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ANNUAL RIVER RUNOFF OF THE ILE-BALKASH BASIN AND PROSPECTS OF ITS ASSESSMENT DUE TO CLIMATIC CHANGES AND WATER ECONOMY ACTIVITIES

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ABSTRACT: The water regime of the rivers of arid territories caused by not only to meteorological features, but also to a greater extent to the factors of the underlying surface of the earth. In addition, changes in river flow is determined by human economic activity. Ile-Balkhash region of Kazakhstan is the most densely populated and economically developed region. Large agro-industrial complexes, numerous settlements and cities are centered here. As a result, consideration and prospects of water consumption are the most important challenges in planning the social and economic development of the region on the basis of changing water resources in modern climatic conditions. The article presents the calculated features of flow for different time periods with the development of economic activity and climate change. It is established that there has been a rather intensive increase in the water content of the basin's watercourses since the seventies of the last century. The changes in the features of the annual flow of rivers for 90-100 year periods are calculated. Thus, the average annual water consumption of the Ile River in the lower reaches has increased over the past 40-50 years by an average of about 45 %, which has led, at present, to an increase in the water level in Balkhash Lake. The level of the lake decreased significantly after the building of the Kapshagai reservoir in the riverbed in 1970, primarily due to losses on its filling and increase in evaporation. Primarily, the development of the region is determined by changes in water resources in the future, its rational use and modern water-saving irrigation systems and hydraulic structures. The calculated flowoff features of the rivers of the Ile-Balkash basin make it possible to make a system of sustainable development of the region with the possibilities of water consumption, as well as regional models of flow formation.

Keywords: Annual runoff, Climate changes, Average air temperature, Total precipitation.

1. INTRODUCTION

The Ile River basin is a unique natural and resource complex of Kazakhstan and plays a huge role in the life of the Republic. Analysis and assessment of water resources, and the prospects for its quantitative changes are undoubtedly important and require consideration when planning the development of the region, with the growth rate of the population (for example, the population of Almaty in 1999 amounted to 1,121,356 people, and in 2009 this figure increased to 1,365,632 people (according to the Agency of statistics of the Republic of Kazakhstan) and the Economy. The development of the Ile-Balkhash region is a priority in the Republic of Kazakhstan. Agriculture has traditionally developed in the region, and large agro-industrial complexes have recently been built.

The characteristics of the rivers runoff in arid areas are determined, by climatic factors and underlying surface conditions. For example, the terrain height in turn significantly affects the water regime of the river. The runoff formation zone of the Ile-Balkhash basin is located mainly in the Zaileiskii and Zhetisu Alatau and its hydrological components are snowmelt, glacier melt, and rain-induced runoff. The Ile-Balkash region is not well studied yet and limited international literature exists about this area. The first information about the hydrology of the Lake Balkhash and the rivers of the Ile-Balkhash basin were received by L.S. Berg (1904) during his journey through Central Asia in 1903. Researches of the conditions for the formation of runoff and the water regime of rivers in this region are contained in the works of Z. Berkaliev (1960), A. Litovchenko (1963), V. Shulz (1965), O. Sheglova (1969), L. Emelyanova (1970), I. Sosedov (1976; 1984), Zh. Dostaev (1990) and others. Among the modern researchers who studied the problem can be distinguished such researchers as Dostay, Zh., Alimkulov, S., Tursunova, A., Myrzakhmetov, A. (2012), Imentai, A., Thevs, N., Schmidt, S., Nurtazin, S., Salmurzauli, R. (2015), Terekhov, A., Dolgikh, S.

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The regime of annual river runoff depends not only on the amount of annual precipitation but also on the melting of high-altitude snow and ice accumulated in the mountains. Besides, hydrogeological processes contribute to the wedging out of groundwater in the foothill zones, creating a whole network of small streams, which are usually difficult to consider in the water balance of the basin. Thus, the water regime of the rivers, although it is a function of precipitation, does not reflect their successive changes. The complex processes of formation of runoff in the conditions of arid territories and mountain zonal patterns do not allow obtaining reliable dependences of precipitation and runoff. However, it is obvious that changes in climatic conditions entail coordinated changes in the water regime, and in general, the values of the annual runoff of rivers in the region. Statistical analysis is more reliable and accurate as the larger period is studied. In hydrological calculations, in assessing the water resources of large areas, the same period is chosen as the identical hydrometeorological conditions, allowing taking into account the data of the entire hydrological network of observations of the runoff characteristics without considering the data on individual long-range hydrological gauging stations.

Moreover, considering the global warming on Earth and intensive human activities, the estimated series of river runoff characteristics for solving water management problems are limited to recent decades.

In the Ile-Balkhash basin, economic activity is developed in the foothill and below zones. The river runoff is used for the water supply of the Almaty city and other populated areas; a large number of small ponds and reservoirs were created in the past to create favorable condition of livelihood, a large Kapshagai reservoir was built in the 1970s in the Ile river (total volume – 28.1 km^3, area of water surface – 1847 km^2) (Dostai, 2009). Moreover, the Akdalinsky and Karatal irrigation networks were built in the lower reaches of the rivers Ile, irrigation canals: Tusmurunskii, Bakanasskii, Ushtobinskii, and others. Since 1984, in the Shelek River, the Bartogay reservoir and the D. Kunaev main channel for transfer of runoff has been functioning, which connects the Shelek and Shemolgan rivers. At different periods, based on the economic tasks, opportunities and plans of the Republic, the development irrigation in the basin was uneven, and account water withdrawals and, in general, a quantitative assessment of the use of water resources is not effective.

The Ile-Balkhash region has great economic and social importance in the Republic of Kazakhstan. 16% of the population of the republic live here and 16% of industrial production and 13% of agricultural products are concentrated. Ile-Balkhash basin includes the largest area of irrigated land, which is about 350 thousand hectares. At the same time, the territory possesses 22% of water resources, of which the estimated hydropower resources make up 42% (Kudekov, 2002). According to the Institute of Geography of the Ministry of Education and Science of the Republic of Kazakhstan, the Ile-Balkhash basin accounts for 29.36 km^3/year, of which 16.05 (55%) are formed in the territory of the Chinese People's Republic, and 13.31 (45%) within Kazakhstan (Malkovskii, 2008). In the basin, there are two largest cities of Kazakhstan - Almaty (1,854 thousand people), Taldykorgan (145 thousand people) and a number of large settlements, which are the main water consumers and water users. As of today, 833 water consumers and water users are officially registered in Almaty oblast and the city of Almaty. At the same time, about 4000.0 million m^3/year of surface runoff is taken. In the future, the development of the region implies an increase in water consumption due to the intensive growth of industry (food, light, electrical, mining - Tekeli pig-zinc plant) and agriculture - animal husbandry and crop production. In this regard, the question of forecasting changing water resources in the face of climate change and increasing economic activity and their rational use in the basin under consideration is already acute (Figure 1.).

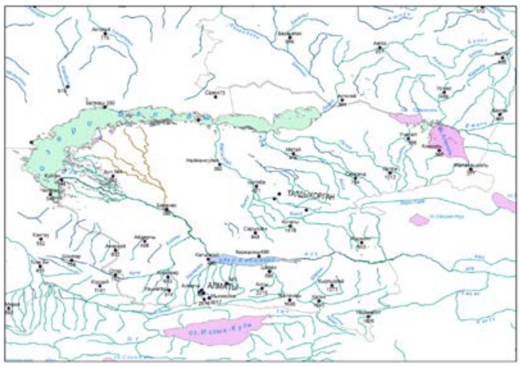


Fig. 1 Map of the Ile-Balkash region

2. MATERIALS AND METHODS

The assessment of the impact of economic activities on the water of the rivers of the basin was made by using statistical analysis of long-term runoff characteristics and meteorological indicators: temperature and precipitation from the meteo- stations located in different regions of the territory under consideration. An analysis of the total integral curves of the annual runoff, which allows detecting changes related to economic activities, made it possible to identify significant changes in the water regime and its impact on the average annual discharge of the considered region. The restoration of gaps in the past observations, but also the reconstruction of the natural runoff series without anthropogenic impacts, were conducted based on the analog points. As points of analogs hydrological gauging stations located on the same river were used, and the correlation coefficients of discharge between different gauging stations ranged from 0.70 to 0.93. The results of the assessment of the economic activity impact the annual runoff of rivers in the region are given in the article (Abdrahimov & Amirgaliyeva, 2018).

A more detailed analysis of changes in meteorological conditions observed in the region according to meteo- stations with the longest observation periods makes it possible to assess the prospects for further fluctuations in meteorological characteristics and their influence on the rivers water regime of the basin.

Analysis of changes in the river runoff for the long period allows detecting the presence of fluctuations in the water flow over the past period. Runoff fluctuations over time manifest themselves in the form of a successive change of high-water (a period with an increase in water content) and low-water (a period with a constant decrease in water content) of groups of years. More reliably cycles can be set by difference integral curves (or the total curve of deviations of the annual values of the flow from its average value over the entire observation period). The integral flow curve is a variation of the total flow curve. It characterizes the sequence of increase in the river runoff from a certain initial point in time. In contrast, the difference integral curve takes into account fluctuations in the runoff for individual short periods. It is constructed by summing the deviations of the modular coefficients from the middle, that is, its ordinates are calculated as:

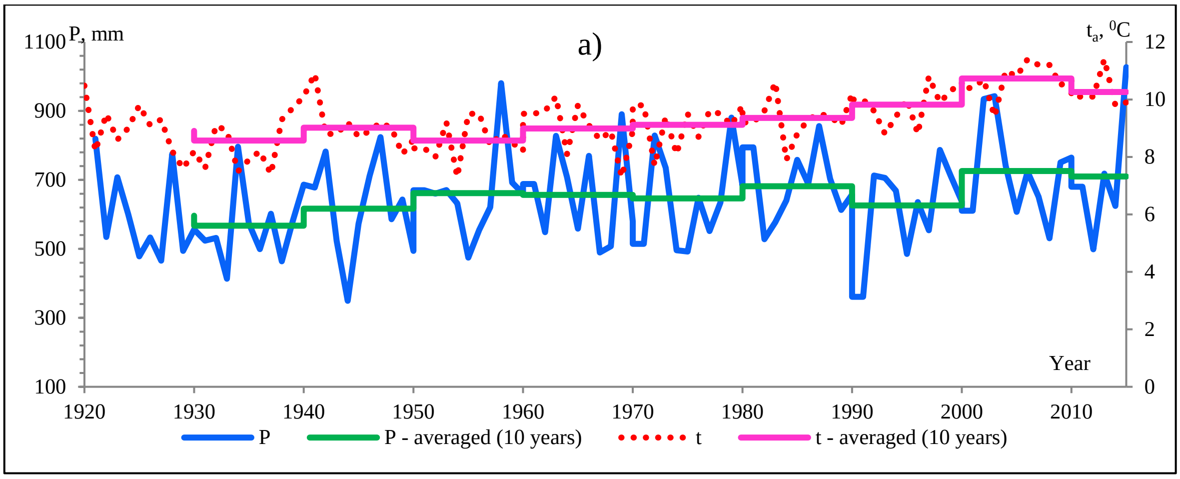
$$\sum_1^i (K-1) \qquad (1)$$

where, $K = Q_i/Q^-$. Thus, the ordinates of the curve give, at the end of each i-th year, an increasing amount of deviations of the annual modular coefficients K from the norm or the average multi-year value ($K^- = 1$). To be able to be able to compare the perennial flow fluctuations of different rivers, the temporary influence of the temporal variability of the runoff, reflected by the coefficient of variation (variability) of several observations (Cv), is made:

$$\sum K - 1 / C_v \qquad (2)$$

Difference integral curves make it possible to determine the runoff (concerning to the average) of individual periods; therefore, they can be used in the selection of river analogs (Vladidmirov, 1980).

For the analyses of climate variation in the study area, authors have used the records from the Almaty, Kogaly, Usharal and Bahty meteo-stations that have significantly long observation records. The instrumental observations of climate records began in the Almaty meteorological station at the end of the nineteenth century but were not regular. The location of meteo- stations changed since then. Since the beginning of observation records, the average annual air temperatures generally retain a tendency of growth with significant fluctuations in their values in certain periods and years.



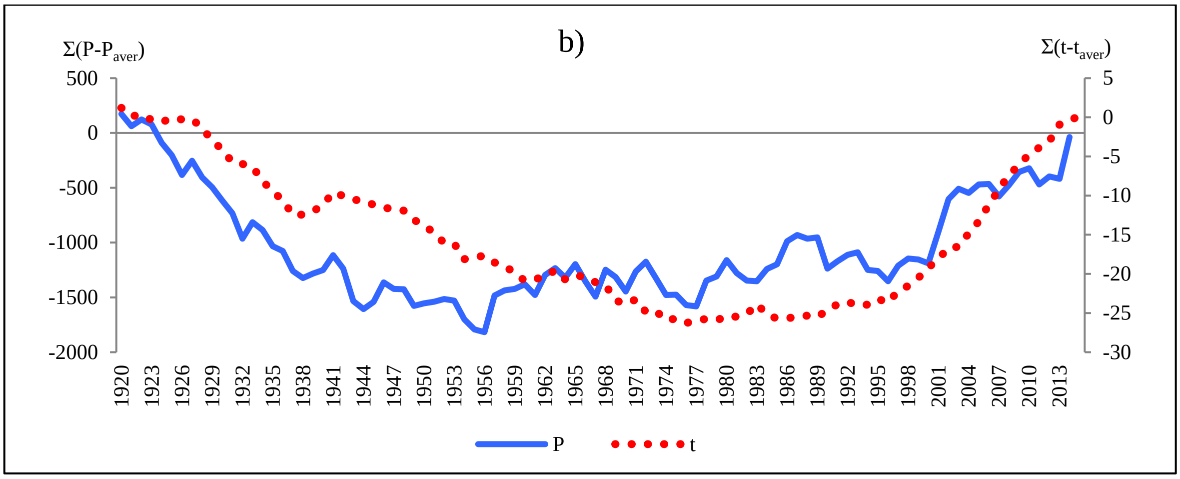


Fig.2 Dynamics of annual mean temperatures (t) and annual precipitation (P), and their averaged values over decades (a); as well as the sum of anomalies of average annual temperatures and precipitation (b) in Almaty meteo-station

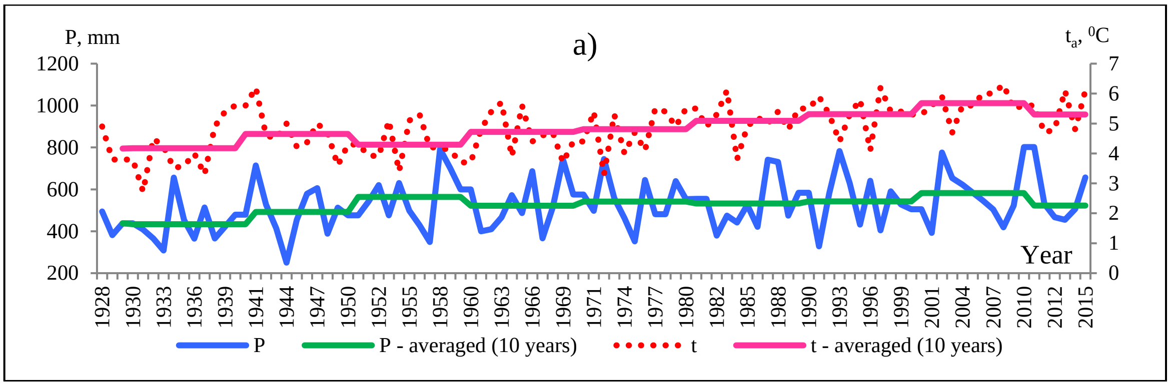
Long-term meteorological observations - since 1928, in the basin are also carried out at the meteo-station Kogaly, located at an altitude of 1410 m in Zhetisu Alatau (see Figure 1). In figure 3 shows the changes related to temperature and precipitation at the Kogaly station.

3. RESULTS AND DISCUSSION

Moreover, they differ from each other both by the deviation from the long-term average runoff for the entire period under consideration and by the duration of one or another group of years. These groups form cycles of different duration and different range of fluctuations in water content. The cause of cyclical fluctuations in river flow is climatic factors. Figure 2a shows the dynamics in mean annual air temperatures and annual precipitation amount, as well as moving average values, averaged over the decades (10 years) starting from the 1920s.

It is known that the annual mean temperature in Almaty for the period from 1881 to 1911 was about 7.2°C, and in the period 1911-1940, it increased to 8.5°C. The most intensive growth of average annual air temperatures was observed since the beginning of the 70s of the last century (6.1°C in 1983s). By 2010-2015 the temperature increased on average to 10.7 °C. The average annual precipitation over the investigated period also increased from 580–600 mm per year in the 1928s – 1950s of the last century to 740 mm per year in the period 2010-2015. An analysis of anomalies of annual mean temperature and annual precipitation (Figure 2b) also allows that since the early 1960s there has been a significant increase in annual precipitation, and average annual air temperatures have steadily increased since the 1970s.

As can be seen, the long-term annual mean temperature here also increases starting from the 1970s, and a significant increase in the annual precipitation began from the end of the 1950s. The temperature increase was from 4.4°C in 1928-1976 to 5.35°C in 1977-2015, and the amount of precipitation from 476 mm in 1928-1955 to 545 mm in 1956-2015.



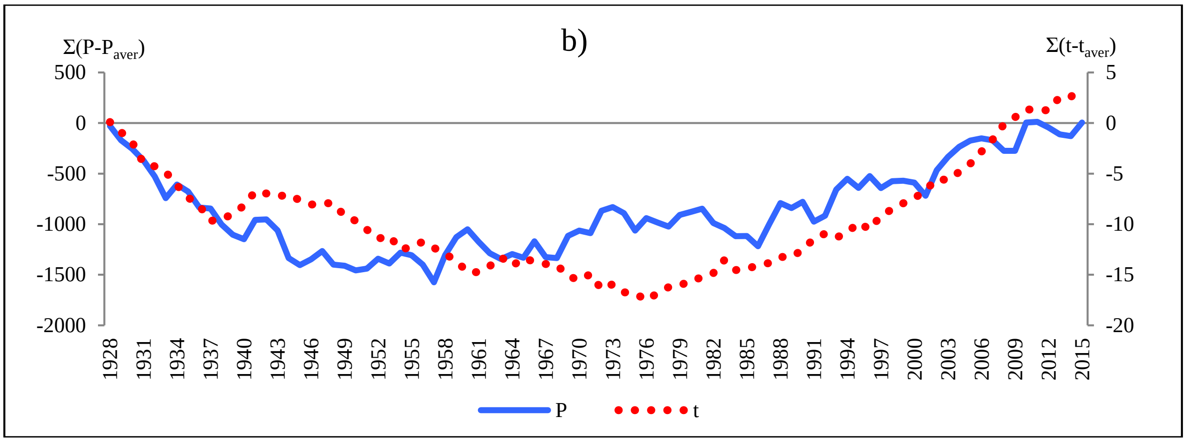


Fig. 3 Dynamics of annual mean temperatures (t) and annual precipitation (P), and their moving average values over decades (a); as well as the sum of anomalies of average annual temperatures and precipitation (b) according to Kogaly meteo-station

According to meteo- stations located in the lower parts of the basin, for example, meteo-stations Usharal and Bakhty located an altitude of 386 m and 441 m, respectively, a steady increase in annual mean temperature was observed since the early 70s (Figure 4). Their values here on average changed from - 1.9 ° C in 1933-1970 to - 0,8 ^{0} C in 1970-2000 according to meteo-station Bakhty and from 6.40 ° C to 7.50°C over the same periods according to meteo- station Usharal (Figure 5). The results indicate changes in the amount of annual precipitation from the 1960s, however, there is a decrease in the values of precipitation from the 1970s to the 1990s.

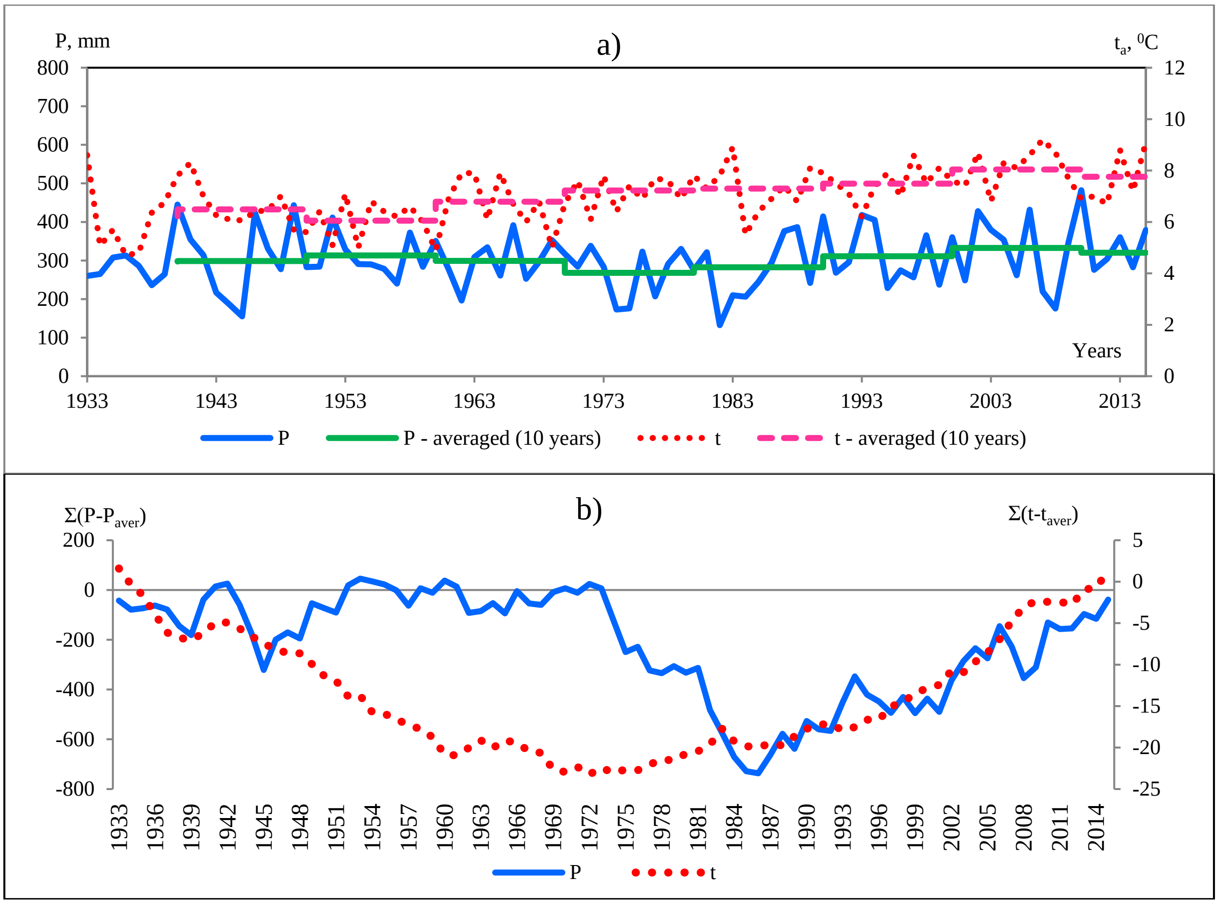


Fig. 4 Dynamics of annual mean temperatures (t) and annual precipitation (P), and their moving average values over decades (a); as well as the sum of anomalies of average annual temperatures and precipitation (b) by Usharal meteo-station

Thus, in the Ile-Balkhash basin, along with global changes in the Earth's climate, there are also changes in mean multiyear values of air temperature and precipitation, the magnitudes of which have increased over the past decades. This circumstance entails an increase in the river runoff. Figure 5, shows the total integral curves of some large rivers in the region. The curves are constructed according to the values of the restored conditionally natural annual runoff, taking into account the influence of economic activity.

The analysis of the significant impact of economic activity on the characteristics of the annual runoff of rivers in the region was carried out using well-known methods for estimating the statistical parameters of the series and the total integrated runoff curves. Which in comparing their hydrological characteristics with the rivers of their counterparts that have a natural water regime.

The total integral curves of conditionally natural runoff (Figure 6.) allow that to state that since the 70s a runoff increase in the main watercourse of the river Ile region was observed. This growth is also detected on the tributaries of the Ile River. On some rivers, for example, the river Kaskelen, restoring the characteristics of conditionally natural runoff is quite a challenge, because the river basin is located in the most densely populated and economically developed area. This river crosses the cities of Almaty and Kaskelen, and its water has been used for industrial and agricultural in this region since the 30s-50s.

The values of the increased annual runoff of some large rivers of the basin are estimated from the difference in their values of the previous conditionally natural period before 1970 and after i.e. over the past decade - 40-50 years and are given in table 1.

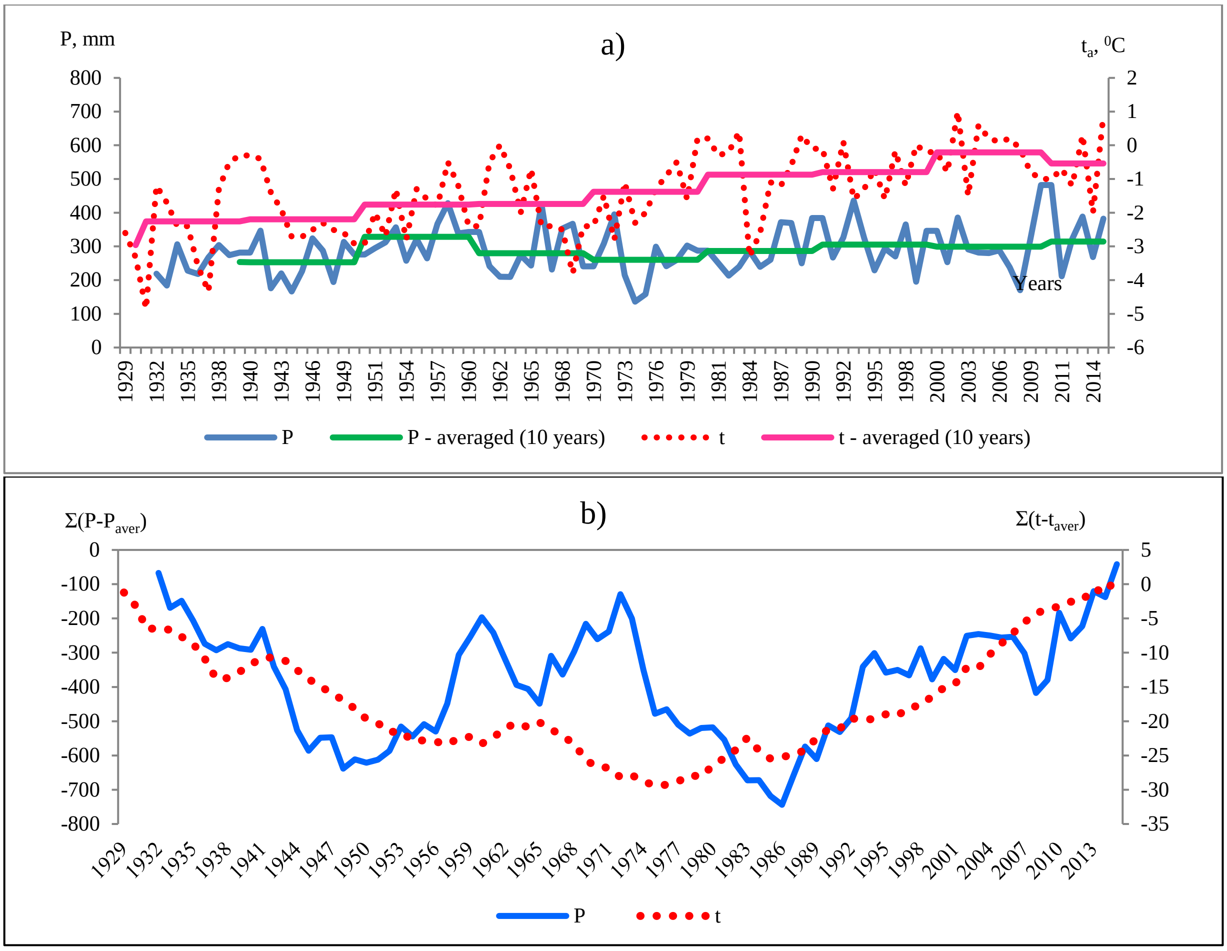


Fig. 5 Dynamics of annual mean temperatures (t) and annual precipitation (P), and their moving average values over decades (a); as well as the sum of anomalies of average annual temperatures and precipitation (b) Bahty meteo-station

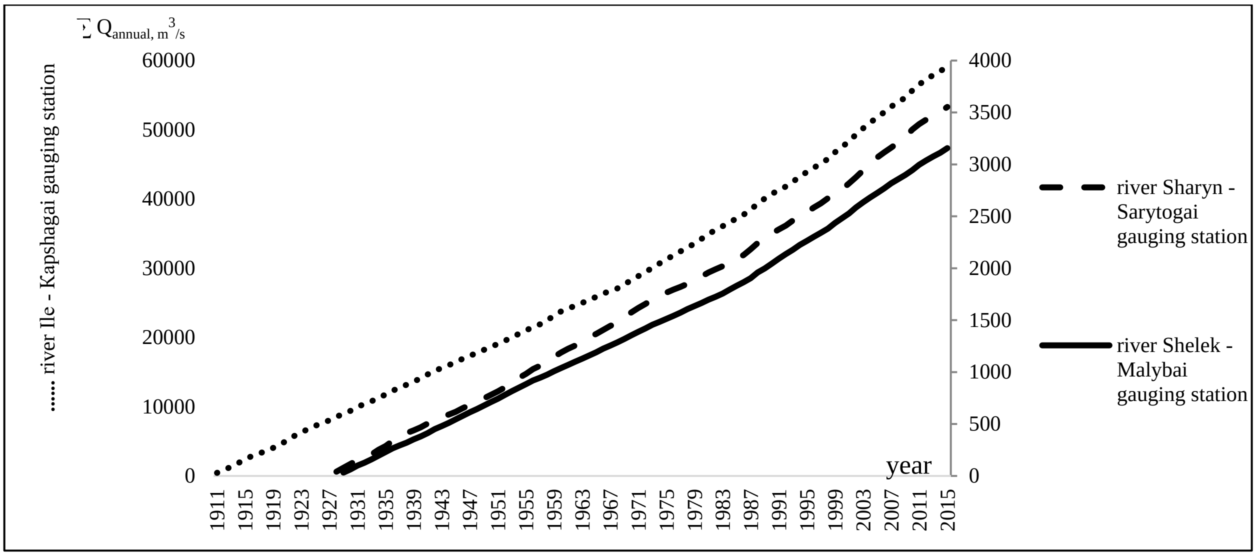


Fig. 6 Total integral curves of annual water discharge of large rivers of the Ile-Balkhash basin

Currently, in the practice of hydrological calculations, the probability of an event occurring is widely determined by the formula of Kritsky-Menkel:

$$P^{*} = \frac{m}{n+1}100\% \quad (3)$$

where, P – probability, %; m – module coefficient; n – number of years.

Empirical security corresponds to the average value of empirical security of a given value in K samples (K → ∞) over n members (Shelutko, 1991).

Table 1. Characteristics of river runoff of the Ile-Balkash basin

Observation period, years	**Q, m^3/s**	**n**	**C$_v$**	**Water discharges of different probabilities, %**			
				1	**10**	**50**	**90**
River Ile - Kapshagai gauging station							
1911-2015	561	105	0.27	967	761	549	376
1911-1970	467	60	0.18	692	578	460	364
1971-2015	685	45	0.19	1058	859	669	532
Difference m^3/s (%)	218 (47%)			366 (53%)	281 (147%)	209 (45%)	168 (46%)
River Ile - Ushzharma gauging station							
1939-2015	588	77	0.25	1067	785	556	435
1939-1970	468	32	0.14	637	554	464	387
1971-2015	673	45	0.19	1089	844	645	540
Difference m^3/s (%)	205 (44%)			452 (71%)	290 (52%)	181 (39%)	153 (40%)
River Sharyn - Sarytogai gauging station							
1928-2015	40.3	88	0.25	68.6	53.7	39.1	28.4
1928-1970	36.6	43	0.20	57.2	46.3	35.7	28.0
1971-2015	43.9	45	0.25	76.2	58.6	42.3	31.2
Difference m^3/s (%)	7.3 (20%)			19.0 (33%)	12.3 (27%)	6.6 (18%)	3.2 (11%)
River Shelek - Malybay gauging station							
1929-2015	36.2	87	0.19	56.9	45.4	35.1	28.4
1929-1970	32.2	42	0.09	39.2	36.0	32.1	28.5
1971-2015	39.9	45	0.19	62.7	50.1	38.7	31.3
Difference m^3/s (%)	7.7 (24%)			23.5 (60%)	14.1 (39%)	6.6 (21%)	2.8 (10%)

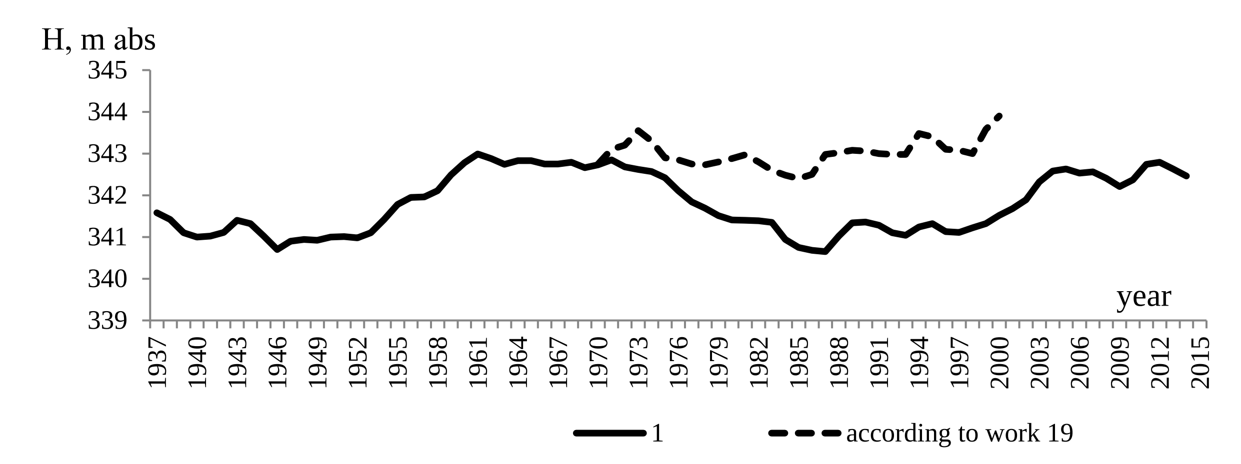


Fig. 7 The change in the actual (1) and restored (2) water levels of the lake Balkash

The average long-term runoff values in the lower reaches of the Ile River over the past decades have increased by 45% since 1970, and the river runoff once every 100 years could reach more than 1000 m^3/s.

To the analysis conducted earlier by other authors (Zaikov, 1946; Abdrasilov, 1994; Samakova, 2003) authors can only add that a noticeable change in the course of the difference integral curve for all posts of the catchment basin of the Ile River has been observed since 1970, which can not be explained by the influence of only anthropogenic factors on the flow, perhaps climate changes increase the runoff of rivers with glacial power in the last 10-15 years.The runoff losses of the Ile River associated with economic activities in the Ile-Balkash Basin, and primarily because of the Kapshagai reservoir created, also affected changes in the level of Lake Balkash (Figure 7). As is known, since 1970, the year of commissioning of the Kapshagai reservoir, the lake level began to decline from 343 m above sea level. to 340.7 m above sea level by 1986. Temporary losses of the river runoff to fill the reservoir and increased evaporation did not allow to respond to climate change, contributing to an increase in the moisture content of the basin. However, at present, the level of Balkash has returned almost to the marks of the 1960s - 1970s. Thus, the natural increase in the water discharge of the rivers of the basin due to the growth in the amount of annual precipitation compensated for the loss of runoff due to economic activity over the past decades. The dynamic analysis of the meteorological features is carried out with the average monthly air temperature and precipitation at 4 meteorological stations located in the Ile-Balkhash region. Diagrams on change of average annual temperatures of air and quantity of annual sums of precipitation and its values averaged on decades are constructed. Let’s take the example of Almaty, Kogaly, Usharal and Bakhty meteo-stations. That is, weather stations were selected which are located in certain areas of the Ile-Balkhash basin, in order to assess changes in meteorological features of the basin as a whole. As a result, the regularity of increasing air temperatures and precipitation along with the increase in the water content of the rivers of the researched region was revealed.

4. CONCLUSION

Based on the considered conditions of the hydrometeorological situation in the region, at present, one of the main tasks should be to increase the liability measures of all water users, increase observation points for the characteristics of the regime of water bodies, monitor industrial, municipal and agricultural water intakes and water discharges to the river network, improve methods and principles of water use. Also, it is necessary to carry out modeling of the formation of river runoff in the basin in the context of different variants of climate change forecasts and the development of economic activities in the region to develop recommendations for the sustainable development of the Ile-Balkhash water basin.

Creating models for the formation of river runoff in the Ile-Balkhash basin is possible using the experience of research and assessment of changes in the water regime of the rivers of the Syrdarya and Amudarya basins depending on various scenarios for the development of hydrometeorological conditions in Central Asia. In particular, previous studies (Kalashnikova & Gafurov, 2017; Unger-Shayesteh et al., 2013; Kriegel et al., 2013), present the results of forecasting the runoff of the Naryn River using ground-based and satellite data on snow covers. As noted here, there are also intense processes of warming and increasing precipitation since the 70s of the last century. Similar hydrometeorological conditions of runoff formation in the basins under consideration suggest using runoff calculation algorithms and creating models of its formation on the Pamir and Tien Shan rivers in the practice of the Kazakh Hydrometeorological Service for the Ile-Balkhash basin rivers, the annual runoff of which is primarily due to snow storage during the winter, melting glaciers in the warm season and rains. In the percentage ratio, on average for this region, the share of these components of the rivers in the annual runoff, respectively snow - up to 85%; glacial - from 12 to 17.5%; rainfall from 7.5 to 23% (Iskakov & Medeu, 2006).

At the same time, an increase in average annual air temperatures and precipitation leads to a retreat of the climatic snow line and an increase in glacial and snow runoff of rivers, which affects their intra-annual regime and requires more in-depth research and analysis of the current changes in the region's water resources and forecasting their future state.
In the future, it is planned to build a number of reservoirs in the region for the purpose of energy and social security of the region. Global climate changes which make significant adjustments in the water regime of rivers in the region contribute to quantitative and regime changes in flow features. It is necessary at planning and designing of economic activity of the region and water use.

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