Review of Technical Interventions to Restore the Northern Aral Sea

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Introduction: A Sea in Decline

The Aral Sea water balance consists of riverine water supply, atmospheric precipitation and underground water income on the one hand and from evaporation loss on the other hand. In 1911-1960 there was equilibrium between the total gains and losses. This equilibrium maintained the level of this giant terminal lake at +53 m a.s.l. and its deviations didn't exceeded 1 meter (Smerdov, 1990).

In the second half of 20th century because of the increasing water withdrawals for irrigation the riverine water supply began to decrease fast. As a result the equilibrium between the total gains and losses of the Aral Sea water balance was lost. If in 1961-1970 average annual water income of riverine water was 43.3 km^3, then in 1971-1980 it was only 16.7 km^3. In the beginning 1980s average annual riverine water supply was only 2.0 km^3. In 1982, 1983 and 1985 there was no water income from Amu Darya, and only waters of Syr Darya reached the Aral Sea (Bortnik, 1990).

In the second half of 1980s the riverine water supply to the Aral Sea increased slightly. However in 1986-1990 average annual riverine water supply was only about 7.0 km^3 (Micklin, 1991). After the USSR ceased to exist in 1991, the annual riverine water supply increased slightly and in 1991-1993 it was in the average some more than 10-15 km^3 (Aladin, Williams, 1993).

This disruption of existed in the first half on 20th century equilibrium between evaporation from the Aral Sea surface and riverine water income has resulted in very a fast water level decrease and increased water salinity in this giant lake. Since 1961 average annual level of the Aral Sea began to decrease steadily. Initially it decreased slowly. In 1961-1974 average annual level decrease was 27 cm, but in 1975-1986 the rate increased and reached 71 cm/year as average (Smerdov, 1990). In 1986-1990 the Aral Sea level decrease was as faster as 88 cm/year as average (Aladin, 1991).

The Aral Sea desiccation resulted salinity increase. Initially salinity increase was relatively slow because in these years evaporation only slightly exceeded gains on the Aral Sea water balance.

- In the first half of 20th century average salinity was about 10.2-10.3 g/l (Solovyeva, 1950; Blinov, 1956). Since 1961 it began to increase steadily because equilibrium between evaporation and total fresh water supply was disrupted. Certainly together with the Aral Sea drying its surface decreased, but the rate of riverine water supply decrease always exceeded the rate evaporation decrease.

- In 1961-1970 Aral Sea salinity increased by 1.6-1.8 g/l and reached 11.50 g/l. During these years the riverine water supply decreased from 9.2 km^3 to 8.0 km^3. Nevertheless the losses by evaporation decreased insignificantly - from 66.0 km^3/year to 65.4 km^3/year. Surface decreased during this time also insignificantly - from 66,086 km^2 to 59,610 km^2 (Bortnik, 1990).

- In 1971-1980 salinity increased by 6.0-7.0 g/l and reached 17.01 g/l. The riverine water supply decreased to 16.1 km^3/year and precipitations decreased to 6.3 km^3/year. Losses by evaporation remained high while decreased to 55.2 km^3/year because of the Aral Sea surface decreased to 50,998 km^2 (Bortnik, 1990).

- In 1981-1990 salinity was increasing fast and reached 30 g/l (Micklin, 1991). When in 1989-1990 the Aral Sea has divided into Small and Large, the volume was 370 km^3 and surface was 40,394 km^2. At the same time the Small Aral volume was less than 30 km^3 and the surface was only about 3,500 km^2. So, when these two independent appeared, the Large Sea exceeded to Small Sea by volume more than by 11 times and by surface more than 10 times. In 1988 average salinity on Small Aral Sea became by 1.5-2.0 g/l lower than salinity of Large Aral.

- At the end of 1980s (autumn 1987 - spring 1989), when the level dropped by about 13 m and reached about +40 m, the Aral Sea divided into two lakes: the Large (Southern) and Small (Northern) Aral.

It should be noted that due to morphology of Aral Sea depression there always been two water areas - the northern Small Aral Sea and the Southern Large Aral Sea. The Small Aral Sea was separated from the large Aral Sea by Kokaral Island lying east-west. On the West both water areas were connected by shallow strait Auzykokaral with maximal depth about 2m and on the East they were connected by relatively deep Berg's strait with maximal depth of 13 m. The first one has dried off still in 1968, the sec-

Figure 1. The Aral Sea before division into two lakes.

ond one dried off in 1989-1990 and the Small Aral became completely separated from the Large Aral Sea.

In 1989 Aral had (Table 1) area 40000 km^2 (60% from 1960) and volume 333 km^3 (33% from 1960), salinity was 30 g/l (in 1960 it was 10 g/l). In both lakes because increased salinity could survive and survived practically the same number of free-living animals. Fishes - 10; Rotatoria - 3; Cladocera - 2; Copepoda - 2; Ostracoda - 1; Decapoda - 2; Bivalvia - 2; Gastropoda - >2; Polychaeta - 1; total: >25.

After the Aral Sea division the difference in salinity between the two water areas became more significant. Average salinity on the Small Aral steadily decreased when in the Large Aral it steadily increased.

Figure 1 shows the Sea just before it was divided into the Large Aral and Small Aral. Table 1 provides a tabular look at some of the data presented above. Figure 2 shows how water level and salinity are dramatically and inversely related.

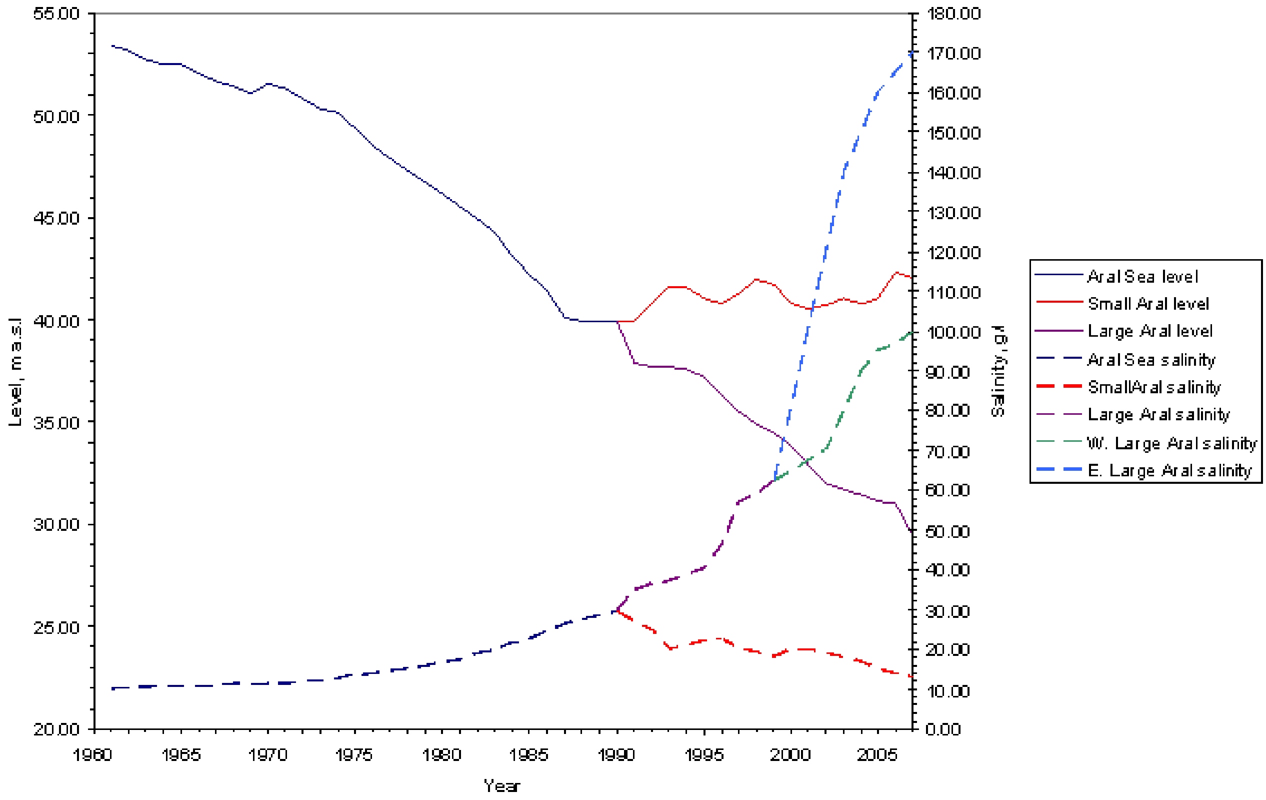
Table 1. Hydrologic and Salinity Characteristics of the Aral Sea

Year	Level (m asl)	Area (km^2)	% of 1960 area	Volume (km^3)	% of 1960 volume	Average salinity (g/l)	% 1960 salinity
1960 (whole sea)[b]	53.4	67,499	100	1089	100	10	100
Large Sea	53.4	61,381	100	1007	100	10	100
Small Sea	53.4	6,118	100	82	100	10	100
1971 (whole sea)[b]	51.1	60,200	89	925	85	10	100
1976(whole sea)[b]	48.3	55,700	83	763	70	14	140
1989 (whole sea)[c]		39,734	59	365	33		
Large Sea	39.32	36,307	60	341	34	30	300
Small Sea	40.2	2,804	46	23	28	30	300
2007 (whole sea)[c]		13,958	21	102	9		
Large Sea	29.4	10,700	17	75	8	East >100 West 100	>1000 1000
Small Sea	42.0	3258	53	27	33	12?	120
2025 (whole sea)		9,058	14	68	6		
Large Sea[d]	21-28	6,400	10	41	4	>100 to 200	>1000 to >2000
Small Sea[e]	42.0	3,258	53	27	33	5?	100

[a]Annual average. [b]As of January 1. [c]The sea will consist of a western and eastern part with the west basin at 21 meters with and the east at 28.3.

Sources: Compiled by Philip Micklin from Asarin and Bortnik, 1987 and Bortnik and Chistyaevaya, 1990, Table 8.4, p. 72 (for 1960, 1971, and 1976); Glavgidromet, 1994-2003; Water Balance, 1990-2006; Final Report, 2004; Ptichnikov, 2000, 2002; and Expedition, 2005 (for 1989, 2006, 2011).

Figure 2. Changing of the Aral Sea level and salinity.



Technical Interventions in Berg's Strait: First Steps

In 1961-1988 when the area between the Small and Large Arals (Berg's strait; figure 3) was still under water, the rate level decrease both in the Large Aral and in the Small Aral was the same. After complete separation of both water areas in 1989-1990 level decrease continued only in the Large Aral. In the Small Sea on the contrary level increase began because evaporation from its surface was lower than water income. This level increase resulted in water overflow to the Large Aral via the channel along the dried area of Berg's strait.

This channel is of artificial origin. In the beginning 1980s existed in the Berg's strait fairway was deepened with dredger in order to sustain navigation through this becoming shallower strait. Later when the strait dried up completely the former artificial recess appeared on the surface as a channel.

In the autumn 1989 the channel was completely filled with silt and on its surface there was a chain of residual water bodies and pools not connected one with another. There was no flow from north to the south. Length of the channel was about 4 km. Later, when the level of the Small Aral Sea began to rise in spring 1990, a stream started to flow along the channel, slowly at first but increasing in volume. At the beginning the overflow channel was wide and shallow but after a while the water cut down through the

Figure 3. Canal in Berg's strait.

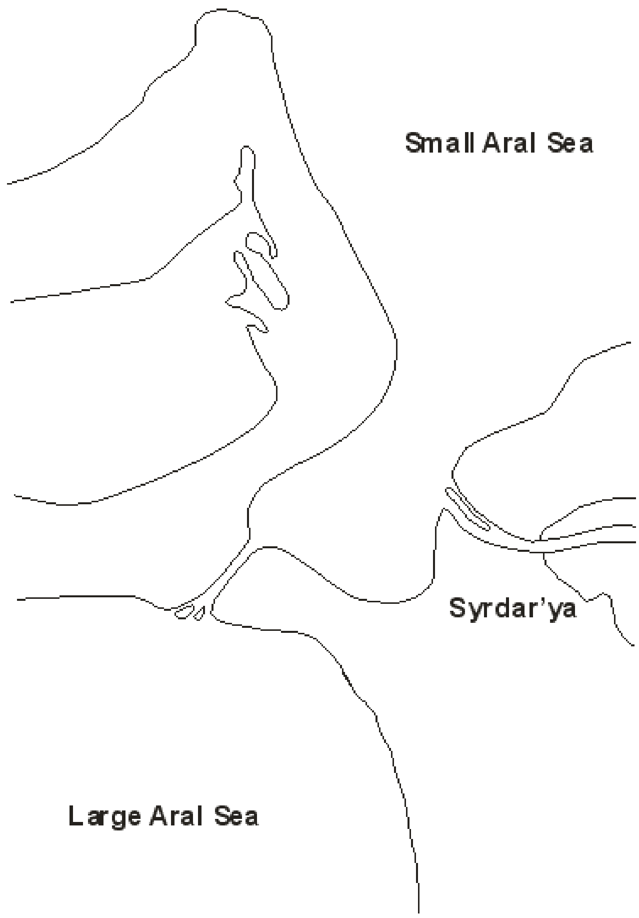
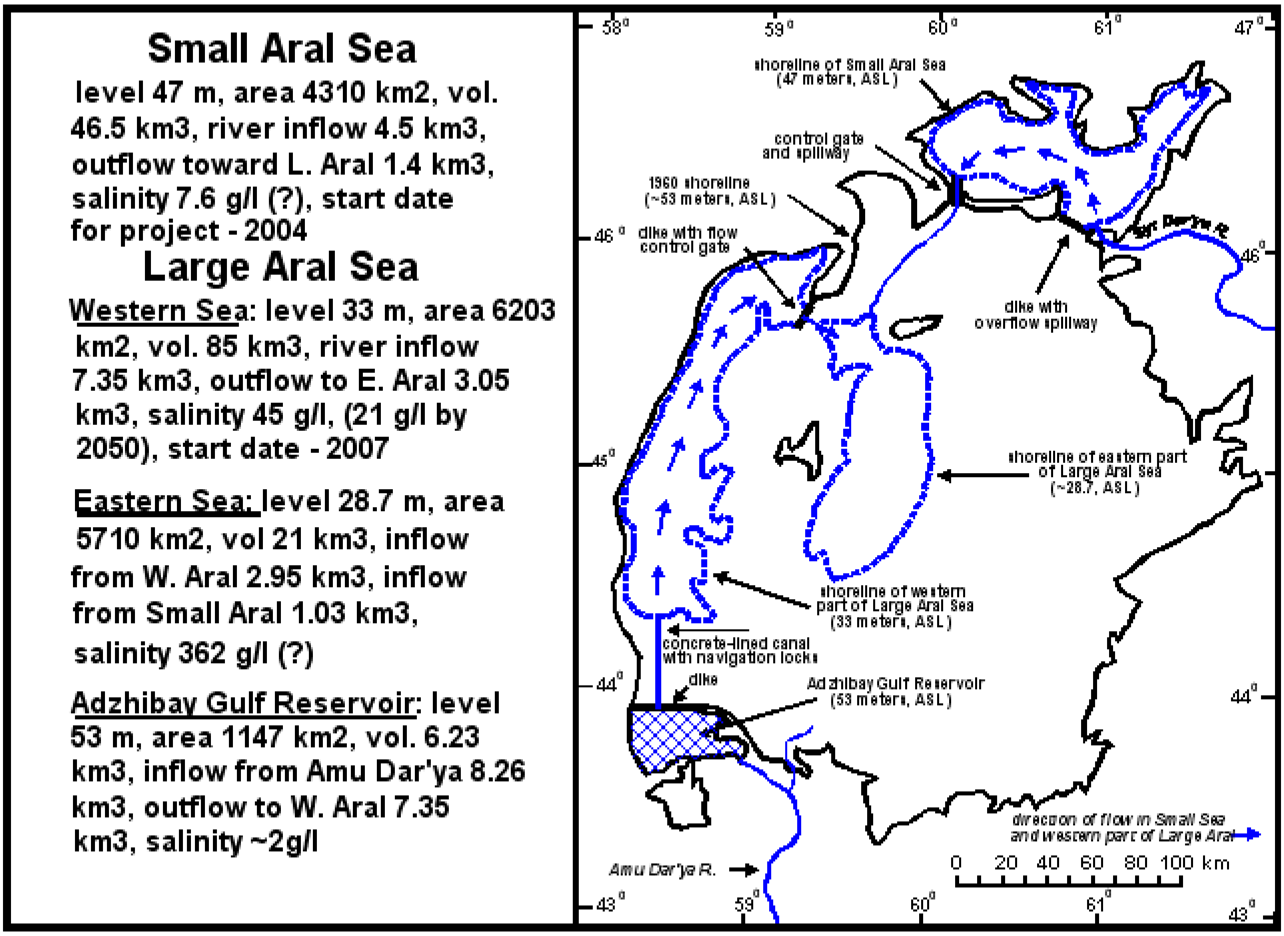


Figure 4. Concept to Partially Preserve Small and Large Aral Seas (proposed by Lvovich and Tsigelnaya, updated and modified by P. Micklin).



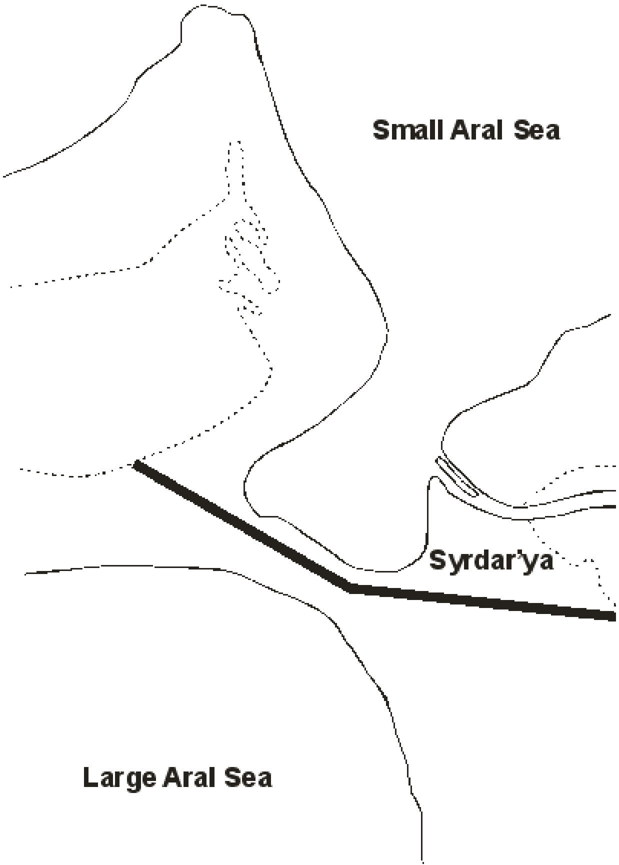
accumulated sediments and the stream now flows between artificial banks. As difference of Small and Large Aral levels increased the stream velocity gradually increased what resulted in the channel bottom erosion and increasing in depth and length. In spring 1992 the channel length was about 5 km, the depth reached 2m and width was about 100 m. Where the channel reached the Large Aral a distinct delta with three branches was formed. By our measures in May 1992 through the channel from the Small Sea to the Large Sea flowed more than 100 m^3/sec of water (Aladin et al, 1995). Discharge of water from Small Aral occurs primarily in Spring-early summer high flow period on Syr Dar'ya.

Because the bottom ground in the former Berg's strait is loose sediment there was a danger that the channel will deepen and as a result the level of the Small Aral will begin to fall again. Moreover after some time this self-deepening channel could cut back to Syr Darya mouth and divert most or all of its flow into the southern basin. In this case there could be a danger of not only fast fall of the Small Aral level but its disappearance. It would be catastrophic for fishing (Aladin et al, 1995).

In 1991 N. Aladin reported to local authorities about these dangers. In May 1992 he suggested to the head of Aral district administration Bigali Kayupov to build a dam in the former Berg's straits in order to maintain water in the Small Sea. The head of Aral district administration Bigali Kayupov in turn reported together with N.Aladin this to the head of administration of Kyzylorda region mr. Shiohomanov. After discussion the idea was accepted and the government of Kazakhstan decided to construct a dike in Berg's strait (see Figure 4). The channel was dammed in August 1992. In September same year the dike was visited by team of World Bank experts headed by Mike Rathnam. Unfortunately in spring 1993 the dike was broken in two places and partly washed away. New major of Aralsk region Alashpay Baimyrzaev (who replaced B.Kayupov) continued to strengthen the dike using local money and money from Aral Sea Fund. Finally a dike across the whole width of Berg's strait of about 13 km long and 4 m high was built.

Unfortunately this first dike lasted less than 9 months (August 1992 - April 1993). It was built from sand and reed fascines; it was very fragile and sensitive to wave action and had no water gates to discharge excess water. In April 1993 when the level of the Small Aral rose more than 1 m the dike was partly destroyed as said above. However, the existence of the dike for this short time allowed making some conclusions. Anyway the water level could be

Figure 5. Dike in Berg strait is preserving Small (northern) Aral and rehabilitating its biodiversity.



maintained at about +42 m a.s.l. Salinity could be maintained at a value less than 20g/l. Conservation of the Small Sea allowed fishing activities and a partial restoration of the Syr Darya delta ecosystem. Until 1999 the first dike every year was partially destroyed during spring floods, but after that it was repaired again.

There were analogical project proposals of damming in Berg's strait (Bortnik, 1978, 1980; Lvovich, Tsigelnaya, 1978; Chernenko, 1983; Micklin, 1991). They appeared before the Small Aral Sea separation. These authors unlike our proposal suggested placing a dike in the narrowest part of the strait, while N.Aladin suggested building dike by 8 km to the south-west where the bottom is dried up already and with quite long dike body up to 13 km. The experience of the first dike confirmed that this location is the best. Figures 5 and 6 show a schematic and some views of the dike.

Fig 6. Some views of the Dike.

Effects of the First Intervention

Blocking the flow of water from the Small Aral to the Large Aral had good as well as bad effects. Some good effects included:

1. After the dike was constructed the fall in the level of the Small Aral Sea was stopped for the first time for 30 years and, soon after that, a relatively fast rise in the level began. In less than 9 months the level rose by more than 1 m.

2. For the first time in the last 30 years the increase in the salinity of the Small Aral Sea was stopped and after a while the water began to freshen.

3. The danger that the artificial channel connecting the Small and Large Aral seas would cut down and drain the Small Sea completely and divert the flow of Syr Darya into the Large Sea was temporarily eliminated.

4. The 1 m rise in the water level in the Small Aral Sea caused a partial filling of some of the gulfs which had earlier dried out. The center of the gulf of Bolshoy Sarychaganak and some of the gulfs were filled with water once again. It is noteworthy that the closing of the channel delayed for some time the disintegration of the Small Aral into several separate small lakes.

Among the negative consequences these should be noticed:

1. Rate of the large Aral Sea level fall increased in some extent. The exact volume of annual discharge from the Small to the Large Aral is not known. By our evaluations it could be nearly 3 km^3/year.

2. The damming to some extent increased the rate of the Large Sea salinity increase. Nevertheless this effect was smaller than the effect on the Large Aral level.

Technical Interventions in Berg's Strait: Next Steps

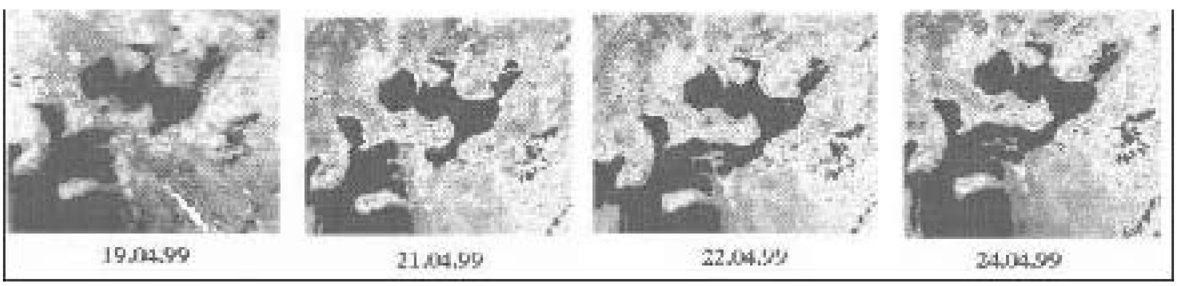
In 1998 the International Foundation for Saving the Aral Sea started financing preliminary studies for the construction of a stronger dam. The World Bank and other international organizations took interest in the project of restoration. Reconstruction of the dike was accepted by the governments of Kazakhstan and Uzbekistan - the latter having the upstream control of Syr Darya waters. It was necessary to improve the release of water and to ameliorate its circulation and use on the lower course of the river. Money could be provided by various organizations, especially the Kuwait government, to the height of 28 million US dollars. This was insufficient, and the help of the Kazakh Government and of the World Bank was necessary.

Unfortunately on April 20, 1999, as a consequence of a storm, waves destroyed the dike. People were yet working on it. Two of them were drowned, 27 workers were rescued by boats and helicopters. Bulldozers and trucks were drowned in sand. After this catastrophe the dike was not repaired. The Small Aral level fall.

Existence of the first dike till April 1999 allowed some rehabilitating biodiversity. Number of free-living animals increased. In April 1999, when the Small Aral Sea level increased more than by 3 m and reached +43.5 m, the dike broke. Water from the Small Sea caused inundation in the dried up northern part of the Large Aral (Fig 7). The second major of Aralsk region (A. Baimyrzaev) was withdrawn from his position and the third major of Aralsk region Aitbay Kusherbaev got an order to build a proper concrete dike with a gated spillway.

The water resources committee of the ministry of agriculture of Kazakhstan headed the project. Experts estimated that the project promised significant profit. Thorough preliminary studies or the projected dams were carried on. A concrete dam was necessary. In addition to the US$62 million forwarded by World Bank from December 2000 to February 2004, US$21.3 was added from the Kazakh government. World Bank granted 9 contracts, the most important going to China-Geoengineering (US$16.6 M) and Russian Zarubezhvodstroy (US$27.8) which won the tender. In October 2003 preparation works were in process, and construction itself was to began in Spring 2004. Water

Figure 7 Inundation after the break.



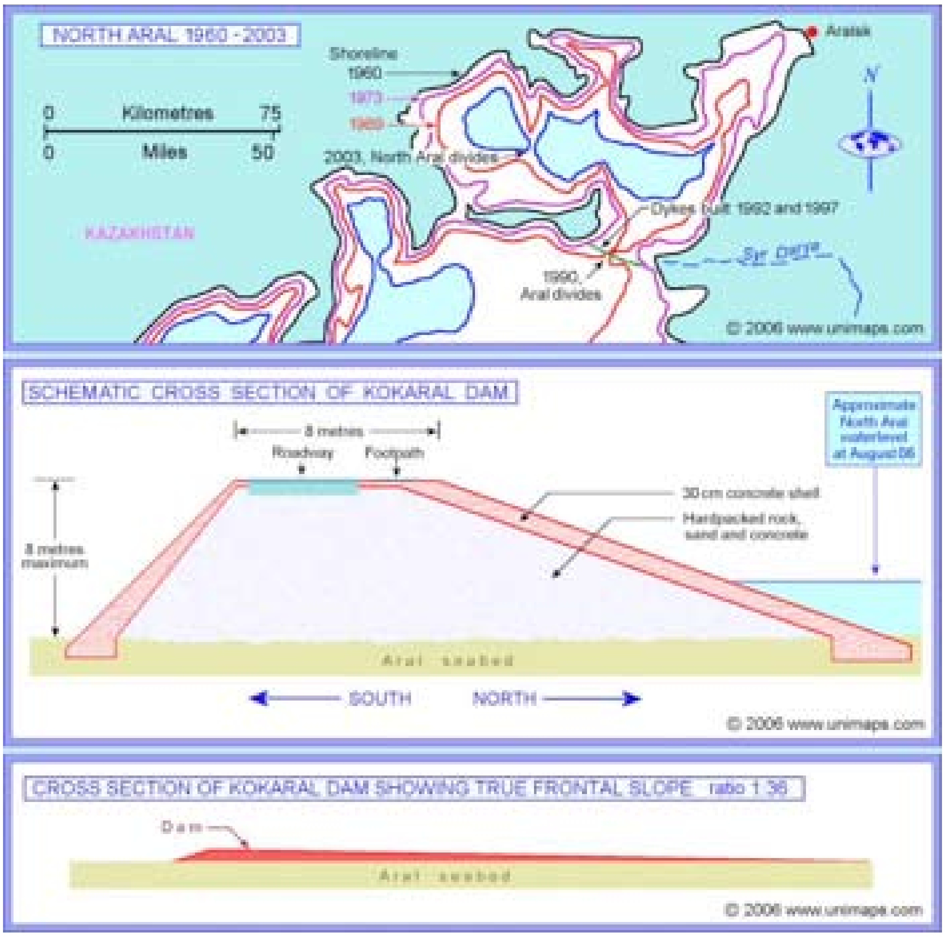
retention began in the autumn of 2005. An annual inflow of around 3 km^3 could sustain the water level at 40 m a.s.l. Details of the new dike are shows in the following set of figures.

The hydro system of Northern Aral Sea Dam includes the dam itself (with a spillway added on), supply and tailrace canals, fish barrier and an access road. The dam is being constructed of sandy soil; its length in the ridge is 13 km, average height is 4 m and width in the ridge is 10 m. The spillway is designed as a broad-crested overflow with a stilling pool deepened on 5 m. Total crest width is 49.5 m. In a cross section the dock construction consists of three sections with three spans in each (span width is 5.5 m). Every span has plain gates that are installed close to the overflow face.

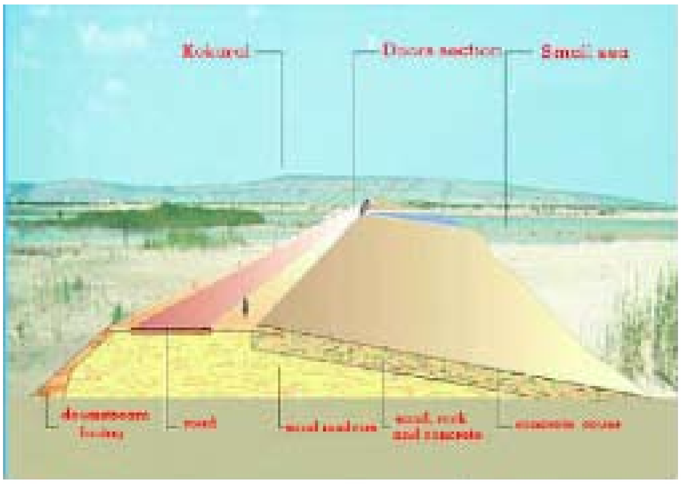
The dam is 11500 m long, 300 m wide at the bottom and 8 m wide with a maximum height of 8 m. The slope on the upstream side is low in order to break waves. The nucleus of the dam is sand mixed with limestone rocks and is covered with a shell of concrete 30 cm thick. In the axis of the east-west branch of the dam nine gates for water evacuation have been constructed in reinforced concrete, using cofferdams to get foundations down to 10 m under the original bottom of the Berg straits. Each door is 5.6m high x 5.3 m wide, and the flood gates may accept 110 m^3/sec. In front of the doors are deflectors to lower the current speed of evacuated water. Below there is a concrete slipway several hundred meters long to avoid undermining by evacuated water.

The following figures show various views of the dike and some of the effects.

Figure 8. New dike was built by Russian company "Zarubezvodstroy".



`Figure 9. Process of construction of 9 water gates of a new dike in the Berg strait, August 2005 (photo by E.Putnam).



Water deflectors

Figure 10. The view from satellite.

Figure 11. Spillway of new dike in the Berg strait in September 2006 (photo by L.Kuznetsov).

Figure 12. Spillway of new dike in the Berg strait in September 2007.

Figure 13. Small Aral Sea after dike construction.

Figure 14. A boat on the dried up bottom in September 2005 (left) and the same boat covered by water in September 2007 (right).

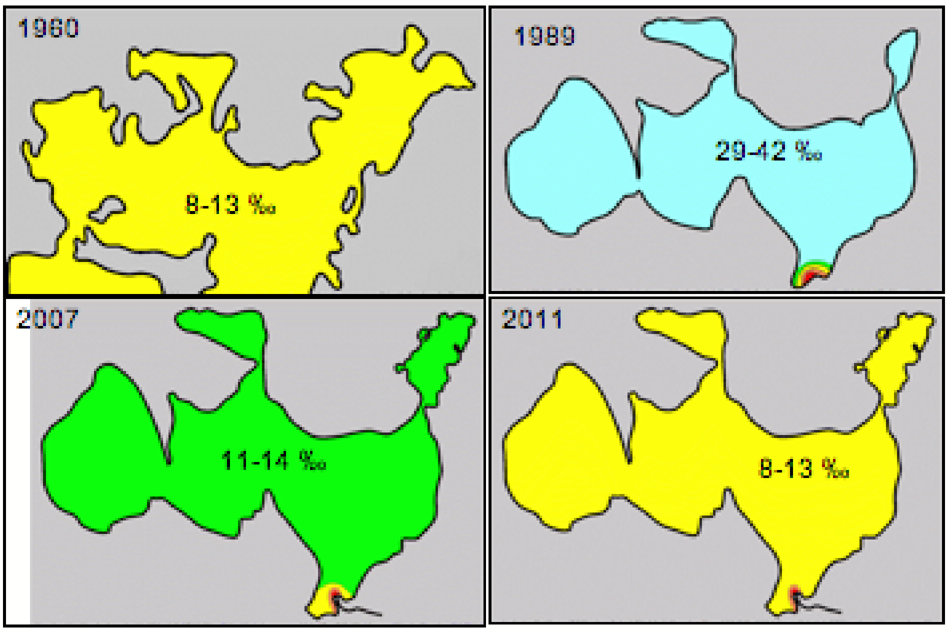


Figure 15. Changes in Salinity through time.

Overall, the dike in Berg's strait funded by GEF and Kazakhstan government allowed to improve brackish water environment of Small (Northern) Aral Sea:

- Dike in Berg's strait allowed increase of level in Small (Northern) Aral Sea to +42 m a.s.l. with "forcing" to 42.5 m.

- Present average salinity in Small (Northern) Aral Sea is about 11-14 g/l. In the nearest future it will reach 8-13 g/l.

- For further improvement of situation there are needed improvements in irrigation efficiency to raise inflow from Syr Dar'ya.

- It is possible to make the present dike a bit higher and raise the level to +45 m a.s.l. This will allow to enlarge the volume and area of Small (Northern) Aral Sea.

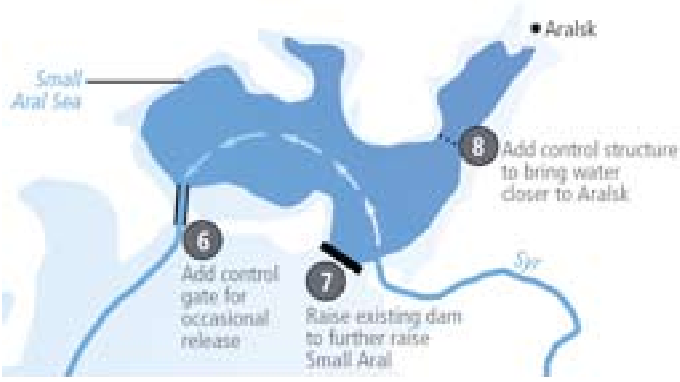
An alternative 2nd phase (Figure 17) of the Small Aral rehabilitation project has been proposed with the following characteristics:

- Alternative 2nd phase of the project would raise level only of Saryshaganak Gulf.

- Second phase would allow further improvement of the health of the local people, to decrease unemployment and increase living standards as well as income to the local families.

- The local economy also will be improved (fishery, shipping, etc.).

Figure 18. Proposed New Gated Spillway.

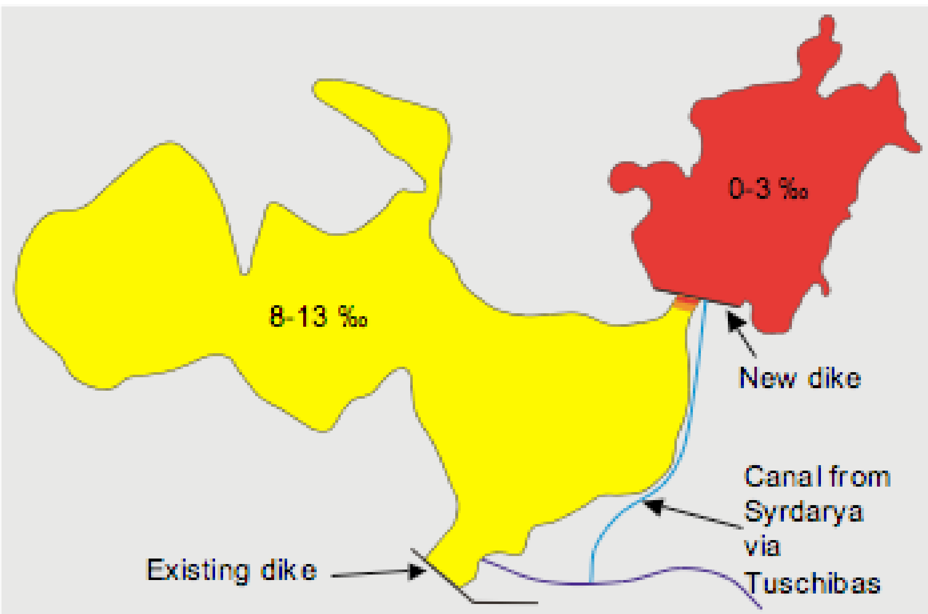


- Local microclimate around Small (Northern) Aral Sea will be much better than now.

AKLAK hydro system on Syr Darya River includes run-of-river dam, spillway, supply and tailrace canals, floodwalls, fish-pass and water-intake facilities. The spillway is designed as a broad-crested overflow with chute and stilling pool added on. The bottom of stilling pool is deepened on 11.3 meters under the weir bulkhead mark. The stilling pool consists of a weir, stilling section, and transition tubes connecting the stilling pool with headrace and tailrace canals. Total crest width is 42 m. In a cross section the dock construction consists of three sections, each having 12 meters-wide rollway. Every section is equipped with sector gates. Slots for plain guard gates are made in the direction of headrace.

Unfortunately at the end of 2006 and even at the end 2007 AKLAK hydrosystem on Syr Darya River was not completed. At present there are plans to fulfill this project this year. It will allow bringing water back to the former Karatern and Karasholan bays as well as some other water bodies in Syr Darya lower riches. Successful realisation of AKLAK hydrosystem will allow starting second phase of the project.

Figure 17. Alternative 2nd phase of the Small Aral rehabilitation project.



One of us (P. Micklin) advised to increase Kokaral dike in height length in order to make Small Aral Sea level as high as +47-48 m a.s.l. He also advised to make new gated spillway in former Auzykokaral strait that was at the most eastern side of the former Kokaral Island. This new gated spillway will allow to bring water quicker and via shorter distance to the remnants of the Large Aral Sea (Eastern depression). To 2007 the Large Aral is divided into three parts (Western Large

Aral, Eastern Large Aral and Tsche-Bas Bay). This new gated spillway will also allow to have a better circulation of currents within the Small Aral Sea (Figure 18).

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