7. WATER RESOURCES

7.1. Water Supply to Farms

The agricultural year may conveniently be divided into two periods of six months, the growing season (April to September) and the dormant period. In both seasons, there are peaks of water supply that are practically invariable in occurrence year by year. For most farms in the region, the growing season peak is July-August, and in February-March there is the peak for pre-irrigation, very often with soil leaching. The water supply during the dormant period tends to be different in each republic. For example:

- In the rice growing farms (01, 02) in Kazakhstan canals are closed throughout the dormant period;
- In the cotton farms (03, 04) in South Kazakhstan canals are closed for one month in March for repair and cleaning since winter wheat is irrigated in October-November and soil leaching takes place in January-February;
- Canals of highland farms (07, 08) in the Chu valley of Kyrgyzstan are practically closed during the dormant period;
- In the cotton growing farms (09, 10) in Osh Oblast winter cereals are irrigated in October-November and for the rest of the period canals are closed.

Total water supply to the WUFMAS farms and specific water supply per hectare are calculated on the basis of official farm reports and presented in Annex 7.1.

For comparability data on monthly water supply are analyzed for 22 farms where the full set of data is available for 1997 and 1998. In Kazakhstan only two rice growing farms (01 and 02) in Kzylorda Oblast were included in the analysis. In 1998 large former state farms (03 and 04) in South Kazakhstan Oblast were split into many small private farms and the latter were excluded from comparative analysis (water supply data on the level of separate fields-private farms are discussed further in the text).

Table 7.1 Irrigation Water Supply and Use by WUFMAS Farms in 1997 and 1998

Item	Units	Kazakhstan (2 farms)		Kyrgyzsan (4 farms)		Tadjikistan (2 farms)		Turkmenistan (2 farms)		Uzbekistan (12 farms)		Overall (22 farms)	
		1997	1998	1997	1998	1997	1998	1997	1998	1997	1998	1997	1998
Water supply to the farms	tcm/ha	25.2	35.6	9.5	7.9	21.2	14.3	7.2	7.1	11.8	10.6	13.0	12.5
including:													
vegetation period	tcm/ha	25.2	35.6	8.7	6.9	20.2	12.2	5.1	5.2	8.7	8.1	10.9	10.5
dormant period	tcm/ha	0.0	0.0	0.8	1.0	1.0	2.1	2.1	1.9	3.1	2.5	2.1	2.0
Number of irrigations	no.	5.5	7.2	3.3	3.5	9.3	7.7	3.7	3.5	6.8	5.9	6.0	5.5
including:													
vegetation period	no.	5.5	7.2	3.0	3.0	8.8	7.1	2.6	2.4	4.8	4.7	4.7	4.6
dormant period	no.	0.0	0.0	0.3	0.5	0.5	0.6	1.1	1.1	2.0	1.2	1.3	0.9
Water supply per application		4.6	4.9	3.2	2.6	2.4	2.0	2.8	3.0	2.5	2.3	2.8	2.7
inluding:													
vegetation period	tcm/ha/applicatio	4.6	4.9	2.9	2.3	2.3	1.7	2.0	2.2	1.8	1.7	2.3	2.3
dormant period	tcm/ha/applicatio	0.0	0.0	2.7	2.0	2.0	3.5	1.9	1.7	1.6	2.1	1.6	2.2

Comparison of overall indices by WUFMAS farms shows some reduction of water supply per hectare in 1998 agricultural year (from October 1997 to September 1998) as compared with 1997 from 13 tcm/ha to 12.5 tcm/ha respectively. Similar trend was noted while comparing average data by WUFMAS farms in all republics. This can be mainly explained by the fact that 1998 was more wet year. But in the rice growing farms (01 and 02) in Kzylorda Oblast of Kazakhstan specific water supply was higher in 1998 (35.6 tcm/ha against 25.2 tcm/ha in 1997). Whereas in South Kazakhstan Oblast (farms 03 and 04) where water is supplied from canal “Dostyk” it was a deficiency of water in 1998.

Apart from rice growing farms in Kzylorda Oblast the biggest water supply in 1998 (14.3 tcm/ha) was recorded in the farms 14 and 37 with stony soils in Leninabad Oblast, although in 1997 on average it was bigger almost by 7 tcm/ha (21.2 tcm/ha). Relatively low water supply volume was in Turkmenistan (farms 17 and 18) 7.2 tcm/ha and 7.1 tcm/ha in 1997 and 1998 respectively. In 1998 water supply to the farms of Kyrgyzstan was short by 1.6 tcm/ha and in Uzbekistan by 1.2 tcm/ha.
Winter wheat and lucerne are irrigated during dormant period in Kyrgyzstan and Tadjikistan and water supply to the WUFMAS farms here in 1998 was higher a little than in 1997.
In Turkmenistan and Uzbekistan leaching and pre-irrigation during dormant period allow to postpone first irrigation of main crop - cotton till the end of June or beginning of July.

Comparison of calculated water supply per irrigation with net irrigation application norm on per hectare basis allows to evaluate approximately the efficiency of irrigation water application on the level “farm intake – irrigated crop”.

In 1998 average number of irrigation applications was reduced down to 5.5 (against 6 applications in 1997), 0.9 out of this number was irrigation during dormant period (against 1.3 in 1997).

The biggest number (7.7) of irrigation applications was in farms 14 and 37 in Leninabad Oblast of Tadjikistan (against 9.3 in 1997).
The least number (3.5) of irrigation applications was in WUFMAS farms in Kyrgyzstan and Turkmenistan (against 3.3 and 3.7 in 1997 respectively).
The biggest number of irrigation during dormant period (1.2) was in Uzbekistan (against 2 in 1997).

7.2 Types of Field Supply Canals and Methods of in-field Irrigation

Information about types of WUFMAS field supply canals and in-field methods of irrigation is static, i.e. was not changed to much in 1998 as compared with 1997.

Table 7.2 Canal Types, Serving Sample Fields
(% of total number of sample fields)

Type of canals	Kazkh-stan	Kyrgyz-stan	Tadjiki-stan	Turkmeni-stan	Uzbeki-stan	Overall
Unlined earth canal	8	73	90	0	70	55
Lined, concrete monolith	50	0	0	0	10	14
Concrete canalettes	0	28	5	0	0	6
Temporary field canals	18	0	0	0	20	12
Temporary field furrows	25	0	0	100	0	14
Pipe, subsurface with hydrants	0	0	5	0	0	0

The large majority of supply canals (81 percent) are unlined, overall more than half are permanent but 26 percent are temporary field canals. Of the lined canals, proportionally more are in Kazakhstan but only a minority is of pre-cast canalette type. In an area of steep slopes and coarse soil on farm in Kanibadam, the supply is by gravity through a subsurface pipe with hydrant outlets. Flexible pipes for reducing water losses in the field are now out of use.

Temporary field canals, supplying water to group of furrows or strips, increase conveyancing losses in the field but have the benefit of reducing the number of primary outlets from supply canal. Specific length of such a temporary distribution network depends on the area of irrigated block and on average varies from 35m/ha (for a block of 20ha) to 80m/ha (for a block of 4ha).
A feature of irrigation design in Central Asia is the prevalence of gravity irrigation systems with low hydraulic heads in the canal above the irrigated area, generally about 0.3-1.0m. In consequence, field irrigation is mostly by surface irrigation methods. The methods recorded in the sample fields are summarised in Table 7.3.

Table 7.3 In-field Irrigation Methods

Type of Irrigation	Kazakhstan	Kyrgyzstan	Tadjikistan	Turkmenistan	Uzbekistan	Overall
Percent of fields actually irrigated:						
Normal furrow	37	79	100	45	59	61
Furrow with erosion control	0	0	0	0	3	1
Basin	50	0	0	0	11	14
Border strip	13	0	0	55	5	10
Border furrows	0	0	0	0	9	4
Wild flooding	0	21	0	0	13	9
Non-irrigated (as % of total)	5	18	0	0	8	8

The methods of surface irrigation is very dependent on the crop and the slope. Irrigation in furrows, spaced mostly at 0.6 and 0.9m down the slope, is the predominant method. It is commonly used for irrigating cotton, winter wheat, maize for grain, apricots, sugar beat, melons, onion, sunflower and tobacco. Sixty-two percent of irrigated fields had furrows, with only one percent protected against soil erosion at the off-take, usually with a small sheet of plastic. In flat terrain ($i \leq 0.0005$), particularly in the delta zone, basin irrigation is common for irrigating rice, lucerne, winter wheat and spring wheat, representing 14 percent overall of irrigated sample fields. Border strip irrigation is particularly common on the Turkmenistan sample farms and together with border furrows represents 14 percent of irrigated fields. Wild flooding is the least efficient method of irrigation and is common in Chu Valley in Kyrgyzstan, where water is plentiful and slopes are are steeper, and locally in the old irrigated lands of Bukhara oblast where the land is level. Nine percent of sample fields overall were irrigated by wild flooding.

Some eight percent of WUFMAS sample fields that were originally selected as irrigated fields were not irrigated in 1997 and 1998 as well. Reasons given were mostly shortage of water and that in places the groundwater is close to the surface so that irrigation is unnecessary.

7.3 Ground Water

Groundwater table depth and its salinity are the main indices of ameliorative regime defining conditions of soil formation process, secondary salinity and other processes affecting the crops.

And **ameliorative regime** is understood (according to N.M. Reshetkina and Rachisky) as a *set of the following factors: volume of irrigation water supply, control of groundwater table depth by drainage (natural or artificial) with certain crop operation providing necessary water, salt, air and nutrient regime within root depth in the certain climate conditions in order to get high yields and increase soil fertility.*

There are three types of ameliorative regimes (according to V.R. Shreder):– automorphic (with groundwater table depth > 3m), semi-hydromorphic (with groundwater table depth 2 – 3m) and hydromorphic (with groundwater table depth less than 2m).

Evaporation losses from groundwater and rate of salt accumulation in topsoil are reduced with decrease of relative groundwater table depth. Main characteristics of ameliorative regimes are summarised in Table 7.4.

Table 7.4. Main Characteristics of Ameliorative Regimes (according to V.A. Dukhovny)

Ameliorative regime	**Type of interaction with groundwater**	**Ge/ETcrop**	**LR**	**(H-δ)/Hk**
Automorphic	There is no groundwater contribution to rooting depth, free infiltration	0	0	>1.2
Semi-automorthic	Groundwater slightly contributes to crop water requirements	0 - 0.2	0 - 0.15	0.7-1.0
Semi-hydromorphic soil	Groundwater significantly contributes to crop water requirements	0.3 - 0.7	0.2 -0.4	0.2 - 0.7
Hydromorphic soil	Crop water requirements are mainly covered by groundwater contribution	0.8	>0.4	0 - 0.2

where:
Ge - ground water contribution for evapotranpiration;
ET_{crop} - crop water requirements;
LR - leaching requirements;
H - groundwater depth below surface;
δ - rooting depth;
Hk - critical groundwater depth.

Specific feature of irrigated land in the Aral Sea Basin is groundwater contribution to crop water requirements.

Overall, in 1994 more than 30 percent of irrigated land in the Aral Sea basin had an average groundwater depth of 2m or less (hydromorphic soil type, see Table 7.5).
There are a lot of land with such conditions in Turkmenistan and Uzbekistan in particular. Kyrgyzstan and Tadjikistan are located in the upper watershed and land area with such conditions is much less there.

Table 7.5 Ranking of Irrigated Land of the Aral Sea Basin by Watertable Depth ('000ha/%)(DATA FOR 1994)

Republic	Irrigated area (‘000 ha)*)	Ground water depth below surface (m)]					
		< 1.0	1.0-1.5	1.5-2.0	2.0-3.0	3.0-5.0	> 5
Kazakhstan	781.4 100	73.9 9.4	77.83 9.9	142.3 18.1	189.47 24.1	209.9 21.4.7	92.8 11.8
Kyrgyzstan	429.9 100	1.7 0.4	4.3 1.0	7.7 1.8	9.4 2.2	9.1 2.1	397.7 92.5
Tadjikistan	719.2 100	17.3 2.4	31.4.7 5.1	59.0 8.2	131.6 18.3	165.4 23.0	309.2 43.0
Turkmenistan	1744.1 100	42.4 2.4	649.2 37.9		673.7 38.7	179.5 10.3	199.3 11.4
Uzbekistan	3751.0 100	85.5 2.2	371.4 9.9	851.95 20.3	1230.3 32.8	589.0 15.7	711.4 19.1
Total	7430.0 100	217.8 2.9	2109.83 28.4		2234.47 30.1	1152.92 15.5	1714.98 23.1

Similar situation by sample fields was described in WUFMAS 1997 Report. Overall average groundwater depth 0-2 m was recorder in 40.4 percent of sample fields.

Table 7.6 Average Groundwater Depth Below Surface in 1997
(as percentage of 220 sample fields by republic)

Republic	Range of ground water depth (cm)							
	0-50	51-100	101-150	151-200	201-250	251-300	301-500	501-1000
Kazakhstan	22.5	12.5	10	10	37.5	7.5	0	0
Kyrgyzstan	2.5	0	5	0	0	0	5	70
Tadjikistan	10	10	5	0	0	0	5	70
Turkmenistan	0	0	5	40	25	30	0	0
Uzbekistan	1	16	13	20	33	7	10	0
Average by 22 farms	5.9	10.5	9.5	14.5	25	7.3	5	22.3

Variation in depth of groundwater mainly depends on irrigation schedule and evaporation from groundwater table. Typical variation patterns are shown on Figures 7.1-7.4. More detailed information is presented in Annex.

In South Kazakhstan (farms 03, 04) the highest groundwater table (on average 1.5m) is observed in February-April due to overly heavy rates of soil leaching and pre-irrigation during dormant period (4-4.5 tcm/ha). Thereafter evaporation from groundwater table starts prevailing over infiltration because during vegetation period water supply is two-three times less as compared with dormant period. At the end of vegetation period groundwater table drops to three meters and even deeper.

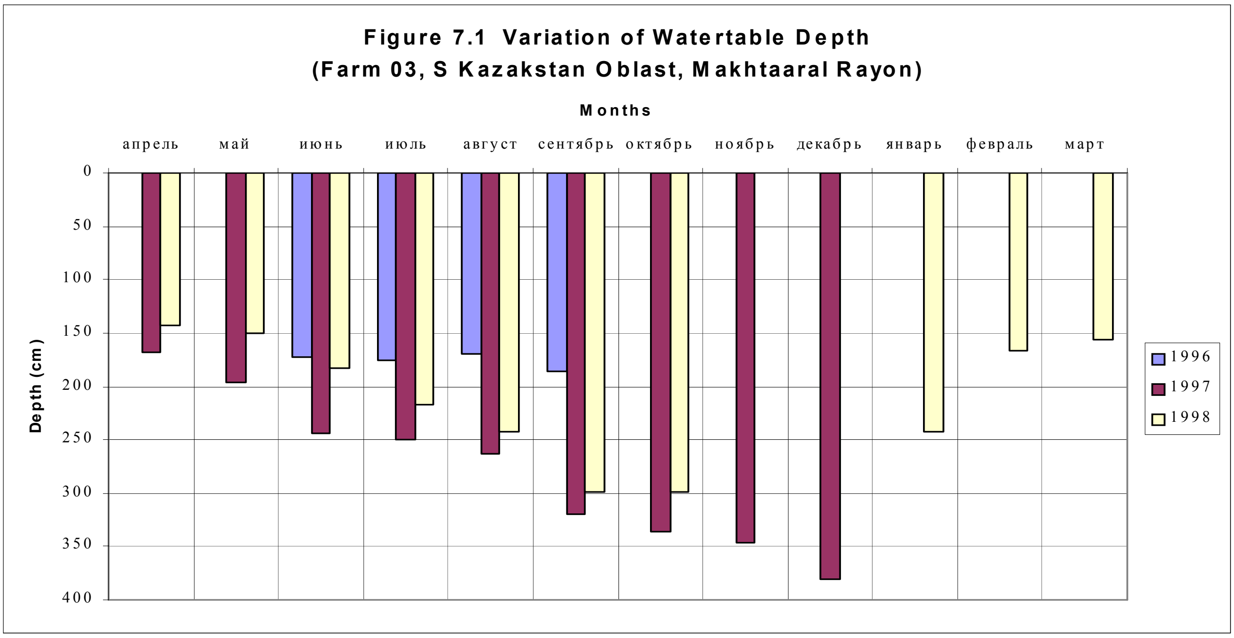
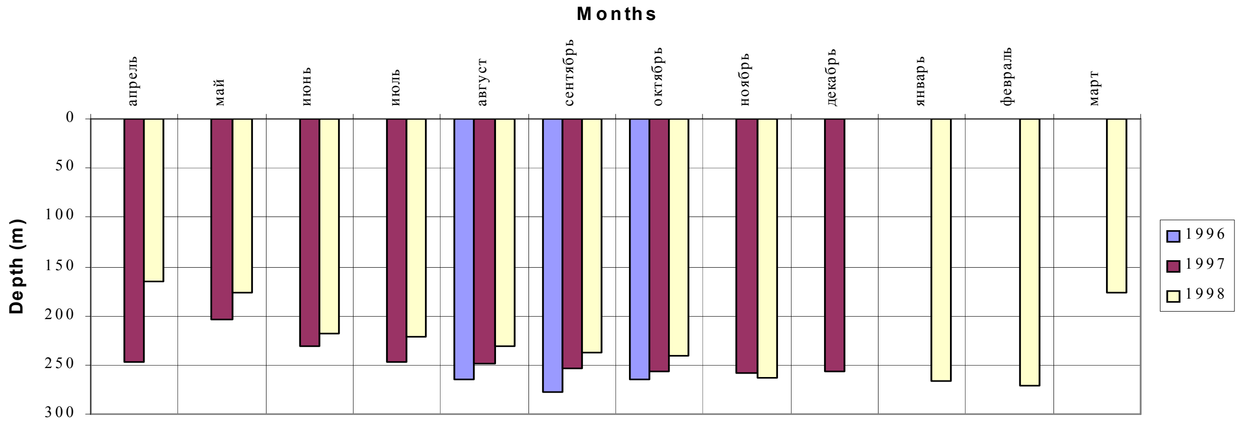


Figure 7.1 Variation of Watertable Depth (Farm 03, S Kazakstan Oblast, Makhtaaral Rayon)

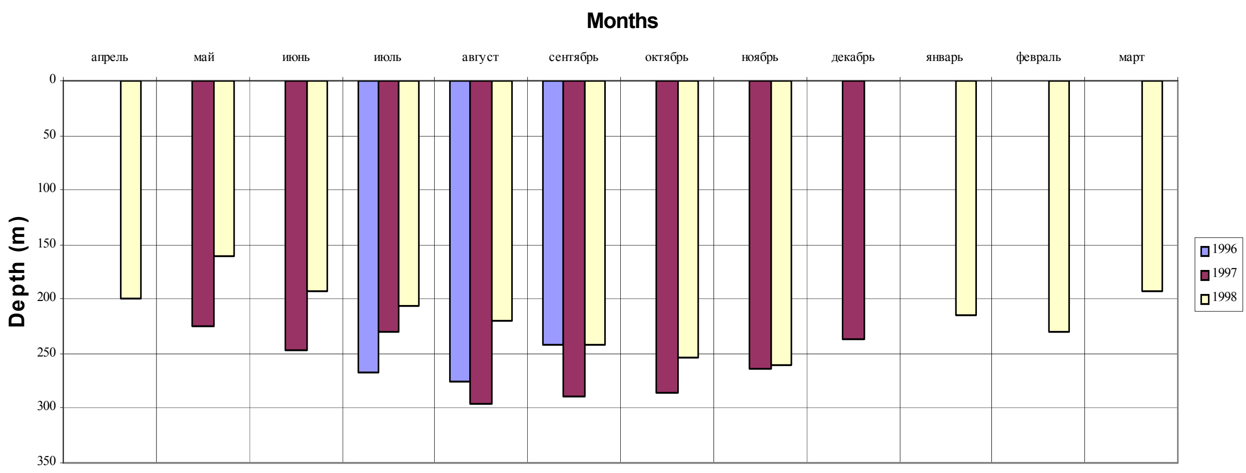
In Turkmenistan within the zone of Karakum canal (Farms 17, 18) variation in depth of groundwater is the same but peak of high ground water table (on average 1.5m) is shifted to March-April, period of massive pre-irrigation. At the end of vegetation period groundwater table drops to 2.5 meters.

Figure 7.2 Variation of Ground Water Depth (Farm 18, Turkmenistan, Mary Oblast, Baitamali Rayon)



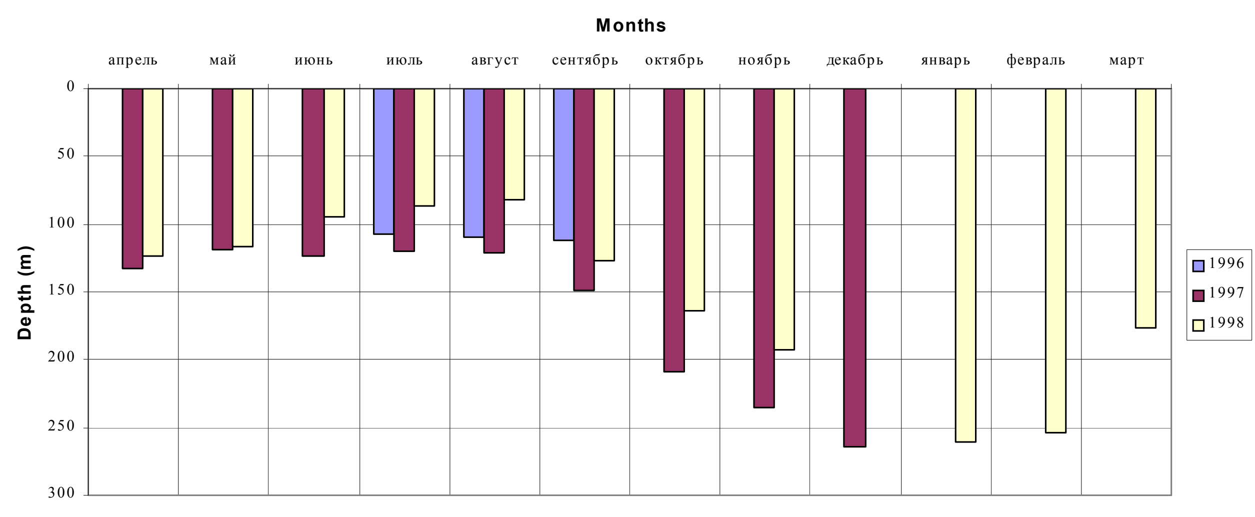
In Uzbekistan within the zone of newly irrigated land in Golodnaya Steppe (Farms 23, 24) peak of high groundwater table (with average depth 1.5m) occurs in May.

Figure 7.3 Variation of Watertable Depth (Farm 24, Uzbekistan, Syrdarya Oblast, Shaf-Rashidov Rayon)



In the zone of old irrigated land in Khoresm Oblast of Uzbekistan (farms 25, 26) peak of high groundwater table (with average depth 1m) occurs in July-August with gradual rise towards surface from February (the beginning of leaching and pre-irrigation) to July. In December groundwater table drops to 2.5m.

Figure 7.4 Variation of Watertable Depth (Farm 25, Uzbekistan, Khorezm Oblast, Khankin Rayon)



In the majority of WUFMAS sample farms trends towards groundwater table rise close to land surface were observed during survey period 1996-1998 (Figures 7.5-7.8).

Figure 7.5 Groundwater Depth Below Surface (Kazakhstan)

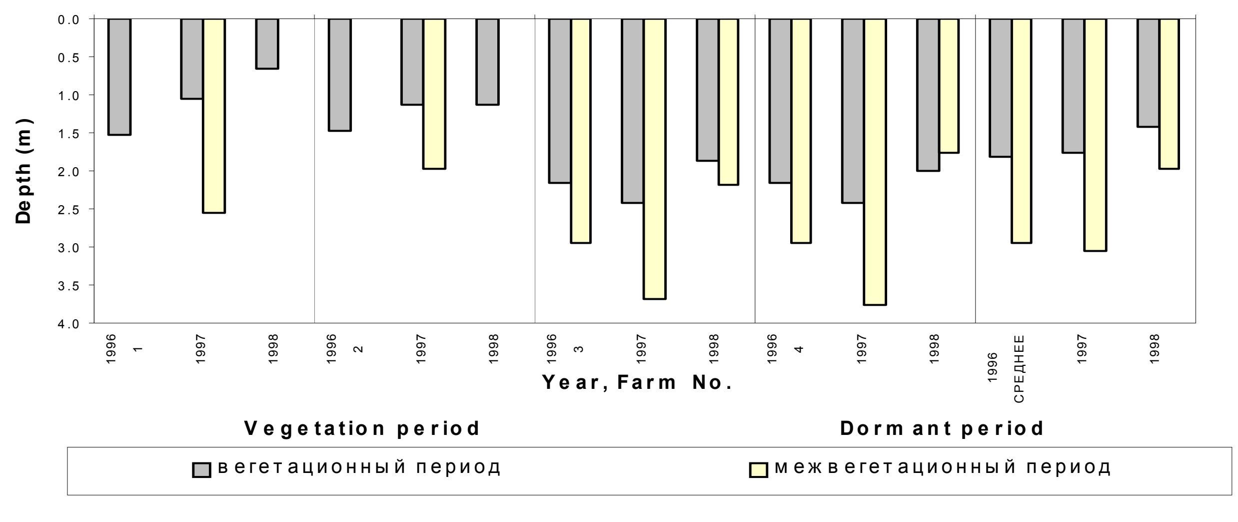


Figure 7.6 Groundwater Depth Below Surface (Turkmenistan)

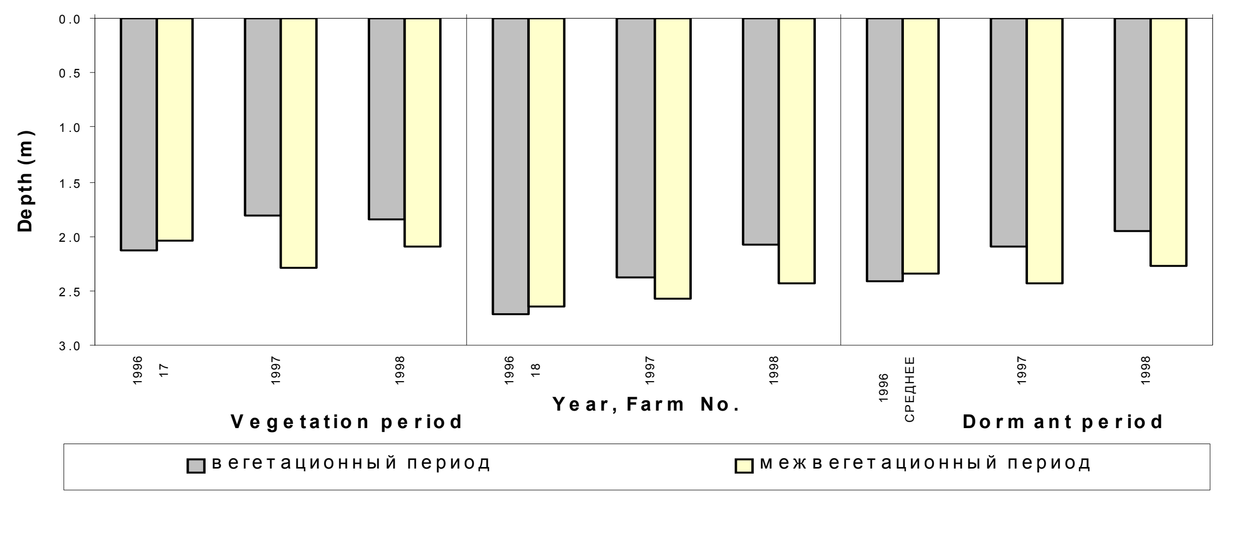


Figure 7.7 Groundwater Depth Below Surface (Uzbekistan)

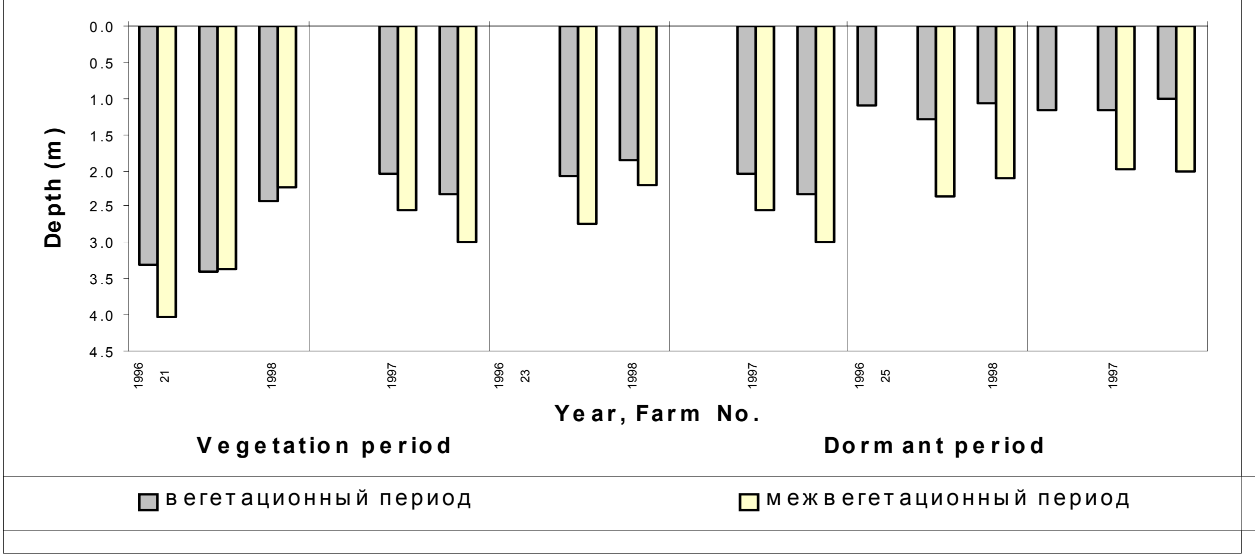
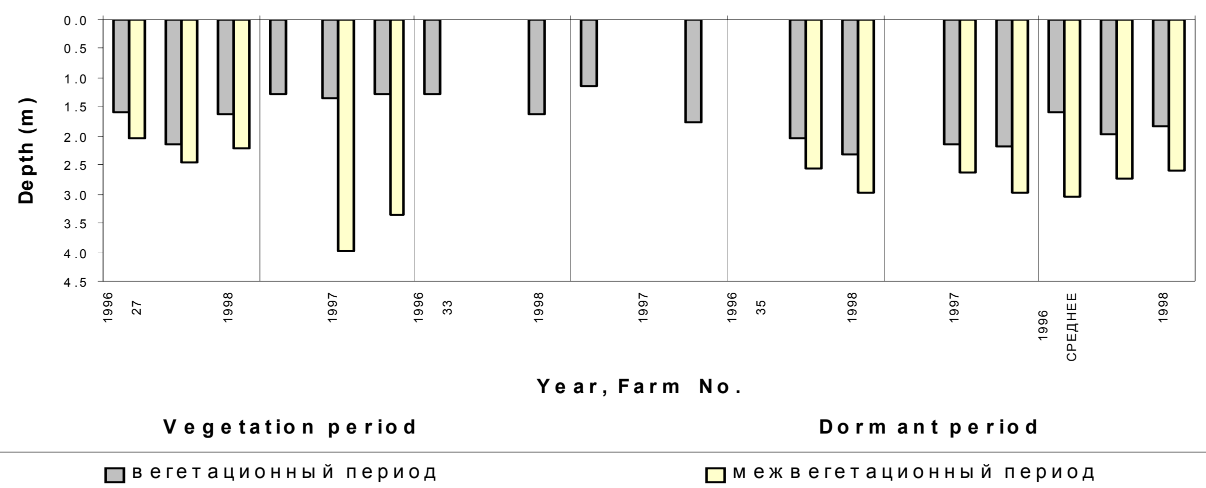


Figure 7.8 Groundwater Depth Below Surface (Uzbekistan)



In the 1997 WUFMAS Report it was noted that drainage systems on the middle and lower river reaches were designed and constructed for maintaining groundwater table on the depth 2.5-3.0m, i.e. to maintain semi-hydromorphic soil conditions. However, only 10 percent of sample fields have groundwater table within this range. Data for 1998 show that situation is getting worse. This is the evidence of unsatisfactory condition of collector and drainage system. The only exception is several farms in Uzbekistan (No 22, 24, 33, 34, 35) where average groundwater table depths were dropped mainly due to reduction of irrigation water supply, but not due to improvement of collector and drainage systems.

7.4 WATER QUALITY

Number and types of analyses of irrigation, drainage and ground water samples are shown in Table 7.7.During survey period the following parameters were measured:

in 1996 – chemical composition, total dissolved solids (TDS), pH value and electrical conductivity;

in 1997 – TDS, Cl^-, pH and electrical conductivity;

in 1998 electrical conductivity and pH were measured in the field using a portable conductivity meter with scale up to 2000µS/cm (so the most precise measurements were salt concentration in irrigation water);

in 1999 in field measurements of EC of irrigation, drainage and ground water were made by the portable conductivity meter developed by SANIIRI specialist, Mr A.K. Chernyshov.

Table 7.7 Types and Number of Water Analyses

Characteristic Units	1996	1997	1998*	1999*
Ecw	1458	292	512	1224
$PH_{1:5}$	1458			
TDS	1458	292		
HCO_3	1458			
Cl	1458	292		
SO_4	1458			
Ca	1458			
Mg	1458			
Na+K	1458			

* measurements were made in field by portable electrical conductivity meter

Value of electrical conductivity of water is indirect measure of salt concentration in water and it is widely used in international practice. Electrical conductivity is measured by special instrument in the following units: dS/m, mS/cm, 1000 μS/cm. FAO criteria for evaluation of the quality of irrigation water are shown in Table 7.8.

Table 7.8 FAO Interpretative Criteria for Irrigation Water

Laboratory measurements	Units	Degree of restriction in use		
		None	Slight/mod	Severe
Salinity:				
Ecw	dS/m	< 07	0.7 - 3.0	> 3.0
(or as TDS)	(g/l)	(< 0.45)	(0.45 – 2.0)	(> 2.0)
ECw in relation to SAR = 0 – 3	dS/m	> 0.7	0.7 - 0.2	< 0.2
3 – 6		> 1.2	1.2 - 0.3	< 0.3
6 – 12		> 1.9	1.9 - 0.5	< 0.5
12 – 20		> 2.9	2.9 - 1.3	< 1.3
20 – 40		> 5.0	5.0 - 2.9	< 2.9
Specific Ion Effects:				
Na^+ – surface irrigation	SAR	< 3	3 - 9	> 9
Sprinkler irrigation	me/l	< 3	> 3	
Cl^- – surface irrigation	me/l	< 4	4 - 10	> 10
Sprinkler irrigation	me/l	< 3	> 3	
B	me/l	< 0.7	0.7 - 3.0	> 3.0
Miscellaneous effects on specific crops:				
NO_3^- – N	me/l	< 5	5 - 30	> 30
HCO_3^-	me/l	< 1.5	1.5 - 8.5	> 8.5
pH (by nutrient imbalance)		Normal range 6.5 - 8.4		

Source: Booker Tropical Soil Manual, Ed Landon J R, Longman (1991)

TDS – Total Dissolved Solids (Total Salt Content, water salinity), g/l
ECw – electrical conductivity, dS/m   Cl – chlorine content, me/l or g/l

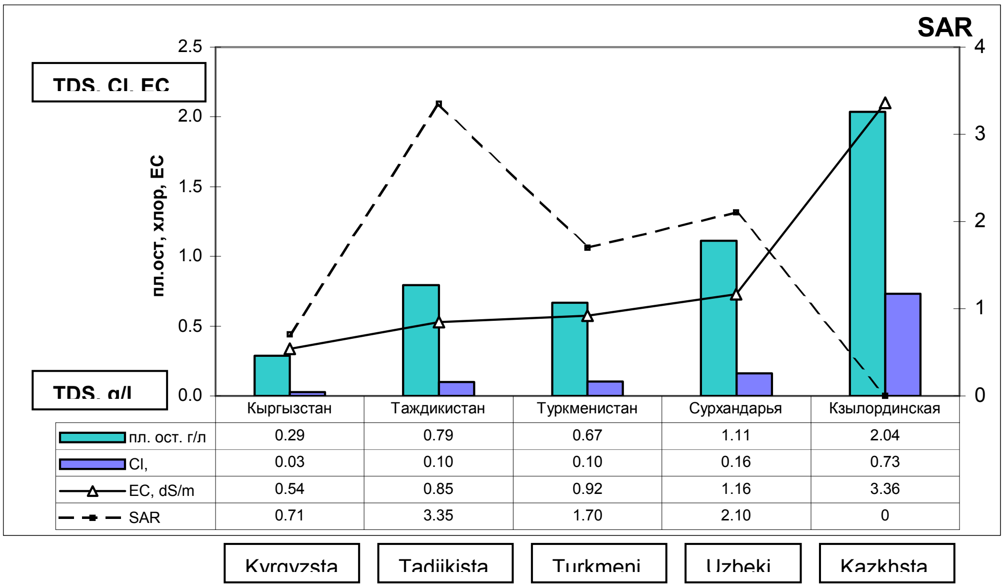
SAR - показатель процесса осолонцевания $SAR = \frac{Na}{\sqrt{Ca + Mg}}$ SAR – Sodium Absorption Ratio

Average values of analyses of irrigation, drainage and ground water samples with degrees of restriction in use for irrigation by FAO criteria are shown in Table 7.9 and Figures 7.9 and 7.10.

Table 7.9 Water Quality Indices and Degree of Restriction in Use for Irrigation by FAO Criteria (average by region)

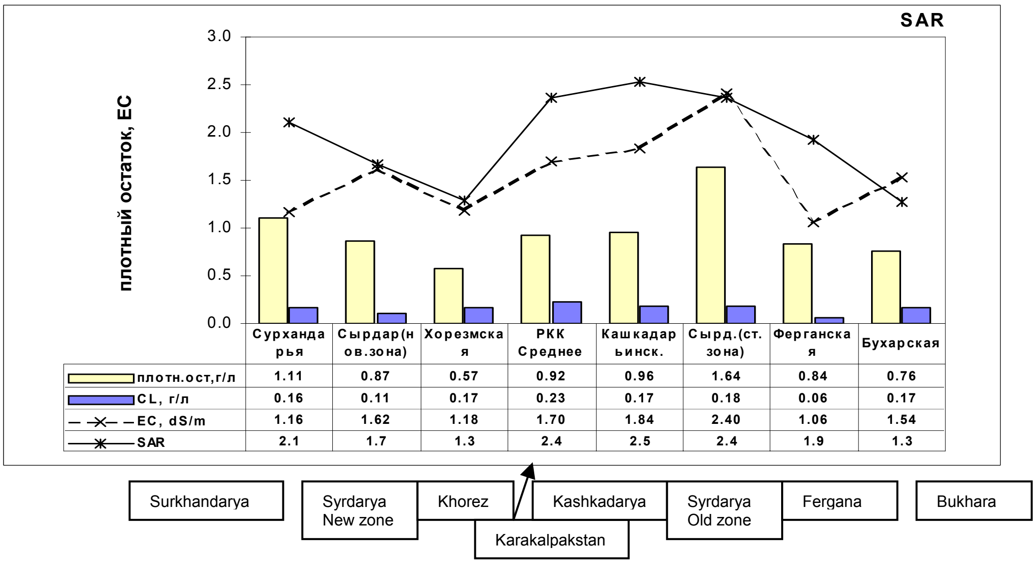
Type of Water	Years	pH	TDS g/l	EC dS/m	Cl g/l	SAR	Degree of Restriction in Use (None=0, Severe=2)		
							EC	Cl	SAR
Irrigation	1996	*8.40*	*0.77*	*1.24*	*0.11*	*1.80*	*1*	*0*	*0*
	1997	*7.92*	*0.88*	*1.30*	*0.12*	*не.опр*	*1*	*0*	*0*
Drainage	1996	*7.10*	*2.98*	*3.81*	*0.50*	*5.61*	*2*	*2*	*0*
	1997	*7.78*	*6.09*	*6.66*	*0.86*	*не. опр*	*2*	*2*	*0*
Drainage	1996	*8.21*	*5.55*	*5.28*	*0.89*	*6.49*	*2*	*1*	*0*
	1997	*7.68*	*5.76*	*6.21*	*0.79*	*не. опр*	*2*	*1*	*0*

Figure 7.9 Average Indices of Irrigation Water Quality by CAR, 1996



	Кыргызстан	Таджикистан	Туркменистан	Сурхандарья	Кзылординская
пл. ост. г/л	0.29	0.79	0.67	1.11	2.04
Cl,	0.03	0.10	0.10	0.16	0.73
EC, dS/m	0.54	0.85	0.92	1.16	3.36
SAR	0.71	3.35	1.70	2.10	0

Figure 7.10 Average Indices of Irrigation Water Quality in Uzbekistan in 1996 (by Oblast)

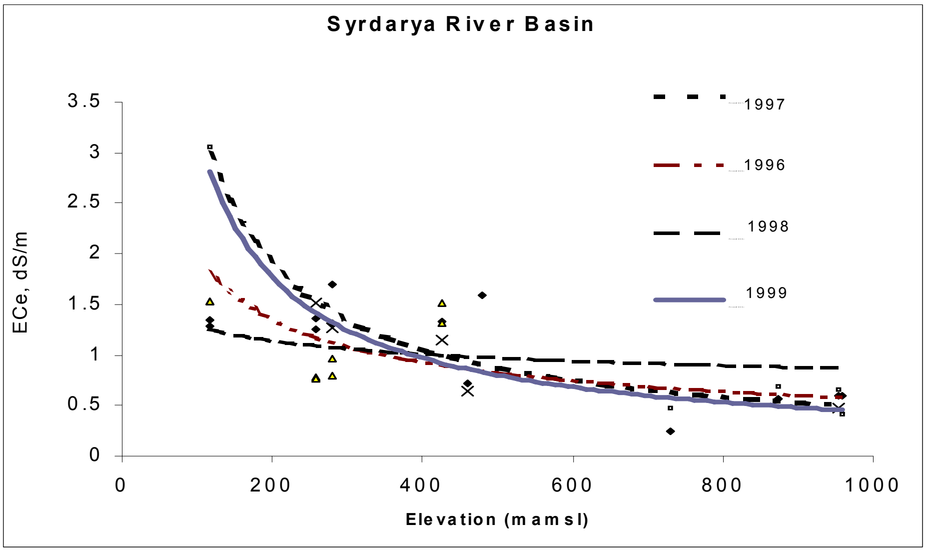


	Сурхандарья	Сырдар(нов.зона)	Хорезмская	РКК Среднее	Кашкадарьинск.	Сырд.(ст.зона)	Ферганская	Бухарская
плотн.ост,г/л	1.11	0.87	0.57	0.92	0.96	1.64	0.84	0.76
CL, г/л	0.16	0.11	0.17	0.23	0.17	0.18	0.06	0.17
EC, dS/m	1.16	1.62	1.18	1.70	1.84	2.40	1.06	1.54
SAR	2.1	1.7	1.3	2.4	2.5	2.4	1.9	1.3

Chemical analyses and electrical conductivity of **irrigation water** in sample farms for the period 1996 –1998 confirm in general the well-known problem of water quality deterioration (Annex 7.4.1).

Irrigation water quality in relation to elevation of sample farms in Syrdarya and Amudarya river basins is shown in Figure 7.11. From these figures it is clear that water contamination is higher at the lower river reaches.

Figure 7.11 Variation of Electrical Conductivity in Syrdarya and Amudarya River Basins (each point represents average value by 10 fields)



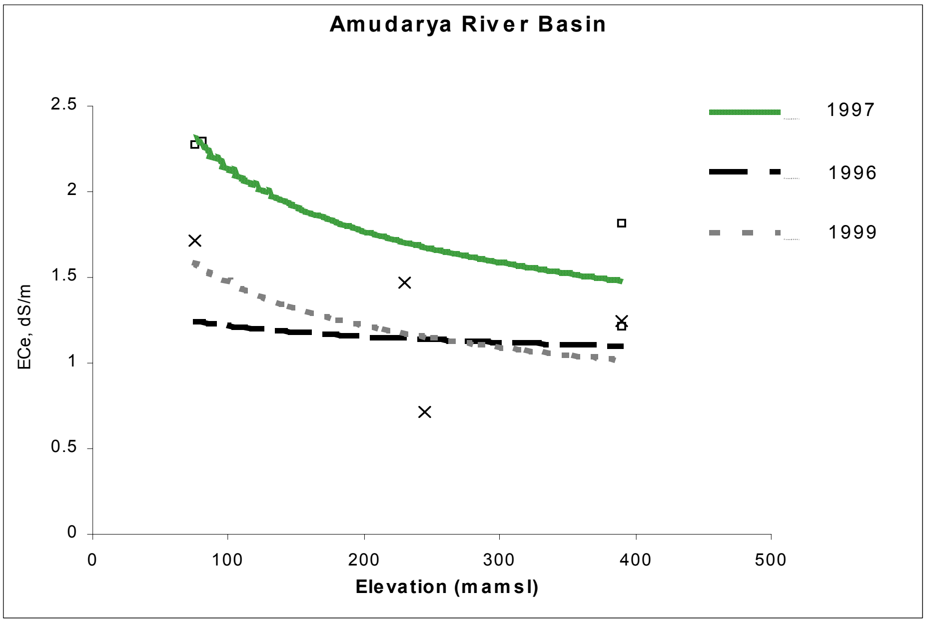


Table 7.10 Variation in EC of Irrigation, Drainage and Ground Water

Republic, Oblast	Farm code	Elevation (mamsl)	EC of irrigation water dS/m				EC of drainage water dS/m			EC of groundwater dS/m		
			1996	1997	1998	1999	1996	1997	1999	1996	1997	1999
Kazkhstan												
Kzyl Orda	1	117.5	1.29	3.06	1.53		1.61	8.4		3.74	5.25	
	2	117	1.34		1.53		5.33	8.2		6.31		
South Kazakhstan	3	257	1.36		0.78	1.52		3.11		1.67	3.75	
	4	257	1.26		0.76		1.35			1.31	4.01	
Kyrgyzstan												
Chu	7	730	0.25	0.47			0.71				0.74	
	8	958	0.59	0.41						0.41		
Osh	9	954	0.60	0.66		0.48						
	10	873	0.57	0.69								
Tadjikistan												
Leninabad	14	425	0.85		1.52	1.14	2.65					
	37	425			1.32							
Turkmenistan												
Mary	17	240	1.05		1.16		2.79			8.13		
	18	244	0.86		1.33	0.71	7.59			6.74		
Uzbekistan												
Surkhandarya	21	390	1.1	1.21	2.41		4.68	5.1		10.69	9.60	
	22	390	1.42	1.82	2.49	1.25	3.66	7.72	6.39	9.98	7.81	6.68
Syrdarya	23	280	1.7		0.97		9.78	5.87		8.75	6.87	
	24	280	1.32		0.79	1.27	6.47	9.2	6.92	9.63	6.24	3.24
Khorezm	25	90	1.22		1.55		3.72			4.03	2.86	
	26	90	0.97		1.54					4.32	2.78	
Karakalpakstan	27	80	1.72	2.3	0.94		7.68	8.35		4	4.62	
	28	75		2.28	1.58	1.71	5.37	2.8	2.75		2.70	
Fergana	33	480	1.59				1.64			3.24		
	34	460	0.72			0.64	1.43		0.32	2.06		0.92
Bukhara	35	230	1.57		1.59	1.47	5.12		5.37	4.65		4.86
	36	230	0.88		1.57		5.66			3.61		

The best water quality was found on the farms of Kyrgyzstan, Tadjikistan and in Fergana Oblast of Uzbekistan (located at the upper reaches of Syrdarya river). The average EC values by sample farms in Kyrgyzstan are varied from 0.25 – 0.60dS/m in 1996 to 0.41 – 0.69 in 1997, that of in Fergana Oblat was from 0.72dS/m in 1996 to 0.64dS/m in 1999.

At the middle reaches of Syrdarya river (South Kazkhstan Oblast and Syrdarya Oblast of Uzbekistan) EC values are varied from 0.8 to 1.7dS/m without stable trends towards rise or drop. EC values of irrigation water in Bukhara Oblast are stable (around 1.5 – 1.6dS/m), and they are approximately in the same range in Khorezm Oblast (1.2 – 1.6dS/m).

In Sherabad rayon of Surkhandarya Oblast EC of irrigation water is around 1dS/m, but the average irrigation water salinity was 1.1 – 1.8dS/m, because mixture of irrigation and drainage water with salinity up to 3dS/m was used for irrigation on some fields.

The poorest quality of irrigation water was found in the farms, located at the lower reaches of Syrdarya and Amudarya rivers: in Kzyl Orda Oblast of Tadjikistan and in Karakalpakstan with EC values in the range 1.3 – 1.7dS/m and there are trend towards their rise from year to year.

Average values of the drainage water analyses (EC, TDS and chemical composition) are also given in Annex 7.4.1. The most saline drainage water on average (more than 5g/l) was found in the fields of Uzbekistan farms (Syrdarya and Surkhandarya Oblasts and Karakalpakstan), in Turkmenistan and Kazakhstan and the least saline drainage water (less than 2g/l) was found in Kyrgyzstan and Tadjikistan. Apart from Kyrgyzstan, the drainage water samples have a high hazard rating for use as irrigation water, particularly on the basis of TDS and ECw. Soil sodicity hazard (on the basis of SAR) is not high.

Monitoring data of drainage water quality during four years (Table 7.10) shows the rise of EC values in Kazakhstan and Uzbekistan. Special study and comprehensive analysis of specific conditions is required to reveal the reasons of drainage water quality deterioration (as tail escapes etc.).

Groundwater depth depends on such factors as general hydrogeological conditions, elevation above water bodies, rate of lateral drainage, type of crop, irrigation schedules and presence and effectiveness of artificial drainage.

Depending on elevation of farmland variation of the average watertable depth is significan during vegetation period.

The Kyrgyzstan and Tadjikistan farms are representative of the upper reaches of the river, where the ground water depth in all fields is mostly 10m or more(apart from two fields in Kyrgyzstan and five in Tadjikistan). The Uzbekistan farms in Syrdarya oblast are representative of the river's middle reaches with average groundwater depth during vegetation period 2.1-2.3m, but it is varied by the fields in the range from 1.8 to 3.0. The Turkmenistan farms are representative of desert land with average groundwater depth 1.8m (with the range from 1.3 to 3.0). In the farms of Sherabad rayon (Surkhandarya oblast in Uzbekistan) groundwater depth is quite different by the fields with the range from 0.9 to 4.8m (representing the evidence of non-uniformity of hydrogeological conditions within one farm due to terrain features). In Bukhara oblast of Uzbekistan the average groundwater depth during vegetation period is below 2.0m with slight variation by the fields. In the lower reaches of Amudarya river the average groundwater depth during vegetation is mainly less than 2m, and in Kzyl Orda oblast of Kazakhstan it is 0.7-0.8m.

The way how groundwater depth affects crop yield depends on its quality. High level of very saline groundwater is the reason of secondary salinization process. Relationship between irrigation and ground water salinity and salt accumulation in soil is shown in Tables 7.11 A and B. It confirms the importance of water quality used for irrigation and the necessity of its control. The distinctive feature of the region is the fact that on average salt accumulation in the top 30cm of soil *to the greater extent depends on irrigation water quality* rather than on groundwater. Therefore, the special attention should be given to the control of salinity hazard while irrigating with drainage water.

But in Sherabad rayon of Surkhandarya oblast with high level of very saline groundwater (on average 9-12g/l) soil salinization process is more dependent on ground water than on irrigation water (Table 7.11). It is well known, that optimal combination of irrigation schedule and operational drainage system can prevent the secondary soil salinization.

Data on groundwater salinity and electrical conductivity with evaluation of groundwater quality by sample farms are shown in Annex 7.4.1.

On average the highest groundwater salinity was found in Surkhandarya (9-12g/l) and Syrdarya (7-9g/l) oblasts of Uzbekistan and in Kzyl Orda oblast of Kazakhstan (8.7g/l). The least groundwater salinity (2.0-2.6g/l) was recorded in Fergana and Khorezm oblasts of Uzbekistan. Variation of groundwater salinity by years depends on irrigation schedule and availability of operational drainage system.

Table 7.11. Correlationship between salinity factors (ECirr of irrigation water, ECgr of ground water, ECe of soil)

A) Overall by the region

Factors	*ECirr, dS/m*	*ECe, dS/m*	*ECgr, dS/m*
ECirr, dS/м	1		
ECe, dS/m	**0.38**	**1.00**	
ECgr, dS/m	**0.31**	**0.15**	**1.00**

B) Farm 22, Sherabad rayon, Surkhandarya oblast, Uzbekistan

Factors	*ECirr, dS/m*	*ECe, dS/m*	*ECgr, dS/m*
ECirr, dS/m	**1**		
ECe, dS/m	**0.3**	**1.0**	
ECgr, dS/m	**0.4**	**0.5**	**1.0**

Chemical composition of ground water depends on both geological and hydrogeological condition of certain zone and genetic types of salinity of soil forming rocks in the zone of ground water flow. Comparison of chemical composition shows the diversity of ground water quality. However, sodium sulphate, magnesium sulphate and calcium sulphate prevail all over the region (Table 7.12).

Table 7.12 Chemical Composition of Groundwater

Republic	**Ions content in decreasing order**
Kazakhstan	SO_4>Na>Mg>Cl>Ca
Kyrgyzstan	SO_4>Mg>Ca>Na
Tadjikistan	SO_4>Na>Ca>Cl>Mg
Turkmenistan	SO_4>Na>Cl>Mg>Ca
Uzbekistan	SO_4>Na>Mg>Ca>Cl

Relationships between salinity of irrigation, drainage and ground water based on survey data from control and demonstration fields in 1999 are shown in Table 7.13. There is a direct correlation between salinity of water in drains and collectors and between irrigation and collector water (Farm 22, Sherabad rayon, Surkhandarya oblast) and this is completely logical.

In Syrdarya oblast (Farm 24) analysis of similar data shows the results which it is difficult to explain (Table 7.13). This allows assuming that planned management of salt regime in irrigated land of Golodnaya Steppe is not achieved in fact. Inspite of water deficiency in this zone a lot of irrigation water is discharged into drainage collectors. Comparison between water salinity in drains and collectors confirms this fact. For example, in farm 22 EC values of water in drains and collectors were 6.4 and 6.7dS/m accordingly, but in the farm 24 EC of water in drain was 6,9dS/m and that of in collector was 3,2dS/m. There is an inverse relationship between salinity of drainage and ground water, but relationship between salinity of collector and ground water is almost absent, even in Sharabad. This is illogical and should be studied in more detail to provide a scientific explanation of this phenomenon.

Table 7.13 Correlation Between Salinity of Irrigation, Drainage, Collector and Ground Water (based on the 1999 data)

A) Farm 22, Surkhandarya Oblast

	ECirr	ECdr	ECcol	ECgr
ECirr	1			
ECdr	0.19	1.00		
ECcol	0.37	0.39	1	
ECgr	0.19	-0.26	-0.07	1

B) Farm 24, Syrdarya Oblast

	ECirr	ECdr	ECcol
ECirr	1		
ECdr	-0.23	1.00	
ECcol	0.004	0.10	1

According to the FAO criteria in the above Table 7.8 evaluation of water quality can be made on the basis of EC value. It is well known that TDS is commonly used for water quality evaluation in local classification. And water with salt content no more than 1g/l is considered as suitable for irrigation. As it is clear from the above information, actual river water salinity is often above this limit.

In order to convert EC measurement into traditional local units of measurements – **total salt content** or mineralization, expressed in grams per litre (g/l), it is necessary to establish zonal coefficients. It is well known that conversion factor of ECw (dS/m) into g/l depends on chemical coposition of water. The relationship between water mineralization and EC value can be expressed by the following equation:

$$M = 0.64 x ECw$$

where:
M is water mineralization in g/l; **0.64** is an empirical coefficient;
ECw is electrical conductivity of water in dS/m.

Monitoring data in WUFMAS program provide the possibilities to derive the zonal coefficients for in-field evaluation water salinity. This is especially important when collector and drainage water is used for irrigation. Analyses of data from WUFMAS regional database allow deriving the following conversion factors ***K:***

K is varied from 0.8 to 1.3 (M = 0.8 – 1.3 ECw) when Na:Cl ratio is in the range from 0.5 to 3.0; and

K = 1, when Na:Cl = 1 (see Figure 7.12).

Figure 7.13 (where n = 790, R = 0.9) is based on summary data by CAR. This curve proves that for approximate calculations it is possible to use ***K = 1.1***, or

$$M = 1{,}1\ ECw$$

Chemical composition of water differs throughout the region and depends on types of soil-water regimes and geological conditions (pairs of WUFMAS sample farms were selected in relation to these conditions). On the basis of these data correlation coefficients between EC values and salinity of irrigation, drainage and ground water were calculated. For details see Annex 7.4.2.

Figure 7.12 Relationship between Chemical Composition of Water and K Factor

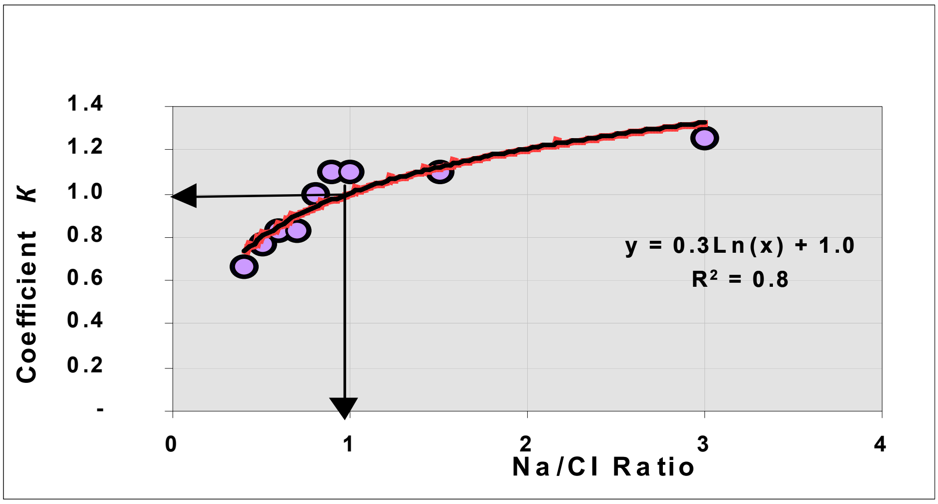


Figure 7.13 Relationship between Water Salinity and EC Value