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The Irtysh River hydrological regime changes on the territory of the Republic of Kazakhstan in the conditions of the Upper Irtysh reservoir cascade functioning

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ABSTRACT

Relevance. The paper considers specific features of water resources formation in the Kazakhstan part of the Irtysh River basin connected with the transboundary nature of the river and the need to assess the ecological runoff required to coordinate long-term water use plans in the transboundary area. The main features of the hydrological regime of rivers of the basin, peculiarities of runoff formation and regulation are discussed. **Methods.** The main research method is a statistical analysis of the time series of annual and seasonal runoff for the main hydrological observation stations at the Irtysh River main channel and a comparative analysis of the obtained characteristics for different periods of economic activities in the basin. **Results**. Based on the collected hydrological monitoring data, there have been obtained estimates of changes in the state of water resources due to large-scale hydraulic engineering construction; changes in the annual and seasonal river flow considered. Quantitative estimates of water resources coming to the territory of the Russian Federation from Kazakhstan for various periods of economic activities have been obtained.

KEYWORDS: the Irtysh River, water resources, runoff regulation, hydrological regime changing, transboundary water problems

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INTRODUCTION

The water resources of the Irtysh River are formed on the territory of four states (Mongolia, China, Kazakhstan, and Russia) under various physical and geographical conditions and experience a noticeable anthropogenic load consisting mainly in

the runoff regulation made mainly for energy purposes, as well as in water intake for various needs.

The transboundary nature of the river determines methodological and informational problems arising when assessing current run-off changes and calculating allowable intakes when solving transboundary water problems between the Republic of Kazakhstan and the Russian Federation. The main difficulty in making water management decisions lies in the lack of reliable information on water consumption and waste water disposal both in the Kazakhstan and Chinese parts of the Irtysh basin.

The hydrological regime of the river is studied at a very limited number of observation stations, which does not contribute to obtaining reliable estimates of the runoff (current and predicted ones).

To provide data necessary for solving the problems of transboundary water use in the part of the Irtysh basin under study, hydrological information was collected from open sources and processed in the form of time series of annual, seasonal and monthly runoff, which eventually made it possible to determine the nature of the changes in the hydrological regime, as well as statistical parameters of flow distributions and bring the estimated values into river stations corresponding to the cross-points of state borders.

The difficulty of obtaining reliable estimates of the characteristics of the Irtysh river flow in conditions of intense economic influence lies in the insufficient number of observation stations in Kazakhstan. The closest to the RF border and more or less reliable open flow data are available at the Ust-Kamenogorsk HPP. There are no significant tributaries in the area from the Ust-Kamenogorsk HPP to the state border, and the floodplain hydrograph is greatly transformed by the floodplain. The lack of data on discharges from the downstream Shulbinskaya HPP and generally reliable measurements at this non-tributary site makes it very difficult to calculate channel water management balances and discuss environmentally acceptable runoff regimes.

The changes taking place under the influence of economic activities in various parts of the Irtysh basin have been discussed in a number of publications by Kazakh and Russian authors in various publications, theses included. The paper presents conclusions about the changes (violations) of stability made on the basis of long-term series, observations of recent years taken into account.

The estimates obtained are necessary to coordinate water use development plans, determine environmentally acceptable volumes of runoff withdrawals and solve other issues on implementation of the Agreement between the Government of the Republic of Kazakhstan and the Government of the Russian Federation on the Joint Use and Protection of Transboundary Water Bodies dated September 7, 2010.[1]

1 Agreement between the Government of the Republic of Kazakhstan and the Government of the Russian Federation on the joint Use and Protection of Transboundary Water Bodies dated September 7, 2010. *Bulletin of International Treaties.* 2011. No. 4. P. 73.

OBJECT AND METHODS OF RESEARCH

General characteristics of the climatic conditions and hydrological regime of the Irtysh

The climate in the Irtysh river basin is continental, which determines a long cold winter (for most of the territory) and a relatively warm, even hot in the south summer. In general, in the northern part of the Irtysh river basin, the average annual air temperature is –1.4 °C, in the central part – about 0°C, in the southern part – +1.5...+2 °C. In the middle course of the Irtysh, transition over 0° C is observed at the beginning of the second decade of April, in the southern part – in early April. Accordingly, there spreads the snowmelt front from south to north, which determines the timing of the onset of flooding on the rivers. Snow cover is formed in the south on average at the end of November, in the north – at the end of October, and it melts in early April and early May, respectively.

Precipitation decreases by zones from west to east and from north to south amounting to 400–500 mm for most of the territory. The greatest amount of precipitation (75–80 per cent) falls in warmer months. In mountainous areas, precipitation is strongly influenced by the terrain; therefore to determine it, there are used dependences on the average height of the catchment area.

Snowmelt conditions are also different in the territory under study. In flat and low-mountain-foothill areas, snowmelt is mainly of the solar type; evaporation of melt water being high at the beginning of snowmelt. The snow cover may completely disappear before positive average daily temperatures.

A characteristic feature of the basin's lowland rivers is the loss of riverine accumulation in low-water years. In low-water years, all or almost all of the runoff of small rivers can be used to fill channels, with subsequent evaporation in summer.

The variety of natural conditions in the area under study determines differences in conditions of runoff formation in different parts of the catchment area. A significant part of the left bank of the Irtysh, as well as its flat right bank belong to areas of insufficient moisture[2] [1]. The surface runoff in flat and low-mountain-plain territories is formed solely due to melt water. In summer, rainfall is almost completely consumed by evaporation and does not form a surface runoff. The underground component of the runoff is small, practically absent in temporary watercourses. On rivers with a predominant low-mountain – mid-mountain relief in the left-bank part of the basin, groundwater supply increases, but melt water also prevails here. The majority of rivers in the right-bank part of the Irtysh basin are supplied by snow melt waters. In the upper reaches of rivers, the underground and rain component increases; glacial factor emerging.

In general, it can be concluded that on the entire territory of the Irtysh basin, high water is the main phase of the water regime when the main part of the run-

2 Surface water resources of the USSR. Vol. 15. Altai and Western Siberia. Issue 1. Gorny Altai and Upper Irtysh. Part 1. Leningrad: Hydrometeorological Publishing House, 1969. 316 p.

off passes and the maximum water flows are formed. Since 1960, the maximum annual water consumption of the Irtysh River in Omsk has been characterized by a decrease under the influence of the Upper Irtysh reservoir cascade, with no statistically significant changes in Tobolsk. The lowest annual minimum water discharges in the Irtysh basin are observed in winter. In recent decades, there has been a statistically significant increase of water consumption primarily due to runoff regulation.

A characteristic feature of multiyear fluctuations of the Irtysh water resources is the presence of high-water and low-water phases, the duration of which can reach several decades, and the absence of statistically significant unidirectional trends. A more detailed description of the features of multiyear fluctuations in runoff and conditions for the formation of water resources in the Irtysh basin is presented in works[3] [2–4].

Hydro-meteorological awareness and climatic changes of runoff

To analyze the water regime of the Irtysh, there have been used data from regular observations of river flow in the Kazakhstan and Russian parts of the basin. There are three river stations in the Russian part of the Irtysh River basin up to Tobolsk (Table 1). Tobolsk is already an internal Russian river station, but its data are used for comparative assessment of the impact of runoff withdrawals on water resources. In Kazakhstan, hydrological observation data are available at two river stations located on the main riverchanel.

The data on the monthly, annual, maximum and minimum summer-autumn and winter runoff for the entire observation period served as the starting materials for the analysis of multiyear fluctuations in the river flow. The hydrological series used in the work are formed on the basis of various sources: the VNIIGMI-MCD database containing water consumption data before 1985, the GMVO AIS – since 2008, the Kazhydromet Hydrological publicly available yearbooks, the archives of the State Hydrological Institute and the Moscow State University prepared by digitizing yearbooks published in different years.

Table 1. Information about hydrological stations in the Irtysh River basin used in this work

Code	Waterbody – station	Distance from		Catchment basin, km^2
		riverhead, km	mouth, km	
11001	the Irtysh (the Black Irtysh) – Buran	560	3688	55 900
11018	the Irtysh – the Ust-Kamenogorsk HPP	700	3089	146 000
11048	the Irtysh – Omsk	2424	1824	769 000
11634	the Irtysh – Tatarka	2226	2022	596 000
11056	the Irtysh – Tobolsk	6470	416	958 000

3 The scheme of integrated use and protection of water bodies in the Irtysh river basin. Nizhny Ob Basin Water Management / FSUE RosNIIVH, 2014. Access mode: https://nobwu.ru/index.php/ndvskiovo (date of application: 25.06.2025).

The analysis of multiyear hydrological observation data and the assessment of flow characteristics were carried out in accordance with recommendations of SP 529.1325800.2023.[4]

In 2016–2019, the State Hydrological Institute carried out research, one of the main tasks of which was to assess changes in the main characteristics of river flow in the conditions of ongoing climatic transformations [5]. The research shows that since the mid-1980s, on the rivers of the Russian part of the Irtysh basin climate changes have led to an increase in the annual runoff in the range of 10–20 per cent compared with the previous multiyear period. Significant positive trends have been identified in the minimum winter river runoff and in general in the runoff during the cold season. Unfortunately, it is difficult to draw the same conclusion about water resources in the Kazakhstan part of the basin because the flow of the Irtysh is highly regulated and up-to-date data on other rivers in the Kazakhstan part are not available. The results of scenario calculations of changes in the Black Irtysh runoff under the influence of predicted climate changes are presented in [6].

RESULTS AND DISCUSSION

Transboundary water use problems and description of the water management complex in the Irtysh basin

In the upper reaches, the Irtysh River (the Black Irtysh) flows on the territory of the Ili-Kazakh Autonomous Okrug of the Xinjiang Uygur Autonomous Region of the People's Republic of China. A small part of the catchment area is located within the boundaries of the Bayan-Ulga Aimag of the Mongolian People's Republic. The catchment area of the Irtysh River in the upper and middle reaches is located on the territory of the Republic of Kazakhstan within the borders of East Kazakhstan, Pavlodar, Akmola, North Kazakhstan and Kostanay regions; small catchment areas being in Karaganda and Ulytau regions (Table 2).

Table 2. The shares of different states in the Irtysh catchment basin

Country	Area in the Irtysh River basin, thousand km^2	The share of each state in the Irtysh catchment basin, per cent
The Russian Federation	683,2	60,6
The Republic of Kazakhstan	392,4	34,8
The People's Republic of China	51,3	4,5
The Mongolian People's Republic	1,4	0,1

The use of the water resources of the Irtysh varies in the Chinese and Kazakhstan parts of the catchment area. Since 2000 when the Irtysh (the Black Irtysh) – Karamai canal was put into operation in China, diversion capacity has increased

4 SP 529.1325800.2023. Determination of the main calculated hydrological characteristics. Moscow: Ministry of Construction of Russia, 2023. 103 p.

from 1–1.5 km^{3}per year to 2 km^3 per year and more at present [7]. On the territory of the Republic of Kazakhstan, the flow of the Irtysh River is regulated by the cascade of Upper Irtysh reservoirs (Bukhtarma, Ust-Kamenogorsk, Shulbinsk), the largest of which is the Bukhtarma reservoir (Fig. 1).

The Irtysh – Karaganda canal transfers part of the river's flow to Karaganda and Akmola regions, as well as provides water to Nur-Sultan (Astana), the capital of the Republic of Kazakhstan [2].

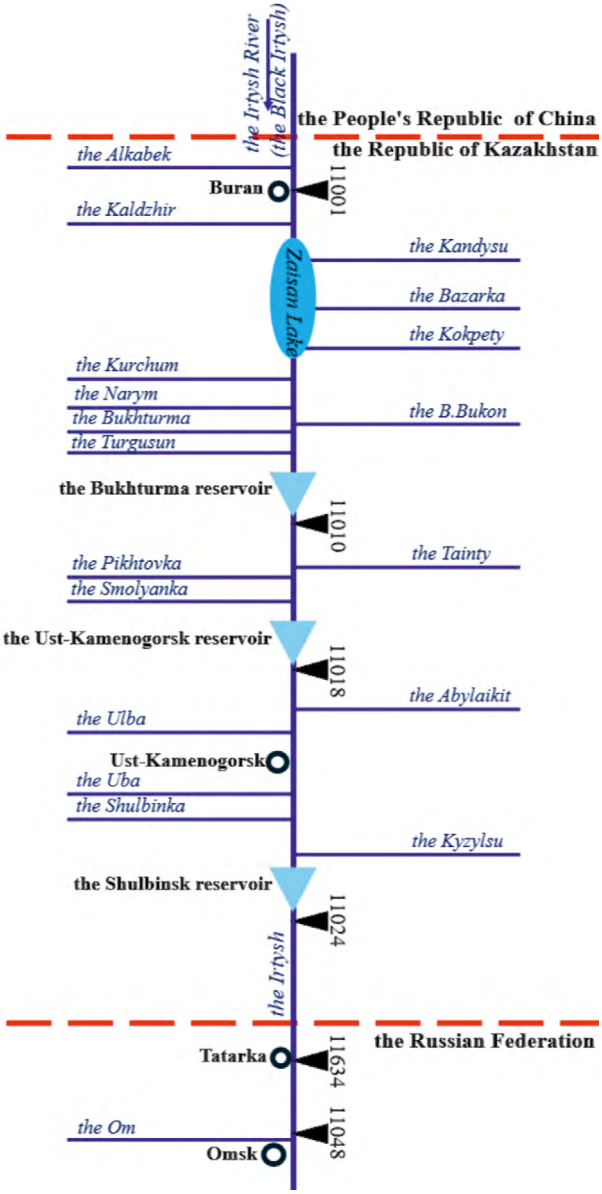


Fig. 1. The scheme of the main reservoirs and hydrological observation stations in the Irtysh River basin on the territories of Kazakhstan and Russia (up to the city of Omsk)

Results of studying water management problems of the Irtysh basin are covered in a number of works [8–12]. Next, we will give a brief description of the basin water management complex and provide basic information about waterworks facilities.

Reservoirs of the Upper Irtysh cascade carry out multiyear and seasonal regulation of the flow of the Irtysh (Table 3). Reservoirs were filled in the period of 1962–1967.

The Bukhtarma HPP carries on multiyear regulation of the flow of the Irtysh and, if necessary, discharges to cover the lack of water for spring flooding of its floodplain. The high degree of flow regulation carried out by the Bukhtarma reservoir determines the operation of the Ust-Kamenogorsk reservoir of small capacity, which is used for intraday regulation. During the navigation period, the Bukhtarma reservoir draughts to ensure the required navigation costs in the lower reaches of the Ust-Kamenogorsk HPP and supply water consumers before the dam of the Shulbinskaya HPP.

The reservoir of the Shulbinskaya HPP carries on seasonal regulation of the lateral inflow and ensures spring flooding of the floodplain by emptying its own useful capacity and creating no barriers to the flood transit of the lateral inflow between the dams of the Bukhturma HPP and the Shulbinskaya HPP; in case of insufficient lateral inflow, the Bukhtarma reservoir operating in compensation mode.

The participants of the Upper Irtysh Water Management Complex (WMC) include: power engineering, water transport, industry and population, fisheries and agriculture.

Table 3. Main characteristics of Upper-Irtysh cascade reservoirs

Characteristics	Measures	Data		
		Bukhtarma HPP	Ust-Kamenogorsk HPP	Shulbinskaya HPP
Normal headwater level (NHL)	m (BSH)	394,84	327,84	240,0
Top of dead storage (TDS)	m (BSH)	387,84	326,84	232,0
Reservoir capacity at NHL	km³	49,62	0,66	2,39
Reservoir capacity at TDS	km³	18,81	0,62	0,92
Conservation zone	km³	30,81	0,035	1,47
Capacity component of long standing	km³	26,02	–	–
Water-surface area at NHL	km³	5490	37,9	254,8
Lake Zaisan included	km³	3750		
Water-surface area at TDS	km³	3140	35,5	130,0
Lake Zaisan (in natural conditions)	km³	2000		

In the spring period, an environmental release is carried out from the Shulba reservoir in order to maintain close to natural conditions in the middle course of the Irtysh River during the passage of spring floods. If the conditions of the release are met, the maintenance of the fodder supplies for agriculture in the Pavlodar region is ensured and conditions for fisheries are improved [13–14].

The amount of discharge consists of the costs of the Bukhtarma HPP operating in the power level, the lateral inflow at the Bukhtarma – Shulbinskaya HPP site and the operating costs of the Shulba reservoir. If necessary (in case of low-water flooding), increased energy discharges at a flow rate of up to 1100 m^3/sec. are provided from the Bukhtarma HPP. The discharge volume is 4.8 km^3 (including costs up to 2000 m^3/sec. in the final phase of the discharge). The discharge duration is from 15 to 21 days.

The water management complex of the Irtysh basin was characterized by significant amounts of water intake and volumes of irretrievable water consumption. By the mid-1980s, the total volume of diversion capacity from the river network and groundwater in river basins within the Soviet Union amounted to more than 10 km^3 per year, with discharge into water bodies being about 5 km^3 per year. At the same time, for the Russian and Kazakhstan parts of the basin, the intake and discharge were approximately 6 km^3 per year and 4 km^3 per year[5], respectively. After the collapse of the USSR, there was a sharp decrease in water consumption. Thus, in the Russian part of the basin, the total intake of surface and groundwater is currently about 2 km^3 per year, with the discharge being about 1.6 km^3 per year. Data on the current use of river and groundwater in the Kazakhstan part of the basin are not available.

The assessment of the current distribution of total water intake in the Irtysh basin of the three countries is as follows: Kazakhstan – 50.8 per cent, China – 25.5 per cent, Russia – 23.7 per cent [7].

Multiyear changes in the runoff of the Irtysh basin' rivers under the influence of economic activities

Of the total runoff of the Upper Irtysh, approximately 25 per cent is formed on the territory of China and 75 per cent – on the territory of Kazakhstan (of which 40 per cent of the annual runoff is from small rivers directly flowing into the Irtysh from the border with China to the mouth of the Bukhtarma River, and 35 per cent from the Ulba, the Uba and small tributaries flowing into the Irtysh River below Ust-Kamenogorsk). Downstream from the inflow of the Uba, there are no significant Irtysh tributaries for about 1,200 km up to Omsk (the Om').

The influence of economic activities in Kazakhstan and China on the flow of the Irtysh is significantly weakened downstream from Omsk due to significant lateral inflow, in Tobolsk the share of river flow formed in Russia being 61 per cent.

5 Surface and groundwater resources, their use and quality. 1982–2015. The annual edition. Water Cadastre of the Russian Federation, 1982–2015..

Data from four hydrological stations on the territory of Russia and Kazakhstan (the Irtysh River – the village of Buran, the Irtysh River – the village of Tatarka, the Irtysh River – the Ust-Kamenogorsk HPP, the Irtysh River – Omsk) were used as the basic information on the regime of the Irtysh River in the area from the border of the Republic of Kazakhstan and the Russian Federation to Omsk) (Fig. 1).

To assess the ongoing changes in the flow of the Irtysh River and calculate the values of permissible withdrawals in adjusting transboundary water relations between the Republic of Kazakhstan and the Russian Federation, it is necessary to determine statistical parameters of the flow distributions and bring them into river stations corresponding to entry points.

In order to explain the proposed calculation method, it is necessary to note the following:

– the Irtysh – Buran water guage station records the flow of the Irtysh coming to Kazakhstan from China. Upstream in the Kazakhstan part of the Irtysh basin, there are several small tributaries having insignificant runoff;

– the Irtysh – Tatarka hydrological station is the closest to the state border of the Republic of Kazakhstan and the Russian Federation, but monitoring of the outflow started in1984;

– data at the Irtysh – Ust-Kamenogorsk hydrological station include measurements before building the hydroelectric power station and its discharges afterwards. There is a slight difference in the catchment areas corresponding to these hydrological stations;

– the longest observation period of the flow of the Irtysh River is at the Irtysh – Omsk hydrological station. The series of observations is 100 years old and can be used to extend the runoff hydrological series on the village of Tatarka;

– during the period from 1962 to 1967 inclusive, the reservoirs of the Upper Irtysh cascade were being filled, therefore, the observation data for this period were not taken into account when analyzing flow regimes and parameters.

The analysis of the hydrological regime of the Irtysh River from the border of the People's Republic of China and the Republic of Kazakhstan to the hydrological station of the Irtysh River – Omsk (inclusive) included the following studies and assessments:

– extending the flow range of the Irtysh River at the river station of Tatarka for the conditionally natural period up to 1961;

– assessing changes in the annual flow of the Irtysh River on the observation sites both for the periods before and after filling reservoirs;

– assessing changes in the seasonal flow of the Irtysh River (in the periods: April – August; September – November; December – March) on the observation sites; the periods before and after filling reservoirs included;

– analyzing the intra-annual distribution of runoff on the observation sites; the periods before and after filling reservoirs included;

– analyzing the average monthly water discharge of the Irtysh River on the observation sites.

Table 4 presents estimates of runoff rates (average values) for selected sites and periods obtained from observational data.

Table 4. Runoff average values for selected periods for the stations on the Irtysh River on the territory from the Chinese – Kazakhstan border to the Kazakhstan – Russian border

River – station	Observation period years.	Annual discharge, m^3/sec.		
		The whole observation period	Period before filling the reservoir in 1961	Period after filling the reservoir in 1968
the Irtysh (the Black Irtysh) – Buran	1938–2022	288	324	274
the Irtysh – the Ust-Kamenogorskaya HPP	1903–1961	589	623	567
the Irtysh – Tatarka	1983–2023	795	–	795
the Irtysh River – Omsk	1923–2023	881	932	861

In order to bring the series of annual and monthly runoff of the Irtysh River at the station of Tatarka to the multiyear period there were used regression, the parameters of which were estimated based on observational data. The graph of the dependence of the amount of annual runoff of the Irtysh River at the station of Tatarka on the runoff at the station of Omsk the periods of 1983/1984–1984/1985, 1989/1990–2022/2023 shows a close relationship between the annual runoffs at doth stations (Fig. 2).

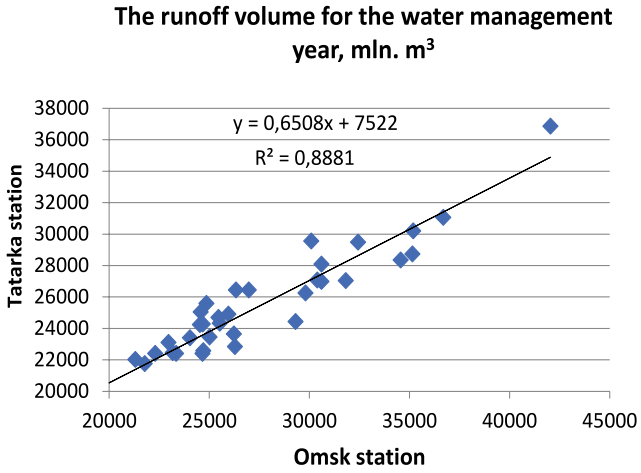


Fig. 2. Dependence of the Irtysh River annual runoff at the station of Tatarka on the annual runoff at the station of Omsk for the periods of 1983/1984–1984/1985 and 1989/1990–2022/2023

The volume of the annual runoff of the Irtysh River at the station of Tatarka is calculated using the regression equation. Intra-annual runoff distribution by month is in the same ratio as at the Omsk station (for corresponding years).

Analysis of changes in the annual flow of the Irtysh River in the periods before and after filling the reservoirs of the Upper-Irtysh HPP cascade

Until 1961 (the beginning of filling the Bukhtarma reservoir) the water regime of the Irtysh River can be conditionally considered as close to the natural one. In subsequent years, there were changes in the parameters and flow regime due to creating reservoirs, increasing water consumption; water intakes into the Irtysh – Karaganda Canal included.

The statistical analysis, the results of which are presented in Fig. 3 and in Table 5, allows us to compare the dynamics of the annual flow of the Irtysh River at the stations under study, assess the change in the average annual flow and standard deviation at the above stations for two periods (before 1961 and since 1968).

Since 1968 the average runoff has been decreasing at each river station, the absolute value of this decrease being the greatest downstream the Irtysh River (Omsk), and as for the average multiyear yield (in per cent) – upstream (the village of Buran). The decrease in the average annual runoff at all stations results from a complex of factors: runoff regulation, rising irretrievable water consumption, increasing number and area of ponds and dams, growing area of agricultural land, etc.

Table 5. Statistical parameters of the Irtysh River annual runoff at the observation stations since 1938/1939

Period	Mean value, mln. m^3				Standard deviation			
	Omsk	Tatarka	Ust-Kamenogorsk HPP	Buran	Omsk	Tatarka	Ust-Kamenogorsk HPP	Buran
before1961 г.	30 552	27 087	19 760	10 273	7456	5746	4902	2403
since 1968 г.	27 273	25 022	17 925	8742	4802	3210	2681	2530
The whole period	27 924	25 415	18 226	9156	5883	4195	3616	2593
Difference: period 1 – period 2	3279	2065	1835	1531	2654	2537	2221	−127
Per cent	11,7	8,1	10,1	16,7	45,1	60,5	61,4	−4,9

The standard deviation (absolute value and in per cent relative to the average for the entire period) decreased significantly at all river stations except the Irtysh River – Buran station upstream. The decrease in the amplitude of fluctuations in annual runoff by years is due to the influence of runoff regulation by reservoirs located upstream. Quantitative estimates of the parameters of the annual runoff at the observation sites for different periods are presented in Table 5 and in the form of graphs in Fig. 3.

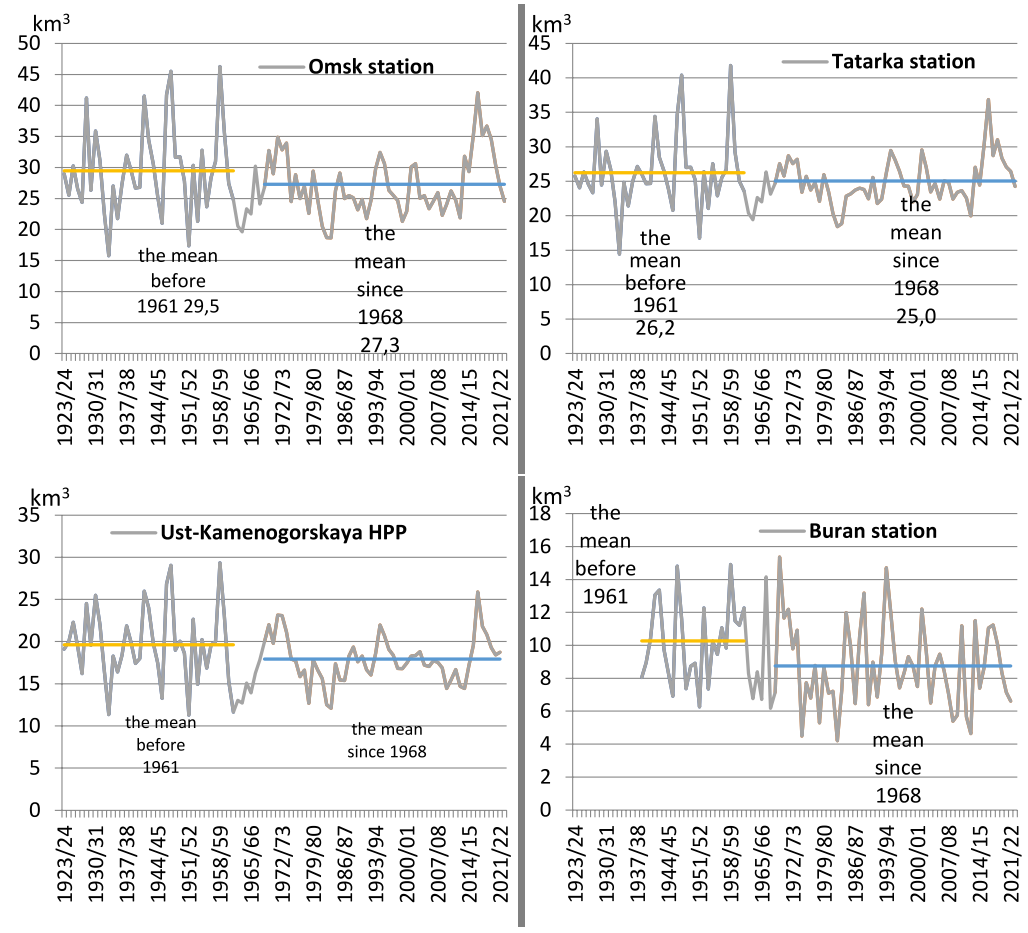


Fig. 3. Changes in the Irtysh River annual runoff at the river stations and the average value for two periods: before 1961 and since 1968

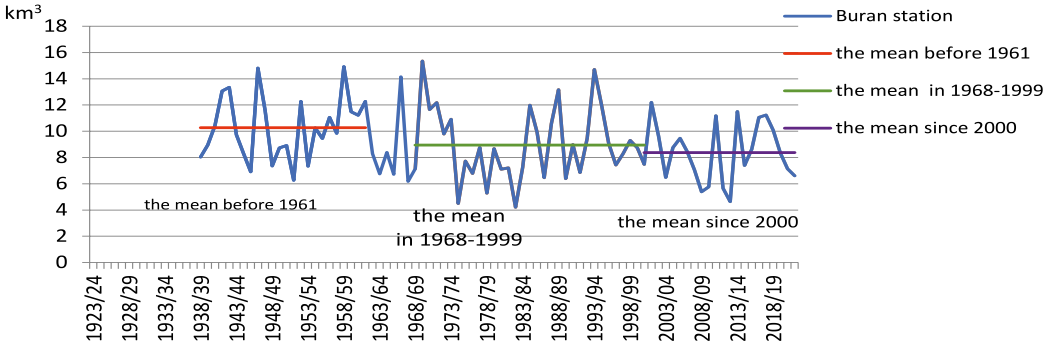


Fig. 4. Changes in the average annual runoff at the Buran station for three periods: before 1961, for 1968–1999, since 2000

For the Irtysh River – Buran station Fig. 4 additionally shows the average annual runoff for the period of 2000/2001–2022/2023 amounting to 8.37 km^3, which indicates a 0.58 km^3 decrease in the average annual runoff compared to the previous period (1968/1969–1999/2000).

To confirm the revealed changes in the runoff, there have been calculated paired coefficients of correlation of annual runoff between the observation sites for the periods up to 1961 and since 1968, which are shown in Table 6. Before 1961, the relationship between the stations was closer than after 1968. For example, the paired correlation coefficient of runoff at Omsk and Buran stations was 0.75 before 1961 decreasing to 0.58 after 1968. This indicates the influence of reservoirs on the annual runoff because the system carries out a rather deep multiyear regulation of it.

Table 6. Paired coefficients of the annual runoff correlation between the Irtysh River stations for the periods before 1961 and since 1968

River station	Period	Omsk	Tatarka	Ust-Kamenogorsk HPP	Buran
Omsk	before 1961	1	0.98	0.94	0.75
	since 1968		0.94	0.79	0.58
Tatarka	before 1961		1	0.92	0.74
	since 1968			0.82	0.53
Ust-Kamenogorsk HPP	before 1961			1	0.71
	since 1968				0.53
Buran	before 1961				1
	since 1968				

Analysis of changes in seasonal runoff of the Irtysh River at the observation stations

Next, let's look at seasonal flow changes. Changes in the runoff for the spring-summer period (April – August) are also characterized by comparing parameters for two periods (Table 7).

Table 7. Statistical parameters of the seasonal runoff for the period of April – August at the stations since 1938/1939

Period	Mean value, mln. m^3				Standard deviation			
	Omsk	Tatarka	Ust-Kamenogorsk HPP	Buran	Omsk	Tatarka	Ust-Kamenogorsk HPP	Buran
Before 1961.	21 310	18 907	–	8166	4975	3857	–	1870
Since 1968	16 499	14 619	8108	6755	3482	2477	1627	2257
The entire period	17 718	15 774	7975	7152	4546	3511	1610	2262
Difference: period 1 – period	4811	4288	–	1411	1493	1380	–	−387
Per cent	27,2	27,2	–	19,7	32,8	39,3	–	−17,1

A comparison of the runoff values at the stations for the period of April – August with the annual data shows a more significant decrease in the runoff for April – August in the period after 1968 compared with the annual volume and a smaller decrease in the standard deviation.

Fig. 5 shows the results of comparing the average runoff value for the period of April – August at the stations. The paired runoff correlation coefficients calculated for April – August at the stations for the periods up to 1961 and since 1968 also show that the relationship of runoff at the stations is closer before 1961 than after 1968.

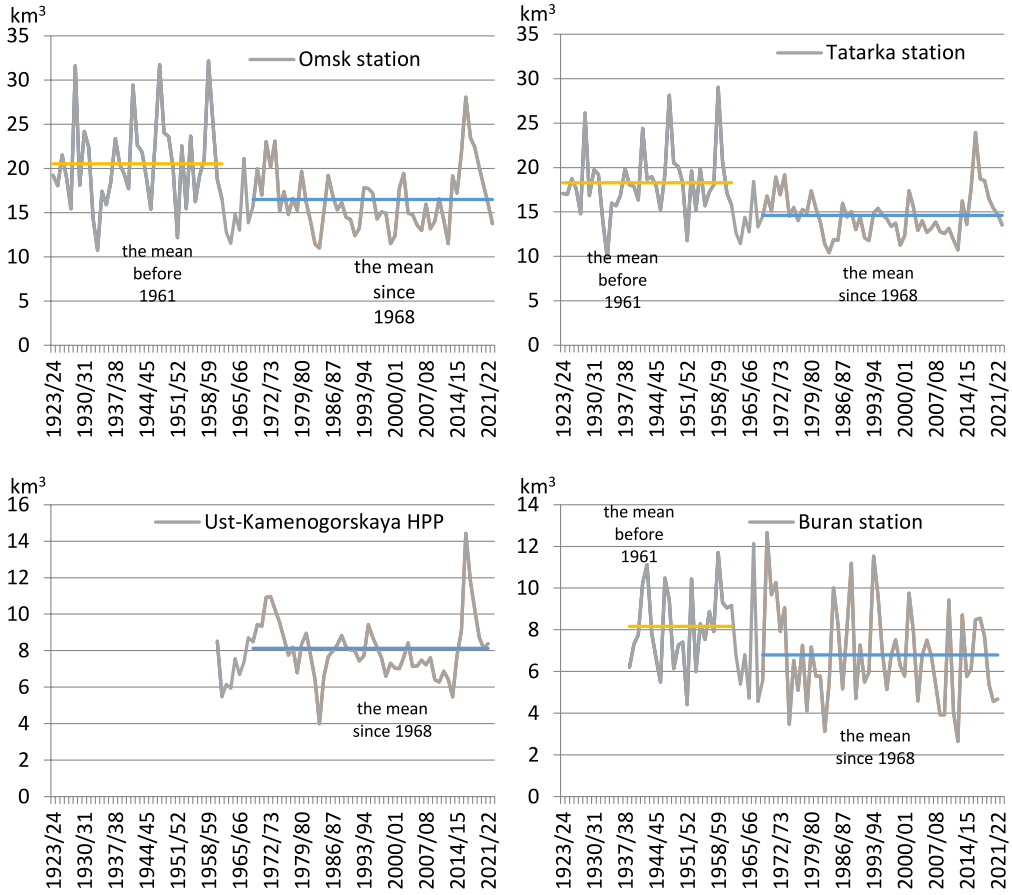


Fig. 5. Changes in the runoff for the period of April – August at the stations and the average value for two periods: before 1961 and since 1968

The average runoff during the autumn low level season (September – November) for the period after 1968 has decreased significantly only at Buran station (a decrease of 20 per cent). At the two lower stations, the average runoff after 1968 has changed slightly relative to the annual average (from 3 to 4 per cent); seasonal runoff data at the Ust-Kamenogorsk station being available only since 1960, so analysis is impossible. The standard deviation in the second period is significantly lower at all stations (Table 8, Fig. 6).

Table 8. Runoff statistical parameters for the period of September – November at the stations since 1938/1939

Period	Mean value, mln. m³				Standard deviation			
	Omsk	Tatarka	the Ust-Kamenogorsk HPP	Buran	Omsk	Tatarka	the Ust-Kamenogorsk HPP	Buran
Before 1961.	5748	5080	–	1429	2081	1664	–	567
Since 1968	5307	5079	4513	1174	771	683	595	389
The entire period	5399	5050	4430	1239	1284	1045	607	450
Difference: period 1 – period	441	1	–	256	1310	982	–	178
Per cent	8,2	0,0	–	20,6	102,1	93,9	–	39,5

Fig. 6 shows graphs illustrating changes in the average runoff value for September – November at the observation stations.

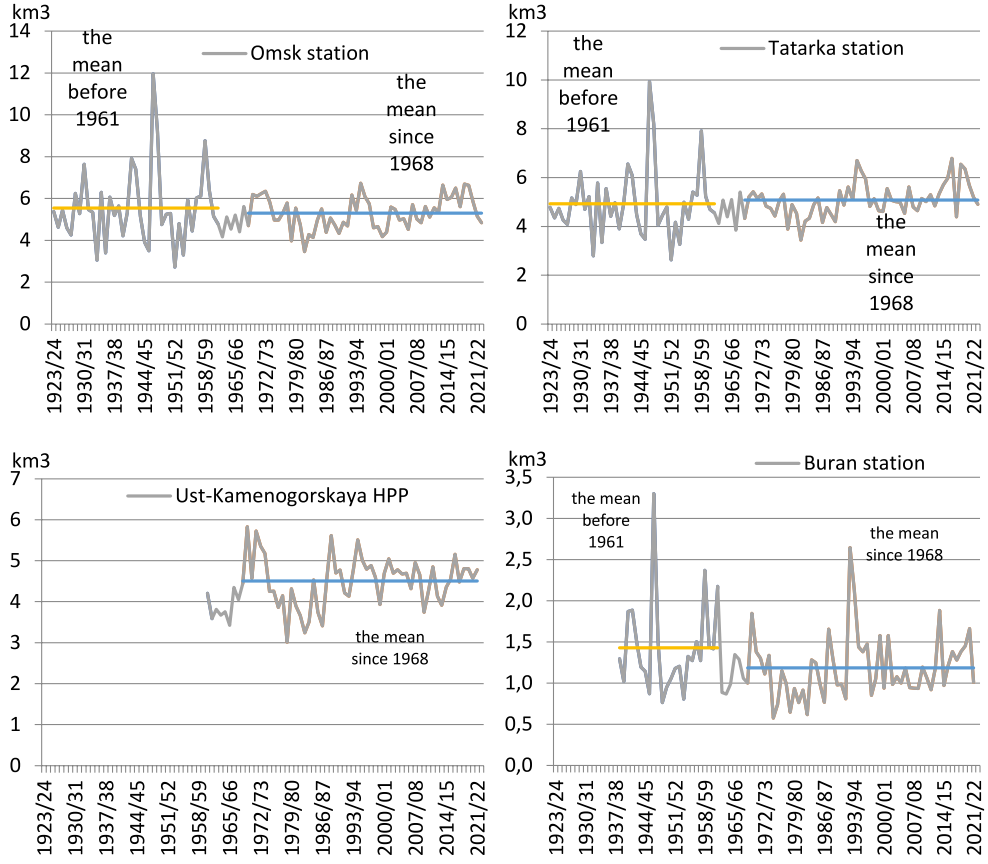


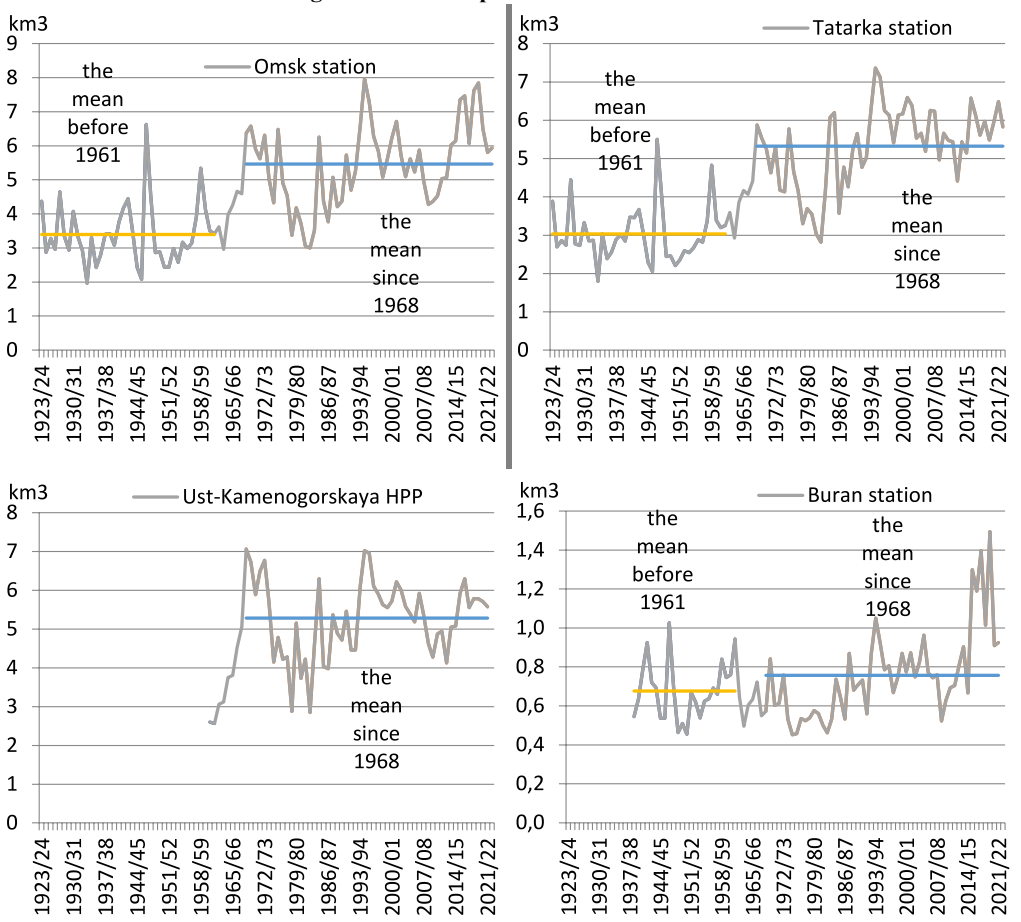
Fig. 6 Changes in the Irtysh River runoff for the period of September – November period at the stations and the average value for two periods: before 1961 and since 1968

Given in Table 9 and Fig. 7 statistical parameters of the runoff for December – March at the stations since 1938/1939 indicate significant changes in the runoff for the winter low water season for two periods – an increase in the average value of the runoff for December – March at all stations.

Table 9. Runoff statistical parameters for the period of December – March at the stations since 1938/1939

Period	Mean value, mln. m³				Standard deviation			
	Omsk	Tatarka	the Ust-Kamenogorsk HPP	Buran	Omsk	Tatarka	the Ust-Kamenogorsk HPP	Buran
Before 1961	3495	3100	–	677	1028	817	–	150
Since 1968	5467	5324	5284	757	1207	1023	974	228
The entire period	4808	4591	5061	723	1440	1378	1121	205
Difference: period 1 – period	−1973	−2224	-	−80	−178	−206	–	−78
Per cent	−41.0	−48.4	-	−11.0	−12.4	−15,0	–	−37,9

Fig. 7. Changes in the runoff for the period of December – March period at the stations and the average value for two periods: before 1961 and since 1968



Calculating paired flow correlation coefficients for December – March at the stations for the periods up to 1961 and since 1968 shows that the connection at the stations is closer before 1961 than after 1968.

As a compiled illustration, Fig. 8 shows the dynamics of annual and seasonal runoff at the Irtysh River – Omsk station. Table 10 provides quantitative estimates of the changes occurred.

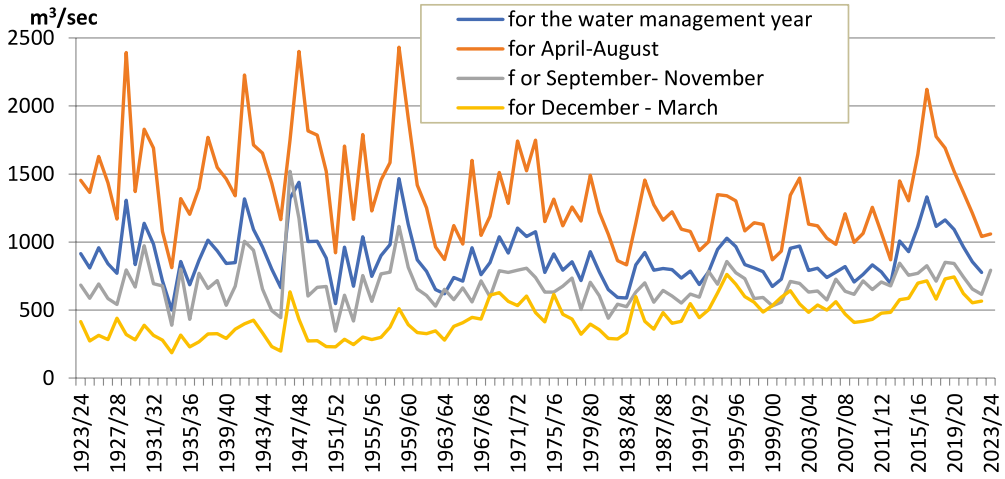


Fig. 8. The Irtysh River annual and seasonal runoff dynamics at the river station of Omsk

After commissioning the reservoirs, there was a redistribution of runoff within the year. As follows from the data in Table 10, before 1961, the average share of runoff for April – August in the annual volume is higher than after 1968. Accordingly, after 1968, the average share of runoff for December – March in the annual volume is higher.

Table 10. Changes in the average runoff volume and shares of seasonal runoff in the annual one at river station of Omsk

Period	Runoff volume, km³				The seasonal share in the annual runoff, %		
	For the water management year	April – August	September – November	December – March	April – August	September – November	December – March
Before 1961	29,48	20,54	5,54	3,40	69,7	18,7	11,6
Since 1968	27,27	16,50	5,31	5,47	60,3	19,6	20,1
The whole period	27,90	17,96	5,37	4,57	64,0	19,3	16,6
Difference:							
period 1 – period 2	2,21	4,04	0,24	−2,07	9,43	−0,98	−8,45
Per cent	7,9	22,5	4,4	−45,3	14,7	−5,1	−50,8

CONCLUSION

Based on the analysis of hydrological observation data in the Irtysh River basin in the Russian Federation and the Republic of Kazakhstan, the following conclusion can be drawn.

The awareness of the hydrological regime makes it possible to assess the ongoing changes in runoff mainly for its annual and seasonal values. The analysis of the monitoring data shows that, compared with the conditionally natural period, there

have been noticeable changes in the state of water resources in the Irtysh basin, mainly due to anthropogenic influence: runoff regulation and irrevocable consumption for the needs of various sectors of the economy. The annual inflow from the territory of Kazakhstan in the main channel of the Irtysh River to the territory of the Russian Federation has decreased compared to the period of the natural regime.

Runoff regulation and water consumption have led to significant disruptions in the regime of multiyear fluctuations in seasonal runoff. Changes in seasonal runoff are multidirectional by season, which is mainly due to the peculiarities of its regulation; energy use of water resources prevailing. For seasonal runoff, there is a decrease in high-water runoff and runoff of the autumn fall; the runoff of the winter fall increasing significantly (up to 45 per cent).

Further research on the use of water resources of the transboundary Irtysh River should include a more detailed study of the hydrological regime of the river in the area below the Shulbinskaya HPP in order to assess runoff losses, the required floodplain irrigation regime in both the Kazakhstan and Russian parts, and the overall water management balance of this area due to the planned increase in water consumption. The construction of the Semipalatinsk HPP proposed by the Kazakh side is particularly relevant to the obtained and planned results. Its construction and operation may have a significant impact on the hydrological regime and ecosystem of the river in both the Kazakh and Russian border sections of the Irtysh.

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