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THE STRATEGIC WAY OF SOLVING THE PROBLEM OF THE SEVAN

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Lake Sevan is a freshwater and highland lake. The lake is bordered by the mountain ranges of Geghama in the west, Vardenis to the southwest and Areguni, Sevan and Eastern Sevan in the north-east. The lake is composed of the Greater and the Small Sevans which are separated from each other by the capes of Artanish and Noratus connected with an underwater hill. Before the artificial lowering of the lake level its length was 75 km long, the average width was 19 km (maximum 32 km), the average depth was 41.3 m and the depth of the deepest part called the Small Sevan was 98.7 m. In these conditions the total capacity of the lake was 58.5 billion cubic meters and after an artificial reduction of water level it comprised about 33 billion cubic meters minimum. 28 rivers are flowing into Lake Sevan: Dzknaget, Gavaraget, Argichi, Vardenis and so on. The Sevan is also fed with underground springs and atmospheric precipitations. Only the Hrazdan originates from the Sevan. The Sevan is the only major natural drinking water reservoir in the region. But over the last decades under the anthropogenic impacts the lake's ecosystem has been damaged causing marsh processes which may become irreversible in the near future. In this work it is proposed to raise the water level in Lake Sevan up to 1915.57 m as a solution to the problem and the technical capabilities of its implementation are given.

Key words: water, spring, evaporation, water level, reservoir, Arpa - Sevan tunnel, ecosystem.

Introduction

In 1930-1960 of the XX century Sevan-Hrazdan cascade was built on the river Hrazdan with its 6 hydropower stations the exploitation of which recessed the stage of the lake. It turned out that during the water runoff the ecological condition of the lake gets worse more quickly than it was supposed. In 1964 the lake had already lost 40% of its ancient supplies, the maximum depth of the lake had reached up to 80 meters, the average water stage was recessed by 13,5 meters. As a result the bed of the Small Sevan recessed by 36,5 km^2, that of the Great Sevan by 116 km^2, the amount of oxygen in water was recessed, the lake began to freeze more often (after 1947 for more than twenty times). To prevet the disaster it was decided not to let the water runoff of the lake any more with the purpose of getting electricity. However, despite the activities being held (mainly the operation of Arpa –Sevan tunnel), for the coutry's survival it was necessary to realize water intake of 1,5 billion cubic meters annually during Artsakh war with energetic purposes. In the beginning of the XXI century the lake stage was recessed by 19,25 meters.

In the last decades of the XX century as a result of physico - chemical and biological changes the lake began to get old and to swamp, to cover with green and blue algaes. These changes had negative influence on the fauna of the lake. The first alarm on the distortion of ecosystem of the lake was in 1958 when by the negotiation of central committee of the Communist party of Armenia and the council of Ministers the government of Soviet Union had recessed the stage of the Sevan till 500 mln cubioc meters from which 380 mln cubic meters were allowed to be used for irrigation. However, even after this important decision the lake stage continued to lower. The distorted ecosystem contributed to swamping of lake Sevan as possible. It was urgent to search for new ways of energetics and providing irrigation and to prevent further recession of lake stage of the Sevan. A new project of utilization of the Sevan was admitted in 1961 which foresaw to keep the lake stage on 1898 meters and in this case, as a result of evaporation and recession of underground flows it would be possible to outlet 180 mln cubic meters water from the Hrazdan without further recession of lake stage (in natural conditions instead of 50 mln cubic meters). To cover the shortage in water for irrigation many pumping stations were built through which the southern rivers of the republic were directed to the working canals of Artashat, the lower Hrazdan and Ejmiatsin. Particularly, Artashat pumping station was built in 1967 which lightened the «bother» of the Sevan for 50 mln cubic meters. Later on the pumping station of

Mkhchyan was built in 1968 which supplies the agriculture with additional 125 mln cubic meters water. In 1966 Aparan, in 1976 Azat and in 1981 Akhuryan reservoirs were exploited with respectively 91 mln, 70 mln and 525 mln cubic meters capacity [1, 2, 3].

By the authorities of the Republic of Armenia consistent activities have recently been done to rise lake stage of the Sevan and to improve the water ecosystem. The Law «On lake Sevan» was accepted [4] and by the order of the president of the RA the Committee on the issues of lake Sevan was created [5].

It is worth to mention that before the collapse of the USSR in the condition of unprecedented capacities of reservoir construction the regular water course of Armenia was already supported by 83 reservoirs which were accumulating 1,1 billion cubic meters water (without Sarsang reservoir) [6]. The problem of energetics was solved by the construction of Metsamor nuclear power station. But our nation had to suffer another great disaster: after the earthquake of Spitak in 1989 the station had been stopped and it was reoperated only in 1995 which had had not only great economic, but also social and political significance.

The construction of Vorotan-Arpa-Sevan hydro-technical complex was of utmost importance for the protection of Lake Sevan and the efficient utilization of its supplies. To rise the lake stage Vorotan-Arpa-Sevan tunnel transports part of the flow of the Vorotan, Arpa and Yeghegis rivers to the lake. The annual technical capacity of the tunnel is estimated as 465 million cubic meters. It is formed by Arpa-Sevan tunnel (built in 1981, it can transport up to 300 million m^3 per year from River Arpa to Sevan) and Vorotan-Arpa tunnel (built in 2004, it can transport additional 165 million m^3 annually from Vorotan River via Arpa-Sevan to Lake Sevan) [7]. For the protection of the ecosystem of Lake Sevan "Sevan" National Park was created in 1978.

It was decided to rise the stage of Lake Sevan up to 1905 m above sea level at the beginning of the 21st century [8]. According to the program, the actual water level will be 1903.5 meters. The remaining 1.5 meters will make the height of the wave. Currently, the lake stage is 1900.13 m which is equal to the lake stage in 1963. During the elevated water level 1697 buildings and structures will be covered with water, only 481 of which are officially registered and the remaining 1216 are illegal. 7 km watercourses, 18 km of electricity transmission lines, 35 substations, 19 km of gas pipelines will be covered under the water. 15 km of road will be covered with water. It was foreseen to rise the level stage of the Sevan by 1903,5 meters up to 2032 meters. Annual water level should rise to approximately 21.6cm [7].

The importance of the work done to prevent the recession of the level of Lake Sevan and to rise it is evident. But today these actions can not be considered sufficient to solve the problem of Lake Sevan. There is a need to adopt a strategic decision to rise the level stage of Lake Sevan up to the recorded rate of 1915.57 m which was registered in 1915. This should become the target for soving the problem of Lake Sevan.

By one of the first steps to solve the problem of Lake Sevan it is necessary to determine the water balance of the lake more completely and accurately and the dimensions of its individual components. It primarily refers to the determination of the dimension of evaporation which is the largest component of the balance and which greatly influences the most important element of the level stage flashing - the active yield of water.

The hydrometeorological monitoring has been done in the basin of lake Sevan for more than hundred years. The necessary measurable dimensions are recorded and necessary analyses have been done. Since the water amount out of the lake exceeded the natural runoff (1933), the controlled water intake is also measured (to the Hrazdan) with its transportation indexes through Arpa-Sevan tunnel (since 1981). However, the calculated dimensions of water balance elements and especially evaporation value are not reliable which make the estimation of total water balance dimension. The main reason of this is the lack of objects of monitoring realized towards the components of the balance, the old equipments and the imperfection of determination of calculating methods. Hence, we have the need to improve the calculating methods and to realize the monitoring [9].

The reliability of the formation of water balance of lake Sevan will increase in case of the complete determination of its components, expanding of the mentioned observations, overviewing the methods of their operations and improving them. It is possible only in realization of hydrological monitoring and improving the methodology of balance projecting. It will enable

- To get complete and reliable hydrological information about Lake Sevan and the description of water objects of its basin for timely calculating intervals,
- For the purpose of making justified decisions on hydroeconomic activities, to determine more precisely the water supply of the lake for the estimated period and the values of water regime change,
- To make an adequate water and hydoeconomic balance of the lake which will include the integrity of its components, the accuracy of its determination and its reliability.

The evaporation of the surface of lake Sevan is greater for 3,5 times than its average water yield. Hence we have the importance of of determination of measuring the evaporation and its summative value. Now the value of evaporation is determined by calculating method using the previous statistical and other empiric relations on the basis of the measurments [10]. The aimed task is to provide the opportunity of realizing the monitoring with contemporary methods and to review the methods of the calculation of evaporation.

The surface indraft is the main in its natural indraft. The flow measurments are not sufficient and the methodology to determine the surface indraft is not reliable through them. It is necessary to operate new approaches by which it will be possible to account the river flows, the water intake of the rivers and flow change.

The precipitations on the lake surface, as a rule, are less than on coastal line and have chronological fluctuations. So they should be immediately measured (mainly on the Great Sevan) and new empiric relations should be created to clarify the seasonal amount of the precipitations.

Measurements of the stage of Lake Sevan the volume of water accumulated in the lake is determined by, along with the measurements of the lake managing components, allow for immediate determination of the lake's active water lubrication and water balance error. The inflow of groundwater in the lake is now taken in the water balance equal to 93 million m^3, stable over the years per month. This size and its ability to be persistent and equal are susseptible. The groundwater inflow rate, as a rule, is estimated by different dimensions at different levels for the gradual stages of the development of the lake’s problem. Particularly, after the cessation of the recession of lake level the inflow was calculated equal to 120 million m^3, the correctness of which is also very suspicious. There is a need to develop a new calculation method for the level rise, taking into account the fact that, along with the rising water level, it is supposed to activate filtration phenomena on coastal ground. While reviewing groundwater inflow it will be necessary to compile the water balance of the lake's catchment basin to determine the flow of deep water and to determine the amount of water filtration and to reconsider calculations done previously.

It is desirable to make the water balance of the catchment basin of the lake making it "correspondent" to the lake's balance and evaluating the annual and seasonal fluctuations of groundwater inflow of the lake. This will require additional climatic observations and episodic measurements.

Conflict setting

To solve the problems of lake Sevan, the following tasks are set forward:

1. Determination of the evaporation amount from the surface of lake Sevan;
2. Estimation of underground runoff and river inflow of lake Sevan;
3. The justification of rising the lake stage up to 1915,57 meters and road map development.

Research results

The following research program is suggested to be applied:

- Review and improvement of the methodology of determination of the evaporation amount from lake surface and development of calculation package program,
- Improvement of surface inflow estimation methodology,
- Revaluation of seasonal and annual precipitation on the surface of lake Sevan, modernization of calculating methods,
- Modernization of prediction of the methodology of natural flow of the lake (active yield of water),
- Making the water balance of the catchment basin and balance estimation of hydrological parameters of underground water inflow of the lake,
- The clarification of the methodology of determination of underground inflow and runoff of the lake according to the lake stage changes,
- Modernization of the method of balance development of the lake and development of guideline of correcting the previous mistakes and balances of the lake,
- Development of the methodology of determination of the influence of climatic change on the lake and water resources of its basin and the determination of calculation characteristics. Development of scenarios on air temperature, moisture and wind speed changes of the Sevan basin on the basis of global change of climate and the results of regional models.

The vaporization is one of the main components of outcome of water balance of the lake Sevan. In the conditions of natural high level of the lake (1915,57 m above sea level) it comprised more than 90 percent of inflow water balance , i.e. more than 90 percent of the water flowing into the lake was lost as a result of vaporization. Parallel with the recession of lake stage as a result of its surface reduction the amount of water used for vaporization was also reduced. Nowadays, i.e. in case of horizon about 15 m below natural level the size of vaporization comprises about 80-85% of its inflow. However, this value needs to be clarified and the issues connected with the evaporation of the lake are modern.

Various methods were developed to determine the factors which the vaporization of lake Sevan is conditioned by such as limnetic air layer temperature, moisture, wind speed and water surface temperature. The evaporation value of lake Sevan was determined by these methods for different times and the predictions have been done on the vaporization.

In Figure 1 the annual sizes of vaporization of lake Sevan calculated by the methods of turbulent diffusion and evaporators are shown. The long term process of lake stage is also shown there.

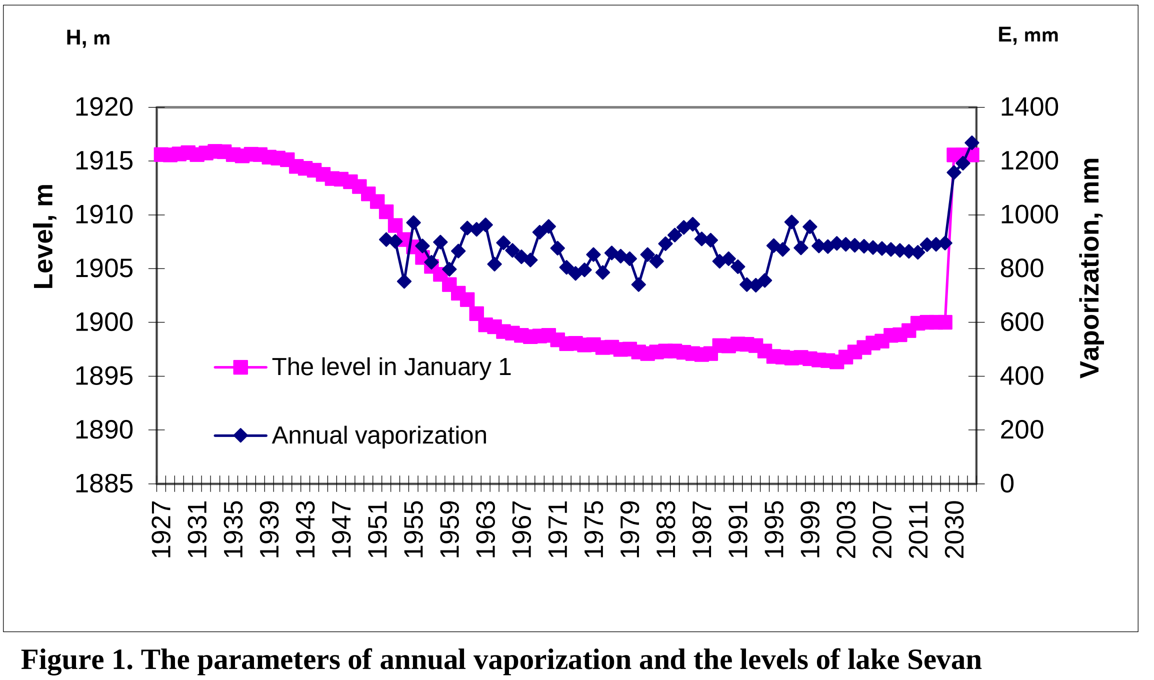

Figure 1. The parameters of annual vaporization and the levels of lake Sevan

Despite the certain annual fluctuations (740…970 mm) according to evaporation size and conditioned by weather and climatic factors its value has not been changed. It means that the thickness of annual layer of evaporation of lake Sevan is not significantly dependant on lake stage. However, in case of the change of mentioned size of lake stage (14 m) any relation between the value of evaporation of the lake and the stage has not been found. The average annual value of evaporation calculated for 1952-2001 observations comprises 865 mm.

Based on the average multi year evaporation value of 865 mm and taking into account that in case of 1896,32 m water level the surface of lake Sevan is equal to about 1240 km^2, the evaporation size will coprise 1240 mln m^2 x 0,865 m = 1073 mln m^3:

In Table 1 the annual sizes of evaporation for different levels of lake Sevan are shown in case of 865 mm evaporation value.

So, we came to the conclusion that the difference in case of the further (1903,5 m) and the previous natural (1915,57 m) indicators of evaporation from lake Sevan will totally comprise only 95 mln $m^{3.}$.

In the first case, accepting the miracle of evaporation indicator as 10%, the annual evaporation size in 1915,57 m indicator we will get 1348 mln m^3 or the difference in case of the further (1903,5 m) and the previous natural (1915,57 մ) indicators of evaporation from lake Sevan will totally comprise only 218 mln m^3 . This almost coinsides with the indicator of 1430 mln m^3 brought in [11 and 14] in case of the worst scenario of development.

Table 1

Annual sizes of evaporation calculated for different levels of lake Sevan

Lake level, m	**Surface , km^2**	**Vaporization , mln m^3**
1896,32	1240	1073
1900,20	1275	1103
1903,50	1306	1130
1915,57	1416	1225

The ways of rising the lake stage till 1915,57 m: is the rising of lake stage of the Sevan till 1915,57 m realistic and what will it give to the Republic of Armenia?

The answers to these two questons are affirmative:

- The solution of the problem is realistic,
- It will give the country additional political importance, will solve the social probolems of the population, will provide stable progress for the development of the economy.

Let us justify our words: according to the example in 2000 of [7] the sum of the components of water balance of inflow to lake Sevan is 1222,7 mln m^3 which has the following components.

- Rivers flowing into the lake comprise 740,5 mnl m^3,
- Precipitations on the lake surface comprise 388 mln m^3,
- Underground flow comprises 94,2 mln m^3.

The above mentiond indicators in case of temperature rise 2^0 and water level of 1915,57 m the river water amount will reduce to 702 mln m^3, and the precipitations on the lake to 352,7 mln m^3 [11]. As a result the sum of natural components in the content of inflow of water balance of lake Sevan, in case of the worst scenario and water level of 1915,57 m will be 1148,9 mln m^3 .

The sum of natural components in the runoff of water balance of the lake comprises 1555,3 mln m^3 in the example of 2000.

- According to [7], along the Hrazdan the maximum runoff is 170 mln m^3,
- Evaporation from lake surface is 1370,9 mln m^3,
- Underground flow is 14,4 mln m^3.

The above mentioned indicators in the worst scenario and water level of 1915,57 m will make the evaporation from lake sutface be 1430 mln m^3 [11] and the underground flow will be 98 mln m^3 [12, 13].

At the same time the runoff of lake Sevan which passes through the Hrazdan will come to its initial size which is 50 m^3. As a result, the sum of natural components in the content of runoff of water balance of the lake in the case of the worst scenario and in 1915,57 m indicator will comprise 1578 mln m^3.

The annual balance of lake Sevan in the worst scenario in the water level indicator of 1915,57 m will be -429,1 mnl m^3.

The rise of the indicator of Arpa – Sevan tunnel terminal will enable to transfer 554 mln m^3 water to lake Sevan through the tunnel.

The annual water balance for 1915,57 m and in case of the realization of the above mentioned activities and in the worst scenario will be affirmative as 125 mln m^3.

So, in the worst scenario it will be possible to rise the lake stage at least for 10 cm.

For the purpose of irrigation the water intake from lake Sevan will be compensated due to the exploitation of Yeghvard reservoir for 90 mln m^3, from Marmarik reservoir 23 mln m^3, in case of Vedi reservoir 20 mln m^3 also. The construction of other reservoirs should also be foreseen.

Conclusions.

In case of rising the water level of lake Sevan to 1915,57 m the solution of the following tasks will be possible:

1. The water quality of the lake will be restored being correspondent to drinking water demands. It should be taken into account that to solve the task set for construction of Yeghvard reservoir about 90 mln US $ will be spent, for Vedi reservoir 60 mln US $, for the new tunnel of 26 km length in Yeghegis - Sevan section about 400 mln US $ and for reconstruction of coastal infrastructures 500 mln US $ will be needed and the same amount of money for water transfer system, in the end we will have 1,5 billion US $ expences. Taking into account that in world market the drinkimg water (bottled) is 370 US $/$m^3$ and the trade discounts, it can be priced as the 29,6 US $/$m^3$. If we admit that as a raw material the water will be sold by 1,0% of its bottled price minimum, we will get 2,96 US $/$m^3$. The exchange price of drinking water of 125 mln m^3 annually will comprise 370 mlnUS $. If we consider that in near future we expect a sharp price rise of drinking water (by 15-50 times), then in rising the water level of lake Sevan to 1915,57 m such conditions will be created for the Republic of Armenia before the realization of the mentioned activities as the oil and gas for our neighbor countries.

2. As a result of inceasing the water pressure in the lake

a) in the lowlands with lower elevations the springs of drinking water will abruptly increase which will be used to solve the drinking water problem in Yerevan and other cities

b) water supplies will be more

c) seismic risk will not become more as lake Sevan has natural origin and the increase of about 1,5 atmospheric pressure will not endanger the situation.

3. Additional 20 bilion cubic meter water will be accumulated. To accumulate such amount of water for the construction of reservoirs about 70 billion US $ will be needed.

Suggestions

The presented program can be realized during at least 35 years. In case of the worst scenario this period can be prolonged for several times. But it is necessary to start the program in close terms as possible. As the first step it is suggested

1. To prevent the lake pollution, firstly the sewage waste water flow into the lake.

2. To forbid the engineering activities in eleveations below 1920 m.

3. To clean the lake bed from the sunk tree roots .

4. To start the development of alternative project of the area Yeghegis-Sevan of Arpa –Sevan tunnel with the purpose of the outcome indicator of the tunnel to rise to 1917 m.

5. To review the exploitation regime of Arpa - Sevan tunnel. To start certain activities immediately to transfer the water from Spandaryan reservoir to lake Sevan.

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ՍԵՎԱՆԱ ԼՃԻ ՀԻՄՆԱԽՆԴՐԻ ԼՈՒԾՄԱՆ ՌԱԶՄԱՎԱՐԱԿԱՆ ՈՒՂՂՈՒԹՅՈՒՆԸ

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Սևանը քաղցրահամ, բարձրադիր լիճ է: Լիճն արևմուտքում լծորդվում է Գեղամա, հարավ-արևմուտքում՝ Վարդենիսի, հյուսիս-արևելքում՝ Արեգունու, Սևանի և Արևելյան Սևանի լեռնաշղթաներին: Սևանը կազմված է Մեծ ու Փոքր Սևաններից, որոնք միմյանցից բաժանվում են Արտանիշի և Նորատուսի հրվանդաններով ու դրանք միացնող ստորջրյա թմբով: Նախքան լճի մակարդակի արհեստական իջեցումը նրա երկարությունը 75 կմ էր, միջին լայնությունը՝ 19 կմ (առավելագույնը՝ 32 կմ), միջին խորությունը՝ 41,3 մ, ամենախոր մասի՝ Փոքր Սևանի խորությունը՝ 98,7 մ: Այդ պայմաններում լճի ընդհանուր ծավալը կազմում էր 58,5 մլրդ $մ^3$, ջրի մակարդակի արհեստական իջեցումից հետո՝ նվազագույնը՝ շուրջ 33 մլրդ $մ^3$: Սևանա լիճ են թափվում 28 գետ՝ Ձկնագետը, Գավառագետը, Արգիճին, Վարդենիսը, և այլն: Սևանը սնվում է նաև ստորգետնյա աղբյուրներով ու մթնոլորտային տեղումներով: Սևանա լճից սկիզբ է առնում միայն Հրազդան գետը: Սևանը տարածաշրջանի խմելու ջրի միակ խոշոր բնական ջրամբարն է: Սակայն վերջին տասնամյակներում անթրոպոգեն ազդեցության հետևանքով խախտվել է լճի էկոհամակարգը՝ առաջացնելով ճահճացման պրոցեսներ, որոնք ամենամոտ ապագայում կարող են անշրջելի դառնալ: Սույն աշխատանքում, որպես հիմնախնդրի լուծում, առաջարկվում է Սևանա լճում ջրի մակարդակը բարձրացնել մինչև 1915,57 մ նիշը, բերվում է դրա իրականացման տեխնիկական հնարավորությունների հիմնավորումը:

Բանալի բառեր. ջուր, աղբյուր, գոլորշիացում, ջրի մակարդակ, ջրամբար, Արփա-Սևան թունել, էկոհամակարգ:

СТРАТЕГИЧЕСКОЕ НАПРАВЛЕНИЕ РЕШЕНИЯ ПРОБЛЕМЫ ОЗЕРА СЕВАН

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Севан высокогорное озеро с пресной водой. Озеро сопрягается с хребтом - Гегама (с западной стороны), Варденис (с юго-западной стороны), Арегани, Севан и Восточный Севан (с северо-восточной стороны). Озеро Севан состоит из Большого и Маленького Севана. До понижения уровня воды, длина озера Севан составила 75 км, средняя ширина – 19 км (максимальная ширина – 32 км), средняя глубина – 41,3 м (максимальная глубина – 98,7 м). Общий объем озера тогда составлял 58,5 млрд м3. После понижения уровня воды минимальный объем составил 33 млрд м3. В озеро Севан впадают 28 рек. Севан питается также подводными родниками и атмосферными осадками. С озера берет начало только одна река – Раздан. Севан является единственным большим хранилищем питьевой воды в регионе. Однако, в последние десятилетия вследствие антропогенных воздействий экосистема озера нарушена, начался процесс заблочивания, который в ближайшее время может стать необратимым. В настоящей работе как решение проблемы предлагается поднять уровень воды озера до отметки 1915,57 м. Приводится техническое обоснование реализации этого проекта.

Ключевые слова: вода, родник, испарение, уровень воды, водохранилище, тоннель Арпа-Севан, экосистема.

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