R E P O R T

Monitoring of the Amudarya river delta and the dried bed of the Aral Sea under the **"CAWA" Project – «Dynamics of surface and ground water change between the Amudarya delta and the dried bed of the Aral Sea»**

ABSTRACT

A dominant factor of environmental destabilization in Prearalie and the Aral Sea was the decrease of runoffs in the Syrdarya river and the Amudarya river. In 1911-1960, the mean annual runoff in the runoff formation zone of those rivers was 117 km^3/yr (including, Amudarya - 80 km^3/yr; Syrdarya - 37 km^3/yr), of which actual inflow into the Aral Sea was not more than 56 km^3/yr (Amudarya - 42 km^3/yr; Syrdarya – 14 km^3/yr). In 1961-1970, this inflow decreased to 30 km^3/yr (53% of the long-term annual average), while in 1971…1980, to 16.7 km^3/yr (30 % of the long-term annual average), in 1981...90 – to 3.45 km^3/yr (6% of the long-term annual average), and in 1991...1999 – to 7.55 km^3/yr (13% of the long-term annual average).

The level lowering in the Aral Sea shifted the focus in natural bio-resources use in this region from the area of the sea to the areas of deltaic wetlands.

The Prearalie's deltaic water bodies that existed mainly through inflows from the Amudarya river, have been subjected to a number of negative changes when their watering had been cut. During the same period of time, with the completed construction of large main drains (collectors) in Prearalie, a new type of water bodies – tail receivers of collector and drainage waters – has occurred. Recent decade, the lake area was 70.2 km^2 in the normal year 1984, and then increased up to 120 km^2 in the wet year 1997 and decreased to 26.0 km^2 in the dry year 2000.

This project is implemented jointly by SIC ICWC, the German Geoscience Research Centre (GFZ) and the Institute «GIDROINGEO» of the State Geological Committee of the Republic of Uzbekistan.

Given report is focused on Prearalie.

According to the plan, monitoring of the Amudarya delta was implemented, with the following outputs:

- every quarter, measurements of water discharge and salinity were made in three points (sections) along the Syrdarya river (Takhiatash, Samanbai, Kyzyljar);
- every quarter, measurements of water discharge and salinity were made at the heads of two canals of Glavmyaso and Porlitou;
- measurements of water discharge and salinity were made also at the tails of four main collectors (GLK, KC-1, KC-3 and KC-4);
- wells were drilled in 44 points throughout the delta and quarterly measurements were made of groundwater levels and salinity;
- soil and water samples in the west sea were taken and passed to German partners;
- a great amount of actual data on regimes and monitoring of groundwater in Neogene Quarternary and Cretaceous deposits within the study area over 1991-2009 was summarized and analyzed.

The whole information on the delta monitoring is given in Annexes to the report.

Introduction

Over the last three decades, as a consequence of the Aral Sea drying, desertification, and environmental pollution processes, a very complex environmental situation is observed in Prearalie. This is, primarily, caused by a change in watering conditions.

The main reason of abrupt environmental and economic deterioration in Prearalie region, especially in the Karakalpakstan, is a severe reduction of inflow from the Amudarya river. In 1963-65, the annual inflow to Prearalie boundary, from Tuyamuyun gauging station was 60 - 65 km^3 and fed the Aral Sea, deltaic lakes and irrigated land, while in 2001 this value decreased to 6 - 7 km^3 and amounted to only 10 %. The drastic reduction of flow in the Amudarya river, in turn, has led to increased river water salinity. Whereas 20-25 years ago, river water salinity in Nukus section was 0.6 – 0.7, currently it has increased 2.0 – 2.5 times, achieving 1.6 – 2.0 g/l. The Amudarya waters contain predominantly ions of Cl^-, SO_4^{2-}. With an increase in water salinity, the content of Ca^{2+}, Mg^{2+}, $N^+ + K^+$ decreases. As a result, water salinity was higher than MPC everywhere and in particular areas, such as Takhtakupyr, Kungrad, Muynak, Chimbay, etc. during the whole year.

In terms of hydro-geology, the Amudarya downstream represents an area of drainless plain.
The groundwater level lowering is caused by the three key factors:
- decrease in surface water inflow to the delta and, hence, lessening of infiltration into groundwater;
- cut in areas immersed by flooding and permanent water bodies that also recharge groundwater;
- drop in draining level in form of Aral Sea level, and, hence, groundwater level lowering in the zone of depression curve of inflow to the sea.

In order to study dynamics of changes in surface (river and drainage) waters, shallow and deep groundwater in the delta and Prearalie, the project is implemented jointly by SIC ICWC, the German Geoscience Research Centre (GFZ) and the Institute of Hydrogeology and Engineering Geology State Corporation "Hydroingeo" SC of Uzbekistan.

The objective of work in 2009 was to implement monitoring (discharge and quality of surface and ground waters) in the Amudarya river delta and the Aral Sea of water (changes in sea level and salinity), soil (salt content), as well as groundwater monitoring. This work is a follow-up of 3-year research completed within the framework of the GTZ Project "Stabilization and Use of the Dried Bed of the Aral Sea in Central Asia". The project results indicated to substantial dynamics of landscapes as the sea desiccated and formation of new landmass.

Given work consists in studying both external and underground processes in their interaction on the ground, in the sea, on the exposed seabed and in Prearalie, in identifying dynamics of deep and shallow groundwater.

In 2009, materials needed for analyzing the processes were collected.

1. Research target

The Amudarya delta has developed under the influence of long-term natural fluctuations of the river runoff. Eventually, under the influence of various processes caused by the sea, river and erosion dynamics, the landscape of delta and its hydrological and hydro-geological profiles with numerous water bodies were formed. These water bodies when the Aral Sea level was 53 m +BSL (lakes Sudoche, Karateren, Kokchiel, Akchakul, Zapadnoe), have represented lakes of the coastal deltaic plain occasionally flooded by river and sea waters and linked with the Adjibay and Djiltirbas bays. During wet years, lakes were completely desalinated with plentiful river waters and have obtained features of water bodies with good flow-through. When inflow of freshwater has decreased during dry years, these lakes were partly flooded with sea water, and that has resulted in abrupt change in physical and chemical properties of water with subsequent modification of their flora and fauna and their biological productivity.

Preservation of biodiversity and improvement of natural productivity of bio-resources are primary environmental-social objectives in Prearalie. Lakes and wetlands that have high potential bio-productivity and serve as natural habitats for local and global fauna are critical for achieving these objectives. To this end, in 1984, SANIIRI Institute developed a plan of engineering structure layout in the delta and on the exposed Aral Sea bed under **«Creation of artificially regulated water bodies and wetlands in the Amudarya river delta and on the exposed bed of the Aral Sea»**. (The Aral Sea problem and environmental protection programs / Dukhovny V.A., Razakov R.M., Ruziev I.B. // Desert development problems. - 1984. - Issue 6. - p. 3-15).

Establishing the buffer protection zones in the form of a series of local water bodies with the purpose of forming artificial wetland ecosystems had been started in the South Priaralie prior to 1995 according to the temporary plans. In that time, unregulated water bodies such as Ribache, Muynak, Djiltirbas, Dumalak and others, with the total water surface of about 1600 sq km, had been constructed in the Amudarya delta and at the dried Aral Sea bed. Despite of a limited scale of implemented measures, an ecological effect was quite significant and resulted in a twofold reduction of a salt and dust transfer to adjacent cultivated lands, partial flora and fauna restoration in the delta, as well as in improvements of fishery and livelihoods of the local population. However, the project works were not being implemented for a long time due to the lack of funds until the GEF Agency has begun to finance the WEMP Project (Component E) and the Small Water Bodies Project at the expense of IFAS' funds, that it has imparted new impetus to those activities. In particular, at the expense of these funds, the Sudoche lakes system was constructed, and the Mezdureche Reservoir was partially reconstructed.

The project NATO SFP – 974357 provides for the construction of water infrastructure and artificial wetland ecosystems in the Amudarya delta and the adjacent dried seabed in order to rehabilitate the natural ecological regime throughout the South Prearalie. In general, the Prearalie rehabilitation is differentiated for three zones: the Amudarya river delta, the dried seabed and the Aral Sea itself. Within the framework of this work the design was performed for two zones:

- ***The first zone*** – to develop the Amudarya river delta in order to rehabilitate as much as possible its natural environmental regime and to create reasonable living conditions for the population. Water bodies to be filled at the first phase included: reservoirs Mezdureche, Ribache, Muynak and Djiltirbas, and lakes Mashankul, Ilenkul, Makpalkul and Dumalak.
- ***The second zone*** – to develop the dried seabed to mitigate negative impacts of the sea level lowering. Water bodies to be filled at the second phase included: Adjibay – 1, Adjibay – 2, Djiltyrbars – 1 (water will be supplied depending on its availability) (Fig. 1).

The Aral Sea shrinkage and loss of a natural linkage with its bays resulted to ceasing of water resources replenishment with sea water, and the delta has become completely dependent on the regime of river water inflow. As a result of permanent reduction of river inflow that started in the 1960s, the lakes began functioning as a natural evaporators followed by drastic reduction of water volumes and increase in salinity.

At present, all water bodies within the Amudarya delta may be divided into two groups according to their water regime:

1. the lakes fed by collector-drainage water (Sudoche, Western Karateren, Akushpa, Eastern Karateren, a part of Djiltirbas lake and others);
2. the lakes fed by the Amudarya river water (lakes Mezdureche, Dautkul, Ribache, Muynak, Dumalak and others).

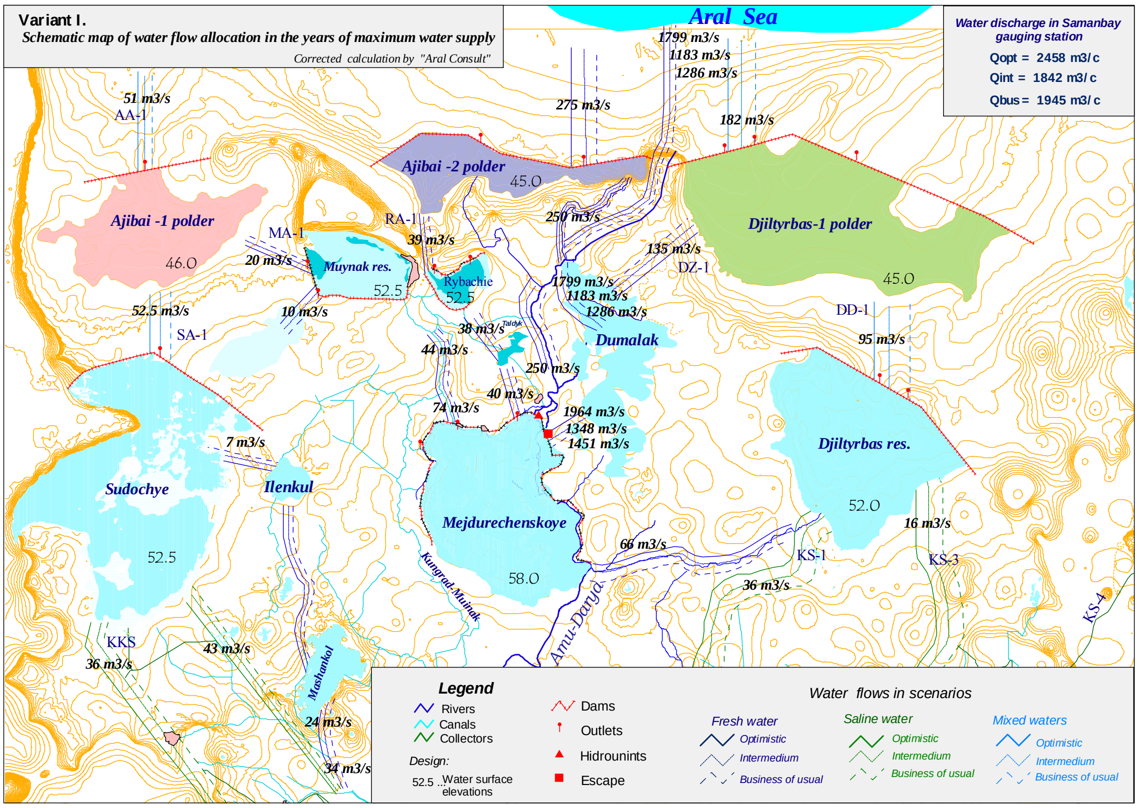


Fig. 1 Schematic map of wetlands in South Prearalie

During many decades such lakes as the Karateren, Akchakul, Sudoche, and Kokchiel have been used as receivers for irrigation waste and drainage water discharged from irrigated lands. In the nearest future, these lakes would be impossible to use for both fishery and reed harvest needed for cattle-breeding if fresh water supply is not rehabilitated.

The volumes of drainage water supply through main drains situated in the left and right bank areas of the Amudarya River depend mainly on annual water availability and the amount of water delivered for irrigation within the command area of the Suenly and Kyzketkent canals.

According to the pattern of water supply and quality of water, the territory of the Amudarya delta may be divided into three zones:

1. The Left Bank Zone is the command area of the Lenin canal and Main Drains GLK, Sudoche lake and Adjibay lake. The main water bodies are lakes of the Sudoche wetland – the Akushpa, Taily, Karateren, Big Sudoche, and Begdulla-Aidyn and lakes of the Karadjar system – the Mashankol, Hojakol, and Ilmenkol.
2. The Preamudaryinskaya zone includes coastal and deltaic lakes fed from the Amudarya river and the large irrigation canals. The main water bodies are the Mezdureche Reservoir, Ribache and Muynak Bays, and Makpakpol Lake.
3. The Right Bank Zone is located along the Kyzketken canal, within the command areas of Main Drains KC-1, KC-3, and KC-4. The main water body is the Djiltyrbas Bay.

According to a water exchange pattern, water bodies of the South Prearalie are divided into: flow-through water bodies – the Mezdureche Reservoir and Makpalkol Lake; water bodies with low (periodical) flow-through – lakes Karateren, Big Sudoche, Begdulla-Aidyn, Mashankol, Hojakol and Ilmenkol, bays Ribache, Muynak, Djiltyrbas; and closed drainage water sinks – lakes Akushpa and Tayli.

2. Description of monitoring observation points

A monitoring plan (discharge and quality of surface and ground waters) was drawn up for the Amudarya river delta and the Aral Sea – water (water levels and salinity) and soil (salt content).

Target	Monitoring frequency	Monitoring parameters	Monitoring points
Amudarya delta (soil)	Once a year	pH and salt content	30 points
Amudarya delta Groundwater	Every decade	Level and salt content	33 points
Amudarya (Takhiatash, Samanbay, Kyzyljar)	Every decade	Discharge, temperature, salinity	Three points – water discharge
Canals – Glavmyaso, Porlytau and others flowing to the delta	Every decade	Discharge and salinity	Two points
Drainage water GLK, KC-1, KC- 3 and KC-4	Every decade	Discharge and salinity	Four points
Aral Sea (information from Karakalpak Hydromet)	4 times a year (twice in 2009)	Water level	West and East parts (if available, in west)
	Twice a year (once in 2009)	pH, hydrochemistry	West and East parts (if available, in west)

Takhiatash section (Takhiatash waterworks) is located 2 km far from Nukus city. Water is distributed between Suenly canal and Kyzketken canal in this section; the waterworks is equipped with hydrometric measurement devices; and water discharge is measured in downstream. The staff of the Delta Authority note that all measurement devices in this section are outdated and need to be replaced by modern ones.

Samanbay section is located within the Nukus city boundaries, 6-7 km far from Takhiatasj waterworks. Besides measurements of discharge in this section, water samples are also taken once a month to measure salinity. This section also has outdated devices that need to be replaced by modern ones.

Kzyldjar section is located 100 km downstream of the Samanbay section. The last 10 years, due to lack of financing, this section has not been operated practically. Therefore, there is a need to rehabilitate this section in order to measure water resources and their quality because this section is a key one, where water is distributed between Mezdureche reservoir and along the old channel of Kazakhdarya. Water accounting is not available throughout the delta, and therefore, uses of water flowing to the delta and its distribution are uncontrolled.

Monitoring points along such canals as Marinka, Muynak and Raushan include outlet structures at Mezdureche reservoir and Suenly canal, respectively. The analysis indicates that water discharge measurements are not accurate in these structures as well due to outdated measurement devices.

Monitoring points along main drains in tail parts are arranged in form of bridges for stream gauge to measure discharge and take samples for chemical analysis. However, in most cases, water accounting is made by sight and water samples are taken once a month.

Monitoring points for groundwater level and salinity are arranged in three zones in the delta:

- **central zone** – the command area of the Amudarya main channel, Glavmyaso and Marinkinuzyak canals: in two plots – one of the shirkat farm Aral (9 wells) and another one in shirkat farm Muynak (16 wells);
- **left bank zone** – the command area of Raushan canal: plot of the shirkat farm Raushan (9 wells);
- **right bank zone** – the command area of Kyzketken canal and Kazakhdarya channel (10 wells).

Based on the plan, the monitoring of the Amudarya river delta was completed:

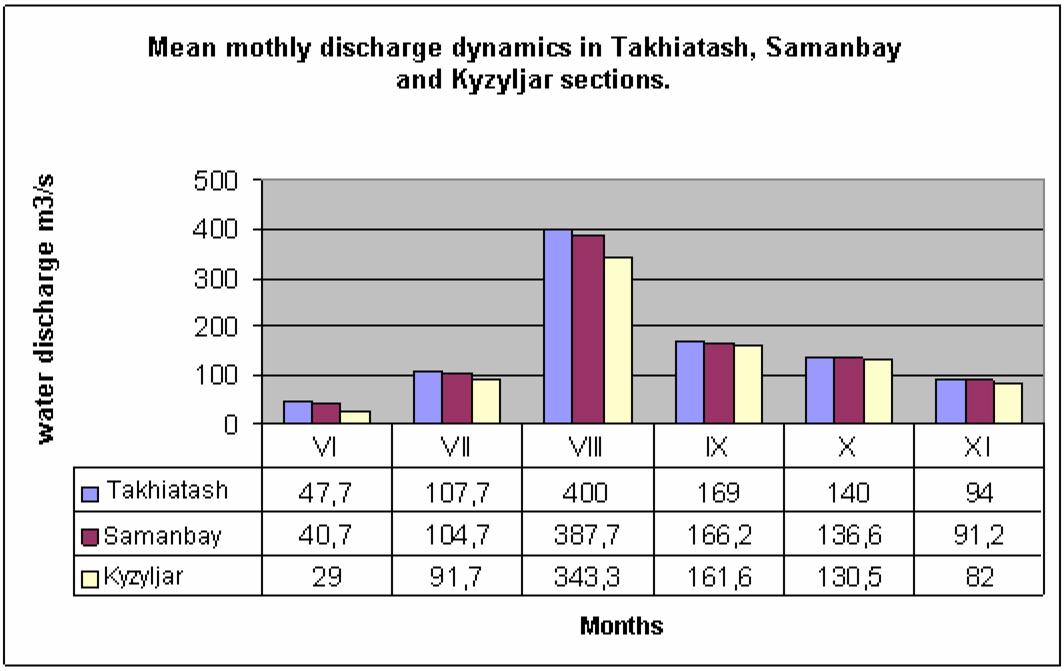
- in the three points (sections) along the Amudarya river (Takhiatash, Samanbay, Kyzyljar), water discharge and salinity measured every quarter. The results are given in the Tables 1 and 2, in the Figure 2, as well as in Annex 1, Table 1;
- at the head of Glavmyaso canal and Porlitau canal, water discharge and salinity measured monthly. The results are shown in Table 3, Annex 1;
- at tails of the four main drains (Ustyurt, GLK, KC-1, KC- 3 , KC-4), water discharge and salinity measured. The monitoring results are shown in the Tables 4 and 5 and Annex 1;
- in 44 points throughout the delta wells drilled and groundwater level and salinity measured every quarter. The monitoring results are given in Annex 1;
- soil profile cuts established in direct proximity to wells, and in total, 30 soil samples taken. Figure 4 shows expedition route and soil sampling points. The monitoring results are given in Annexes 2 and 3.

2.1.1. Inflow to the delta from the river. The monitoring of inflow to the delta was implemented in Samanbay section. The Table 1 below shows the actual inflow through Samanbay into the delta for series of years and the Figure 2 gives a diagram of mean monthly discharge dynamics in Takhiatash, Samanbay and Kyzyljar sections over 2009.

Table 1

Actual water inflow into the Amudarya river delta

Section	Hydrological years							
Samanbay	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009	Over CY 2009
Water volume, Mm^3	9655	4605	13060	3103	731.2	676.1	1944	2712.3



	VI	VII	VIII	IX	X	XI
Takhiatash	47,7	107,7	400	169	140	94
Samanbay	40,7	104,7	387,7	166,2	136,6	91,2
Kyzyljar	29	91,7	343,3	161,6	130,5	82

Fig.2 Mean monthly discharge dynamics in Takhiatash, Samanbay and Kyzyljar sections over 2009

2.1.2. Water supply to the Left Bank system was made through the Suenly canal, while the Right Bank received water through the Kyzketken canal from Takhiatash waterworks. The Table 2 gives the total water diversion and spills from Suenly and Kyzketken canals by delta system for hydrological years.

Table 2

Total water diversion and spill from Suenly and Kyzketken canals by delta system for hydrological years

Structure	Hydrological years						
Suenly and Kyzketken	2002-2003	2003-2004	2004-2005	2005-2006	2006-2007	2007-2008	2008-2009
Water volume, Mm^3 (diversion)	3628	3255	3552	3186	1440	3196	3206
Water volume, Mm^3 (spills)	1403	1873	719	1414	1511	369	283,5

2.1.3. Water supply to deltaic lakes, such as Muynak, Rybache and Sudoche was performed through Muynak, Marinkin and Raushan canals, Ustyurt and KKC main drains. The Table 3 shows volumes of water supply by canal, since July till November 2009.

Table 3

Canal	Month				
	July	August	September	October	November
Marinkin, Mm^3	12.7	85	97.5	-	-
Muynak, Mm^3	-	38.2	77.0	39.8	13.0
Raushan (Ustyurt and KKC), Mm^3	36.4	89.5	153.6	77.4	15.1

2.1.4. Inflows from main drains. Water supply to the delta is arranged from both the river and main collectors: KC-1, KC-3, KC-4, KKC and Ustyurt (here, it is necessary to note that Raushan canal flows to Sudoche lake through Ustyurt main drain). The Table 4 gives inflows from the main drains into the delta for July-November 2009.

Table 4

Main drain	Month				
	July	August	September	October	November
KC-1, Mm^3	16.5	37.8	29.5	26.8	35.5
KC-3, Mm^3	10.5	13.7	26.2	9.9	2.3
KC-4, Mm^3	4.6	11.5	8.8	3.5	1.1
Raushan (Ustyurt and KKC), Mm^3	26.7	52.8	52.7	35.0	14.8

Actual inflow into the delta from the main drains. The Table 5 shows data on inflow from all the main drains for series of years since 2002 till 2009.

Table 5

Main drain	Year							
Main drainage system (whole)	2002	2003	2004	2005	2006	2007	2008	2009
Water volume, Mm^3	437	1061	1083	1156	1432	1117	663.5	991.1 as of 1.12.09.

The analysis of data on inflows to the delta from the Amudarya river showed that in 2009, the inflow, including drainage water, was about **3.7 billion m^3** (Table 6). According to the limit value approved at ICWC meeting for 2009, the planned value was **4.2 billion m^3**. We estimated that up to **3.5 billion m^3** of water are needed to keep ecological stability in the delta. Hence, the amount of water flown downstream of Samanbay section is enough to keep the ecological stability in the delta and Prearalie in 2009.

Table 6

Inflows to the delta from the Amudarya river in 2009 год, Mm^3

No.	Name of section	1st quarter				2nd quarter				3rd quarter				4th quarter	
		I	II	III	total	IV	V	VI	total	VII	VIII	IX	total	X	XI
1	Takhiatash	25.5	26.3	21.0	72.8	18.1	36.9	123.7	178.7	287.1	1095.5	437.0	1819.6	362.0	242.3
2	Sudoche	0.9	7.2	15.3	23.4	6.4	8.1	9.1	23.6	34.6	89.5	153.6	277.7	77.4	15.1
	a. KKS	0.9	7.2	15.3	23.4	6.4	8.1	-9.1	23.6	28.7	50.1	49.0	127.8	34.3	14.8
	b. Ust. Main drain	-	-	-	-	-	-	-	-	5.9	39.4	104.6	149.9	43.1	0.3
3	Karadjar	-	-	-	-	-	-	-	-	1.3	4.5	7.7	13.5	7.9	3.2
4	Djiltirbas	4.8	4.6	3.5	12.9	2.9	2.7	2.8	8.4	82.4	144.0	98.4	324.8	79.1	84.7
	a. KC-1	4.8	4.6	3.5	12.9	2.9	2.7	2.8	8.4	18.5	37.8	29.5	85.8	26.8	35.5
	b. Kazakdarya	-	-	-	-	-	-	-	-	63.9	106.2	68.9	239.0	52.3	49.2
5	Toutkol	-	-	-	-	-	-	-	-	8.2	23.2	14.9	46.3	-	0.4
	Total	31.2	38.1	39.8	109.1	27.4	47.7	135.6	210.7	413.6	1356.7	711.6	2481.9	526.4	345.7

The results of implemented monitoring over groundwater levels and salinity were obtained on the basis of 44 wells, including 27 newly drilled wells along the perimeter of Prearalie, from the shirkat farm Rushan to the shirkat farm Kazakhdarya, including between them farms Muynak and Aral. Groundwater levels vary from minimum of almost 3 m to maximum of 10 m. This indicates that groundwater levels revert to those levels observed before the development of Prearalie lands. Water flowing through rivers, canals and main drains into the delta is lost anywhere and does not reach the delta. Figure 3 shows the average groundwater levels all round the Amudarya delta.

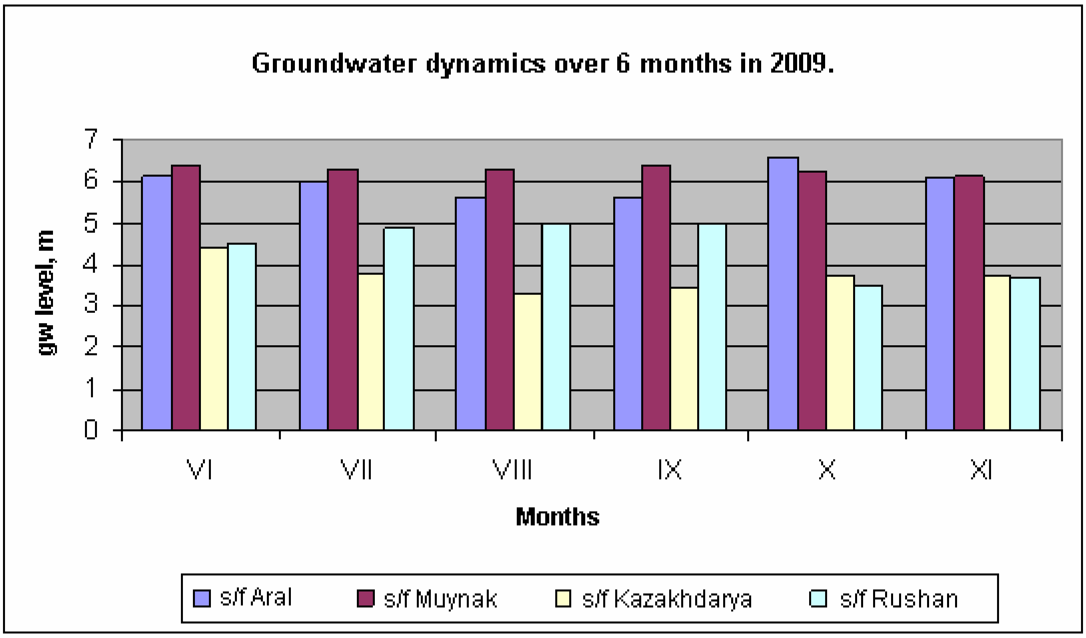


Fig.3 Groundwater level dynamics (average values) all round the delta

3. The soil monitoring was implemented during two expeditions held in spring and autumn 2009.
The objective of expeditions was to monitor shallow and deep ground waters and the soil cover.
Figure 4 shows the expedition route. It mainly covered transects of groundwater observation wells.
The soil profiles were cut directly near the wells. The German specialists carried out shallow and deep groundwater observations. Preliminary field data are given partially in the Table below.
The soil observation consisted of the description of 15 soil profiles, numbered from 61 to 615 (according to the order number of profiles and demonstration of typical profiles). (Annex 1)
Soil samples were analyzed in SANIIRI’s laboratory. (Annex 2).

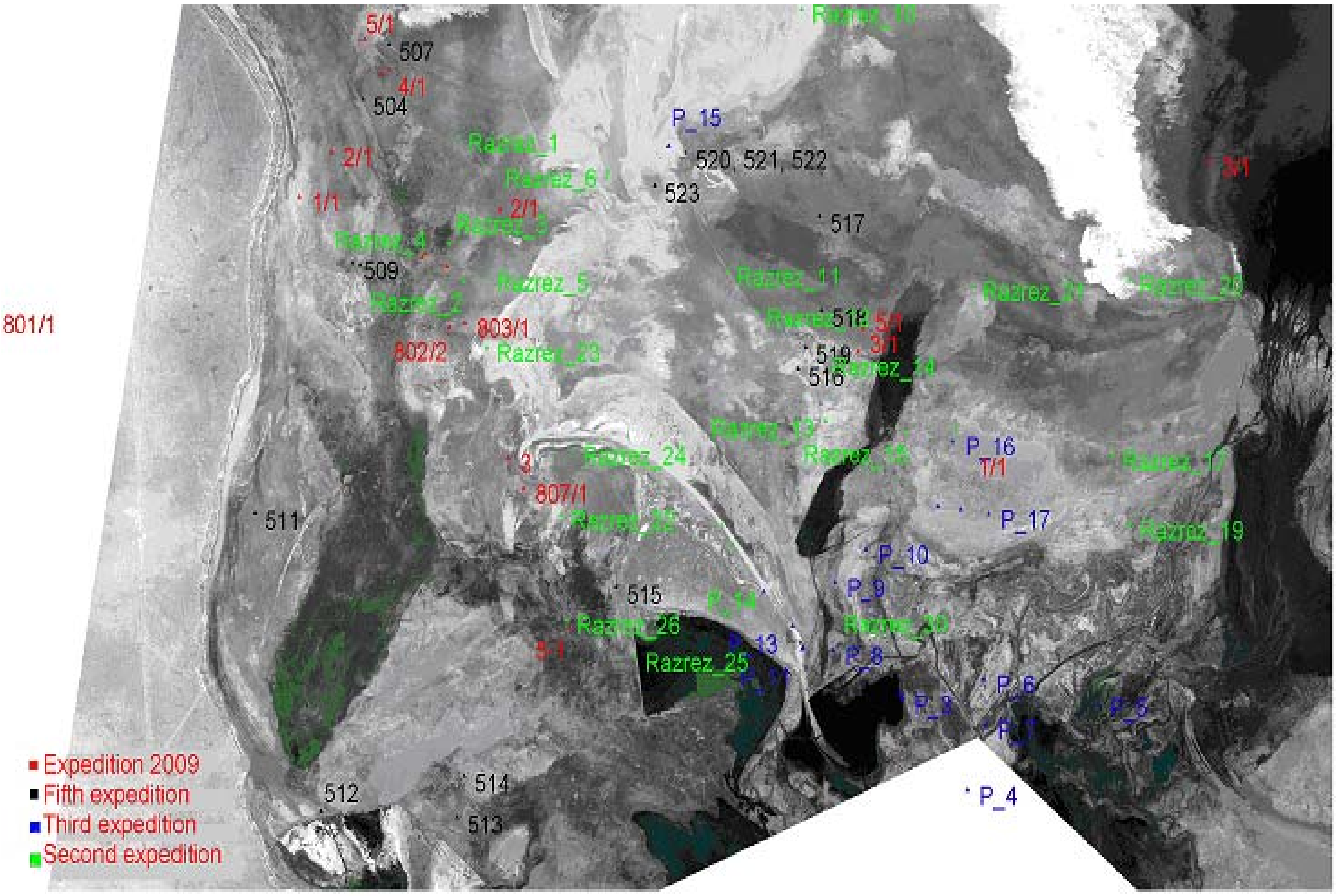


Fig. 4 Expedition route and soil sampling points

4. Assessment of delta conditions based on images and the expedition results

The expedition surveys were conducted for the selected targets. According to the expedition carried out at the end of May and the beginning of June, we found out that such lakes as Sudoche, Ribache, Muynak, Mezdurechenskoye either do not have absolutely or have very small water surfaces, although water availability has suddenly increased in the Amudarya.

Given the minimum water surface of 120 ths ha under the plan of delta's water bodies, according to satellite images, the actual surface area was 8280 ths ha in June, 16230 ths ha in July, and 22794 ha at the beginning of August (Table 7). The same was observed in the river delta at the end of the dry period of 2000-2001!!!

However, data that were received later – in October and December 2009 – on filling of lakes showed that in some lakes water levels approached design ones (Annex 1, Table 6), for instance in Djiltirbas, Rybache, Mezdureche, while this is not the case in Muynak and Sudoche lakes. As the representative of Amudarya Delta Authority stated, currently water to the Prearalie lake system should flow from both the river and main drains. The Table below gives data obtained from NOAA image processing on wetland areas (lake systems) in hectares for September, October, and November 2009.

Table 7

The water surface area in the Amudarya river delta, ha
Data obtained from Landsat images processing

№	Water body	Date		
		8.04.2000	***14.06.2001***	***4.08.2002***
1.	Sudoche	41897,73	9570,04	6497,2
2.	Mezdureche	10050,42	592,79	18375,21

3.	Rybache	5317,64	2019,68	5513,1
4.	Muynak	8623,34	1292,23	5163,2
5.	Djiltirbas	29357,73	5277,33	27620,5
6.	Dumalak	4576,89	927,23	6784,9
7.	Mashan Karadjar	16835,18	726,27	2813,9
	Total	116658,9	20405,57	72768,01

Preliminary assessment of water surface area in the Amudarya river delta, ha
Data obtained by processing NOAA images

№	Water body	*2009*		
		June	***July***	***August***
1.	Sudoche	863,47	1172,54	2575,38
2.	Mezdureche	534,73	5581,92	6147,65
3.	Rybache	1207,36	1472,63	1965,32
4.	Muynak	134,47	147,21	163,24
5.	Djiltirbas	3982,87	4324,57	5095,36
6.	Makpalkol	231,42	641,86	2020,78
7.	Dumalak	441,95	1137,42	1203,16
8.	Mashan Karadjar	884,55	1753,69	3623,43
	Total	8280,82	16231,84	22794,32

Table 8

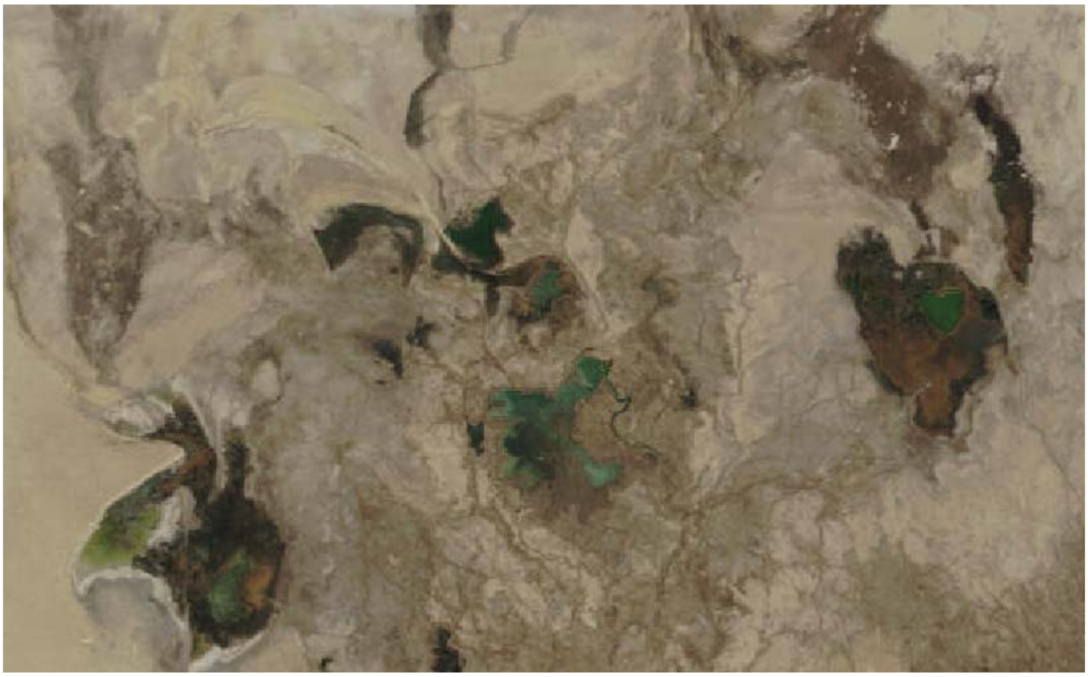
Wetland areas, ha
Data obtained by processing NOAA images

№	Water body	2009		
		September	October	November
1.	Sudoche	12648,24	32733,24	31365,50
2.	Mezdureche	19908,48	14794,54	10677,52
3.	Rybache	2065,75	15724,73	16841,11
4.	Muynak	2133,51	6606,02	5355,89
5.	Djiltirbas	27473.0	29615,43	30180,17
6.	Makpalkol	7235,98	7710,05	4930,84
7.	Dumalak	2700,66	2746,61	2882,24
8.	Mashan Karadjar	1005,16	3116,32	2630,16
	Total	75170,78,	113046,94	104863,43

September

October

November



The inspection on 14-17 August together with the representatives of Dam Administration, after the joint meeting of the head of the Nizhneh-Amudarya Basin Organization, Mr. M. Abdirov, with the head of BWO «Amudarya», Mr. B.Kdirniyazov showed the following:

1. There is no a clear-cut plan for water supply to the delta, water is supplied on the leftover principle. Moreover, though at present the growing season is completed practically, a priority is given to basin irrigation and to water provision for cotton, rice and other crops.
2. The Delta Authority virtually does not control water distribution in the delta – based on staff quantity, it able to control only the headworks of canals delivering water. Further, distribution in the delta is uncontrollable absolutely – water flows anywhere: roads and old abandoned fish hatchery fields are flooded, while inflow to the lakes is minimal.

3. The environmental state of all water bodies is quite unfavorable. Sudoche lake, which served as a place of transit for birds and where more than 1 million species inhabited in a season, has not been fulfilling this function for already three years. Evidently, the birds, after having discovered no open water surface, have shifted to other lakes in Turkmenistan (Sarykamysh) or in Kazakhstan (Northern Sea). Since almost three years of lack of water in the lakes, the reed resources have been lost, though even in 2002 the reed covered about 30 thousand ha. Fish productivity is almost zero. Some fish-farms that rent lake areas, for example Sudoche lake, try themselves to cut ditches to their areas, thus causing conflicts between the fish farms.

Taking into account a possibility of demonstrating of the Uzbekistan's aspiration to keep the delta environmentally stable, at least as minimum as possible, and in order to avoid dissemination of any harmful information in this respect, the proposals were developed and submitted to the Government of Uzbekistan.

Taking into account multiple stakeholders interested in equal and equitable water distribution between delta's water bodies and for encouraging of efficient water use, an Association of delta water users should be established among stakeholders (fishermen, hunters, cattle-farmers, khokimiyats (local authorities) of Muynak, Kungrad, and Takhaulta). This WUA should be charged with receiving of water from NABO (Nizhneh Amudarya Basin Organization), as well as with supervision over equitable water use. Discussions with water users in different parts of the delta indicated to a strong interest in organization of such WUA.

5. Groundwater monitoring (report by GIDROINGEO Institute)

To accomplish the task, a huge amount of factual material over 1991-2009 was summarized and analyzed on regimes and monitoring of groundwater in Neogene Quaternary and Cretaceous deposits within the study area.

In 1990-2009, "stationary research at a scale 1:200 000 was carried out to justify selection of polygons for monitoring of geological environment in the Republic of Karakalpakstan". As a result, it was found that major factors of change and development of negative exogenous geological and hydro-geological processes in South Prearalie were the intensive development of irrigated agriculture, deterioration of river water quality, and continuous lowering of the sea level. Within the exposed seabed area, shallow groundwater regime is characterized by a decrease, according to the Aral Sea level lowering. The impact of sea level lowering on the shallow groundwater regime is local, as well as of the absolute lowering value – on a distance of up to 15-20 km from the bedrock coast of the year 1960.

In the near-delta zone of the Amudarya river, the impact of sea level lowering on the decrease of shallow groundwater level was from 0.19-0.36 m (1991), 0.29-0.65 m (1999) to 0.59-1.22 m (2009). In irrigated area, shallow groundwater levels do not decrease practically since these levels are subjected to irrigation regimes. Based on the research, the boundaries of dried, transient and irrigated zones were identified and next tasks for stationary monitoring observations were set.

In 1989-95, an environmental and hydro-geological and engineering survey was made at a scale of 1:200000 on the exposed bed of the Aral Sea. Thus, subsurface geology and hydro-geological conditions of the exposed bed formed by Neogene-Quaternary deposits have been studied. The long-term observations (1990-2000) show that within the Amudarya delta, the sea level lowering does not have a considerable impact on deep groundwater regime since the latter is controlled only by hydrological factors of the developed polder systems (1988-92) and, first of all, depend on amount of seasonal inflows to the polders.

Within the exposed seabed area, the dynamics of level and hydro-chemical regimes of groundwater and the development of exogenous geological processes (EGP) are impacted directly by the sea level lowering and the drying period. An influence of the polder systems located in the south (30-40 km) is not observed here, except for a narrow strip of periodical surface runoff from Dumalak and Djiltirbas polders. Thus, the research identified that over 18-20 years, GWL decreased by 1.22 -1.56 m (0.6-0.22 m/yr), while for the same period of time, the water level in the Aral Sea lowered from 38.2 m (1990), 35.6 m (1998), 29.7 m + BSL (2006) to 28.7 m + BSL (2009) that is 9.5 m (0.33 -0.47 m/yr). Therefore, the rate of GW level drop in heavy loam and clay is 1.5-2 time slower against the sea level lowering.

The observations over groundwater salinity through the observation lines arranged on the dried seabed identified that salinity increases from 36-38 g/l in the south to 60-80 g/l in the north, within the area of recent drying or near the present coastline.
Since 2001, due to formation and expansion of a dried strip along the sea coast, the discharge of ground (stratal) and artesian (upward) waters occurred both under the sea water and on the exposed bed.
Before the start of the Aral Sea level lowering, groundwater of coastal strip, except for areas of some lake-shor sinks in South-East Prearalie, was discharged directly into the sea. That time, it amounted to about 4.35 m3/s or 137 Mm3/yr. However, as early as the beginning of shoaling (in 1965), when the area of dried strip reached 4 thousand km2, and the total extent exceeded 550 km, groundwater discharge was about 1 m3/s or 31 Mm3/year there. Further on, as the strip extended, particularly in the east and south-east of the sea hollow, the total groundwater discharge has increased.
Due to high salinity of rocks in the aeration zone, the salinity of groundwater that discharged on the dried part of hollow is quite high and, at present, varies from 13-16 g/l in the west and south, where the strip is not wide, to 25-28 g/l in the rest, wider part of the strip. According to those data, salt influx with groundwater was 34.4 kg/s or 1,07 Mt/yr here.
The rate of underground salt influx with artesian water on the dried area of the sea hollow ranges from 0.3-1.0 g/s-km2 in the north and 1- 1.5 g/s-km2 in north-west, north-east and east to 1.5-5 g/s-km2 in south-east and west 3-10 g/s-km2. These data allowed estimating the amount of salt influx with discharged artesian water at 21 kg/s or 0.6 Mt/yr.
The total amount of dissolved salts brought with ground and artesian water to the aeration zone of dried Aral hollow is 55.4 kg/s or about 1.7 Mt/yr, whereas the mean rate of salt influx is 3.7 g/s-km2.
At present (by 2009), the regional network of Karakalpakstan hydro-geological station for deep groundwater monitoring consists of 83 observation points, including 205 wells. Those are designed to study the conditions of deep groundwater of Quaternary and Upper Cretaceous deposits. Information on mean annual heads, discharge and salinity of deep groundwater as obtained from 10 wells is given in the Table 1 (see Annex 3). The depth of observation wells ranges from 10-30 m (in irrigated and dried sea areas) to 100-350 m (in non-irrigated and desert areas). The map of observation wells in shown in Figure 1 (Annex 3).
Besides the regional network, the deep groundwater monitoring system includes observation points in a specific network, which consists of 7 points of 21 wells (at deep groundwater abstraction points) and 6 points of 13 wells (geo-ecological transect). Information about dynamics of mean annual head, discharge and salinity of deep groundwater as obtained from these observation points will be given in the final report of present research.
Analysis of data shows that, as before, the Amudarya river delta is an area of intensive groundwater generation through seepage of surface water from rivers, irrigation canals, and irrigated land.
Recently, due to drastic decrease in the flow discharge in the Amudarya river to 200-700 m3/s, water salinity increased to 0.6–1.0 g/l during flood period and to 1.0–1.2 g/l in low water period. Water hardness increased to 9.8-11.7 mg-eqv/l, and only in June-August it drops to 6.5–7.8 mg-eqv/l. The changes in hydrochemistry of Amudarya river water exactly have led to deterioration of fresh groundwater reserves.

Table 9

Seasonal observations over salinity and total hardness in the Amudarya river at section of Saragatch settlement, Nukus city, 2004-2008.

Year	Period	Salinity, g/l	Total hardness, mg-eqv/l
2004	January-June	0.8	7.8
2004	June-December	0.9	8.2
2005	January-June	0.8	9.8
2005	June-December	1.2	11.6
2006	January-June	0.6	6.6

2006	June-December	1.0	8.8
2007	January-June	0.7	7.0
2007	June-December	1.1	9.5
2008	January-June	0.6	6.4
2008	June-December	1.0	8.5

Nukus city, Saragatch settlement, Amudarya river

No.	HCT	Well	Year, start of observations	Depth	Filter placement interval
1	76	37p	1970	9.60	6.33 – 8.68
2	76	37b	1970	30.50	24.35 – 29.50
3	76	37a	1970	107.30	101.85 – 106.30
4	76	37k	1970	341.0	302.85 – 322.50

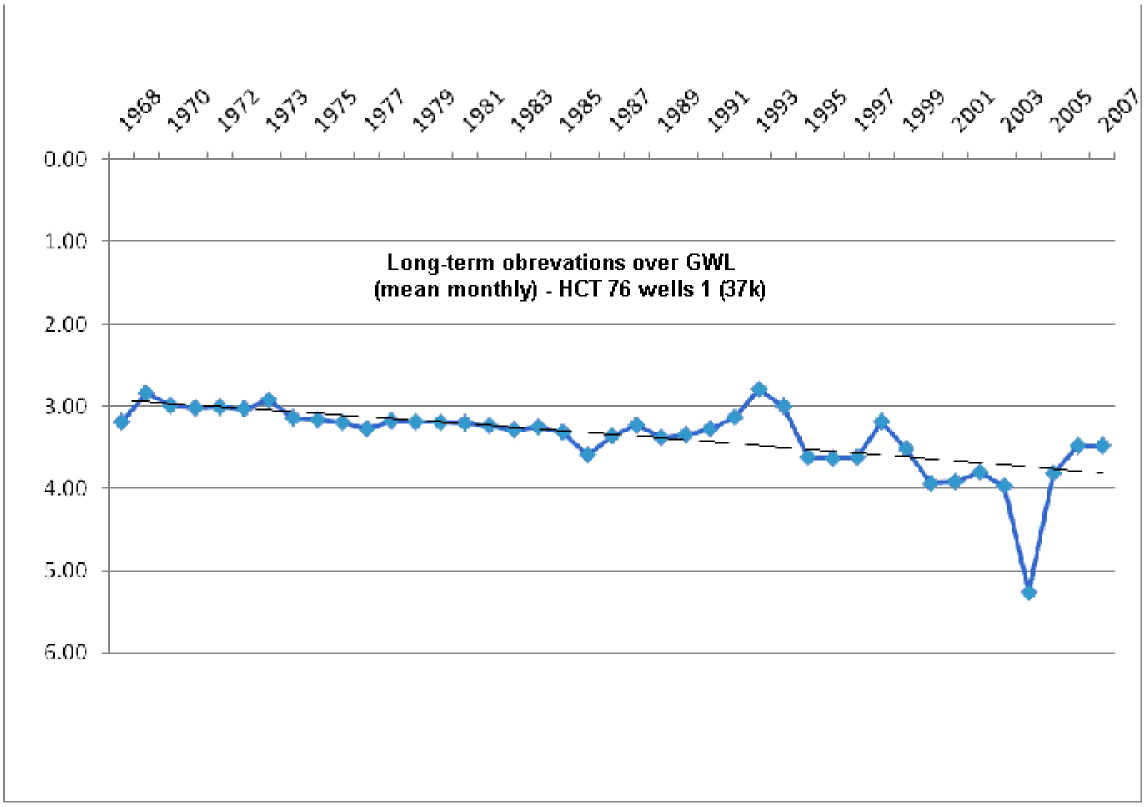


Fig. 5 Mean monthly groundwater level dynamics by year (1968-2007); HCT – hydrochemical transect

Impact of sea level lowering on the regime of groundwater on the dried seabed

The assessment of impact of sea level lowering on levels and hydrochemistry of groundwater on the dried seabed was made using the data of long-term monitoring observations by three hydro-geological section lines located in western area of the dried seabed (Fig.6). Hydro-geological conditions of section line location zone are characterized by prevalence of aquifers of marine Novoaral deposits (m2) and underlying alluvial-lacustrine deposits (al), as well as of marine Drevne-aral (m1) Holocene and Eopleistocene deposits (Atynykol series) that are described above.

Akbulak section line is located in west, near-cliff area of the dried bed of the Aral Sea and consists of five hydrochemical transects (Fig.1). Wells are equipped specifically for aquifers of Holocene and Eopleistocene deposits. Observations have been made since 1990. Dynamics of groundwater levels and salinity by wells of the section lines (HCT-1, 2, 3, 4) (upper aquifer) over the long-term is shown in Figure

6.1. In all the wells, groundwater level drop is observed since 1990 till 2007 because of sea level lowering. The relationship between groundwater level and the sea level is linear, with the correlation coefficient of 0.88 – 0.95. (Table 10)

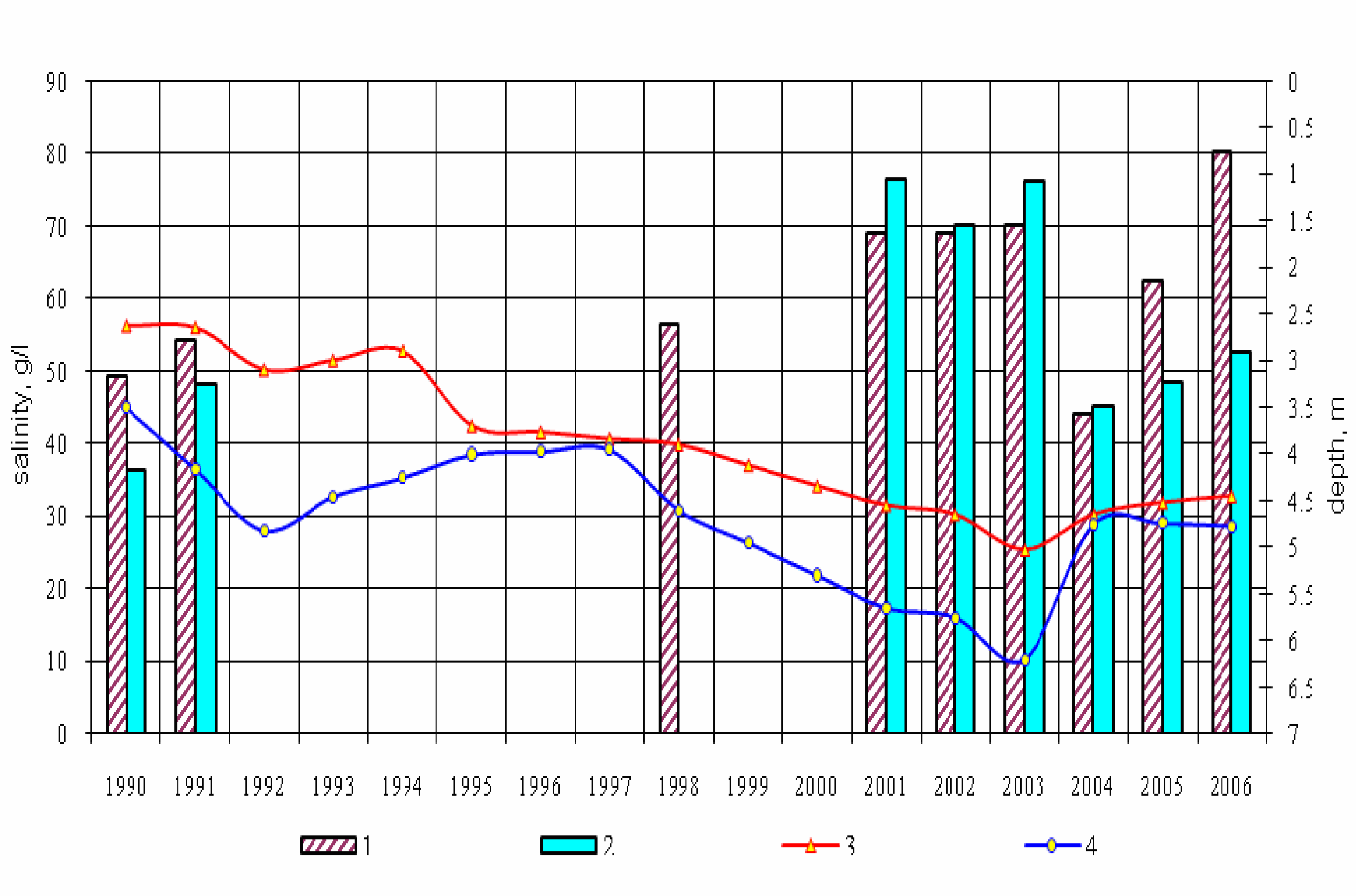


Fig. 6 Dynamics of groundwater levels and salinity by wells of Akbulak section line over long-term. Salinity: 1 – HCT-1; 2 – HCT -2. Groundwater level depth: 3 – HCT -1; 4 – HCT -2

The actual levels differ from those reconstructed from the relationships by 0.25 – 0.75 m, reflecting the effect of a change in subsurface inflow from the Amudarya delta and, in recent years (2003 – 2006), of releases from Sudoche lake (Fig. 7).

Table 10

Relationship between the groundwater level depth (y) and the sea level + (x) by wells of Akbulak and Sudoche-Adjibay section lines

Transect, well	Period applied to build relationship	Series extent	Relationship	Accuracy of approximation
Akbulak section line				
HCT -1, well 3	1991 – 2003	13	*y = -0.2741x + 13.314*	0.95
HCT -2, well 3	1991 – 2003	13	*y = -0.261x + 13.821*	0.88
Sudoche-Adjibay section line				
HCT -4, well 2	1991-2002	12	*y = -0.1901x + 12.828*	0.84
HCT -3, well 2	1991 – 2002	12	*y = -0.0352x2 + 2.333 – 32.866*	0.63

HCT -803, well 3	1991 – 2002	12	$y = -0.1473x + 9.6824$	0.91

The decrease in groundwater level due to recession of the sea is accompanied by a considerable increase in salinity from 40–50 to 70-80 g/l. Under an influence of releases from Sudoche lake, salinity drops virtually down to initial values (Fig. 1). In terms of composition, waters refer to sulphate-chloride and magnesium-sodium type.

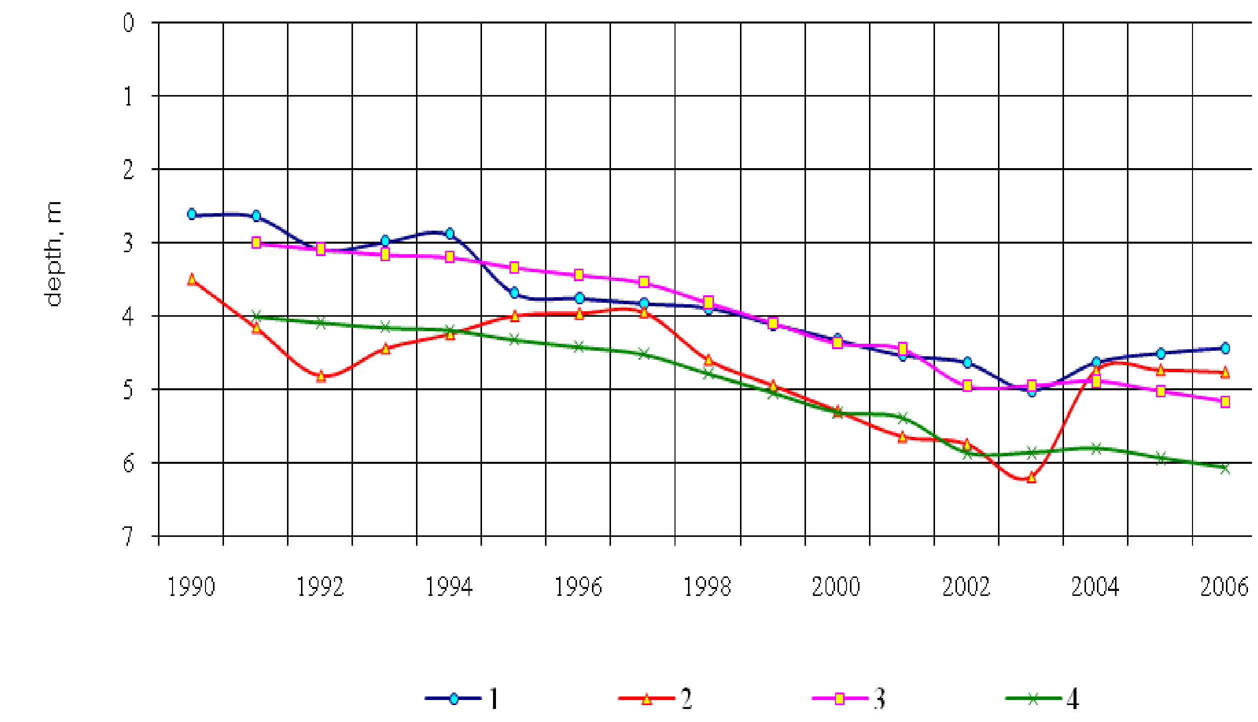


Fig. 7 Calculated and actual groundwater level depths by wells of Akbulak section line. Actual data series: 1 – HCT -1; 2 – HCT -2. Calculated: 3 – HCT -1; 4 – HCT -2

Dynamics of groundwater levels and salinity as obtained from wells located in northern part of the section line (HCT -4, 5), where observations has been made since 2001, is less subjected to the influence of releases, and, to a larger degree, linked to the sea level lowering process. Consequently, in 2004 – 2007, groundwater level decreased by 0.22 – 0.55 m.

The conditions of groundwater regime formation on irrigated area are characterized by irrigation regimes and inflows to artificial water drive systems of the Amudarya river – Right Bank canals (Kyzketken, Kegeili, Kuvanyshdjarma) and Left Bank canals (Suenli-yab, Shumanai, Muynak-Kungrad).

Because of dry period (1999-2001, 2006-2007), shallow groundwater level depths have decreased, whereas in terms of water availability of 2008-2009, an impact of the Amudarya river and the water drive canal system on the dynamics of deep groundwater level depths and chemism was insignificant.

Therefore, the description of changes in Amudarya river water's hydrochemistry and in shallow groundwater regimes will be given separately for the Left-bank and the Right-bank of the Amudarya river, based on water and land conditions of the area. Besides, current analysis of deep groundwater use per aquifer in the above mentioned hydro-geological areas will be discussed.

Deterioration of water quality in the Amudarya river in recent years has caused that almost all places with the approved reserves of fresh groundwater with the salinity less than 1.0 g/l were completely replaced by low-saline water, with the salinity of 1.5 – 2.0 g/l (see Table 9).

Table 11

Initial data on salinity and total hardness by observation point in 2006

Name of site	Water sampling place	Sampling date	Dry residue, mg/l	Total hardness, mg-eqv/l
Chimbay	HCT 2, well4	22.12.06	1245	10,60
	HCT 2, well5	26.06.06	478	3,60
Kamysaryk	HCT 1, well1	22.12.06	985	10,60
	HCT 1, well2	22.12.06	986	6,80
Koibak	HCT 1, well1	27.06.06	1704	14,60
	HCT 1, well 2	23.12.06	1285	10,00
Chimshikkul	HCT 1, well 1	27.06.06	1773	16,60
	HCT 1, well 4	23.12.06	1280	14,00
Khodjeili	HCT 2, well 666	30.06.06	1740	13,40
	HCT 2, well 666A	30.06.06	1202	9,00

Preliminary conclusions and recommendations on monitoring of surface and ground waters in the delta and Prearalie (SIC ICWC)

The analysis of monitoring data on surface and ground waters in the delta and Prearalie showed that:

1. The ICWC's decision regarding environmental flows to maintain the ecosystems in the Amudarya river delta and Prearalie was not fulfilled.
2. There was no accounting of surface water flowing into the delta and Prearalie due to lack of good gauging stations and up-to-date measuring devices along the river, canals and main drains.
3. Water resources management in the Amudarya river delta and Prearalie was not implemented virtually.
4. Groundwater levels and salinity were not measured on a regular basis due to lack of transport facilities and funds at the Karakalpakstan's Hydrogeological and Land Reclamation Expedition.

Recommendations:

1. Enhance the role and powers of BWO Amudarya for ensuring guaranteed water supply (environmental flows) to meet demands of the environment and natural systems in the delta and Prearalie. There is a need to put the environmental demands of the delta and Prearalie into the form of a legislative act.

2. Equip water bodies and structures in the delta and Prearalie with up-to-date measurement devices and gauging stations.

3. Arrange 6 gauging stations as proposed in the Project's Terms of Reference.

4. In order to improve water management in the delta, establish Water User Associations by uniting delta's stakeholders (fishers, hunters, cattle-farmers, khokimiyats, etc.).

Preliminary conclusions on deep groundwater monitoring in the delta and Prearalie (GIDROINGEO)

The hollow of the Aral Sea has been and is served as a base of both ground water and artesian water discharge. The draining effect of the sea hollow is explained by much lower hypsometric depth as compared to mountainous and dividing margins of the basin and by its association with deeply eroded folds of positive structures (major of them – Nizhne-Amudarya-Kulandinskaya) characterized by tectonic deformation and hydro-geologic openness.

The draining of aquifers of groundwater and particularly of artesian waters occurs due to considerable slopes and the higher piezometric levels of deep groundwater as compared to the sea level, as well as because of reduction of their strata pressure upward the profile.

The general lowering of both ground and artesian waters in the basin being observed since the sixties takes place as a result of both the Aral Sea shoaling and the exposing of aquifers though numerous flowing wells and exploitation of these waters.

Frequent droughts, reduced river runoff in the basin and economic activities have considerable impact as well. The total effect of these factors on the regime of ground and artesian waters spreads almost throughout the basin, with particular intensive appearance near the Aral Sea, especially in east and south-east Prearalie.

The level lowering and changes of configuration of the Aral Sea over the last 18-20 years have reflected, first of all, on groundwater of the coastal strip. Levels of groundwater have decreased and salinity increased. Moreover, a new aquifer was formed within the borders of dried strip. Here, groundwater is bedded not deeply, has high salinity and is refreshed quickly through intensive evaporation from the surface of the strip.