CHAPTER 3.

WATER RESOURCES

CHAPTER 3 WATER RESOURCES

3.1 Watershed

3.1.1 Mountain Watershed

The Study deals with the extent of 31,600 sq.km, comprised of the direct Study Area of 16,100 sq.km and the related river basins of 15,500 sq.km. Of 16,100 sq.km of the direct Study Area, 7,270 sq.km are mountainous including watersheds of Kan river located northwest of Tehran City, Karaj river where Karaj dam is being operated, Kordan river at the northeast of Hashtgerd, Taleghan, Almout and a part of Shah-rud rivers, southern foot of Taleghan mountains from where numbers of small streams originate, and southern and eastern foot of watershed of three rivers of Qazvin plain such as Abhar-rud, Khah-rud and Haji Arab. Related river basins of 15,500 sq.km comprises remaining part of watershed of Shah-rud river between Shiahdasht and Sefid-rud dam and three river basins of Qazvin plain, and they are therefore categorized into mountainous areas.

The northern part of the Study Area is drained by rivers of Taleghan and Almout that traverse southern foot of the Alborz mountains producing average annual runoff of 440 MCM at Galinak on the Taleghan river and 325 MCM at Baghkalyeh on the Almout river. Both rivers join at Shirkuh and the lower reaches of the stream is called as the Shah-rud river that forms one of the major tributary of Sefid-rud river and empties finally into the Caspian Sea after joining with the Qezel Ozan river at the Manjil dam. Specific runoff yields of both rivers, Taleghan and Almout, are calculated at 568 mm and 479 mm, respectively.

Taleghan river originates at the Asalak mountain apart about 50 km north of Tehran and flows down towards the north-north-west, surrounded by the Alborz mountains and Taleghan hills. Taleghan hills run in parallel with the Alborz mountains with peaks of some 2,500 m above mean sea level and confront the Qazvin plain of the Central Iranian Plateau. Taleghan river forms a deep valley with the river bed of as wide as 1 km between Shahrak town and Roushanadbad village and the narrowest width of 350 m around Kumakan village. The average river slope is about 1 to 100.

Almout river follows a slightly meandering course having a direction approximately from east to west. The river forms a V-shaped valley with a river bed slope of 3.6%. General pattern of drainage is a trellis system consisting of numbers of more or less right (N to S or S to N) streams flowing into the main stream of Almout river.

In most of these basins, sedimentary rocks are exposed, which belong to Mio-pliocene strata. Houses are scattered where spring water is available. Perennial tree crops are planted or grown near the river courses and around residential areas, and only seasonal vegetation is seen after the time of melting snows in most part of the basins. Runoff coefficients of these mountainous basins are reported at 50% to 75%.

In the western and southwestern parts of the Study Area, Khah-rud, Abhar-rud and Haji Arab rivers flow into Qazvin plain. On the northern slope of Qazvin plain, there are numbers of small streams which have only seasonal flows with low basic discharge. The Kordan river locates north-east of Qazvin plain retaining considerable amount of seasonal and basic flow. All surface water of these rivers flows into Qazvin plain and being used for irrigation and other purposes. Some part of these water recharge groundwater aquifer of the plain. The Shoor river is located on the extreme south-east of Qazvin plain flowing into the Salt Lake. Concentration of salinity in the water of this river is high and hence river water is not suitable for any kind of application. Runoff coefficients of these basins are estimated at 10 to 30%. In the area between Karaj and Tehran city, the Karaj and Jaj-rud rivers traverse north to south on the western and eastern boundaries of the area. Several tributaries including Kan river flow southward on the northern part of the area and all of these tributaries empty into the Jaj-rud river.

3.1.2 Plain Watershed

Of 16,100 sq.km of the direct Study Area, 8,830 sq.km are classified as plain watershed extending between Tehran and Qazvin. Tehran and Qazvin are connected by the national highway that runs in the direction of north-west-west in parallel with the railway. There extends a narrow belt of land on the north of the highway, however, this belt is not generally utilized since the Taleghan mountains are close, with exception of the New Hashtgerd area where residential zone is being constructed at present. Densely populated Tehran City is located on the southern slope of Alborz mountains with elevations about 1,800 m at the northernmost edge and 1,200 m in the southern margins. Adjacent south to Tehran City between Tehran and Karaj, there extend a large extent of farmland with Shahriyar and Robatkarim as the center. The Amir Kabir dam (Karaj dam) on the Karaj river is under operation since 1963 and majority of stored water in the dam is being transmitted to Tehran city through water pipelines. The Latian dam on the Jaj-rud river has been operated since 1968 and major part of water from the dam is brought by a diversion tunnel to Tehran. Karaj dam provides a part of water stored in the reservoir to irrigation performed in Karaj area. Relatively narrow zone of about 20 km wide lying between Karaj and Abyek and between the highway and the salt marsh has also been utilized for agriculture receiving water mainly from groundwater resources. Qazvin plain has a large agricultural area of about 350,000 ha, divided into two parts depending of sources of water. In the northern Qazvin plain, Qazvin irrigation system has been under operation for more than 30 years provided water from the Taleghan river through the diversion tunnel and supplemented by groundwater. About 76,000 ha of farmland is covered by this irrigation system. Remaining part of the plain is left under rainfed conditions with water supplied partly from natural streams and groundwater. Distribution of annual precipitation in the plain watershed varies from some 150 mm in the southeastern corner to exceeding 400 mm at the northern edge on the border to the mountainous watershed. Renewable annual surface water, in terms of specific runoff yield, is distributed between values from less than 50 mm in the central and southern parts of the basin to 150 mm at most near the northern border, indicating runoff coefficient of 10% to 35%.

3.2 Precipitation

3.2.1 Observation and Data

A comprehensive network of meteorological observation has been established within the Study Area, consisting of exceeding 250 stations of which about 130 stations are under operation by the Ministry of Energy and 125 are under the Iranian Meteorological Organization. Among various meteorological factors such as precipitation, temperature, relative humidity, evaporation, sunshine hours, wind speed and cloudiness, precipitation data of 130 rain gauge stations are collected from two different sources, Tehran Regional Water Board (TRWB) and Jamab Consulting Engineers who has just prepared the report on “National and Regional Water Resources Master Plan Study (the Master Plan)”. Meteorological factors other than precipitation are gathered from only selected stations.

Average Annual and Monthly Precipitation at Selected Stations

(Unit = mm)

Code (M/P)	Station	MEH	ABN	AZR	DEY	BAH	ESF	FAR	ORD	KHR	TIR	MOR	SHA	**YEAR**
136550	Galinak	21.5	50.9	55.3	42.0	52.7	73.7	74.5	76.6	23.4	5.5	3.2	3.9	**483.3**
136564	Baghkalyeh	23.4	42.2	49.6	36.0	45.8	60.1	60.1	57.5	20.9	7.1	3.3	1.9	**407.8**
136568	Loshan	8.3	17.6	20.1	21.0	17.6	21.8	28.1	27.2	4.9	1.7	1.9	0.3	**170.5**
711586	Abegarm	11.2	21.8	26.5	24.3	26.6	36.4	37.4	41.1	10.0	3.0	1.3	1.7	**241.5**
711626	Takestan	16.5	31.4	37.2	28.1	32.2	41.3	41.0	46.1	11.6	2.1	2.3	2.7	**292.4**
711694	Ziyalan	13.2	35.6	49.5	38.1	49.2	57.3	57.0	50.5	13.7	3.3	2.2	2.8	**372.3**
711696	Abyek	13.6	24.5	33.8	31.1	37.3	43.5	39.4	36.2	9.7	1.3	2.0	1.6	**274.2**
711700	Karimabad	14.8	18.2	29.6	22.9	25.9	30.9	32.0	26.8	8.3	3.1	3.8	4.8	**221.3**
711776	Qazvin	18.4	33.8	42.8	41.5	45.0	58.3	52.0	56.1	14.8	3.1	2.5	2.8	**370.9**
711778	Roudak	11.6	23.8	31.9	32.9	38.6	50.5	36.2	43.4	8.3	2.8	2.7	1.7	**284.4**
712718	Sira	26.5	54.2	81.0	68.2	84.2	103.2	95.6	82.3	22.9	5.9	3.9	7.0	**634.9**
712722	Bileghan	12.5	30.8	41.4	42.9	48.4	50.5	47.3	45.6	11.3	1.8	1.6	2.4	**336.4**
712762	Latian	16.1	34.7	54.3	51.9	63.6	68.1	55.4	47.7	12.4	4.8	2.3	2.6	**413.8**
712792	Varamin	13.8	13.3	17.5	10.5	14.3	10.6	8.8	10.1	4.4	4.8	4.0	9.2	**121.3**

Figure 3.2.1.1 shows the distribution of meteorological stations in the Study Area. Existing rain gauging stations at about 250 locations are distributed properly in the area. Meteorological observation works are carried out well and most data are computerized already, however, many stations ever installed on the small streams flowing down from the Taleghan mountains were closed in 1985.

3.2.2 Characteristics of Precipitation

Figure 3.2.2.1 shows isolines of precipitation over the area. Relatively higher annual precipitation of 600 to 800 mm is observed in the Alborz mountain area where Taleghan and Almout basins locate, while smaller values of less than 200 mm are collected from stations located in the southeastern end of Tehran plain. 250 to 300 mm of annual precipitation are distributed in most of plains between Tehran and Qazvin.

Monthly distribution of precipitation is moderate in most regions in the Study Area. About 65% of annual rain or snow is concentrated in winter season from October to March, however, spring and summer season from April to September still keeps 35% of annual precipitation. Distribution of monthly precipitation is visualized also in Figure 3.2.2.2.

Droughty climates that continued in the most recently years, 1998/99 to 2000/01 has brought anxiety that precipitation over the Study Area has been decreasing due to global change of the climate. Long record of annual precipitation is available at Mehr-abad station of Tehran City as plotted in Figure 3.2.2.3. A long-term tendency of annual precipitation is approximated by a straight line showing a delicate and negligibly small ascending incline, and no evidence of decreasing tendency can be found.

Since about 65% of annual precipitation is concentrated during winter season when irrigation is not practiced in the Study Area, use of rain or snow water is not significant. Soil moisture after saturated by flood on the eve of plantation of the winter crops such as wheat and barley is however utilized effectively in the area especially where irrigation system is not distributed.

3.3 Surface Water

3.3.1 River System and Observation of Surface Water

The Study Area is divided into six sub-basins; namely, 1) Taleghan and Almout river basins as the donor basin of water resources, 2) Tehran City, 3) Tehran region surrounding Tehran City, 4) Karaj region, 5) Hashtgerd region and 6) Qazvin plain. Five sub-basins other than Taleghan/Almout are the consumers of water supplied and are drained by rivers of Karaj, Jaj-rud and Shour.

The Taleghan and Almout rivers traverse the Alborz mountains westward and join each other at about 15 km upstream of Siahdasht, located on the northwestern boundary of the Study Area. After joining, the river has been renamed Shah-rud that runs further westward until flowing into the Sefid-rud (Manjil) dam. The other main tributary branch of Qezel Ozan river joins at the Manjil dam and the river downstream is called Sefid-rud river. The total catchment of Manjil dam is reported at 56,600 sq.km of which about 5,070 sq.km is drained by Shah-rud river.

The Shoor river is drained by numbers of rivers and small streams. In its western part, Khah-rud river and Abhar-rud river have a wide outflow basins. Tributary branches of Khah-rud river are Avaj, Kalanjinchay located to the south of Haji Arab river. On the northern part, there are several small creeks that are considered as drains for higher part of the Qazvin plain having seasonal discharges with a low basic flow only. In the northeastern part of the basin, there is Kordan river draining the highest mountainous part of the basin having a considerable amount of seasonal stream and basic flow. Various small and seasonal streams such as Mortezaabad, Aloolak, Barajin, Rashtghan, Ashnestan, Shotrak, Behjatabad, Ziaran, Sarab, Fashand, Ardehe and Valian are also originated from the northern ridge of the mountainous part and flowing into Qazvin plain. Some part of these seasonal flows is used for irrigation and majority is considered as the source of groundwater recharge. The Shoor river drains surplus of surface water during the peak flood season and excess of groundwater from a deep aquifer underlain Qazvin plain, and finally empties in to the Salt Lake.

The Karaj and Jaj-rud rivers, originated from the northern deep mountains in the Study Area, keep perennial flows and are the major source of surface water supplied to Tehran City. Amir Kabir dam (Karaj dam) on Karaj river is under operation since 1963 and outflow released from the dam is diverted at Bileghan and conveyed through pipeline to No.1 and 2 treatment plants in Tehran City. Latian dam on Jaj-rud river has also been operated since 1968 and major part of river water is brought together with water transferred from Lar dam to Tehran City through a diversion tunnel. Both rivers flow southward and after joining small rivers of Kan and Damavand finally empty into Shoor river. River system related to the Study is visualized as given in Figure 3.3.1.1.

Figure 3.3.1.2 shows the distribution of hydrological gauging stations. In total 64 stations are installed in the Study Area measuring daily and monthly river discharges that are sufficient for the Study. Observation works are carried out well and most of data are computerized already. Table 3.3.1.1 describes inventory of such hydrological stations while Table 3.3.1.2 summarizes monthly runoffs collected from selected stations. More details are given in Tables 3.3.1.1 to 3.3.1.3 of the Supporting Report.

3.3.2 Runoff Characteristics

Figure 3.3.2.1 shows the distribution of specific runoff yields estimated on the basis of average annual runoffs observed at hydrological stations. Higher yields of 450 mm to 500 mm are seen in the Alborz mountain area, while much smaller values of 30 mm to 50 mm are obtained at many stations located in the western and southern edges of Qazvin plain. This may be due to small amount of precipitation, high evaporation and high rate of deep percolation into the groundwater aquifer. Flow regimes of major rivers showing such characteristics of runoff are visualized in Figure 3.3.2.2 and monthly patterns of flow in an average year, wet year and critically dry year are presented in Figure 3.3.2.3. Hydrological data are collected also from the Study and Research Division of TRWB and Jamab Consulting Engineers.

Hydrological studies involved in the National and Regional Water Resources Master Plan (M/P) worked out by the Ministry of Energy and Jamab Consulting Engineers were based on the data covering 30 years from 1963/64 to 1992/93. Since the duration of data corrected from various hydrometric stations are different as summarized in Table 3.3.1.1, and considering that 1) the hydrological study should be based on reliable data of, at least, recent 20 to 30 years and 2) hydrological data collected from various stations should cover the same period of years, the JICA Study was also based on the records given in the Master Plan study after making update to cover the latest data of 1997/98 whenever data are available. Hydrological data of the water year 1998/99 was also corrected at major stations, however, those were excluded from the analyses because that the year 1998/99 was evaluated from statistical study as the critical drought year that would be occurred once in 100 years or more, as explained in the paragraph 3.3.4.

Figure 3.3.2.4 shows the long-term fluctuation of annual runoff of Karaj, Taleghan and Almout rivers. Almost same pattern of annual fluctuation and volume of annual runoff are observed for three rivers with the closest correlation between Karaj and Taleghan rivers. Gentle decline of trend curve observed for Taleghan river at Galinak and Almout river at Baghkalyeh is due to prominent runoff in 1968/69, and in general decreasing tendency of river runoff due to change of climate and/or water resources development in the upstream reaches can not be realized on all of three rivers. Abnormal wet year appeared in 1968/69, while dry years were observed in 1976/77, 1990/91 and 1998/99 with a return period of 15 years. Recurrence period of critical dry year observed in 1998/99 is evaluated at 34 years for Taleghan river and 117 years for Almout river as is seen in the paragraph 3.3.4.

3.3.3 Potential Annual Runoff and Specific Yield

Figure 3.3.3.1 illustrates the present use of surface water resources, summarized from existing records of river runoff as well as water application. Out of 2,460 MCM of potential surface water resources in the Study Area, about 1,390 MCM are being utilized at present.

Potential Surface Water Resources and Present Use

Rivers	Water Resources (MCM)	
	Potential	Present Use
Taleghan River at Dam-site	480	200
Taleghan River Downstream up to Confluence	40	-
Almout River at Proposed Dam-site	325	-
Small Streams from Taleghan Mountains	200	170
Qazvin Northern Streams	95	60
Thee Rivers of South Qazvin Area	250	125
Kordan River	120	60
Karaj River at Bileghan	490	435
Jaj-rud at Latian Dam (Lar Included)	460	340
Total	**2,460**	**1,390**

3.3.4 Statistical Evaluation of Flood and Drought Runoff

Annual runoffs recorded at major hydrological stations are put into statistical analysis in order to evaluate flood and drought runoffs and also to evaluate return period of drought that occurred in hydrological year 1998/1999. Result of analysis is as follows:

Flood Runoff by Return Period

(Unit: MCM)

River and Station	Return Period (year)					
	2	5	10	20	50	100
Sefid-rud River at Manjil Dam	4,418	5,800	6,603	7,310	8,159	8,759
Shah-rud River at Loshan	1,035	1,459	1,724	1,969	2,275	2,500
Taleghan River at Galinak	408	581	603	667	745	800
Almout River at Baghkalyeh	302	395	451	502	566	612
Shah-rud River at Siahdasht	722	1,027	1,230	1,425	1,680	1,873
Khah-rud River at Rahimabad	144	220	272	322	389	440
Abhar-rud River at Poletakestan	35	60	79	98	124	146
Haji Arab River at Rostamabad	25	45	61	77	99	117
Kordan River at Dehsommeh	109	155	186	215	254	283
Karaj River at Karaj Dam	425	529	593	652	725	778

Drought Runoff by Return Period

(Unit: MCM)

River and Station	Return Period (year)					
	2	5	10	20	50	100
Sefid-rud River at Manjil Dam	4,417	3,214	2,649	2,212	1,750	1,459
Shah-rud River at Loshan	1,035	700	554	446	337	271
Taleghan River at Galinak	408	302	253	215	176	151
Almout River at Baghkalyeh	303	228	195	170	145	130
Shah-rud River at Siahdasht	722	502	412	349	287	251
Khah-rud River at Rahimabad	144	91	70	55	41	32
Abhar-rud River at Poletakestan	35	19	13	9	5	3
Haji Arab River at Rostamabad	25	13	8	5	2	1
Kordan River at Dehsommeh	109	76	63	53	44	38
Karaj River at Karaj Dam	425	342	305	277	249	232

From the above analysis, return period of drought runoff occurred in 1998/1999 is evaluated as in the following table:

Recurrence Period of 1998/99 Runoff at Major Stations

River and Station	Recurrence Period (Year)
Sefid-rud River at Manjil Dam	230
Shah-rud River at Loshan	144
Taleghan River at Galinak	34
Almout River at Baghkalyeh	117
Shah-rud River at Siahdasht	960

3.3.5 Surface Water Quality and Suspended Sediment Load

Data on surface water quality are collected also from two sources, TRWB and Jamab Consulting Engineers. Because of huge volume of raw data especially on water quality, analyzed values for selected stations are extracted from the Master Plan Report as shown in Table 3.3.5.1 It is remarked here that, even though high salinity of water taken from the Shoor river is reasonable because the river originates from the salt marsh, however, salinity is also concentrated in the water of three rivers of Qazvin plain, Abhar-rud, Khah-rud and Haji Arab even if water is collected from the station located far upstream of the salt marsh, such as Abegarm on Khah-rud river. It is therefore important that careful attention is to be paid on the quality when preparing a plan of water use from these rivers.

Direct measurements of suspended sediment concentration on the Taleghan and Shah-rud rivers are analyzed to derive rating curves as shown below:

$y= 7.3984x^{1.8569}$, for Taleghan river at Galinak, and

$y= 1.6405x^{2.2365}$, for Shah-rud river at Loshan

where x: suspended sediment discharge in ton/day, and

y: water discharge in liter/sec.

Annual suspended load can be accumulated on the basis of observed record of water discharge in order to estimate the volume of sedimentation in the proposed dam/reservoir. There is no definite guideline to estimate the volume of bed load, and therefore experienced values will be collected from other regions/districts of the country to estimate the total deposit of sediment in the reservoir. Analyzed values of sediment routing given in the Master Plan Report are also employed to evaluate the specific sediment yield of major rivers in the Study Area.

Specific Sediment Yield of Major Rivers (Master Plan)

River	Station	Drainage Area (sq.km)	Annual Runoff (MCM)	Suspended Sediment (ton)			Sediment Concentration gr/liter	Specific Sediment Yield (ton/sq.km)
				Computed Value	Adj. Factor	Adjusted Value		
Taleghan	Galinak	775	426.86	905,000		905,000	2.12	1,168
Shah-rud	Loshan	5,070	1111.29	6,685,125	1.45	9,693,430	8.72	1,912
Khah-rud	Abegarm	2,520	102.18	480,074	1.3	624,000	6.12	248
Abhar-rud	Ghorve	1,926	53.93	57,681	1.3	75,000	1.39	39
Kordan	Dehsomeeh	360	110.38	39,307	5.5	217,900	1.97	605
Karaj	Bileghan	1,048	500.79	125,264	1.28	160,337	0.32	153
Jaj-rud	Latian Dam	691	210.03	11,359	1.26	14,312	0.07	21

The largest value of the specific sediment yield is obtained from Shah-rud river at Loshan. And in fact massive volume of sediment has been deposited in the reservoir transported from major tributaries of Sefid-rud river, Shah-rud and Qezel Ozan. There is no data available for estimation of the sediment transport within the Almout river system. Almout river may yield a larger amount of sediment as compared with that observed on Taleghan river at Galinak. More important is the fact that considerable part of sediment to be accumulated in reservoir area is due to collapse of bank of the reservoir caused by fluctuation of water level. Careful attention is therefore needed in planning and design of water diversion facilities for the proposed Almout water diversion plan.

3.4 Groundwater

3.4.1 Hydrogeological Structure

(1) Aquifer Structure and Classification of Groundwater Basin

In groundwater basin, water supply and irrigation water have been traditionally used to depend on qanats-system. At the mother wells of qanats, the groundwater tables range from as much as 50 m below the surface near the mountains, and is rising to within one (1) meter in central part of the plain In last few decades, these qanats-system have been replaced by a pumped supply system with tube wells sunk into aquifer even to 300 m deep. Since 1960's, TRWB have tried to clarify the aquifer structures of groundwater basin with vicarious methods, especially with geophysical surveys and exploratory drillings. The geophysical survey, using with resistivity soundings, detected the basement of aquifer at as deep as even 500 m form the surface (refer to Figure 3.4.1.1 to 3.4.1.4, Geophysical Studies and Survey-1966, 1967,1976 and 1985). However, most of exploratory wells, of which were subsequently executed for the confirmation of geophysical result, could not sunk into such deep horizon. Based on the existing hydrogeologic studies, the main aquifers are thought of "Recent Fan Deposits", "Upper Quaternary and recent alluvial - proluvial deposits" and "Upper Quaternary and recent lacustrine deposits".

(2) Groundwater Table and Changes

Though the measurement of groundwater table is a relatively easy task, the data thus obtained are rich and valuable. The measured data can be utilized for qualitative as well as quantitative review on recharge, storage, and flow of groundwater. Records of groundwater tables were observed by seasonal or monthly-basis operation. The collections of records were made for 10 years from 1990 to 1999. Among these, the set of records in the month of Oct.1994 were presented as rather high quality/density than those in other duration. (refer to Figure 3.4.1.5). Therefore, the month of Oct.1994 was selected as the calibration timing for the evaluation of groundwater resources. Two analytical maps: "Groundwater Table in "Elevation" and "Depth to Groundwater Table (refer to Figure 3.4.1.6 and 3.4.1.7)": were drawn at the time of Oct 1994. The groundwater table change judged from groundwater hydrographs (refer to Figure 3.4.1.8 and Supporting Report 3.4.1.1 to 3.4.1.122) was summarized as follows:

Tehran City: A periodical fluctuation responding to groundwater extraction was traced in the records. So far as review of continuous data, lowering of groundwater level was recognized in the most of records especially since 1996/97 within the range of 20m.

Tehran: A periodical fluctuation responding to the precipitation and water utilization was found in the records. It shows decreasing in the summer while increasing in the winter. Simultaneously, the lowering of groundwater level was found out at the southern part of the Tehran. This lowering were commenced from the 1992, and have been reached to 20m since 1992/93.

Karaj: The most of well are in the lowering condition, in particular since 1996/97 and in the southern part of the Tehran. Quickest drop of groundwater table showing in observation records was of exceeding 50m within the 10 years.

Hashtgerd: Data were characterized by seasonal rising of groundwater table responding to the recharge and inflow from the surface water source such as Kordan river. However, the gradual lowering of groundwater table were chronically presented in the most of observation wells. As an average, the lowering of groundwater table have been partly taken place at pace of several meters drop during last 10 years.

Qazvin north: Observation wells are located near Qazvin city. Groundwater table have been almost keeping on a level, or rising-up until 1996/97. Particularly at the margin of groundwater basin, stretching along the mountain fringe, the groundwater tables were rising-up with the range of several to 20 meters. Within a year, the highest peak was traced in the period of spring to summer, it might indicate an effects form the recharge caused by irrigation water supply, or possibly supposed to be accelerated by artificial recharge-ponds. However, groundwater table was again lowered since 1996/97 by over-extraction.

Qazvin south: The seasonal fluctuation of groundwater table, reaching 6-7m, was recognized with a clear peak during winter to spring season. These pneumonia were expected to be caused by strong groundwater recharge through river beds of Khah-rud and Haji-Arab river. However, the most of observation wells represented the lowering of groundwater table since 1996/97. Larger decreasing of groundwater table were found in the centre of sub-areas. In particular, highest drop of groundwater table has been taken place at the summer of 1999's.

(3) Well yield

Well yield and specific capacity were analyzed from several data-resources of which were "Well Inventory" and "Exploratory Well Records". The extremely high value of average "Well yield" accounting to 80 lit./sec was obtained from Qazvin. The “well yield” of respective sub-area recognized is summarized as follows:

Well Yield of Production Well

Sub-Areas	Number of Data	Discharge
	Nos.	(litter/sec)
Tehran City	9,199	6
Tehran	6,336	9
Qazvin South	3,399	80
Qazvin North	877	66
Karaj	3,153	14
Hashtgerd	3,026	18
Total (Average)	**25,990**	**(32)**

(4) Aquifer Property

Aquifer Characteristics

The hydrogeology of the Groundwater Basin has not been clarified with clear correlation in between existing wells. Many places, by the lithologic logs, the multiple layers were recognized and was generally viewed as an equally complex system with a much higher horizontal than vertical permeability. The clayey, and possibly the carbonate horizons may represent local confining or semi-confining layers in the aquifer system, that isolate the various gravel layers from each other.

Transmissivity and Storativity

The value of “Transmissivity and Storativity” were obtained from the existing data. However, most of the existing pumping tests were made without accompanied observation wells. If doing so, the storativity could not be determined, and the transmissivity values obtained were less accurate as they had to be corrected for well loss effects. Transmissivity obtained were delineated in the “Transmissibility Map” as shown in Figure 3.4.1.9 Value as high as over 4,000 m2/day was found at south of Takestan, of which are locating river-bed of Khah-rud river. Simultaneously, the storativity were reviewed and revised by relevant information to well yield and geologic log, then were finalized in “Storativity Map” as shown in Figure 3.4.1.10 Average storativity is 6% and maximum value was 15 % found at the south of Takestan.

3.4.2 Potential Storage Capacity of Aquifer

With the use of “Storativity” obtained in the Study Area, the amount of groundwater (Storage Capacity”) enclosed in aquifers of the Qazvin and Tehran groundwater basins are empirically estimated as below:

Groundwater Storage of Aquifer Estimated from Storage Coefficient and Aquifer Thickness

(MCM/year)

Sub-areas	1990/91	1991/92	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99	999/2000
Tehran city	878	876	887	891	885	879	870	857	843	836
Tehran	4,360	4,360	4,368	4,349	4,332	4,313	4,290	4,263	4,259	4,237
Karaj	6,555	6,498	6,517	6,472	6,465	6,433	6,382	6,305	6,267	6,174
Hashtgerd	2,819	2,818	2,830	2,835	2,834	2,823	2,804	2,764	2,718	2,666
Qazvin (north)	10,737	10,788	10,838	10,890	10,948	11,040	11,071	10,967	10,927	10,780
Qazvin (south)	22,538	22,528	22,519	22,507	22,513	22,581	22,582	22,368	22,327	22,028
Total	**47,887**	**47,867**	**47,959**	**47,943**	**47,977**	**48,069**	**47,999**	**47,525**	**47,342**	**46,721**

In case that the economical depth of groundwater pumpage is settled as less than 100m, the distribution of available storage within the marginal depth is shown in Figure 3.4.2.1.

3.4.3 Existing Production Wells and Qanats

(1) Existing Production Wells

In order to summarize features of groundwater facilities, reference was made to “Statistical Reports of Groundwater Resources” prepared in 1992/93 and 1996/ 97 for five sub-areas by TRWB. It should be noted here, however, that the data collection works were still on the way and existing available data probably contained some incorrect data and therefore was not quite accurate. Aside from that, according to existing available data of groundwater wells, about 10,800 of deep wells and 15,100 of shallow wells have been excavated in the area.

(refer to Figure 3.4.3.1 to 3.4.3.4). Average features of groundwater wells are summarized as follows:

Average features of groundwater wells

Sub-Areas	Number of wells			Average features of Groundwater Wells			
	Deep	Shallow	Total	Depth of Well	Depth of Water	Discharge	Operation Hour
	Nos.			(m)	(m)	(lit./sec)	(hrs)
Tehran City	2,374	6,825	9,199	79	35	6	1,095
Tehran	3,848	2,488	6,336	80	43	9	2,450
Qazvin South	1,894	1,505	3,399	87	33	80	3,592
Qazvin North	476	401	877	113	29	66	3,497
Karaj	1,393	1,760	3,153	61	29	14	1,828
Hashtgerd	860	2,166	3,026	69	27	18	2,715
Total (Average)	**10,845**	**15,145**	**25,990**	**82**	**33**	**32**	**2,530**

(2) Existing Qanats

With reference of “Statistical Reports of Groundwater Resources” prepared in 1992/93 and 1996/ 97 by TRWB, the number facilities for regions of Qazvin and Tehran and Tehran City is 870 and total discharge amount are summed up as 340 MCM/year as summarized below and Figure 3.4.3.5.

Qanat Discharge

Sub-area	Qanats Discharge (MCM/year)
Tehran city	147
Tehran	125
Qazvin North	31
Qazvin South	38
Total	**342**

3.4.4 Evaluation of Existing Groundwater Use

According to existing statistics of wells, about 296 MCM of groundwater were extracted from 9,200 deep and shallow wells in the area of Tehran city. In the Tehran region, about 590 MCM were extracted from 6,340 wells, while in the Karaj region, 833 MCM was withdrawn by 3,150 wells. Simultaneously, 328 MCM by 3,030 wells in the Hashtgerd region and 1,240 MCM by 4,280 wells in Qazvin plain were consumed in 1996/97, as shown below:

Summary of Groundwater Extraction

Summary of Groundwater Extraction JICA Study (1996, MCM/year)				Groundwater Extraction Estimated in Water Master Plan (MCM/year)		
No.	Nos. of wells	Extraction Total		Agriculture	Water Supply	**Total**
Tehran Capital Area						
Tehran City	9,199	296	⇔	0	269	**269**
Tehran	6,336	590	⇔	526	160	**686**
Karaj	3,153	833	⇔	433	414	**847**
Hashtgerd	3,026	328	⇔	288	32	**320**
Subtotal	21,714	2,047	⇔			**2,122**
Qazvin	4,276	1,244	⇔	1074	93	**1,167**
Total	**25,990**	**3,291**	**⇔**	**2,321**		**3,289**

It is noted here that statistics of groundwater wells are rather old except for Qazvin plain, and therefore rapid increase of extraction to cope with population growth especially in the Tehran capital area in recent years is not reflected. Further, the actual usage of well was not surveyed and accessed properly in aforesaid report (Statistical Reports of Groundwater Resources" 1992/93 and 1996/ 97).

Hence, this extraction value is regarded as "facility capacity of production wells to be extracted in maximum usage". In other words, net value accounted as actual extraction must be less than this extraction amount which is exceeding 3,000 MCM/year.

Accelerated trend of groundwater extraction has already resulted in severe downfall of groundwater level as shown in Figure 3.4.4.1, as well as production in many parts of aquifers inevitably requiring monitoring and management of limited groundwater resources for future rational groundwater exploitation. Figure 3.4.4.2 presents consumption of groundwater based on presently available data by grid.

3.4.5 Evaluation of Potential Groundwater

The present state of social and economic development throughout the Study Area is characterized by a sharp increase in groundwater exploitation. This is due in part to the fact that the available surface water is often fully developed and committed; surface water is utilized throughout the Study in large amounts for irrigation, industrial, and domestic water supplies. In stead of the use of surface water, the groundwater resource is utilized as a result of man's activity in the recent drought. Especially in Karaj and Hashtgerd and even in Qazvin south, the mining of the non-renewal water has been habitually progressed.

In case that exploitation in those areas is to be planned in the M/P, strict control within a "Permissible Yield" against either water demand or a planned period of time must be considered throughout the "Groundwater Balance Study". Then, the reliability of groundwater exploitation recommended in M/P must be guaranteed.

(1) Method of Groundwater Balance Study

Water balance studies was carried out to evaluate groundwater potential and the reasonable limit of groundwater utilization for renewal groundwater resources. On regional water balance, the equation consists of rainfall, surface runoff, evapo-transpiration, drafting, inflow and outflow of groundwater and so forth is commonly applied, these are:

Change in Groundwater storage (Δ S)

Groundwater Recharge (Gr) - Groundwater Runoff (Gf) - Groundwater Withdrawal (Wwd)

As per equation, the current groundwater balance as well as an available groundwater resource were provisionally examined in the Study.

(2) Groundwater Recharge (Gr)

In previous studies completed since 1960's at Qazvin, Tehran and Shahriyar areas, the potential of groundwater recharge was elaborated by using several kinds of methods. In these studies, the estimation of groundwater recharge was followed in three approaches due to different sources for recharges:

Sources of Groundwater Recharge
(a) Direct recharge from precipitation
(b) Seepage through streambeds
(c)Return flows from city water supply, well and qanat extraction for industrial and irrigated areas

<u>Direct recharge from precipitation</u>

To identify initial infiltration form precipitation in the plain area, "Infiltration Coefficient" as same rate as those of exiting studies was set down. Thus, three (3%) was selected as an applied coefficient for "Area Precipitation".

Area Precipitation
Total catchment area for groundwater basin was calculated as about 21,000 km^2, and 7,000 MCM/a was obtained as precipitation discharge. Area precipitation accounted to a range of 180 mm/year to 590mm/year with an average of 322 mm/year as shown in Supporting Report 3.4.5.1.

However, the coverage of calculation was selected in different way from those of existing studies Recharged area here were restricted to which were "Terrain having rechargeable-surfaces", such as farmland, irrigation land, flat plain and silt flat. Other areas: city, town, terraces (inclined terrain) and salt marsh: were eliminated from the calculation.

Seepage through streambeds

The infiltration along the riverbed is mainly controlled due to the amount of water supplied to groundwater basin. These areas were classified by respective condition related to possible amount to be discharged through steam flow and/or to be conveyed by irrigation networks. The recharge type (divided recharge-sources into points/lines/areas) adopted in this calculation are determined (refer to Supporting Report 3.4.5.2).

Return flows from city water supply, well and qanat extraction for industrial and irrigated areas

Return flows from return-flow were assumed with the rate to discharged amount from groundwater pumpage or form city water supply. and in the irrigation area Rates for estimation of return flows were selected in accordance with those of using in existing studies, The rate of return flow and amount obtained in the existing studies were shown below:

Rate of Return Flow Applied in the Study (1/2)

Existing water balance studies (water year treated)	Rate of Return-flow for Groundwater pumpage / (city water supply)			
	City water supply	Qanats	pumpage for industrial	pumpage for irrigation
Qazvin (1964-67)	not concerned	10 %	not exist	10 % - 35%
Tehran (1994-94)	(ca. 400 MCM/a)	13 %	35 %	20 %
Shahriyar (1994-95)	(37 MCM/a)	no concerned	25 %	18 %

Among the above, the rate of irrigation water was particularly verified in the Study. Taking a the extent of farming/irrigation land (refer to "Coverage Types of Groundwater Recharge") into account, possible height of water-loss form irrigated water were calculated as shown below:

Rate of Return Flow Applied in the Study (2/2)

Areas	Qazvin north	Qazvin south	Hashtgerd	Karaj	Tehran	Tehran City	Average
Rate of return flow	0.25		0.12	0.14	0.20	-	0.20
height of return flow	Irrigation canal:80mm Other :50-65 mm		65-115mm			-	80 mm

Result of the Estimation of Groundwater Recharge

After several ten times of iterations with trial calculations, the final parameters or coefficients were determined as an appropriate amount matched with the those of existing studies. Resulting in provisional estimations, 48 MCM/year direct by precipitation, 605 MCM/year by river flow and 471 MCM/year by return flow were calculated as amount of natural groundwater recharge in the Study Area. In addition to above, 31 MCM/year (average 1991/92-1997/98) through artificial recharge ponds was account to the recharged amount. Totaled with 155 MCM/yea was obtained from all over the groundwater basin as shown in Table3.4.5.1.

(3) Groundwater Runoff

The amount of groundwater flow into the groundwater basin is considered to be only recharged water caused by precipitation and applied/irrigation water outside the basin (refer to Supporting Report 3.4.5.3). Meanwhile the groundwater outflow outside the watershed is taking place near its outlet. This generally occurs as a form of groundwater outflow through Quaternary deposit underlain along the basin border. In the Study Area, these deposits were recognized all the surroundings of groundwater basin. Their transmissivity was relatively assumed to be 500 to 4,000 m2/day as shown in Figure 3.4.1.9 With the use of these values, the inflow and outflow crossing basin border was estimated. Groundwater in/outflow amount were estimated as 1,172 MCM/a while 92 MCM/year out-flow amount as shown below:

Summary of Groundwater Inflow

Groundwater In/out-flow through Sections					Groundwater In/out-flow into Sub-Areas						
Calc. Section	G.In/out flow Rate	Width of Section	G. In/out-flow through Sections		Qazvin south	Qazvin north	Hasht-gerd	Karaj	Tehran	Tehran City	**Total**
-	m^3/day/m	m	(m^3/d)	(MCM/a)	(MCM/a)						
1	16.9	47,239	796,443	291	291						**291**
2	7.9	4,431	34,827	13	13						**13**
3	4.4	51,637	227,668	83	83						**83**
4	0.2	4,824	1,000	0	0						**0**
5	0.8	60,441	45,788	17	17						**17**
6	1.7	68,953	115,193	42	17	25					**42**
7	1.7	43,821	76,609	28		28					**28**
8	2.6	32,910	85,592	31		31					**31**
9	5.6	24,839	138,878	51		51					**51**
10	4.0	37,514	148,317	54		5	49				**54**
11	11.4	31,203	355,054	130			39	91			**130**
12	0.5	12,999	6,630	2				2			**2**
13	16.4	33,599	549,693	201					201		**201**
14	3.2	24,040	77,066	28					3	25	**28**
15	9.3	59,456	552,105	202					20	181	**202**
16	1.7	100,792	170,526	62							**0**
17	5.3	80,035	426,724	156	-12						**-12**
15-16	-1.0	51,651	-53,357	-19					-19		**-19**
salt-marsh	-1.9	39,032	-74,423	-27	-27						**-27**
salt-marsh	-1.2	24,310	-28,496	-10		-10					**-10**
salt-marsh	-4.7	13,076	-60,838	-22			-22				**-22**
				In-flow:	**420**	**141**	**88**	**93**	**224**	**207**	**1,172**
				Outflow:	**-40**	**-10**	**-22**	**0**	**-19**	**0**	**-92**
				(In) – (Out):	**381**	**130**	**65**	**93**	**204**	**207**	**1,080**

Note: Calculation was made based on “Oct.1994” record

1,172 MCM/year of total amount of groundwater inflow accounts for 26 % of all rainfall discharge (4,404 MCM/year) of all the surrounding sub-basins. This can be regarded as very possible rate in view of regional hydrogeology.

(4) Change in Groundwater Storage

Each of the hydraulic water balances in the basin contains item on “change in groundwater storage (±ΔS)”, which signifies the change in the water contents of aquifer or the groundwater storage or both. The interpretation as to which of this storage locations are used in the balance equation depends on the definition or zone to which the equation is applied.

The change of storage term(±ΔS) is significant only if the hydrologic balance equation is applied for a short period of time. If the period is longer and steady state, this term becomes insignificant in relation to the other terms and may be taken to be zero. In the Study Area, the hydrologic balance may be being as a negative balance from 1980’s. The system therefore has not been in a steady-state or in a quasi-steady state. The “change in storage volume (±ΔV) form Oct.1990 to Sep.2000 calculated the observation record of groundwater table, net groundwater storage (±ΔS)” is presumably estimated as below:

Annual Change in Groundwater Storage from 1991 to 2000

(MCM/year) *1

Sub-areas	1370	1371	1372	1373	1374	1375	1376	1377	1378	
	90/91	91/92	92/93	93/94	94/95	95/96	96/97	97/98	98/99	99/00
Tehran city	-5	1	19	4	-1	1	-21	0	-20	-1
Tehran	-8	31	-13	5	-12	2	-39	44	-10	-26
Karaj	-14	12	-27	4	15	93	-160	-88	-66	-288
Hashtgerd	-15	13	15	51	77	156	-34	-13	-69	-273
Qazvin (north)	-20	34	-17	14	-2	32	-51	-2	-58	-47
Qazvin (south)	-50	27	-74	16	-1	-21	-66	-15	-49	-125
Total	**-112**	**118**	**-97**	**95**	**77**	**262**	**-371**	**-74**	**-272**	**-760**

Note: the change in groundwater storage is calculated as a difference within each water year (from Oct. to Sep)

In the groundwater basin, the drastic decreasing of groundwater table is recorded since 1996/97. Thus, the saturated zone has been lost in last four (4) years at the rate -74 to -760 MCM/year. In particular, Karaj, Hashtgerd and Qazvin south area were suffering by serious deficits in these days as shown in Figure 3.4.5.1 and 3.4.5.2.

The periods of 10 years using the analysis of the Study is though to be insufficient to discuss and to conclude the “hydrogeological balance of the Qazvin-Tehran basin”. Theoretically, 30 years is at least required for understanding their water balance. However, available data for such analysis, particularly in terms of their continuation and precision, are very much limited. During the Study, the record of 10 years is solely obtained due to the discontinuation of record and unreliable information of observatories. Thus, the re-organization of “Monitoring System” which is focusing on the data processing, storing and evaluation is to be required in the future (refer to sub-section 7.7.3).

(5) Assessment of Usable Water Potential

In evaluating the available water resources, either in the renewal of groundwater resources or fossil water, two factors must be substantially considered: (1)permissible yield from the groundwater basin, and (2)how well the groundwater basin is managed. Considering these needs, the appropriate amount of groundwater that can be exploited from groundwater resources can be determined. In this paragraph, only physical conditions that related to item (1) has been considered to give an index of available quantity of groundwater resources (usually use as same means as. "Renewal Groundwater Resources") in the future water use.

With this concept, the hydrologic balance of the current situation was estimated with the use of settled amount in relevant hydrogeologic items. According to provisional analysis for meteorological records as described above, 70,00 MCM/year of rain water is carried by the precipitation (average about 300 mm/year) within the catchment area of groundwater basin. Of these, about 5,100 MCM/year is lost by both evapo-transpiration and surface runoff. The remaining 1,850 MCM/year is allocated as groundwater recharge. The ratio of groundwater recharge against precipitation is estimated as 26% for all the precipitation water. In addition to above, 950 MCM is taken into account of return flow form consumed water of irrigation and water supply. Total 2,800 MCM/year is summing up as "Renewal Groundwater Resources". Out of this, 2660 MCM/a of the groundwater withdrawal and 90 MCM/year of the groundwater runoff are subtracted from the basin. This expenditure, 2,750 MCM/year (total of the groundwater extraction and the groundwater runoff) is however less amount of "Renewal Groundwater Resources", hence the 80 MCM/ year are accounted at surplus in the groundwater balance of (1994/95).

On the other hand, the deficit of 760 MCM/year is resulting in balance study in drought year of 1379 (1999/2000). The groundwater balance estimating for the period of 1374 (1994/95) and 1379 (1999/2000) is given in Table 3.4.5.2 and Figure 3.4.5.3 and 3.4.5.4.

In the estimation of groundwater balance, various existing records, inclusive of geologic structure, aquifer coefficients, groundwater table, area precipitation, infiltration coefficients were applied. These data and records however were being different observation-timings and sources. Therefore, the background of this result were being indistinct, of which is not to be defined its implication. In the future studies, time-series and spatial analysis is to be required for obtaining more concrete water balance.

3.4.6 Quality of Groundwater

The measurements of groundwater quality have commenced from 1996, and their results are accumulating in TRWB's library. However, most of those records are being for limited purposes in conjunction with geochemical analysis and adoptability for irrigation use, as well. In fact, those items are composed of EC, pH, Total Hardness, TDS, SAR as general indexes, and geochemical items of CO^3, HCO^3, Cl, SO_4, Ca, Mg, Na, K and Na, which can represent the geochemical composition of water. With use of such results, “EC distribution”, “Geochemical Water Type” and “Agricultural Classification”have been discussed in the previous studies conducted by TRWB as follows:

- **EC distribution:** For initial understanding the salinity distribution in the Qazvin to Tehran Plain, EC map was delineated. EC is represented with various range from 500 to over 5,500 μS/cm. Although the saline is concentred in the salt marsh, salinity is diluted by recharged water from the mountains. Especially at the downstream of Kordan, Karaj and Haji Arab and Khah-rud river, the fresh water mass is formed and intruded in to the saline water with linguoid form. In the common wells which is used for domestic use in Qazvin south and the south of Tehran, high salinity zone exceeding 2,250μS/cm was extended and used, as shown in Figure 3.4.6.1.
- **Geochemical Water Type:** geochemical water type in the Study Area is recognised as two of “HCO^3”, and “SO_4 + Cl”. The “HCO^3” type dominates widest area in particular the upper portion (northern part) of groundwater basin, where fresh water is supplied by groundwater recharge and groundwater inflow form the neighbouring mountain area. “SO_4+ Cl” type somewhat occupies the lower reach (southern part) of basin. In the sense of “groundwater evolution”, The “HCO^3” type of groundwater supposed to be newly recharged water form surface water , while “SO_4+Cl” types indicate the “old water” storing long duration in the strata.
- **Agricultural Classification:** In the studies examined in TRWB, the adoptability for agricultural use is evaluated by indexes of SAR and EC (based on Water Quality Standard of US Salinity Laboratory), In the classification. the saline water indicating C3 to C6 and S2 to S4 which are required some improvement of soil or shows un-adoptable water for agriculture, is extending the southern parts. The coverage of these saline water is nearly coincided with aforesaid “SO_4+Cl” types of water.

For the drinking water quality, the necessity testing items to evaluate the potability is not fully engaged in water wells in spite of detecting a contamination of groundwater up to now. Metals have been detected in 1996 at the west to south-west of Tehran as wide as about 400 km^2 (refer to Figure 3.4.6.1). In the Study, the type and concentration of such metals are not checked up yet, but their pollution sources were tried to be traced using with backward (pathline)- analysis during 30 years. In the analysis, it cab be guess that such pollution may have been spread out form particular places in western Tehran, which is used to be industrial areas.

Aiming at confirmation of distinct condition of pollution, the (continuous and) seasonal survey by complete items for drinking water must be recommended for all the metal-detecting coverage as a part of the future monitoring networks, stated in sub-section 7.7.1 and 7.7.2.

Figure 3.2.2.1 Isolines of Precipitation over the Study Area

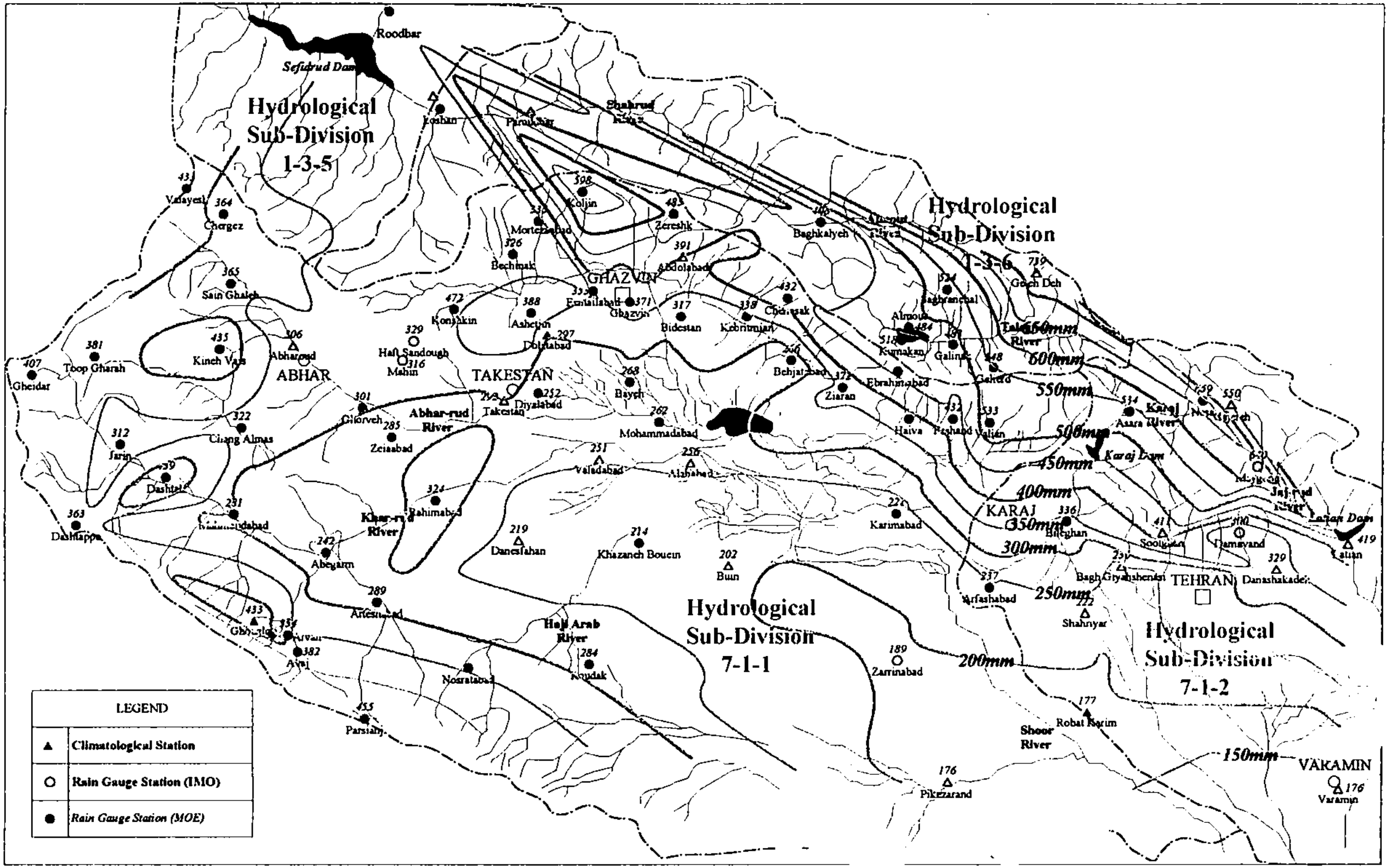


Figure 3.2.2.2 Monthly Precipitation at Major Stations in the Study Area

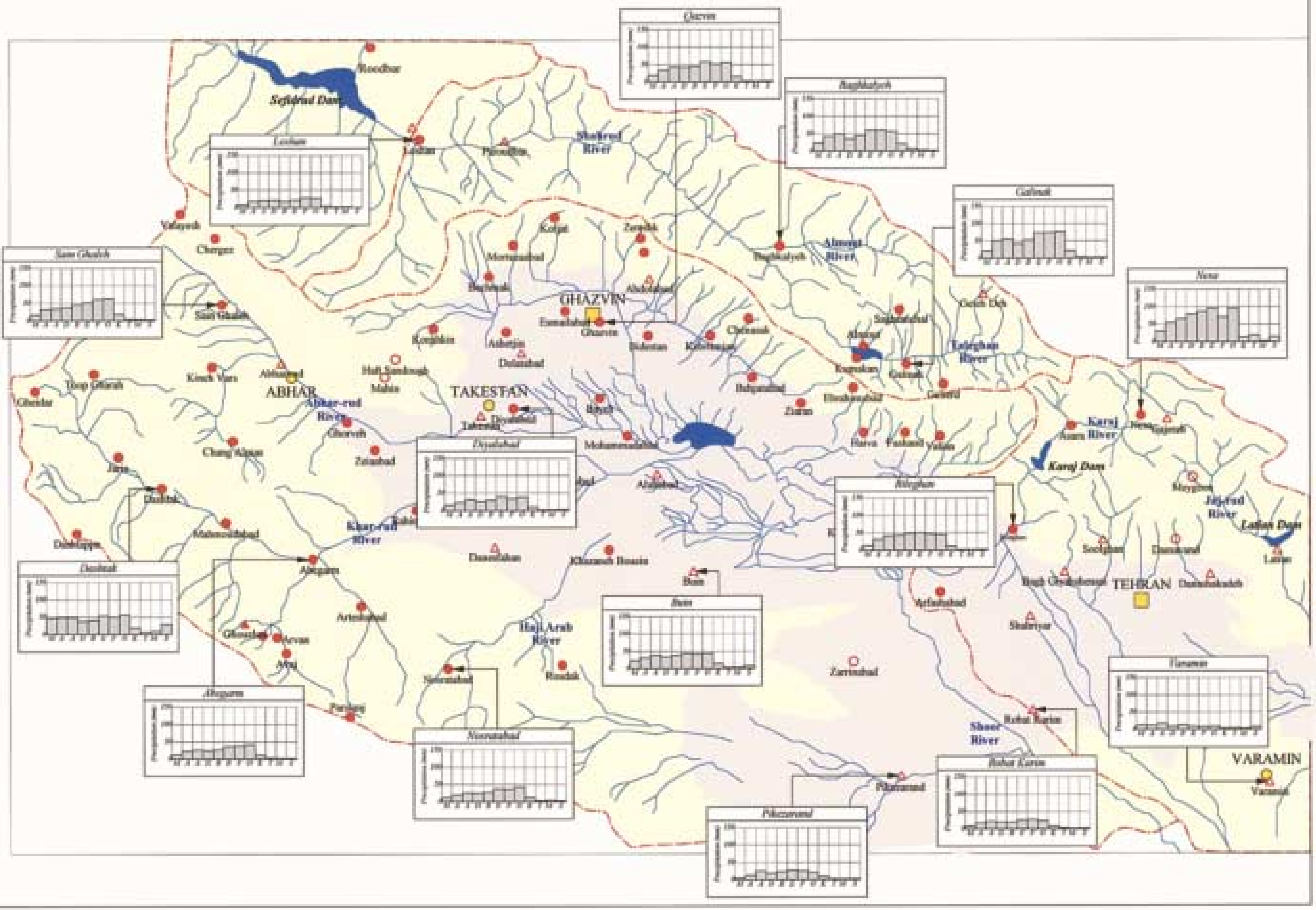


Figure 3.2.2.3 Long-term Fluctuation of Precipitation at Mehrabad in Tehran City

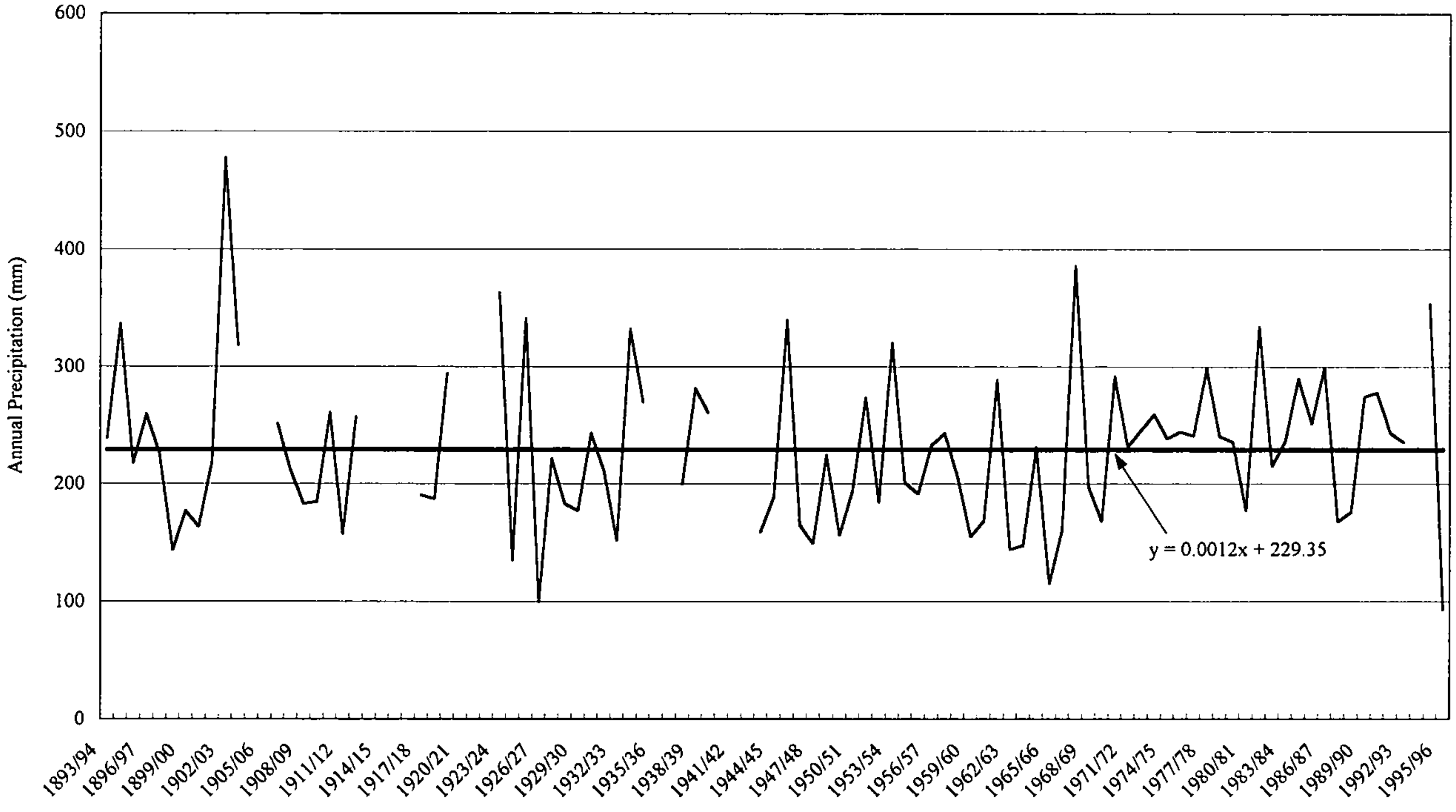


Table 3.3.1.1 List of Monthly River Runoff Data Collected (1/2)

Code		River	Station	Feature of Gauging Station			C.A.	Data Collected by Source	
TRWB	M/P			Longitude	Latitude	Elevation	(sq.km)	TRWB	M/P
	1-3-5-01	**Sefidrud**	**Sefidrud Dam**	49-23	34-46	350	56,606.0	**69/70 - 98/99**	((63/64 - 92/93))
	1-3-5-10	Sefidrud	Roodbar	49-23	36-46	300	56,280.0		49/50 - 95/96
17-037	1-3-6-01	Taleghan	Kumakan	50-41	36-11	1,700	960.0	74/75 - 83/84	((59/60 - 95/96))
	1-3-6-07	**Taleghan**	**Ziaran Tunnel**	50-41	36-11	1,700		**70/71 - 98/99**	76/77 - 94/95
17-835	1-3-6-10	**Taleghan**	**Galinak**	50-46	36-10	1,800	775.0	**60/61 - 98/99**	59/60 - 95/96
17-039	1-3-6-11	**Almout**	**Baghkalyeh**	50-28	36-26	1,150	678.0	**66/67 - 98/99**	((63/64 - 95/96))
	1-3-6-13	**Shahrud**	**Loshan**	49-32	36-37	300	5,070.0		**54/55 - 95/96**
17-201	1-3-6-15	**Shahrud**	**Siahdasht**	50-17	36-27	970	2,445.0	**(84/85 - 98/99)**	((63/64 - 95/96))
41-063	7-1-1-11	**Arvan**	**Polearvan**	49-12	35-38	1,770	96.1	**64/65 - 97/98**	((63/64 - 95/96))
	7-1-1-12	**Avajchay**	**Avaj**	49-12	35-38	1,765	306.3		**((63/64 - 92/93))**
41-193	7-1-1-13	Khar-rud	Mahmoodabad	49-04	35-50	1,635	2,050.0	83/84 - 85/86	closed in 1985
41-067	7-1-1-14	**Khar-rud**	**Abegarm**	49-16	35-45	1,560	2,520.0	**65/66 - 92/93**	**63/64 - 95/96**
41-069	7-1-1-15	**Kolanjinchay**	**Arteshabad**	49-25	35-40	1,750	449.0	**64/65 - 96/97**	63/64 - 95/96
41-199	7-1-1-16	**Kolanjinchay**	**abbasabad**	49-19	35-46	1,540	695.1	77/78 - 85/86	closed in 1985
41-071	7-1-1-17	**Khar-rud**	**Rahimabad**	49-33	35-52	1,400	4,089.4	**64/65 - 98/99**	63/64 - 95/96
41-075	7-1-1-18	**Shoor**	**Poleshahabbasi**	50-04	35-56	1,170	5,408.0	**(65/66 - 98/99)**	((63/64 - 95/96))
41-073	7-1-1-19	**Abhar-rud**	**Qerveh**	49-23	36-03	1,430	1,926.0	**(64/65 - 98/99)**	63/64 - 95/96
41-207	7-1-1-20	**Abhar-rud**	**Poletakestan**	49-38	36-01	1,305	2,600.0	**77/78 - 85/86**	closed in 1985
41-077	7-1-1-21	**Haji Arab**	**Nosratabad**	49-37	35-33	1,900	105.6	78/79 - 85/86	closed in 1985
41-079	7-1-1-22	**Haji Arab**	**Hajiarab**	49-45	35-36	1,670	560.0	**(64/65 - 98/99)**	63/64 - 95/96
41-081	7-1-1-23	**Haji Arab**	**Rostamabad**	49-52	35-40	1,470	905.0	(77/78 - 85/86)	closed in 1985
41-215	7-1-1-24	Mortezaabad	Mortezaabad	49-48	36-25	1,590	33.0	77/78 - 85/86	closed in 1985
41-083	7-1-1-25	**Aloolak**	**Amirabad**	50-01	36-21	1,430	72.0	80/81, 84/85	closed in 1985
41-219	7-1-1-26	**Barajin**	**Barajin**	50-03	36-20	1,405	104.0	**(65/66 - 98/99)**	((63/64 - 95/96))
41-221	7-1-1-27	**Rashtghan**	**Rashtghan**	50-09	36-20	1,565	43.0	77/78 - 85/86	closed in 1985
41-085	7-1-1-28	**Ashnestan**	**Ashnestan**	50-11	36-17	1,450	38.0	77/78 - 85/86	closed in 1985
41-087	7-1-1-29	Shotrak	Shotrak	50-14	36-16	1,450	62.0	77/78 - 85/86	closed in 1985
41-089	7-1-1-30	**Behjatabad**	**Behjatabad**	50-23	36-09	1,400	55.0	(78/79 - 92/93)	**63/64 - 95/96**
41-091	7-1-1-31	**Ziaran**	**Ziaran**	50-30	36-06	1,700	96.0	(77/78 - 85/86)	closed in 1985
41-136	7-1-1-32	**Sarab**	**HIV**	50-39	36-02	1,470	32.0	(73/74 - 85/86)	closed in 1985

Note: TRWB(1) denotes the Tehran Regional Water Board while M/P means data used in the M/P Study for National and Regional Water Resources by Jamab Consulting Engineers.
Parenthesis means that data include missing period while (( )) shows all or some data are estimated.

Table 3.3.1.1 List of Monthly River Runoff Data Collected (2/2)

Code		River	Station	Feature of Gauging Station			C.A.		
TRWB	M/P			Longitude	Latitude	Elevation	(sq.km)	TRWB	M/P
41-093	7-1-1-33	**Fashand**	**Darband**	50-45	36-03	1,780	34.0	**(77/78 - 98/99)**	((63/64 - 92/93))
41-235	7-1-1-34	Ardehe	Ardehe	50-47	36-02	1,660	14.5	73/74 - 76/77	73/74 - 79/80
41-137	7-1-1-35	**Valian**	**Valian**	50-50	36-02	1,740	20.0	73/74 - 85/86	closed in 1985
41-239	7-1-1-36	Galin-rud	Aghasht	50-48	35-57	1,640	20.6	(77/78 - 85/86)	77/78 - 85/86
41-243	7-1-1-37	**Kanale-Kordan**	**Dehsomeeh**	50-50	35-57	1,425		**73/74 - 96/97**	((63/64 - 95/96))
41-095	7-1-1-38	**Kordan**	**Dehsomeeh**	50-50	35-57	1,410	360.0	**(47/48 - 96/97)**	47/48 - 95/96
41-097	7-1-1-39	Kordan	Najmabad	50-30	35-50	1,190		87/88 - 91/92	83/84 - 95/96
41-099	7-1-1-40	**Shoor**	**Poleasefoldoleh**	50-45	35-41	1,122	16,400.0	(69/70 - 92/93)	**((63/64 - 95/96))**
41-935		Mourood	Pole-Khab (Mourood)	51-09	36-02			**90/91 - 98/99**	
41-987		Nashtarood	Pole-Khab (Nashtrood)	51-09	36-04			**90/91 - 98/99**	
41-255		Sharestanak	Doab (Karaj)	51-18	36-01			81/82 - 85/86	
41-932		Haft Cheshme	Aderan	51-05	35-56			90/91 - 92/93	
41-989		Varyan	Varyan	51-07	35-59			90/91 - 92/93	
41-249	7-1-1-41	Lar(Alishar)	Qarahghbola	49-47	35-25	2,000	57.2	75/76 - 76/77	75/76 - 76/77
41-278	7-1-1-43	Sirud	Aghesht	50-53	36-00		103.0	84/85 - 85/86	84/85 - 85/86
41-222	7-1-1-44	Kordan	Darvan	51-02	36-02	2,200	41.0	(87/88 - 92/93)	(87/88 - 95/96)
	7-1-1-45	Khoroji-Kordan	Khoramabad	50-32	35-54	1,172			90/91 - 91/92
41-986	7-1-1-47	Arvan	Dehearvan	49-11	35-37	1,880	28.0	(82/83 - 92/93)	90/91 - 95/96
	7-1-2-01	**Karaj**	**Amirkabir Dam**	51-05	35-57	1,588	850.0	**63/64 - 98/99**	((54/55 - 95/96))
	7-1-2-02	**Jaj-rud**	**Latian Dam(Inflow)**	51-41	35-47	1,580	690.0	**67/68 - 97/98**	((46/47 - 95/96))
	7-1-2-04	**Tehran Tunnel**	**Bileghan**	51-02	35-50	1,360	1,408.0	**63/64 - 98/99**	63/64 - 95/96
	7-1-2-05	**Tonnel Telo**	**Tunneltelo**	51-41	35-47	1,580		**53/64 - 98/99**	68/69 - 95/96
41-101	7-1-2-13	**Karaj**	**Sira**	51-09	36-02	1,790	718.0	**54/55 - 98/99**	54/55 - 95/96
41-103	7-1-2-14	**Karaj**	**Bileghan**	51-03	35-50	1,390	1,048.0	**47/48 - 97/98**	47/48 - 97/98
41-105		Karaj	Pole-Saloor	51-12	35-32			73/74 - 74/75	
41-236		Karaj	Parandak	51-05	35-32			74/75 - 76/77	
41-107		Chitgar	Chitgar	51-10	35-44			72/73, 85/86, 92/93	
41-109		Kan	Soolaghan	51-16	35-47			**67/68 - 98/99**	
41-227		Kan	Hesarak	51-18	35-47			(72/73 - 91/92)	
41-111		Kan	Kahrizak	51-21	35-30			(80/81 - 92/93)	
	7-1-2-46	**Jaj-rud**	**Latian Dam(Outflow)**	51-41	35-47	1,560	691.0	**67/68 - 98/99**	46/47 - 95/96

Note: TRWB(1) denotes the Tehran Regional Water Board while M/P means data used in the M/P Study for National and Regional Water Resources by Jamab Consulting Engineers. Parenthesis means that data include missing period while (( )) shows all or some data are estimated.

Table 3.3.1.2 Monthly River Runoff at the Selected Gauging Stations

(unit = MCM)

Code	River	Station	CA(km2)	Year	MEHR	ABAN	AZAR	DAY	BAH.	ESF.	FAR.	ORD.	KHO.	TIR	MOR.	SHA.	ANNUAL
13501	Sefidrud	Manjil Dam	56,606	69/70-97/98	98.2	206.3	252.1	251.9	283.2	485.6	1252.1	1113.6	468.9	138.6	54.9	50.9	4656.3
13607	Taleghan	Ziaran Tunnel		77/78-98/99	7.2	7.1	4.7	1.9	1.9	2.4	8.4	36.3	39.8	21.0	11.6	7.3	149.7
13610	Taleghan	Galinak	775	68/69-97/98	11.1	15.3	14.2	12.1	12.4	22.7	73.1	118.6	94.3	41.1	17.8	11.3	443.8
13611	Almout	Baghkalyeh	678	68/69-97/98	10.8	13.9	12.6	11.9	12.3	19.3	47.8	74.2	61.2	32.9	16.7	11.4	324.8
13613	Shahrud	Loshan	5,070	54/55-95/96	28.7	41.6	47.7	43.0	47.7	93.8	225.3	281.1	198.1	85.3	34.9	24.7	1151.7
13615	Shahrud	Siahdasht	2,445	63/64-95/96	19.2	31.3	33.9	29.8	33.8	68.4	143.2	177.4	151.5	81.4	32.0	13.7	815.6
71111	Arvan	Polearvan	96	63/64-95/96	0.2	0.5	0.8	1.0	1.4	2.5	5.1	3.9	1.3	0.3	0.1	0.1	17.2
71112	Avajchay	Avaj	306	63/64-92/93	1.0	2.0	2.5	2.6	3.0	5.7	12.6	9.7	2.5	1.7	0.3	0.3	44.0
71114	Kharrud	Abegarm	2,520	63/64-95/96	4.7	7.7	8.9	8.2	9.2	14.5	24.2	18.7	5.2	1.6	1.7	2.2	106.7
71115	Kolanjinchay	Arteshabad	449	63/64-95/96	0.5	0.8	1.2	1.5	1.7	3.0	7.4	6.4	2.0	0.4	0.4	0.2	25.4
71117	Kharrud	Rahimabad	4,089	63/64-95/96	3.4	7.8	10.6	11.7	14.9	25.9	44.3	31.2	8.1	0.7	0.5	0.8	160.0
71118	Shoor	Poleshahabbasi	5,408	63/64-95/96	0.4	1.7	2.1	1.1	1.1	3.1	9.7	8.1	1.8	0.1	0.2	0.1	29.7
71119	Abharrud	Poletakestan	2,600	63/64-92/93	0.3	0.9	1.5	2.8	3.8	8.7	16.3	5.6	2.0	0.0	0.0	0.0	41.9
71122	Haji Arab	Haji Arab	560	63/64-95/96	0.6	0.9	1.0	1.1	1.2	2.8	6.9	6.3	2.5	0.7	0.7	0.4	25.1
71124	Mortazaabad	Mortezaabad	33	63/64-90/91	0.0	0.0	0.1	0.1	0.3	1.2	1.8	0.8	0.1	0.0	0.0	0.0	4.6
71125	Aloolak	Amirabad	72	63/64-93/94	0.1	0.3	1.1	1.4	2.6	4.1	4.7	2.0	0.5	0.1	0.1	0.1	17.2
71126	Barajin	Barajin	104	63/64-95/96	0.1	0.5	0.8	0.8	1.3	3.7	5.3	2.8	0.9	0.3	0.1	0.1	16.7
71127	Rashtghan	Rashtghan	43	63/64-92/93	0.1	0.1	0.2	0.2	0.5	1.4	1.9	0.9	0.2	0.0	0.0	0.0	5.7
71128	Ashnestan	Ashnestan	38	63/64-92/93	0.0	0.1	0.2	0.1	0.3	1.3	1.8	0.8	0.2	0.0	0.0	0.0	4.8
71129	Shotrak	Shatrak	62	63/64-90/91	0.1	0.4	0.4	0.6	1.0	2.0	2.5	0.9	0.3	0.0	0.0	0.0	8.2
71130	Bahjatabad	Behjatabad	55	63/64-95/96	0.2	0.3	0.3	0.4	0.8	1.8	2.5	1.3	0.7	0.1	0.0	0.1	8.4
71131	Ziaran	Ziaran	96	63/64-92/93	0.1	0.3	0.3	0.4	0.5	1.8	2.1	1.3	0.5	0.1	0.1	0.1	7.6
71132	HIV	HIV	32	63/64-92/93	0.1	0.1	0.2	0.3	0.3	0.6	0.8	0.7	0.4	0.2	0.1	0.1	3.8
71133	Fashand	Darband	34	63/64-92/93	0.3	0.3	0.3	0.4	0.5	1.6	2.5	2.2	1.2	0.7	0.5	0.3	10.9
71135	Valian	Valian	20	63/64-92/93	0.2	0.2	0.2	0.3	0.4	0.9	1.7	1.8	0.7	0.3	0.2	0.1	7.0
71138	Kordan	Dehsomeeh	360	47/48-95/96	1.3	3.3	4.7	4.8	6.5	14.9	32.7	31.6	12.4	3.7	1.5	0.8	118.1
71140	Shoor	Poleasefoldoleh	16,400	63/64-95/96	1.1	1.5	1.4	1.8	4.4	9.8	21.4	13.2	2.3	0.1	0.1	0.1	57.2
71142	Shoor	Pikezarand	3,048	75/76-95/96	0.5	0.1	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.1	0.1	0.2	2.3
71201	Karaj	Karaj Dam	850	54/55-95/96	14.2	16.1	14.9	13.2	13.9	24.5	61.5	102.3	88.4	49.1	27.2	17.8	443.2
71202	Jajrud	Latian Dam	690	46/47-95/96	12.2	16.4	16.7	13.3	13.3	21.2	48.1	72.2	47.3	22.3	16.4	13.2	312.5
71204	Tehran Tunne	Bileghan		63/64-95/96	20.3	17.8	15.9	15.4	15.2	16.9	17.4	19.9	23.5	25.0	24.7	24.2	236.1
71205	Tunneltelo	Tunneltelo		68/69-96/97	25.4	23.3	21.6	21.3	20.5	19.8	0.0	0.0	0.0	0.0	0.0	0.0	131.9
71213	Karaj	Sira	718	54/55-95/96	12.8	14.4	13.4	11.9	12.5	22.1	55.3	92.1	79.6	44.2	24.5	15.9	398.7
71214	Karaj	Bileghan	1,048	47/48-97/98	26.6	23.9	21.1	19.1	18.7	28.4	55.5	101.0	91.8	54.8	41.9	34.1	516.7

(unit = MCM)

MonRunSum.xls

Figure 3.3.1.1 River Systems Related to the Study and Potential Surface Water Resources

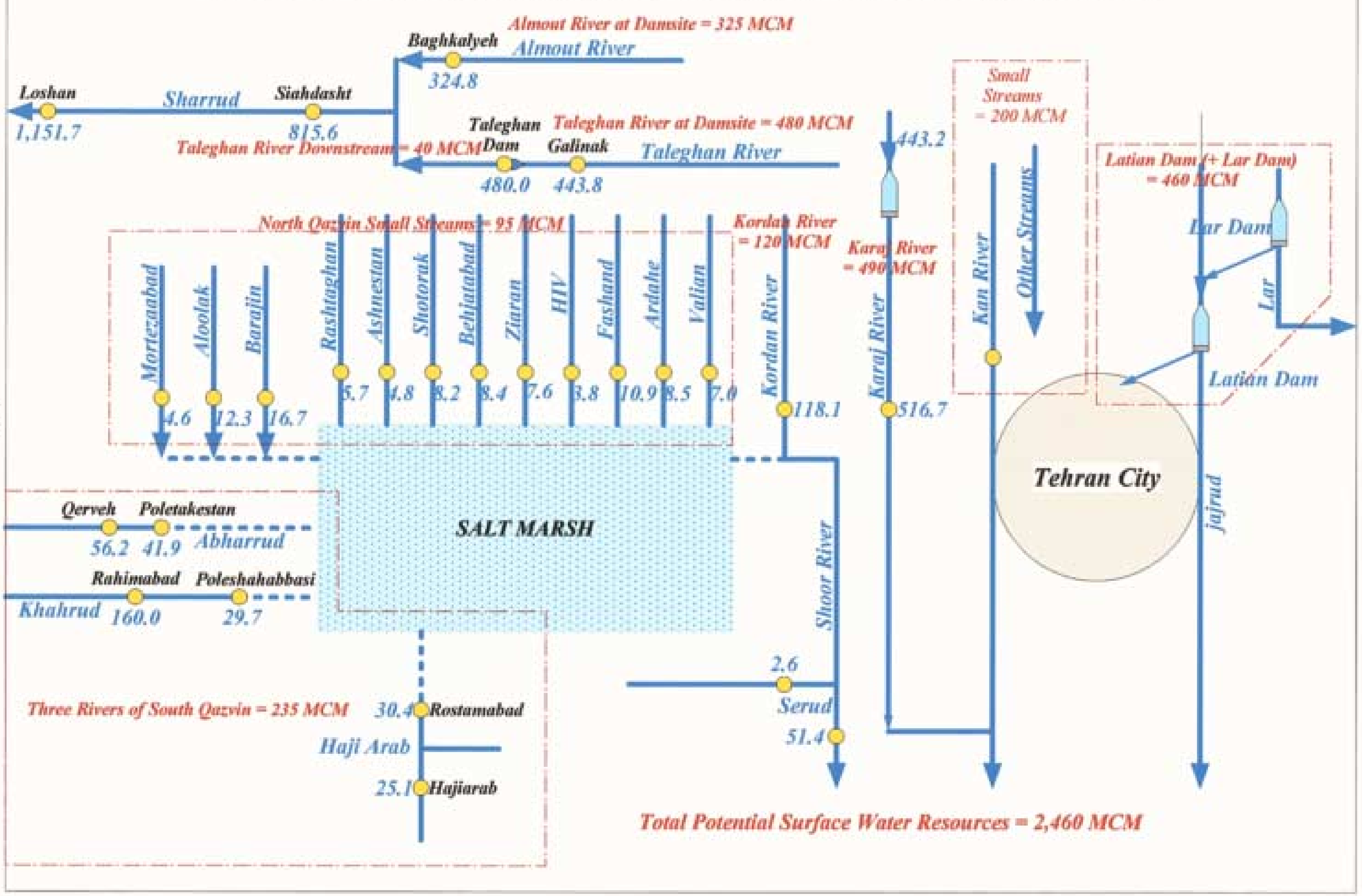


Figure 3.3.1.2 Distribution of Hydrological Stations

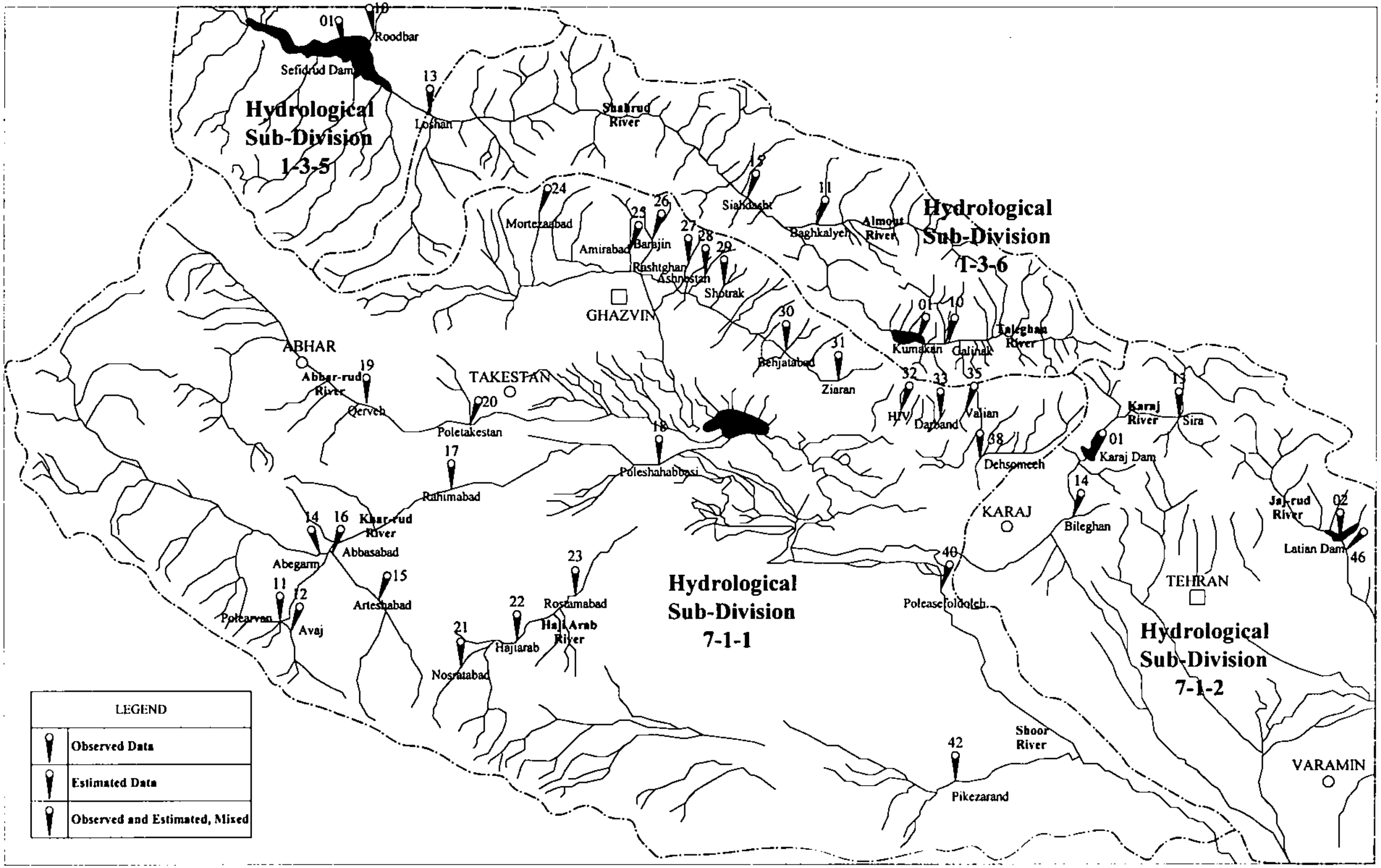


Figure 3.3.2.1 Specific Runoff Yield

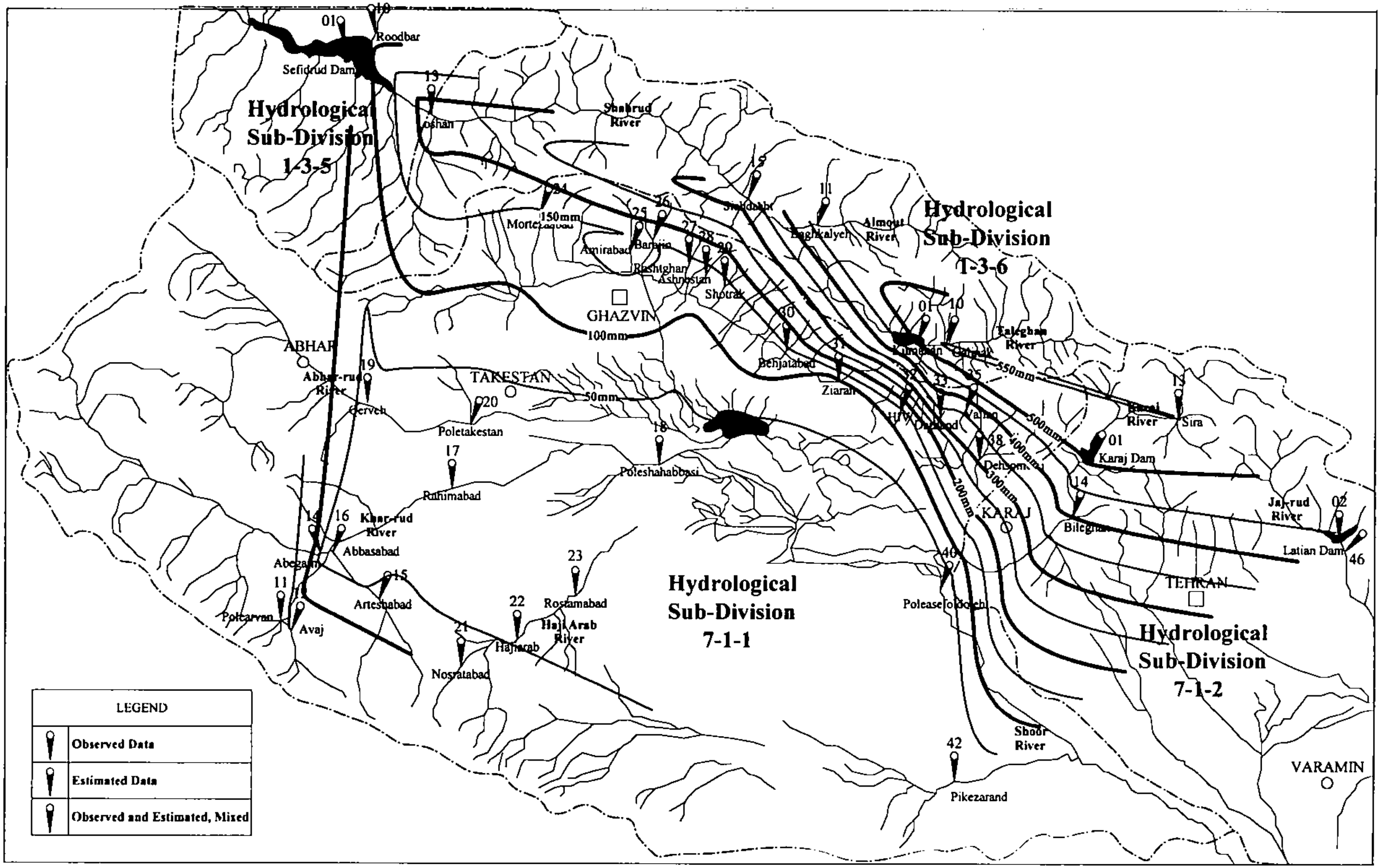
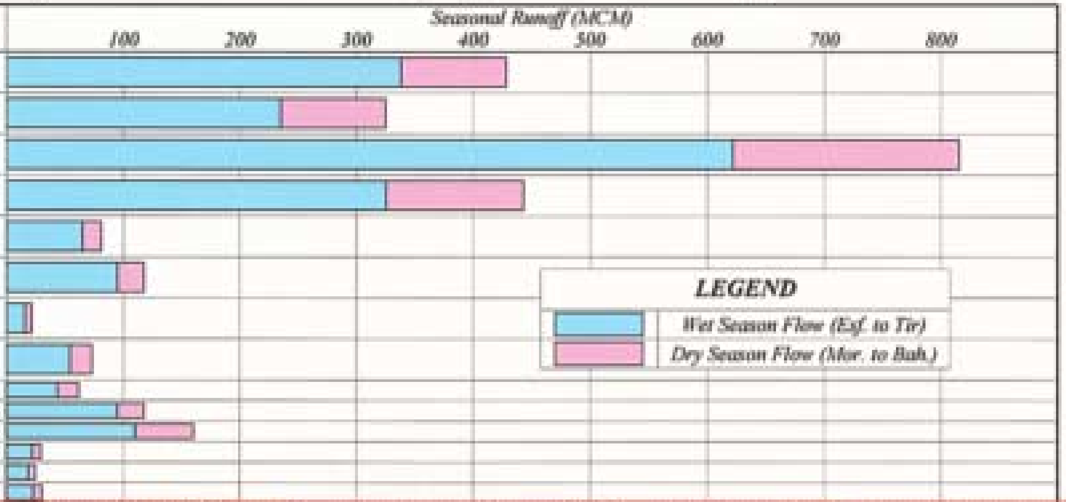
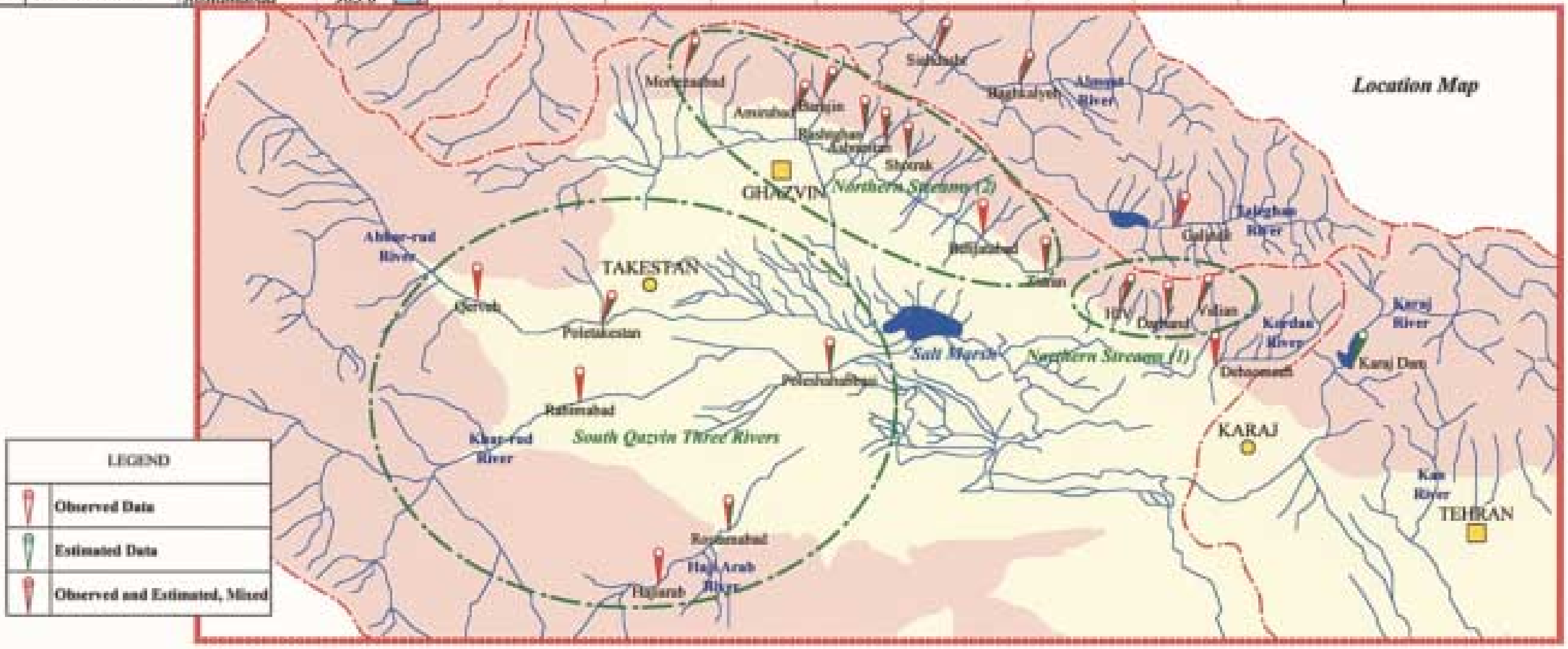


Figure 3.3.2.2 Seasonal Flow of Major Rivers in the Study Area

	River	Gauging Station	C.A. (sq.km)
Major Sources of Water	Taleghan River	Galinak	775.0
	Almout River	Baghkalyeh	678.0
	Shah-rud River	Siahdasht	2,445.0
	Karaj River	Karaj Dam	690.0
Small Rivers and Streams	Kan River	Soolaghan	
	Kordan River	Dehsomeeh	360.0
	North Streams (1)		
	North Streams (2)		
South Qazvin Three Rivers	Abhar-rud River	Qerveh	1,926.0
		Poletakestan	2,600.0
	Khah-rud River	Rahimabad	4,089.4
		Poleshahabbasi	3,408.0
	Haji Arab River	Haji Arab	560.0
		Rostamabad	905.0





SeasonalFlow.mxd

Figure 3.3.2.3 Distribution of Monthly Runoff at Major Gauging Stations

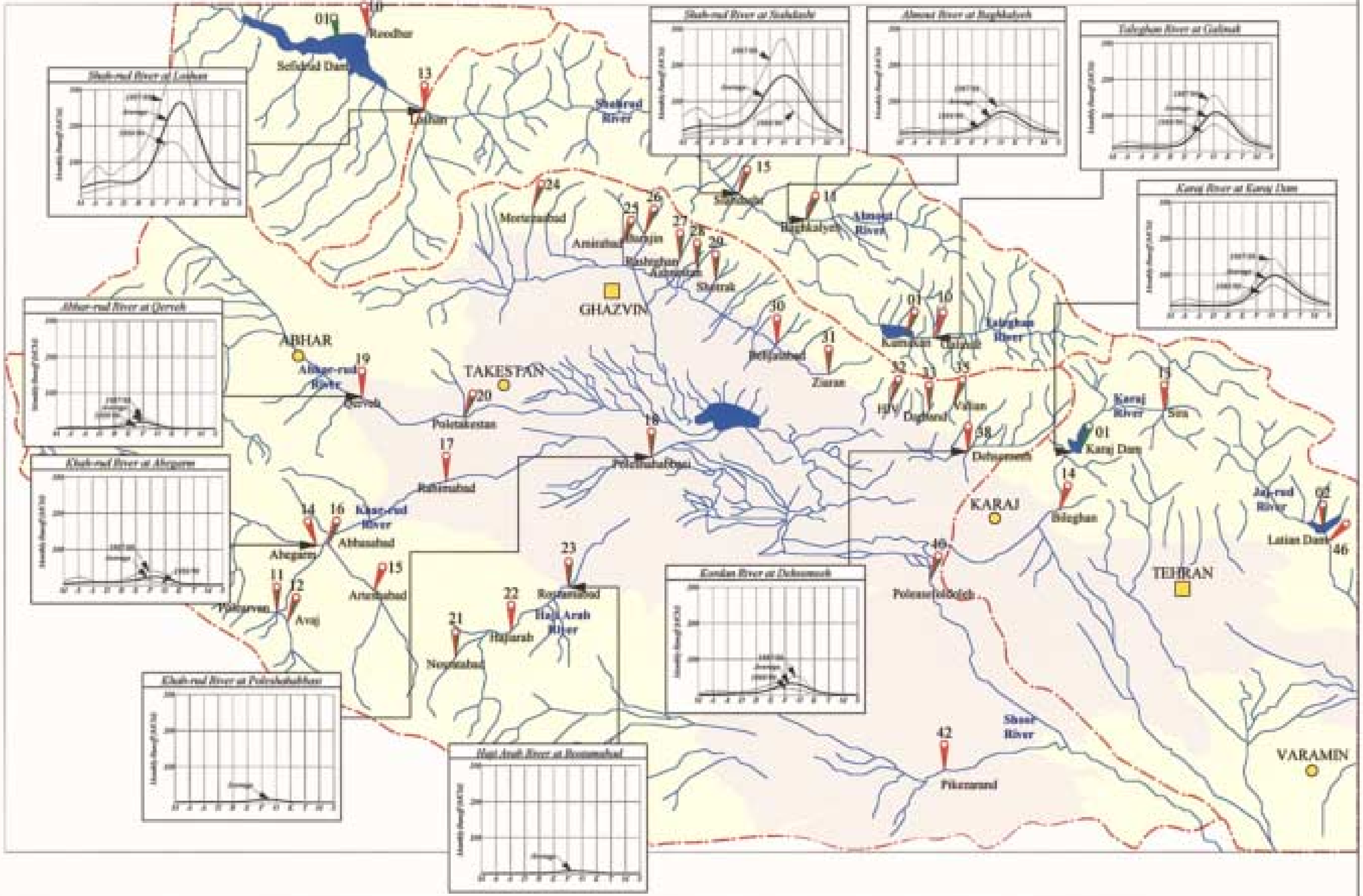


Figure 3.3.2.4 Long-term Fluctuation of Annual Runoff of Major Rivers

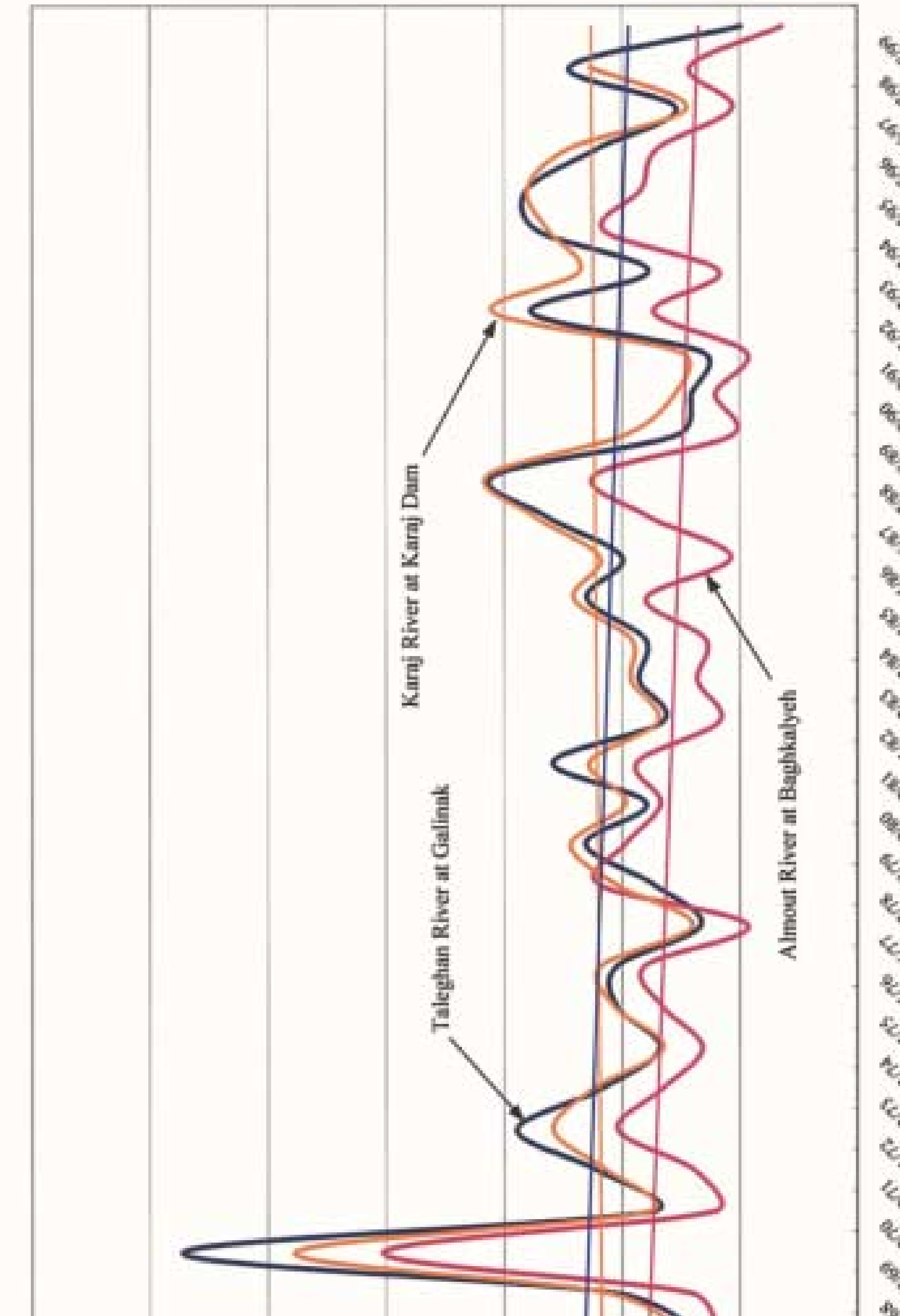


Figure 3.3.3.1 Present Use of Surface Water Resources

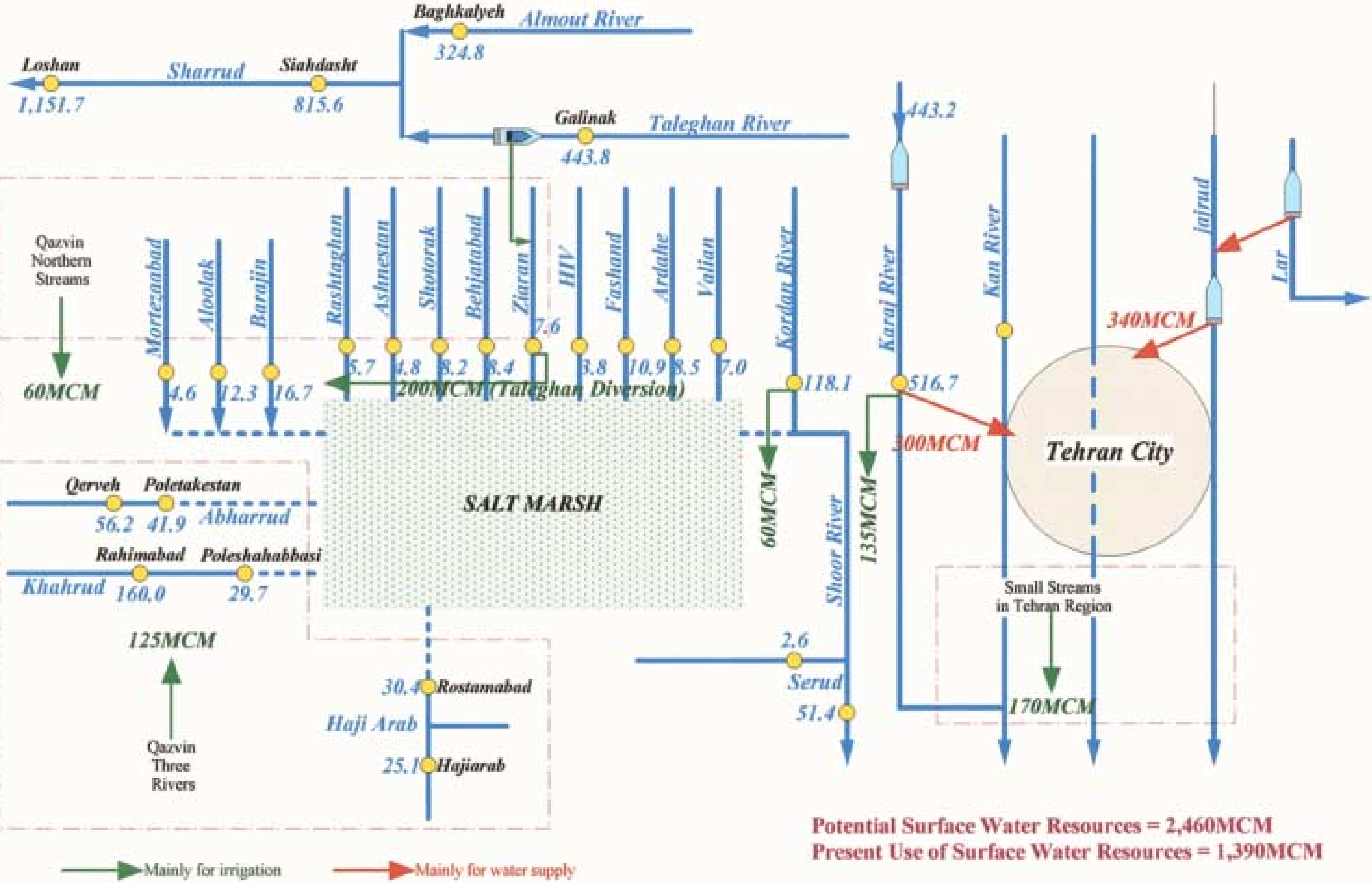


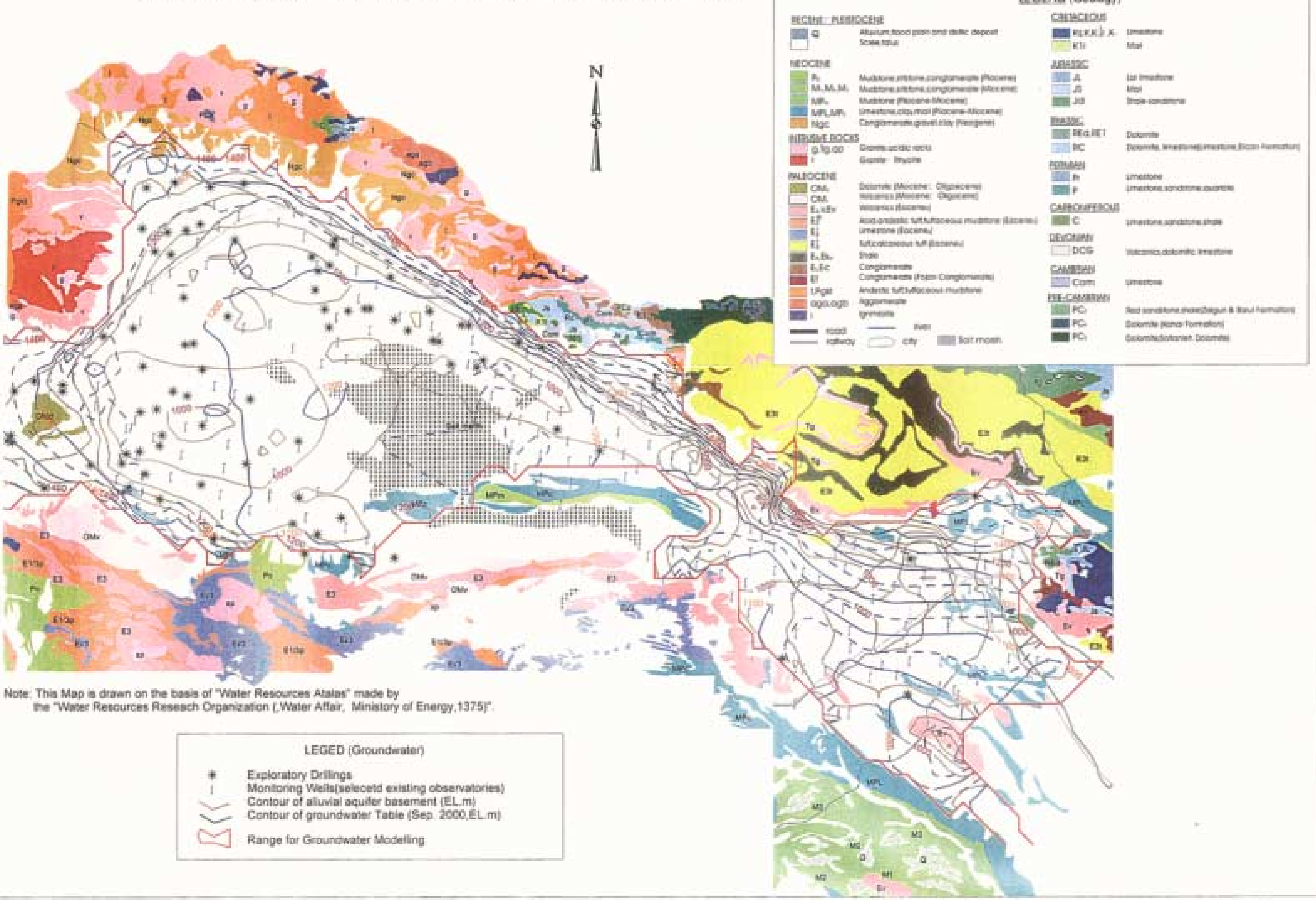
Table 3.3.5.1 Analyzed Values of Water Quality at Selected Stations

Station Code	River	Station	SAR	K+	NA	CA	MG	SO4	CL	HCO3	CO3	PH	EC moh E-6	TDS mg/l	DIS SMC
71111	Arvan	Polearvan	2.57	0.07	3.99	2.2	2.23	2	2.42	4.05	0	7.93	827.92	494.62	0.76
71112	Avajchay	Avaj	5.7	0.16	10.39	2.9	2.8	2.77	9.33	4.36	0	7.92	1660.33	952.68	1.1
71113	Khah-rud	Mahmoodabad	5.43	0.11	10.29	4.1	2.98	3.97	9.51	4.58	0.1	7.9	1781.29	1088.67	2
71114	Khah-rud	Abegarm	7.34	0.15	13.86	4.06	3.04	4.11	12.3	4.94	0.15	7.91	2123.98	1299.06	4.8
71115	Kolanjinchay	Arteshabad	3.45	0.09	5.46	2.59	2.5	3.82	2.93	4.03	0.06	7.92	1062.19	661.77	0.66
71117	Khah-rud	Rahimabad	5.76	0.11	11.12	4.04	3.43	6.24	8.74	3.93	0.08	7.94	1858.51	1191.05	10.47
71118	Shoor	Poleshahabbasi	24.39	0.34	81.43	10.67	4.97	30.32	62.06	5.41	0.44	8.16	8853.09	4914.94	6.01
71120	Abhar-rud	Poletakestan	2.12	0.04	3.43	3.09	2.03	3.28	1.14	4.44		8.01	790.4	493.93	1.73
71122	Haji Arab	Hajiarab	3.02	0.1	5.45	3.29	3.24	5.97	2.67	3.62	0	7.92	1179.47	783.96	0.72
71124	Mortezaabad	Mortezaabad	1	0.02	1.31	1.14	1.79	0.49	0.64	3.07	0.33	8.01	399.48	246.03	0.18
71125	Aloolak	Amirabad	0.98	0.02	1.24	1.32	1.82	0.8	0.45	3.19	0	7.92	404.28	249.45	0.75
71126	Barajin	Barajin	1.02	0.03	1.34	1.26	2.23	1.74	0.42	2.67	0.02	7.95	472.53	293.06	1.11
71128	Ashnestan	Ashnestan	1.2	0.03	1.48	1.28	1.96	0.76	0.38	3.6	0.4	7.97	437.71	268.38	0.26
71129	Shotorak	Shotorak	1.57	0.03	2.02	1.28	2	0.91	0.52	3.81	0.05	7.99	484.85	293.16	0.34
71130	Behjatabad	Behjatabad	1.15	0.04	1.35	0.89	1.96	1.13	0.42	2.62	0	7.95	407.74	251.35	0.52
71131	Ziaran	Ziaran	0.69	0.02	0.91	1.59	1.95	0.51	0.38	3.52	0.08	8.04	413.89	260.5	0.14
71133	Fashand	Darband	0.22	0.02	0.28	1.51	1.94	0.75	0.2	2.76	0.05	7.9	353.76	217.22	1.88
71134	Ardehe	Ardehe	0.3		0.4	1.98	1.92	0.43	0.32	3.51	0.47	7.99	429.21	279.74	0.12
71135	Valian	Valian	0.46	0.02	0.77	2.46	2.13	0.8	0.42	4.13	0.45	7.92	502.97	316.85	0.16
71136	Galinrud	Aghasht	0.83	0.02	1.19	1.65	2.32	1.1	0.28	3.79	0.2	7.98	468.82	298.59	0.09
71138	Kordan	Dehsomeeh	0.42	0.02	0.54	1.17	2.11	0.77	0.24	2.81	0.07	7.79	365.67	227.1	12.84
71140	Shoor	Poleasefoldoleh	28.69	0.32	166.79	23.87	26.69	29.67	185.99	2.93	0	7.73	19308.57	13667.46	1.37
71144	Kordan	Drban	0.27	0.02	0.32	0.86	2.09	0.74	0.19	2.34	0	7.68	315.53	173.87	7.57
71147	Arvan	Dehearvan	0.64	0.01	0.82	0.91	2.18	0.79	0.48	2.62	0	7.91	379.14	232.88	0.69
71213	Karaj	Sira	0.33	0.02	0.41	0.89	2.11	0.85	0.29	2.28	0.05	7.81	330.58	209.41	19.21
71214	Karaj	Bilaqan	0.39	0.01	0.46	0.77	2.05	0.86	0.31	2.17	0.03	7.8	321.35	197.43	27.74
71246	Jajrud	Latian	0.47	0.03	0.59	1.08	2.08	0.78	0.46	2.53	0.05	7.84	366.37	230.49	18.01
13610	Taleghan	Galinak	0.85	0.04	1.36	1.34	3.61	2.71	1.12	2.46	0	7.72	609.95	398.44	16.86
13611	Almout	Baghkalyeh	0.62	0.04	1.02	1.63	3.68	3.29	0.64	2.47	0	7.72	599.7	387.84	10.31
13613	Shahrud	Loshan	1.56	0.05	2.54	1.89	3.27	2.9	1.91	2.95	0.05	7.72	756.37	481.35	70.39
13615	Shahrud	Siahdasht	1.41	0.04	2.26	1.61	3.23	3.17	1.87	2.22	0	7.78	705.93	422.91	78.35

Note: SAR=NA/SQRT(MG+CA)*0.5
K+ to CO3 are given in Milliequivalent/liter

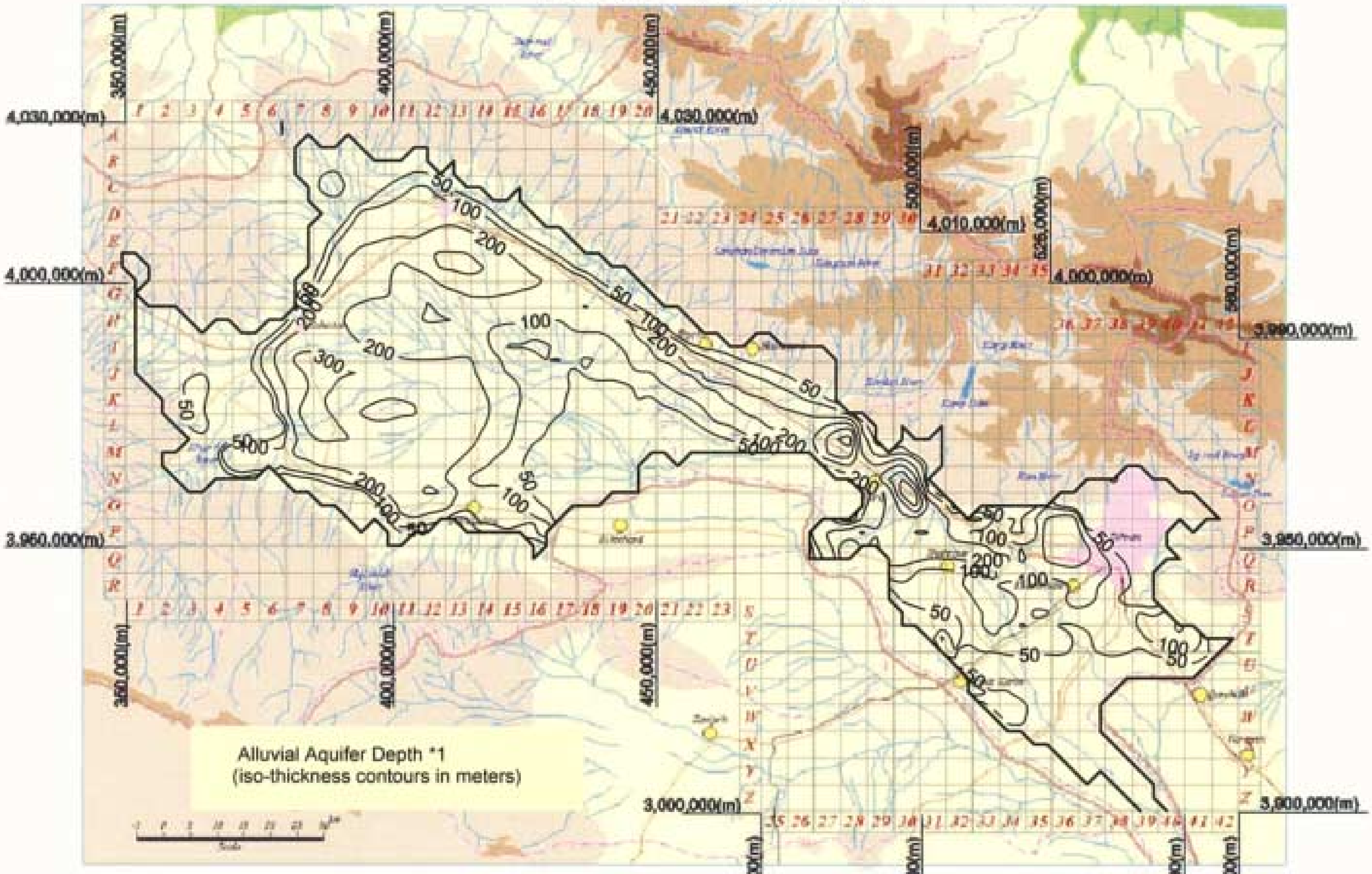
QualitySum.xls

Figure 3.4.1.1 Hydrologic Map of Groundwater basin (West of Tehran Capital Area)



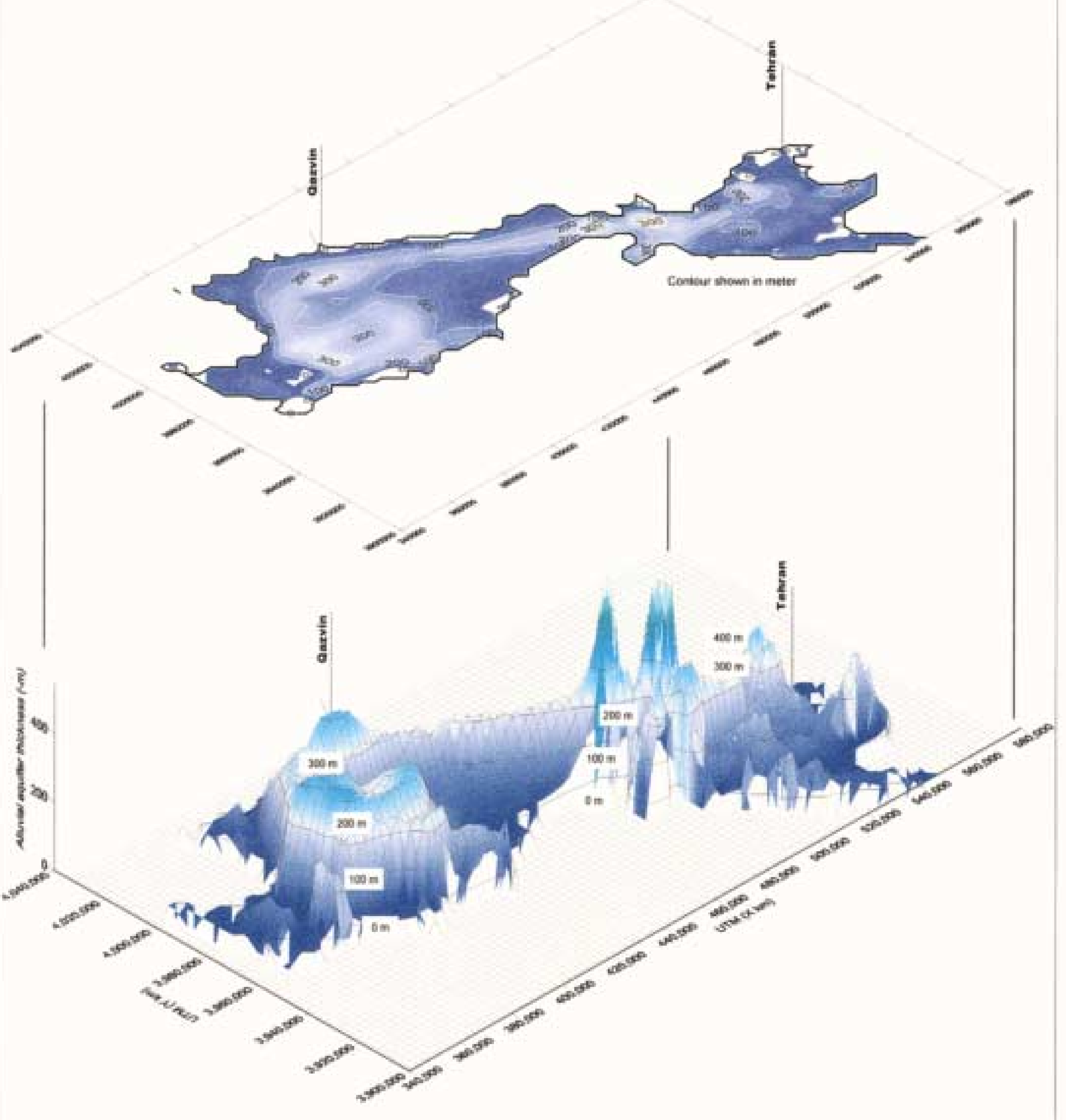
Note: This Map is drawn on the basis of "Water Resources Atalas" made by the "Water Resources Reseach Organization (,Water Affair, Ministory of Energy,1375)".

Figure 3.4.1.2 Alluvial Aquifer Depth



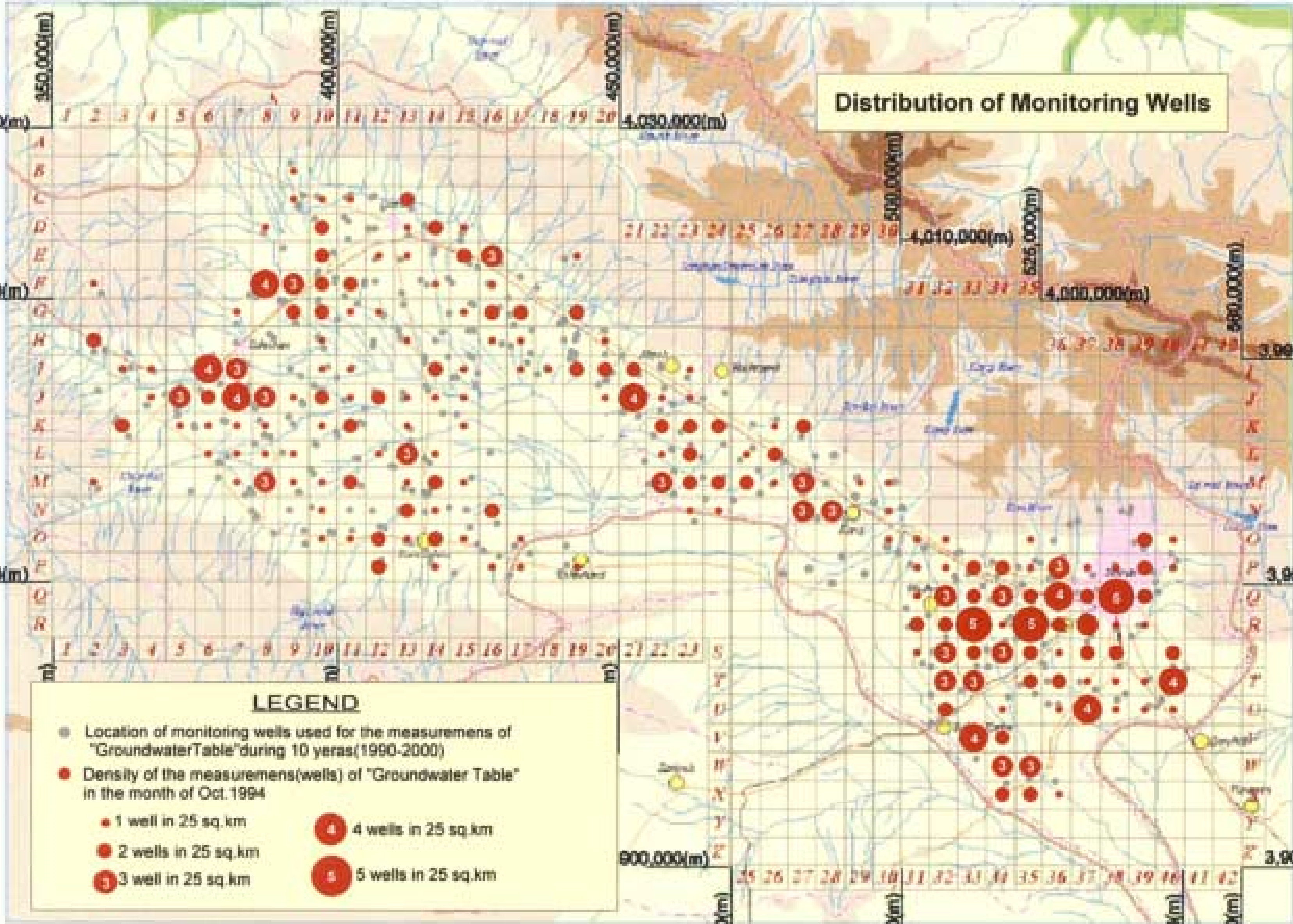
*1 Note: Contours of "Quaternary Aquifer" are delineated form the results of exsisting resistivity-sounding surveys carried out in 1976 and exploration wells. The constituents of "Quaternary Aquifer" however includes older formations consisting of Tertiary layers.

Figure 3.4.1.3 3-D View of Alluvial Aquifer



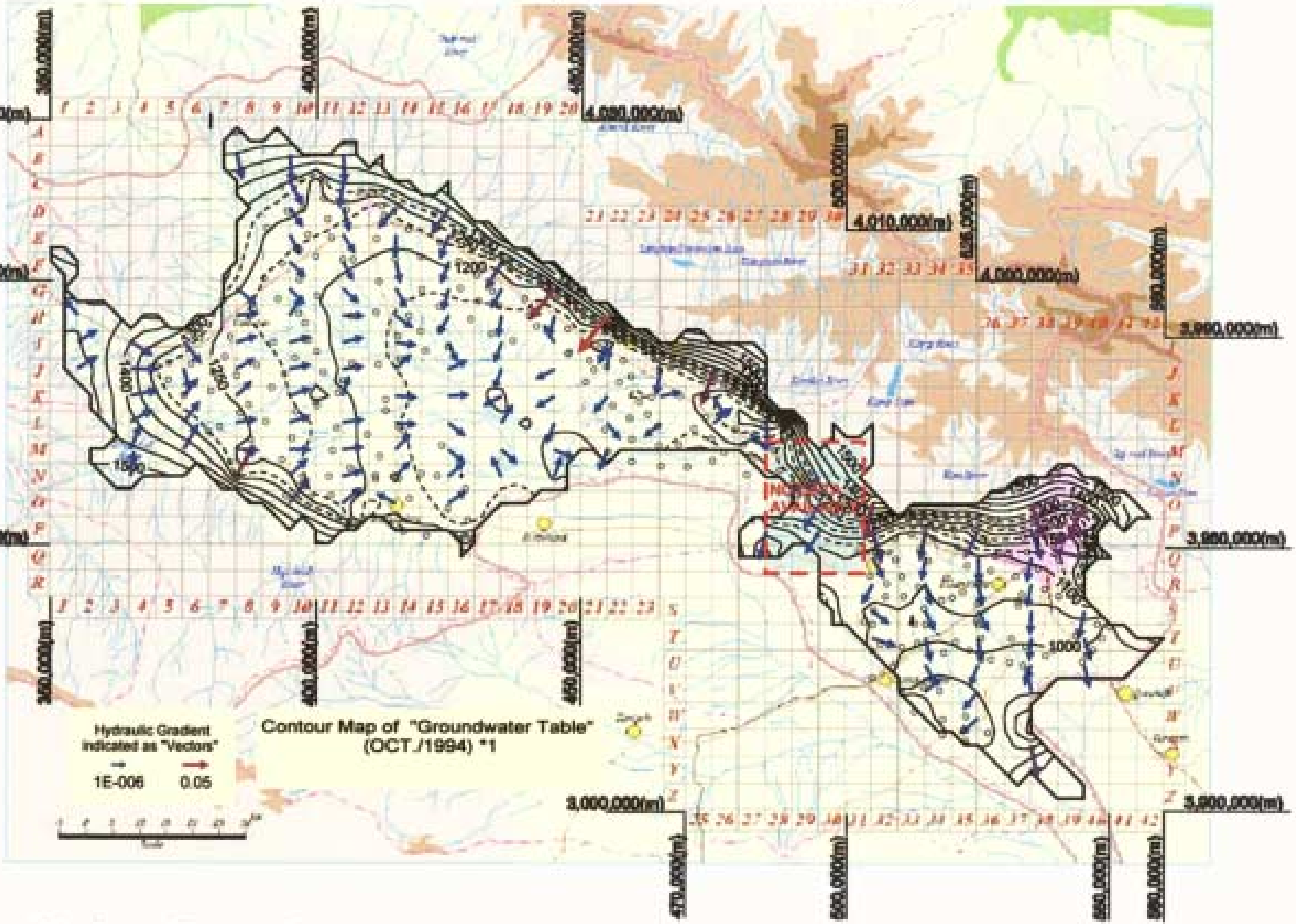
Alluvial Aquifer Thickness Estimated form "Exiting Electrical-Sounding Survey(1976,TRWB)"

Figure 3.4.1.5 Distribution of Monitoring Wells



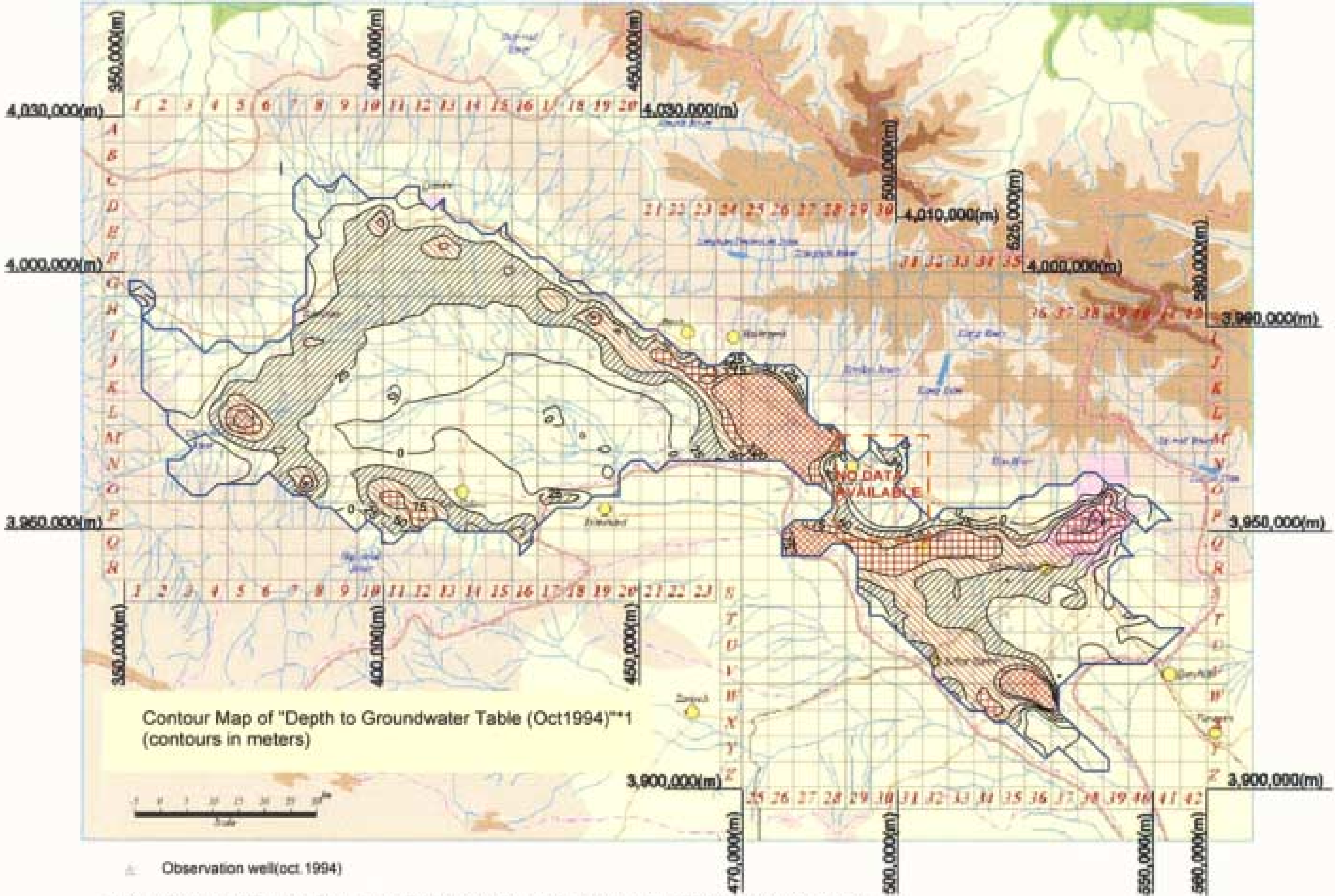
*1 Note: Locations of "Monitoring Wells" are plotted on the basis of the TRWB's observation records of 1990-2000.

Figure 3.4.1.6 Contour of Groundwater Level (October 1994)



*1 Note: Contours of "Groundwater Tabler" are delineated form the TRWB's observation records.
The coverages of "Observation Data" however does not include Karaj area.

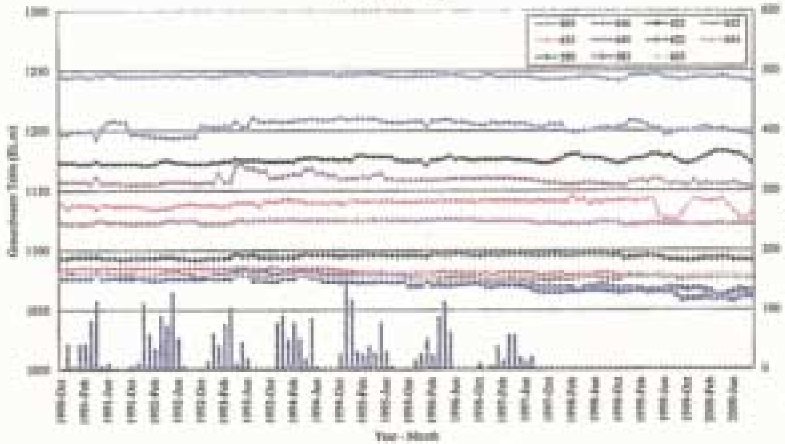
Figure 3.4.1.7 Contour Map of Depth to Groundwater Table



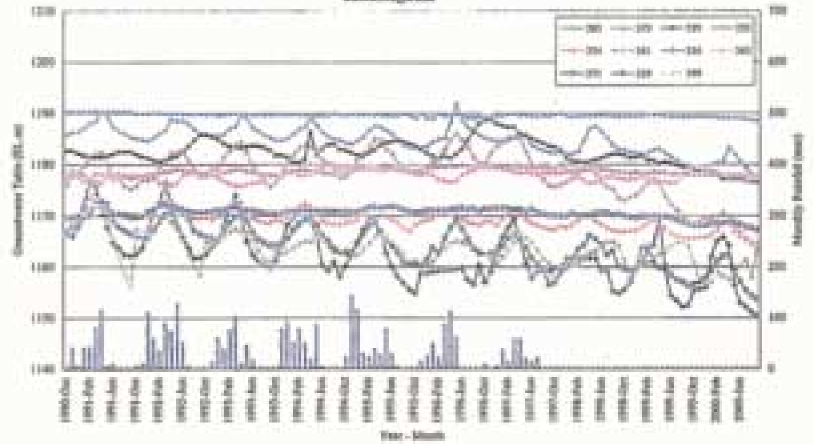
*1 Note: Contours of "Depth to Groundwater Tabler" are delineated form the results of TRWB's observation records
The coverages of data however does not includes Karaj area.

Figure 3.4.1.8 Groundwater Table in TRWB's Observation Wells(Selected wells, Oct.1990 – Sep.2000)

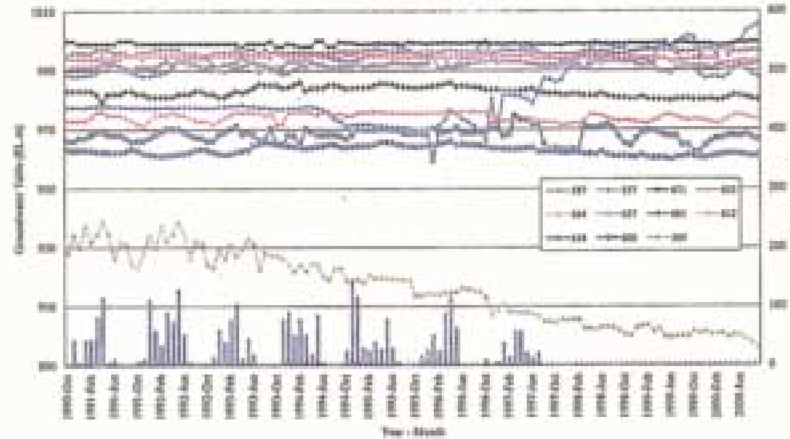
Tehran City



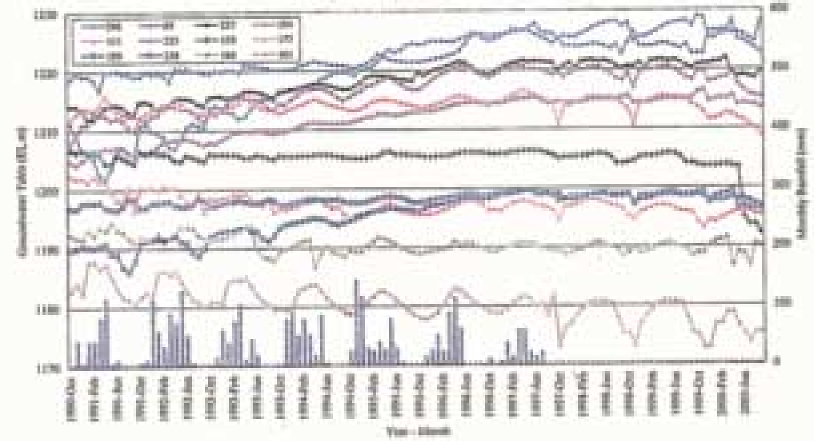
Hashtgerd



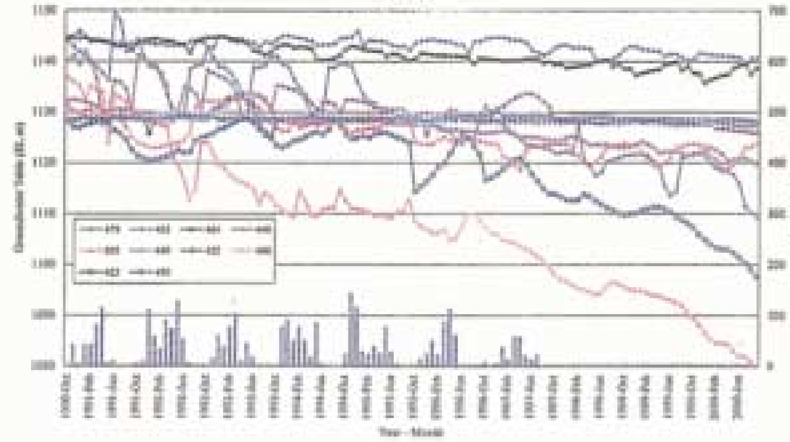
Tehran



Qazvin (north)



Karaj



Qazvin (south)

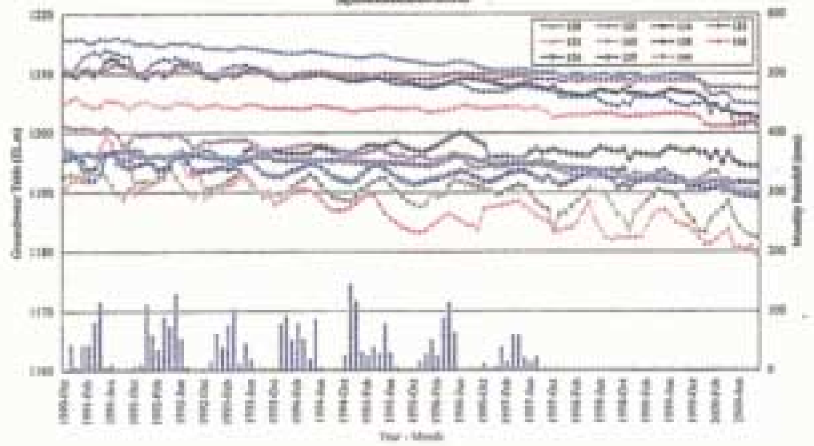
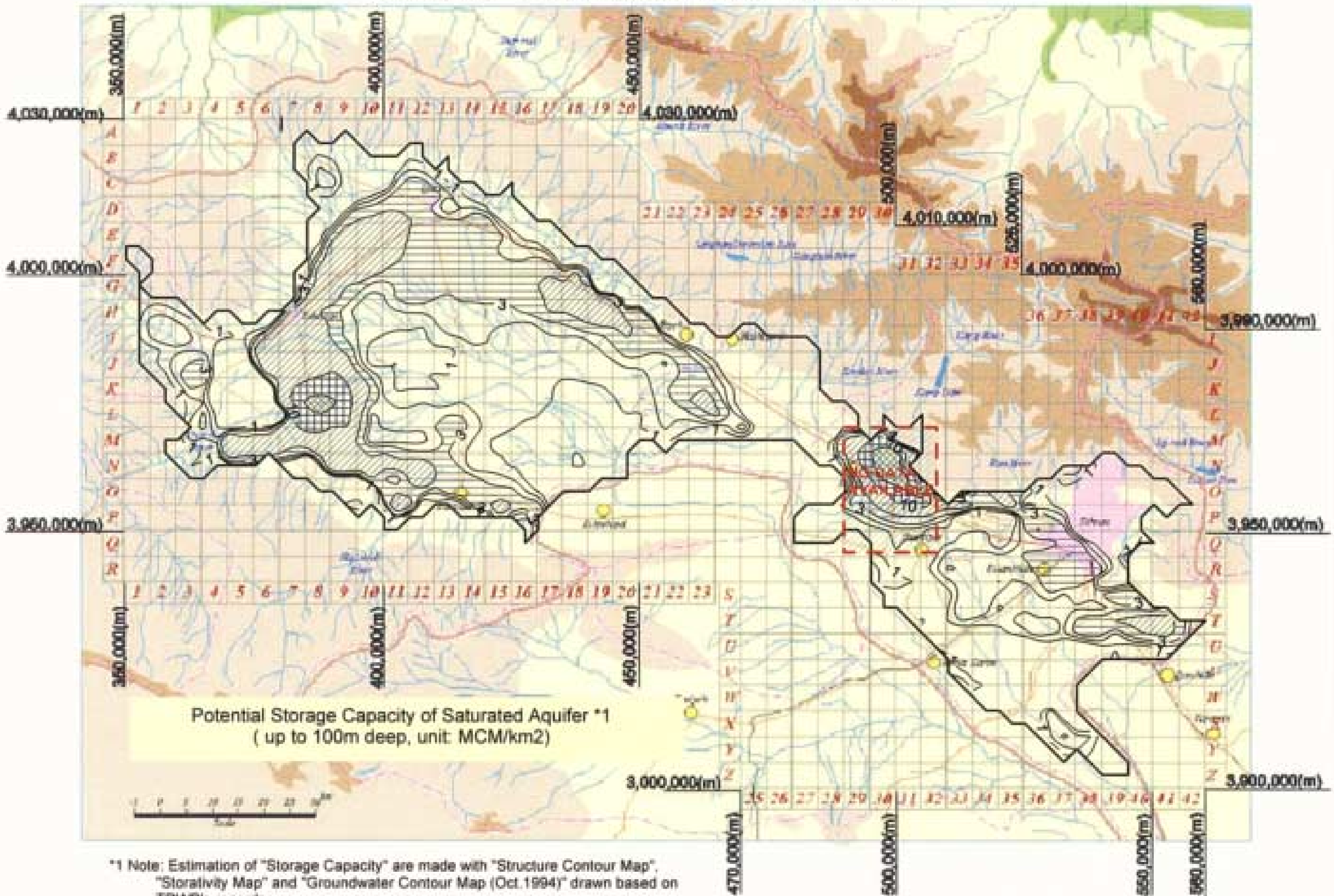


Figure 3.4.2.1 Potential Storage Capacity of Saturated Aquifer



*1 Note: Estimation of "Storage Capacity" are made with "Structure Contour Map", "Storativity Map" and "Groundwater Contour Map (Oct.1994)" drawn based on TRWB's records