Tehran from far distances.

References

A short report about various activities to face Tehran water crisis during 2001. Available in TWWC crisis secretary archive.

Gardener-Outlaw and Engelman (1997). p.69.

Lean and Hinrichsen (1994). p.107.

Peoples, Mass media and Tehran Water Crisis Dr. Badeie. Available in TWWC crisis secretary archive.

Strategic plan of TWWC to overcome 2001 Tehran water crisis.

Tehran water crisis (past, present, future). Available in TWWC crisis secretary archive.

TWWC Conference of Planning , Dec. 1999. Available in TWWC library.

TWWC Activities Report (past, present future). Available in TWWC research office.

Various reasons for Tehran water crisis occurrence and strategic planning to overcome that, Vojdani Fowad, available in TWWC library.