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Restoration of the Northern Aral Sea with the help of Kokaral dike

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The Aral Sea water balance consists of riverine water supply, atmospheric precipitation and underground water income on one hand and from evaporation loss on the other. 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. Average salinity was about 10.2-10.3 g/l.

In the second half of 20th century the riverine water supply began to decrease rapidly because of the increasing water withdrawals for irrigation. As a result the equilibrium between the total gains and losses of the Aral Sea water balance was lost. Since 1961 this disruption of existed equilibrium has resulted in water level decrease and increased water salinity in this giant lake. Water salinization caused significant decrease in the biodiversity of the Aral Sea, only small part of its indigenous flora and fauna could survive.

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

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 2 m and on the East they were connected by relatively deep Berg's strait with maximal depth of 13 m. The shallow strait dried off still in 1968, while the deeper one dried

off in 1989-1990, resulting in complete separation of small Aral from the large Aral Sea. In 1989 Aral had area as 60% of that in 1960 and volume as 33% of volume in 1960, with salinity reaching to as high as 30 g/l.

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 while in the large Aral it steadily increased.

In 1961-1988 when the Berg's strait between the small and large Arals was still under water, the rate of surface level decrease in both the large and the small Aral was the same. But after complete separation of two water areas in 1989-1990, decrease in water level continued only in the large Aral. In the small Sea on the contrary, the water level began to increase as evaporation level was lower than input water. This increase in water level resulted in overflow of water to the large Aral via the channel along the dried area of Berg's strait.

This channel is of artificial origin. In the beginning of 1980s, the Berg's strait was deepened with dredger in order to sustain navigation. However, 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 slowly to flow along the channel, increasing in volume later.

At the beginning the overflow channel was wide and shallow but after a while the water cut down through the 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. Discharge of water from Small Aral occurs primarily in spring and early summer, during 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 Dar'ya 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.

In 1991 we reported to local authorities about these dangers and in May 1992 we suggested construction of a dam in the former Berg's straits in order to maintain water in the Small Sea. Fortunately our proposal was accepted and a dike was constructed in the Berg's strait by the government of Kazakhstan in August 1992. The dike 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 and partially washed away. Fortunately Aral received an International support from UNEP "Aral Sea Fund" to help the local funding to complete a stronger dike across the whole width of Berg's strait of about 13 km long and 4 m high. Until 1999 the first dike every year was partially destroyed during spring floods, but after that it was repaired again.

In spring 1999 the Small Aral Sea level increased by more than 3 m and reached +43.5 m a.s.l. Unfortunately on April 20 same year the dike was destroyed by a storm. Therefore construction of a proper concrete dike with a gated spillway was planned.

However, the existence of the dike for this short time allowed making some conclusions. The water level could be maintained at about +42 m a.s.l. Salinity could be maintained at a value less than 20 g/l. Biodiversity was partially rehabilitated, allowing fishing activities. Syr Darya delta ecosystem was also partially restored.

Construction of the dike and 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 first 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.
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.
2. The damming to some extent increased the rate of the Large Sea salinity increase.

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.

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 on 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 begin in spring 2004. Water 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.

The hydro system of Northern Aral Sea Dam includes the dam itself with spillway, 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 $110 \text{ m}^3/\text{sec}$. 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.

Overall, the Kokaral dike in Berg's strait allowed to improve brackish water environment of Small (Northern) Aral Sea:

- Level in Small (Northern) Aral Sea has increased to +42 m a.s.l. with "forcing" to 42.5 m.

- Average salinity in Small (Northern) Aral Sea has decreased significantly. Now it reached less than 10 g/l.
- Stabilization of the hydrological regime and, above all, freshening of the water has allowed the return of aboriginal commercial fishes to the Small Aral Sea via their migration from the lacustrine system of the lower Syr Dar'ya. Now these fish species are being commercially caught.
- It is possible to make the present dike a bit higher and raise the level to +45 m a.s.l. This will allow enlarging the volume and area of Small (Northern) Aral Sea.
- For further improvement of situation there are needed improvements in irrigation efficiency to raise inflow from Syr Dar'ya.

All above mentioned information about restoration of the Northern Aral Sea with the help of Kokaral dike could be used in the forthcoming restoration projects for Urmia Lake.

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