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About Changes in The Amount of The Lower Amudarya Flow Under the Influence of Anthropogenic Factors

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Abstract. The article examines the issues of changes in the amount of water flowing from the Amu Darya to its lower part under the influence of large hydraulic structures built on the river. For this purpose, multi-year fluctuations of the river flow were analyzed based on the data of the Tuyamuyun hydrological station. Analyzes were performed for three accounting periods. It is shown that in the first accounting period (1930-1955), the amount of water flowing into the Lower Amudarya was stable, and in the second (1956-1990) and third (1991-1920) accounting periods, it gradually decreased.

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Key words: river, water regime, discharge, anthropogenic factor, hydraulic facilities, flow volume, change, assessment**.**

1. Introduction

World experience shows that since the second half of the last 20 th century, the possibilities of using water resources in countries located in different parts of almost all transboundary rivers have been sharply different. More precisely, compared to the countries upstream of the rivers, the access to water of the downstream ones remains much weaker. The main reason for this is that all kinds of water management activities have been carried out in the upper reaches of the rivers, including the construction of reservoirs, hydroelectric power plants, and large irrigation canals. As a result, water resource shortages and deterioration of their quality in the countries located downstream of the rivers are increasing year by year. This situation, in turn, is manifested in various interstate social, economic and even political events, more precisely, conflicts.

It is known that from the second half of the last 20 th century, the area of newly irrigated lands in the transboundary Amudarya basin began to expand rapidly. For this purpose, the construction of large hydrotechnical facilities – water reservoirs, hydroelectric power plants and irrigation canals - for one-way irrigation and hydropower in the upper, middle and lower reaches of the river basin has started. As a result, these hydrotechnical, hydropower, and water management facilities began to have a stronger negative impact on the downstream hydrological regime of Amudarya every year.

As a result, the flow of the Amudarya has decreased sharply along the length of the river and over the years. Of course, this situation led to serious negative changes in the quality of river water. Unfortunately, this process is still going on with intensity today. In particular, the completion of the construction of the first stage of the Kushtepa canal, which receives 15% of water from the Amudarya to Afghanistan, and the fact that the second stage is now 60% completed, accelerated this process.

In order to mitigate the impact of such negative consequences, it is of great scientific and practical importance to accurately assess the quantitative changes of the Amudarya flow, especially this process for the last few decades. Studying this problem on the example of the lower reaches of the Amudarya, where the ecological situation has worsened, is considered one of the most urgent issues today.

Initial studies dedicated to the study of the Amu Darya hydrological regime, its general theoretical and methodological issues were done by following scientists: A.K.Proskuryakov (Proskuryakov, 1953), G.V.Lopatin (Lopatin, 1957), G.V.Lopatin (Lopatin, 1957), M.Rogov (1968), M.Rogov, V. L.Shultz and L.I.Shalatova (Shultz, Shalatova, 1975). Later, in the last quarter of the last century, the water regime of Amudarya under the influence of strong anthropogenic factors was studied by A.A.Rafikov (Rafikov, 1981), I.A.Shiklomanov (Shiklomanov, 1989), V.E.Shiklomanov (Shiklomanov, 1989), V.E.Chub (2000), F.Chub (2000), Rubinova (Rubinova, 2005), E.I.Chembarisov (Chembarisov, 2016), E.Kurbanbaev (Kurbanbaev, 2011) and others. Currently, research in this direction is being continued by P.O.Zavyalov (Zavyalov, 2012), F.Khikmatov (Khikmatov, 2008, 2020), V.A.Rafikov (Rafikov, 2009), Kurbaniazov (Kurbaniazov, 2017), E.Adenbaev (Adenbaev, 2020, 2021), R.T.Khozhamuratova (Khozhamuratova, 2020) and others. It should be noted separately that the dynamics of the amount of flow reaching the Lower Amudarya was not studied as a separate research object in the researches of the above-mentioned scientists.

2. Main Goal

The main goal of this study is to evaluate the quantitative changes in the flow of river flowing into the Lower Amudarya region under the influence of anthropogenic factors. In order to achieve this goal, the following tasks were defined in the research work: 1) collecting data on the observed water regime during the years 1930-2020 at the Tuyamuyun hydrological station located in the beginning of the Lower Amudarya; 2) primary processing, summarization of the collected data and their division into accounting periods, taking into account the level of anthropogenic factors; 3) quantitative assessment of changes in the river flow under the influence of anthropogenic factors in separate accounting periods.

The Lower part of Amu Darya was selected as a research object**.** The subject of the research is the assessment of the quantitative changes of the river flow under the influence of anthropogenic factors in the research object, the analysis of the results, and the drawing of relevant conclusions from them.

In the course of the work, the monthly and average annual discharge observed in 1930-2020 at the Tuyamuyun hydrological station located in the lower reaches of the Amudarya under the disposition of Uzhydromet were used as primary data.

In the process of research, geographical generalization, hydrological similarity, modern hydrological calculations, probability theory and mathematical statistics methods, as well as hydrological comparison method were used in the analysis of the achieved results.

3. Main Results and their Discussion.

The research began with the summarization of discharge data observed during the years 1930-2020 at the Tuyamuyun hydrological station located in the lower reaches of the Amudarya. In this regard, the calculations and their results were analyzed. Based on them, the following accounting periods were allocated.

In particular, the period 1930-1955 in the Tuyamuyun hydrological station was considered as the first calculation period with a natural hydrological regime. Because, during this period, between Kerki and Tuyamuyun hydrological stations of the Amudarya, the amount of water taken from the river for irrigation was constant and did not exceed 10 percent of the annual flow of the river (Proskuryakov, 1953).

It is known that since 1956 water has been taken from the Amudarya to the Karakum canal. Considering this situation, 1956 was accepted as the beginning of the II accounting period. In the middle of this II accounting period, more precisely, from the 1970 s, water was taken from the Amudarya to the Karshi main canal (KMK) and the Amu-Bukhara canal (ABK) and other large irrigation canals (Adenbaev, Umarov, 2013). The year 1990 was taken as the end of this II accounting period.

After the Republic of Uzbekistan gained independence in 1991, there were serious changes in the water management system of our country. Taking these circumstances into account, the 1991-2020 period was accepted as the III accounting period.

Based on the purpose of the work, annual fluctuation graphs [Qy=f(T)] of average annual discharge for each accounting period were drawn and analyzed based on the collected hydrological data (Figure 1).

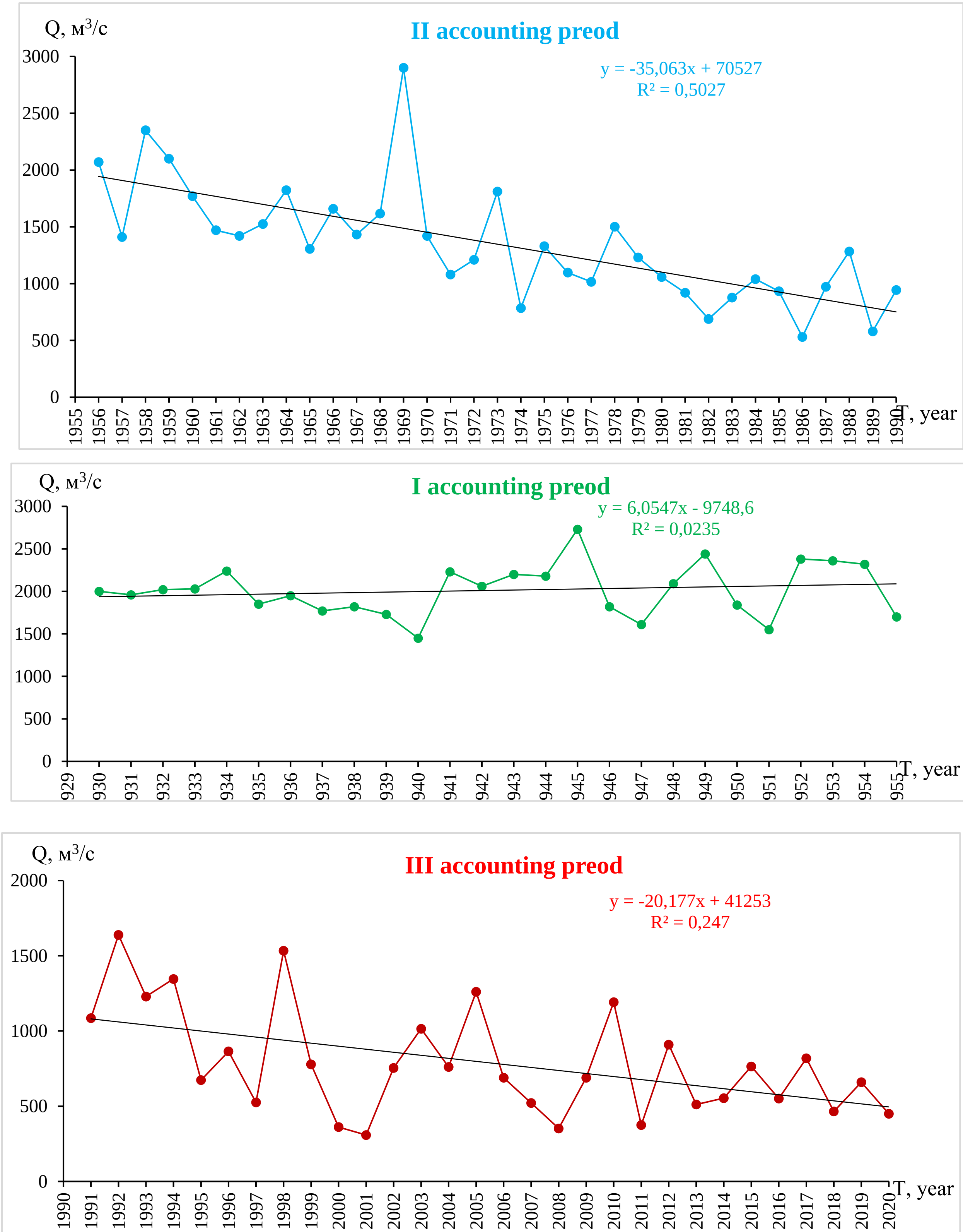

Figure 1. Amudarya average annual discharge in different accounting periods interannual fluctuation graphs (Tuyamuyun HS)

The analysis of the graph drawn for the accounting **period I** shows that the average long-term discharge in the period from 1930 to 1955 was equal to 2013 m^3/s. This amount is close to the average annual discharge in 1932. During these years, the largest average annual discharge in the river was observed in 1945, and its value was equal to 2730 m^3/s. The smallest average annual discharge was observed in 1940, and its amount was 1450 m^3/s (fig. 1).

As it was mentioned above, during the II accounting period, that is, between 1956 and 1990, along the length of Amudarya, a number of large hydrotechnical and hydropower facilities were built and water was supplied to large irrigation canals. In particular, the Norak Reservoir (1972) in the upper reaches of the Amudarya River, the Karshi Highway (1965-1973) and the Amu-Bukhoro (1965-1976) canals in its middle reaches were commissioned. In the lower reaches of the river, the Tuyamuyun reservoir was built and put into operation (1978-1983). These large hydrotechnical structures have had a negative effect on the change of the Amudarya flow along its length, or rather, its decrease. As a result, compared to the first accounting period, the average multi-year discharge in the second accounting period decreased by 1,5 times and amounted to 1347 m^3/s.

At the next stage of the work, that is, in the period of the third account, when the former Union disintegrated and our country gained independence, special attention was paid to the assessment of the quantitative changes of the Amudarya flow. In the last years of this accounting period, the influence of anthropogenic factors on the Amudarya flow was more strongly felt. At the same time, as a result of climate change on a global scale, the Amudarya basin, especially in its lower reaches, has frequently had low-water years. In addition, the situation was further complicated by the inconsistency of the operating mode of large reservoirs such as Nurek and Tuyamuyun, as well as the full operation of the Karakum, Karshi highway and Amu-Bukhara machine canals. It is clear that the beginning of the withdrawal of large amounts of water from the Amudarya to Afghanistan will exacerbate the water shortage in the area we are studying in the coming years.

Based on the tasks established in the research, analyze the values of the characteristic discharge and corresponding flow volumes determined for the above three accounting periods (Table 1).

Table 1. Quantitative changes of the Amu Darya flow in different accounting periods (Tuyamuyun HS)

Calculation cycles	Characteristic miqdors					
	dry spenders, $м^3/с$			flow volumes, $км^3$		
	$\bar{Q}$	Q_{max}	Q_{min}	$\bar{W}$	W_{max}	W_{min}
I. 1930-1955 yy.	2013	2730 / 1945	1450 / 1940	63,5	86,1	45,7
II. 1956-1990 yy.	1347	2900 / 1969	531 / 1986	42,48	91,5	16,7
III. 1991-2020 yy.	788	1639 / 1992	308 / 2001	24,8	51,7	9,7

Note: $\bar{Q}$, $\bar{W}$, *– average discharge and flow volume*; Q_{max}, W_{max} *– maximum discharge and maximum flow volumes;* Q_{min}, W_{min} *– minimum discharge and minimum flow volumes*

As it can be seen from the data of this table, the amount of average multi-year discharge in the II accounting period has decreased compared to the I accounting period. In particular, the average long-term discharge in the I accounting period was 2013 m^3/s, in the II accounting period 1347 m^3/s, and in the last 30 years, that is, in the III accounting period, it was 788 m^3/s. Correspondingly, the average multi-year values of flow volumes have also decreased.

It should be noted separately that the extreme (maximum and minimum) discharge of the Amudarya flow has also decreased as a result of the exploitation of large hydrotechnical structures built for irrigation and hydropower purposes along the length of the Amudarya. These comments are valid, except for 1969, during the II reckoning period. On the basis of the table data presented above, using the multi-year average, maximum and minimum values of the flow volume, diagrams of the change of the flow amounts for the separate accounting periods were drawn (Fig. 2).

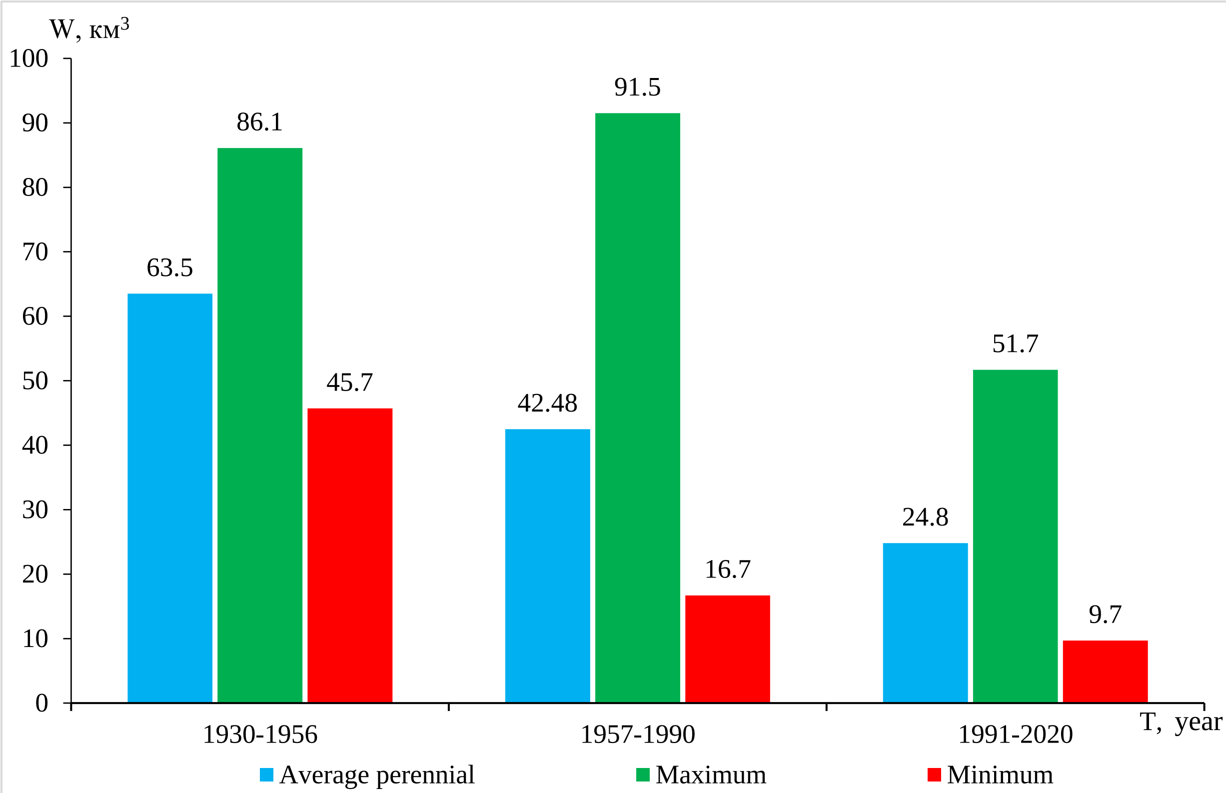

Figure 2. According to calculation periods of characteristic flow volumes quantitative changes

As can be seen from the graph, the average value of the multi-year flow volume calculated for the total calculation period in the first calculation period is 63,5 km^3, in the second calculation period it has decreased by 1,5 times compared to the first calculation period, to 42,48 km^3, and in the third calculation period it has decreased by 1,5 times compared to the first calculation period. it decreased by 1,71 times and was 24,8 km^3.

The largest annual values of the maximum flow volumes determined for the specified calculation periods corresponded to 1969 of the II calculation period, and the flow volume in this year was equal to 91,5 km^3. The main reason for this can be explained by the fact that 1969 was very wet compared to other years of observations. It is followed by the year 1945 (W=86,1 km^3) of the I accounting period. The smallest value of the maximum flow volume corresponds to the III calculation period, this value is equal to 51,7 km^3 and it corresponds to 1992.

The largest minimum values of the flow volumes were in the I calculation period, in the low-water year 1951, by 45,7 km^3, in the II calculation period - in 1986, by 16,7 km^3, and in the III calculation period, this value was 9,7 km^3 in the low-water year 2001 organized. It should be noted that the minimum annual flow of Amudarya in the II and III calculation periods is due to the influence of anthropogenic factors, and secondly, the above-mentioned years are characterized by low water.

Studying the changes in the amount of water flowing into the Lower Amudarya in separate five-year accounting periods is also of great scientific and practical importance. Taking into account these situations, the changes in the flow rates for separate five years were analyzed in accordance with the accounting periods mentioned above (Fig. 3).

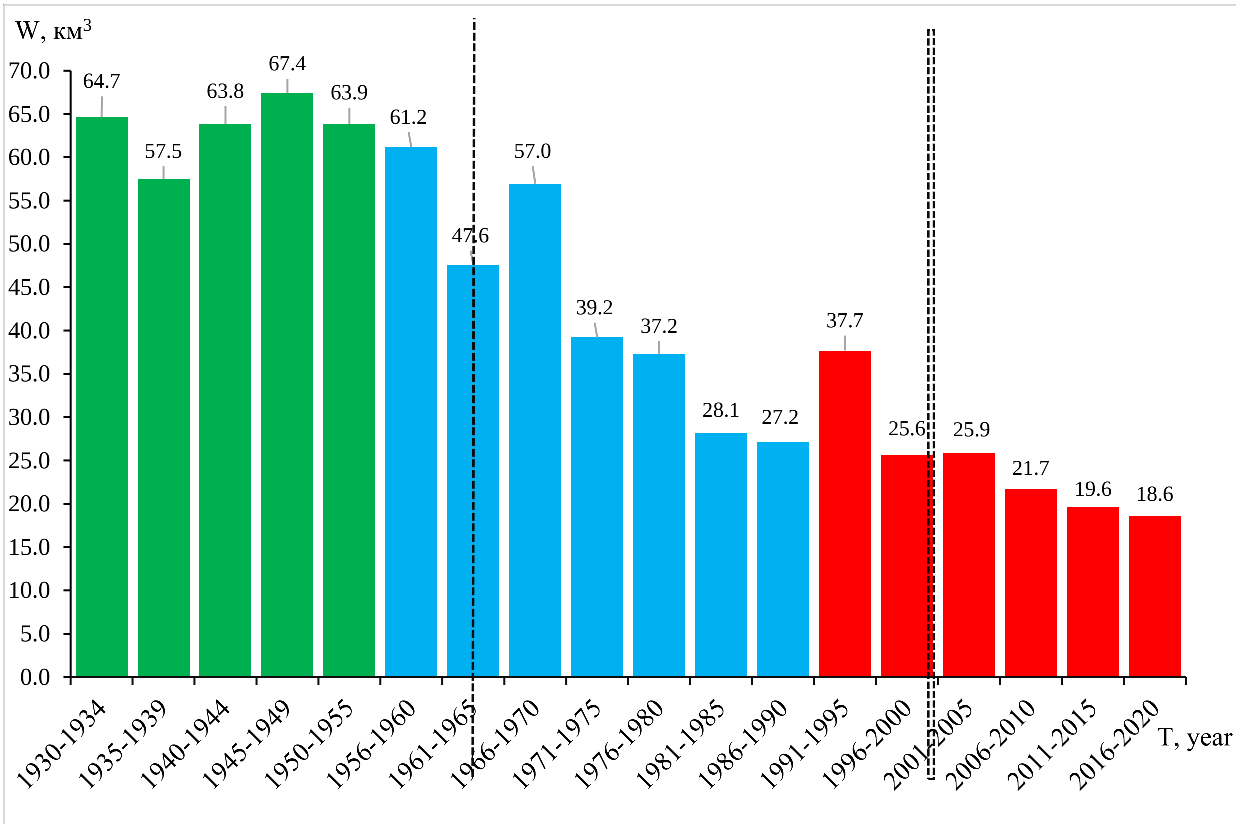

Figure 3. Changes in the flow of the Amu Darya for 5 years in different t accounting periods

According to the results of the analysis, the smallest value of the average multi-year flow amount was observed in the period of 1935-1939 and was 57,5 km^3, and the largest value was 67,4 km^3 in 1945-1949 . The maximum value of the average annual flow amount according to the calculations made for five-year intervals in the next, i.e. II accounting period, is equal to 61,2 km^3, and this amount corresponds to the years 1956-1960. The smallest value was observed in 1986-1990 and was 27,2 km^3. In the last, i.e. III calculation period, in the five-year period of 1991-1995, the tendency of the Amudarya flow to increase was observed. The main reason for this can be explained by the influence of the year 1992, which is characterized by a lot of water compared to other years. During this period, the average annual flow volume was 37,7 km^3. The smallest value of the river flow was equal to 18,6 km^3 and corresponded to the period of 2016-2020.

Summarizing the results of the research, the following can be noted as a conclusion:

1. Data on discharge observed at the Tuyamuyun hydrological station of the Lower Amudarya were collected and summarized, primary processed, and a database was created. Based on the results of the analysis, the total observation years were divided into three accounting periods: I accounting period (1930-1956), II accounting period (1957-1990), III accounting period (1990-2020);

2. Average multi-year and extreme discharges and flow volumes based on them were determined for each calculation period. According to the results of the calculations, the amount of Amudarya flow in the II calculation period (W=42,48 km^3) compared to the I calculation period (W=63,5 km^3) is 21,02 km^3 or 44%, the flow amount in the next III calculation period is W=24,8 km^3 It is equal to, which is 38,7 km^3 (61%) less compared to the first accounting period;

3. Changes in the amount of water flowing into the Lower Amudarya in separate five-year periods were studied. In the 1st accounting period, the smallest value of the five-year average flow volume was equal to W=57,5 km^3, corresponding to the period 1935-1939, and the largest value (W=67,4 km^3) to the years 1945-1949. A sharp decrease in the amount of flow in terms of five years was observed in the II and III accounting periods;

4. It should be noted separately that the reduction of the Amudarya flow over five years continued in the III accounting period in more intensive pictures. As a result of this reduction, only W=18,6 km^3 of water flowed into the Lower Amudarya in the last five years (2016-2020). It can be seen that this number is 3,5 times less than the average long-term amount (W=67,4 km^3) in the I accounting period;

5. As a general conclusion, we believe that the results of the research should be taken into account when drawing up perspective plans for socio-economic development of the Republic of Karakalpakstan, Khorezm and Tashkhovuz regions of the Republic of Turkmenistan located on the Lower Amudarya.

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