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Modern changes in climatic characteristics and minimum flow of the rivers in the basin of lake Sevan

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ABSTRACT

Formulation of the problem. Studies and data on modern changes in the winter minimum average monthly flow of the rivers of the Lake Sevan basin and their climatic characteristics have acquired great practical importance and considerable interest due to the increased use of water resources for the purposes of various types of economic activities, in particular, in connection with the development of the economy, hydropower, irrigation, population growth and rising living standards. Especially relevant are the calculations of the minimum flow in relation to solving the problems of water supply for settlements, industrial enterprises.

The aim of the work. Assessment of modern changes in the winter minimum average monthly runoff of rivers in the Lake Sevan basin and their climatic characteristics.

Methods. The following methods were used in the work: mathematical-statistical, extrapolation, interpolation, spatial analysis, analogy, correlation and cartography.

Results. A physical map has been compiled with a network of meteorological stations and hydrological posts in the Lake Sevan basin. Close correlations were obtained between the values of the winter minimum average monthly runoff and the average runoff of the winter period for a hydrological year. These dependences can be used for preliminary estimates of the minimum runoff of the winter low-water period of unstudied rivers in the territory under consideration. In the course of the research, the winter minimum average monthly discharges were calculated by months and for the entire observation period, the average value of the minimum runoff for the winter low water, and the linear trend of the climatic characteristic. Based on the obtained results, a map of the distribution of the modul of the average minimum runoff of the winter low-water period and the coefficients of the linear trend of the winter air temperature were constructed. Examples of curves of long-term changes in precipitation amounts for the autumn and winter periods, the sum of positive temperatures and the number of days with a positive average daily air temperature in the winter period for a series of meteorological stations in the study area are presented.

The rivers of the Lake Sevan basin are characterized by an uneven spatio-temporal distribution of winter minimum runoff and climatic characteristics, changes in the winter average monthly minimum runoff, precipitation amounts for the autumn and winter periods are multidirectional, and air temperature changes are only an upward trend. In the area under consideration, there is mainly (by 8 out of 12 stations under study) a tendency to decrease in the values of the minimum average monthly river flow. The conducted studies lead us to the conclusion that the main factor causing changes in the low-water runoff of the rivers in the Lake Sevan basin in winter is the air temperature, or rather, its increase. It follows from this that when calculating and forecasting winter runoff, it is necessary to relate the values of runoff and air temperature.

Keywords: *rivers of the Lake Sevan basin, low water, winter minimum average monthly runoff, air temperature, precipitation, Long-term changes, water regime changes, Coefficients of the linear trend.*

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Problem description. The problem of assessing current and expected changes in the water regime becomes a theoretical and actual practical task [1, 3, 7, 10]. It becomes obvious that the ongoing climate change in a number of large regions has led to significant changes in the water regime of rivers [22–25].

Considering the warming that has already taken place and the high probability of this trend continuing in the coming decades, the problem of assessing runoff changes becomes relevant, especially since solving the problems of water management and hydraulic engineering design requires a reliable determination of the parameters characterizing the river runoff regime [4-6, 12-16]. A sharp increase in the level of water consumption with an uneven distribution of water resources across the territory and the practically uncontrolled impact of water use on the environment, as well as pollution of water resources, makes us pay more attention to the study of seasonal river flow, especially in limiting periods. In addition, the intensified processes of global warming cast doubt on the concept of stationarity of long-term fluctuations in hydrometeorological values, which, in turn, requires the development of methods for processing non-stationary sequences of river runoff and the consideration of new stochastic models that make it possible to describe non-stationary processes.

The minimum river flow is one of the most important hydrological characteristics that must be considered when designing hydraulic structures, when using the flow for economic purposes. In the watersheds of mountainous areas, the minimum river flow is usually observed during the winter low water period, when the rivers are fed by groundwater. In general, winter minima are less than summer ones due to a decrease in underground feeding.

Formation, calculation and spatio-temporal distribution of the winter minimum ten-day runoff of the rivers of the lake Sevan basin were discussed in the following works [8–9, 11, 18].

Since the basin of Lake Sevan is presented as a triangular basin surrounded by high mountain ranges (fig. 1), except for the northwestern part near the city of Sevan, where the watershed line of the basin drops to the level of the lake and the only river flowing from the lake, Hrazdan, originates. The study area is located within the altitude range of 1900–3600 m and extends from the northwest to the southeast. It occupies an area of 4891 km^2, equal to approximately 1/6 of the territory of the republic.

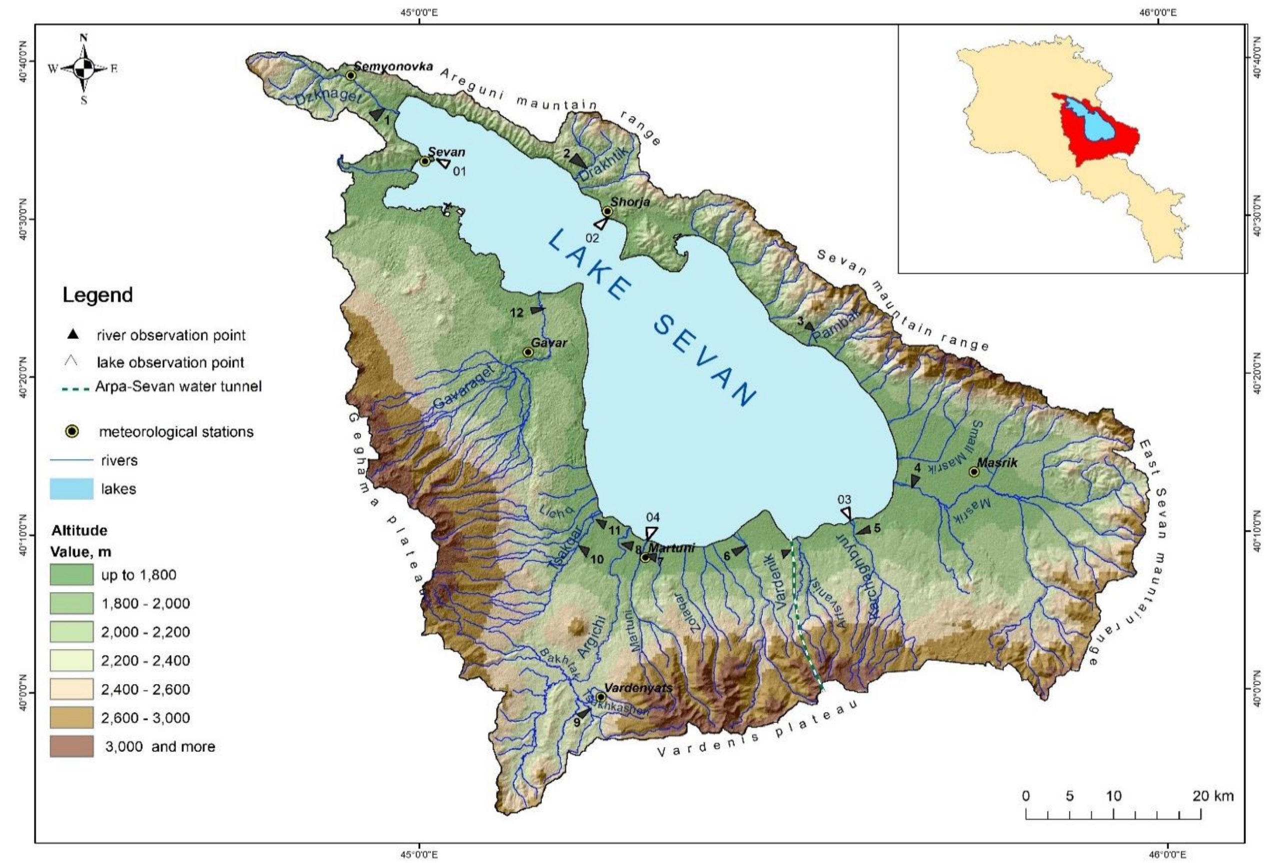

Fig. 1. Physical map, network of meteorological stations and hydrological posts in the lake basin Sevan (the position of the lake basin Sevan basin among the main river basins in Armenia)

The bottom of the depression is occupied by Lake Sevan. Lake Sevan is a strategic storage of fresh waters in Armenia. As a result of long-term and intensive use of the age-old reserves of the lake, its water level has significantly decreased (from 1934 to 2002 – 18,5 m), which led to drastic changes in the natural conditions (climatic, hydrological, biological, etc.) of the lake and the entire basin, to the violation of the ecological balance. The study area has a temperate continental climate with a well-defined vertical zones.

In general, this is a complex region not only in terms of geological structure and morphology, but also in terms of climate conditions and the hydrological regime of rivers. The lake basin in the north is bounded by the slopes of the Areguni and Sevan mid-altitude fold-fault ranges (from 2000–3300 m) of the Paleogene and Cretaceous, strongly dissected by numerous valleys of predominantly short mountain streams. To the southeast coast of the lake Sevan adjoins the Masrik lake plain (1900-2200 m), bounded by the slopes of the Sevan and Vardenis ranges. The western slopes of the lake depression are formed by the slopes of the volcanogenic Geghama Highlands, composed of lavas and tuffs, in their southern part they are cut by canyon-like valleys of a few rivers**.**

A common characteristic feature of the regime of the rivers of the lake Sevan basin is that in the annual course of their levels and runoff, two periods of increased water content are clearly distinguished - in spring (spring flood) and autumn (the first due to melt water, the second from rains) - and two periods of low runoff observed in summer and winter (summer and winter low water). In addition to the commonality of certain features of the regime, individual watercourses and even groups of rivers have significant differences among themselves in the distribution of runoff within the year, the nature of nutrition, and some other characteristics, which is mainly due to the peculiar geological structure, morphological features of watersheds and several factors that have a local effect. meaning.

For this reason, the lake Sevan basin, despite its relatively small size, is divided into several characteristic sub-regions, namely: the eastern slope of the Geghama massif, the basin of the Dzyknaget river, the slopes of the Areguni and Sevan ranges, the Masrik basin, the northern part of the Vardenis range.

The goal of the study. To resume the contemporary ideas about the impact of climate change on the winter average monthly minimum runoff of the rivers of the Lake Sevan. The solution of this important task can help prevent economic damage, raise the issue of extreme runoff risk management.

Material and methodology. As the source material were used the data of actual hydrometeorological observations of the "Center for Hydrometeorology and Monitoring" of the SNCO of the Ministry of Environment of the Republic of Armenia.

The values of the average monthly runoff during the winter low water period of twelve rivers flowing into the lake Sevan were studied with a duration of observations of more than 50 years and a minimum number of gaps in observations. Wherever it was possible the available gaps were restored, considering analogue rivers using standard and generally accepted methods in hydrological calculations. The winter low water in the study area is established from the end of November-December to February-March, in this work, data on runoff were used for November to March period Twelve posts, the data for which are considered, are distributed unevenly within the basin of the lake Sevan: three of them are in the north and northeast of the territory, one is in the west, and the remaining eight are in the south. The catchment areas related to these twelve hydrological posts are practically in the range from 20,4 to 673 km^2, and the altitudes are from 1900 to 2300 m.

The base of initial meteorological data includes winter daily actual values of air temperature and precipitation in the autumn and winter months (September - November) for a long-term period. The data series on air temperature and precipitation have different lengths (1966-2021). The precipitation series can be considered representative and homogeneous only since 1966. Currently (as of January 1, 2023) there are seven meteorological stations operating on the territory of the Sevan basin, the data of which (except for the Vardenyats meteorological station - since 1995 it has been operating only in the warm season) have become the basis for research. The results would be much more complete if there were posts and meteorological stations with a catchment height of more than 2300 m on the territory. Especially the altitudinal zone of the basin is not completely covered by observational data.

To assess the ongoing changes in the water regime of rivers based on observational data, two main approaches are used: 1) comparison of average values or indicators of variability of runoff characteristics for the contemporary period with the corresponding values of the previous (base) period; 2) identification of a linear trend in the observational data of the considered runoff characteristic. Both approaches assume that there is a unidirectional change in runoff characteristics under the influence of global warming. In this study, to assess the current changes in the average monthly minimum runoff during the winter low water for the rivers of the lake basin Sevan, according to observations, the second approach is used.

The following methods were used in the work: mathematical-statistical, extrapolation, interpolation, analysis, analogy, correlation and cartographic. In this work, the significance of the trend is proposed to be reduced to an estimate of the correlation coefficient R of the dependence $Y = f(t)$, where Y is the characteristic under study; t is time. A trend is considered statistically significant if the ratio is true $(R/\sigma_R \geq s)$, where σ_R – random mean square error. At 5% significance level or at 95% confidence limit s = 2.

Results and discussion. The winter minimum river runoff is formed in difficult natural conditions and under the influence of anthropogenic factors, the influence of which was reflected in its uneven distribution. In the area under discussion of the lake basin, the winter minimum average monthly discharges are in the range of 0,015 (Drakhtik river - Drakhtik village) – 1,68 m^3/s (Gavaraget river - Noratus village) (table 1).

The largest of them was 4,61 m^3 / s (1974/1975) and was observed on the river Argichi - the village of Getashen, and the smallest - on the river Drakhtik - Drakhtik village - there was no runoff (1956/1957).

Small values of the winter minimum average monthly runoff are observed on rivers fed by rain and melt water on small rivers. Relatively large values stand out on those rivers that have a large natural runoff regulation (greater underground feeding). In the study area, the rivers Masrik, Lichk, Gavaraget stand out with a relatively large underground supply (underground supply exceeds the surface supply by 51% or more) (table 2).

During the research, the average value of the winter minimum runoff was also calculated. Using the obtained calculated values, a map of the distribution of the modulus of the average minimum runoff of the winter low-water period was constructed (fig. 2). As a rule, the values of the modulus of the average minimum runoff of the winter period increase with height: at average heights of the catchment area up to 2100–2200 m - from 1,0 to 1,5 l / (s km^2), and at altitudes of 2600 m they reach almost 6,0 l/(s km^2). This map can be used to estimate the average minimum runoff of the winter low water of unstudied and little-studied rivers in the territory under consideration.

For the study area, the value of the coefficient of variation Cv of winter minimum average monthly discharges is 0,15–0,64, and the values of the asymmetry coefficient are 0,15–1,06.

Close correlations have been obtained between the winter minimum average monthly runoff and the average runoff of the winter period for a hydrological year. These relationships can be used to obtain the winter minimum average monthly discharges of unstudied and poorly studied rivers in the basin (fig. 3). The presence of a rather close relationship between them indicates that how small the minimum average monthly runoff is, how small the average runoff for the winter period is, and vice versa. As the average monthly minimum water consumption, the smallest value of the monthly consumption of the winter pe-

Table 1

Average monthly minimum runoff (m^3/sec) for the winter low water period of the rivers in the Sevan basin

№ according to the list of observation points	River - point	Observation period	Average monthly minimum runoff					
			XI	XII	I	II	III	during the period
1	R.Dzknaget – p.Tsovagyugh	1927-31, 33–34, 37-39, 41–45, 1948–2021	0,10	0,054	0,018	0,017	0,019	0,017
2	R.Drakhtik – p.Drakhtik	1972–92, 1998–2021	0,023	0,015	0,024	0,024	0,058	0,015
3	R.Pambak – p.Pambak	1947–50, 53–54, 56–68, 1971–89, 1998–2021	0.039	0,038	0,031	0,033	0,053	0,031
4	R.Masrik – p.Tsovak	1967–2021	1,38	1,23	0,99	1,15	1,40	0,99
5	R.Karchaghbyur – p.Karchaghbyur	1927–30, 53–95, 1998–2021	0,32	0,30	0,27	0,33	0,34	0,27
6	R.Vardenis – p.Vardenik	1927–38, 40-43,46–48, 50–95, 1998-2021	0,16	0,11	0,098	0,11	0,12	0,098
7	R.Martuni – p.Geghhovit	1955–2021	0,21	0,19	0,22	0,22	0,28	0,19
8	R.Argichi – p.Getashen	1927–2021	1,11	1,28	0,90	1,19	1,35	0,90
9	R.Tsaghkashen – p.Vaghashen	1971–2000, 2005–2019	0,16	0,20	0,23	0,24	0,30	0,16
10	R.Lichk – p.Lichk	1960-62, 77-95, 1998-2021	0,87	0,89	0,89	0,90	0,84	0,84
11	R.Bakhtak – p.Tsakkar	1928-30, 1952-2021	0,038	0,031	0,023	0,033	0,048	0,023
12	R.Gavaraget – p.Noratus	1927-42, 44, 49-50, 53-92, 1998-2021	1,68	1,74	2,10	2,14	2,17	1,68

Table 2

The ratio of river feeding sources from the annual (%) rivers of the basin lake Sevan

№ according to the list of observation points	River - point	Catchment area, km^2	Average catchment height, m	Power Sources		
				melt-waters	rain water	ground-water
1	R.Dzknaget – p.Tsovagyugh	82,6	2220	47	35	18
2	R.Drakhtik – p.Drakhtik	39,2	2270	41	23	36
3	R.Pambak – p.Pambak	20,4	2540	49	15	36
4	R.Masrik – p.Tsovak	673	2310	14	8	78
5	R.Karchaghbyur – p.Karchaghbyur	116	2650	22	6	72
6	R.Vardenis – p.Vardenik	117	2680	56	13	31
7	R.Martuni – p.Geghhovit	84,5	2760	50	14	36
8	R.Argichi – p.Getashen	366	2470	55	9	36
9	R.Tsaghkashen – p.Vaghashen	92,4	2570	–	–	–
10	R.Lichk – p.Lichk	33,0	2060	3	1	96
11	R.Bakhtak – p.Tsakkar	144	2570	45	14	41
12	R.Gavaraget – p.Noratus	467	2430	11	6	83

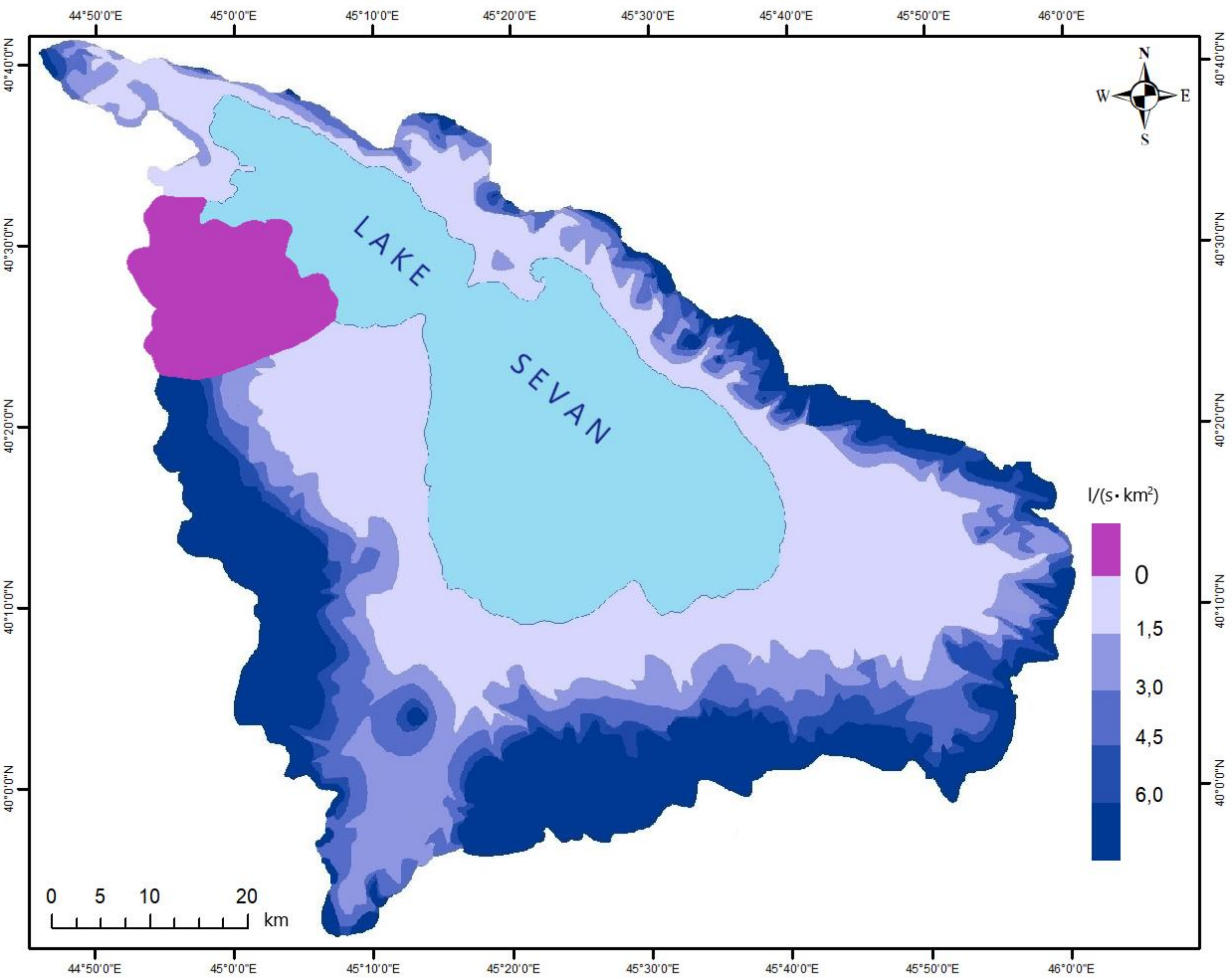

Fig. 2. Distribution of the module of the average minimum flow of the winter period (November - March) on the territory of the Lake Sevan basin

riod was chosen. Therefore, the minimum average monthly runoff is much less than the average runoff of the winter period - from about 2 (R. Gavaraget – p. Noratus) to 21 times (R. Dzyknaget – p. Tsovagyukh). This close relationship is since in winter, in general, the variability of runoff is small, which is mainly due to the underground feeding of rivers during this period of the year. The values of the average runoff of the winter period vary within 0,10–3,03 m^3/s (fig. 3).

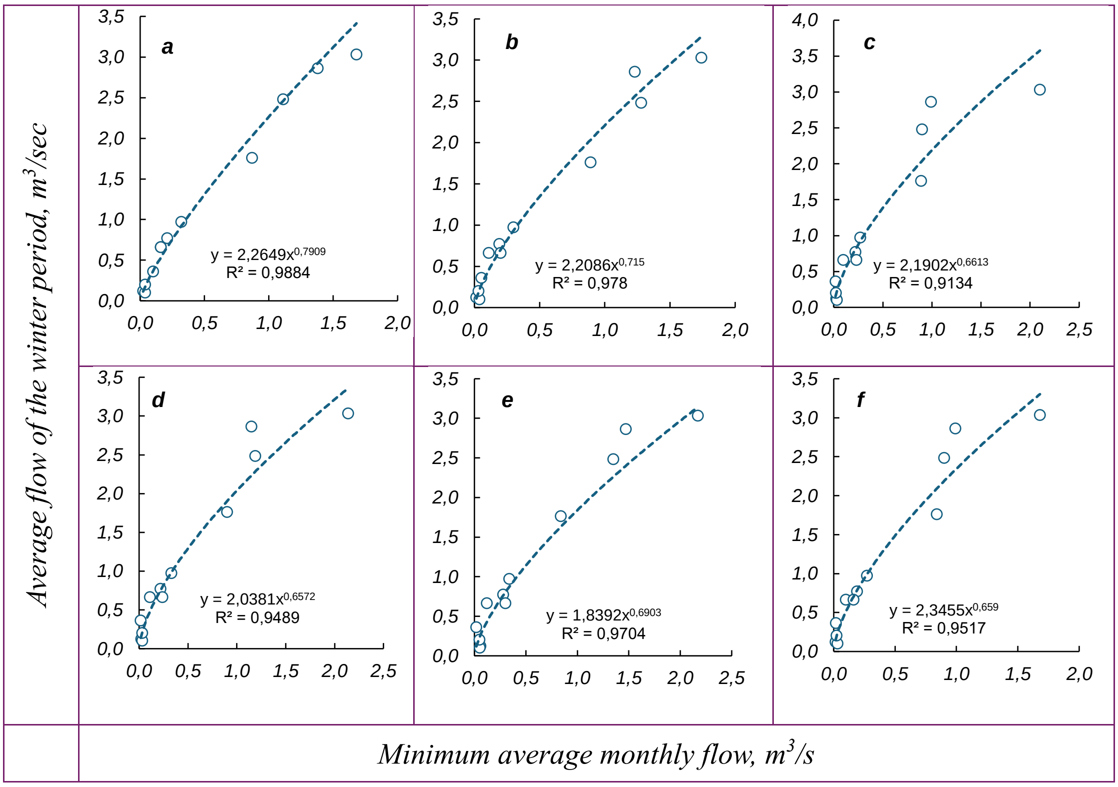

Fig. 3. Correlation relationship between winter values minimum average monthly flow and average winter flow. a – November; b – December; c – January; d – February; e – March; f – November – March

The runoff of low-water periods is determined to the greatest extent by the level of groundwater, which depends on the amount of precipitation of previous periods. Depending on the physical and geographical conditions (climatic zone, geological or hydrogeological structure of the territory, etc.), these may be precipitation of a given or previous month, previous season, year or longer period. In addition, in the case of significant warming, the snow that melted as a result of the thaw can serve as a source of food for the river in winter.

Changes in precipitation amounts for the autumn period. Autumn precipitation plays a major role in the formation of groundwater, which is the main source of river nutrition during the winter low water period. Changes in the amount of precipitation in the autumn months (September - November) for the period from 1966 to 2021 are analyzed (fig. 4).

The coefficient of the linear trend of this characteristic is statistically insignificant for almost all-weather stations. In general, at three meteorological stations of the study area, their values are growing, and at three meteorological stations, a decrease is detected. The coefficient of the linear trend of autumn precipitation at three meteorological stations in the basin is negative and does not exceed –8 mm / 10 years, at other meteorological stations it has small positive values (table 3). Thus, the change in the amount of precipitation during the autumn period cannot be the main reason for the observed increase and decrease in low-water winter runoff in the Lake Sevan basin.

On figure 4 shows examples of curves for changes in winter precipitation totals for various meteorological stations in the Lake Sevan basin, from which it follows that the long-term course of winter precipitation varies significantly at different meteorological stations. A statistically significant weak positive linear trend can be traced over most of the study area (table 3). Thus, in these regions, the linear trend coefficient varies from +1,73 mm/10 years to 7,60 mm/10 years. However, there are areas (northern and northeastern parts of the lake basin) with a negative trend. Thus, the change in the amount of precipitation during the winter period cannot also serve as the dominant cause of the observed change in the low-water winter minimum runoff in the Lake Sevan basin.

Change in winter precipitation amounts. One of the factors that determine the flow of low-water peri-

Table 3

Coefficients of the linear trend of climatic characteristics of precipitation for meteorological stations in the basin of the lake. Sevan for the period from 1966/67 to 2020/21

Meteorological station	Linear trend of climate characteristic	
	sum amount of precipitation for autumn, mm/10 years	sum amount of precipitation for the winter, mm / 10 years
Semyonovka	–8,01	-10,3
Sevan	+3,86	+7,60
Shorzha	–5,62	–0,50
Gavar	–4,46	+3,12
Masrik	+2,30	+1,73
Martuni	+0,15	+5,14

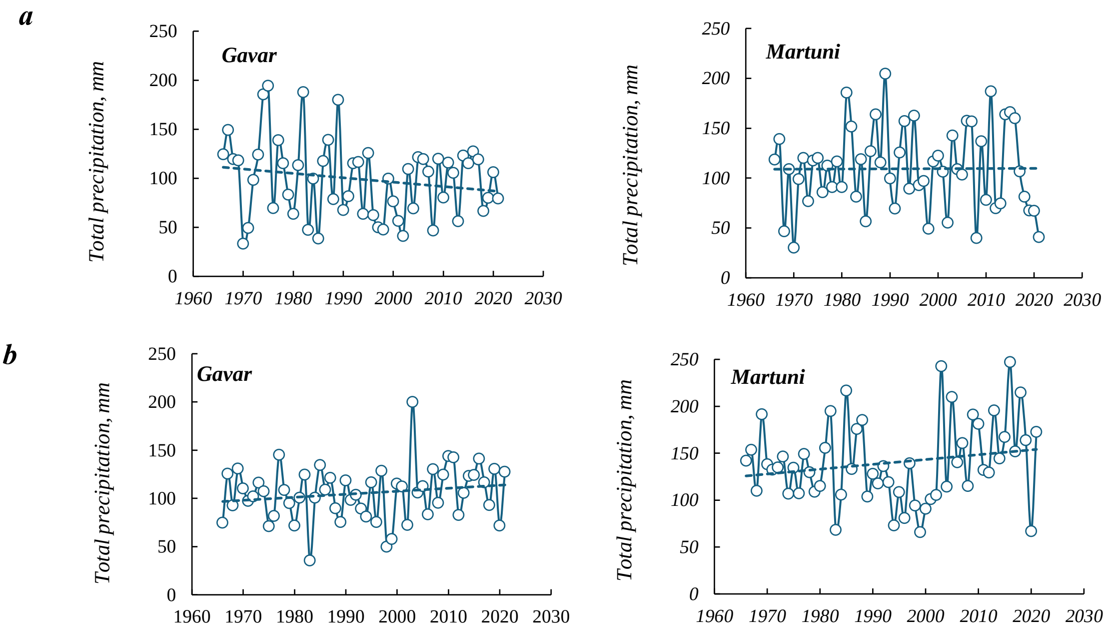

Fig. 4. Long-term changes sum amount of precipitation for the autumn (a) and winter (b) periods for several meteorological stations in the basin lake Sevan

ods is winter precipitation: in case of their growth, the groundwater level will be higher due to the greater volume of snowmelt and groundwater recharge. For this purpose, changes in the amount of precipitation for the winter period (for December - March) were studied.

Changes in the temperature regime of the winter period. As a rule, a sufficiently large frequency and duration of thaws can play an important role in the formation of winter runoff. As it is known, the modern period is characterized by an increase in surface air temperature, which is most pronounced just in winter [24-25]. The increase in the share of winter runoff is due to an increase in the frequency of positive winter anomalies, the magnitude of the values and duration of winter thaws.

At all meteorological stations of the basin of the lake. Sevan during the entire study period (November-March) an increase in winter air temperature was recorded, the most intense in Sevan, Shorzha and Martuni (table 4), where the linear trend coefficient is +0,44 - +0,45 °C / 10 years.

The winter warming is decreasing as per increasing in altitude (fig. 5). It was also used the data of the high-altitude meteorological station Aragats h/m. The linear trend coefficient at altitudes of 2000–2200 m is +0.30 – +0,40 °C/10 years, and above 2500 m it is less than +0,20 °C/10 years. At most meteorological stations of the lake Sevan basin revealed trend is statistically significant. At all weather stations, there is a pronounced increase in air temperature in winter (fig. 6).

At all weather stations there is also a pronounced increase in the sum of positive temperatures (fig. 6, a) and the number of days (fig. 6, b) with a positive average daily temperature for the winter period.

The course of the spatial distribution of the coefficient of the linear trend of the winter average air temperature and the sum of positive temperatures of the winter period coincide. Here, the most intensive growth is also observed in the area of Sevan, Shorzha and Martuni (table 3) - the coefficient of the linear

Table 4

Coefficients of the linear trend of climatic characteristics of air temperature
for meteorological stations of the basin lake Sevan for the period from 1966/67 to 2020/21

Meteorological station	Linear trend of climate characteristic		
	air temperature during the winter, °C/10 years	average daily positive temperatures for the winter period	
		sums °C/10 years	number of days, days/10 years
Semyonovka	+0,27	+5,44	+1,74
Sevan	+0,45	+14,3	+4,03
Shorzha	+0,34	+10,1	+3,70
Gavar	+0,29	+2.52	+0,90
Masrik	+0,32	+3,78	+0,87
Martuni	+0,44	+12,4	+3,84

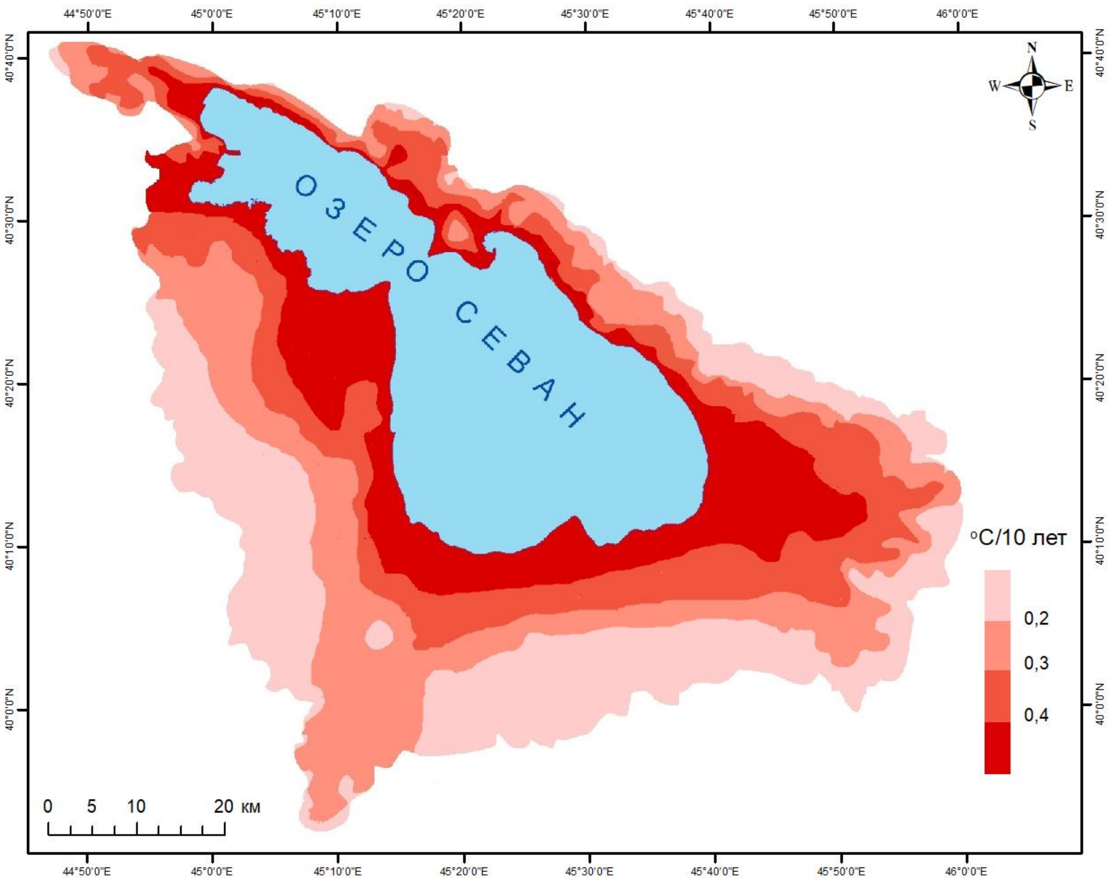

Fig. 5. Coefficients of the linear trend of winter air temperature in °C/10 years
for the period from 1966/67 to 2020/21 on the territory of the Lake Sevan basin

trend of the sum of positive temperatures exceeds +10,0 °C/10 years, and the coefficient of the linear trend of the number of days with a positive average daily temperature is +3,5 days/10 years.

The most significant changes in the sums of positive air temperatures (fig. 4) and the number of days with a positive average daily temperature can be traced in the coastal zone of Lake Sevan up to a height of 2000 m. Statistically significant trends are observed here, the maximum values reach +14,3 °C/10 years and +4,03 days/10 years, respectively (table 4).

At all meteorological stations of the basin of the lake. There was recorded an increase in winter air temperature and in the sum of positive temperatures and in the number of days with a positive average daily temperature during the winter period in Sevan area during the study period (November–March) 1966–2021, the most intense in the Sevan, Shorzha and Martuni regions. With height, the intensity of winter warming decreases.

It was revealed that predominantly (among 12 studied posts by 8) there is a tendency to decreasing

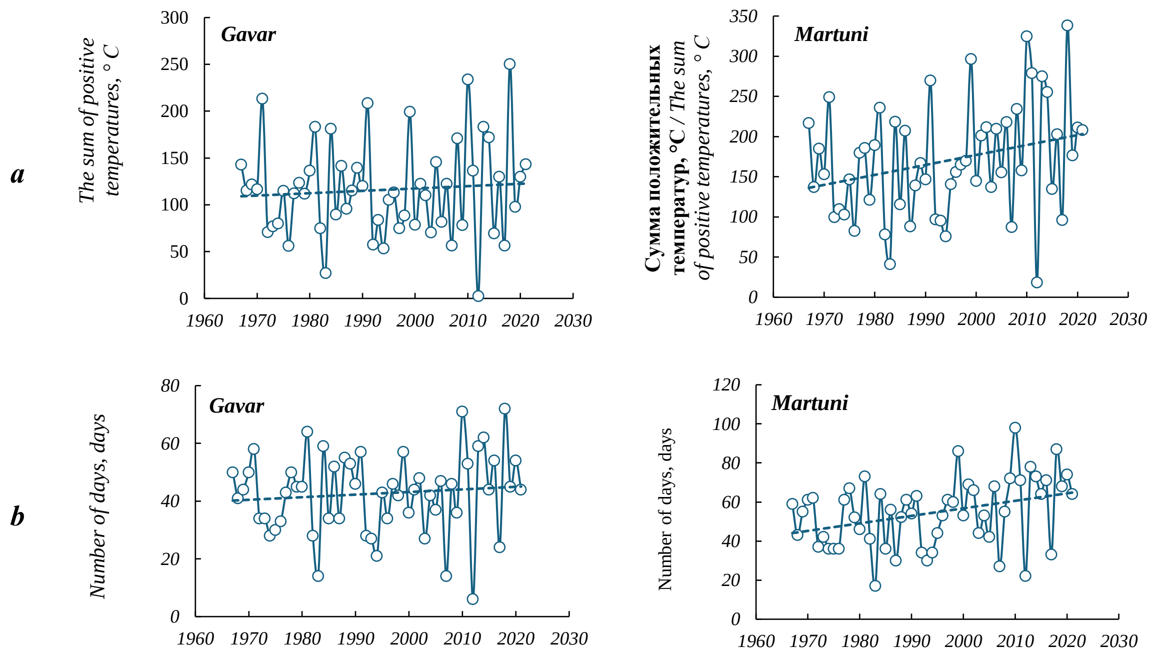

Fig. 6. Long-term changes in the sum of positive temperatures in °C (a) and the number of days with a positive (in days) average daily air temperature (b) in the winter period for meteorological stations in the lake Baikal basin Sevan

in the values of the average monthly minimum river flow; Sevan has undergone significant changes in recent decades (mainly in the mid-1990s) in the winter minimum monthly water discharges.

The increase in water content in the winter low water in most of the rivers of the lake Sevan basin happened due to the impact of climate change. These changes differ in different physiographic regions. The most intensive increase in the winter minimum average monthly runoff occurs in the Argichi River basin, where the minimum water discharge almost doubled (by 60 % or more).

As a result, to ensure the integrated use of water resources, it is necessary to consider the current trends in the long-term distribution of the river flow in the Lake Sevan basin.

Thus, the conducted studies lead to the conclusion that the main factor causing changes in the winter low-water runoff of the rivers of the lake Sevan basin is a change in the temperature regime of the winter period (an increase in winter temperatures and their characteristics).

As the analysis shows, a decrease in the winter minimum average monthly flow was revealed for the Masrik, Bakhtak, Lichk and Gavaraget rivers, that is, on the rivers for which underground feeding exceeds surface feeding by 51% or more. Hence, it should be concluded that in the river basins where the winter minimum average monthly runoff decreased, there is a decrease in groundwater reserves.

In general, for the study area in recent decades, there have been significant changes in the winter minimum average monthly water discharges. Most of the changes took place in the mid-1990s.

Changes in the winter low-water runoff of rivers create the prerequisites for positive and negative hydrological, water management and environmental consequences. For those rivers where there is a tendency to reduce the winter minimum average monthly flow, river ecosystems are becoming more vulnerable, especially in river basins with intensively developed hydropower (Dzoragyugh, Masrik, Vardenis, Martuni, Argichi, Karchaghbyur). On the other hand, the flow of small rivers is often almost completely consumed due to inefficient water intake, as a result of which some of them freeze in winter.

Conclusions. The dynamics and transformation of the leading natural factors determine the uniqueness and anomalies of the winter minimum average monthly runoff in the current climatic period and create the prerequisites for positive and negative hydrological, water management and environmental consequences. Under such conditions, the risks of problems of sustainable use of water resources in the Lake Sevan basin increase, which requires an increase in the efficiency of water use in all sectors of the economy.

It has been established that the rivers of the basin Lake Sevan are characterized by an uneven spatio-temporal distribution of the winter minimum runoff and their climatic characteristics, so that the changes in the winter minimum average monthly runoff, the amount of precipitation for the autumn and winter periods are multidirectional - a growth trend is predominantly observed, and air temperature changes have only a growth trend.

It is determined that the rivers of the lake Sevan basin are distinguished by the diversity of the risk of the minimum average monthly runoff in the winter period - in some rivers there is a decrease in the latter, and in other rivers - an increase.

The results of the research make it possible to develop ways for the efficient use of water resources for water supply, water consumption and operation of irrigation systems, as well as to optimize in advance the needs of water consumers and water users and to conduct the correct policy of water distribution and water consumption.

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Сучасні зміни кліматичних характеристик та мінімального стоку річок басейну Севан

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У статті наводяться результати дослідження змін основних кліматичних характеристик та зимового мінімального середньомісячного стоку річок басейну озера Севан. В якості вихідних даних використовувалися щодобові витрати води на дванадцяти гідрологічних постах та кліматичні ряди температури повітря, атмосферних опадів на шести метеорологічних станціях «Центру гідрометеорології й моніторингу» ДНКО Республіки Вірменія. Проведено аналіз гідрологічних та кліматичних показників, визначені закономірності їх просторово-часового розподілу, а також нестаціонарність в рядах мінімального зимового стоку. Отримано тісні кореляційні зв'язки між значеннями зимового мінімального середньомісячного стоку та середнім стоком зимового періоду за гідрологічний рік. Отримані залежності допомагають провести попереднє оцінювання мінімального стоку річок взимку, що мало дослідженні на представленій території. Розраховано мінімальні середньомісячні витрати води за кожен місяць та весь період спостережень, середнє значення мінімального стоку під час зимової межені та лінійний тренд основних кліматичних показників. Встановлені дати зміни стаціонарних режимів мінімального зимового стоку, що дає підставу корегувати заходи управління екстремальними мінімальними витратами води. Побудовано карти розподілу модуля середнього стоку межені в зимовий період та коефіцієнтів лінійного тренду температури повітря. Встановлено, що зміни мінімального стоку річок озера Севан взимку мають різноспрямований характер, де переважають тенденції до збільшення. Визначено, що для змін кількості опадів на досліджуваній території взимку та восени характерним є двох спрямований процес. Температури повітря взимку характеризуються тенденцією до зростання. Доведено, що в межах басейну озера Севан існують різноспрямовані ризики екстремальних мінімальних витрат води у зимовий період. Так, в деяких ріках відбувається зменшення мінімального стоку, в інших – незначне зростання. Створені картографічні твори відбивають характер змін мінімального стоку на базі даних до 2021 року. Отримані результати мають практичне спрямування під час розв'язання гідроекологічних задач щодо раціонального використання та управління водними ресурсами басейну озера Севан, їх охорони та захисту від деградації, проєктування, будівництва водосховищ та інших гідротехнічних споруд в гідроенергетиці.

Ключові слова: *річки басейну озера Севан, межень, зимовий мінімальний середньомісячний стік, температура повітря, кількість опадів, багаторічні зміни, зміни водного режиму, коефіцієнти лінійного тренду.*

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