

## **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 average, which is very unevenly scattered across the country and in the recent years; renewable water sources have dramatically declined with respect to the population growth and enhanced lifestyles. This has called for the requirement of water conservation. One recommended idea is to separate the potable water network from non-potable water distribution network. With the annual precipitation rate of less than 135 mm and a population of over one million people, Qom city has been historically facing up to the water scarcity problem. To implement this idea, design and execution of separating the potable water from non-potable water network was launched in 2000. At the first phase, supplying suitable potable water from a number of water wells to the distribution network, utilizing the existing pipes that could be separated from the main network then, water distribution network was extended and the number of potable water distribution stations utilizing RO desalination equipments increased, thus, the water of a higher quality was produced and distributed in the city. At this stage, all steps related to investment, water production, distribution and sales of potable water in addition to the maintenance of water distribution network and other water utilities and revision to the consumption pattern are necessary, was transferred to the private sector following tendering.

Besides, after the project duration of the first contractor ended and following a new tendering, all above said commitments relating to providing services to the public was transferred to the next contractor without any problems.

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Implementation of the above said project solved and addressed one of the most crucial issues of supplying the suitable potable water to the city of Qom, encountered by the national and provincial authorities, as the quality of available potable water sources in Qom province had lowered due to inadequate rainfall in the previous years. For instance, EC of water in the distribution network exceeded 4000 umhos/cm in the years of 2000-2002 and 2009-2010.

**Key Words: separate potable water network, Reverse Osmosis method, water distribution stations, water scarcity**

### **Introduction:**

Only 3% of household water consumption is used for drinking, whereas the remainder is used for sanitary uses. In the recent years, population growths of cities and enhanced lifestyles have resulted in increased water consumption and water demand.

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

Therefore, serious studies regarding effective management of the existing water sources and supplying the potable water of suitable quality have been conducted in Qom Water and Wastewater Company since 1998. Finally, 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 potable and non-potable networks across the city of Qom. Besides, it should be noted that financing the project and investments made for production and distribution of potable water were all done by the private sector.

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

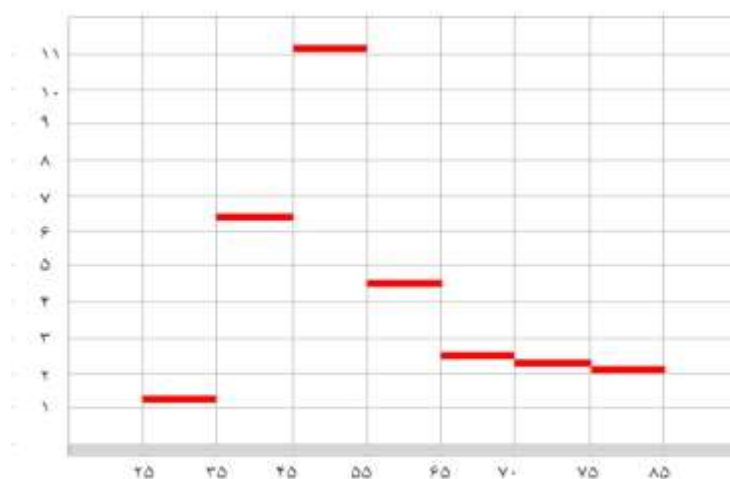
### **Background of the Project Execution:**

Iran, with an average annual precipitation of 260 mm which is less than one third of the world's average, is classified as an arid country in the world. Besides, this little annual precipitation is unevenly scattered across the country, as 1% of the country's area get a rainfall of over 1000 mm whereas 28% of the country has less than 100 mm. Further, 70% of the total annual precipitation of Iran is evaporated. Factors such as population growth, necessity for enhancement of the sanitation level 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 utilizing a number of technical, administrative and legal measures will become a serious concern for Iran.

## Separating Potable Water Network from Non-potable Water Network

Qom province, geographically located in the central dessert of Iran, has historically suffered from water scarcity problem. Water scarcity and unavailability of suitable potable water has been the most critical problem of this city since a long time ago. Annual precipitation rate of Qom province has been 135 mm with an extremely high evaporation rate owing to dessert climatic conditions. Besides, immigration to this city has been extremely high in the years after the Islamic revolution due to its various attractions which may not be compared with any other place in the country (<sup>1</sup>a population growth of more than 8 percent in 1360s as an example), all dramatically increasing the water demand.

### Average Population Growth (%)



| Census Year           | 1956 | 1966 | 1976  | 1986 | 1991 | 1996 | 2006 |
|-----------------------|------|------|-------|------|------|------|------|
| Population Growth (%) | 1.17 | 6.32 | 11.01 | 4.54 | 2.53 | 2.27 | 2.1  |

### Water supply sources of Qom city:

Water supply issue of Qom has been considered at various times and related studies were launched by French and Iranian engineers since 1952. Ever-increasing population growth and pilgrim susceptibility of this city has lead to an increase in water demand, resulting in various water supply schemes being high on the agenda as detailed below:

#### 1. Underground waters of Qom Desert

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<sup>1</sup> Statistical Year Book of Qom Province

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2. Underground waters of Ali-abad Desert (wells)

3. 15-Khordad Dam

Underground waters of Qom dessert generally contain various salty elements and compounds with a high solvability as the result of contact with their surrounding formations. They quickly lose their quality and turn salty. Chlorine ions inside these waters, 2000 to 3000 milligram per liter on average, have made these sources <sup>2</sup>undrinkable.

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

### **Water Quality of 15-Khordad Dam:**

Water quality of 15-Khordad dam with a capacity of 200 million cubic meters is mainly dependent on the volume of water entering the dam and the precipitation rate. <sup>3</sup>EC of the dam water is often high, thus, the water is not suitable for drinking mainly due to a salty river discharging very low-quality water into the dam. Although EC of the dam water fell to around 2000 umhos/cm in some years with a lot of rainfall (drinkable), it has increased to 5000 umhos/cm in the years with little rainfall such as the last year.

Analysis of the results of chemical tests conducted on the above said sources and their comparison with the standards of potable water quality measurement have indicated that these water sources are classified as bad or unfavorable, which are not suitable for drinking.

In the years when the volume of 15-Khordad dam water is acceptable, 70% of the total water demand is supplied from 15-Khordad dam, whereas 17% is supplied from Ali-abad water wells and the remainder from water wells within the city. However, in the years when the volume of 15-Khordad dam is reduced, potable water is mainly supplied from the water wells within the city.

### **Problem Areas:**

Continuous drought in the country during the years 1998-2002 resulted in a dramatic decline in the rainfall, so that many cities in Iran faced water supplying problems and, thus, continuous water-cuts and water rationing. The quality of water wells within Qom province also had an all-time decline and EC of 15-Khordad dam increased to 5000 umhos/cm, which was acceptable by any standard for drinking due to a high salinity and bitterness. Therefore, citizens of Qom sought other methods for supplying their potable water as follows:

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<sup>2</sup> Water Quality Standards 1053

<sup>3</sup> Electrical Conductivity of Water

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1. Purchase of water from tankers supplying potable water from the neighboring areas, which caused several hygienic problems for people because the supplying method and <sup>4</sup>water quality measurements were not supervised.
2. Use of bottled water which was only affordable by few citizens.
3. Transport of water from the neighboring villages and cities in their personal vehicle, which caused many difficulties for people and was only possible for few people.

As it may be noted, supplying of potable water has always been the main concern of people and authorities. Besides, it was the legal responsibility of Water and Wastewater Company, which was always discussed as the major problem in meetings with experts and managers. To solve this problem, several solutions were discussed and reviewed, some of which as below:

1. Desalination of water transferred from 15-Khordad dam and mixing with water from Ali-abad water wells
2. Separate storage of good-quality water and periodic distribution at specific hours
3. Mixing of dam water with water obtained from city wells and Ali-abad wells
4. Transmission of water from neighboring urban areas such as Kebar dam
5. Creating a dual distribution network
6. Creating stations for distribution of potable water
7. Transmission of water from remote areas by rail

### **Evaluation of Proposed Options:**

Some research was conducted on desalination of 15-Khordad dam and it was revealed that huge costs and a large area would be required, which would not be cost effective for large quantities of water.

Option 2 was also reviewed and was not approved due to the following reasons:

1. Distribution of potable water in the distribution network would result in people using it for potable and non-potable uses, which would increase the potable water consumption, which is not feasible to supply.
2. A huge quantity of non-potable water would need to be emptied from the network, which would increase the water consumption.

Option 3 was not effective due to the little volume of water from Ali-abad well and its negligible impact on the total quality of water.

Implementation of option 4 would also cause some legal and social problems due to the drought in adjacent areas. This transmission could cause the following problems:

- Drilling water well would not be possible given the negative water budget of the dessert and would require water well owner's approval, thus, approval of well owners would be difficult to seek.

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<sup>4</sup> Potable Water Quality Standard 1011

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- Given the little precipitation and rainfall, salt content and water salinity was increasing in the above said area.
- Given that fact that potable water of some villages located downstream of Kebar dam is supplied from 4 water wells, under the responsibility of Jihad-e-Sazandegi, thus, continuous extraction of water from underground aquifers could cause water quality problems for the above said water wells.

Discussions were held with the railway authorities regarding option 7, while construction of hygienic steel tanks was evaluated. However, given the multiplicity of factors involved in water distribution (such as tankers and railway), water pollution would be very likely. Besides, transmission and distribution costs within the city would be very expensive with respect to the large quantity of consumed water.

Among other reviewed options, separation of potable water from non-potable water and distribution into the network was envisaged. At the first glance; huge investment costs of this separation as the main inhibitor, high risk of executing a new idea and this that short-time results might not be achieved, were discussed. Given this that huge investments and projects were required, it was proposed to carry out the separation operation in phases.

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

- Given the low ratio of potable water to the total consumed water, supplying water from very high-quality sources would be more practical, if advanced treatment methods were required.
- Water treatment utilities of most big cities including the treatment plant of 15-Khordad dam will not meet the future water demands and, thus, huge costs will be required for construction of treatment plants.
- In case of creating a separate potable water network, non-potable water could be easily supplied from available sources.
- Costs of supplying a high-quality water and treatment are very high. Therefore, creating potable water stations will reduce costs of supplying non-potable water, which can make up for huge construction costs of the distribution stations. This is mainly due to the fact that a small proportion of the produced water (less than 0.03) will require complete treatment rather than the total quantity of water production.
- Proper quality control of potable water (physical, chemical and biological) with respect to limited distribution network and volume of production
- Reduction of wear and tear in the distribution network and lower maintenance costs
- Reduction of stresses resulting from likelihood of water pollution in the non-potable water distribution network because of accidents

Desalination and water quality improvement technology has had significant advancement in terms of quantity and quality in the recent years. In other words, 38 million cubic meters of water is desalinated every day in more than 130 countries around the world, 60 percent of which relates to desalination of sea and ocean water and the remainder to other water sources. Half of the sea water desalination is

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carried out in the Middle East, while Saudi Arabia accounts for 20 percent of the global share of desalination.

### **Description of the Project Execution:**

#### **1<sup>st</sup> Phase:**

**In the first phase of the project, supplying potable water with an EC of around 1850 umhos/cm from Ali-abad wells and potable water sales at potable water stations across the city was envisaged.**

It was decided to distribute potable water through potable water stations within the city. Following some investigations, it was revealed that people would welcome the idea of creating these stations. Then, following some investigations to utilize the existing facilities and bear out the above said idea (people welcoming these stations), it was revealed that a 400 mm main pipe could be laid from the most northern point of the city to the most southern, to be used as an independent separate network connecting to the existing reservoir in Salarieh zone.

This pipeline was separated by way of the existing isolation valves and some minor revisions to the distribution network. In addition to this, water from 6 nos. of Ali-abad wells, which are of a higher quality than other water sources, was transmitted to Salarieh reservoirs. After that, some water in-take stations (11 nos.) were built at proper locations along the 400 mm pipe, geographically covering the length of the city.

Distribution of water among these stations practically tested this plan. In the beginning, people welcomed this plan and stood in line at these stations to purchase water. Meanwhile, there was a demand for more stations and, thus, provincial executive authorities and the ministry of energy supported execution of this plan.

#### **2<sup>nd</sup> Phase:**

**At this phase, increase of the distribution stations to 120 nos. and extension of the potable water distribution network to 110 km along main streets and zones were aimed so that a maximum spacing of 250 m between stations may be achieved.**

People welcoming this plan encouraged the idea of extending this separate network for the whole 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 will be laid based on this plan with the final aim of creating two independent networks for the city. Per capita water consumption was assumed 10 lit/day in the design. To fund the pipe laying costs, a justificatory report was prepared and presented to the authorities of the province and ministry of energy. A percentage of the investment costs were supplied through the civil budgets and the remainder from the local funds.

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With respect to the allocated budgets, the number of active stations increased to 120 nos. and length of the new network to around 100 km.

The experience of operating this network, distributing and selling water at the stations and planning the network extension has indicated that managing this system by direct administration would require a huge organization with various problems relating to costs and human resources. Besides, people have asked for a better quality of water distributed in the network.

### **3<sup>rd</sup> Phase:**

**This phase was planned based on enhancement of the potable water quality, reduction of EC from 1850 to 350 umhos/cm, and improvement of the sales system.**

In 2001, qualified companies were invited for investing, operating the utilities and the distribution network, selling water and calculating the final water price through tender notices published in the newspaper.

According to the stipulated contract, no financial relation would be established between Qom Water and Wastewater Company and the selected contractor. Instead, the selected contractor will collect water bills from people.

Given that a similar experience was not available at the time, discussions were held with various companies to understand the problem areas and select the best method. Finally, the contractor was selected through tendering.

The collaboration type was envisaged in the contract such that responsibility of investments, construction, commissioning and management of all desalination equipments, water treatment, production and sales would be transferred to the contractor.

**Obligations of the company and contractor with respect to 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 umhos/cm
- Provision of two steel storage tanks, 5000 cubic meter each
- Raw water sales at a fixed price of IRR500 per each 1 cubic meter for 5 years
- Provision of two storage tanks and a separate water supply network
- Supervision on the fulfillment of obligations and ensure safety of water

#### **Obligations of the Contractor**

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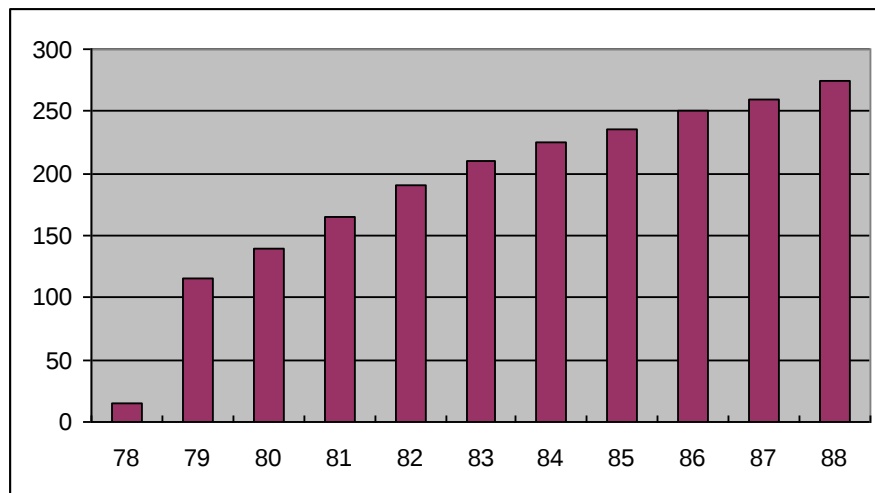
- Creating the production capacity of 1500 cubic meters per day, with the possibility of capacity increase to 4000 cubic meters per day
- Covering costs of supplying, installing and commissioning desalination equipments and other supplementary machineries
- Conducting (daily) physical and bacteriological tests and (monthly) chemical tests along with regular reporting 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 120 stations, minimum
- Delivery of water of acceptable specifications according to the standards and of a favorable quality at stations

Contract duration: 23/07/2001 till 23/10/2006

In the beginning, potable water was manually sold by the contractor staff in two working shift. However, to improve the sales system and reduce sales costs, utilization of P.O.S (point of Sales) for mechanized sales was envisaged. Finally, stations were equipped with P.O.S system for mechanized sales 24 hours a day, for which credit cards were distributed in all stores.

As profitability of this plan depends on the quantity of water sales, methods to increase water sales have always been envisaged and, thus, the number of potable water stations was increased from 120 in the year 2002 to 250 in 2005.

**Graph showing the increased number of station:**



| Construction Year | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 |
|-------------------|------|------|------|------|------|------|------|------|------|------|
| Number of Annual  | 14   | 104  | 22   | 40   | 15   | 19   | 13   | 13   | 11   | 6    |

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| Constructions                        |    |     |     |     |     |     |     |     |     |     |
|--------------------------------------|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| 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 route was carried out as another measure. In this method, following obtaining 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 and in accordance with contracted water tariffs. Potable water bills are collected from consumers and the number of connected consumers amount to 700.

### Current problems of collaborating with the contractor and solutions:

Collaboration with the contractor faced some problems owing to no previous experience and unclear division of some tasks. One critical problem was the water loss in the potable water network as compensation for this loss was always a matter of disagreement and conflict.

At the end of the first contractor's contract, a team of experts including deputy planning, supervisors of the desalination scheme, financial controller, and deputy manager of legal department analyzed all of the previous issues and problems. Then, they prepared a new T.O.R (term of reference) for the new tendering. Finally, the 2<sup>nd</sup> contractor was selected in 2007.

Handover of works from first contractor to the second contractor was a serious challenge for the company, as services had to be continued without any interruptions.

Issues related to this handover were as follows:

1. Water cards distributed by the first contractor were remaining and had to be collected.
2. More than 80 workers were hired by the first contractor and they were worried about their jobs.
3. New cards had to be issued and distributed to avoid any likely problem.
4. Existing facilities such as P.O.S and software belonged to the first contractor and replacing them with new facilities could halt services.

In addition to the issues above, it is worth mentioning that the new contractor was selected in very competitive condition with a little difference with the first contractor. Therefore, as the existing facilities belonged to the first contractor, he was willing to continue his presence in Qom and considered this handover unfair. Thus, long protracted meetings were held between the first contractor, second contractor and the company to reach some agreements.

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Following some meeting with managers and experts, the first contractor was required to transfer all equipments to the new contractor and the new contractor agreed with the proposed prices and payment terms.

As for water cards, a transition period was defined starting two months prior to the end of the first contractor's contract until two months after effectiveness of the new contractor's contract.

In the mean time, a software was designed which could work with both kinds of water cards. According to the agreements, the first contractor halted selling water cards in the last two months of his contract, while the new contractor started selling his new cards two months earlier than effectiveness of his contract. Therefore, sufficient cards were issued and old cards were used within four times. At the same time, old cards were refunded through some notices in the local newspapers.

As for the workforce, local workers who were willing to continue their jobs were hired by the new contractor to avoid social problems.

### Obligations of the new contractor:

- Minimum production capacity of 4500 cubic meters per day and capacity increase to 6000 cubic meters
- Conducting (daily) physical and bacteriological tests and (monthly) chemical tests along with regular reporting to the client
- Storage of produced water in two 5000 cubic meter tanks supplied by the company
- Delivery of water of acceptable specifications according to the standards and of a favorable quality at stations
- Direct delivery and sales of potable water at 250 stations equipped with P.O.S systems
- Direct delivery and sales of water to potable water consumers
- Managing all issues relating to maintenance of the distribution network and utilities such as water loss, network accidents and obtaining necessary permits from relevant authorities

Contract duration is from 23/10/2006 till 23/10/2010, which may be extended for two years subject to the client's approval, after which time it may be extended again subject to the mutual agreement of both parties.

### Current situation of the <sup>5</sup>potable water network:

|                                                      |                         |
|------------------------------------------------------|-------------------------|
| <b>Length of Potable water distribution network</b>  | <b>180 km.</b>          |
| <b>Number of potable water distribution stations</b> | <b>257 no.</b>          |
| <b>Untreated water consumption rate</b>              | <b>6000 cubic m/day</b> |
| <b>Potable water consumption rate</b>                | <b>4500 cubic m/day</b> |
| <b>Number of potable water connections</b>           | <b>700 nos.</b>         |

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<sup>5</sup> GIS of Qom Water and Wastewater Company

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### **Final Analysis:**

In fact, scarcity of water resources, unfavorable water quality and ever-increasing population are three constraints causing difficulties for supplying water to the city of Qom. These factors have always been the major concerns for the relevant authorities of the city and country, particularly, during the years with low rainfall as the quality of water sources declines dramatically so that water in the distribution network may not be used by people.

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

For instance, as the quality of water in the distribution network dropped in the current year, with an EC of about 5000 umhos/cm, supplying water to people was allowed for utilizing the second network.

### **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 credit card technology and equipping stations with P.O.S in addition to revision of the stations structure for an easier and more effective use should be noted.
- Execution of the above said project was a good experience for completing the T.O.R of the contractors with regard to ambiguities of collaboration between the company and contractor.
- Due to the little quantity of potable water required, it could be easily supplied and distributed in the city. Therefore, charging consumers the total costs will not affect the average costs of families significantly.
- Considering the centralized water production system and water distribution, water safety may be easily supervised by the company and other qualified authorities.
- Reduction of stresses resulting from likelihood of water pollution in the non-potable water distribution network because of accidents.
- Utilizing the private sector services has assisted execution of the project. This is mainly due to the fact that investment, production, distribution and water sales are carried out directly by the private sector, while no additional works are imposed on the company.
- 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, in the beginning, water with an EC of about 2000 umhos/cm was distributed into the potable water network. However, following replacement of the contractor and distribution of water with an EC of approximately 350 umhos/cm, two points should be noted. Firstly, in case of an increased EC due to an accident, consumer complaints will increase. Secondly, although the quality of non-potable water was improved owing to increased rainfall and quantity of 15-

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Khordad dam's water in 2004-2005 (as EC of water declined to less than 2000 uhmos/cm in some months), the welcome given by people to the potable water network did not diminish.

Due to similarity of many cities to Qom city, this project may serve as a good pattern for resolution of water-related problems. Many cities in the country do not have access to sufficient quantities of water or water of good quality. However, water transmission from remote areas should be envisaged with more care. Anyway, some other cities have also adopted the pattern used in Qom city.

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