AN EXPERIENCE OF CREATING A DUAL WATER DISTRIBUTION NETWORK IN THE CITY OF QOM

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Abstract:

Average precipitation in Iran is less than one third of the world's, and is very unevenly distributed across the country. In recent years, renewable water sources have dramatically declined in the face of growing population and enhanced lifestyles. This has made water conservation an unavoidable necessity. With the annual precipitation rate of less than 135 mm and a population of over one million, the city of Qom has historically tackled the water scarcity problem. To address the issue the idea of separating the potable water network from non-potable water distribution network was put forward. To implement this idea, design and execution of separating the potable water from non-potable water network was launched in 2000. At this stage, the revision of all procedures related to investment, water production, distribution and sales of potable water in addition to the maintenance of water distribution network and other water utilities as well as the consumption patterns became imperative. The responsibility of supplying quality water from a number of wells to the distribution network, using the existing pipes that could be separated from the main network, was transferred to the private sector following a bidding process. Then, the water distribution network was extended and the number of potable water distribution stations utilizing RO desalination equipment increased, thus, the water of a higher quality was produced and distributed in the city. Moreover, a production capacity of 1500 cubic meters per day has been created, with the possibility of increasing it to 6000 cubic meters per day, distributed in the second network through the stations.

The execution of the above said project addressed one the most crucial issues faced by the national and provincial authorities related to the supply of potable water to the city of Qom, as the quality of available potable water resources in the province of Qom had lowered due to insufficient rainfalls in the previous years. For instance, the Electrical Conductivity (EC) of water in the distribution network exceeded 4000 µmhos/cm in the years 2000-2002 and 2009-2010. The potable water quality at the stations is EC= 420 µmhos/cm, TDS = 320 mg/l and TH= 81 mg/l $CaCO_3$.

Introduction:

About 5 – 10% of household water consumption is used for drinking and cooking, whereas the remainder is used for sanitary uses. In recent years, population growth of cities and enhanced lifestyles have resulted in increased water consumption and water demand.

On the other hand, given the limited water sources available, the importance of maintaining the quality of potable water has always been the primary concern of planners in the water industry.

Therefore, since 1998 Qom Water and Wastewater Company have undertaken serious studies on the effective management of existing water resources and supplying the potable water of suitable quality. Finally, the separation of the potable water from non-potable water distribution network was approved and highly prioritized as an effective solution to resolve the problem in the short and long terms. Efforts made by planners and implementation managers of the company for more than a decade have resulted in creation of two separate networks for potable and non-potable water across the city of Qom. Moreover, the financing of the project and investments for production and distribution of potable water were made by the private sector.

This paper is aimed at explaining the problem areas, justifications behind approval of this plan and its results. It is hoped that the above said experience would prove useful for cities with similar water supply problems.

Background of the Project Execution:

Iran, with an average annual precipitation of 250 mm which is less than one third of the world's average, is classified as a semi-arid country in the world. Moreover, this little annual precipitation is distributed unevenly across the country, as 1% of the country's area gets a rainfall of over 1000 mm while 28% of the country has less than 100 mm. Furthermore, 70% of the total annual precipitation of Iran is evaporated. Factors such as population growth, need for enhanced sanitation and social welfare and industrial development increase the water demand every day. In other words, the annual per capita amount of the renewable water sources has dropped from 7000 cubic meter in 1956 to less than 1900 cubic meter in 2007. According to the classifications of the UN, Iran will enter the severe water scarcity conditions this year and, thus, management of water sources through a number of technical, administrative and legal measures will become a serious concern for Iran.

Qom province, located in the central desert of Iran, has historically suffered from water scarcity problem. The shortage of water and the unavailability of suitable potable water has been the most critical problem of this city for ages. Annual precipitation rate of Qom province amounts to 135 mm with an extremely high evaporation rate owing to desert conditions. Besides, immigration to this city has been extremely high and incomparable to anywhere else in the country since the years after the Islamic revolution (growth rate of over 8% since 1980's) due to its various attractions, boosting demands for water.

Table 1: Status of Renewable Water Resources in the World

Area	Renewable water resources per square km	Per capita rate of renewable water resources (cubic meters per year)
Europe	277000	4230
North Americas	324000	17400
Africa	134000	5720
Asia	311000	3920
South America	672000	3820
Oceania & Australia	269000	83700
Middle East & North Africa	41000	1400
World	317000	7600
Iran	79000	1900

Figure 1: Average Water Budget of Iran (Long-Term)

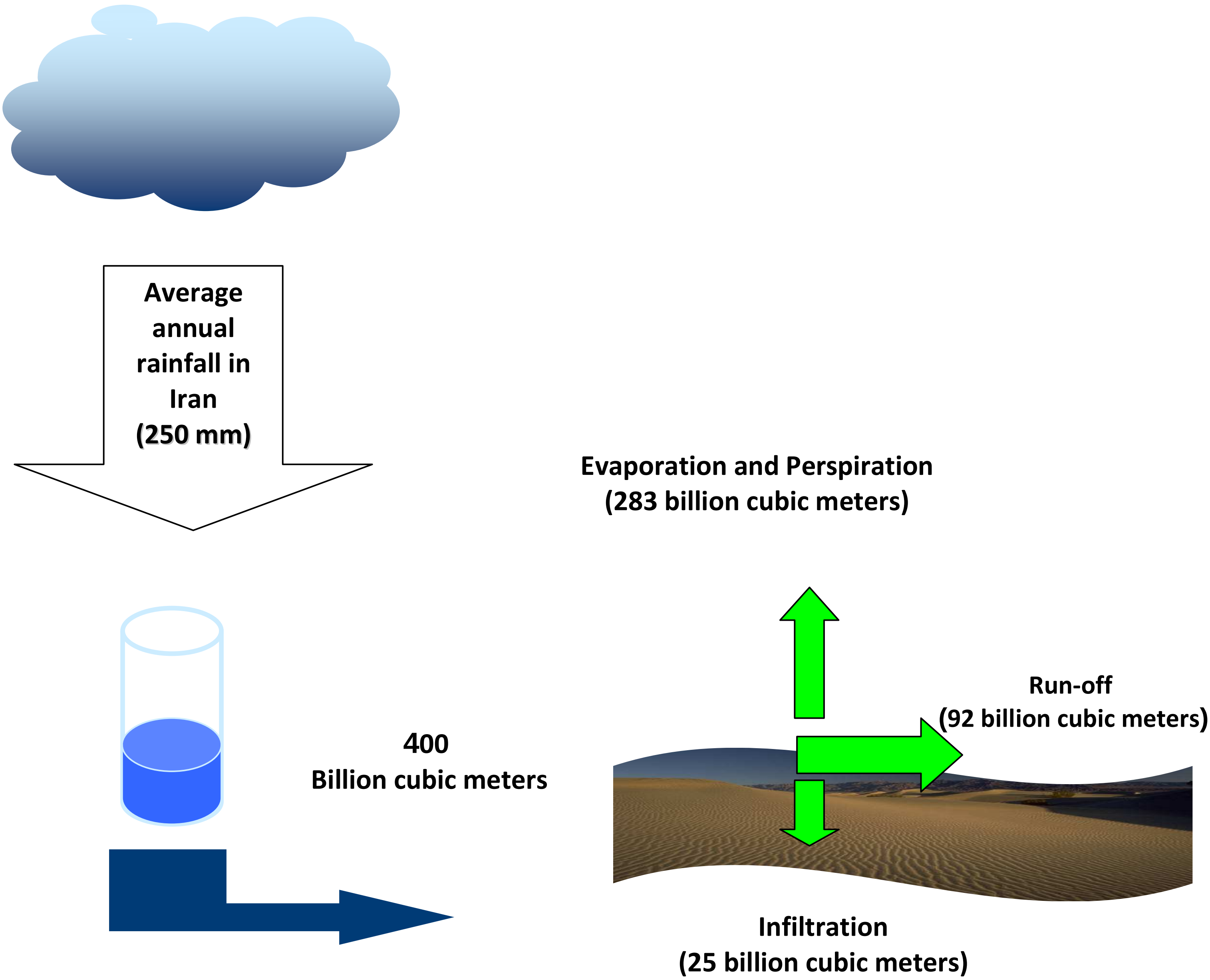
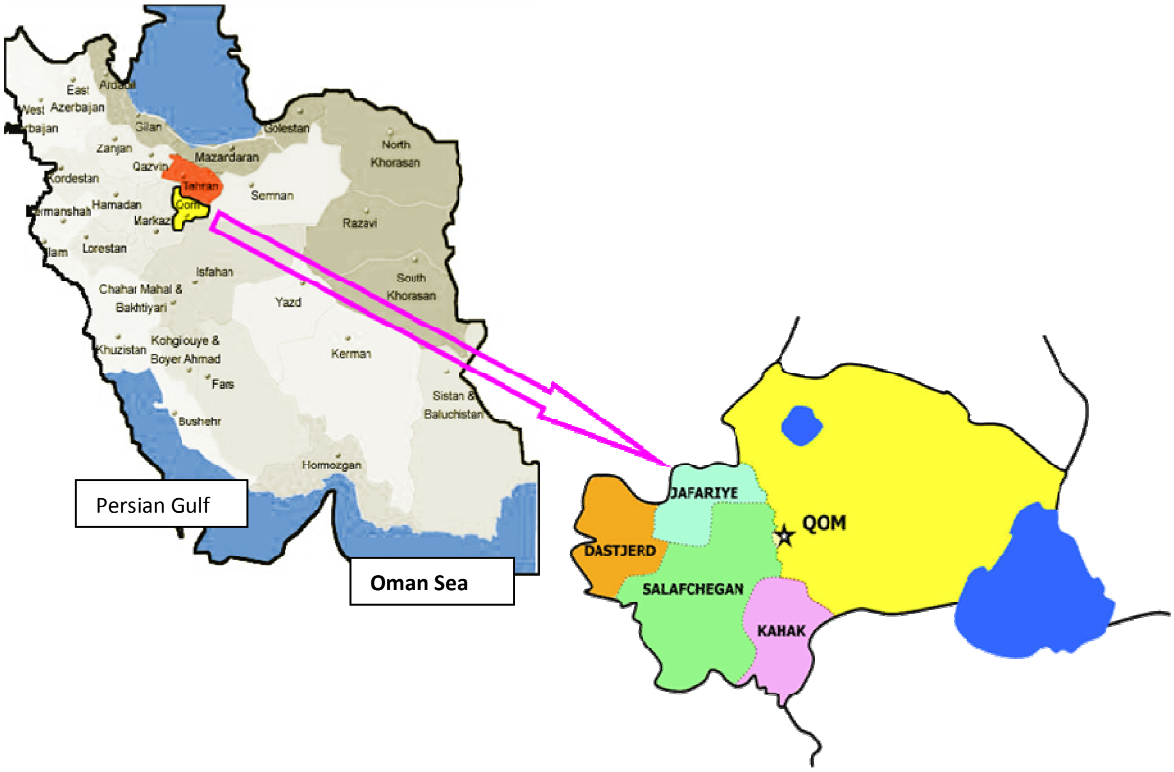


Figure 2: Position of Qom Province (Located at the Central Desert of Iran, with pilgrim admission and a high population growth)



Water supply resources for the city of Qom:

Water supply issue of Qom has been has been raised at various intervals and the initial studies for a modern system were launched by French and Iranian engineers in 1952. The ever-increasing population and pilgrim admittance by this city has led to an increase in water demand, resulting in various water supply schemes being high on the relevant officials' agenda as detailed below:

1. Ground waters of Qom Plateau

2. Ground waters of Ali-Abad Plateau (wells)

3. Panzdah-Khordad Dam

The groundwater resources of Qom plateau generally contain various salts and compounds of high solubility as the result of contact with their surrounding formations. They quickly lose their quality and turn brackish. Chloride ion concentrations in these waters in the range of 2000 to 3000 milligram per liter on average, have made these resources [1]unfit for drinking purposes.

Ali-Abad zone has 13 wells with an approximate discharge rate of 60 lit/sec and the electrical conductivity (EC) in the range of 1900 to 2700 µmhos/cm.

The length of water transmission line from Panzdah Khordad Dam to the city of Qom measures 75 km, while the water supply line from Ali – abad wells to Qom is 40 km long.

Description:

Continuous droughts in the country during the years **1998**-2002 have led to a dramatic decline in the rainfall.Consequently many cities in Iran are faced with water supply problems and experience continuous water cut-offs and rationing. The quality of wells within Qom province also had an all-time decline and EC at the Panzdah-Khordad dam increased to 5000 µmhos/cm, which is not acceptable for drinking by any Iranian National standard due to high salinity and bitterness. Therefore, citizens of Qom sought other methods to meet their potable water needs, such as:

1. Purchase from tankers supplying potable water from the neighboring areas. This caused several health problems as neither the method of supply nor the [2]water quality measurements were supervised.
2. Use of bottled water , which could only be afforded by a number of people.
3. Transport of freshwater from the neighboring villages and cities by personal vehicles, which was both difficult and achievable by a few.

As can be noted, the supply of potable water has always been the main concern of people and authorities alike. Moreover, this issue is the legal mandate of Water and Wastewater Company and is always raised during the periodical meetings of the Company's managers and executives. To solve this problem, several solutions were discussed and reviewed, some of these are described below:

[1] Iranian National Standard for drinking water Quality (1053)
[2] Iranian National Standard for microbiological specifications of drinking water (1011)

Table 2: Options for freshwater supply to Qom

Proposed Solutions	Disadvantages
Desalination of water transmitted from Panzdah-Khordad dam and mixing with water obtained from Ali-abad wells	Cost ineffectiveness
Separate storage and intermittent distribution of potable quality water at specific hours	Impossibility of supplying a huge volume of potable water, as it is used both for drinking and for sanitary purposes Increased water consumption in the city, as unsuitable water in the water supply network would need to be drained in order to allow for citizen's access to the potable water
Mixing dam water with waters from wells in the city as well as from Ali-abad	Low quantity of water obtained from Ali-abad wells, which leaves little impact on the total quality of water
Water transmission from neighboring urban areas such as Kebar Dam	Various legal and social problems due to the drought in the neighboring areas such as: Negative water table of the plain Increased water salinity in the above said area due to drought Probable water quality problems in villages located downstream of Kebar dam
Water transmission from distance areas by rail	Water contamination risk during distribution (tankers and railway transport) High transmission and distribution costs within the city
Creating a dual distribution network*	Huge investment costs of the separation Risks associated with this project, as it was a new idea No short-term results may be expected Huge costs and complicated projects required
Mobilization of stations for distribution and sales of the potable water	

General advantages of separating potable water from non-potable water:

- Given the low ratio of potable water to the total water consumption, supplying water from very high-quality resources would be more practical, if advanced treatment methods were required.
- Water treatment utilities of most big cities including the treatment plant of Panzdah-Khordad dam will not meet the future water demands and, therefore, huge investments will be required for the construction of new treatment plants.
- In case of creating a dual water network, non-potable water could be easily supplied from available resources.
- The costs of a high-quality water supply and treatment are very high. Therefore, creating potable water stations will reduce these costs, and can compensate the huge construction costs of the distribution stations. This is mainly due to the fact that a small proportion of the produced water (less than 3-5%) will require complete treatment rather than its total volume.
- Proper quality control of potable water (physical, chemical and biological) given the limited distribution network and volume of production
- Reduction of wear and depreciation in the distribution network and lower maintenance costs
- Reduction of stresses resulting from likelihood of water pollution caused by accidents in the non-potable water distribution network

Materials and methods

1st Phase:

For the first phase of the project, supplying potable water with an EC of around 1850 µmhos/cm from Ali-Abad wells and potable water sales at relevant stations across the city was considered.

The final plan consisted of distributing potable water through potable water stations within the city. The surveys revealed that people would welcome the idea of creating these stations. Then, following some studies on the possibility of using the existing facilities and based on the above results (people welcoming these stations), it became clear that a 400 mm main pipe could be laid from the extreme northern point of the city to the extreme south, to be used as an independent separate network connected to the existing reservoir in Salarieh.

This pipeline was separated by the existing valves on the line and some minor changes to the distribution network. In addition to this, water from 6 Ali-Abad wells, which had a higher quality than other resources, was transmitted to reservoirs. Thereafter, a number of water in-take stations (11 in total) were built at proper locations along the 400 mm pipe, to geographically cover the length of the city.

Distribution of water among these stations put the plan in practical test. At the beginning, people welcomed this plan and stood in line at these stations to purchase water. Meanwhile, demands for more stations grew and, therefore the provincial authorities and the Ministry of Energy announced their support for its execution.

2nd Phase:

At this phase, the distribution stations were increased to 120 and the potable water distribution network was extended to 110 km along main streets and zones to achieve a maximum spacing of 250 m between stations.

The positive reaction of people to this plan encouraged the idea of extending this network to cover the entire city. Therefore, with the idea of creating an independent network merely for distribution of potable water in mind, a master plan was prepared by a technical consultant to ensure that all pipes would be laid based on this plan with the final aim of creating two independent networks for the city. The per capita water consumption was assumed to equal to 10 lit/day in the design. To fund the costs of the pipeline a justification report was prepared and presented to the authorities of the province and the Ministry of Energy. A percentage of the investment costs were met through the development budgets and the remainder from the local funds. Consequently, the number of active stations increased to 120 and the length of the new network to around 100 km.

The experiences of operating this network, distributing and selling water at the stations and planning the network extension indicated that managing this system by direct administration requires a large organization with its own costs and human resources problems. Moreover, demands for a better quality of water distributed in the network were also growing.

3rd Phase:

This phase was planned to enhance the potable water quality, to reduce EC from 1850 to 350 µhmos/cm, and to improve the sales system.

In 2001 tender notices in local newspapers invited qualified companies to invest, operate the utilities and the distribution network, sell water and calculate the final water price.

According to the contract provisions, no financial relation would be established between Qom Water and Wastewater Company and the selected contractor. Instead, the latter had to collect the water price by directly billing the people.

Given that no similar experience was available at the time, discussions were held with various companies to understand the problem areas and to select the best method. Finally, the contractor was selected through a bidding process.

The collaboration type considered in the contract was designed in a way as to transfer the responsibility of investments, construction, commissioning and management of all desalination equipment, water treatment, production and sales to the contractor.

The obligations of the company and the contractor in this collaboration were as follows:

Obligations of the company:

- Provision of a roofed building covering an area of 400 square meters
- Provision of water connections and delivery of raw water with a maximum EC of 3000 µmhos/cm
- Provision of two steel storage tanks, 5000 cubic meter each
- Sales of Raw water at a fixed price for 5 years
- Provision of two storage tanks and a separate water supply network
- Supervision on the discharge of obligations and monitor the safety of water

Obligations of the Contractor

- Creating the production capacity of 1500 cubic meters per day, with the possibility of increasing the capacity to 6000 cubic meters per day
- Covering the costs of supplying, installing and commissioning of desalination equipment and other supplementary machineries
- Conducting (daily) physical and bacteriological tests and (monthly) chemical tests and submission of regular reports to the client
- Storage of produced water in two 5000 cubic meter tanks supplied by the company
- Direct delivery and sales of potable water at minimum 240 stations
- Delivery of water of acceptable specifications and quality according to the relevant standards at stations

Figure 3: The increasing trend of potable water stations

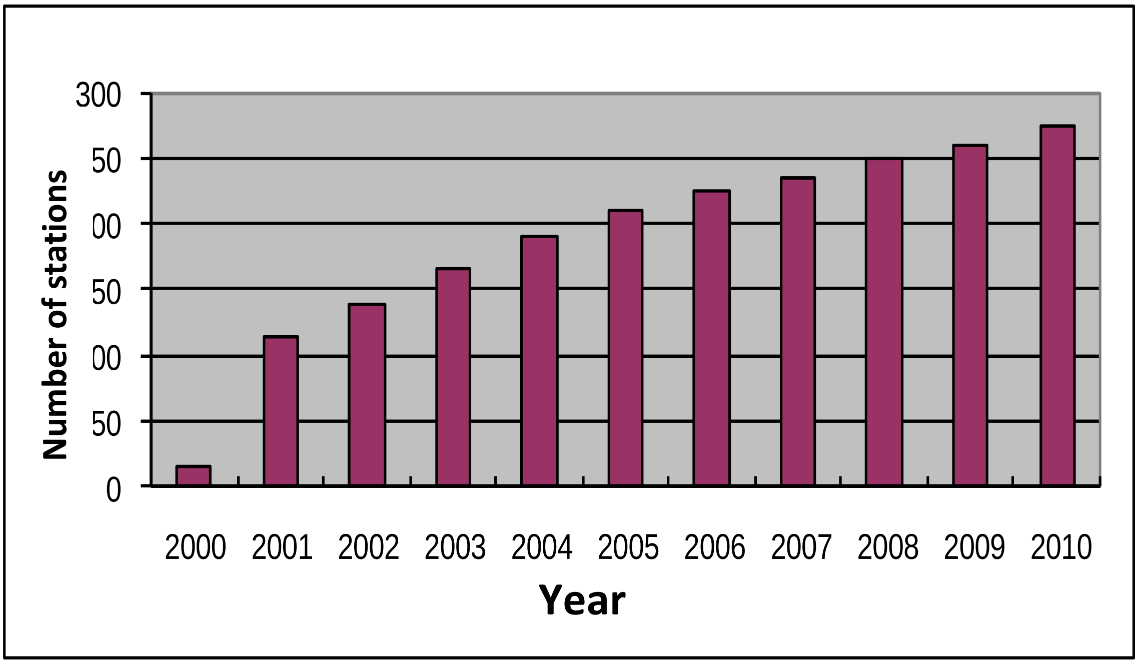


Table 3: The construction progress of potable water stations from 1999 - 2008

Construction Year	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Number of Annual Constructions	14	104	22	40	15	19	13	13	11	6
Total Number of Constructed Stations	14	118	140	180	195	214	227	240	251	257

Provision of potable water connections to public places, residential buildings of more than three stories, schools, administrative buildings and some industries located along the potable water network's route was among measures taken during the project. In this method, after obtaining the relevant permit from the Ministry of Energy, potable water connections were provided by the contractor to applicants without charging any connection fees, complete with installation of separate water meters set in accordance with contracted water tariffs. Potable water bills are collected directly from consumers and there are currently 700 connections available.

Table 4: Current Situation of Potable Water Distribution Network

Length of Potable water distribution network	180 km.
Number of potable water distribution stations	257
Untreated water consumption rate	6000 m^3/day
Potable water consumption rate	4500 m^3/day
Number of potable water connections	700

Table 5: Economical Comparison of Water Prices between the Separate Potable Water Network and Other Potable Water Resources

<table>
<tr><td>Sale price of water at the potable water network per liter</td><td>*0 . 15 US cents</td></tr>
<tr><td>Whole price of bottled water per liter</td><td>20 US cents</td></tr>
<tr><td rowspan="2">Daily water costs of a four-persons family with a per capita water of 8 liters per day</td><td>Using the potable water distribution network: 0. 48 US cents</td></tr>
<tr><td>Using bottled water: 6.4 USD</td></tr>
<tr><td>Tariffs of non-potable water as notified by the government (Per liter)</td><td>0. 03 US cents</td></tr>
</table>

Table 6: Comparison of Main Parameters between Potable and Non-potable water

Parameters	Potable water	Non-potable water	Max. Allowed according to NIS
Electrical Conductivity (µmhos/ cm)	420	5200	---
Total Dissolved Solid (mg/ lit)	320	3100	1500
TH (mg /lit $CaCO3$)	81	1050	500

Results and Discussion

In fact, the scarcity of water resources, the low quality of water and the ever-increasing population are three constraints causing difficulties for water supply in the city of Qom. These factors have always been the major concerns for the relevant authorities of the city and the country alike, particularly, during the years when rainfall is low, as the quality of water sources declines dramatically to a level that makes water unfit for consumption.

Separating the potable water network from non-potable distribution network was an effective and practical solution, which had invaluable results for the company. Execution of the above project made the supply of the potable water by national and provincial authorities to people during the drought periods possible.

For instance, in the current year when the quality of water in the distribution network dropped drastically while its EC reached to 5000 µmhos/cm, the second network made the supply of safe water possible.

Project Outcomes:

- Flexibility of the construction schedule during project execution allowed for some revisions to the methods used and, thus, increased the efficiency (sales). For example, use of the debit card technology and equipping stations with Point of Sale (P.O.S) devices in addition to revision of the stations structure for an easier and more effective use should be noted.
- Execution of the above said project provided a basis to complete the T.O.R of the contractors as it clarified ambiguities about collaboration between the company and contractor.

- Given the low quantity of potable water required, it could be easily supplied and distributed in the city. Therefore, charging consumers the total costs did not leave a significant impact on the family cost basket.
- Considering the centralized water production and distribution system, water safety may be easily monitored by the company and other qualified authorities.
- Reduction of stresses resulting from likelihood of water pollution in the non-potable water distribution network following accidents.
- The participation of private sector greatly assisted project execution. This is mainly due to the fact that investment, production, distribution and water sales are carried out directly by the private sector, without the company having to bear additional work load.
- At present, most schools and administrative buildings are connected to the potable water network, and demands for extension of the network are high.
- One of the most important outcomes was the increased expectations of people in the long run. In other words, at the beginning, water with an EC of about 2000 µmhos/cm was distributed into the potable water network. However, following replacement of the contractor and distribution of water with an EC of approximately 350 µhmos/cm, two major points were noted. Firstly, when EC increased after an accident, consumer complaints also increased. Secondly, although the quality of non-potable water was improved following a heavy rainfall and increased volume of water in Panzdah Khordad Dam in 2004-2005 (when EC of water declined to less than 2000 µhmos/cm for some months), the level of sales at potable water stations did not diminish.

Since the situation in Qom is similar to many cities, this project may serve as a good pattern to solve water-related problems. Many cities in the country do not have access water of adequate quality and quantity. However, water transmission from remote areas should now be considered more cautiously. At any event, a number of cities have also adopted the Qom model for their problems.