Takhtakupyr, Yangibazar, Khazarasp, Bagat, Yangiaryk, Khanka, Gurlen, as well as villages along the pipelines.

However, the system has not been constructed on the western side of Amudarya river located at the down stream end of Amudarya river, where the river water quality is poor, except for a water main from Khodjeili to Kungrad and water mains to the regional centers of Shumanai and Leninabad laid already. The water main from the Tuyamuyun-Nukus water treatment plant to Nukus is under construction. The people in these areas are looking forward to better quality water from the Tuyamuyun System. At Kaparas Reservoir, the intake pump station and one of the two planned conveyance pipelines to Tuyamuyun-Urgench water treatment plant are under construction. Construction of two planned conveyance pipelines to Tuyamuyun-Nukus water treatment plant has not been started yet.

3.5.6 Proposed Treatment Process by Uzbek Side

Process of the Tuyamuyun treatment plants in the second stage is proposed as follows, taking into account the chemical compounds in the raw water of the Amudarya river which might be polluted with agricultural pesticides. In the process, treatment by ozone and activated carbon are included to remove organic substances.

1. Coagulant feeding (Alum)
2. First Coagulo-sedimentation (Radial clarifiers)
3. Second Coagulant feeding (Alum)
4. Second Coagulo-sedimentation (Horizontal flow)
5. Treatment by ozone (ozone reactor)
6. Feeding (sulfuric acid)
7. Rapid sand filter
8. Activated carbon reactor
9. Chlorination (or Chlorammonization)

The proposed process will improve the quality of drinking water. However, some problems still remain, and new ones may arise as explained below.

1. Mineralization and hardness, which are to be removed first, cannot be removed. However the problem of mineralization and total hardness of drinking water can be solved by constructing facilities for filling the Kaparas Reservoir, and taking

water from it, as stated in the chapter 5 and 8 in this report; and constructing canals along the Amudarya river in the Republic of Uzbekistan and the Republic of Turkmenistan for accumulating all the collected drain water. Construction of these facilities is under way, and it is necessary to speed up the completion of these facilities.

2. Ozonized organic substances may adversely affect the health of human beings.

3. It is difficult to control chlorammonization reactions.

Except for these problems, it is necessary and important to pre-treat the raw water up to acceptable quality level for treatment and desalination. Presently, the Tuyamuyun treatment plant is not operating efficiently because the raw water has high turbidity especially in summer, and because of the lack of reagents in some periods. The facilities are also blocked by the sand. Deep treatment and desalinization will be inefficient unless these problems are solved.

3.6 Problems in the Operation and Maintenance of Water Supply Facilities

3.6.1 General

In general, the water treatment plants are operated and maintained in relatively good condition by skilled workers and engineers. Major problems in the operation and maintenance are shortage of treatment materials in some period, especially reagent stocks for the settlement of sludge due to the intake of high turbidity water from Amudarya river in summer.

3.6.2 Tuyamuyun Treatment Plants

The Tuyamuyun-Urgench treatment plant had the following problems: (as of June 1995)

1. In May and June 1995 when the Tuyamuyun Reservoir was being washed, the turbidity of water in the river rose considerably (to 30,000 ppm), which led to blocking of intake canals and radial clarifiers by sludge.

2. Treatment of turbidity at the facilities is not always carried out according to standards due to the irregularity of shipments of coagulants.

3. For the same reason, a large amount of sand settles on the surface of rapid sand filter because sludge has not settled in the first and second sedimentation basins.

4. Exchange and addition of filter materials were not carried out irregularly.

3.6.3 Other Treatment Plants

Other ordinary water treatment plants, except the Tuyamuyun treatment plants, are also operated and maintained in a relatively good condition in spite of the aging of the facilities. These facilities have the same problems as that of the Tuyamuyun plants in maintenance and operation.

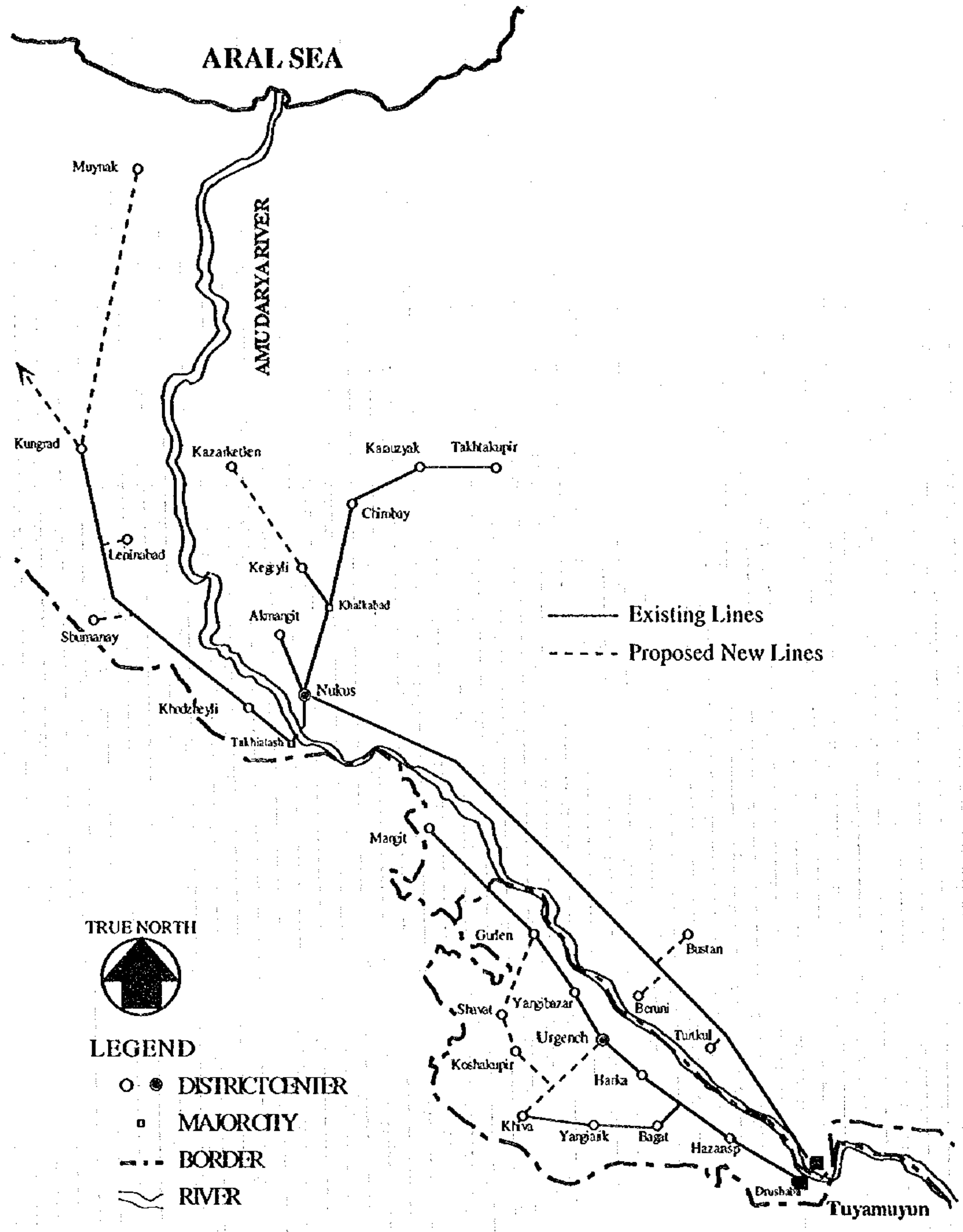


Fig. 3.2 Tuyamuyun Water Supply System

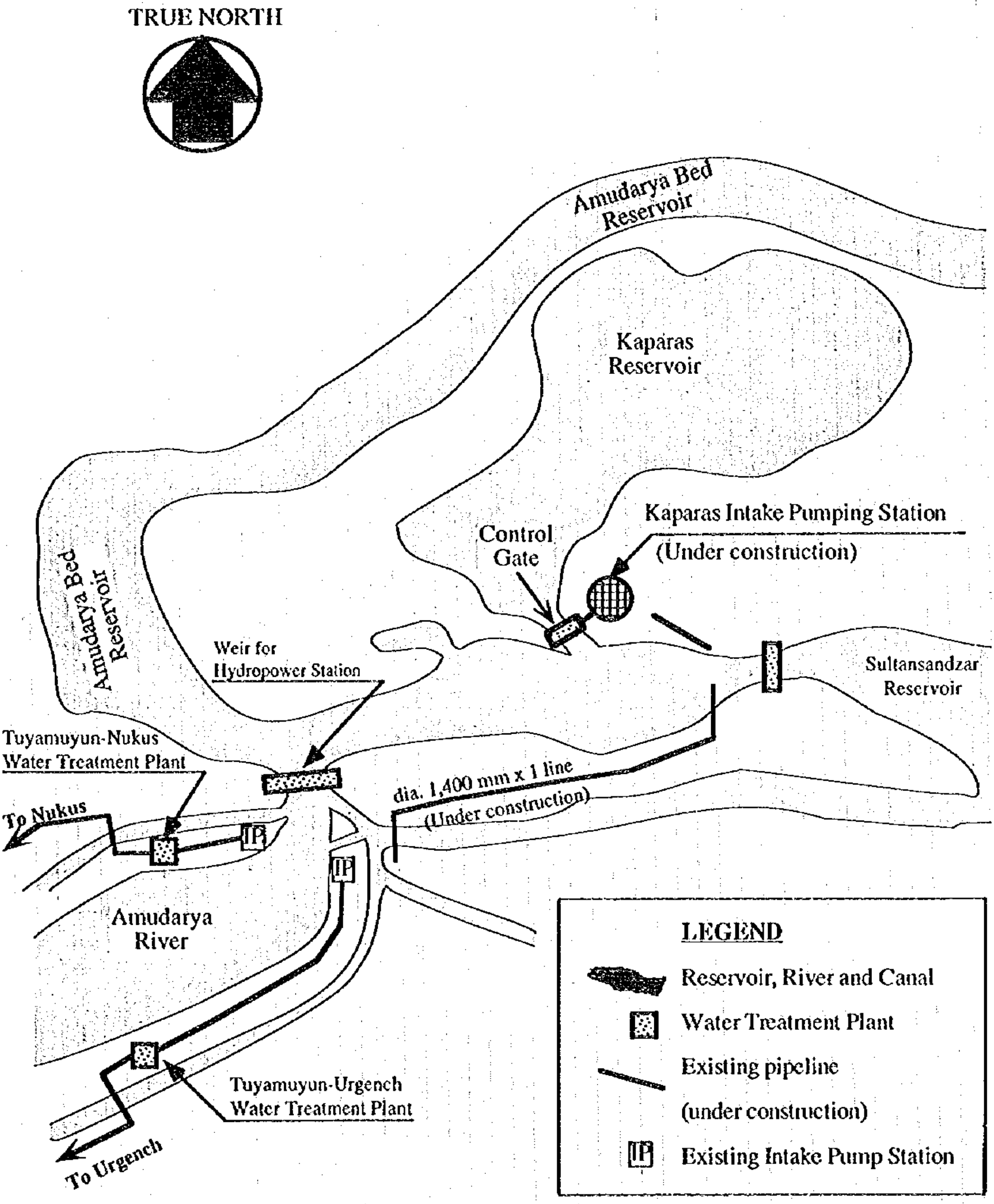


Fig. 3.3 Existing Kaparas Intake Facilities and Tuyamuyun Water Treatment Plants

CHAPTER 4

WATER DEMAND PROJECTION

B/P

CHAPTER 4 WATER DEMAND PROJECTION

4.1 Framework

4.1.1 Basic Concept

Currently, water is being supplied to the six cities in the Study Area by water supply systems owned by the Public Waterworks Corporations (VodoKanal). VodoKanal supplies drinking water from its own water treatment plants and also purchases treated water from the Tuyamuyun water supply system and from the water supply system of the gas supply company, UzTransGas.

The dependence of the major cities of Nukus and Urgench on Tuyamuyun is very high. Kungrad depends on UzTransGas as well as its own water sources for its water supply. Muynak completely depend on its own water source. Chimbai depended on underground water to a large extent until recently, but after the completion of Tuyamuyun pipeline, it largely depends on the Tuyamuyun system. Water is supplied to Khiva from Urgench. In this way, the water source to each city varies depending on the city.

In addition to these six cities, other cities and rural area in the Republic of Karakalpakstan and Khorezm province also use water supplied by the water sources mentioned above.

There are two water supply master plans with the year 2010 as the target year for Karakalpakstan and Khorezm in which the water supply system for the entire region has been planned systematically and rationally. According to the plan, the water supply system for both regions will be integrated with the Tuyamuyun water supply system in future, and many facilities are under construction. Presently, about 60 % of the total water consumption in both regions is covered by the system

In view of this background, in order to improve (qualitatively and quantitatively) the status of water supply to the six cities in the Study Area, improvements are necessary mainly to the Tuyamuyun water supply system. Only studying the status of water supply and demand to the Six Cities is inadequate for carrying out improvements; the status of water supply to all the regions covered by the Tuyamuyun water supply system at present and in the future should be studied. Consequently, a study of the water supply status and demand prediction is necessary not only for the six cities in question but also for the entire region. Subsequently, integration with the water supply master plan, which has the Tuyamuyun system at the nucleus, is to be checked and reviewed.

The current water supply situation and its analysis are presented by region: Karakalpakstan and Khorezm, and by urban and rural water supply for which VodoKanal and Agro-Vodokanal respectively are responsible. However, the analysis of water supply situation is mainly focused on the urban water supply because the JICA Study does not cover rural areas. Regarding the rural water supply, please refer to the water supply project of the World Bank, which is mainly in charge of rural water supply plan in the both regions.

4.1.2 Procedure for Future Water Demand Estimation

Fig. 4.1 shows the flowchart for demand prediction in future. After analyzing the current water supply situation, future demand can be predicted according to this flow chart.

First, future population is projected. Next, the daily average water demand in future for domestic use and non-domestic use (such as water for industries, public utilities and businesses) is separately estimated. By summing up the domestic and non-domestic demand, the daily average water demand in future, excluding leakage is obtained. This demand is called the water for effective use (effective water demand). By adding the leakage (non-effective water demand), the daily average water demand is obtained. Subsequently, the maximum daily water demand is calculated by multiplying the daily average water demand with the maximum daily variation coefficient. The maximum hourly water demand is calculated by multiplying the maximum daily water demand by hourly maximum variation coefficient and dividing by 24.

4.2 Service Population

4.2.1 Total Population

(1) Current Population

The current population is shown in Tables 4.1- (a) and 4.1-(b). The total population of Karakalpakstan is about 1,400,000 and about half of this population resides in the cities. The population in the four cities of Karakalpakstan in the Study Area is 331,000. This figure accounts for approximately half of the total urban population of 675,000.

Nukus city council accounts for nearly 70% of this population in the Study cities of Karakalpakstan.

The total population of Khorezm is 1,170,000. The urban population accounts for 20% of this figure, which is quite small compared with Karakalpakstan. The population in the two Study cities of Khorezm is about 180,000; this is for 60% of the urban population.

Most of the urban population in these two regions resides in small cities with a population of less than 100,000. Only Nukus and Urgench, the main cities in these two regions, have populations of more than 100,000. The population of these two cities account for more than 70% of the total population of the six cities.

Table 4.1-(a) Total Population of Karakalpakstan in 1994

as of Jan. 1st 1994 (Unit: thousand)

	Six Cities					Karakalpakstan		
	Nukus	Chimbai	Kungrad	Muynak	total	Urban	Rural	total
Population	229.5	31.8	56.0	13.6	331.0	675.8	716.7	1,392.6

Source: VodoKanal of Karakalpakstan
Note: Population of city councils given for Nukus and Kungrad.

Table 4.1-(b) Total Population of Khorezm in 1994

as of Jan. 1st 1994 (Unit : thousand)

	Six Cities			Khorezm		
	Urgench	Khiva	total	Urban	Rural	total
Population	135.6	45.0	180.6	294.2	875.3	1,169.5

Source: Main Department of oblprognozstat (oblast prognostication & statistics)

(2) Past Population Trend

The past populations and their growth rates in Karakalpakstan and Khorezm are shown in Table 4.2 (a) and (b). In general, the past population in each region apparently shows a decreasing trend. This is shown in table 4.3, which also shows the average yearly growth rate for 5 years from 1985.

Table 4.2-(a) Past Total Population in Karakalpakstan

	Urban		Rural		Total	
	Population thousand	Growth rate %	Population thousand	Growth rate %	Population thousand	Growth rate %
1985	500.3	5.4	589.3	1.1	1,089.6	3.1
1986	527.2	3.3	595.7	2.1	1,122.9	2.7
1987	544.5	4.4	608.4	1.4	1,152.9	2.8
1988	568.5	2.7	616.7	2.2	1,185.2	2.4
1989	583.7	2.8	630.1	2.2	1,213.8	2.5
1990	599.8	2.4	644.9	2.2	1,244.7	2.3
1991	614.4	3.3	659.4	2.5	1,273.8	2.9
1992	634.7	3.1	676.0	1.8	1,310.7	2.4
1993	654.4	2.0	688.4	2.3	1,342.8	2.1
1994	667.7	1.5	703.9	2.1	1,371.6	1.8
1995	677.9		718.8		1,396.7	

Source: SCFS

Table 4.2-(b) Past Total Population in Khorezm

	Urban		Rural		Total	
	Population thousand	Growth rate %	Population thousand	Growth rate %	Population thousand	Growth rate %
1986	-		-		919.3	2.9
1987	-		-		946.4	2.9
1988	-		-		973.7	4.2
1989	-		-		1,015.0	2.4
1990	294	2.4	745	3.1	1,039	2.9
1991	301	4.3	768	2.3	1,069	2.9
1992	314	1.6	786	3.9	1,100	3.3
1993	319	2.2	817	3.3	1,136	3.0
1994	326	1.8	844	2.6	1,170	2.4
1995	332		866		1,198	

Source: SCFS

Table 4.3 Average Yearly Population Growth Rate at 5 Years Intervals

(unit : %)

	Karakalpakstan			Khorezm		
	Urban	Rural	Total	Urban	Rural	Total
1985 - 1990	3.7	1.8	2.7	-	-	3.1
1990 - 1995	2.5	2.2	2.3	2.5	3.1	2.9

calculated by the JICA Study Team

4.2.2 Service Population

VodoKanal, which is responsible for supplying water to urban area, supplies treated water to 32 cities, towns and regional centers including the Six Cities in the Study. The cities to which water is supplied, and total population and total service population in Karakalpakstan and Khorezm are shown in table 4.4-(a) and -(b) respectively.

Table 4.4-(a) Total Population and Service Population in 1994 for Urban Water Supply in Karakalpakstan

City, Town, Regional Center	Total Population	Service Population of VodoKanal		Except for VodoKanal	Total	
	thousand	thousand	%	thousand	thousand	%
Nukus	229.5	176.2	76.8	2.5	178.7	77.9
Beruni	44.6	31.8	71.4		31.8	71.4
Kungrad	33.2	24.8	74.6	6.0	30.8	92.7
Khodjeili	70.5	36.3	51.5	14.5	50.8	72.0
Takhiatash	49.3	45.2	91.8	2.3	47.5	96.4
Turtkul	44.8	33.7	75.3		33.7	75.3
Chimbai	31.8	25.1	78.8		25.1	78.8
Mangit	27.2	18.0	66.1		18.0	66.1
Kazanketken	3.6	3.3	91.0		3.3	91.0
Karauzyak	12.9	9.4	74.7		9.4	74.7
Kegeili	12.8	9.4	73.2		9.4	73.2
Kanlykol	9.0	7.4	82.7		7.4	82.7
Muynak	13.6	12.6	92.3		12.6	92.3
Akmangit	7.5	5.6	74.8		5.6	74.8
Takhtakupyr	16.8	10.7	63.8		10.7	63.8
Shumanai	12.5	8.8	70.6		8.8	70.6
Bustan	10.9	1.7	15.6		1.7	15.6
Altynkul	22.7	20.3	89.2		20.3	89.2
Khalkabad	10.9	6.5	59.7		6.5	59.7
total	663.7	486.8	73.3	25.3	512.1	77.2

Source: VodoKanal of Karakalpakstan

Table 4.4-(b) Total Population and Service Population in 1994 for Urban Water Supply in Khorezm

City, Town, Regional Center	Total Population thousand	Service Population thousand	%
Urgench	137.1	135.0	98.5
Khiva	45.4	44.0	96.9
Druzhba	14.9	14.1	94.6
Bagat	7.8	4.9	62.8
Gurlen	19.4	13.4	69.1
Koshkupyr	14.7	11.2	76.2
Urgench(Karaul)	14.5	12.8	88.3
Khazarasp	14.5	11.8	81.4
Khanka	28.7	21.4	74.6
Shavat	13.5	12.5	92.6
Yangiaryk	9.5	3.1	32.6
Yangibazar	5.2	2.4	46.2
Buston	5.3	1.5	28.3
Total	330.5	288.1	87.2

Source: VodoKanal of Khorezm

With regard to the population served by VodoKanal in the two regions, Nukus and Urgench occupy a large portion of the total population of each region, with a share of approximately 36% and 41% respectively of the total served population in each region. The total water supply percentages for the two regions are: 77% for Karakalpakstan and 87% for Khorezm. The percentage of the latter is higher by 10%. Considering percentages by city, excluding the particularly low percentages for Bustan, Chalish Settlement, Yangiaryk and Yangibazar, the percentage for all the other cities exceeds 60%.

The water supply percentage for all the Six Study Cities exceeds 70%, and the figure for Kungrad, Muynak, Urgench and Khiva exceeds 90%. The population of the Six Study Cities in Karakalpakstan and Khorezm served by public water supply is 50% and 62% of the total served population respectively.

4.3 Water Consumption for Urban Water Supply

4.3.1 Type of Water Consumer

Water consumption for both Karakalpakstan and Khorezm is categorized into three groups: First group, Second group and Third group for the purpose of collecting water charges.

- Group (1): The Residents (basically without an individual water meter).

- Group (2): Budgetary Institutions, Self-Sufficient Sanatoria and Health Resorts, Medical and Sanitation Institutions, Public Dietary Enterprises, Municipal and Public Services Enterprises, Collective Farms and State Farms (partly with a water meter).
  More detail as per Table 7.5.
- Group (3): Industrial, Construction, Commercial and other Enterprises, Organizations and Establishments (with water meters in general).

4.3.2 Water Consumption Recorded by VodoKanal

The actual delivered water quantity and sold water quantity by group from 1990 to 1995 recorded by VodoKanal are shown in table 4.5-(a) and -(b).

Table 4.5-(a) Water Consumption Records for Urban Water Supply in Karakalpakstan

Year	Total Pop.	Service Population		Actual Delivered		Sold Water Quantity		Group (1)		Group (2)		Group (3)		Effectiveness
	ths.	ths.	%	mld	lcd	mld	lcd	mld	lcd	mld	lcd	mld	lcd	%
90	594	435.8	73	162	273	153.1	258	40.4	93	70.3	118	42.4	71	95
91	609	454.1	75	163	268	154.4	254	32.3	71	82.7	136	39.4	65	95
92	612	469.7	77	185	302	159.9	261	40.6	86	86.9	142	32.4	53	86
93	640	497.2	78	181	237	156.2	244	56.6	114	71.3	111	28.3	44	86
94	618	483.6	78	189	306	147.5	239	61.2	127	61.8	100	24.4	39	78
95	660	512.1	78	180	273	157.1	238	72.3	141	60.5	92	24.2	37	87

mld: million liters per day = thousand m^3 per day
lcd: liter capita per day
Effectiveness: Sold water / Actual supply
Source : VodoKanal Karakalpakstan

Table 4.5-(b) Water Consumption Records for Urban Water Supply in Khorezm

Year	Total Pop.	Service Population		Actual Delivered		Sold Water		Group (1)		Group (2)		Group (3)		Effectiveness
	ths.	ths.	%	mld	lcd	mld	lcd	mld	lcd	mld	lcd	mld	lcd	%
90	339	270	80	177.8	524	157.8	465	41.8	155	91.0	268	25.0	74	88.8
91	333	285	86	189.5	569	175.3	526	44.7	157	72.7	206	58.0	174	92.5
92	363	285	78	219.8	605	182.4	502	59.4	208	99.3	274	23.7	65	83.0
93	319	264	83	195.0	611	176.0	552	67.2	255	53.3	167	55.5	174	90.3
94	321	291	91	201.2	627	183.0	570	74.7	257	64.4	201	44.0	137	91.0
95	331	303	92	199.2	602	183.3	554	73.8	254	47.4	143	42.7	129	92.0

mld: million liters per day = thousand m^3 per day
lcd: liter capita per day
Effectiveness: Sold water / Actual supply
Source : VodoKanal Khorezm

Not all the water consumed by groups in both regions is measured by water meters. Besides water meters, a norm per capita consumption or water consumption according to the diameter of service pipe is applied to the estimated water consumption. Therefore, water consumption recorded by VodoKanal is not necessarily the actual consumption. Moreover, the effectiveness in the tables show a considerably high percentage of about 90 %. Taking into consideration the existing water supply condition, especially large leakage quantity as stated in the latter section, the figures are not necessarily realistic.

Therefore, a survey of the actual water consumption, especially domestic consumption is necessary.

4.3.3 Water Consumption of Group (1) (Domestic)

The quantity of usage of water for domestic use in both regions is not measured by water meters. Instead, a norm per capita consumption is determined beforehand according to supply methods such as standpipe, yard tap and house connection, and the lifestyle of the consumer, and water charges are collected based on the norm consumption. In order to estimate the actual per capita consumption accurately, the JICA Study Team have installed about 150 water meters in various households and flats.

Besides the normal domestic consumption, the quantity used for watering gardens is considerable in the Study area. Consequently, domestic use is analyzed by dividing into three categories; water for gardens, water for daily life and water for other purposes such as for domestic animals and car washing.

(1) Norm Consumption

The norm consumption for domestic use for both regions according to supply method and lifestyle is shown in table 4.6-(a) and -(b). According to the norm consumption, consumption per square meter of domestic garden area for gardens is given only for 6 months and 7 months, namely for garden irrigation season, in Karakalpakstan and Khorezm, respectively. For other applications, per head consumption for domestic animals and per vehicle consumption for vehicle are given.

Table 4.6-(a) Norm Consumption in Karakalpakstan

Symbol	Water user type		Norm consumption: Daily life m³/ca/month	Garden l/m²/day	Cattle m³/head/year	Sheep m³/head/year
A	Non-sewerage	stand pipe outside	1.24	50	40.1	9.0
B		yard tap	2.3			
C		water tap (in the house)	3.0			
D		water tap, toilet	4.5			
E		sink, bath/shower, water heater	5.3			
F		sink, bath/shower, water heater, toilet	6.8			
G	With-sewerage	sink	3.5			
H		sink, toilet	4.4			
I		sink, bath/shower, water heater	6.1			
J		sink, bath/shower, water heater, toilet	7.0			
K		hot water service	8.1			
K'		hot water service *1)	10.53			

Source : VodoKanal Karakalpakstan
Note: 1) for sewerage tariff

Table 4.6-(b) Norm Consumption in Khorezm

same symbols in table 4.5-(a)	Water user type		Daily life m³/month	Garden m³/month/m²	Cars m³/day	Animals m³/ca./day
A	Non-sewerage	stand pipe outside	1.5	3.2	0.25	0.012
B		yard tap	3.0			
C		water tap in the house	4.2			
E		sink, bath/shower, water heater	6.9			
J	With-sewerage	sink, bath/shower, water heater, toilet	7.5			
K		hot water service	10.5			

Source : VodoKanal Khorezm
Note: For meanings of symbols A,B,C,... refer to the Table 4.6-(a)

(2) Per Capita Consumption in Japan

For reference and for future projection of per capita consumption, the per capita consumption by equipment using water in a house in Japan in 1995 is shown in table 4.7.

Table 4.7 Per Capita Consumption by equipment using water in Japan in 1995

Water-use equipment	lcd or l/car/d	Remarks
Kitchen	26.4	148 l/connection 5.6 persons/connection
Washing	33.8	189 l/connection 5.6 persons/connection
Cleaning	2.7	15 l/connection 5.6 persons/connection
Washroom	20.0	
Manual toilet	5.0	
Flash toilet	40.0	
Bathing	30.0	
Car washing	10.0	300 l/car/month

(3) Results of Actual Water Consumption by JICA Study Team

During this field study, data of water meter reading from November 1994 to August 1995 was collected for four cities in Karakalpakstan. In Karakalpakstan, the number of water meters installed last year was 99 with the following breakdown: Nukus (37), Chimbai (18), Kungrad (26), and Muynak (18). However, due to breakdown of meters and non-cooperation in the reading of water meters, the number of meters actually in operation as of date is 77, which is 78% of the total, and the breakdown is as follows: Nukus (18), Chimbai (18), Kungrad (23), Muynak (18).

Based on the data of the meter readings by JICA Study Team for the four cities in Karakalpakstan, the monthly average per capita consumption (hereafter referred to as "Meter per capita consumption") for living use by consumer type and the per square meter consumption for garden watering were estimated. The results are shown in table 4.8.

Table 4.8 Meter Per Capita Consumption by Consumer Typer Garden Area (m²) Consumption for Garden Watering

Consumer type	1994 Dec.	1995 Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.
Daily life use per month (m^3/ca./month)									
B	-	0.48	0.85	0.73	1.19	1.48	1.43	1.61	1.61
C	-	0.94	1.50	1.63	2.10	2.53	2.56	2.95	2.71
E	-	1.22	1.22	1.56	2.15	2.56	2.81	3.48	2.85
J	1.23	1.62	2.31	2.15	2.65	2.95	2.50	3.00	3.15
K	1.8	2.0	2.5	3.5	3.8	4.8	5.3	5.0	4.5
Garden watering per month (m^3/m^2/month)									
	0.10	0.27	0.98	1.00	1.52	1.00	1.22	1.20	1.30
Daily life use per day (l/ca./day)									
B	-	16	28	24	40	49	48	54	54
C	-	31	50	54	70	84	85	98	90
E	-	41	41	52	72	85	94	116	95
J	41	54	77	72	88	98	83	100	105
K	60	67	83	117	127	160	177	167	150
Garden watering per day (l/m^2/day)									
	3	9	33	33	51	33	41	40	43

Source: JICA Study
Note: For meanings of symbols A,B,C,... refer to Table 4.6-(a)

Analysis of the monthly variation in actually delivered water quantity to Nukus and Kungrad, and in the total delivered water quantity by VodoKanal of Karakalpakstan, showed that the water consumption quantity in May or June was the average for the year. Therefore, for the daily life water consumption, the meter per capita consumption (average for June and May) was taken as the annual average. For the water consumption for gardens, the average meter consumption per square meter for May to August, was taken as annual average for the gardening seasons.

(3) Comparison of Per Capita Consumption

The results are shown together with the Norm consumption in Table 4.9.

Table 4.9 Comparison of Per Capita Consumption
- Annual average -

Consumer Type	Norm KKP	Norm Khorezm	Meter KKP	Japan in 1995
Living Use (unit : l/ca./day)				
Non-sewerage service				
A Street Hydrant(Stand Pipe)	41	50		
B Yard Hydrant & Tap	77	100	49	
C Room Tap	100	140	85	
D Room Taps, Toilet	150			135
E Internal Water pipe, Sink, Bath, Water Heater	177	230	90	125
F E + Toilet	227			130
Sewerage Service				
G Sink	117			
H Sink, Toilet	147			
I Sink, Bath/shower, Water heater	203			
J Internal Water pipe, Sink, Bath, Water Heater	233	250	91	165
K Internal Water pipe, Sink, Bath, Centralized WH	270(351)	350	169	
Non-Living Use				
Vehicle Washing (l/car/day)	19	17	-	33
Domestic Animals (l/head/day)	25 - 110	12	-	25 - 60
Garden irrigation (l/m²/day)	50	107	39	

Note: (351) : consumer using sewerage.
Per capita consumption in Japan is estimated from water consumption by facility.
For meanings of symbols A,B,C,... refer to table 4.6-(a)

Meters were installed for user types B, C, E, J and K. The existence of cars and domestic animals did not have an appreciable effect on the consumption quantity; therefore, these quantities were not calculated. We believe that these quantities are very small and they can be ignored.

Comparing the meter consumption and the norm consumption for Karakalpakstan, it is observed that the meter consumption is less than the norm consumption for all consumer types.

The norm consumption for watering gardens is used for 6 and 7 months in the garden irrigation season in Karakalpakstan and Khorezm, respectively. It was observed that the meter consumption for watering gardens started from February as shown in Table 4.8. Average meter consumption for garden watering is estimated as 39l/m^2/day, by taking average during February and August.

(4) Population by Domestic Consumer Type

Percentages of the service population by domestic consumer registered in VodoKanal are shown in table 4.10-(a) (Karakalpakstan) and 4.10-(b)(Khorezm). A large number of yard taps (65%) still exist in Karakalpakstan. On the other hand, in Khorezm, flats account for 44 % and yard taps account for only 10 %. Water supply conditions vary depending of the city. For instance:

- in the regional centers; Nukus and Urgench, sewerage service rate is high
- in Kegeili and Takhtakupyr in Karakalpakstan, the percentage of stand pipes exceeds 50 %, followed by Kazanketken(46.4%) and Nukus(45.5%)
- in Karauzyak, the percentage of yard taps is 100 %

In general, the water supply standard of Karakalpakstan is lower than that of Khorezm.

Table 4.10-(a) Percentage of Population by Domestic Consumer Type in Karakalpakstan in 1995

(unit : %)

City name	Non- sewerage						Sewerage	
	Stand pipe	Yard tap	Sink, No bath	Sink, Bath,	Bath, Sink, Water heater	Sink, Bath, Water heater, Toilet	Sink, Bath, Water heater	Sink, Bath, Hot water service
	A	B	C	D	E	F	J	K
Nukus	1.4	45.7	15.6	0.0	3.0	1.5	26.2	6.6
Takhiatash	4.0	87.8	6.0	0.0	2.2	0.0	0.0	0.0
Turtkul	3.2	79.1	17.7	0.0	0.0	0.0	0.0	0.0
Muynak	45.5	52.7	1.8	0.0	0.0	0.0	0.0	0.0
Khodjeili	4.9	88.0	7.1	0.0	0.0	0.0	0.0	0.0
Beruni	15.9	81.3	2.8	0.0	0.0	0.0	0.0	0.0
Chimbai	17.2	82.1	0.7	0.0	0.0	0.0	0.0	0.0
Mangit	9.3	89.3	1.2	0.0	0.2	0.0	0.0	0.0
Shumanai	7.9	92.1	0.0	0.0	0.0	0.0	0.0	0.0
Kungrad	4.6	85.2	8.6	0.0	1.2	0.4	0.0	0.0
Kegeili	69.1	30.9	0.0	0.0	0.0	0.0	0.0	0.0
Akmangit	37.8	62.2	0.0	0.0	0.0	0.0	0.0	0.0
Karauzyak	0.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0
Takhtakupyr	50.7	49.3	0.0	0.0	0.0	0.0	0.0	0.0
Kanlykol	19.7	80.3	0.0	0.0	0.0	0.0	0.0	0.0
Kazanketken	46.4	38.7	14.9	0.0	0.0	0.0	0.0	0.0
Bustan	14.0	86.0	0.0	0.0	0.0	0.0	0.0	0.0
total	9.2	65.2	9.8	0.0	1.5	0.7	10.9	2.7

Source : VodoKanal of Nukus Note: For meaning of symbols A,B,C,... refer to Table 4.6-(a)

Table 4.10-(b) Percentage of Population by Domestic Consumer Type in Khorezm in 1995

(unit : %)

	Supplied by VodoKanal					Departmen -tal supply
	Stand pipe	Yard Tap	Flat	Bath Houses	Sewerage	
	A	B	C	E	J, K	E, J, K
Urgench	0.0	0.0	34.0	14.0	39.4	12.6
Khiva	1.8	29.4	36.9	4.7	21.3	5.9
Druzhba	4.6	10.0	36.4	12.2	36.8	0.0
Khanka	4.0	40.9	51.8	3.3	0.0	0.0
Khazarasp	2.4	17.7	75.4	4.5	0.0	0.0
Shavat	0.1	0.2	87.5	12.2	0.0	0.0
Gurlen	14.2	29.2	54.7	1.9	0.0	0.0
Karaul	0.0	0.0	83.1	2.4	14.5	0.0
Koshkupyr	25.1	9.6	38.1	6.7	0.0	20.5
Bagat	17.8	13.4	66.9	1.9	0.0	0.0
Yangiaryk	6.3	0.0	51.1	12.8	0.0	29.8
Yangibazar	0.0	0.0	99.0	1.0	0.0	0.0
total	2.9	10.8	44.3	9.5	24.5	8.0

Source : VodoKanal of Urgench

Note: Departmental supply means that water supply system is covered by other than VodoKanal.
For meaning of symbols A,B,C,... refer to Table 4.6-(a)

(5) Estimated Water Consumption

Water consumption is estimated based on Norm and Meter per capita consumption. The results of estimated domestic water consumption by living, garden watering and other uses, using service population by consumer type in 1995, are shown in table 4.11-(a) and -(b) respectively.

Table 4.11-(a) Estimated Domestic Water Consumption by Per Capita Consumption in Karakalpakstan

	Based on Norm consumption			Based on Meter consumption		
	Total consump.	Average per capita consumption		Total consump.	Average per capita consumption	
	mld	l/ca./day	%	mld	l/ca./day	%
Living	37.8	101	41.4	22.7	60.5	35.9
Garden	52.0	139	57.0	40.6	108	64.1
Others	1.4	4	1.6	-	-	
Total	91.2	244	100.0	63.3	168.5	100.0

Table 4.11-(b) Estimated Domestic Water Consumption by Per Capita Consumption in Khorezm

	Based on Norm consumption			Based on Meter consumption		
	Total consump.	Average per capita consumption		Total consump.	Average per capita consumption	
	mld	l/ca./day	%	mld	l/ca./day	%
Living	50.2	176	44.7	25.5	89	40.6
Garden	58.8	206	52.3	37.2	130	59.4
Others	3.3	12	3.0	-	-	
Total	112.3	394	100.0	62.7	219	100.0

The average per capita consumption for watering gardens in each region exceeds 50% of the total domestic consumption for both Norm and Meter per capita consumption. The consumption of such a large quantity of treated water for gardens, which does not need a quality equal to that of drinking water, is a waste of precious resources; improvements in the use of water in domestic households are necessary.

4.3.4 Water Consumption for Group(1) and Group(2)

Non-domestic water consumers are categorized into Group(1) and Group(2) consumers. In contrast to domestic consumption, no norm consumption is set for consumers of these groups. Meter readings and values of water consumption negotiated with VodoKanal are used. Meter readings and negotiated consumption accounted for about 40 % and 60% in 1995. For determining the negotiated water consumption, the bore diameter and the following formula is used:

$$Q = S \times t \times v \ (m^3)$$

Q : negotiated water consumption (m^3)
S : sectional area of connection pipe (m^2)
t : time (sec)
v : velocity (m/sec); the value 1.5 is normally used.

In general, the negotiated consumption quantity tends to be higher than the real consumption, therefore consumers are trying to install water meters at their own expenses in recent years.

The water consumption for the Group(1) and Group(2) have been decreasing in recent years since the water tariff for these groups increases year after year.

4.3.5 Leakage

In this Study, detailed investigations on leakage quantity are not included. Consequently, leakage quantity has been estimated from available data. The estimation method is described below; the calculations are shown in Table 4.14. From this table, it is observed that the rate of water leakage from 12 noon, June 7, 1995, to 12 noon the next day is 33,960 m^3/day. The ratio of leakage as a percentage of the total supply quantity was estimated as 30%. This figure includes water that has been wasted; since calculations have been made assuming that no water is consumed late at night when the consumption is minimum, the estimate may be slightly on the higher side. However, considering that approximately 30 years have elapsed since the pipes were laid, this is a reasonable figure.

The percentage of water leakage varies depending on the annual water supply variation and the location. Since these coefficients are not constant throughout the year, the average values of leakage quantity and supply pressures for June were assumed, and 30% was taken as the annual average water leakage.

Estimation Method

The leakage was estimated using the daily variations in quantity of water delivered from the Nukus Treatment Plant (measured by the JICA Study Team: June 7-8, 1995, the pumping head (28 m) and the assumptions given below.

i) Equation for estimating leakage water quantity

$$V = (P/Po)^n \times Vo$$

where;

n=1.15 (constant for orifice hole)
Vo(m^3/s): Water quantity at night when flow is minimum (observed)
V(m^3/s) : Calculated water quantity
Po: Service pressure at night when flow is minimum (estimated)
P : Service pressure (assumed)

ii) Assumptions

- No water is consumed at late nights or early mornings when water flow from the treatment plant is minimum.
- Leakage quantity includes wasted water (leakage from service taps etc.).
- Water supply pressures in the city are classified into 3 patterns based on the quantity of delivered water from the Nukus Water Treatment Plant (5 m, 15 m, and 25 m water head)

Table 4.12 Estimation of Leakage Quantity and Ratio

as of June 7th to 8th, 1995

service pressure (head)	Duration times	Duration hours	Leakage		Leakage ratio
			velocity	total quantity	
(m)	(from - to)	(hours)	(m^3/s)	(m^3)	(%)
5	8 - 15 (day time)	7	0.10	2,520	
15	15 - 23, 6 - 8	10	0.36	12,960	
25	23 - 6 (night time)	7	0.73	18,480	
total		24		33,960	31
Total delivered water quantity in a day				107,570	

Table 4.13 Delivered Water Quantity Measured by JICA Study Team

Date	Measured Time			Total Vol. (m^3)	Section Vol. (m^3)	Remark
June/9/1995	15:00	~	16:00	5,140	5,140	
	16:00	~	17:00	10,110	4,970	
	17:00	~	18:00	15,090	4,980	
	18:00	~	19:00	19,940	4,850	
	19:00	~	20:00	24,720	4,780	
	20:00	~	21:00	29,490	4,770	
	21:00	~	22:00	34,430	4,940	
	22:00	~	23:00	38,790	4,360	
	23:00	~	0:00	42,160	3,370	
June/10/1995	0:00	~	1:00	45,450	3,290	
	1:00	~	2:00	48,640	3,190	
	2:00	~	3:00	51,740	3,100	
	3:00	~	4:00	54,800	3,060	
	4:00	~	5:00	57,560	2,760	Minimum
	5:00	~	6:00	60,400	2,840	
	6:00	~	7:00	64,660	4,260	
	7:00	~	8:00	69,620	4,960	
	8:00	~	9:00	75,040	5,420	
	9:00	~	10:00	80,460	5,420	
	10:00	~	11:00	85,880	5,420	
	11:00	~	12:00	91,310	5,430	
	12:00	~	13:00	96,730	5,420	
	13:00	~	14:00	102,150	5,420	
	14:00	~	15:00	107,570	5,420	

4.3.6 Total Water Consumption by Consumer Group

As stated in the previous section, it is difficult to grasp the actual water consumption by consumer group because of the lack of meters. However, based on the assumption that the Meter per capita consumption is appropriate for the Group(1) and leakage ratio is nearly equal to effectiveness (30 %), both of which have been measured by the JICA Study Team, the water consumption by consumer group is estimated as shown in Table 4.14.

Table 4.14 Estimated Water Consumption by Consumer Group in 1995

(unit : mld)

	Actual distributed water	Group(1)	Group(2) and (3)	Leakage
Karakalpakstan	180.0	63.3	62.7	54.0
Khorezm	199.2	62.7	76.7	59.8

Note: Actual distributed water derives from Table 4.5(a) and (b) water consumption for Group(1) derived from Table 4.11-(a) and 4.11-(b).

4.3.7 Time Variation in Water Consumption

(1) Annual Variation of Monthly Average Water Consumption

The monthly average water quantity and monthly to average annual consumption ratio of water supplied by VodoKanal in Karakalpakstan and in Khorezm are shown in table 4.15-(a) and -(b). The annual variation in monthly water quantity supplied is not so high, and varies from 0.84 to 1.15. This is because the consumption is averaged out due to the records of the bulk water supply to all the regions.

Table 4.15-(a) Monthly Average Water Quantity by VodoKanal in Karakalpakstan and its Monthly to Average Annual Consumption Ratio

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
90	160.5	161.5	161.7	164.3	163.3	163.9	163.4	163.2	162.9	158.4	155.0	157.9
	0.99	1.00	1.00	1.02	1.01	1.01	1.01	1.01	1.01	0.98	0.96	0.98
91	164.7	164.7	164.7	170.3	163.6	163.6	161.6	161.8	162.0	161.4	162.1	160.9
	1.01	1.01	1.01	1.04	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.98
92	160.9	108.0	99.3	184.0	275.8	296.4	183.9	183.9	189.6	180.5	180.4	180.5
	0.87	(1.05)	(1.05)	0.99	(1.05)	(1.05)	0.99	0.99	1.02	0.97	0.97	0.97
93	131.8	188.3	255.3	188.1	152.7	173.6	171.6	164.9	164.9	177.9	196.0	203.2
	(1.00)	1.04	(1.00)	1.04	(1.00)	0.96	0.95	0.91	0.91	0.99	1.09	1.13
94	194.5	214.3	204.2	190.3	182.6	202.7	207.3	193.5	189.3	164.5	166.5	158.4
	1.03	1.14	1.08	1.01	0.97	1.07	1.07	1.02	1.00	0.87	0.88	0.84
95	156.6	149.4	151.8	183.1	180.6	195.8	195.8	203.4	192.1			
	0.88	0.83	0.83	1.02	1.00	1.09	1.09	1.14	1.07			

Upper : Quantity of water (ths. m^3 per day)
Lower : Monthly ratio to yearly average quantity of water
Source : VodoKanal Karakalpakstan

Table 4.15-(b) Monthly Average Water Quantity by VodoKanal in Khorezm and its Monthly to Average Annual Consumption Ratio

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
90	166	186	166	174	167	174	169	168	175	168	169	164
	0.98	1.10	0.98	1.02	0.98	1.02	1.00	0.99	1.03	0.99	1.00	0.97
91	187	210	177	185	181	186	180	179	190	175	184	164
	1.02	1.15	0.97	1.01	0.99	1.02	0.98	0.98	1.04	0.96	1.01	0.90
92	223	217	243	210	202	212	202	202	235	229	220	235
	1.02	0.99	1.11	0.96	0.92	0.97	0.92	0.92	1.07	1.02	1.00	1.07
93	182	203	215	192	194	201	198	193	194	188	189	177
	0.94	1.05	1.11	0.99	1.00	1.04	1.02	1.00	1.00	0.97	0.98	0.91
94	191	211	188	201	217	205	201	198	199	196	202	200
	0.95	1.05	0.94	1.00	1.08	1.02	1.00	0.99	0.99	0.98	1.01	1.00
95	198	212	196	200	193	170	184	191	183			
	1.03	1.11	1.02	1.04	1.01	0.89	0.96	1.00	0.95			

Upper : Quantity of water (ths. m^3 per day)
Lower : Monthly to annual average consumption ratio
Source : VodoKanal Khorezm

(2) Daily Variation of Hourly Average Water Consumption

Table 4.16 shows the daily variation of hourly delivered water on the day the maximum daily distributed quantity occurs at Nukus and Kungrad.

Table 4.16 Daily Variation of Hourly Average Water Quantity

City	Year	Ratio of hourly distributed water to average distributed water					Distributed Quantity (m^3/day)	
		0 - 6	6 - 9	9 - 15	15 - 18	18 - 24	total	hourly Ave.
Nukus	1991	0.8	0.96	1.44	0.96	0.80	111,390	4,641
	1992	0.8	0.96	1.44	0.96	0.80	111,995	4,666
Kungrad	1992	0.67	1.33	1.33	1.33	0.67	25,824	1,076
	1993	0.66	1.34	1.34	1.34	0.66	23,916	997

Source : VodoKanal Karakalpakstan

4.4 Water Consumption in Rural Areas

Agro-Vodokanal is responsible for rural supply.

4.4.1 Karakalpakstan Rural Area

Water is supplied in rural area of Karakalpakstan from three types of water sources:

i) Supply from Tuyamuyun water supply system (piped water supply)
ii) Supply from EKOS plant (Piped water supply)
iii) Supply from groundwater with handpump (non-piped water supply and non-service area of Agro-Vodokanal)

Quality of water from EKOS is best with total hardness of 2.0 to 2.5 meq/l. Water from Tuyamuyun system ranks next best but in the winter and the early spring its water quality deteriorates worse (Total hardness 9 -10 eq/l), falling below the standard. Water from handpump is unfit for drinking.

Presently, the percentage of supply quantity of each source to the total is as follows: Tuyamuyun system (20%), EKOS plant (22%), and handpump (58%). Piped water is supplied mostly by standpipes installed at 100 m intervals. The current per capita consumption is estimated as 85 to 90 l/ca./day.

Tuyamuyun Water Supply

The Tuyamuyun system presently covers 7 regions in Karakalpakstan: Turtkul, Beruni, Ellikkala, Nukus, Kegeili, Chimbai and Takhtakupyr. The maximum quantity received currently from the Tuyamuyun system is approximately 7,300 m^3/day, which is 20% of the total quantity supplied by Agro-Vodokanal. By the end of this year, 25 % of the total supply will be received from the Tuyamuyun system. To receive water from the Tuyamuyun system, distribution reservoir and distribution pipelines are necessary, in addition to the existing distribution network.

4.4.2 Khorezm Rural Area

Agro-Vodokanal of Khorezm supplies water from the three sources listed below to rural areas:

i) Tuyamuyun system
ii) VodoKanal
iii) Wells

The quality of water from Tuyamuyun system is good but in early spring its quality deteriorates. Although the quality of water from wells is not bad, it is poorer than of Tuyamuyun's quality.

The annual average water supply quantity is 87,700 m^3/day, of which 70 % comes from the Tuyamuyun system, 20 % from VodoKanal and 10 % from wells. The current per capita consumption is estimated as 150 l/ca./day.

The number of connections to consumers is 6,900, most of which are standpipe. The number of house connections and yard taps is very small. The norm consumption (l/ca./day) is as follows: standpipes (60), yard taps and house connection (150). Standpipes are installed at 100 m intervals.

The remaining amount of well water is small now since water has been drawn for 15 years. Water from wells is supplied only for 6 hours a day intermittently, two hours each in the morning, noon, and evening.

Outside the service area, water is supplied by ground water with handpump, Ground water level is about 6 m below the ground surface.

Tuyamuyun Water Supply

Presently, the Tuyamuyun system covers 6 regions in Khorezm: Kyzylkum, Khazarasp, Bagat, Yangiaryk, Khanka, Yangibazar and Amudarya region in Karakalpakstan. The current annual average daily water quantity received from the Tuyamuyun system is approximately 66,000 m^3/day with a maximum of 81,000 m^3/day. From 1997, Shavat and Koshkupyr are scheduled to be connected to the Tuyamuyun system.

4.5 Future Water Demand Projection

4.5.1 Target Year

This project may start in 1997, the year after the Study is completed, and this construction starts from 1998. The target year for this project was set as 2010 after discussions between the JICA Study Team and the Uzbek side, that has the water supply master plans for this region with at 2010 as the target year.

4.5.2 Population Projection

(1) Total population

The total population projected by the Uzbek side was used as total future population for this plan. This is shown in Table 4.17 by urban and rural areas and at five-year intervals up to 2010. For details of population by city and by rural settlement, refer to the Table 4.30-(a) on page 4-33 and -(b) on page 4-34.

The projected population considers decreasing trend of population growth rate in the past, and offer realistic figures for the future.

(2) Service Population

The coverage rate of piped water supply projected by the Uzbek side was used. The Uzbek side has planned a 100 % coverage rate of urban areas in 2010 and 100 % of rural areas in 2015, and aim to supply piped water with good quality to all regions. Table 4.17 shows the coverage rate and service population by urban and rural areas at by five-year intervals up to 2010.

Table 4.17 Total population, Coverage Rate and Service Population Projected by the Uzbek Side

	1995			2000			2005			2010		
	T. pop	C.R	S. pop	T. pop	C.R	S. pop	T. pop	C.R	S. pop	T. pop	C.R	S. pop
	ths.	%	ths.	ths.	%	ths.	ths.	%	ths.	ths.	%	ths.
Karakalpakstan												
Urban	660.0	76	501.6	734.7	90	661.2	787.0	95	747.7	850.6	100	850.6
Rural	722.0	41	296.0	809.3	54	437.0	893.7	71	634.5	985.8	85	837.9
Total	1,382.0	58	797.6	1,544.0	71	1,098.2	1,680.7	82	1,382.2	1,809.4	93	1,688.5
Khorezm												
Urban	336.0	87	292.3	361.5	96	347.0	378.2	98	370.6	397.4	100	397.4
Rural	899.8	51	458.9	1,041.8	64	666.8	1,182.5	77	910.5	1,342.0	90	1,207.8
Total	1,235.8	61	751.2	1,403.3	72	1,013.8	1,560.7	82	1,281.1	1,739.4	92	1,605.2

T. pop: Total population, C.R: Coverage rate, S. pop: Service population
Source: State Committee on Forecasting and Statistics

The projected coverage rate of urban areas may be realized, but rural areas will incur high investment costs for increasing the rate of coverage, and its realization is very difficult.

4.5.3 Per Capita Consumption for Urban Areas

(1) Domestic per capita consumption

1) Daily life use

The current per capita consumption by consumer type was estimated based on the JICA meter reading survey. The future per capita consumption by region was estimated from the future population estimates and future per capita consumption by consumer type (see Table 4.18). Future population by consumer type was estimated from future total population and percentage of service population by consumer type. The future percentage was set as shown in Table 4.19-(a) and -(b). The results of future per capita consumption are shown in the same tables.

Table 4.18 Norm, Meter and Projected Per Capita Consumption by Consumer Type

(unit: l/ca./day)

Consumer type	norm per capita consumption		per capita by JICA survey	projected per capita consum.	method of water supply and water use facilities in house
	KKP	Khorezm			
A	41	50		41, 50	Stand pipe
B	77	100	49	60	Yard tap
C, D	100,150	140	85	105	In-house water tap, Sink, Bath
E, F	177,227	230	90	120	Sink, Bath/shower, Water heater
J	233	250	91	155	Sewerage, Sink, Bath/shower, water heater
K	270	350	168	170	Sewerage, Sink, Bath/shower, Hot water service

Note: Projected per capita consumption was estimated from water use in Japan and per capita consumption by JICA survey.

Table 4.19-(a) Percentage of Population by Consumer Type and Per Capita Consumption (Karakalpakstan)

	1991	1992	1993	1994	1995	2000	2005	2010
1. Percentage of population by consumer type (%)								
Consumer type	Percentage from past records					Projected percentage		
A	12.5	10.0	10.0	11.3	9.2	6	5	4
B	76.0	79.2	72.3	74.1	65.2	45	30	10
C, D	10.5	9.9	11.7	10.4	9.9	10	10	10
E, F	1.0	0.9	3.8	2.1	2.1	6	11	16
J	0.0	0.0	0.0	0.0	10.9	23	24	30
K	0.0	0.0	2.2	2.1	2.7	10	20	30
total	100.0	100.0	100.0	100.0	100.0	100	100	100
2. Per capita consumption (l/ca./day)								
	Estimated past per capita consumption					Projected per capita		
Using JICA per capita consum. by type	52	52	57	55	60	76	91	107
Using projected per capita consum. by type	63	63	68	66	77	100	115	135
Projected per capita consum.					60	85	110	135

Note: Projected percentage of population is estimated based on projections by the Uzbek side.

Table 4.19-(b) Percentage of Population by Consumer Type and Per Capita Consumption (Khorezm)

Consumer type	1991	1992	1993	1994	1995	2000	2005	2010
1. Percentage of population by consumer type (%)								
Consumer type	Percentage from past records					Projected percentage		
A	2.9	1.2	1.5	2.4	2.9	0	0	0
B	14.0	5.8	19.0	10.1	10.8	8	5	0
C	40.8	37.6	40.2	48.1	44.5	34	23	16
E	19.3	34.8	13.4	16.2	16.6	16	16	16
J	11.5	10.3	13.0	11.6	12.6	21	28	34
K	11.5	10.3	12.9	11.6	12.6	21	28	34
total	100.0	100.0	100.0	100.0	100.0	100	100	100
2. Per capita consumption (l/ca./day)								
Item	Estimated past per capita					Projected per capita		
Using JICA survey per capita consum. by type	90	96	90	85	89	107	124	137
Using projected per capita consum. by type	113	119	112	115	115	128	137	147
Projected per capita consum.					89	108	127	147

Note: Projected percentage of population is estimated based on projections by the Uzbek side.

2) Garden watering

The current consumption for garden irrigation watering of 39 l/m²/day, was estimated based on the JICA meter survey. This value is about two to three times the value for efficient consumption for gardens, calculated from evaporation, leaching and effective consumption for crop or vegetable as shown below.

Evaporation in Nukus	7.5 - 7.7 mm	
Leaching and effective consumption		
- rice farming	15 mm	
- vegetable farming	5 mm	
total		
- rice farming	22.3 - 22.7 mm (= 23 mm)	
- vegetable farming	12.3 - 12.7 mm (= 13 mm)	
average water consumption for rice and vegetable farming		18 mm

In the future, water consumption for gardens should be reduced to the average efficient consumption of 18 mm, which is 46% of the current consumption for watering gardens (39 l/m²/day).

To project the future consumption for gardens watering, four alternatives for garden water are given below. In comparison of the Alternatives, per garden area consumption is converted to per capita consumption for easy handling.

Alternative 1	using current per capita consumption
Alternative 2	using efficient per capita consumption
Alternative 3	prohibiting the watering of gardens by piped water by 2010 (Consumption for garden watering is zero in 2010.)
Alternative 4	using per capita consumption linearly interpolated from the current consumption in 1995 to the efficient consumption in 2010.

Note: Per capita consumption of water for gardens is used only for the gardening season eight months from February to September. This period was estimated from the JICA meter survey.

Table 4.20 Projection of Per Capita Consumption for Garden Watering

(unit: l/ca./day)

Alternative		1995	2000	2005	2010
1. current consum.	KKP	108	108	108	108
	Khorezm	130	130	130	130
2. efficient consum.	KKP	108	50	50	50
	Khorezm	130	60	60	60
3. zero consum. in 2010	KKP	108	108	54	0
	Khorezm	130	130	65	0
4. interpolated consum.	KKP	**108**	**89**	**69**	**50**
(average for eight months)	Khorezm	**130**	**107**	**83**	**60**

Note: Per capita consumption for water for garden is used only for eight months

To achieve water consumption in Alternative 2, strict control and monitoring are required. Similarly, irrigation networks should be developed for the Alternative 3. Installation of individual meters is effective in restricting water used for gardens.

Finally, Alternative 4 is selected as the projected per capita consumption for watering gardens to reduce the water demand to the efficient level in 2010. Basically, using drinking water for gardens is improper, but many inhabitants in depend on their livelihood on garden products, therefore their the right to make a living must be ensured. In the future, this improper water consumption should be reduced, unless it reduces naturally with economic growth.

3) Other uses

The consumption per head of water for washing cars and for domestic animals was set as below based on the norm consumption and standard consumption level in other countries.

- cattle 30 l/head/day (standard level in other countries)
- sheep 25 l/head/day (norm consumption of the study area)
- vehicle 33 l/car/day (norm consumption of the study area)

Using the above figures and the total number, the total consumption is calculated. Then current per capita consumption (1.1 for Karakalpakstan and 1.4 for Khorezm), is calculated by dividing the total consumption by service population. The same per capita consumption is used for future projections as shown in the following table.

Table 4.21 Projected Per Capita Consumption for the Other Uses (domestic animal and vehicle washing)

(unit: l/ca./day)

	1995	2000	2005	2010
Karakalpakstan	1.1	1.1	1.1	1.1
Khorezm	1.4	1.4	1.4	1.4

(2) Per capita consumption for the Second Group

Past per capita consumption for the second group, dividing total consumption for the second group by the population, is shown in the following table.

Table 4.22 Past and Projected Per Capita Consumption for the Second Group

(unit : l/ca./day)

	1990	1991	1992	1993	1994	1995	1995[1]	2000	2005	2010
Karakalpakstan	118	136	142	111	100	92	97	108	119	130
Khorezm	268	206	274	167	201	143	137	140	144	147

Source: VodoKanal and the Ministry of Public Utilities
1) Data is obtained from the Ministry of Public Utilities. Past data is obtained from VodoKanal.
Per capita consumption is calculated by dividing the total consumption by the total population.

This per capita consumption has a decreasing trend. Compared to other countries, especially developed countries, the per capita consumption for this category is much higher. One reason for the high consumption is that this group includes centralized hot water service for which water is supplied from the water supply system. The Uzbek side projects per capita consumption for this group based on the increase in centralized hot water service in future, as shown in the same table. Per capita consumption for Karakalpakstan shows a sharp increase because the Uzbek side predicts that hot water service for Karakalpakstan will reach nearly that for Khorezm in the future.

(3) Per capita consumption for the Group(3)

Total industrial demand in the urban is projected by Uzbek side as given in table 4.23. Consequently, the per capita consumption for this group calculated from this demand and the population is shown in the same table.

Table 4.23 Projected Third Group Demand and Per Capita Consumption

		unit	1995	2000	2005	2010
Total demand	KKP(1)	mld	19.1	48.6	61.9	73.0
	KKP(2)	mld	-	70.0	70.0	70.0
	total(KKP(3))	mld		118.6	131.9	143.0
	Khorezm	mld	35.8	57.0	73.1	90.0
Per capita consumption	KKP(1)	l/ca./day	38.1	73.5	82.8	85.8
	total(KKP(3))	l/ca./day	-	179.4	176.4	168.1
	Khorezm	l/ca./day	121.9	164.0	196.9	226.5

Note: KKP(1) demand or per capita consumption excluding UrgenchTransGas and Sodany plant.
KKP(2) demand or per capita consumption for UrgenchTransGas and Sodany plant
KKP(3) including demand or per capita consumption for UrgenchTransGas and Sodany plant.

(4) Leakage

Leakage is a waste of money because a considerable amount of money is used for intake, conveyance, treatment and distribution of water. In addition, when water resources are limited, prevention of leakage is beneficial as it helps in increasing the effective water quantity and using water resources effectively.

The current annual average leakage ratio has been estimated as 30% of the total distributed water volume. This ratio is high compared to the leakage ratio of developed countries, but not very high compared to that of developing countries. In the future, the leakage ratio should be reduced to a rational and efficient level. Considering the available water resources, level of quality of treated water in the future, available costs and technology for leakage prevention, plans should be framed for the future to reduced the leakage ratio. However, it is difficult to frame detail plans. Consequently, it is presumed that the ratio decreases by one percent per year. A plan to reduce the leakage ratio has been proposed as shown in table 4.24. The leakage ratio is estimated to reach 15% in 2010.

Table 4.24 Plan for Leakage Ratio and Per Capita Leakage Amount

	unit		1995	2000	2005	2010
Leakage	%		30	25	20	15
Per capita Leakage	l/ca./day	KKP	115	144	113	82
		Khorezm	187	161	131	99

(5) Total per capita consumption

Per capita consumption is summarized in the following table.

Table 4.25 Per Capita Consumption

(unit: l/ca./day)

			1995	2000	2005	2010
Group(1)	Living	KKP	60	85	110	135
		Khorezm	89	108	127	147
	Garden watering	KKP	72	59	46	33
		Khorezm	87	71	56	40
	Others	KKP	1.1	1.1	1.1	1.1
		Khorezm	1.4	1.4	1.4	1.4
	Total	KKP	133.1	145.1	157.1	169.1
		Khorezm	177.4	180.4	183.4	188.4
Group(2)		KKP	97	108	119	130
		Khorezm	137	140	144	147
Group(3)		KKP	38	74	83	86
		Khorezm	122	164	197	226
Sub-total		KKP	268.1	327.1	359.1	385.1
		Khorezm	436.4	484.4	524.4	561.4
Leakage		KKP	115	144	113	82
		Khorezm	187	161	131	99
Total		KKP	383.1	471.1	472.1	467.1
		Khorezm	623.4	645.4	655.4	660.4

Note: Per capita consumption for garden watering is annual average, and is different from the seasonal average per capita consumption for the gardening season.
excluding consumption for Urgench Transgas and Sodany plan.

The total per capita consumption is very high compared to that of developed countries; e.g. 450 l/ca./day in Japan in 1995. Taking into consideration the existing water supply conditions, such as endorsement of water resource, decrease in investments and further reduction of subsidy in the future, the per capita consumption should be reduced by reducing wastage, by proper use of piped water on the consumer side and by a combination of installation of water meters and appropriate water charges on the supply side.

4.5.4 Per Capita Consumption for Rural Areas

The study of water supply systems in rural areas does not include in the JICA Study. However, for planning purpose of Tuyamuyun water supply system it is necessary to project the rural water demand. The projected per capita consumption proposed by the Uzbek side and the World Bank is used as the consumption for the rural area (Table 4.26). This per capita consumption includes all consumption: 1st, 2nd and 3rd group, and leakage.

Table 4.26 Per Capita Consumption in Rural Areas

(unit: l/ca./day)

	1995	2000	2010	2010
Karakalpakstan	180	88	125	168
Khorezm	183	114	150	150

Source: Interim report of the World Bank

4.5.5 Time Variation in Water Demand

(1) Daily Maximum Variation

According to the design criteria report of Construction Norms and Regulations of Former Soviet Union, Moscow 1985, the daily maximum variation coefficient is in the range of 1.1 to 1.3.

The daily maximum variation coefficient is set at 1.15, which is the current daily maximum variation as a result of current demand variation. This value is considered to be slightly low, but during the day, when the daily maximum demand occurs, the use of water for gardens is maximum. For restricting this consumption, the value is taken slightly lower than the actual coefficient.

(2) Hourly Maximum Variation

According to the design criteria report, the hourly maximum coefficient (Kmax) is expressed by the equation given below, according to population size. The coefficient and calculated results are shown in table 4.27.

$$Kmax = \alpha \max \times \beta \max$$

Table 4.27 Calculation of Hourly Maximum Coefficients

	Number of population				
	10,000	20,000	50,000	100,000	300,000
α max	1.2 - 1.4				
β max	1.3	1.2	1.15	1.1	1.05
Kmax	1.56-1.82	1.44-1.68	1.38-1.61	1.32-1.54	1.26-1.47

According to the calculations of current hourly maximum variation, the coefficients in Nukus and Kungrad are 1.44 and 1.34 respectively. The hourly maximum coefficient should be set at nearly 1.4 taking into consideration the criteria and actual coefficients.

4.5.6 Future Water Demand by Territory

The water demand for Karakalpakstan and Khorezm are calculated from per capita consumption, leakage and demand variation coefficients projected in the previous sections. A summary of future water demand by territory is shown in table 4.28 and detailed values are shown in table 4.30-(a) and 4.30-(b).

Table 4.28 Summary of Future Water Demand by Territory

(unit: thousand m^3/day)

	1995		2000		2005		2010	
	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.
Karakalpakstan								
urban	192.3	221.1	287.5	330.6	330.2	379.7	376.3	432.9
rural	53.7	61.7	38.8	44.7	79.2	91.1	140.8	161.9
total	246.0	282.8	326.3	375.3	409.4	470.8	517.1	594.8
Khorezm								
urban	183.1	210.6	224.5	258.2	243.4	279.9	262.7	302.1
rural	83.7	96.3	75.4	86.7	136.5	157.0	182.2	209.5
total	266.8	306.9	299.9	344.9	379.9	436.9	444.9	511.6

Ave. : daily average water demand, Max.: daily maximum water demand
excluding the demand for UzTransGas and Sodavy plant town, for which water is supplied from UzTransGas.

4.5.7 Future Water Demand by Tuyamuyun System

Presently, the treated water is supplied not by territory, Karakalpakstan and Khorezm, but by the Tuyamuyun System, the Tuyamuyun-Nukus system and the Tuyamuyun-

Urgench System. Therefore, the future water demand for the Tuyamuyun System is calculated as shown in table 4.29, table 4.31, Fig.4.2 and Fig.4.3. The difference between water demand by territory and by Tuyamuyun system is that the water demand for Amudarya region in Karakalpakstan is included in the Tuyamuyun-Urgench System in Khorezm.

Table 4.29 Summary of Future Water Demand for the Tuyamuyun System

(unit: thousand m^3/day)

	1995		2000		2005		2010	
	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.
Tuyamuyun-Nukus (T-N)								
urban	184.2	211.9	269.9	310.4	310.8	357.4	355.4	408.8
rural	49.2	56.6	34.1	39.2	68.8	79.2	122.1	140.4
total	233.4	268.5	304.0	349.6	379.6	436.6	477.5	549.2
Tuyamuyun-Urgench (T-V)								
urban	191.2	219.8	242.1	278.4	262.7	302.2	283.6	326.1
rural	88.2	101.4	80.1	92.1	146.9	169.0	200.9	231.1
total	279.4	321.2	322.2	370.5	409.6	471.2	484.5	557.2

Ave. : daily average water demand, Max.: daily maximum water demand
excluding the demand for UzTransGas and Sodavy plant town, for which water is supplied from UzTransGas.

Table 4.30-(a) Future Water Demand in Karakalpakstan

		1995					2000					2005					2010				
		Population	Coverage Rate	Served Population	Ave. Water Demand	Max Water Demand	Population	Coverage Rate	Served Population	Ave. Water Demand	Max Water Demand	Population	Coverage Rate	Served Population	Ave. Water Demand	Max Water Demand	Population	Coverage Rate	Served Population	Ave. Water Demand	Max Water Demand
		ths.	%	ths.	ths.m3/day		ths.	%	ths.	ths.m3/day		ths.	%	ths.	ths.m3/day		ths.	%	ths.	ths.m3/day	
KKP	(Urban)																				
	Nukus	230.3	77	176.6	66.1	76.0	247.3	90	222.6	90.9	104.5	260.2	95	247.2	101.3	116.5	272.0	100	272.0	111.3	127.9
	Takhiatash(G.P)	49.3	92	45.4	19.2	22.1	52.9	95	50.3	21.4	24.6	55.6	95	52.8	25.7	29.5	58.2	100	58.2	28.7	33.0
	Turtkul	45.0	75	33.7	12.7	14.6	48.3	90	43.5	19.0	21.9	51.8	95	49.2	21.7	25.0	53.1	100	53.1	24.2	27.8
	Muynak	13.7	92	12.6	5.3	6.1	14.6	95	13.9	6.4	7.3	15.4	95	14.6	7.0	8.1	16.1	100	16.1	7.8	8.9
	Khodjeily(G.P)	65.0	76	49.5	17.4	20.0	70.0	90	63.0	28.1	32.3	73.6	95	69.9	32.3	37.1	77.0	100	77.0	35.5	40.8
	Beruny	44.6	72	31.9	12.3	14.1	47.5	90	42.8	19.2	22.1	50.0	95	47.5	23.9	27.5	52.3	100	52.3	28.3	32.5
	Chimbay	31.9	79	25.1	9.0	10.3	34.2	90	30.8	16.1	18.6	36.0	95	34.2	18.2	20.9	37.7	100	37.7	19.9	22.8
	Shumanay	12.5	70	8.8	3.8	4.3	13.5	90	12.2	4.3	4.9	14.2	95	13.5	5.0	5.8	14.9	100	14.9	5.8	6.7
	Kungrad(G.P)	56.1	81	45.3	18.8	21.7	60.3	90	54.3	21.9	25.2	63.5	95	60.3	24.3	28.0	66.4	100	66.4	26.7	30.7
	Khalkabad	10.9	60	6.5	2.5	2.9	11.7	90	10.5	5.0	5.8	12.4	95	11.8	5.5	6.3	13.0	100	13.0	5.9	6.8
	Kegeily	12.9	73	9.4	3.2	3.7	13.9	90	12.5	5.7	6.5	14.6	95	13.9	6.2	7.1	15.3	100	15.3	6.8	7.8
	Akmangit	7.5	75	5.6	2.0	2.3	8.1	90	7.3	2.9	3.3	8.6	95	8.2	3.2	3.7	9.0	100	9.0	3.5	4.1
	Karauzyak	12.6	75	9.5	3.6	4.1	13.6	90	12.2	4.6	5.3	14.3	95	13.6	5.3	6.1	15.1	100	15.1	5.9	6.8
	Takhtakupyr	16.8	64	10.7	3.9	4.5	18.0	90	16.2	6.2	7.1	19.0	95	18.1	7.1	8.1	20.0	100	20.0	7.8	9.0
	Kanlykul	9.0	83	7.5	2.6	2.9	9.7	90	8.7	3.3	3.8	10.2	95	9.7	3.7	4.3	10.7	100	10.7	4.3	4.9
	Bozatau	3.7	89	3.3	1.1	1.3	4.1	90	3.7	1.4	1.6	4.3	95	4.1	1.6	1.8	4.5	100	4.5	1.8	2.1
	Ellikaly	10.9	21	2.3	0.9	1.0	11.7	90	10.5	7.7	8.8	12.3	95	11.7	9.6	11.0	12.9	100	12.9	11.1	12.8
	Karatau						2.7	90	2.4	1.5	1.7	5.0	95	4.8	4.2	4.8	25.0	100	25.0	14.5	16.6
	Djumurtau						3.5	90	3.2	1.8	2.1	3.7	95	3.5	2.0	2.3	3.9	100	3.9	2.4	2.8
	Komsomol						0.6	90	0.5	0.2	0.2	0.6	95	0.6	0.2	0.2	0.7	100	0.7	0.3	0.3
	Karakalpakia						4.0	90	3.6	1.2	1.4	4.2	95	4.0	1.4	1.6	4.4	100	4.4	1.6	1.8
	Zhaslyk						4.0	90	3.6	1.2	1.4	4.2	95	4.0	1.4	1.6	4.4	100	4.4	1.6	1.8
	Vodnik						6.2	90	5.6	1.9	2.2	6.5	95	6.2	2.1	2.5	6.8	100	6.8	2.4	2.8
	Sadovy plant						5.0	90	4.5	1.5	1.8	16.0	95	15.2	5.3	6.0	25.0	100	25.0	8.8	10.1
	Mangit	27.3	67	18.4	8.1	9.3	29.3	90	26.4	15.8	18.1	30.8	95	29.3	17.3	19.9	32.2	100	32.2	18.5	21.2
	Urban Area	660.0	76	502.1	192.3	221.1	734.7	90	664.8	289.0	332.4	787.0	95	747.9	335.4	385.7	850.6	100	850.6	385.2	443.0
	(Rural)																				
	Amudaria	95.9	15	14.1	4.5	5.1	107.5	50	53.8	4.7	5.4	118.7	70	83.1	10.4	12.0	131.0	85	111.4	18.7	21.5
	Takhtakupyr	25.4	57	14.6	1.3	1.5	28.5	60	17.1	1.4	1.7	31.5	75	23.6	3.0	3.4	34.7	85	29.5	5.0	5.7
	Kungrad	36.8	70	25.6	1.5	1.8	41.3	71	29.3	2.6	3.0	45.6	75	34.2	4.3	4.9	50.3	85	42.8	7.2	8.3
	Karauzyak	28.3	37	10.6	1.2	1.3	31.6	50	15.8	1.4	1.7	35.0	70	24.5	3.1	3.5	38.7	85	32.9	5.5	6.4
	Kegeily	31.9	32	10.3	2.9	3.3	36.0	50	18.0	1.6	1.8	39.6	70	27.7	3.5	4.0	43.7	85	37.1	6.2	7.2
	Kanlykul	25.9	69	18.0	1.1	1.2	29.0	71	20.6	1.6	1.9	32.1	75	24.1	3.0	3.5	35.4	85	30.1	5.1	5.8
	Chimbay	52.7	54	28.5	9.5	10.9	59.1	58	34.3	3.1	3.5	65.2	70	45.6	5.7	6.6	72.0	85	61.2	10.3	11.8
	Ellikaly	89.4	65	58.0	12.0	13.8	100.2	68	68.1	6.3	7.2	110.6	75	83.0	10.4	11.9	122.2	85	103.9	17.5	20.1
	Khodjeily	62.6	25	15.8	3.1	3.5	70.2	40	28.1	2.2	2.5	77.5	60	46.5	5.8	6.7	85.6	85	72.8	12.2	14.1
	Turtkul	93.9	55	51.7	7.1	8.1	105.2	57	60.0	5.5	6.4	116.2	75	87.2	10.9	12.5	128.3	85	109.1	18.3	21.1
	Nukus	36.7	62	22.6	2.2	2.5	41.1	63	25.9	2.4	2.7	45.4	75	34.1	4.3	4.9	50.1	85	42.6	7.2	8.2
	Shumanay	28.0	11	3.1	1.0	1.1	31.4	40	12.6	1.0	1.1	34.7	60	20.8	2.6	3.0	38.3	85	32.6	5.5	6.3
	Beruny	85.3	15	12.6	3.5	4.1	95.6	40	38.2	3.5	4.0	105.5	70	73.9	9.2	10.6	116.5	85	99.0	16.6	19.1
	Muynak	14.2	47	6.7	0.8	0.9	15.8	55	8.7	0.8	0.9	17.5	70	12.3	1.5	1.8	19.3	85	16.4	2.8	3.2
	Bozatau	15.0	39	5.9	2.2	2.5	16.8	50	8.4	0.8	0.9	18.6	70	13.0	1.6	1.9	19.7	85	16.7	2.8	3.2
	Rural Area	722.0	41	298.1	53.7	61.7	809.3	54	438.9	38.8	44.7	893.7	71	633.6	79.2	91.1	985.8	85	838.1	140.8	161.9
	Grand Total	1382.0	58	800.2	246.0	282.8	1544.0	71	1103.7	327.8	377.1	1680.7	82	1381.5	414.6	476.8	1836.4	92	1688.7	525.9	604.9

Sodavy Plant in Karakalpakstan is supplied by water from the Water Supply System of Urgench Trans Gas

Table 4.30-(b) Future Water Demand in Khorezm

		1995					2000					2005					2010				
		Population	Coverage Rate	Served Population	Ave. Water Demand	Max Water Demand	Population	Coverage Rate	Served Population	Ave. Water Demand	Max Water Demand	Population	Coverage Rate	Served Population	Ave. Water Demand	Max Water Demand	Population	Coverage Rate	Served Population	Ave. Water Demand	Max Water Demand
		ths.	%	ths.	ths.m3/day		ths.	%	ths.	ths.m3/day		ths.	%	ths.	ths.m3/day		ths.	%	ths.	ths.m3/day	
Khorezm	(Urban)																				
	Urgench	138.6	98	136.0	88.2	101.5	150.0	100	150.0	95.2	109.4	156.0	100	156.0	98.8	113.7	164.0	100	164.0	101.0	116.1
	Khiva	46.3	95	44.1	22.7	26.1	50.0	100	50.0	25.0	28.7	52.0	100	52.0	27.4	31.5	55.0	100	55.0	34.7	39.9
	Khanka	29.2	87	25.5	14.3	16.5	31.5	90	28.4	15.6	17.9	33.0	95	31.4	17.1	19.7	34.5	100	34.5	18.1	20.8
	Khazarasp	14.7	87	12.8	7.5	8.7	15.6	90	14.0	8.9	10.3	16.5	95	15.7	10.2	11.7	17.3	100	17.3	11.1	12.7
	Shavat	13.8	77	10.6	5.7	6.5	14.7	90	13.2	9.8	11.2	15.5	95	14.7	11.8	13.6	16.3	100	16.3	12.8	14.7
	Gurlen	19.9	70	13.9	7.4	8.6	21.2	90	19.1	15.1	17.4	22.4	95	21.3	16.5	19.0	23.5	100	23.5	17.5	20.1
	Karaul	14.0	96	13.5	10.5	12.0	15.0	100	15.0	11.4	13.1	15.7	100	15.7	12.1	13.9	16.5	100	16.5	12.9	14.8
	Koshkupyr	15.2	76	11.6	6.6	7.6	16.2	90	14.6	7.7	8.8	17.1	95	16.2	8.4	9.6	17.9	100	17.9	9.4	10.8
	Bagat	8.6	50	4.3	4.8	5.5	9.2	90	8.3	7.6	8.7	9.7	95	9.2	9.1	10.5	10.2	100	10.2	10.1	11.7
	Yangiaryk	9.9	34	3.4	3.2	3.7	10.6	90	9.5	8.6	9.9	11.2	95	10.6	9.0	10.3	11.8	100	11.8	9.2	10.6
	Druzhba	15.0	95	14.2	9.4	10.8	16.0	95	15.2	11.8	13.6	17.0	100	17.0	13.2	15.2	17.7	100	17.7	15.1	17.4
	Yangibazar	5.4	54	2.9	2.0	2.4	5.8	90	5.2	5.3	6.1	6.1	95	5.8	7.0	8.1	6.4	100	6.4	7.9	9.1
	Chalysh	5.4	19	1.0	0.7	0.9	5.7	90	5.1	2.7	3.1	6.0	95	5.7	2.8	3.3	6.3	100	6.3	3.0	3.4
	Urban Area	336.0	87	293.8	183.1	210.6	361.5	96	347.6	224.5	258.2	378.2	98	371.3	243.4	279.9	397.4	100	397.4	262.7	302.1
	(Rural)																				
	Gurlen	76.5	58	44.6	1.5	1.8	88.5	65	57.5	6.6	7.6	100.5	75	75.4	11.3	13.0	114.0	90	102.6	15.4	17.7
	Koshkupyr	94.0	25	23.8	1.4	1.6	109.1	50	54.6	6.3	7.2	123.0	70	86.1	12.9	14.9	139.6	90	125.6	18.8	21.7
	Khanka	87.5	83	73.0	5.1	5.9	101.2	85	86.0	8.9	10.2	114.9	90	103.4	16.7	19.2	130.5	95	124.0	18.6	21.4
	Khazarasp	130.6	47	61.6	4.4	5.0	151.1	60	90.7	10.4	12.0	171.5	75	128.6	18.1	20.9	194.6	90	175.1	26.3	30.2
	Shavat	94.0	43	40.7	2.5	2.9	109.4	60	65.6	7.5	8.7	124.2	75	93.2	14.0	16.1	140.9	90	126.8	19.0	21.9
	Urgench	112.7	37	41.2	10.7	12.3	130.5	55	71.8	8.3	9.5	148.2	75	111.2	16.7	19.2	168.2	90	151.4	22.7	26.1
	Khiva	102.5	70	72.2	9.0	10.4	118.6	80	94.9	10.9	12.6	134.4	85	114.2	17.1	19.7	152.5	90	137.3	20.6	23.7
	Yangibazar	49.2	38	18.9	2.7	3.1	56.9	50	28.5	3.3	3.8	64.7	70	45.3	6.8	7.8	73.4	90	66.1	9.9	11.4
	Yangiaryk	61.8	30	18.7	7.1	8.2	71.5	50	35.8	4.1	4.7	81.2	70	56.8	8.5	9.8	92.2	90	83.0	12.5	14.3
	Bagat	91.0	69	62.5	39.3	45.1	105.0	75	78.8	9.1	10.4	120.0	80	96.0	14.4	16.6	136.2	90	122.6	18.4	21.2
	Rural Area	899.8	51	457.2	83.7	96.3	1041.8	64	664.2	75.4	86.7	1182.6	77	910.2	136.5	157.0	1342.1	90	1214.5	182.2	209.5
	Grand Total	1235.8	61	751.0	266.8	306.9	1403.3	72	1011.8	299.9	344.9	1560.8	82	1281.5	379.9	436.9	1739.5	93	1611.9	444.9	511.6

Table 4.31 Population and Water Demand

	1996				1997				1998				1999				2000			
	Total population	Served population	Ave.water demand	Max water demand	Total population	Served population	Ave.water demand	Max water demand	Total population	Served population	Ave.water demand	Max water demand	Total population	Served population	Ave.water demand	Max water demand	Total population	Served population	Ave.water demand	Max water demand
	ths.		ths.m3/day		ths.		ths.m3/day		ths.		ths.m3/day		ths.		ths.m3/day		ths.		ths.m3/day	
T-N																				
urban	645.5	513.1	201.3	231.6	658.4	542.5	218.5	251.3	671.2	571.9	235.6	271.0	684.1	601.3	252.8	290.7	696.9	630.7	269.9	310.4
rural	641.2	304.2	46.2	53.1	656.4	324.4	43.2	49.6	671.5	344.7	40.1	46.2	686.7	364.9	37.1	42.7	701.8	385.1	34.1	39.2
total	1,286.7	817.3	247.5	284.7	1,314.8	866.9	261.7	300.9	1,342.7	916.6	275.7	317.2	1,370.8	966.2	289.9	333.4	1,398.7	1,015.8	304.0	349.6
T-U																				
urban	369.5	325.2	201.4	231.5	375.7	338.2	211.6	243.2	381.9	351.2	221.7	255.0	388.1	364.2	231.9	266.7	394.3	377.2	242.1	278.4
rural	1,026.4	520.6	86.6	99.5	1,057.1	570.0	85.0	97.7	1,087.9	619.3	83.3	95.8	1,118.6	668.7	81.7	94.0	1,149.3	718.0	80.1	92.1
total	1,395.9	845.8	288.0	331.0	1,432.8	908.2	296.6	340.9	1,469.8	970.5	305.0	350.8	1,506.7	1,032.9	313.6	360.7	1,543.6	1,095.2	322.2	370.5

	2001				2002				2003				2004				2005			
	Total population	Served population	Ave.water demand	Max water demand	Total population	Served population	Ave.water demand	Max water demand	Total population	Served population	Ave.water demand	Max water demand	Total population	Served population	Ave.water demand	Max water demand	Total population	Served population	Ave.water demand	Max water demand
	ths.		ths.m3/day		ths.		ths.m3/day		ths.		ths.m3/day		ths.		ths.m3/day		ths.		ths.m3/day	
T-N																				
urban	704.8	644.5	278.1	319.8	712.7	658.4	286.3	329.2	720.7	672.2	294.4	338.6	728.6	686.1	302.6	348.0	736.5	699.9	310.8	357.4
rural	716.4	418.2	41.0	47.2	731.1	451.3	48.0	55.2	745.7	484.3	54.9	63.2	760.4	517.4	61.9	71.2	775.0	550.5	68.8	79.2
total	1,421.2	1,062.7	319.1	367.0	1,443.8	1,109.7	334.3	384.4	1,466.4	1,156.5	349.3	401.8	1,489.0	1,203.5	364.5	419.2	1,511.5	1,250.4	379.6	436.6
T-U																				
urban	398.0	382.6	246.2	283.1	401.7	388.0	250.4	287.9	405.3	393.3	254.5	292.6	409.0	398.7	258.7	297.4	412.7	404.1	262.8	302.1
rural	1,179.7	773.1	93.5	107.5	1,210.1	828.1	106.8	122.9	1,240.5	883.2	120.2	138.2	1,270.9	938.2	133.5	153.6	1,301.3	993.3	146.9	169.0
total	1,577.7	1,155.7	339.7	390.6	1,611.8	1,216.1	357.2	410.8	1,645.8	1,276.5	374.7	430.8	1,679.9	1,336.9	392.2	451.0	1,714.0	1,397.4	409.7	471.1

	2006				2007				2008				2009				2010			
	Total population	Served population	Ave.water demand	Max water demand	Total population	Served population	Ave.water demand	Max water demand	Total population	Served population	Ave.water demand	Max water demand	Total population	Served population	Ave.water demand	Max water demand	Total population	Served population	Ave.water demand	Max water demand
	ths.		ths.m3/day		ths.		ths.m3/day		ths.		ths.m3/day		ths.		ths.m3/day		ths.		ths.m3/day	
T-N																				
urban	747.1	717.8	319.7	367.7	757.7	735.7	328.6	378.0	768.3	753.7	337.6	388.2	778.9	771.6	346.5	398.5	789.5	789.5	355.4	408.8
rural	791.0	585.7	79.5	91.4	806.9	621.0	90.1	103.7	822.9	656.2	100.8	115.9	838.8	691.5	111.4	128.2	854.8	726.7	122.1	140.4
total	1,538.1	1,303.5	399.2	459.1	1,564.6	1,356.7	418.7	481.7	1,591.2	1,409.9	438.4	504.1	1,617.7	1,463.1	457.9	526.7	1,644.3	1,516.2	477.5	549.2
T-U																				
urban	416.9	410.0	267.0	306.9	421.0	415.9	271.1	311.7	425.2	421.7	275.3	316.5	429.3	427.6	279.4	321.3	433.5	433.5	283.6	326.1
rural	1,335.7	1,059.8	157.7	181.4	1,370.0	1,126.3	168.5	193.8	1,404.4	1,192.9	179.3	206.3	1,438.7	1,259.4	190.1	218.7	1,473.1	1,325.9	200.9	231.1
total	1,752.6	1,469.8	424.7	488.3	1,791.0	1,542.2	439.6	505.5	1,829.6	1,614.6	454.6	522.8	1,868.0	1,687.0	469.5	540.0	1,906.6	1,759.4	484.5	557.2

Population and water demand for Amudarya region are included in Khorezm
Water demand for Sadovy plant is supplied from Uztransgas.
(Pop. and water demand for Sadovy plant is not included in KKP(urban).

Fig. 4.1 Flowchart for Water Demand Estimation

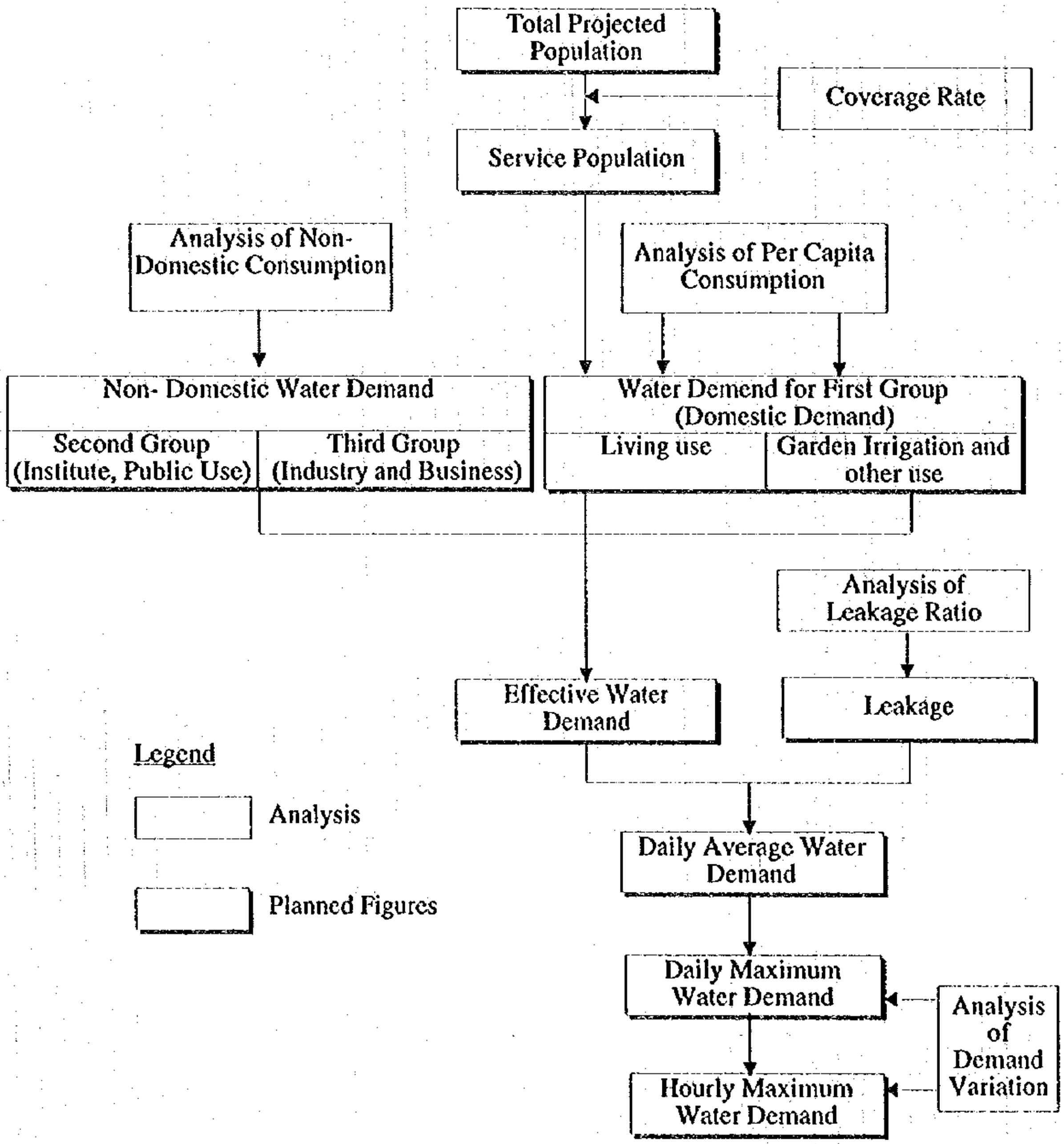


Fig. 4.2 Daily Maximum Water Demand for Tuyamuyun-Nukus Water Supply System

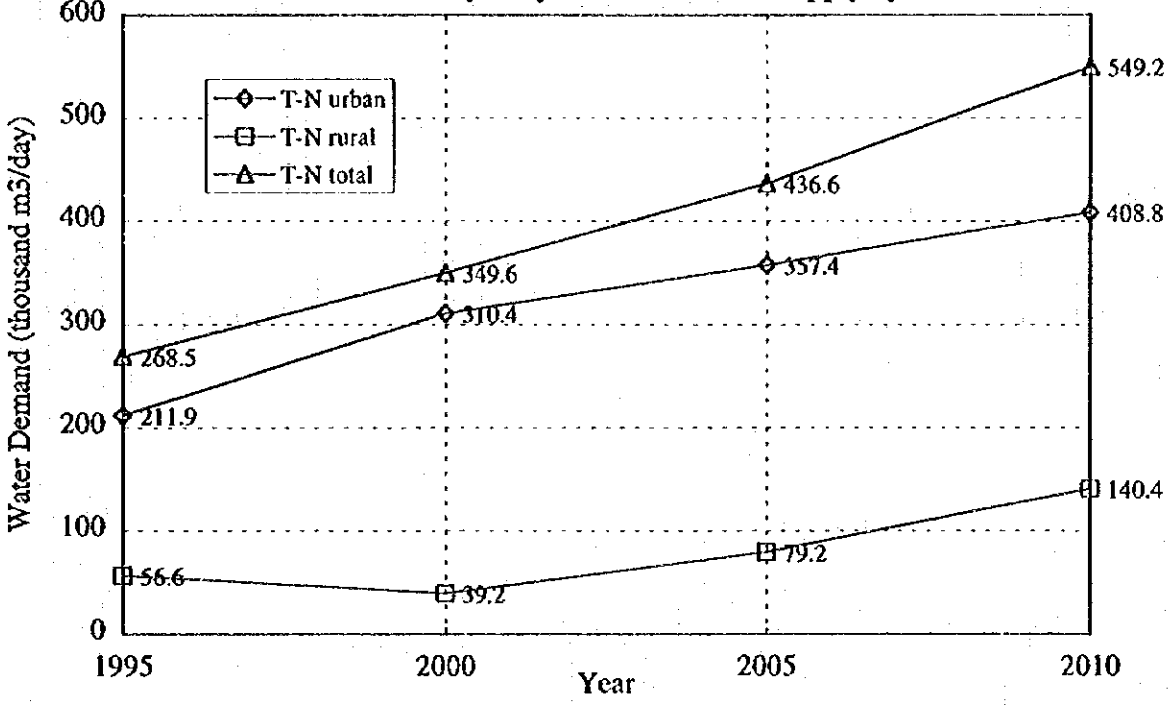
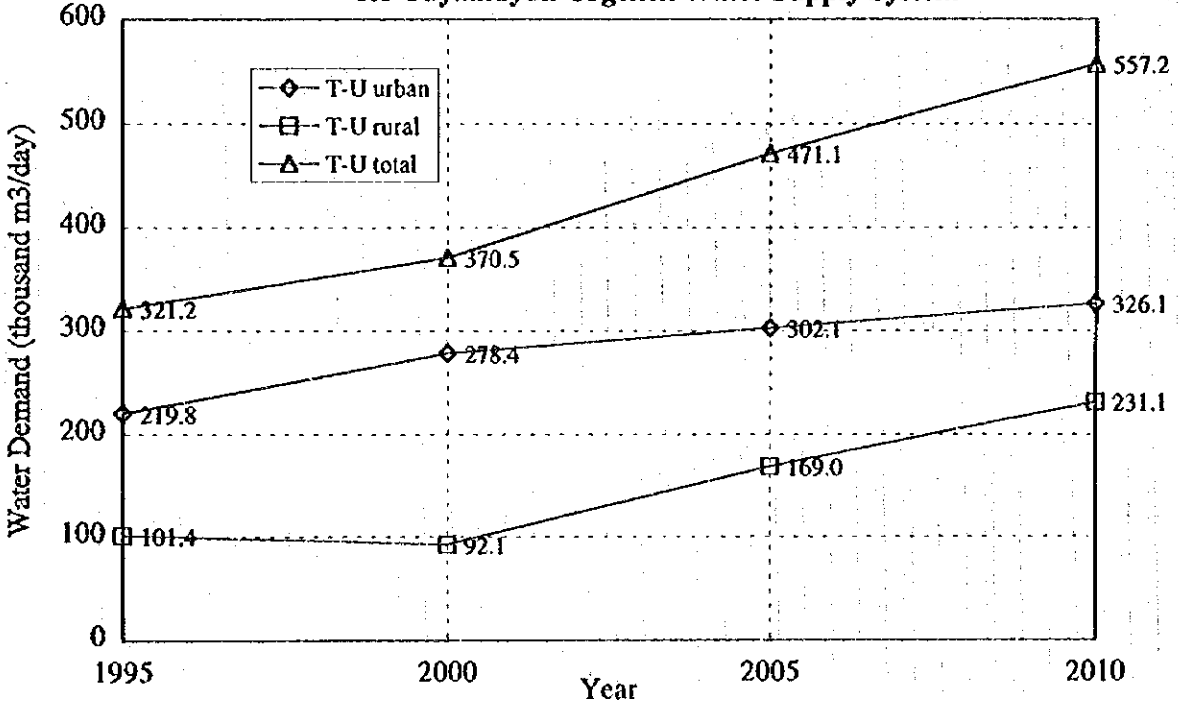


Fig. 4.4 Daily Maximum Water Demand for Tuyamuyun-Urgench Water Supply System



CHAPTER 5

WATER SOURCES AND WATER QUALITY

B/P

CHAPTER 5 WATER SOURCES AND WATER QUALITY

5.1 Introduction

5.1.1 Objectives of the Water Source Study

Sources of drinking water in the Study Area are as follows;

- Main stream of Amu Darya river
- Canals drawn from the main stream of Amu Darya river
- Reservoirs in Amu Darya river
- Ground water

Objectives of the study on the water sources are as follows;

- to review past and current conditions(quantity and quality) of the water sources,
- to study usability of the water sources with respect to quality and quantity as drinking water, and
- to propose countermeasures to problems of water sources used as drinking water.

A study of the following water sources is conducted:

- Surface water
- Groundwater
- Kaparas reservoir

Note : The Kaparas reservoir has been developed to store domestic and drinking water in the Study Area.

5.1.2 Existing Water Source in the Study Six Cities

Water sources in the six cities consist of the three sources mentioned above; main stream of Amu Darya river, canals drawn from the main stream of Amu Darya river and lens ground water. Table 5.1 shows the major water sources of the six cities.

Table 5.1 Major Water Sources in the Six Cities

	Ground water	Surface water	Tuyamuyun water supply	UrgenchTrans Gas water supply	own water sources
Tuyamuyun-Nukus		O	-		Tuyamuyun canal connecting to Tuyamuyun Dam
Tuyamuyun-Urgench		O	-		the left bank main canal
UrgenchTrans Gas water supply		O		-	Amu Darya river directly at Takhiatash
Nukus		O	O		Amu Darya river through Kyzketken canal
Chimbai	O	O	O		lenses located along Kegeili canal for natural / artificial lens
Kungrad		O		O	Amu Darya river through Rafshan canal
Muynak		O			Amu Darya river through Cartabay canal
Urgench	O	O	O		Amu Darya river through Shavat canal and lenses near canals.
Khiva		O			Water is distributed from Urgench water treatment plant.

Note: Circles indicate water sources of the cities.

Among the six cities, Nukus, Chimbai, Urgench and Khiva are mainly supplied by water from the Tuyamuyun water supply system as well as from their own water sources. Kungrad is mainly supplied by water from the UrgenchTransgas water pipeline through VodoKanal, while Muynak depends on its own water sources only.

5.2 Aral Basin and Amu Darya River Basin[1]

5.2.1 Aral Basin

The Aral Basin is situated on the western side of the Pamir Mountains. The rivers in the Aral Basin rise from the glaciers. The discharge of the rivers in the Aral Basin is basically governed by the climatic conditions such as variation in temperature, snowfall and rainfall.

The Aral Sea Basin includes several countries: Uzbekistan, Tadzhikistan, parts of Kazakhstan, Kirghistan, parts of Turkmenistan and parts of northern Afganistan and northeastern Iran. The total area is about 1.8 million km^2. The region has a complicated geomorphology , ranging from the vast Turanian Plain to large mountain ranges. The plains cover about 80 % of the total area of the basin, while the mountains occupy only 20%.

[1] The content of this section mainly depends on the report of "the Review of the Amu Darya Right Bank Collector Drain'.

The climate in the northern parts of the Aral Basin is continental. The southern part has a dry climate. The territory receives considerably more sunshine than any other part of the former USSR. Temperatures during the remarkably long summer are high (average temperature in July is 25 to 33°C). In the winter months however, cold air masses reach this area causing temperatures of -10 to -15°C in January.

On the plains of the Aral Sea Basin, the annual precipitation is 90 to 120 mm. In the Piedmont areas it is 400 to 500 mm while on the western slopes of Tienshang it is more than 2,000 mm. The total precipitation in the region reaches 500 km^3/y. Atmospheric precipitation (100 mm/y) is mostly limited to the influence of humid air masses of the Atlantic Ocean, resulting in an extremely arid climate.

5.2.2 Amu Darya River Basin

The Amu Darya river has the largest river basin in Central Asia with a total area of about 1 million km^2. The Amu Darya river starts at the confluence of two tributaries: Pianj and Vaksh rivers. The length of the river, from the origin of the Pianj to the Aral Sea, is 2,574 km. Measured from the confluence with the Vaksh river, the length is 1,445 km.

The river basin is divided into the mountainous eastern area and the low lying western area with deserts and steppe. The mountainous area has peaks as high as 7,495 m.

The main tributaries of the Amu Darya river are:

- Pianj and Vaksh rivers
- Kundus on the left bank
- Kafringan, Surkhandarya and Sherabed rivers on the right bank

The Pianj and Vaksh rivers contribute to 85% of the river flow and the remaining 15% comes from the other four tributaries. The tributaries Zerafshan and Kashkadarya river, located in the middle reach, do not reach the Amu Darya river anymore and as such do not directly contribute to the river flow.

Major reservoirs in the basin are Nurek in Tadzhikistan on the Vaksh river and Tuyamuyun in the delta. The Nurek reservoir has a total capacity of 10.9 km^3 with a effective storage of 4.5 km^3. For Tuyamuyun, these figures are 7.8 and 5.3 km^3 respectively.

Seasonal regulation is possible with both reservoirs; annual regulation is not possible.

Annual regulation becomes possible once the Rogun reservoir on the Vaksh river in Tadzhikistan is completed. Total and effective storage of this reservoir are 11.8 and 8.6 km^3, respectively.

5.3 Surface Water Sources

5.3.1 Amu Darya River Discharge Characteristics

(1) Inflow and Outflow Mechanisms in the Amu Darya river

The Amu Darya river is being used as the source of water for irrigation, industry and water supply in the Republic of Uzbekistan and surrounding countries. The largest share of the water is for irrigation, accounting for approximately 70%; domestic water supply accounts for approximately less than 10%. Water for these purposes is being supplied through canals. The drain water after irrigating the agricultural land and other drain waters from miscellaneous applications are returned to the river again through irrigation drain canals called collectors. A part of the drain water flows into depressions.

(2) Discharge Characteristics of Main Flow of the Amu Darya River

1) Available Data

About 70 flow observation posts (hydro-posts) have been installed in the Amu Darya river catchment area. Flow rate is periodically measured at these observation posts. The measurements are used to appropriately regulate the flow. However, after the collapse of the former Soviet Union, the Amu Darya river has become an international river flowing through several countries (in the past too, the upper reach formed the national boundary with Afghanistan); flow measurements and flow regulation in all these regions by Uzbekistan alone is becoming a difficult proposition.

The observation posts from which data was collected from Department of Hydrometeorology includes 13 typical hydro-posts[2] in the Amu Darya, Vaksh and Zerafshan (Karadarya) catchment area. Data of monthly average flow from 1966 to 1993 is available.

The data from five observation posts (Kishlak(Kijildzar), Chatli(Sumanbay),

[2] The locations of the 13 hydro posts are given in the Supporting Report.

Tuyamuyun Gorge, Dargonata, Kerki) in the Amu Darya, which have observation records since the last 20 years, were used for the analysis.

2) Overall trend

Table 5.2 shows the maximum, minimum and average values of discharge rates for a period of 28 years (20 years in case of Dargonata) at each observation post in the Amu Darya river. In general, the flow rate becomes smaller as you go downstream; the smallest value was zero at Chatli (Sumambay) at the downstream end for several years. The average discharge rate exceeds 1,000 m^3/sec up to Tuyamuyun, but at Chatli (Sumambay) it reduces to half the value, that is about 500 m^3/sec. Chatli (Sumambay) is not blessed with water resources.

Table 5.2 Discharge Characteristics of Amu Darya River

(unit: m^3/sec)

Location	Maximum	Minimum	Average	Nos. of Year Data	Data used for Calculation
Kishlak (Kijildjar)	3,530	0.0	463	28	1966 to 93
Chatli (Sumambay)	5,360	0.0	543	28	1966 to 93
Tuyamuyun gorge	5,440	69.4	1,196	28	1966 to 93
Dargonata	5,010	204.0	1,162	20	1971 and 75 to 93
Kerki	7,470	312.0	1,531	28	1966 to 1993

Source Department of Hydrometeorology

3) Discharge Characteristics by Month

Fig. 5.1 shows the discharge rate variation by month at five posts in the Amu Darya river. The trend for the entire region shows that the discharge rate during October to March is small; from April onward, water starts increasing because of the melting snow in the Pamir highland, so that in summer, particularly in July, the flow rate reaches its maximum value. Throughout the year, the discharge rate reduces as you go downstream. Especially, in the area downstream of Chatli (Sumambay), the discharge rate reduces sharply.

4) Discharge Characteristics by Year

Fig. 5.2 shows the discharge rate variation by year at five posts in Amu Darya river. Throughout the observed period(for 28 years), the discharge rate variation is small at Kerki located in the midstream part of the river, but becomes large as you go downstream. This trend is pronounced downstream of Chatli (Sumambay); in the sixties and the early seventies, the discharge was comparatively good; but subsequently, it started reducing so that in the eighties the discharge reduced drastically. However, on entering the nineties, the discharge rate shows an increasing trend again.

5) Minimum Probabilistic Discharge Rate

Discharge characteristics in the catchment areas are calculated using the approach of minimum probabilistic discharge rate. Generally, probabilistic methods are effective in analyzing systems dependent on natural phenomena, such as precipitation and natural discharge rate of rivers. In case of the Amu Darya river, natural discharge mechanisms are pronounced in the upstream part of the river; however, in the mid reaches of the river, many irrigation canals take water from the river and water from collectors discharge into the river. These outflows and inflows are not governed by natural phenomena, but controlled by humans. Consequently, the use of the concept of probabilistic discharge rates for river flow in the mid reaches and downstream parts is fundamentally unsound, but since the concept gives flow characteristics in the catchment areas easily, we have used the minimum probabilistic discharge rate approach. If the probabilistic distribution of actual discharge rates is plotted on logarithmic graph paper, a regression straight line is obtained; therefore, it is meaningful to consider probabilistic discharge rates.

If the ratio of occurrence of a discharge rate less than X is once in T years, then T is called the return period of X, and X is called the minimum probabilistic discharge rate for T years. That is, the minimum discharge rate that occurs once in T years is called the minimum probabilistic discharge rate for T years (return period).

Table 5.3 shows the minimum probabilistic discharge rates (2 years, 5 years, 10 years, 15 years, 20 years) for February, July and throughout the year. The minimum discharge rate occurs in February and the maximum discharge rate in July in a year.

Minimum probabilistic discharge rate for 2 years, 5 years, 10 years, 15 years and 20 years are equivalent to exceeding the probability of 50%, 80%, 90%, 93.3% and 95%, respectively.

Table 5.3 Minimum probabilistic discharge rates for the Amu Darya river

(unit : million m³)

Prob. Year	Exceeding (%)	Kishlak		Sumambay		Tuyamuyun	
		Feb.	Jul.	Feb.	Jul.	Feb.	Jul.
2	50	56	402	64	472	419	2,601
5	80	11	59	14	67	260	1,850
10	90	5	22	6	24	203	1,549
15	93.3	3	13	4	14	179	1,417
20	95	2	10	3	10	165	1,337
Prob. Year	**Exceeding (%)**	**Dargonata**		**Ilchik**		**Kerki**	
		Feb.	Jul.	Feb.	Jul.	Feb.	Jul.
2	50	426	2,493	322	2,642	618	3,432
5	80	291	1,770	199	1,780	481	2,559
10	90	238	1,480	154	1,449	423	2,195
15	93.3	215	1,353	136	1,307	396	2,033
20	95	202	1,276	125	1,222	380	1,934

Note : Prob. Year : minimum probabilistic discharge rate for T years (return period)
Exceeding : exceeding probability (%)

(2) Discharge Characteristics of Inflow(Canal) and Outflow(Collector)

1) Discharge Characteristics in Three Typical Discharges of the Amu Darya River

The inflow/outflow mechanisms of canals, collectors and rivers from Verhneamudarya on the Amu Darya river to the Aral Sea is analyzed here. The total number of waterways for inflow/outflow is 96; these are divided into 10 jurisdictions. From these waterways, 34 are outflows from the Amu Darya river; 62 are inflows into the Amu Darya river. Three types of data of flow rates of these waterways have been collected: flow rate in typical drought year (1982), normal flow year (1980), and abundant flow year (1978)[3] of Amu Darya main river.

Table 5.4 shows the monthly inflow, monthly outflow, and the inflow/outflow balance by month. Although more water can be used in an abundant flow year compared to a normal flow year, there is almost no change in the inflow and outflow for these years. On the other hand, comparing the drought year flow with normal year flow the inflow and outflow during the drought year has decreased drastically to less than 10% of a normal flow year. We have considered the inflow and outflow for a normal flow year (1980) here. Table 5.5-(a) and-(b) shows the inflow/outflow divided into eight sections.

[3] Observation data is given in the Supporting Report.

Table 5.4 Monthly Inflow, Outflow and Inflow/Outflow Balance from Verhneamudarya to the Aral Sea

(unit : m^3/sec)

year	1978 The Year of Abundant River Flow			1980 The Year of Normal River Flow			1982 The Year of Drought River Flow		
	Outflow	Inflow	Balance	Outflow	Inflow	Balance	Outflow	Inflow	Balance
Jan.	-947	56	-890	-812	59	-753	-259	4	-255
Feb.	-997	81	-916	-946	62	-883	-284	4	-279
Mar.	-1,338	109	-1,229	-1,374	98	-1,276	-616	7	-609
Apr.	-1,140	105	-1,035	-1,292	133	-1,160	-536	11	-525
May	-1,439	107	-1,332	-1,782	110	-1,673	-722	9	-713
Jun.	-2,395	114	-2,280	-2,528	111	-2,417	-1,230	9	-1,221
Jul.	-3,263	118	-3,145	-3,278	126	-3,152	-788	7	-782
Aug.	-3,086	118	-2,969	-3,013	107	-2,906	-1,300	4	-1,296
Sept.	-1,412	97	-1,315	-1,078	88	-990	-338	4	-333
Oct.	-467	77	-390	-734	57	-677	-20	5	-15
Nov.	-814	47	-767	-830	39	-791	-346	5	-342
Dec.	-876	34	-842	-903	44	-860	-373	7	-366

Note: inflow/outflow Balance =(Outflow)+(Inflow)
Minus(-) indicates the outflow from Amu Darya river.

Table 5.5 -(a) Monthly Outflow Rate from Amu Darya River

(unit : m^3/sec)

Section	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Verhneamudarya - Kelif	8.9	1.0	6.5	14.6	13.4	19.7	19.5	22.2	17.1	11.5	4.7	0.0
Kelif - Mukri	8.0	8.6	12.2	15.5	19.4	24.9	28.9	23.9	15.9	11.3	9.5	11.1
Mukri - Kerki	282.8	337.2	488.3	466.1	494.8	703.8	752.6	709.3	530.1	409.8	289.3	286.9
Kerki - Ilchik	189.0	237.1	256.8	198.6	228.3	422.2	561.0	535.7	312.6	182.5	59.9	22.9
Ilchik - Dargonata	1.2	1.6	2.4	2.3	1.2	2.9	4.1	4.1	2.7	0.02	0.0	0.0
Dargonata - Tuyamuyun	20.8	45.1	91.9	53.3	63.9	104.6	127.7	127.4	20.6	0.6	0.0	1.0
Tuyamuyun - Sumambay	301.4	315.0	515.8	542.2	949.9	1,239.0	1,777.5	1,583.7	179.1	118.0	466.3	581.5
Sumambay - Kijildjar	0.0	0.0	0.0	0.0	11.4	11.0	7.0	6.9	0.3	0.0	0.0	0.0
Total	812.0	945.5	1,373.8	1,292.4	1,782.4	2,528.1	3,278.3	3,013.3	1,078.4	733.7	829.7	903.4

Table 5.5 -(b) Inflow Rate to Amu Darya River

(unit : m^3/sec)

Section	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Verhneamudarya - Kelif	2.6	3.7	5.8	11.6	14.9	9.3	10.6	8.9	7.6	6.7	6.0	2.9
Kelif - Mukri	6.0	4.9	6.5	6.0	6.9	6.2	6.0	5.6	3.3	3.9	5.9	10.9
Mukri - Kerki	3.8	5.0	8.6	10.8	6.8	6.1	12.0	6.5	6.6	3.0	1.2	1.1
Kerki - Ilchik	25.0	22.8	30.5	31.1	28.3	30.8	35.5	32.9	24.6	13.0	6.7	13.5
Ilchik - Dargonata	21.9	25.8	45.7	71.9	52.5	57.4	59.3	51.6	45.4	29.7	18.8	14.9
Dargonata - Tuyamuyun	0.0	0.3	1.0	1.3	0.4	1.6	2.6	1.9	0.9	0.3	0.3	0.3
Tuyamuyun - Sumambay	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sumambay - Kijildjar	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total	59.3	62.4	98.1	132.7	109.8	111.3	125.9	107.3	88.5	56.5	38.8	43.5

Observing the annual outflow rates, the outflow rate between Tuyamuyun Gorge and Sumambay is maximum, followed by outflow rates between Mukri and Kerki, and between Kerki and Ilchik. The outflow rate from Tuyamuyun Gorge-Sumambay is used as irrigation water downstream of the Amu Darya river; the outflow rate from Mukri - Ilchik is used as irrigation water in the mid reaches. By month, the outflow rate is maximum during summer, particularly in July.

Observing the annual inflow, the inflow between Ilchik and Dargonata is maximum, followed by the inflow between Kerki and Ilchik. These inflows are from the irrigation drain waterways at the mid reaches of the Amu Darya river. By month, the maximum and the following maximum flow is observed in the months of April and July, respectively.

The ratio of total inflow to total outflow is seen to be 6%; almost all the water used for irrigation does not return to the Amu Darya river. A major part of the water that does not return to the river is irrigation water that seeps underground; however, excessive evaporation in dry, desert climate, leakage from waterways that are not waterproof, flow of drain water after irrigation into natural depressions, and man-made inflows into lakes should also be considered as reasons for the water not returning to the river.

2) Outflow and Inflow trend during 1974 to 1993

Fig. 5.3 -(a) and -(b) show the annual trend of canal outflow rate from the Amu Darya river and collector inflow rate into the Amu Darya river in 1976 to 1993 by three sections: Tuyamuyun - Kerki, Kerki - Tuyamuyun and Tuyamuyun - Sumambay. According to the figures increasing trend with respect to the canal flow is not seen in

spite of expansion of irrigation land, but a slightly increasing trend with respect to the collector flow is observed. This increase probably indicates that wash out water for the irrigation land has increased because of land deterioration by salt.

Fig. 5.4 -(a) and -(b) show the monthly flow trend of water in canals and collectors during 1976 to 1993 by the three sections stated above. The flow rate in canals become maximum during summer, particularly in July. Regarding the collector flow there are two peaks in spring and summer. The first peak perhaps indicates water increase for washing out irrigation land. On the other hand, the second one probably indicates an increase in the irrigation water.

5.3.2 Water Quality in Amu Darya river

(1) General

The Amu Darya river water is utilized mainly for irrigation; and supplies water to agricultural land and washing out salt from salt-damaged agricultural land after irrigation. The drain water after the irrigation is returned to the river again through irrigation drain canals called collectors, whose water has been reported to be deteriorated by agro-chemicals and high salinity.

The use of domestic and drinking water, whose volume is quite small compared to that for irrigation use, is taken directly from irrigation canals and the main stream of the Amu Darya river or an aquifer where the water has infiltrated from a canal and mainstream. Therefore the quality of the water in the Amu Darya river is especially important for inhabitants in the region.

Water quality standards for domestic and drinking purpose and surface water for domestic and drinking purpose are shown in section 5.6.

(2) Pollution Sources in the Amu Darya river

Pollution in the Amu Darya river is due to the discharge of the collector drains as stated above, most of which are located in middle and down stream parts of the Amu Darya river, especially, Bukhara and Kashkadarya regions.

These regions have one of the largest agricultural land area in the Amu Darya river basin, taking irrigation water from the Amu Darya river and discharging the polluted water after irrigation and washing out salty soil into the Amu Darya river. In ninety percent of the agricultural land in Bukhara, it is necessary to wash out the salts.

The local laboratory of the SCNP and the other related agencies are monitoring the water quality of rivers, canals and waste water from factories. Table 5.6 shows the current quality of collector water and Zerafshan river water in the Bukhara region. High mineralization (or dry residue) of more than 3,000 mg/l was observed in collectors. Almost all water quality values also exceed the standards.

Table 5.6 Water Quality of Collector Drains and Zerafshan River in the Bukhara Region

(unit : mg/l)

	RW Standard	Parallel collector	Djandal Bridge	Northern Collector	Zerafshan (Gidzhuvan- bri.)
Dissolved Oxygen	>4		8.4		9.4
BOD_5	3.0	5.0	1.4		3.0
NH_3-N	2.0	3.5	1.5		0.2
Dry Residue (Mineralization)	1,000	4,040.5	3,385	3,108.5	1,340
NO3-N	10	12.0			12.4
NO2-N	1	0.3	0.09		0.09
Chlorides	350	709	357	417	89.0
Sulfates	500	1,825	1,450.3	1,488	384.2
Ca	-	200.4	204.4	220.4	72.1
Mg	-	370	183.5	311	53.5
Na	-	559	488	317	191
Bicarbonate alkalinity	-	6.8	6.6	7.0	3.6
Carbonate alkalinity	-			0.6	0.2
Hardness (meq/l)	7	40.5	25.5	36.5	8.0

Source : Bukhara SCNP laboratory
Note : RW standard indicates standard of river water for drinking purpose in Uzbekistan.

Table 5.7 shows the past trend of mineralization of the South Collector drain. Until 1977 it was more than 10 g/l and declined sharply in the late seventies. Since the beginning of the eighties it has become stable at a level of about 7 g/l.

Table 5.7 Mineralization of the South Collector Drain

year	1974	75	76	77	78	79	80	81	82
mineralization(g/l)	13.0	11.4	10.3	10.4	9.0	8.3	8.0	8.0	7.4
year	83	84	85	86	87	88	89	90	91
mineralization(g/l)	6.7	6.8	6.4	7.7	7.3	7.0	7.4	6.8	7.7

Source: The report of "Right Bank Collector Drain"

The average mineralization concentration of the major collector drains is shown in Fig. 5.5 -(a) for the years 1990 to 1994, and for two sections of Termez - Kerki and Kerki -

Tuyamuyun. Fig. 5.5 -(b) shows annual mineralization volume during the same years and for the same sections. The mineralization concentration evidently decreases. Nevertheless, the total mineralization volume are rather constant. These relations are due to the increase in the discharge rates of the collectors. The above figures show yearly trends. On the other hand, Figs. 5.6 -(a) and -(b) show monthly data for the years 1990 to 1994.

In addition to high mineralization concentration, the collector drains probably discharge the water polluted by agro-chemicals to the Amu Darya river, although their data could not be collected,. These agro-chemicals, which adversely affect the health of human beings, should be monitored.

(3) Water Quality of the Amu Darya River

What quality indicators to be watched in this regions are mineralization and total hardness, whose concentrations are extremely high. High mineralization, it is said, adversely affects the health of human beings. Therefore, water quality is mainly reviewed for mineralization and hardness here. In addition, agro-chemical compounds, which may have large concentration in the water sources, should be reviewed. However, The data of agro-chemical compounds in the Study Area is limited. The JICA Study Team analyzed them, whose results are shown in the section 5.7. In this section, mineralization and total hardness are reviewed especially in detail. Uzbekistan's standards for maximum allowable concentration (MAC) of mineralization and total hardness are 1,000 mg/l and 7.0 meq/l respectively.

Based on analyzed data by the JICA Study Team and GosSIAK, evaluation results for other indicators except for mineralization and total hardness are shown in section 5.7.

Mineralization and Total hardness

Table 5.8 -(a) and -(b) show maximum, average and minimum of monthly mineralization and total hardness concentrations at four sites in the middle and down stream parts of the Amu Darya river, respectively. In general, it is observed that their concentrations downstream are lower than upstream, and the concentrations in summer, which are less than the standard, are lower than in other seasons.

Table 5.8 -(a) Maximum, Average and Minimum Monthly Mineralization in the Amu Darya River

(unit: mg/l)

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Termez	Max.	978	1,356	1,323	1,363	962	960	750	701	786	990	910	962
	Ave.	718	788	784	821	632	545	450	468	503	634	710	674
	Min.	520	590	568	563	433	364	304	321	365	329	474	528
Nos. of Year		14	17	18	18	18	19	19	19	19	16	16	14
Tuyamuyun	Max.	1,162	1,373	1,618	2,147	1,505	1,129	1,042	946	980	1,469	1,418	1,054
	Ave.	1,044	1,156	1,277	1,295	1,009	797	675	639	702	912	973	930
	Min.	907	1,030	889	832	678	561	442	462	504	578	738	859
Nos. of Year		4	4	20	18	21	20	20	20	15	14	17	3
Sumâmbay	Max.	1,836	1,706	2,170	2,312	1,691	1,764	1,176	889	1,568	1,339	2,111	1,534
	Ave.	1,138	1,144	1,156	1,412	1,250	924	709	641	800	884	1,097	1,074
	Min.	795	727	518	726	654	557	447	400	547	257	801	756
Nos. of Year		18	18	19	18	19	19	20	20	21	20	18	19
Kijildjar	Max.	942	1,642	1,833	2,344	1,130	1,917	2,157	1,477	1,047	1,886	1,646	1,259
	Ave.	942	1,131	1,126	1,472	1,057	985	918	850	821	988	1,001	1,100
	Min.	942	699	800	421	929	481	432	499	659	658	638	941
Nos. of Year		1	18	21	20	3	19	19	11	10	18	18	2

Note: This is the summary of the data from Goskompriroda
Nos. of year is the number of available annual data.
Date is for twenty years, from 1974 to 1993

Table 5.8 -(b) Maximum, Average and Minimum Monthly Total Hardness in the Amu Darya River

(unit: mg/l)

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Termez	Max.	13.1	10.4	11.4	12.6	9.6	9.3	6.9	7.1	9.7	9.9	10.4	10.0
	Ave.	7.3	7.5	7.3	7.5	6.2	5.4	4.4	4.4	5.1	6.3	6.8	6.7
	Min.	5.7	5.4	5.6	5.4	4.5	3.6	3.1	3.2	3.7	4.7	4.9	5.0
Nos. of Year		14	17	17	18	18	19	19	19	19	16	16	14
Tuyamuyun	Max.	8.2	10.8	14.2	15.3	11.6	11.8	11.0	8.6	9.7	11.1	11.5	8.5
	Ave.	8.0	9.3	10.8	11.4	8.6	7.1	6.1	5.8	6.8	8.1	8.9	7.7
	Min.	7.7	8.2	7.9	6.0	5.9	3.7	4.0	4.4	4.7	5.5	6.6	7.0
Nos. of Year		3	3	19	18	21	20	20	20	16	12	15	4
Sumambay	Max.	14.4	14.9	16.8	22.6	18.2	14.4	11.8	27.9	13.9	21.5	12.7	12.1
	Ave.	10.1	10.7	10.9	13.1	11.2	8.3	6.7	7.2	7.6	8.8	9.5	9.6
	Min.	7.4	7.0	4.9	6.6	6.7	5.6	4.1	4.5	4.5	5.7	6.8	6.9
Nos. of Year		18	17	17	17	17	19	18	19	20	20	17	16
Kijildjar	Max.	8.6	13.4	27.5	19.4	10.9	18.6	16.5	12.8	9.2	12.4	12.2	8.4
	Ave.	8.6	10.2	10.7	13.0	9.1	8.9	8.0	7.5	6.7	8.0	8.9	8.4
	Min.	8.6	6.6	6.6	5.3	8.0	4.7	3.8	4.3	5.1	5.6	6.8	8.4
Nos. of Year		1	18	21	19	3	19	20	11	10	17	18	1

Note: This is the summary of the data from Goskompriroda
Nos. of year is the number of available annual data.
Data in 1974 to 1993 is used.

Table 5.9 -(a) shows monthly mineralization concentrations at four sites in March and July from 1974 to 1993. The concentrations in March and July are considered to represent usually the worst and best quality throughout a year, respectively. In March, the mineralization concentrations at the three sites except Termez, exceeded the

standard. While in July, the mineralization concentrations for almost all years except in the late eighties and at all sites are below the standards. Since the beginning of the nineties, the mineralization in July has remained below the standard. Average mineralization in July increases as the river goes down but in March the value for Tuyamuyun was highest. The highest value at Tuyamuyun are probably caused by the fact that water is stored in Tuyamuyun Hydro-Unit during winter season for the irrigation purpose in spring.

Table 5.9 -(b) shows monthly total hardness at four sites in March and July from 1974 to 1993. The general trend of total hardness is similar as that of mineralization. As seen in the percentage of the number of years that meet the standards, the total hardness concentration is more severe than mineralization.

Table 5.9 -(a) Mineralization Concentration at four Sites in the Amu Darya River in March and July

(unit : mg/l)

	March				July			
	Termez	Tuyamuyun	Sumambay	Kijildjar	Termez	Tuyamuyun	Sumambay	Kijildjar
1974	-	1,530	-	875		688	-	-
1975	-	1,330	518	948		442	483	768
1976	1,323	1,519	-	1,116	650	665	731	-
1977	760	1,205	906	864	328	551	564	765
1978	694	1,618	1,350	1,177	452	867	660	432
1979	698	1,312	1,108	975	377	552	576	701
1980	726	-	1,236	986	396	565	617	673
1981	809	1,470	2,170	1,833	399	543	691	1,504
1982	805	1,284	1,463	1,369	507	837	910	1,863
1983	807	1,482	1,112	1,385	389	1,042	1,065	1,480
1984	666	1,318	1,345	1,324	377	552	638	602
1985	614	1,076	1,033	969	474	791	772	1,116
1986	721	1,236	1,340	1,675	377	609	1,176	2,157
1987	675	1,231	1,019	1,162	304	605	743	559
1988	568	1,117	953	883	335	801	447	761
1989	864	1,185	1,113	1,085	437	1,010	810	1,104
1990	891	1,323	1,110	1,056	339	533	618	618
1991	-	889	810	800	750	597	648	450
1992	687	919	1,037	907	445	618	669	698
1993	889	1,159	1,224	1,154	597	-	641	660
1994	919	1,331	1,111	1,104	618	633	713	530
Ave.	784	1,277	1,156	1,126	450	675	709	918
%*	95	10	21	43	100	90	90	74

Note: Standard for maximum allowable concentration for mineralization is 1,000 mg/l.
* Percentage of the number of mineralization below the standard.

Table 5.9 -(b) Total Hardness Concentration at four Sites in the Amu Darya River in March and July

(unit : meq/l)

	March				July			
	Termez	Tuyamuyun	Sumambay	Kijildjar	Termez	Tuyamuyun	Sumambay	Kijildjar
1974	-	10.8	-	6.6	-	5.3	-	7.2
1975	-	13.7	4.9	6.6	-	4.0	4.1	6.5
1976	7.8	14.2	-	9.8	5.2	6.4	-	-
1977	6.4	9.6	6.7	6.8	3.1	4.5	5.0	6.6
1978	5.6	11.6	-	9.3	3.2	7.1	5.6	5.8
1979	6.2	10.9	10.0	8.8	3.7	4.2	5.0	5.9
1980	6.7	-	-	8.3	3.5	4.7	-	5.2
1981	6.2	7.9	16.8	14.5	3.4	4.5	5.8	11.8
1982	6.6	10.1	11.2	10.5	3.9	6.6	6.3	13.9
1983	6.2	10.0	8.7	27.5	4.1	8.4	9.3	12.1
1984	5.9	7.9	9.9	9.6	3.9	4.5	5.9	5.1
1985	5.6	8.5	8.8	7.8	4.9	5.9	6.8	7.9
1986	5.6	9.9	12.9	13.2	3.8	4.8	9.2	16.5
1987	7.6	13.3	13.0	13.1	3.9	6.8	9.4	6.0
1988	7.0	11.2	11.8	10.6	4.2	10.3	4.8	9.2
1989	10.7	14.2	14.4	13.1	5.8	11.0	8.7	13.5
1990	11.4	12.8	14.5	10.6	4.9	6.6	7.1	6.7
1991	-	9.2	9.9	8.7	4.7	6.9	11.8	3.8
1992	8.9	-	12.3	9.8	4.8	5.1	5.6	5.6
1993	9.2	9.3	10.1	10.1	6.9	-	5.5	5.9
1994	-	10.4	9.4	8.7	5.1	4.8	5.5	5.7
Ave.	7.3	10.8	10.9	10.7	4.4	6.1	6.7	8
%*	61	0	17	18	100	86	68	62

Note: Standard for maximum allowable concentration for Total Hardness is 7.0 meq/l.
* Percentage of the number of Total Hardness below the standard.

5.3.3 Relationship between Mineralization and Discharge Rate of the Amu Darya River

Fig. 5.7 -(a) and -(b) show the relationship between discharge rate and mineralization concentration in the Amu Darya river at Tuyamuyun gorge during 1974 to 1993. The annual variation in concentrations apparently have the same seasonal trend, fluctuating with the discharge rate. The concentrations are low when discharge rate is high. Especially in the summer when the discharge rate is high, the concentrations are lower than in the other seasons. Generally, the months when the concentration is less than the standards are June, July, August and September. From these, August has the best

quality.

It is difficult to explain the relationship between water quality and discharge rate. The relationships are probably as described here. The relationships are shown in Fig. 5.8 -(a) and -(b) for months between 1974 and 1994 at Tuyamuyun and Sumambay. At Tuyamuyun, mineralization is high, exceeding the standard of 1,000 mg/l and discharge rates are less than 1,250 m^3/s in March and April. In May, discharge rates increase and mineralization decreases. Discharge rates further increase in June and July and mineralization decreases. In August, the discharge rate hits the peak and mineralization becomes minimum. Mineralization is also low in September although discharge rate is lower than in August. Mineralization increases in October and November because the discharge rate decrease. At Sumambay, similar relations are observed.

Further study and data, especially on pollution sources upstream of Tuyamuyun is necessary for analyzing in detail the relationship between discharge rate and mineralization.

5.3.4 Study on Potential Drinking Water Sources

This section analyses the question of whether the Amu Darya river can be used as a water source for the water supply system. The two points at Tuyamuyun, where Kaparas reservoir is located, and at Sumambay are considered in this study, considering the existing intake points, future possible intake points and availability of data.

1) Tuyamuyun (Kaparas reservoir)
The Kaparas reservoir is an intake point planned as domestic and drinking water source for Karakalpakstan and Khorezm in the Water Supply Master Plan by the Uzbeki side and in this Study, as stated in the Chapter 8. It is located in the upper reaches of the Study Area.

2) Sumambay
i) intake point of Kyzketken canal from where the Nukus water supply system takes water.
ii) close to Takhiatash where water is taken for the water supply system on the left bank area of the Amu Darya river.

The two points above are considered to represent the quality of water in the entire Amu

Darya river in the Study Area, except Muynak.

Statistical methods are used for the analysis in this section. Here, analysis is mainly conducted based on non-exceeding probability.

(1) Study on Water Quality

1) Study Procedure

Analysis is conducted using the following procedures :

1. Building of water quality estimation model in the river system
2. Verification of the model
3. Estimation of water quality using the model

Mineralization is severe in the Study Area so it is selected as the item to be estimated. Besides, data of water quality indicators other than mineralization is not inadequate for constructing a model. Here, a simple model is constructed because of limited data.

Non-exceeding probabilities of 90 % and 75 % are used for the analysis. For reference, in Japan, the quality of river water should comply with the standards for more than 275 days a year, that is, water quality is evaluated based on 75 % non-exceeding probability.

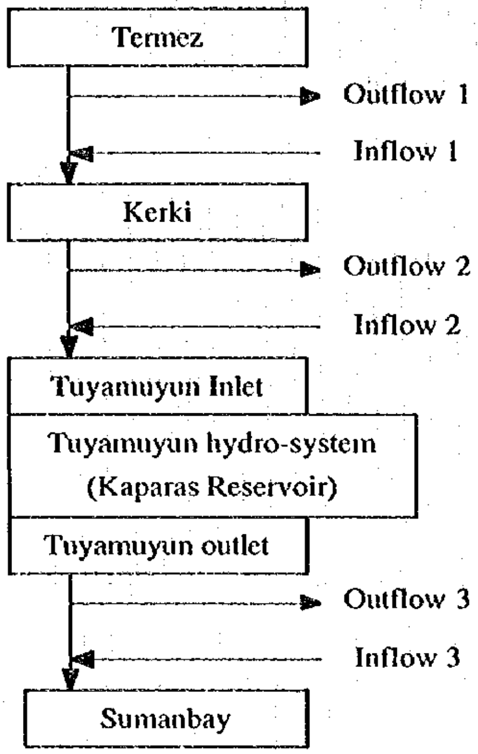
In the Amu Darya river, monthly variations in discharge and quality are very large. Consequently, water quality estimation is conducted by constructing the model by month.

2) Concept of Model

i) River Model

The model as shown in below consists of 1) flow rate in the river, 2) outflow rate from the river , 3) inflow rate to the river and 4) storage. In the model, four base points are selected; Termez (where collector drains increase rapidly), Kerki, Tuyamuyun hydro-system inlet (or Dargonata), Tuyamuyun hydro-system outlet and Sumambay. Between the base points, one inflow and one outflow is assumed in the model.

Amu Darya river Water Quality Balance Model



ii) Mineralization Balance

Total mineralization volumes between the neighboring base points are balanced in the model. For example, the mineralization volume at Kerki equals that at Termez, the neighboring upper base point, plus inflow and minus outflow between the two points.

In the Tuyamuyun hydro -unit, water is regulated for irrigation use. Mineralization is also balanced within the system.

iii) Water Quality Model

First, flow rates are balanced at all points. That is:
- Assume discharge rate of Amu Darya river at the all points based on the past records.
- Then, assume inflow rates.
- Finally, assume outflow rates.

If water volumes are not balanced, outflow rates are adjusted to obtain water balance.

Mineralization is then assumed as follows :

- Assume mineralization concentration at Termez.
- Assume that mineralization concentrations of inflows are the same as in the past by base point.
- Assume that mineralization concentrations in the outflow are the same as those at the upper base points.

3) Conditions of the Model

The flow rates and mineralization concentrations used in the model are explained below.

i) Outflow Rate from the Amu Darya River

Non-exceeding probability of 75 % (see Table 5.10) is used in the model. The flow rates do not increase in the past, as shown in the section 5.3.2(2), and consequently, are considered to not increase in the future.

Table 5.10 Characteristics of Monthly Outflow Rate of Canals by Month

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Termez-Kerki												
90%	39.9	43.6	56.1	57.8	62.0	80.4	68.6	71.5	54.8	47.0	47.2	45.5
75%	37.5	39.8	45.5	51.9	58.1	65.7	66.5	67.1	51.3	41.9	43.4	35.3
50%	25.5	34.7	39.2	40.9	44.4	55.1	63.5	62.4	46.9	40.1	33.9	28.4
Kerki-Tuyamuyun												
90%	34.4	32.3	40.4	33.1	40.9	78.7	68.2	68.7	38.3	17.7	7.0	9.2
75%	29.3	31.8	32.0	31.9	38.8	59.6	63.3	61.1	36.1	15.8	5.5	6.1
50%	22.7	27.8	27.8	22.1	26.5	50.1	58.5	56.8	29.3	15.3	4.8	4.5
Tuyamuyun-Sumambay												
90%	53.8	46.0	77.3	84.6	114.4	137	167	150	63.5	47.1	48.9	74.5
75%	36.7	34.5	65.6	51.2	96.6	108	149	139	35.9	39.4	42.8	57.9
50%	26.0	27.2	44.6	45.5	80.2	99.4	132	131	32.0	17.0	34.9	48.7

Note : 1) These values are estimated based on monthly canal outflow rate during 1976 and 1993.
2) The first column is non-exceeding probability.

ii) Inflow Rate and Mineralization Concentration of Inflow

Flow rates and mineralization concentrations are averaged between 1990 and 1993 (see Table 5.11) and used in the model. The mineralization volumes of inflows are kept constant. They have not increased as shown in section 5.3.2(2) but rather have decreased, although slightly. In practice, they are expected to decrease as the RBCD (Right Bank Collector Drain) project further continues.

The average mineralization between the Termez base point and the Tuyamuyun base point is used between Tuyamuyun and Sumambay where mineralization data is not available.

Table 5.11 Collector Drain Flow Rate and Mineralization Concentration

	unit	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Termez - Kerki													
outflow rate	m^3/s	13.6	15.3	23.4	27.8	22.3	21.8	19.4	18.5	15.9	15.9	14.9	18.1
mineralization	g/l	5.7	6.1	4.3	3.7	3.2	2.7	2.5	2.9	3.1	3.0	3.8	4.5
Kerki - Tuyamuyun													
outflow rate	m^3/s	54.4	70.6	98.7	92.7	64.1	64.6	59.5	55.7	51.2	60	50.8	43.3
mineralization	g/l	4.9	4.9	4.9	4.9	5.7	5.8	5.8	6.0	5.9	6.2	6.0	6.8
Tuyamuyun -Sumambay													
outflow rate	m^3/s	9.3	18.5	38.2	41.7	28.9	28.9	40.5	41.7	33.6	22	13.9	12.7

Note : These outflow rates and mineralization concentrations are average values for 1990 to 1993.

4) Verification

The model is calibrated against the flow rates in the years 1980, and 1990 for verification. The estimated water quality is adequate judging from the observed mineralization concentration. The values are computed in Tables 5.12 and 5.13 -(a) and -(b). Therefore, the model can be used for estimation of mineralization concentration.

Table 5.12 Mineralization Estimation in 1990

unit: Flow (million m^3), Mineral.(g/l)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Termez												
Flow	107.6	97.4	82.9	110.3	251.6	290.1	287.4	222.3	162.7	122.5	100.8	111.6
Mineral.				0.84	0.53	0.43	0.34	0.37	0.51	0.62	0.70	0.67
Outflow 1												
Flow	34.3	31.9	34.2	46.3	58.4	68.3	68.1	67.0	46.9	40.5	45.0	44.2
Inflow 2												
Flow	1.2	1.9	2.5	3.2	2.1	2.0	1.9	1.9	1.7	1.4	1.2	1.5
Mineral.	**7.1**	**5.9**	**4.9**	**4.2**	**3.5**	**3.0**	**3.0**	**3.0**	**3.9**	**2.9**	**4.8**	**5.5**
Kerki												
Flow	74.5	67.4	51.2	67.2	195.3	223.8	221.2	157.2	117.5	83.4	57.0	68.9
Mineral.				**0.97**	**0.56**	**0.45**	**0.36**	**0.40**	**0.55**	**0.65**	**0.77**	**0.76**
Outflow 2												
Flow	27.2	32.2	27.8	26.7	39.6	59.5	63.1	58.3	36.0	15.4	5.5	5.3
Inflow 2												
Flow	4.2	9.8	12.3	9.5	8.4	7.1	6.5	6.4	6.1	5.5	4.9	3.9
Mineral.	**5.6**	**5.4**	**5.3**	**5.5**	**7.5**	**6.9**	**6.8**	**7.2**	**7.0**	**6.7**	**5.7**	**5.0**
Tuyamuyun Inlet												
Flow	51.5	45.0	35.7	50.0	164.1	171.4	164.6	105.3	87.6	73.5	56.4	67.5
Mineral.				**1.71**	**0.89**	**0.69**	**0.59**	**0.75**	**0.95**	**1.08**	**1.19**	**1.00**
Tuyamuyun Outlet												
Flow	39.5	66.7	66.3	53.3	140.9	150.6	168.5	140.1	93.9	76.1	40.5	33.0
Mineral.						**0.72**	**0.62**	**0.72**	**0.94**	**1.08**	**1.19**	**1.03**
Outflow 3												
Flow	34.4	65.8	67.0	54.1	133.8	126.8	137.0	112.5	63.4	41.5	20.1	10.7
Inflow 3												
Flow	0.7	2.0	3.2	3.3	2.3	1.9	2.5	2.8	1.5	1.1	0.9	0.9
Mineral.	**5.6**	**5.4**	**5.3**	**5.5**	**7.5**	**6.9**	**6.8**	**7.2**	**7.0**	**6.7**	**5.7**	**5.0**
Sumambay												
Mineral.						**0.80**	**0.71**	**0.85**	**1.04**	**1.16**	**1.29**	**1.14**

Note: Mineral. indicates mineralization concentration.
Bold values are the estimated mineralization concentrations.

Table 5.13 -(a) Comparison between estimated and observed mineralization concentrations in 1990

(unit : g/l)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Kerki												
estimated	1.06	0.97	1.05	0.97	0.56	0.45	0.36	0.40	0.55	0.65	0.77	0.76
fact	-	-	-	-	-	-	-	-	-	-	-	-
Tuyamuyun Outlet												
estimated	1.21	1.44	1.81	1.73	0.92	0.72	0.62	0.72	0.94	1.08	1.19	1.03
fact	-	-	1.32	1.10	0.84	0.69	0.53	0.53	0.72	0.69	0.80	
Sumambay												
estimated	1.40	1.79	2.30	2.39	1.23	0.80	0.71	0.85	1.04	1.16	1.29	1.14
fact	1.07	1.03	1.11	1.21	1.54	0.57	0.62	0.61	1.01	0.80	0.85	0.96

Table 5.13 -(b) Comparison between estimated and observed mineralization concentrations in 1980

(unit : g/l)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Termez (fact)	-	0.79	0.73	0.74	0.54	0.42	0.4	0.38	0.41	-	0.81	-
Kerki												
estimated	-	0.90	0.81	0.79	0.57	0.44	0.42	0.40	0.46	-	0.86	-
fact	-	-	-	-	-	-	-	-	-	-	-	-
Tuyamuyun	Outlet											
estimated	-	-	-	1.06	0.84	0.66	0.64	0.67	0.76	-	-	-
fact	-	-	-	1.42	0.94	0.87	0.57	0.62	0.76	-	-	-
Sumambay												
estimated	-	-	-	1.06	0.84	0.66	0.64	0.67	0.76	-	-	-
fact	-	-	-	1.11	1.21	0.93	0.86	0.58	0.62	-	-	-

5) Estimation of Mineralization Concentration

Mineralization concentration is estimated by using the model. Table 5.14 shows the estimated mineralization in drought flow and low water flow.

Table 5.14 Drought and Low Water Flow Rate of Amu Darya River

(unit: m³/s)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Kerki												
drought flow	569	524	528	748	863	1681	2230	1819	606	429	530	622
Low water flow	645	560	593	846	1515	2050	2785	1890	793	595	609	692
Dargonata												
drought flow	356	230	319	525	513	1230	1550	1310	473	296	466	524
Low water flow	421	324	355	691	1041	1405	2110	1620	587	487	559	602
Tuyamuyun												
drought flow	356	230	319	525	513	1230	1550	1310	473	296	466	524
Low water flow	421	324	355	691	1041	1405	2110	1620	587	487	559	602
Sumambay												
drought flow	0	0	0	0	0	3	6	6	106	10	5	0
Low water flow	12	12	2	6	8	21	21	45	159	159	41	10

Mineralization concentrations are estimated at the Tuyamuyun Hydro-Unit outlet and at Sumambay for the four cases below.

Case	River water balance model	Mineralization concentration at Termez by non-exceeding probability
1	drought flow	90%
2	drought flow	75%
3	low water flow	90%
4	low water flow	75%

Case 1 is the most severe case, with non-exceeding probabilities in both flow and quality reaching 90 %, which is rare in practice. The estimated mineralization concentrations are shown in Table 5.15.

Table 5.15 Results of Estimated Mineralization Concentrations

(unit: g/l)

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.
Tuyamuyun												
Case 1	1.55	1.82	2.06	2.01	1.79	1.18	0.9	0.96	1.21	1.59	1.54	1.48
Case 2	1.42	1.68	1.95	1.79	1.62	0.95	0.77	0.8	1.1	1.44	1.44	1.35
Case 3	1.48	1.78	2.05	1.92	1.34	1.14	0.88	0.94	1.11	1.41	1.43	1.40
Case 4	1.35	1.65	1.95	1.66	1.18	0.91	0.74	0.78	1.00	1.25	1.32	1.27
Sumambay												
Case 1	1.64	2.02	2.27	2.28	1.94	1.34	1.06	1.14	1.67	1.89	1.70	1.62
Case 2	1.52	1.89	2.17	2.08	1.77	1.11	0.94	0.99	1.57	1.75	1.61	1.50
Case 3	1.56	1.95	2.23	2.15	1.48	1.27	1.02	1.09	1.49	1.61	1.56	1.52
Case 4	1.43	1.82	2.14	1.91	1.32	1.05	0.88	0.94	1.39	1.46	1.46	1.4

From the estimation results, water in the Amu Darya river is evaluated as shown in Table 5.16. The maximum allowable standard mineralization concentration in the Uzbekistan is taken as 1.0 g/l

Table 5.16 Evaluation Results of Surface Water Source as Drinking Water

Case	Tuyamuyun	Sumambay
1	Mineralization during July and August comply with the standard	Mineralization through a year dose not comply with the standard
2	Mineralization during June to August comply with the standard	Mineralization during July and August comply with the standard
3	Mineralization during July and August comply with the standard	Mineralization through a year dose not comply with the standard
4	Mineralization during June to August comply with the standard	Mineralization during July and August comply with the standard

(2) Water Quantity Study

As stated in previous section, mineralization concentrations of Amu Darya river complies with the standard for three months from June to August at Tuyamuyun(Kaparas reservoir) and for two months from July and August at Sumambay, respectively.

With this water quality condition of water source, the best way to use the surface water for drinking purpose is to store the river water during the months when good-quality water is available. In this section, the potential discharge amount to be stored during the above-mentioned months at the Kaparas reservoir and Sumambay point is studied.

1) Kaparas Reservoir

The minimum probabilistic discharge rate of the Amu Darya river at Kaparas reservoir in June, July and August and their total discharge volumes during the three months are shown in Table 5.17. This discharge rate becomes maximum in July, followed by high rates in June and August. About 10,000 million m^3 in total for the three months for the 10-year probability can be stored at the Kaparas reservoir, neglecting the volume required for irrigation canals in the downstream area.

Table 5.17 Minimum Probabilistic Discharge Rates and Total Discharge Volume at Tuyamuyun

(unit : m^3/sec)

Probability year (return period)	Jun. (m^3/sec)	Jul. (m^3/sec)	Aug. (m^3/sec)	Total discharge volume for the three months (million m^3)
2	2,012	2,601	2,068	17,317
5	1,315	1,850	1,510	12,117
10	1,052	1,549	1,281	10,062
20	876	1,337	1,118	8,635

Note : Based on the monthly data from 1966 to 1993

Table 5.18 shows characteristics of the irrigation canal outflow rates for the Amu Darya river downstream of Tuyamuyun. Although there are a few collector drains downstream of Tuyamuyun, their flow rates to the Amu Darya river are negligible compared to that of irrigation canals. The Amu Darya river and canals have a discharge amount level of the order of billion or ten billion m^3.

Table 5.18 Canals' Outflow Rates Downstream of Tuyamuyun

(unit: million m^3)

	Total discharge volume for the three months
Maximum	14,151
Average	10,385
Minimum	5,406

Note: Based on the monthly canal outflow rate from 1976 to 1993.

The maximum stored capacity of 680 million m^3 for the Kaparas reservoir (see section

5.4) is about 5.6% of the discharge volume of Amu Darya river for the 5 -year probability. This capacity is also extremely small compared to the outflow rate of the downstream canals. Consequently, even when the probability year increases and the outflow rate of the Amu Darya river decreases, an adequate quantity of water supply can be assured if the water at the downstream end is utilized efficiently.

(2) Sumambay

If a reservoir is used as water sources in this area, a simple check should be made to verify the volume of water that can be stored for the above-mentioned months.

The minimum probabilistic discharge rate of the Amu Darya river at Sumambay in July and August and their total discharge volumes during the two months are shown in Table 5.19. Unlike the discharge characteristics at the Kaparas reservoir, the total discharge volume decreases drastically according to the increase in the probability year.

Table 5.19 Minimum Probabilistic Discharge Rates and Total Discharge Volume at Sumambay

(unit : m^3/sec)

Probability year (return period)	Jul. (m^3/sec)	Aug. (m^3/sec)	Total discharge volume for the two months (million m^3)
2	715	438	3,088
5	104	77	485
10	9	17	70
15	3	8	29
20	1	5	16

Note : Based on monthly data from 1996 to 1993

Table 5.20 shows characteristics of the irrigation canal outflow rates for the Amu Darya river downstream of Sumambay. There are almost no collector drains downstream of Sumambay.

Table 5.20 Canals' Outflow Rates Downstream of Tuyamuyun

(unit: million m^3)

Amu Darya river flow	Total outflow rate for the two months
Abundant	260
Normal	36
Drought	0

Note: Abundant: Canal outflow rate in abundant flow of Amu Darya river
Normal: Canal outflow rate in normal flow of Amu Darya river
Drought: Canal outflow rate in drought flow of Amu Darya river

Total discharge volume is quite a small for a large probability year. If the probability year increases and the discharge rate of the Amu Darya river decreases, an adequate volume of water can be ensured if the water at the upstream reach, whose volume is quite a large, is managed efficiently.

5.4 Study on the Kaparas Reservoir

5.4.1 Introduction

The Tuyamuyun Water Supply Master Plans of Karakalpakstan and Khorezm were planned based on the premise of using the Kaparas reservoir as domestic and drinking water source in both regions, where reservoirs are utilized to store good quality water of the Amu Darya river during the summer season from June to September. Subsequent to these plans, the following resolutions have been issued by the Cabinet of Ministers of the ROU regarding this utilization.

1) Resolution No. 200 of April 15, 1986
2) Resolution No 275 of August 4, 1990

These resolutions state that the ROU has adopted the decision to use the Kaparas reservoir as the main water source for domestic and drinking water supply to the inhabitants of the both regions.

A consultation meeting on this matter was held on July 18, 1996, with the participation of the organizations concerned: MPU, SCNP, SCFS, MM&WM, etc. In this meeting, the water rights of the Kaparas reservoir as a domestic and drinking water source for the both regions were reconfirmed and continuation of further consultations among these organizations was decided.

In addition to these domestic solutions and consultations, the water rights of the Tuyamuyun Hydro Unit (TMHU) located within the territory of Turkumenistan have been resolved between both governments of ROU and Turkmenistan recently, including rights for all canals and other reservoirs upstream of the Amu Darya river within the territory of Turkmenistan.

Presently, facilities for using the Kaparas reservoir are under construction. The water control gate at the entrance of the Kaparas reservoir has been completed, thus enabling control over filling and emptying of the reservoir. The pumping station and raw water main for delivering raw water to the two existing Tuyamuyun water treatment plants are under construction.

In the previous section, water quality and quantity were studied at several points in the Amu Darya river. In this section, under the recommended operation mode of filling during June to September and supplying raw water during the other months, quality and quantity of the stored water in the Kaparas reservoir are studied and the potential of the Kaparas reservoir as a domestic and drinking water source is evaluated.

5.4.2 Tuyamuyun Hydro Unit

(1) Geographical and Dimensional Characteristic of TMHU

Before 1979, there only several natural depressions existed in the area of existing TMHU, formed by erosion of the Amu Darya river. In 1979, the Amu Darya river was dammed at the section of the existing hydro-unit (dam structure) in the main stream. Starting from 1981, first the Ruslovoye (Amu Darya bed or main stream) reservoir and the Kaparas reservoir were filled with water, followed by the Sultansadjar reservoir in 1983, and Koshbulak in 1985. Presently, the TMHU consists of these four reservoirs. They are located on the boundary line at mid- and downstream parts of the Amu Darya river in the Tuyamuyun gorge, at the joining of administrative boundaries of Karakalpakstan, Khorezm Region of the ROU and Chardjou region of Turkmenistan. The Kaparas reservoir, the Sultansandjar reservoir and the Koshbulak reservoir are located within the territory of Turkmenistan, and the Ruslovoye reservoir forms the boundary line between Uzbekistan and Turkmenistan. Dimensions, storage volumes and water levels of these reservoirs are shown in Table 5.21 and a location map of these reservoirs is shown in Fig. 5.9.

Table 5.21 Characteristics of Reservoirs in Tuyamuyun Hydro-Unit

Length	Width Max. / Ave.	Depth at HBL Max. / Ave.	Water Table Area at HBL	Volume Total	Volume Effective	Water levels HBL	Water levels DVL	Water Table Area at DVL
km	km	km	km²	mil. m³	mil. m³	m	m	m
Ruslovoye Reservoir								
102	11.0 / 4.0	20 / 7.7	303	2,340	2,070	130	120	87
Kaparas Reservoir								
15	9.0 / 4.0	36 / 13.7	70	960	550/ 680*1	130	120/ 116*2	43.5
Sultansandjar Reservoir								
24	12 / 8.0	38 / 18.0	149	2,690	1,630	130	116	86
Koshbulak Reservoir								
28	11.0 / 6.0	41 / 14.2	128	1,810	1,020	130	120	78.5

Source : SANIIRI Reports attached to the Supporting Report
HBL: Highest Back Up Level (130m)
DVL: Dead Volume Level
*1 : Effective water volume from water level of 116 m
*2 : Water Level of 116 m is equivalent to the minimum operation water level of the planned Kaparas pumping station (refer to Chapter 8.)

(2) Existing operation mode of reservoirs

The "Rules of TMHU Operation" include provisions for the operation process for TMHU reservoirs, and the process under normal conditions envisages:

1) Safe operations of dams forming the TMHU;
2) Safety of the population and farms in the area surrounding the reservoir and the river flatland downstream;
3) Supply of water to consumers living downstream of the Amu Darya river.

In addition to these main purposes, the TMHU is used for hydro-power generation at the dam of the Ruslovoye reservoir.

The Operation Schedules for reservoirs have been developed considering the operations of the Nurek water reservoir, upstream of the Amu Darya river in the territory of Tadzhikistan. The major principles controlling the Amu Darya river discharge by TMHU reservoirs for ensuring a stable development of water-consuming sectors downstream, as recommended by the "Rules of TMHU Operation", are as follows:

- During the period September to May, all basins of reservoirs are filled in cycles with some minor emptying periods. Whereas the first to fill are the Ruslovoye reservoir and Kaparas reservoir; filling of the two other basins, i.e. Sultansandjar reservoir and Koshbulak reservoir is possible only when the first two basins - Ruslovoye and Kaparas- have been completely filled.
- During the period June to August, all basins of the TMHU reservoirs are completely emptied in the following sequence: first - Ruslovoye and Kaparas, and then - Sultansandjar and Koshbulak.

According to a dispatching Schedule, the adjustment of the Amu Darya discharge flow is mainly maintained by the Ruslovoye and Kaparas reservoirs. The Sultansandjar and Koshbulak reservoirs, after being fully filled by January, do not play any adjusting role until July, and during the following two months - July and August, are completely emptied to the DVL (Dead Volume Level).

Until now the TMHU has been mainly operated for irrigation and not for storing domestic and drinking water. The Tuyamuyun hydropower station has been operated under the irrigation mode.

(3) Relationship between Ruslovoye and Kaparas reservoirs

Filling and emptying of the TMHU reservoirs are mainly effected by the water level of mainstream reservoir, the Ruslovoye reservoir, since the Ruslovoye reservoir is interconnected with the other reservoirs by a canal. The water levels in the Ruslovoye and the Kaparas reservoirs are practically equal and fluctuate together. Therefore, quality of water in both reservoirs are almost equal under the existing operation mode. The dynamics of water levels during 1985-1993 for both reservoirs under the existing operation mode is shown in Fig 5.10.

5.4.3 Evaluation of Water Quality in the Kaparas Reservoir

(1) Evaluation results by SANIIRI

The SANIIRI has studied water quality and quantity of the TMHU including the Kaparas reservoir since the seventies. They also recommended that the Kaparas reservoir be used as a domestic and drinking water source in the Aral Sea Region when the Water Supply Master Plan for Karakalpakstan and Khorezm was formulated.

In this study, the JICA Study Team obtained detail information on the Kaparas reservoir from the SANIIRI that prepared the report on the Kaparas reservoir, as attached in the Supporting Report. According to this report, they conclude and recommend the followings regarding water quality and quantity of the Kaparas reservoir:

1) The Amu Darya river gets polluted from Termez due to waste water discharge from industrial enterprises, utilities, and collector drains from the irrigated land.

2) Both Ruslovoye and Kaparas reservoir are now operated in the irrigation mode that effects the dynamics of the water qualitative composition in the reservoirs.

3) Filling of the Kaparas depression was started from June 1981 through the watercourse connecting this reservoir with the Ruslovoye reservoir. This depression, prior to filling, was estimated to contain salt amounting to 8.7 million tons. By the end of 1993, the salt contents reduced by 30%, according to the preliminary estimates. During the last year, the leaching of salts was estimated at about 8,000 tons per month.

4) The operating period of the Kaparas reservoir from the start may be divided into three periods.

Period		Operation Mode
First	June, 1981 to August, 1991	irrigation mode operation period
Second	August, 1991 to September, 1993	period of isolation when the watercourse was dammed to construct the control gate
Third	September to 1993 and until now	the rehabilitation period for water recirculation after construction was completed and water was fed again

5) Those periods were characterized mainly by mineralization concentration

a) During the first period the lowest mineralization concentration was observed between June to August and September to October, which was lower than the standard value.

b) During the second period, mineralization gradually increased and by the end of the period it reached 2,400 mg/l. In the meantime, for the 26 months of the reservoir isolation period, the total amount of salt increase was estimated as 280,000 tons from which 80,000 tons were due to evaporation and filtration of salt water from the reservoir side walls, and 200,000 tons through leaching of salts from the bed. On an average, the mineralization was increasing every month by 50 mg/l during this period.

c) During the third period, when feeding of water from the Ruslovoye reservoir started again, mineralization started to decreasing, and by December, 1993, it dropped down to 1,300 mg/l, and by July-August, 1994, - it reached 800 mg/l below the standard value.

6) Throughout observation in the Kaparas reservoir, only eight indicators exceeded MAC (Maximum Allowable Concentration) values; mineralization, total hardness, BOD, COD, sulphate and chloride ions, phenols and turbidity.

7) Prior to the period of isolation, the best quality of water was observed during June to August. During this period, the mineralization, sulphates and chloride concentrations did not exceed the MAC values, while the indicators which needed to be clarified were total hardness, phenols, COD and turbidity.

8) Preliminary forecast of the Kaparas reservoir water quality has been performed on the basis of field observations of water quality in this reservoir and the drought year - 90 to 95 % flow rate (the worst hydrological condition). Computations showed that before the 2005, under the recommended operation mode for filling from July to September and emptying for the other months, the MAC values are expected to be exceeded by <u>turbidity</u>, <u>BOD</u>, <u>COD</u>, <u>phenol</u> and <u>total hardness</u>. All other indicators of water quality will be lie within the standards.

9) For further improving the Kaparas reservoir water quality the following arrangements are necessary:

- partial or complete termination of collector drain water discharge mid-stream of the Amu Darya river;
- control of water quality during the period filling the reservoir;
- establishing a system for monitoring water quality and distributing information using automated hardware and software;
- arranging water protection and sanitary zones around the reservoirs and reservoir dam structures.

(2) Evaluation of water quality from data measured by the JICA Study Team

The JICA Study Team in association with GosSIAK, the Uzbeki side counterpart, measured water quality of water sources, treated water and piped water at several points from March 1995 to September 1996. Their results are attached to the Data Book of this Report and the evaluation results are described in section 5.7.

Here, the measured data of water quality in the Kaparas reservoir is extracted from the above data and evaluated. According to this data, five water quality indicators: Se, Fe, total hardness, mineralization and COD exceed the MAC of surface water for domestic and drinking water as shown in Table 5.22.

Table 5.22 Water Quality Indicators Exceeding the Standard Values and Measured Water Quality Data at Kaparas Reservoir

Item	Se		Fe		total hardness		mineralization		COD
unit	μg/l		mg/l		meq/l		mg/l		mg/l
MAC	1.0		0.3		7.0		1,000		15
Year	1995	1996	1995	1996	1995	1996	1995	1996	1995
Jan.	-	0.23	-	0.10	-	7.4	-	933	-
Feb.	-	1.19	-	0.06	-	6.4	-	1,208	-
Mar.	0.30	-	0.16	-	9.6	-	1,128	-	-
Apr.	1.14	1.51	0.21	0.18	8.8	7.7	1,178	1,161	-
May	2.20	1.74	0.21	0.20	7.6	6.8	1,009	1,132	62
Jun.	1.50	1.95	0.11	0.05	6.0	4.8	552	648	-
Jul.	0.54	1.44	0.21	0.26	5.0	5.2	528	905	49
Aug.	1.94	2.19	0.89	0.29	5.8	5.5	660	786	-
Sept.	0.76	2.63	0.62	0.16	5.4	6.7	724	889	-
Oct.	1.06	-	0.10	-	5.0	-	350	-	-
Nov.	2.49	-	0.19	-	6.4	-	888	-	-
Dec.	2.03	-	0.17	-	7.8	-	1,079	-	-
Min.	0.3		0.1		5		350		49
Ave	1.39		0.29		6.7		810		55.5
Max.	2.49		0.89		9.6		1,178		62

Source: JICA Study Team
Shaded values : values exceeding the MAC (Maximum Allowable Concentration)

Selenium (Se) exceeded the MAC for almost all the months. The MAC of Se by Uzbeki standards is ten times lower than that of WHO and Japan, 10 μg/l. When an MAC of 10 μg/l is adopted, all values fall below the standards.

Ferrum (Fe) exceeded the MAC for two months - August and September in 1995. These values (0.87, 0.62 mg/l) are not so high that Fe can be easily treated by ordinary water treatment process.

Both total hardness and mineralization had the same tendency of exceeding the MAC from December to May. Those in the other months laid within the MAC. The MAC of mineralization according to Japanese standards is 500 mg/l, half that of the Uzbeki standards. These compositions can not be removed by ordinary water treatment processes.

COD was measured for only two months, and both exceeded the MAC. However, the consumption of $KMnO_4$ measured for 8 months, the same indicator as COD for measuring the degree of organic pollution, did not exceed the Japanese standards for drinking water. Judging from these results, Kaparas reservoir water mainly consist in organic substances that are hardly oxidized.

(3) Evaluation of quality of water in the Kaparas reservoir

Based on the above results by SANIIRI and JICA Study Team, the indicators exceeding the MACs under the recommended operation mode of the Kaparas reservoir are evaluated as follows.

1) Turbidity

Only the SANIIRI results showed that turbidity will exceed the MAC. However, no forecasts are made on turbidity in their report. The measurement results by the JICA Study Team shows no excess. Consequently, turbidity should not be a problem.

2) BOD and COD

BOD and COD slightly exceed 1.03 and 1.15 times the MAC, respectively, according to the SANIIRI results. This forecast was made based on the drought year - 90 to 95 % flow rate (the worst hydrological condition), which is the most severe condition for forecasting, and it ignored the self-cleaning process in the reservoir estimated as 20 - 25 % reduction of concentration by the SANIIRI. Based on these assumptions, BOD and COD are minor problems.

3) Phenol

The data for this indicator measured by JICA shows nearly no trace of phenol. However its forecast by the SANIIRI shows 3 times the MAC. If pollution by phenol is confirmed after further analysis, countermeasures against the pollution sources like industrial discharge should be taken at first by identifying the pollution sources and controlling the polluted discharge at its site. Then it may be necessary to re-evaluate the standard value for phenol since the Japanese standard value is 0.005 mg/l, which is five times higher than the Uzbeki standard value of 0.001 mg/l.

4) Selenium (Se)

When the MAC of 10 μg/l, which is the standard value for WHO and Japan, is adopted, all values fall below the standards. Therefore, the JICA Study Team found no problems in Se.

5) Ferrum (Fe)

According to evaluation by the JICA Study Team, Fe does not pose any problem.

6) Mineralization

Under the recommended operation mode of the Kaparas reservoir this indicator does not exceed the MAC during filling periods and forecasts also show it to be within the MAC, even if leached salt from the river bed and evaporation are considered.

7) Total hardness

Under the recommended operation mode of the Kaparas reservoir, this indicator does not exceed the MAC during the filling period. Forecasts by the SANIIRI, however, show that it exceeds the MAC during the latter several months of reserved periods if leached salt from the river bed and evaporation are considered. For the improving in total hardness, recommendations of the following section (5) need to be adopted.

(4) River Water Quality Improvement by RBCD Project

The RBCD project (construction of the Right Bank Collector Drain) shown in the Chapter 2 of this report is in progress and is meant to improve water quality of the Amu Darya river in the Aral Sea Region. At present, 30 % of the drains have bee completed. The forecast by Credazigprovokhlopok shows that the following mineralization concentration is expected after completion of the first stage collector drain main line in 2000.

Table 5.23 The forecast for mineralization concentration after the completion of the first stage collector drain main line in 2000

(unit : mg/l)

Location	Without the project	With the project
Termez	420	420
Tuyamuyun	1,200	610
Takhiatash	1,260	670

Source : Credazigprovokhlopok, VodGEO's second stage recommendation, 1995

Annual Average values

Although much lower mineralization concentration is expected after completion of the RBCD, the improvement in water quality for domestic and drinking water cannot depend on this project considering the present construction progress and the lack of funds for further construction.

(5) Recommendations for further improving the quality of water in the Kaparas reservoir

The following realistic countermeasures based on the SANIIRI's proposals are necessary for further improving quality of water in the Kaparas reservoir.

1) establishing a system for monitoring water quality and quantity and distributing information using automated hardware and software for storing the best quality water in a year
2) partial or complete termination of collectors in the mid-stream part of the Amu Darya river during the filling period of the Kaparas reservoir

Although it is difficult to implement the second countermeasure, the related organization on the Uzbeki side has mentioned that it can be implemented by operating collectors and using partially completed RBCD and natural depressions.

(6) Preliminary estimation of water quality improvements

Preliminarily water quality at the Ruslovoye reservoir is estimated when collectors in the mid-stream part of the Amu Darya river is terminated partially or completely during the filling period. Concentration of mineralization and total hardness at Tuyamuyun will be estimated for the following three cases, based on the calculation conditions in section 5.3.4 (1), where mineralization concentration is estimated based on flow rate in drought and low water year. Concentration of total hardness is estimated by adopting the rate of increase between the base points in mineralization concentration and total hardness because concentration of both indicators have a strong positive correlation.

1) Without termination of collectors (Without)
2) Half termination of any collector between Kerki and Tuyamuyun (Half)
3) Complete termination of any collector between Kerki and Tuyamuyun (Complete)

The estimated results are shown in Table 5.24. According to this results, even in the worst cases of river flow and total hardness concentration in Termez, total hardness concentrations at Tuyamuyun for July and August comply with the standard by the half termination of collectors.

Table 5.24 Estimated Mineralization and Total Hardness at Tuyamuyun in the Termination of Collectors upstream of Tuyamuyun

Case	June			July			August		
	Without	Half	Complete	Without	Half	Complete	Without	Half	Complete
Mineralization (mg/l)									
Case 1	1,180	1,010	880	900	790	700	960	820	720
Case 2	950	770	630	770	650	560	800	670	560
Case 3	1,140	990	880	880	780	710	940	810	720
Case 4	910	760	640	740	640	560	780	660	560
Total hardness (meq/l)									
Case 1	9.64	8.25	7.19	7.25	6.37	5.64	7.51	6.42	5.63
Case 2	9.58	7.76	6.35	7.11	6.01	5.17	7.47	6.26	5.23
Case 3	9.31	8.08	7.19	7.09	6.28	5.72	7.35	6.34	5.63
Case 4	9.18	7.67	6.46	6.84	5.92	5.78	7.29	6.17	5.23

Source : JICA Study Team
Note: For calculation conditions see section 5.3.4 (1).

5.4.4 Study on Volume of Water to be Stored in the Kaparas Reservoir

In this section, volume of water that can be stored and water levels during the period from June to September in the TMHU reservoirs are evaluated.

(1) Characteristics of the Kaparas reservoir

1) Low water level (LWL)

LWL of the Kaparas reservoir for delivery of raw water to the Tuyamuyun water treatment plants is 116 m, which is equivalent to the minimum operating water level of the planned Kaparas intake pumping station (refer to Chapter 8.)

2) Water level and water storage volume

Total and effective water storage volumes and corresponding water levels are as shown in Table 5.25.

Table 5.25 Water Level, Volume and Days Required for Filling to the Respective Water Level of the Kaparas Reservoir

Water Level	Total Water Volume	Effective Water Volume	Required Days for Filling up to Respective Water Level	
			Daily average stored volume	
			39 mil. m^3/day	18 mil. m^3/day
m	million m^3	million m^3	days	days
130 (HWL)	960	680	17.4	37.8
129	900	620	15.9	34.4
128	830	550	14.1	30.6
127	770	490	12.6	27.2
126	710	430	11.0	23.9
125	650	370	9.5	20.6
124	600	320	8.2	17.8
123	540	260	6.7	14.4
122	500	220	5.6	12.2
121	450	170	4.4	9.4
120	410	130	3.3	7.2
119	380	100	2.6	5.6
118	350	70	1.8	3.9
117	320	40	1.0	2.2
116 (LWL)	280	0	-	-

Source : SANIIRI
HWL: High Water Level, Highest Back Up Level(HBL)
LWL: low water level of planned Kaparas pumping station

3) Passage flow capacity through control gate of the Kaparas reservoir

The design passage flow capacity through the control gate (storing speed) of the Kaparas reservoir is 450 m^3/sec (39 million m^3/day) according to the SANIIRI, although it depends on the water level of the TMHU reservoirs.

(2) Required period for filling

Based on above passage flow capacity, the required period for filling from the LWL are calculated in Table 5.25.

In practice, the required period depends on the fluctuation of water level in the reservoir which is influenced by the discharge rate of the Amu Darya river and the Ruslovoye reservoir operation mode. In the actual operation mode, the water levels in the Ruslovoye reservoir and the Kaparas reservoir fluctuate together. The actual observed fluctuations of water levels in the filling mode of the Ruslovoye reservoir from October 1991 to August 1993 are as shown in Table 5.26, and storage volume during each filling period and its daily average stored volume for the Kaparas reservoir were calculated in Table 5.26 from the water level fluctuations of the Ruslovoye reservoir. During that period, maximum daily average stored volume is 28 mil. m^3/day, which is 72 % of the design passage flow capacity and the average of volumes from June to August is about 18 mil. m^3/day. When this value is used as the daily average stored volume for the Kaparas reservoir, the required period for filling up to the respective water revel is shown in the Table 5.25.

(3) Observed water level and storage volume in current operation mode

Monthly average water levels of Ruslovoye reservoir and Kaparas reservoir for June to August from 1985 to 1994 are as shown in Table 5.27. Average values of the water levels in June and July of both the reservoirs are above 123 m except during the period the Kaparas reservoir was isolated from the Ruslovoye reservoir. From Table 5.25, an effective volume of 260 mil. m^3, equivalent to the water level of 123 m, can be stored on an average. However, in drought year such as 1986, it might be difficult to raise the water level up to the required level.

Table 5.26 Ruslovoye Reservoir Operating Performance from Oct. 1991 to Aug. 1993

Operating Mode	Operation Cycle			Water Level		Amplitude of Fluctuations	Intensity of Modification		Calculated Storaged Water Volume in Kaparas Res. during Cycle	Daily Average Storaged Water Volume in Kaparas Res.
	Start	Finish	Duration	Start	Finish		Ave.	Max.		
	date	date	days			m	cm/day	cm/day	mil. m3	mil. m3/day
Filling	5-Oct-91	28-Dec-91	85	120.08	129.73	9.73	11.44	26	531	6.2
Filling	11-Jan-92	17-Jan-92	7	129.14	129.62	0.48	6.85	13	29	4.1
Filling	30-Jan-92	7-Feb-92	9	129.23	129.52	0.29	3.22	9	17	1.9
Filling	19-May-92	27-May-92	9	126.26	128.77	2.51	27.89	49	158	17.6
Filling	10-Jun-92	23-Jun-92	14	126.40	128.94	2.54	18.14	37	162	11.6
Filling	16-Jul-92	6-Aug-92	22	123.18	128.22	5.04	22.91	49	294	13.4
Filling	3-Sep-92	15-Sep-92	13	118.55	119.35	0.80	6.15	45	24	1.8
Filling	1-Oct-92	31-Oct-92	30	116.63	126.60	9.87	32.80	204	441	14.7
Filling	30-Nov-92	29-Jan-93	31	125.62	129.67	4.05	13.00	15	253	8.2
Filling	13-Apr-93	17-May-93	35	122.63	128.76	6.13	17.40	40	358	10.2
Filling	30-May-93	6-Jun-93	7	125.92	127.73	1.81	26.00	53	109	15.6
Filling	29-Jun-93	4-Jul-93	5	121.53	123.21	1.68	33.60	45	76	15.2
Filling	15-Jul-93	20-Jul-93	5	122.55	124.17	1.62	32.40	49	87	17.4
Filling	28-Jul-93	1-Aug-93	4	119.93	122.51	2.58	64.50	106	112	28.0
Filling	2-Aug-93	13-Aug-93	2	116.71	118.16	1.45	72.50	74	47	23.5
Filling	16-Aug-93	19-Aug-93	3	116.49	118.00	1.51	50.30	74	50	16.7

Source : SANNIRI report

Table 5.27 Monthly Average Water Levels of Ruslovoye and Kaparas Reservoir

(unit: m)

Year	Ruslovoye Reservoir			Kaparas Reservoir		
	Jun.	Jul.	Aug.	Jun.	Jul.	Aug.
1985	119.9	118.4	120.3	119.7	118.5	120.3
1986	117.5	120.4	116.4	117.8	120.3	116.7
1987	126.1	125.9	125.9	126.2	125.9	125.9
1988	121.5	126.7	128.1	127.6	126.7	128.1
1989	123.6	117.7	116.4	123.6	117.7	116.5
1990	125.6	125.5	119.7	125.6	125.5	119.7
1991	127.2	126.4	120.5	127.2	126.4	*116.2*
1992	127.6	125.1	124.6	*116.0*	*116.0*	*116.0*
1993	125.2	122.5	117.9	*115.7*	*115.7*	*115.7*
1994	125.3	125.8	120.7			
Ave.	123.9	123.4	121.0	122.1	121.4	119.5
Ave. without period of isolation of Kaparas res.				123.9	123.0	121.2

Source : SANIIRI

Note : Figures in italics indicate the water level when the Kaparas reservoir was isolated from the Ruslovoye reservoir

(4) Planned water volume to be stored in the Kaparas reservoir

The annual water storage volume required in 2010 for the Basic Plan in the Chapter 8 (Basic Plan in 2010) will amount to 300 million m^3/year according to the annual water demand for Tuyamuyun water treatment plants of Nukus and Urgench. On the other hand, annual water storage volume required in 2002 and 2010 for the revised water demand plan in the Feasibility Study of the Part II report will amount to 190 and 238 mil. m^3/year respectively.

For storing this volume in the reservoir, the water level required in the reservoir and the period required for filling from the LWL using 18 mil. m^3/day as passage flow rate are shown in Table 5.28.