Forecast of the Water–Salt Balance in the Turkmen Lake Altyn Asyr

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Abstract This chapter provides the forecast of formation of the artificial lake Altyn Asyr after transfer here of the collector and drainage waters from the irrigated lands of Turkmenistan and nearby territories. The balance estimates have shown that about 50 years will be required to fill this lake with the design disposal of the collector and drainage waters. At the same time approximately one billion tons of salts are expected to get into the lake with these waters.

Keywords Balance, Collector and drainage waters, Evaporation, Forecast, Infiltration

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1 Introduction

Summing up the results of the regime and balance investigations in Turkmenistan has shown that long-time irrigation of oasis lands leads to considerable increase in the volume of collector and drainage waters. Until recently, saline collector and drainage waters from irrigated fields were disposed directly into rivers and natural depressions in the Karakum Desert. As a result, the near-oasis pasture lands

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surrounding the irrigation systems have already degraded or are threatened with waterlogging and salinization.

In this context the problem of regulation of the water–salt balance in irrigated lands of oases should be addressed in combination with the forecasted alterations in the natural land reclamation and environmental situation in desert pastures near oases. Such approach seems helpful to optimize the water–salt balance in the oasis lands if the technical feasibility and environmental admissibility of improvements, including land reclamation with the assigned level of economic return, satisfy the present-day requirements.

In the face of the growing volumes of saline collector and drainage waters in Turkmenistan, it seems advisable, apart from their utilization, to recycle them for irrigation. As a result of withdrawal of a part of drainage waters disposed into the desert, the crop cultivation on the near-oasis lands will permit, on one hand, to improve significantly the forage base of the region and, on the other hand, to alleviate the environmental stress in the near-oasis zone of the Karakum Desert.

2 The Altyn Asyr Lake Project

For augmentation of water resources and improvement of the desert environment, Turkmenistan initiated a magnificent project being in close control of the Turkmen President on construction of the artificial lake Altyn Asyr or Turkmen Lake. This is the grandest project of the century envisaging transfer of great volumes of collector and drainage waters into the natural depression Karashor, thus resolving the whole complex of scientific and economic problems. As concerns land reclamation and wise nature management it seems very important to evaluate, primarily, the likely hydrological changes in Northwestern Turkmenistan, including water–salt balance of pastures in the watershed zone and feeding networks.

It should be noted that Karashor Depression locates between two lakes – the Kara-Bogaz Gol Bay of the Caspian Sea and Sarykamysh [1]. The depression area is no more than 2,000 km^2 (length 100 km, width 20 km) with the maximum depth being 75 m. The water volume in the lake, the area of its water surface, and the average depth of the water body under design filling will be about 130 km^3, 2,000 km^2, and 70 m, respectively. At present the annual flow of all collector and drainage waters in Turkmenistan is approximately 7 km^3, out of which more than the half accounts for Lebapsky and Dashoguzsky velajats (provinces). Adding here the flow of collector and drainage waters from the nearby territory of Uzbekistan, the total flow may reach 11 km^3 [2, 3].

The flow transfer project envisages that the collector and drainage waters will flow into the terminal point – the Turkmen Lake via the Northern Route – Dashoguz canal 350 km long and via the Southern Route – Main Header 720 km long. Herewith the Dashoguz canal will divert a part of the flow from the Ozerny and Daryalyk headers which will result in drawdown of groundwater level by approximately one meter and a half, and this, in its turn, will normalize the water outflow from irrigated fields and soil salt regime.

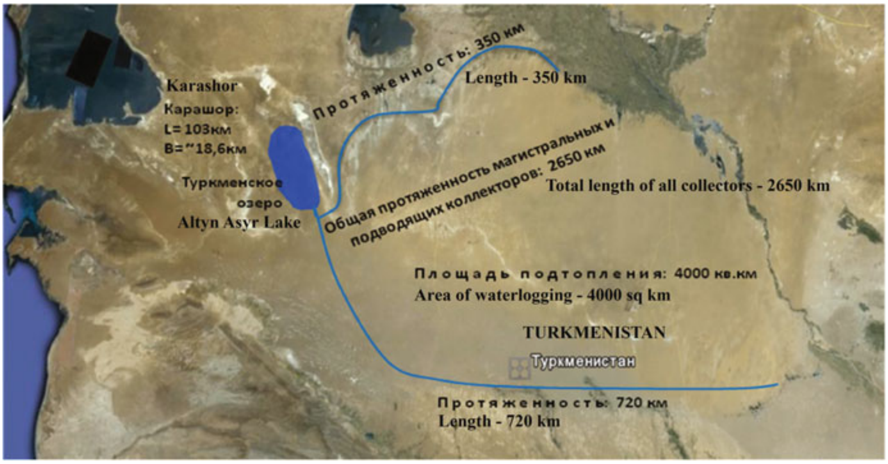

Fig. 1 Scheme of transfer of the collector and drainage waters into the Altyn Asyr Lake

At present diversion of collector and drainage waters from Dashoguz and Khorezm velajats into the Sarykamysh Lake leads to overwetting and waterlogging of agricultural lands, increases the risk of destruction of engineering structures and communications, including gas pipelines, communication lines, and power transmission lines [4]. According to the project, the Main Header will be used for diversion of drainage waters from irrigated lands in the Mary and Akhalsky velajats and also flood waters of the Tedjen and Murghab rivers that are presently disposed directly into the sand desert which results in waterlogging and salinization of valuable pasture lands.

It should be said that very low air humidity and high temperatures in Central Karakums may cause great water losses to evaporation. Even the water balance of the Caspian Sea possessing such potent source of recharge as the Volga River remains at present negative and loses annually over 20 km^3 of water. More than 400 km^3 are lost here only to evaporation. It means that still greater water losses may be expected also in the Turkmen Lake.

The results of long-time monitoring of the water flow into the Sarykamysh Lake and the condition of nearby lands permit to forecast development of similar natural and soil-hydrogeological processes in the zone of Karashor Depression filling and water feeding routes.

In estimates of formation of artificial Altyn Asyr Lake, the inflow routes and the volume of saline collector and drainage waters diverted from oases are assumed the same as in the project, i.e., via the northern and southern route over 1,000 km long and in the amount of 10 km^3 a year. In this case, according to our estimates, the water resources of the lake should grow about 2 km^3 a year or 20% of the annual flow of collector and drainage waters. The remaining part of water will be invariably lost to evaporation and infiltration from the lake and feeding network of headers and canals. These losses are distributed rather evenly over the transit zone forming in the future a vast space of overwetted and saline lands with an area of approximately 4,000 km^2 (Fig. 1).

Table 1 Epignostic estimates of the water balance of the Sarykamysh Lake for the period 1970–2010

	Design time, years				Total for 40 years
Water balance elements	1–10	11–20	21–30	31–40	1–40
CDW flow into the lake, km^3	46	52	58	65	221
Total evaporation, km^3	23	30	40	48	141
Infiltration, km^3	17	13	7	3	40
Inflow into the lake, km^3	6	9	11	14	40
Lake surface area, km^2	1,600	2,100	2,800	3,400	3,400
Lake average depth, m	4	7	9	12	12

Such redistribution of the collector and drainage waters may bring about certain changes in the natural, soil, hydrogeological, ecological, and economic situation practically across the whole territory of the Central Karakums. Let us demonstrate the likely changes of the hydrological regime in the Turkmen Lake zone taking as an example the estimations of the water balance for the Sarykamysh Lake.

3 The Sarykamysh Lake Water Balance

The forecast of formation and development of the Sarykamysh Lake was prepared taking into account the present condition of the lake applying the following scheme. The year of 1970 was adopted as the initial reference time. From this time on during the first decade no less than 4.6 km^3 of collector and drainage waters should flow into the Sarykamysh Depression via two headers Daryalyk and Ozerny. In the subsequent years the volume of the collector and drainage waters diverted into the lake increased by 0.6 km^3 a year in each 10 years, so that by the end of the design period of the Sarykamysh Lake formation the real volume of water inflow into it is attained. In the estimates the water losses to evaporation from the lake surface and from headers were assumed equaling the mean daily evaporation from the water surface in the hot season of a year (April–September) making some 7–8 mm, while losses to infiltration equaling 1.3–0.3 km^3 a year in the conditions of backup infiltration. For the period with unsteady regime of free filtration, the infiltration losses from the lake were assumed 35% of the total water flow into the lake which fits the real water losses from irrigated lands in the Dashoguz velajat (Table 1).

Given these initial values of the water balance components, the estimates have shown that the total inflow into the lake for 40 years was about 40 km^3. The average water body depth in the period from 1980 to late 2010 increased from 4 to 12 m, while the lake area from 1,400 to 3,400 km^2 (Table 1).

Table 2 Forecast estimates of the water balance of the Turkmen Lake for the period 2009–2059 with the permanent annual CDW flow

	Design time, years					Total for 50 years
Water balance elements	1–10	11–20	21–30	31–40	41–50	1–50
CDW flow into the lake, km^3	100	100	100	100	100	500
Total evaporation, km^3	34	35	36	37	39	181
Infiltration, km^3	45	42	39	36	25	187
Inflow into the lake, km^3	21	23	25	27	36	132
Lake surface area, km^2	1,900	1,910	1,920	1,930	1,950	1,950
Lake average depth, m	11	23	36	50	68	68

4 The Altyn Asyr Lake Water Balance

Similar forecast estimations were conducted for the Turkmen Lake. In these estimates the year of 2009 was taken as a reference time point. From that time on about 10 km^3 of the collector and drainage waters were supplied annually into the Turkmen Lake via the northern Daryalyk and Ozerny headers and the southern Main Header, out of which every year over 3.5 km^3 were disposed into the lake via the northern route and about 7.4 km^3 via the southern route. The total water losses from the canal network with the backup filtration regime will make about 0.23 km^3 a year; the water losses to evaporation from the surface of the lake and open headers were taken equaling the mean daily evaporation of 8–9 mm in the hot season of a year (April–September) making the year average of 5–6 mm a day for climatic conditions of Central Karakums. At the initial filling of the lake, the infiltration losses accounted for 40–45% of the total water inflow at a free filtration regime. Later on the infiltration losses decreased gradually reaching 20–25% of the total volume of water in the lake.

The balance estimates have shown that with the unchanged flow of the collector and drainage waters in the forecasted period (full filling of the lake) about 500 km^3 of water will be transferred from oases (Table 2). Out of this amount the annual flow for the "net feeding" of the lake will average 2.64 km^3. The greater part of the flow (about 73%) gets lost to infiltration and evaporation from the water surface of the lake and feeding canals. The Table 2 also shows that the water losses to evaporation are 3.6 km^3 a year with the annual evaporation equaling approximately 1,800 mm, while the water losses to infiltration and underground outflow – about 3.8 km^3 a year or approximately 37% of the total flow of the collector and drainage waters.

If we take that the maximum capacity of the whole system of depressions in the Karashor area is equal to 132 km^3, it will be required about 50 years to fill it completely, in other words, the Karashor Depression will be filled completely in 2060.

For stabilizing the water level in the lake with the area of its water surface being 1,950 km^2, we will have to withdraw part of the water (about 2 km^3/year) to irrigate lands in the canal zone. This amount will be sufficient to irrigate over 200,000 ha of

Table 3 Forecast estimates of the salt balance in the Turkmen Lake for the period 2009–2059 with the permanent annual CDW flow equaling 10 km^3 and salinity of 3 g/L, in million tons

	Design time, years					Total for 50 years
Salt balance elements	1–10	11–20	21–30	31–40	41–50	1–50
Total salt inflow into the lake with CDE	300	300	300	300	300	1500
Salt outflow into ground waters	135	123	117	108	75	558
Salt stock in the lake, km^3	165	177	183	192	225	942

soils with the light granulometric composition along the route of the northern and southern headers.

It should be noted that apart from water this transfer project involves salt, the level of which varies broadly in CDW. Depending on the salt content in water its salinity varies from weak to heavy. Even assuming that the salinity of collector and drainage waters does not exceed the critical threshold of 3 g/L, then every year about 30 million tons of salts will be imported into the lake with water and by year 2060, by the time of the Turkmen Lake filling about 1.5 billion tons of salts will be transported from oases into the desert (Table 3). Out of the total amount of toxic salts brought into the lake, over of 500 million tonnes of salts are evacuated with water infiltrating into ground waters, and the remaining amount of salts (approximately one billion tons) dissolves in the lake water.

5 Conclusions

It is also worth noting that the Turkmen Lake Project envisages development of the lands along the northern and southern water feeding canals. In this context it becomes necessary to conduct here various investigations, including monitoring of the land condition.

These investigations and observations should be based on simulation modeling in combination with land and remote sensing monitoring. This will permit to get answers to many questions connected with transfer of collector and drainage waters from oases into the desert. In particular, it is possible to substantiate:

- Areas of waterlogged and saline lands in the zone of transit of collector and drainage waters into the Altyn Asyr Lake
- Assessment and allocation of lands fit for growing fodder crops under irrigation with saline waters
- Estimates of the water application rates with regard to the soil cover structure and structure of the zone of aeration
- Identification of the case-and-effect relationships in the system soil–environment–man
- Forecast of changes in land fertility affected by natural and anthropogenic factors
- Operative managerial solutions and others

Therefore, even the roughest estimates indicate that we deal with the grand project on transfer of the enormous amounts of water and salts from oases into the desert during 50 years and more which will invariably induce global natural, ecological, and socioeconomic changes in the whole region of Northwestern Turkmenistan.

This circumstance requires the scientific community and the engineering-technical services to focus their attention on the Altyn Asyr Project in Turkmenistan. Special attention should be paid to the methodology and technique of monitoring and forecast of the water–salt balance applying modern mathematical models and computation technique. It is also advisable to build the permanently operating mathematical model of the Turkmen Lake and water supply canals to "play" different situations that may arise at various stages of collector and drainage water transfer from oases into the desert. Such model will be helpful for prediction of the object behavior and, accordingly, for taking appropriate managerial solution, thus optimizing the regime of the Altyn Asyr Lake formation.

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