Water-Ecological Problems of the Syrdarya River Delta and Measures to Solve Them

V. A. Dukhovny, ICID, Vice-President; SIC ICWC, Director

N. K. Kipshakbaev, Kazakhstan branch of SIC ICWC, Director

k.t.s. I. B. Ruziev

k.b.s T. I. Budnikova

s.s.r. V. G. Prikhodko

The tragedy of the Aral Sea Basin has been known for decades in scientific and public circles. Aggravation of ecological tension in this region has been caused in the first place by economic activities. Expansion of irrigated agriculture in the Kyzylorda province - particularly the development of new lands at the upper and middle reaches of the Syrdarya river, coupled with the introduction of more productive and innovative natural-economic complexes, has led to disturbances of the natural environmental balance between aquatic and subaquatic geo-systems, and to the initiation and development of adverse natural processes.

All of these eventually have started to exert negative impacts on human beings. Trends, rates, and scope of desertification processes are characterized by a number of specific features, but human activities have become a decisive factor in determining environment degradation.

Lack of radical enabling political and legal frameworks at the interstate level throws doubt upon the probability of sustaining the Aral Sea Basin nature system as a single whole, in the foreseeable future.

Development of institutional and legal approaches to addressing ecological crises in the territory of the Kazakh Priaralye may be conditionally divided into three periods.

1) During the latest Soviet period (1986-1991), all measures to tackle the Aral Sea problems were initiated from central agencies of the former Soviet Union, which defined the strategy of actions based on federal and regional interests taking into consideration the ecological and socio-economic living conditions of local population.

2) The initial period of independence of the Republic of Kazakhstan (1992-1993) when measures aimed at addressing the consequences of the Aral Sea desiccation were noted for their unjustified euphoria. Some decisions take no account of the realities of the situation and the lack of necessary resources. The Supreme Council of the Republic of Kazakhstan's Enactment of 18 January 1992 "on urgent measures aimed at radical transformation of living conditions for the population in Priaralye" declared the Zone of Ecologic Disaster, which included all districts of the Kyzylorda province, several districts of the Aktubinsk, Chimkent, and Djezkazgan provinces.

3) During the current period, in the course of implementing measures aimed at the elimination of ecological disaster consequences, the Republic of Kazakhstan has encountered considerable economic difficulties. This has compelled the Republic to abstain from adapting the State Program "Aral 2006" and abandon implementation of actions stipulated by the Decision of the Cabinet of Ministers of 25 March 1992, No. 280 "on urgent measures aimed at the improvement of socio-economic and ecological conditions for the population living in Priaralye".

Only lately has the situation started changing for the better.

Implementation of the "INTAS-Aral 2000-0059" project is an important step made by the European Union with regard to evaluating socio-economic and ecological damage caused by lowering of the Aral Sea level. It will justify the necessity of further state measures to protect Priaralye. Similar works carried out with the support of INTAS permitted giving decision makers at the governmental level an understanding of the necessity of adequate measures to provide a new ecologically sustainable nature protection system. (Dukhovny et al, 2001)

The major zone where negative impacts caused by the Aral Sea desiccation are most apparent includes two areas of the Kyzylorda province: the Aral and Kazalinsk districts.

The following key factors give rise to the degradation of nature complexes in the region:

- Disturbance of water-salt balance in the Aral Sea;
- Changes in conditions of lakes in the delta;
- Activation of deflationary-accumulative and impulverization processes;
- Lowering of ground water table and increase in their mineralization;
- Degradation and salinization of hydro-morphological soils of the Syrdarya river basin;

• Overgrazing of pastures and excessive mowing;
• Irrigation and other impacts caused by man.

The dominant factor determining destabilization of the environment is the Syrdarya river flow reduction. During the period of 1961-1970, the Syrdarya river flow diminished down to an average of 6.7 km^3/year, with a minimum flow of 3.2 km^3/year in 1965 and a maximum of 10.6 km^3/year in 1969. During the period of 1971-1980, the average annual flow was 2.3 km^3/year. In 1981-1986, it was 0.72 km^3/year (Fig. 1). In some low-water years the Syrdarya river flow actually failed to reach the sea.

In 1987, the division of the Aral Sea started. The water area was separated by a natural undersea shoal in Berg Straits (level of 40.7 abs m) into two parts: the Small (northern) Sea and the Large (southern) Sea (Fig. 2). The Berg Straits shoal is an important element of undersea relief. It represents a flat, slightly inclined height that is formed by fine and loamy sands and is 14.0 - 15.0 km long, and 17.0 - 17.5 km wide. The Berg Straits shoal, which is located at the level of 42 – 41 abs m, is a natural barrier preventing overflow of water from the Small Sea to the Large Sea. Due to the Syrdarya river inflow a positive water balance started developing, the surplus of which overflowed to the Large Sea. By 1992, the height of overflow between these two water bodies constituted about 3 m: the Small Sea level was 40.2 abs. m, and the Large Sea level was 37 abs m. As a result of these processes, more than 33,000 km of the former sea bottom were exposed, with their inherent lithogenous complexes, forms, and elements of sea relief. (Dukhovny *et al*, -)

In natural conditions within the boundaries of the current delta, the Syrdarya river channel, which spreads over 189 km, provided inflow to the Aral Sea of an average annual capacity up to 490 m^3/sec, supplying the delta with water

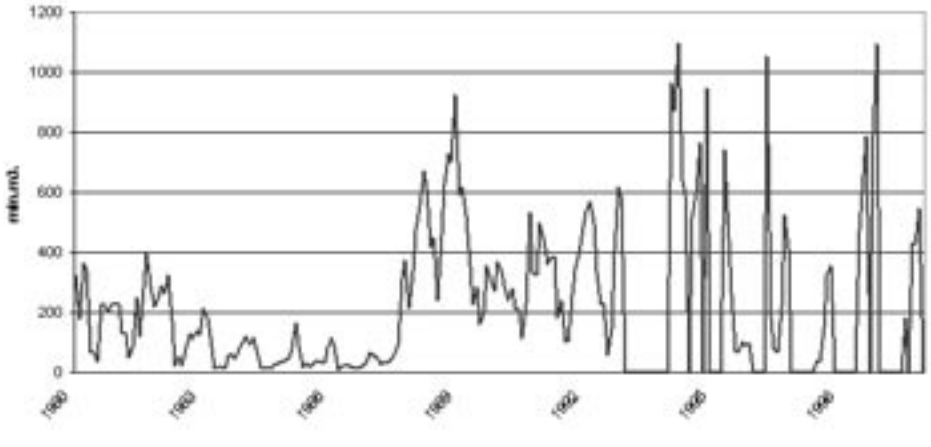

Fig.1: Retrospective analysis shows the share of natural river ow in the water balance of the Aral Sea. With regard to long-term observations, it has uctuated within a rather wide range, especially in the second half of the last century (Table 1).

Table 1: Minimum and maximum values of the Aral Sea levels and total river in ows averaged over time periods

Years	Sea level, abs. m**		River in ow, km^3	
	Min.	Max.	Min.	Max.
1941-1945	52.67 (I)*	52.97 (VII)		
1946-1950	52.68 (XII)	53.03 (VII)	58.6	76.2
1951-1955	52.82 (I)	53.13 (VII)	40.4	64.4
1956-1960	53.13 (I)	53.46 (VII)	28.5	48.6
1961-1965	52.54 (XII)	52.98 (VII)	35.2	81.2
1966-1970	51.29 (XII)	51.69 (VI)	8.2	49.5
1971-1975	49.81 (XII)	50.38 (VI)	7.4	19.3
1976-1979	47.03 (XII)	47.68 (VI)	1.8	10.05
1980-1984	42.75	45.75	0.6 (0.72)	21.8 (2.7)
1985-1989	39.08 (40.50)	41.10 (42.15)	11.41 (2.14)	32.24 (4.9)
1990-1994	36.9 (39.70)	38.24 (42.15)	5.17 (2.62)	28.53 (4.73)
1995-2000	33.98 (39.5)	36.5 (42.20)		

* Values for levels of the Small Sea and months are given in parentheses.
** Values for levels of the Large Sea.

Fig. 2: Dynamics of the Aral Sea water surface changes by year

Table 2: Dynamics of changes of water areas in lakes and wetlands (thousands)

NN	Names of delta parts and some of the lakes	According to space images, lakes				lakes	wetlands	lakes	wetlands	lakes	wetlands	lakes	wetlands
		1967	1981	1989	1997	Aug. 1999	Oct. 1999	Oct. 1999	Jul. 2000	Jul. 2000	Mar. 2003	Mar. 2003	Max.
1	Coastal zone	-	-	-	-	-	-	-	-	-	-	-	3.29
2	Seaside delta												
2.1	Seaside right bank	14.71	6.12	1.4	7.1	0.96	9.4	5.56	5.73	3.53	6.58	2.74	9.4
2.2	Seaside left bank	9.61	4.67	0.55	4.43	0.00	14.23	8.37	2.14	0.77	4.62	1.26	14.23
	Total area in seaside delta	**24.32**	**10.79**	**1.95**	**11.53**	**0.96**	**23.63**	**13.93**	**7.87**	**4.29**	**11.20**	**4.01**	**23.63**
3	Middle delta												
3.1	Kamysh-lybash	26.7	20.10	17.70	21.45	19.18	22.59	16.99	28.16	16.42	34.21	23.26	34.21
3.2	Akshatau	19.8	12.7	10.2	9.97	8.41	15.50	8.27	15.42	8.21	37.42	24.65	37.42
	Total area in middle delta	**46.5**	**32.80**	**27.9**	**31.42**	**27.59**	**38.09**	**25.26**	**43.58**	**24.64**	**71.63**	**47.91**	**71.63**
4	Aksay-kuandarya zone	**37.3**	**29.40**	**8.70**	**12.7**	**11.30**	**27.35**	**12.22**	**21.28**	**9.13**	**64.49**	**43.87**	**64.49**
	Total	**99.12**	**72.99**	**38.55**	**55.65**	**39.85**	**89.07**	**51.41**	**72.73**	**38.06**	**147.32**	**95.79**	**159.75**

at a discharge of about 60 m^3/sec.

The lowering of the northern Aral Sea has caused the activation of river channel processes in the Syrdarya River. Water inflow for the internal lakes of the delta has become constrained and even impossible due to the reduction of the general basis of erosion.

The unsatisfactory condition of connecting canals always has been, particularly at present day, a complicating factor to the situation. Even if the state formerly has allocated certain funding for the reconstruction of connecting canals, today they are in a state of complete neglect. During the period of 1988-1997, many lock gates were destroyed by the spring floating of ice and back waters from lake systems. Repairs and precautions have not been carried out because of lack of funding. Flow capacity of canals has decreased due to vegetation overgrowth, silting, and erosion of embankments. Temporal dams on canals are often washed away, with water flowing back to the Syrdarya river, leading to disturbance of water-salt regimes in lake systems.

In connection to this, the Government of the Republic of Kazakhstan and local authorities have undertaken radical measures to alleviate ecological crises in Kazakh Priaralye. In particular, some ecological stress in northern Priaralye was alleviated by the construction of the Amantkul and Aklak hydro schemes in 1975-1976, as well as the construction of the Kokaral dam in 1998. Unfortunately, all ecosystems restored at that time due to these constructions came to be on the brink of collapse following the breach in the Kokaral dam in 1999 and the Aklak hydro scheme in 2002. The consequent lowering of water levels in the river leads to a situation where substantial amounts of water accumulated in the lake systems outflow back to the river and further on to the sea.

Space remote sensing data allowed the evaluation of actual changes of water area in the lakes, during years of various levels of water availability in the Syrdarya river delta over the last decade:

- In the medium-water year of 1967, water area in the lakes constituted 339.2 ^{k}m2;
- In the high-water year of 1997, water area in the lakes increased up to 429.^{4} km2;
- In the low-water year of 1989, water area in the lakes decreased to ^{2}45 km2 compared with 30^{6}.2 km2 in 1981 (Table 2).

Desertification processes in the downstream parts of the delta have developed and still are developing on a large scale. Also, the ecological situation remains aggravated. Today, moisture conditions in the downstream delta (Aralsk district) remain much as before, far from being favorable. Therefore, processes of hydro-morphological soil degradation continue. The evidence of this is:

- Complete transformation of soils in formerly reed-covered flats and marshes with drying-up soil varieties predominating in the areas of grassland-marsh and alluvial-grassland soils, which have become very highly saline.
- Expansion of takyr-like soils and areas covered with sands and salt marshes (solonchaks). The area of hydro-morphological soils has shrunk in the process of sea delta desiccation from 630,000 ha in 1950s to 80,000 ha today. The total area covered with solonchaks has increased up to 273,000 ha (34%) against 85,000 ha (7%) in 1953. It is expected that, in the future, there

will be expansion of sandy desert soils, takyrs, and residual and dried-up salt marshes. As a result of wind erosion, humus content has decreased from 0.5 - 0.6% to 3-4%.

Based on a similar analysis with regard to South Priaralye, all landscapes are divided into the following types: stable, fully overgrown, partly overgrown, and unstable areas. According to these types, the assessments are given as to vegetation cover of unstable landscapes in the water area of the Small Sea, which is being connected with the designed height of the dam to be constructed on this territory. (Dukhovny et al, 2001)

The work within GIS has been carried out as follows. In the first stage, the areas of all the above-named types of landscapes were determined in 2000 (Table 3). Following that, assessments of current landscapes and those expected to develop under sea level changes reaching 42 m and 48 m were determined (Table 4). Two types of unstable landscapes were defined on the Map of "comparison of unstable landscapes over Syrdarya delta". The first type was defined in accordance with the Landscapes Map of 2000 and the second type was selected on the basis of the Map of Soils, dated 1992. Sandy soils and dunes represent the second type of unstable landscapes. Their total area is 183,782.42 ha. (Dukhovny et al, 2004a)

Data given in Table 3 shows that the rise in the level of the North Sea (the Small Sea) does not exert significant influence on the transformation of landscapes on the dried-up former sea bottom in the northern part of the Aral Sea. Therefore, detailed assessment of landscape changes on the dried-up former Small Sea bottom has been carried out with regard to rise of water level to 42 and 48m. The relevant data is given in Table 4.

At present, the total area under all types of landscapes on the dried-up Small Sea bottom is 788,527.7 ha. When the Small Sea level rises up to 42 and 48m, landscape areas will be 736,997.9 ha and 587,061.6 ha, respectively.

When the Small Sea level changes, the unstable sea bottom landscape area decreases by 31,155.6 ha at the sea level of 42m, and by 83,255.6 ha at the level of 48m. Since some recharge from groundwater occurs at the level of 48m and part of unstable landscapes will be transformed into overgrown landscapes, the area of unstable landscapes will decrease against the current state by 98,817.9 ha.

Apart from this, if designed hydrotechnical schemes are constructed or restored, the area of unsustainable watering (defined as the second type of unstable landscapes) will be partly covered by water and will be 119,742.79 ha.

Intensification of wind erosion processes and the removal of salt and dust from the dried-up bottom of the Aral Sea to adjacent territories are among the major causes of desertification in Priaralye. Experimental field surveys revealed that long-term average values of sand/salt removal beyond the dried-up sea bottom amount to 7.3 million ton/year, while salt constitutes 0.7 - 1.5% of all removed solid mass. Thus, the average annual amount of salt removal from the Kazakh part of the dried-up sea bottom constitutes 50,000 – 70,000 ton/year.

In general, ecological disaster in this region has caused the sharp deterioration of living standards of local population in coastal zones, particularly in the delta, as well as loss of income. This, coupled with water scarcity, has created a critical socio-economic situation in the region.

Analysis of available materials provided by partners, information obtained during visits to the Syrdarya delta, and interviews with local population lead to the conclusion that the issue of water body management needs to be addressed. First of all, it concerns natural lake system management. Issues of guaranteed provision of water supply and lake system management need to be addressed on the basis of a thoroughly elaborated scheme of ensuring water inflow to all lakes of the system, establishing infrastructure for research, and the regulation of water transportation to the Northern part of the Aral Sea. It is impossible to work out a more or less reliable long-range forecast with regard to the evolution of the situation without in-depth and comprehensive analysis of ongoing processes in the region.

The economic and ecological damage caused by the Aral Sea desiccation and reduction of river runoff flowing into the delta basically is evident in losses relating to fishing, cattle-breeding, transport navigation (fleet of boats, port facilities, harbors, moorages, and canneries), stocking up reeds, muskrat trapping, etc. Most important are the negative impacts exerted by the sharp deterioration of the environment on people's health in this region (Table 5). (Ruziev & Prikhodko, 2003)

For the purpose of improving the ecological and socio-ecological situation in Priapalye, Heads of Central Asian states approved in January 1994 the program "on concrete actions to improve the ecological situation in Priaralye for the period of 3 - 5 years, taking into account socio-economic development of the region – major directions" (PASB).

At present, the draft has been developed "on regulating

Table 3: Areas calculated according to the Landscape Map of 2000 with regard to all Kazakh Priaralye (ha)

Landscape	Stable	Unstable	Overgrown	Partly overgrown
Current state*	265,303.2	1,585,325.8	549,058.2	237,034.9
Dam level at 42 m**	257,722.2	1,552,946.8	547,971.3	224,581.3
Dam level at 48 m***	251,681.8	1,499,677.7	940,550.3	204,181.5

* 2000
** filling the Small Sea to the level of 42 m
*** filling the Small Sea to the level of 48 m

Table 4: Areas calculated according to the Landscape Map of 2000 with regard to the Small Sea area (ha)

Landscape	Water area of the sea	Area under conditions of additional in ow rising sea level ****	Stable	Unstable	Overgrown	Partly overgrown
Current state*	249,840		123,658.3	368,406.4	209,073.8	87,389.2
Dam level at 42 m**	310,550	60,710	116,932.8	337,250.8	208,014.4	74,799.9
Dam level at 48 m***	456,290	206,450	101,438.1	285,150.8	145,942.1	54,530.6
Recharge at the level of 49.50 m			98,603.1	269,588.5	123,731.2	47,452.6

**** Areas covered by additional watering are given at levels of 42 and 48 m

Table 5: Breakdown of damage caused by the ecological disaster of the Aral Sea desiccation in Kazakh Priaralye (per year)

Damage components	Amount of damage (million USD a year)
1. Losses in agriculture (total)	25.8
Including:	
Irrigated agriculture	13.5
Fishing	2.6
Muskrat trapping	0.3
Meat production	5.8
Dairy production	3
Muskrat fur trade	0.8
2. Losses in recreation and tourism	4.3
3. Indirect losses in industries (total)	5
Including:	
Fishing	0.8
Muskrat fur processing	1.6
Reed processing	2.6
4. Reduction of freight by sea and river transport	0.3
5. Social losses (total)	14.1
Including:	
Damage caused by migration processes	1.1
Indirect compensation payments to the population living in adverse ecological conditions	11.3
Damage caused by reduction of life expectancy	0.4
Damage caused by increase in sickness rate of the population	1.3
TOTAL DAMAGE	49.5

the Syrdarya river channel and the Northern Aral Sea". First and foremost objects were selected for implementation (investments are stipulated at 78.25 million USD). Construction works started in 2003. Among these objects are:

- Dam and a spillway to the Aral Sea - 23.2 million USD
- Hydro scheme Aklak - 17.6 million USD
- Hydro scheme Aytek 15.25 million USD
- Major repairs of Kyzylorda and Kazalinsk hydro schemes - 4.4 million USD
- Protection dams - 3.7 million USD
- Rehabilitation of Chardara Dam - 14.1 million USD

Analysis shows that to solve the problems, in addition to planned measures (construction of CAM, reconstruction and rehabilitation of hydro-technical structures, and protection dams) full implementation will require the construction of dams in the end-parts of lakes (about 36 km), canals (about 15 of conveying, diversion, and connecting canals), and head hydro technical structures on these canals.

If sustained at a certain sea level (47 - 47.5 abs m), the Small Aral Sea will be the end-reservoir for northern Kazakh Priaralye. It would meet the requirements of nature (for migrating birds, transport, improvement of climate, etc.) and serve socio-economic and ecological functions (mainly ensuring sustainable fishing and other economic activities) that would improve the welfare of the local population.

In general, the Syrdarya river delta is a very complex water management system with water facilities scattered over the large territory. Every facility represents a compound network of connecting and feeding canals, tens of kilometers long, with numerous water bodies intended for various purposes. All this network of water management facilities needs is to be organized in compliance with the requirements of nature in the first place, and according to socio-economic and ecological objectives. To this purpose, special detailed field surveys are required in the

lower reaches of the Syrdarya river and in the northern part of the Aral Sea, so that measures to sustain and regulate the water/ecological situation in the region could be implemented based on scientific and engineering justification. Since the issue of creating controlled wetland complexes at the lower reaches of the Syrdarya river has not been studied sufficiently, it is necessary to thoroughly clarify contents, scope, and regime of operating water bodies and connecting canals with the application of modeling and simulation tools. Clear justification is needed as to what lakes should be preserved - what parameters (area of water surface, depth) and what regimes of water inflow should be taken into consideration, and which lakes are to be excluded from water management system as inexpedient.

Apart from the above-mentioned additional measures, there is a necessity to establish a consortium (or some other water association) for delta management, which could perform its functions with the participation of all water users and other stakeholders, including governmental agencies and provincial authorities. This organization should arrange its interrelations with BWO "Syrdarya" on a contractual basis, collecting charges for mutual services and clear definition of reciprocal obligations.

Suggested measures imply the stabilization of the situation in the Priaralye delta zone and the provision of guaranteed water levels in lakes, and will facilitate restoration, protection, and well-balanced use of water resources. They could become a key factor, which allows rapid retrieving of a normal state for currently distorted ecosystems and retains the NAS in the capacity of a natural object.

Major consequences of the Aral Sea desiccation, alongside the reduction of its volume, water surface area and aggravation of mineralization processes, are reflected in the formation of a vast salt desert on the dried-up former sea bottom, the area of which has reached almost 3.6 million ha. As a result, the unique fresh water reservoir has been replaced by a vast bitter saline lake combined with an enormous salt-and-sand desert located at the junction of three sand deserts. In 1985 – 1986 when the sea level reached 41 abs m, the full partition of the Small Sea from the Large Sea took place. This led to the formation of a new desert territory covering an area of 6,000 km2 with salt storages in the topsoil layer reaching up to 1 billion ton. Thus, the Aral Sea, a single inland lake in the past, will become in the nearest future a set of separate water bodies, each with its own water-salt balance. The fate of the future depends on what policies the five Central Asian countries will choose to pursue with regard to the Aral Sea. (Dukhovny et al, 2004b)

Reduction of the river runoff to the delta has caused a decrease in inflow to all delta lakes and flood plains of the Syrdarya river, bringing ecosystems to the brink of collapse and exceeding the bounds of socio-economic and ecological problems of the region.

If the current situation in the Syrdarya river delta and in Priaralye in general is not changed, then the critical ecological situation here will be retained.

References

Dukhovny, V. A. Avakyan, I. S. Rubin, M. G. Van Dike, A. Malygin, S. A. & Prikhodko, V. G. (2001) Assessment of the Social-Economic Damage Under the Influence of the Aral Sea Level Lowering (Uzbek Part of the Aral Sea Coastal Zone). INTAS-RFBR 1733 [final report].

Dukhovny, V. A. Kipshakbaev, N. K. Prikhodko, V. G. Ruziev, I. B. & Budnikova, T. I. Influence of the Aral Sea Shrinkage on Socio-Economic and Environmental Changes in Northern Priaralye [final report].

Dukhovny, V. A. Kipshakbaev, N. K. Prikhodko, V. G. Ruziev, I. B. & Budnikova, T. I. (2004a) Water-Ecological Problems of the Syrdarya River Delta and Measures to Solve Them. IN: ECWATECH, 1 – 4 June, Moscow.

Dukhovny, V. A. Prihodko, V. G. & Ruziev, I. B. (2004b) North Aral Sea, the Syrdarya Delta and Priaralye. IN: ECWATECH, 1 – 4 June, Moscow.

Ruziev, I. B. & Prikhodko, V. G. (2003) Influence of the Aral Sea Shrinkage on Socio-Economic and Environmental Changes in Northern Priaralye. IN: International Regional Conference for Central Asia - Environmental Sustainability and Advanced Approaches to Water Resources Management in the Aral Sea Basin, 5 – 7 May, Almaty.