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DETERMINATION OF THE AMOUNT OF SEDIMENTS IN AZAT RESERVOIR BY HYDRAULOGICAL METHODS

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Abstract

The project space of the reservoirs constantly decreases due to the amount of sediments accumulated in it during operation. Those changes were estimated by the studies carried out in Azat Reservoir. The hydrometric measurement data of Azat and the neighboring Vedi Rivers were collected and as a result of their processing, the average outflow of the sediments entering the reservoir, and then the amount of their accumulation were determined using three hydrological methods. According to calculations, during the 45 years of operation, the total project space of the reservoir (70 million m^3) has decreased by about 2.8 million m^3. A forecast was made regarding the possible growth of sediments in the following decades. According to calculations, by 2050 the accumulating ground can occupy no more than 7% of the space of the reservoir which will not significantly interfere with its effective operation.

Key words: reservoir, useful capacity, suspended and bottom sediments, hydrometric observation point, sedimentation regime.

Introduction

The mudstone particles coming down the river are continuously filling and accumulating in the reservoirs. This leads to a permanent decrease in the regulation (useful) space of the reservoir [1, 2].

Fig. 1 Denata reservoir in Eritrea completely filled up with sediments (North-Eastern Africa) Photo by Adriano de Vito (Google Maps)

Many reservoirs, being built on rivers with a high flow regime, have been filled with sediments during several decades of operation. Due to this, the structure either goes

completely out of operation or loses most of the possibility of regulating the river flow (Fig. 1, 2).

It is very important to carry out periodic studies to determine the value of the change of reservoir space [3]. In many countries such works have rarely been carried out, as a result of which the parameters set at the design stage are taken as a basis when drawing up reservoir operation schedules. It is clear that such an approach leads to an incorrect assessment (overestimation) of the actual amount of water in the reservoir and the resulting negative consequences. About 7 dozen small and large reservoirs are operated in the Republic of Armenia the vast majority of which have been operated for more than half a century. However, of all those hydrotechnical structures only the condition of the Aparan and Azat reservoir rims have so far been studied in 2020-2021.

Fig. 2 Sediment accumulation of about 20 m in Sarsang reservoir in front of Drmbon Photo by the author

As the studies conducted in the reservoirs of the Republic of Artsakh (Sarsang, Khachen, Varanda, Mataghis) have shown, the useful capacity of the first three reservoirs decreased by 5-20% due to the accumulation of sediments during about 40 years of operation and in the case of Mataghis, the decrease was more than 60% [4, 5]. The amount of sediments accumulated in the reservoir and, consequently, the decrease in the space of regulation is caused by the water supply regime of the river feeding the reservoir [6]. From that point of view, the studies carried out for the assessment of the water supply regime of Kasakh River which feeds Aparan reservoir, enabled us to clarify the space W-H characteristics of Aparan reservoir [7]. The results of studies carried out for Azat reservoir are presented here.

The aim of the work is to determine the amount of sediments accumulated in Azat reservoir using hydrological methods, to evaluate the changes in the space of the reservoir during operation and to predict their further developments.

Azat Reservoir is located in the middle flows of the same river in Ararat Region, RA. The reservoir was operated in 1976. The total space of the reservoir is 70 million m^3, useful capacity of which is 61 million m^3. The impound water surface of the reservoir is 28.5 ha. The dam of the reservoir is made of earth and the main feeding source is Azat River. There is partial feeding from underground springs on the bottom and banks of the reservoir.

Conflict setting

The amount of ground accumulated in Azat reservoir was formed by the suspended and bed sediments that flowed down the river during 45 years of operation. Therefore, in order to obtain a reliable solution to the problem, it is necessary to correctly assess the river's sediment regime. Compared to the liquid debit, measurements of the sediment debit in the most part of the rivers of the republic were either not made or they are very incomplete. Taking into account that circumstance, three parallel methods of hydrological calculation were used in order to increase the reliability of the assessment of sediment regime of Azat River. They are:

1. The average annual values of the debits of Azat River sediments were determined by the measured values of liquid debit.
2. These values were determined by the method of similarity of rivers in the area, using the data of sediment debit of the nearby Vedi River,
3. Sediment flow was calculated using regional map data estimating the average turbidity of rivers.

Research results

In order to adequately assess the sediment regime of Azat River it is necessary to determine the multi-year distribution of the debit of debris coming down the stream. For this purpose, the average annual values of liquid debits of Azat River and the nearby Vedi River were obtained from the Hydrometeorological Service. They were obtained from the processing of measurement data made at “Garni” and “Urtsadzor” hydrometric observation points of those rivers. Using the methods of comparison of catchment basins and similarity of basins of the same area, the debits of the observation points were recalculated corresponding them to the river section of Azat Reservoir.

The following relation between debits of suspended sediments ($\boldsymbol{Q_S}$) and liquid debits (Q) is suggested for the Transcaucasian rivers [8]

$$Q_S = 0{,}72\, Q^{0{,}95} \tag{1}$$

The average annual values of suspended debits of sediments of Azat and Vedi Rivers were calculated by this formula given to Azat Reservoir (Table 1 and 2).

Research on the sediment regime of the reservoir has shown that suspended particles larger than 0.05 mm in size are mainly accumulated in the reservoir [9]. According to natural measurements, the amount of placed particles is around 40-50% of the total amount of suspended sediments. Small sizes leave the reservoir during conduit. In addition to them, the sediments coming through the bottom layers of the flow are placed in the reservoir. Their amount is considered to be about 46% of the total amount of suspended particles for regional rivers. It turns out that the sediment debits accumulating in the reservoir can be taken with an insignificant error as equal to the total debits of suspended particles flowing down the river (the amounts of small particles leaving the reservoir and bottom sediments are a little different from each other). Taking into account the justifications given, the total debits of sediments accumulated in Azat reservoir according to the data of Azat River (Fig. 1) can be accepted as 4.4 kg/s, and according to the data of Vedi River (Fig. 2) 1.7 kg/s.

During operation, the amount of sediments accumulated in the reservoir will be

$$W = \frac{Q_S\, T}{\rho_S}, \tag{2}$$

Where Q_S is the total output of accumulated sediments (kg/s), T is the period of operation of the reservoir (s), ρ_S is the density of accumulated sediments (average 1800 kg/m3).

Taking into account that Azat Reservoir has been in operation since 1976 (45 years), then according to the first method (according to Azat River's water sedimentation of 4.4 kg/s) the amount of accumulations will be $W = 3{,}5$ mln. m^3.

According to the second method (similarity of river basins with the neighboring Vedi river), in the case of a hard conduit value of 1.7 kg/s, the amount of accumulations will be 1.35 mln. m^3.

Table 1

***Q and Q_S* debits of Azat reservoir (catchment basin 526 km²) according to data of «Garni» observation centre on Azat River (catchment basin 326 km²)**

Year	Q m^3/s	Q_S kg/s	Year	Q m^3/s	Q_S kg/s	Year	Q m^3/s	Q_S kg/s
1964	8.59	5.56	1981	6.00	3.95	2003	10.85	6.94
1965	6.47	4.24	1982	6.41	4.21	2004	4.91	3.27
1966	8.68	5.61	1983	5.40	3.57	2005	9.23	5.94
1967	9.99	6.41	1984	7.45	4.85	2006	7.51	4.89
1968	10.10	6.47	1985	6.18	4.06	2007	8.88	5.73
1969	9.79	6.29	1986	5.56	3.67	2008	6.78	4.44
1970	8.17	5.30	1987	6.89	4.50	2009	7.98	5.18
1971	5.39	3.57	1988	8.30	5.38	2010	8.85	5.71
1972	6.75	4.42	1989	5.71	3.77	2011	11.48	7.32
1973	5.53	3.65	1990	5.17	3.43	2012	5.84	3.85
1974	5.08	3.37	1991	4.10	2.75	2013	5.96	3.92
1975	5.60	3.70	1992	6.54	4.29	2014	4.64	3.09
1976	8.55	5.53	1993	6.71	4.40	2015	7.30	4.76
1977	4.46	2.98	1994	5.02	3.34	2016	5.80	3.83
1978	6.91	4.51	2000	3.76	2.53	2017	4.61	3.07
1979	5.13	3.41	2001	4.16	2.79	2018	2.62	1.80
1980	5.27	3.49	2002	6.31	4.14			
Multi year average liquid debit 6.67 m^3/s, Sediment debit 4,36 kg/s								

The average turbidity regional map was used to determine the amount of accumulated sediments by the 3rd method when the average turbidity of Azat River basin is indicated as 0.4 kg/m^3. According to Table 2, the total liquid debit of Azat River is 9.47 billion. m^3 during 45 years. Therefore, the value of the flow of suspended sediments will be: $W = 2{,}1$ mln. m^3.

Table 2

***Q and Q_S* debits of Azat reservoir (catchment basin 526 km²) according to data of «Urtsadzor» observation centre on Vedi River (catchment basin 348 km²)**

Year	Q m³/s	Q_S kg/s	Year	Q m³/s	Q_S kg/s	Year	Q m³/s	Q_S kg/s
1969	4.28	2.87	1984	2.79	1.91	2006	0.62	0.46
1970	2.16	1.49	1985	3.12	2.12	2007	2.65	1.81
1971	2.07	1.43	1986	1.99	1.39	2008	1.57	1.10
1972	3.22	2.19	1987	3.60	2.43	2009	1.61	1.13
1973	2.23	1.54	1988	4.75	3.17	2010	3.69	2.49
1974	2.05	1.43	1989	1.19	0.85	2011	4.18	2.80
1975	2.09	1.45	1990	2.09	1.45	2012	3.36	2.28
1976	3.45	2.33	1991	1.87	1.31	2013	2.81	1.92
1977	1.92	1.34	1992	2.19	1.52	2014	1.31	0.93
1978	4.12	2.76	1993	3.61	2.44	2015	2.38	1.64
1979	2.08	1.44	1994	2.68	1.84	2016	4.12	2.76
1980	2.53	1.74	2002	0.97	0.70	2017	2.17	1.50
1981	2.38	1.64	2003	1.10	0.79	2018	2.65	1.82
1982	2.86	1.95	2004	0.54	0.40			
1983	1.91	1.33	2005	0.61	0.45			
Multi year average liquid debit 2.46 m³/s, Sediment debit 1.68 kg/s								

Thus, with 3 calculation methods, very different values were obtained for the total amount of sediments accumulated in Azat reservoir (3.5 million m^3, 1.35 million m^3 and 2.1 million m^3). The reliability of these values was assessed by the values of the debits used to receive them. In the case of Azat River, the values obtained for the average discharges of liquid and sediment debits are: 6.67 m³/s and 4.36 kg/s. In the case of the second method (river density), the following values are obtained: liquid debit- 2.46 m³/s, sediment debit -1.68 kg/s.

It is clearly seen that the values obtained for the Azat reservoir based on the data of Vedi River, which is accepted as an analog river, do not reflect the reality at all. Being neighboring river basins, the feeding conditions of the catchment basins of Azat and Vedi rivers are most likely very different from each other. Taking into account the above mentioned, 1.35 million of the 3 values of the amount of accumulations in the Azat reservoir determined by the method of similarity of river basins. The value of m^3 is not considered as unreliable. The average of the values determined by the first and third methods is 2.8 mln. m^3 volume. Thus, during 45 years, the decrease in the space of the Azat reservoir is 4%. In order to verify the calculated values of the amount of accumulations, it is necessary to make actual measurements of that volume in the reservoir and evaluate the reliability of the calculation methods.

It is also very important to assess the possible risks arising during the further operation of the Azat reservoir, to predict the possible reduction of the space during the further

operation of the reservoir and to find out their effect on the efficiency of the structures. If there are no significant changes in the liquid and water debits of Azat River in three decades, according to calculations, the decrease in the space of the reservoir will not exceed 7-8% in 2050. It can be stated that the upcoming changes occurring in the reservoir due to the accumulations will not significantly reduce the possibility of regulating the river flow by the structure.

Based on the results of the study, the design schedule of the space W-H characteristics of the Azat reservoir was adjusted (Fig. 3). The graphic views of design characteristic, current state and that in 2050 are shown in the figure below.

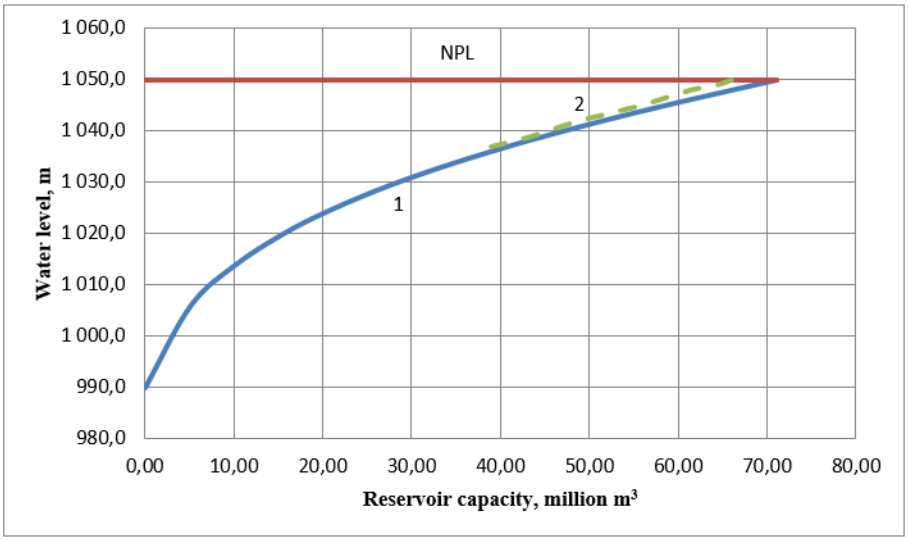

Fig. 3 Graph of the volumetric W-H characteristics of the Azat reservoir

1- estimated state, 2- current state

The hydrological series of Azat River were also analyzed to find out the impact of climate change and the human factor on the river flow. The hydrometric series of Azat River begin in 1936. It was divided into 4 periods: 1936-1965, 1966-1980, 1981-2001 and 2002-2018. The average debits of sediments during these periods is respectively: 5.8 kg/s; 4.8 kg/s; 3.8 kg/s and 4.3 kg/s.

Determining the amount of accumulations in this work, a part of the measurements performed in the period 1964-2018 was used as more characteristic data. 4 debits values show that the flow rate of Azat River in terms of liquid and sediment debits decreases by 1.12 times in the stated periods. It should be noted that according to studies conducted on the rivers of neighboring countries, the decrease in flow there was 10-20%. Average debits of Azat River for 1981-2001 are small compared to the rest. This is probably due to the cyclical nature expressed in watercourses by periods of high and low water.

Conclusion

The hydrological studies carried out for Azat reservoir show that during 45 years of operation, the accumulation of sediments has led to a decrease of about 4% in the space of the reservoir. It is predicted that in the coming decades, the design parameters of the rim of the reservoir will undergo insignificant changes which will make it possible to realize sufficient regulation of river flows. Corrections made for the space characteristics of the reservoir rim can be used when reassessing the volumes of the conduit during the operation of the structure.

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ԱԶԱՏԻ ՋՐԱՄԲԱՐՈՒՄ ԿՈՒՏԱԿՎԱԾ ՋՐԱԲԵՐՈՒԿՆԵՐԻ ՔԱՆԱԿԻ ՈՐՈՇՈՒՄԸ ՀԻԴՐՈԼՈԳԻԱԿԱՆ ՄԵԹՈԴՆԵՐՈՎ

Բալայան Ա.Վ.
Շուշիի տեխնոլոգիական համալսարան

Շահագործման ընթացքում ջրամբարների նախագծային ծավալը մշտապես նվազում է նրանում կուտակվող ջրաբերուկային զանգվածի պատճառով: Այդ փոփոխությունները գնահատվել են Ազատի ջրամբարում կատարված ուսումնասիրություններով: Հավաքագրվել են Ազատ և նրան հարևան Վեդի գետերի հիդրոմետրական չափման տվյալները, որոնց մշակման արդյունքում հիդրոլոգիական երեք մեթոդով որոշվել է ջրամբար մտնող ջրաբերուկային բազմատարյան միջին ելքը, այնուհետև կուտակման ծավալը: Համաձայն հաշվարկների շահագործման 45 տարվա ընթացքում ջրամբարի նախագծային ընդհանուր ծավալը (70 մլն. մ^3) նվազել է շուրջ 2,8 մլն. մ^3 չափով: Կատարվել է կանխատեսում հետագա տասնամյակներում կուտակումների հնարավոր աճի վերաբերյալ: Համաձայն հաշվարկների մինչև 2050 թ. կուտակվող գրունտը կարող է զբաղեցնել ջրամբարի ծավալի ոչ ավել քան 7%-ով, ինչը էապես չի խանգարելու ջրամբարի արդյունավետ շահագործմանը:

Բանալի բառեր. ջրամբար, օգտակար ծավալ, կախյալ և հատակային ջրաբերուկներ, հիդրոմետրական դիտակետ, ջրաբերուկային ռեժիմ:

ОПРЕДЕЛЕНИЕ КОЛИЧЕСТВА СКОПИВШИХСЯ В АЗАТСКОМ ВОДОХРАНИЛИЩЕ НАНОСОВ ГИДРОЛОГИЧЕСКИМИ МЕТОДАМИ

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В процессе эксплуатации расчетный объем водохранилищ постоянно уменьшается из-за количества скапливающихся в нем наносов. Эти изменения были оценены в ходе исследований, проведенных в Азатском водохранилище. Были собраны данные гидрометрических измерений рек Азат и Веди, в результате обработки которых, тремя методами гидрологических исследований был определен среднемноголетний объем наносов, входящих в водохранилище, а затем и объем накопления. Согласно расчетам, за 45 лет эксплуатации общий расчетный объем водохранилища (70 млн м^3) уменьшился примерно на 2,8 млн м^3. Был сделан прогноз относительно возможного увеличения отложений в последующие десятилетия. Согласно расчетам, до 2050 года накапливающийся грунт может занять не более 7% объема водохранилища, что почти не помешает эффективной эксплуатации водохранилища.

Ключевые слова: водохранилище, полезный объем, взвешенные и влекомые (донные) наносы, гидрометрический пункт наблюдения, режим наносов.

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