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# ASSESSMENT OF CHANGES AND USE OF WATER RESOURCES IN THE SYRDARYA RIVER

*Abstract*

Rational use of water resources is of current importance in the integrated use and regulation of flow. Therefore, a water management calculation is needed that will allow water resources to be distributed efficiently and unacceptably, without allowing them to be overused. The article discusses issues of assessing the water resources of the Aral-Syrdarya water basin. To analyze the hydrological characteristics of the basin under study, series of annual water runoff were reconstructed and chronological graphs of annual runoff were constructed. At calculating the parameters of the annual runoff, total and difference integral curves were constructed, the values of the annual runoff were determined using all sets of data from hydrological posts of the studied Syrdarya River basin. The main statistical parameters of the annual river runoff, random errors in the mathematical expectation and the coefficient of variation were assessed.

For water management calculations, data from the report of the Aral-Syr Darya Basin Inspectorate on regulation of the use and protection of water resources for 2016, as well as the Scheme for the integrated use and protection of water resources in the river basin, were used. Syrdarya for 2018.

Analysis of the water balance for the periods 2010-2018. takes into account that the incoming part of the water balance of the Aral-Syrdarya river basin was 81,690.69 million m3, the outgoing part was 82,446.35 million $m^3$. Based on the data, a water balance was compiled and an analysis was made that the flow decreased by 755.66 million $m^3$, which naturally affected the decrease in the level of the Aral Sea. Also, according to the water balance of the Shardara, Badamskoye, Bugunskoye and Kapshagai reservoirs, accumulation was positive. But in the Koshkurgan reservoir, accumulation was negative.

***Key words:*** *water discarges, annual runoff, statistical methods, water management calculations, water balance of reservoirs.*

## *Introduction*

Rational use and protection of water resources in the Syrdarya river basin have been and remain one of the urgent problems in the system of integrated use and protection of water resources in this region. Increasing anthropogenic load is becoming more and more problematic given climatic changes [1, 2].

As it known, in the lower reaches of the Syrdarya River already in the second half of the last century water deficit was acutely felt and about 30 years ago in its mouth the runoff reduced to almost zero. According to the results of scientific studies [3-5, p. 15-28], the annual runoff of the Syrdarya

River over a multi-year period characterized by instability, which is due to both natural and anthropogenic factors. In the present period, the influence of anthropogenic factor on the natural ecological system is very high. One of the main negative factors is irrational use of water resources.

Over the last ten years, significant changes have occurred in the Syrdarya river basin, having a significant impact on the runoff regime in the lower reaches of the river - the Koksarai counter-regulator was constructed downstream of the Shardara reservoir with a capacity of about 3.0 km$^3$ and a water mirror area of 465.0 km$^2$. Due to this, a part of water that earlier left the reservoir into the Arnasay depression irretrievably (where a reservoir with a length of more than 160.0 km was formed), now returns to the Syrdarya river channel through the counter-regulator, which should eventually lead to an increase in water flow in its lower reaches. (It may be noted here that the Koksarai reservoir itself, having such a large area, annually evaporates up to 0.5-0.6 km$^3$ of moisture into the atmosphere) [6].

Irrigation and reclamation construction are also developed in the Syrdarya river basin. Irrigated lands have increased from 1073 thousand hectares (up to the border of the Republic of Kazakhstan) in 1913 to 3500 thousand hectares at present. The upper reaches of the Syrdarya River used for hydropower purposes. A total of 25 relatively large regional and several dozen small hydropower plants with a total installed capacity of 776.7 thousand kW have been built [4, p. 25-50]. Water requirements of municipal, industrial and agricultural water supply and ponding sectors are approximately 0.6-0.8 km3 of water per year.

Therefore, for effective use of water resources it is necessary to assess changes and use of water resources of the Syrdarya River with the help of information-analytical data, characterizing their changes in a multi-year section as well as calculation and analysis of hydrological characteristics of the Syrdarya River.

Using observational data at hydrological posts located in the Syrdarya River basin, an analysis of long-term changes in water flows for 1990-2020 was carried out according to Kazhydromet data. Data on hydrological stations for which the flow change analysis was carried out are shown in Figure 1.

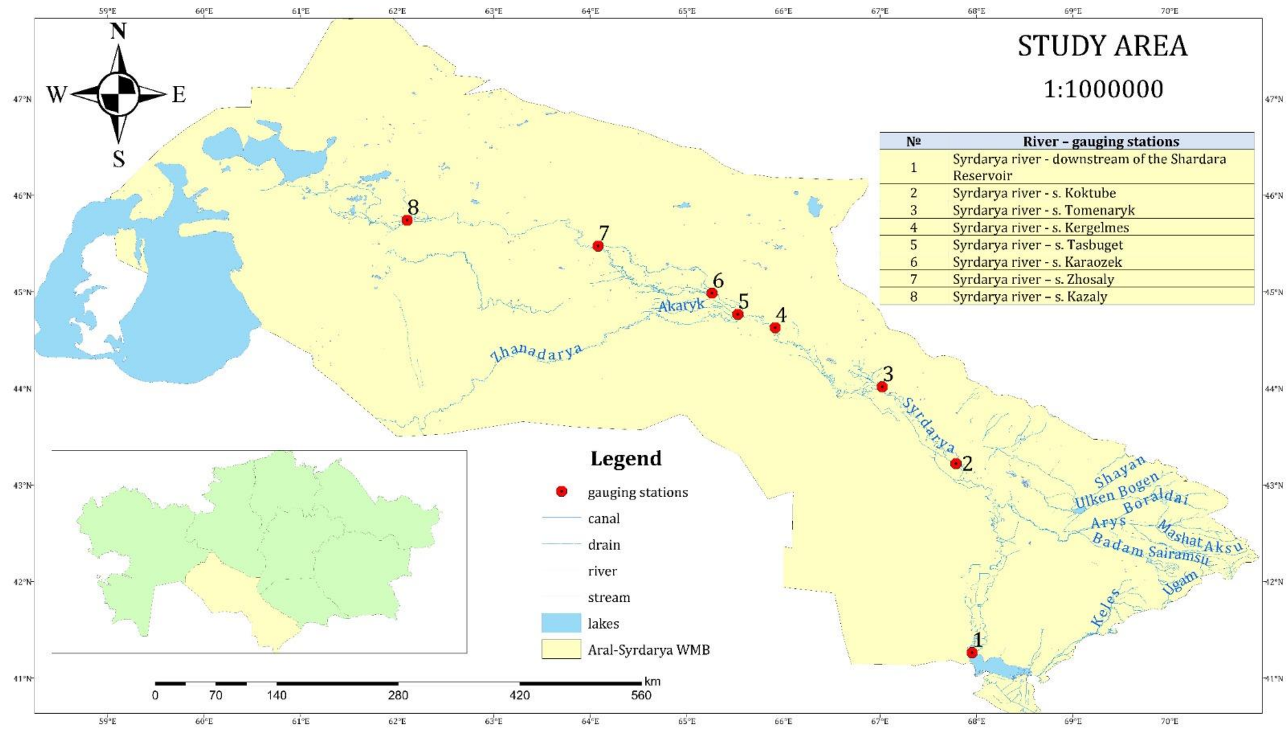


**Figure 1** – Geographical location of the Syrdarya River basin

Observations of runoff characteristics at the hydrometric gauging stations accepted for calculations have omissions of observations. The method of analogy was used to restore the omissions and to calculate long-term average water discharge values. Correlation dependence between water discharge of the studied river and the river-analogue was determined in compliance with the requirements of the absence of anthropogenic factors that distort the natural regime of the river. [8, p. 24; 9, p. 7].

***Methods and materials***

A static series of hydrological observations at a specific river gauging station or observation point is part of the general data set. Therefore, it is necessary to assess how the existing series or the period selected for calculation (calculation period) reflects the typical pattern of runoff change over time in the considered territory, i.e. how representative is the number of observations assumed for calculation [8-10].

Estimation of average annual water discharges is carried out depending on the completeness of the observation series and the reliability of the initial data using the methods described in [10, p. 29]. Statistical methods are widely used in the practice of hydrological research and calculations. In the conditions of the study area, there are incomplete series of observations. The duration of observation periods for average annual water discharges from 6 to 90 years.

In the article [11] analyses of the dynamics of water resources change in the Syrdarya River for different periods (up to 1960, up to 1970, up to 1980, up to 1990 and up to 2000) were made. The assessment of water resources change shows that in all stations there is a decrease in runoff compared to previous periods. For example, in the Kyzylorda gauging station, the average annual discharge of the river decreased from 673.6 $m^3/s$ in the period up to 1960s to 470.5 $m^3/s$ in the period up to 1980s and to 456.2 $m^3/s$ in the period up to 2000s. Correspondingly, at the Kazaly gauging station - from 507.2 m3/s in the period up to the 1960s to 315.9 $m^3/s$ in the period up to the 2000s. The decrease in runoff is 30-40%. Total water withdrawals in the river basin increased from 25.7 km3 in 1931-1960 to 49.8 km3 of water per year in 1986-1990.

The main water consumers are regular irrigation, hayfields, pastures, agricultural water supply, pond farms, natural complexes and including the Aral Sea. The table of water consumption of all indicators for the Aral-Syrdarya water basin is given below. The data were obtained in ASWB [12].

**Table 1 -** Water consumption in the total Aral-Syrdarya basin

| Indicators | **Water consumption in the total Aral-Syrdarya basin, mln $m^3$** | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **2010** | **2011** | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** |
| Collection of all | 8657,7 | 8413,99 | 8908,94 | 8581,20 | 9242,59 | 9077,18 | 8732,670 | 11012,610 | 9064,932 |
| surface | 8449,44 | 8197,83 | 8690,29 | 8364,01 | 9023,60 | 8856,78 | 8513,794 | 10796,886 | 8871,926 |
| Groundwater | 208,26 | 216,16 | 218,65 | 217,19 | 218,99 | 219,27 | 218,876 | 215,724 | 193,006 |
| Transport losses | 1266,66 | 2129,53 | 1870,24 | 1558,48 | 1851,18 | 2075,42 | 1674,498 | 1717,155 | 2046,099 |
| Forced abstraction | 1431,63 | 182,53 | 0 | 0,00 | 172,12 | 0,00 | 0,000 | 1842,170 | 0,000 |
| Usage. Total: | 5959,41 | 6471,2 | 7038,7 | 7022,72 | 7219,29 | 7388,70 | 7058,172 | 7453,285 | 7017,163 |
| domestic drinking water | 71,23 | 76,26 | 83,56 | 77,45 | 84,92 | 94,82 | 88,533 | 83,633 | 69,781 |
| production | 43,45 | 43,62 | 42,33 | 44,01 | 48,21 | 41,05 | 38,024 | 39,889 | 43,199 |
| irrigation reg. | 5137,67 | 5337,06 | 5240,11 | 5656,52 | 5811,33 | 6681,20 | 5638,651 | 5967,004 | 5670,532 |
| hayfield irrigation. | 541,62 | 847,88 | 878,58 | 921,25 | 950,05 | 951,15 | 986,910 | 985,300 | 972,650 |
| agricultural water supply. | 86,4 | 87,33 | 79,93 | 79,29 | 80,31 | 80,41 | 80,741 | 80,361 | 77,886 |
| pasture watering | 60,05 | 60,05 | 62,05 | 62,05 | 63,05 | 63,05 | 63,050 | 63,050 | 63,050 |
| irrigation of green areas | 6,49 | 1,32 | 1,78 | 4,04 | 2,94 | 19,89 | 2,582 | 1,679 | 2,133 |
| fish ponding | 18,63 | 18,77 | 20,19 | 20,19 | 20,19 | 5,14 | 14,349 | 7,797 | 7,380 |
| other needs | 0,36 | 0,23 | 630,17 | 157,92 | 158,29 | 125,08 | 145,332 | 224,572 | 110,552 |

The following paper deals with the construction of reservoirs and their impact on river runoff. The construction of reservoirs, especially for long-term water regulation, has a very significant impact on runoff, including the maximum runoff, and reduces the risk of flooding of territories [13, 14].

Regulation of river runoff in the conditions of the Syrdarya River basin is of great water management importance. The construction of reservoirs allows accumulating spring runoff, which makes up most of the annual runoff volume, and increasing water availability for various sectors of the economy. At present, 24 reservoirs with a total capacity of over 1 million $m^3$ are functioning in the basin. The total usable capacity of the reservoirs is 7.32 $km^3$.

The largest reservoir is the Shardara Reservoir on the Syrdarya River with a designed usable capacity of 4,230 mln $m^3$. The Shardara reservoir is used for irrigation and power generation. Smaller reservoirs with a usable capacity of 0.3 to 365 mln $m^3$ are mainly used for irrigation.

In 2010, the Koksarai flood control reservoir with a usable capacity of 2.5 $km^3$ was constructed. It is designed to protect the lower reaches of the Syrdarya River from floods.

There are 136 hydraulic structures in the Aral-Syrdarya basin (in South Kazakhstan province - 102 HS, in Kyzylorda province - 34 HS). Of them, in republican ownership - 65, in communal ownership - 52, in private ownership - 19.

Total number of reservoirs in the basin - 28, hydroelectric installations - 19, dams - 2, spillway structures - 2, main canals - 74, protective dams - 2 (625.12 km long), ponds - 9. Table 2 shows the main reservoirs of the Aral-Syrdarya water basin [12].

**Table 2 -** Information on the main reservoirs of the Syrdarya River [15]

| NN | Name of reservoir | Watercourse or place of reservoir formation | Volume by project, mln. $m^3$ | | Water level mark, m | |
|---|---|---|---|---|---|---|
| | | | Full | Useful | NSL | DVL |
| 1 | Shardara | r. Syrdarya | 5200 | 4230 | 252 | 244 |
| 2 | Koksaray | r. Syrdarya | 3000 | 2500 | 212,9 | 206 |
| 3 | Akylbeksay | r. Keles | 25 | 24 | 326,5 | 316 |
| 4 | Badamskoe | r. Badam | 61,5 | 59 | 649,4 | 644 |
| 5 | Kapshagai | r. Shayan | 34 | 32 | 451,6 | 435 |
| 6 | Bogen | r. Bogen with feeding from the Arys River | 370 | 363 | 259,8 | 247,6 |
| 7 | Koshkurgan | r. Karashik | 37,3 | 36,3 | 381 | 369 |

The study of consequences of large reservoirs formation is of great scientific interest and has important practical significance in solving problems of rational use and protection of water resources. The basis for its solution is the study of regularity of water resources formation in reservoirs, their influence on river runoff and characteristics of reservoir water balance.

Water balance calculations, based on which quantitative and qualitative indicators of current and future state of water resources in reservoirs are formed, are an effective means of solving water problems in different water management administrations and economies.

Along with graphical methods, the tabular method of flow regulation calculation is applied, which is reduced to solving the reservoir balance equation. For time interval Δt, the balance equation is as follows:

$$\pm \Delta V = Q_a \Delta t = (Q_{inf} - Q)\,\Delta t = [Q_{inf} - (Q_u + Q_c + Q_{loss})]\,\Delta t$$

where ΔV - change in reservoir filling (accumulation). A plus sign corresponds to an increase in reservoir filling, a minus sign to a decrease (drawdown); $Q_a$ - accumulation runoff rate, i.e. the difference between the inflow runoff rate $Q_{inf}$ and the regulated gross flow rate Q; $Q_u$ - used runoff rate; $Q_{idf}$- idle discharge flow; $Q_{loss}$ - total flow rate of water losses and withdrawals from the reservoir [16, p. 189].

***Results and discussions***

During the statistical analysis of the source data, observation gaps in the annual runoff observation series were reconstructed using data from analogue rivers. For each hydrological station under study, several methods were tested and the most effective was selected. The correlation coefficients of the average annual water discharge of the studied river and the analogue river were high: 0.87-0.98.

As a result of the restoration of observational data, the duration of series at many hydrological stations increased.

At choosing analogues for calculating the flow rate and assessing the errors in its determination, the generally accepted recommendations set out in [17] were taken into account.

In the runoff formation zone and in the lower reaches of the Syrdarya River basin, water is used for water supply to the population, development of horticulture, generation of electricity, for grazing livestock, technical and other purposes.

Information on the reconstructed series of annual water discharges, regression equations, correlation coefficients and analogue sites is presented in Table 3.

**Table 3 -** Information on the reconstructed series of annual water discharges, regression equations, correlation coefficients and analogue sites

| River – gauging stations | Observation period | Regression equation | Correlation coefficient, r | Reconstructed years | δ, % | Analogue - river |
|---|---|---|---|---|---|---|
| Syrdarya river - downstream of the Shardara Reservoir | 1961-1963 1965-2020 | y = 0,89x - 3,09 | 0,91 | 1964 | 4,76 | Syrdarya river – s. Tomenaryk |
| Syrdarya river – s. Koktube | 1976-1994 2000-2001 2014-2020 | y = 0,91x + 42,7 | 0,87 | 1961-1975 1995-1999 2012-2013 | 4,74 | Syrdarya river – s. Tomenaryk |
| Syrdarya river – s. Tomenaryk | 1960-1996 2014-2020 | y = 0,94x - 29,2 | 0,95 | 1997-1998 2012-2013 | 5,36 | Syrdarya river - downstream of the Shardara Reservoir |
| Syrdarya river – s. Kergelmes | 1962-1990 1994, 2000-2020 | y = 0,92x - 13,1 | 0,98 | 1960-1961 1991-1993 1995-1999 | 5,57 | Syrdarya river – s. Tomenaryk |
| Syrdarya river – s. Tasbuget | 1961-1994 2003-2020 | y = 0,96x + 102 | 0,91 | 1995-2002 | 7,11 | Syrdarya river – s. Kergelmes |
| Syrdarya river – s. Karaozek | 1961-1992 2006-2020 | y = 1,37x + 73,2 | 0,97 | 1993-2005 | 16,2 | Syrdarya river – s. Kergelmes |
| Syrdarya river – s. Zhosaly | 1981-1992 2009-2010 2012-2020 | y = 1,13x + 6,75 | 0,98 | 1961-1980 1993-2008, 2011 | 22,7 | Syrdarya river – s. Karaozek |
| Syrdarya river – s. Kazaly | 1962-1994, 1996, 1998-1999, 2004-2020 | y = 1,17x + 55,7 | 0,93 | 1961, 1995,1997, 2000-2003 | 7,23 | Syrdarya river – s. Tasbuget |

The main characteristic of river water resources is the average long-term water discharges or runoff rate. The grouping of runoff into low-water and high-water phases indicates the presence of a connection between the runoff of nearby years.

The study area belongs to areas of insufficient moisture, characterized by low precipitation and high evaporation values.

Chronological graphs of annual runoff were constructed (Figure 2); from the graphs, it can be seen that the fluctuations are cyclical in nature, which is expressed in the sequential change of low-water and high-water groups of years. These periods vary both in their duration and in the degree of deviation from the average. Some cycles are expressed quite clearly, while in others there is no obvious trend.

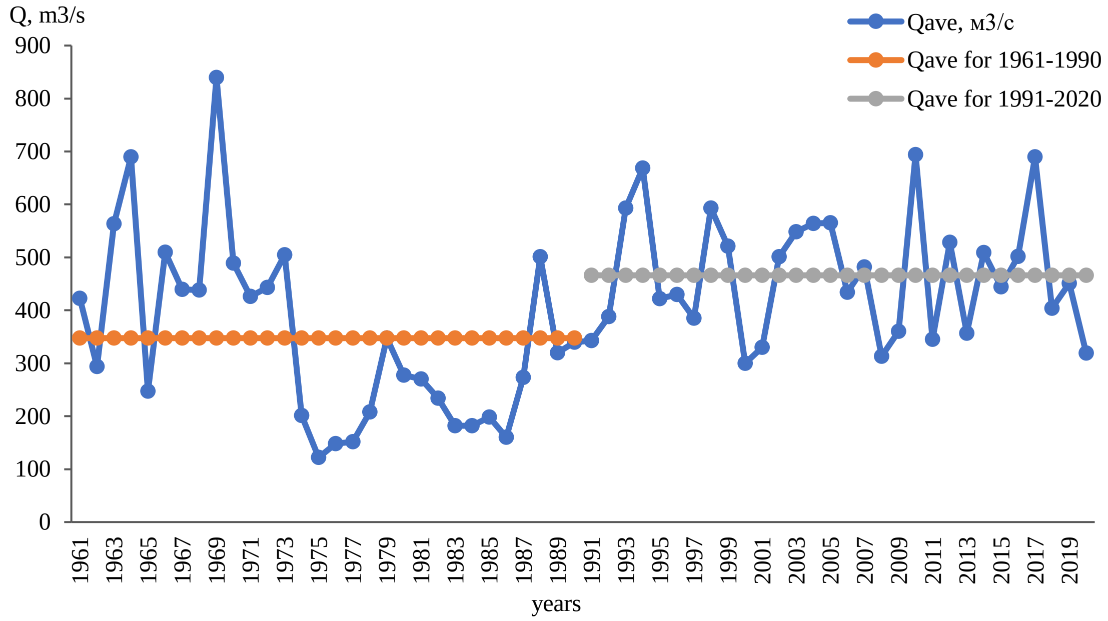


**Figure 2** – Hydrograph of average annual runoff of Syrdarya river - s. Tomenaryk

To compare the results of the calculated characteristics of river runoff in the considered water basins for the calculation periods and for 1961-2020. The annual runoff values were determined using all sets of data from hydrological posts in the study basin. At table 6 shows the main statistical parameters of annual river flow, random errors in the mathematical expectation and coefficient of variation, which for values of Q should not exceed 15%, and for Cv - 20% [17].

**Table 4** – Probabilistic values of the annual river runoff of the Syrdarya water management basin

| № | River-gauging station | Calculation period | Main statistical characteristics of river runoff | | σQ | σCv |
|---|---|---|---|---|---|---|
| | | | Qср, $м^3/с$ | Cv | | |
| 1 | Syrdarya river - downstream of the Shardara Reservoir | 1961-2020 | 459 | 0.36 | 30.4<br>6.6% | 0.04<br>10.5% |
| | | 1961-1990 | 407 | 0.40 | 52.7<br>13.0% | 0.06<br>14.8% |
| | | 1991-2020 | 511 | 0.26 | 22.6<br>4.40% | 0.04<br>13.5% |
| | | Δ | 104<br>25.7% | | | |
| 2 | Syrdarya river – s. Koktube | 1961-2020 | 455 | 0.36 | 31.2<br>6.9% | 0.04<br>10.7% |
| | | 1961-1990 | 402 | 0.44 | 54.0<br>13.4% | 0.07<br>14.9% |
| | | 1991-2020 | 507 | 0.26 | 22.5<br>4.4% | 0.04<br>13.4% |
| | | Δ | 105<br>26.2% | | | |
| 3 | Syrdarya river – s. Tomenaryk | 1961-2020 | 407 | 0.39 | 32.0<br>7.9% | 0.04<br>11.1% |
| | | 1961-1990 | 347 | 0.45 | 53.0<br>15.3% | 0.07<br>15.1% |
| | | 1991-2020 | 466 | 0.32 | 19.8<br>4.2% | 0.04<br>13.4% |
| | | Δ | 118<br>34.2% | | | |
| 4 | Syrdarya river – s. Kergelmes | 1961-2020 | 362 | 0.41 | 32.0<br>8.8% | 0.05<br>11.6% |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | 1961-1990 | 312 | 0.54 | 54.4<br>17.5% | 0.09<br>15.7% |
| | | 1991-2020 | 412 | 0.25 | 20.6<br>5.00% | 0.04<br>13.4% |
| | | Δ | 99.7<br>31.9% | | | |
| 5 | Syrdarya river – s. Tasbuget | 1961-2020 | 298 | 0.53 | 41.9<br>14.1% | 0.07<br>14.0% |
| | | 1961-1990 | 232 | 0.58 | 55.3<br>23.9% | 0.11<br>16.4% |
| | | 1991-2020 | 363 | 0.34 | 37.4<br>10.3% | 0.11<br>16.4% |
| | | Δ | 131<br>56.5% | | | |
| 6 | Syrdarya river – s. Kazaly | 1961-2020 | 256 | 0.84 | 50.7<br>19.8% | 0.14<br>16.8% |
| | | 1961-1990 | 181 | 0.99 | 57.9<br>32.1% | 0.16<br>16.2% |
| | | 1991-2020 | 332 | 0.68 | 64.0<br>19.3% | 0.2<br>21.2% |
| | | Δ | 150<br>83.5% | | | |

As a result of calculations of annual runoff and analysis of chronological graphs over the last 30 years (from 1990 to 2020), an increase in river runoff is observed in the Syrdarya water basin compared to the previous period 1961-1990 by 1.5-2 times. The findings also indicate that the runoff of water in the river largely depends on lateral inflows, in particular on the runoff of water flowing into the Syrdarya and tributaries and climate changes.

Therefore, an analysis and assessment of hydrological and water management calculations in the areas under consideration is required. The objects of the study are the southern regions, which are more prone to variability in climatic factors and densely populated areas. Due to the increase in population every year, the use of water resources increases accordingly, which can lead to desertification and land degradation.

Measure calculations take measures to manage water resources more efficiently, allowing water to be allocated between different needs, such as agriculture, industry and public water supplies.

Thus, river runoff rates provide significant information for reducing the risk of desertification, and their observation and analysis are key components of strategies to combat desertification and manage water barriers.

**Table 5 -** Areas of regular irrigation and water withdrawal in the Aral-Syrdarya basin [12]

| Years | Regular irrigated area, ha | Water withdrawal for regular irrigation, mln $m^3$ |
|---|---|---|
| 2004 | 451075 | 6909,64 |
| 2005 | 424580 | 6566,82 |
| 2006 | 446271 | 6861,45 |
| 2007 | 429041 | 6724,21 |
| 2008 | 392710 | 5777,63 |
| 2009 | 408367 | 6412,81 |
| 2010 | 412316 | 6286,68 |
| 2011 | 543420 | 6716 |
| 2012 | 420600 | 6759,19 |
| 2013 | 415405 | 6899,81 |
| 2014 | 483334 | 7126,22 |
| 2015 | 495358 | 7439,99 |
| 2016 | 497184 | 7083,84 |
| 2017 | 489549,6 | 7450,1 |
| 2018 | 498020 | 7465,872 |

Water resources of the Syrdarya River are formed mainly in the upper and middle parts of its basin [11], on the territories of the Kyrgyz Republic and partially the Republic of Uzbekistan, Republic of Tajikistan. In the Republic of Kazakhstan, the Syrdarya River is fed by its right-bank tributaries Keles and Arys rivers, as well as a few small watercourses within the Karatau Range.

In the Aral-Syrdarya water basin 1/3 of the irrigated land fund of the Republic of Kazakhstan is located and the socio-economic and ecological situation of the region and food security of the republic as a whole depends on how effectively it is used. The lands of the Aral-Syrdarya water basin due to high heat availability have the highest productivity potential in the republic and under favourable reclamation regime on these lands it is possible to obtain very high and sustainable yields of various agricultural crops [14].

Table 5 shows the dynamics of changes in regular irrigation of the Aral-Syrdarya basin for the period 2005-2018. The figure shows that the irrigated area increased in 2011 by 543 thousand ha and the following years 2012-2013 decreased by about 20%. Starting from 2014 the irrigated area increased by 68 thousand ha and the following years was approximately 490 thousand ha. But according to the data of the state registration of the total in the project area as of 1 January 2017 in the basin irrigated land amounted to 798.98 thousand ha: in South Kazakhstan province - 558.993 thousand ha, of which used under crops 499.935 thousand ha, not used for various reasons 59.058 thousand ha; in Kyzylorda province 239.987 thousand ha, of which used 168.077 thousand ha and for various reasons not used 59.424 thousand ha.. [12, 15]

For a number of reasons, in recent years about 100 thousand ha of irrigated lands have not been used in agricultural production, which is associated with the deterioration of land reclamation condition, as well as with the state of irrigation and collector-drainage network. The main reasons for such situation on irrigation systems are organizational and economic conditions, as well as practically uncontrolled situation of meliorative degradation of irrigated lands.

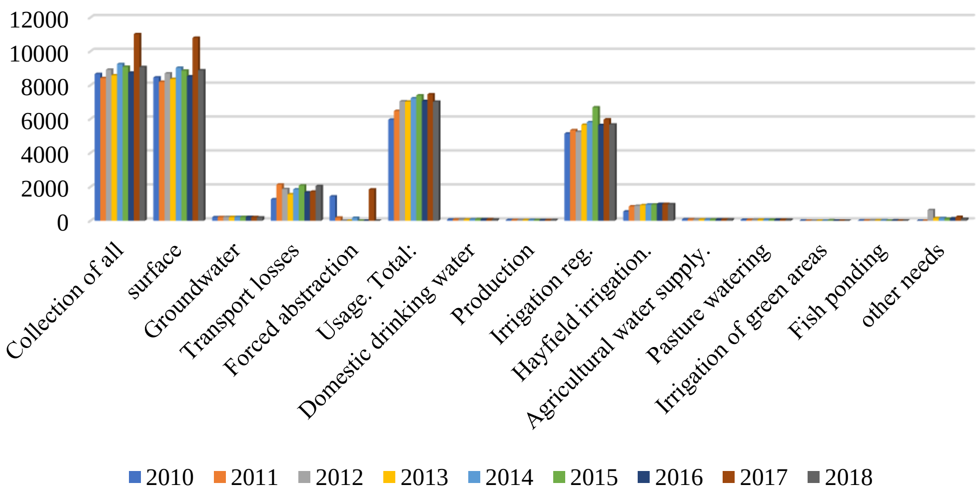


**Figure 3.** Dynamics of changes in water consumption in the total Aral-Syrdarya basin

If we compare surface waters from different years, we can see an increase in 2017 of approximately 22% compared to 2010. But the use of water for irrigation in 2017-2018 shows a small increase of about 12%. also, if we compare the water used in total with 2010 and 2018, we can see an increase of 18%. but the result of the water balance in the following table shows a lack of flow.

**Table 6 -** Water balance of the Aral-Syrdarya river basin, mln m$^3$ for the period 2010-2018

| Water inflow | | Water outflow | |
|---|---|---|---|
| Surface water | 79764,56 | Transport losses | 16189,26 |
| Groundwater | 1926,126 | Forced water withdrawal | 3628,45 |
| | | Total usage | 62628,64 |
| Total | **81690,69** | Total | **82 446,35** |
| | | | **-755,66** |

Analysis of the balance for the periods 2010-2018 allows to note the following. The main source of water supply is surface water. Taking into account the dynamics of surface water change 79764.56 mln m$^3$, groundwater amounted to 1926.126 mln m$^3$. Also, water losses during transport 16189.26 mln m$^3$, and forced water withdrawal amounted to 3628.45 mln m$^3$, and 62628.64 mln m$^3$ were used (all water users are included).

The inflow part of the water balance of the Aral-Syrdarya river basin for the period 2010-2018 was 81690.69 mln m$^3$, the outflow part was 82,446.35 mln m$^3$. Taking into account the above data, it is possible to draw up a water balance and analyze that the flow has decreased by 755.66 mln m$^3$, which naturally reflected in the lowering of the Aral Sea level.

**Table 7 -** Dynamics of water releases to the Aral Sea, mln m$^3$ [12]

| Years | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Annual water releases to the Aral Sea | 10,1 | 9,89 | 6,76 | 6,62 | 3,69 | 4,11 | 9,2 | 4,6 | 4,58 | 4,11 | 5,13 | 5,54 | 5,15 |

Analysing annual water discharges according to [12] the runoff of the Syrdarya River into the Aral (Small) Sea for the last six years was recorded in 2010. - 9198 mln m$^3$. In 2011, the annual runoff was 4636 mln m$^3$, such a decrease in runoff is apparently due to water withdrawal to irrigated lands in summer-autumn time in sufficient quantity. Analysis of data for 2012...2014 showed that the values were 4,106...5,134 mln m$^3$.

According to the results of data from Kyzylorda Centre "KazHydromet" the value for 7 months of 2015 was 3.473 mln m$^3$, for the 8th month of 2016 was 2600 mln m$^3$, there is a tendency to decrease every year, but in the current period of 2018 there is a decrease in runoff to a minimum value, associated with the construction of a bridge on the Syrdarya River in Kazaly district. [3].

**Table 8 -** Water balance of the Shardara reservoir for 2016 full volume-5200 mln m$^3$

| № | Components of balance | mln. m3 |
|---|---|---|
| 1 | Reservoir volume at the beginning of the period | 3276 |
| 2 | Inflow to the reservoir | 16148 |
| 3 | Evaporation and filtration losses from the reservoir | 735 |
| 4 | Release from the reservoir | 16007 |
| | including to: | |
| | Kyzylkum MC (including for fishery needs) | 968 |
| | Release through HPS turbine | 8642 |
| | Discharge via CWS (idle spillway) | 6067 |
| | Arnasay depression | 22,86 |
| | Makhtaral section | 280,22 |
| | State Enterprise "Communal Service" of Shardara city | 1,20 |
| | NSS (National Socialist Society) Khantaniri | 5,24 |
| | NSS (National Socialist Society) Turar | 4,40 |
| | NSS (National Socialist Society) Kazbek | 4,53 |
| | NSS (National Socialist Society) Tilek | 8,09 |
| | NSS (National Socialist Society) Bars | 4,08 |
| 5 | Reservoir volume at the end of the period | 3227 |
| 6 | Total | ± ΔV=141 |

The analysis of the Shardara reservoir water balance for 2016 shows that the main part of the reservoir filling (99-100%) depends on the inflow to the reservoir 16148 mln $m^3$, and in the discharge part of the flow is the release from the reservoir, namely irrigation of BMK and sanitary releases and losses along the channel 16007 mln $m^3$ (98%) of which evaporation and filtration losses is 735 mln $m^3$ (4%), reservoir accumulation (drawdown) ± ΔV= 141 mln $m^3$. Disconnect +141 mln. $m^3$

**Table 9-**Water balance of Badam reservoir for 2016 full volume-61.5 mln $m^3$

| № | Components of balance | mln. m3 |
|---|---|---|
| 1 | Reservoir volume at the beginning of the period | 48,146 |
| 2 | Inflow to the reservoir | 72,54 |
| 3 | Evaporation and filtration losses from the reservoir | 5,05 |
| 4 | Discharge from the reservoir | 57,403 |
| | including for: | |
| | Large main channel (LMCh) irrigation | 12,992 |
| | Sanitary releases and losses along the channel | 44,411 |
| 5 | Reservoir volume at the end of the period | 48,986 |
| | Total | ± ΔV=15,137 |

The analysis of the water balance of the Badam reservoir for 2016 shows that the main part of the reservoir filling (99-100%) depends on the inflow to the reservoir of 72.54 mln $m^3$, while the discharge from the reservoir, namely irrigation of the LMCh and sanitary releases and losses along the channel of 57.403 mln $m^3$ (79%), and in the discharge part of the flow is the release from the reservoir, namely irrigation of LMCh and sanitary releases and losses along the channel 57.403 mln $m^3$ (79%) of which evaporation and filtration losses are 5.05 mln $m^3$ (6.9%), reservoir accumulation (drawdown) ± ΔV=15.137 mln $m^3$. Disconnect +15.137 mln $m^3$

**Table 10 -** Water balance of the Bugun reservoir for 2016 full volume-370 mln $m^3$

| № | Components of balance | mln. m3 |
|---|---|---|
| 1 | Reservoir volume at the beginning of the period | 190,46 |
| 2 | Inflow to the reservoir | 980,65 |
| 3 | Evaporation and filtration losses from the reservoir | 96,38 |
| 4 | Discharge from the reservoir | 898,53 |
| | including for: | |
| | Irrigation | 490,62 |
| | environmental releases | 407,90 |
| 5 | Reservoir volume at the end of the period | 189,27 |
| | Total | ± ΔV=82,12 |

The analysis of the water balance of the Bugun reservoir for 2016 shows that the main part of the reservoir filling (99-100%) depends on the inflow to the reservoir 980.65 mln $m^3$ and the outflow part of the flow is the release from the reservoir, namely irrigation and environmental releases 898.53 mln $m^3$ (91%), of which losses for evaporation mln $m^3$, and in the discharge part of the flow is the release from the reservoir, namely irrigation and environmental releases 898.53 mln $m^3$ (91%) of which evaporation and filtration losses are 96.38 mln $m^3$ (9.8%), reservoir accumulation (drawdown) ± ΔV=82.12 mln $m^3$. Disconnect +82.12 mln. $m^3$

**Table 11** - Water balance of the Koshkurgan reservoir for 2016 full volume-37.3 mln $m^3$

| № | Components of balance | mln. m3 |
|---|---|---|
| 1 | Reservoir volume at the beginning of the period | 20,081 |
| 2 | Inflow to the reservoir | 164,09 |
| 3 | Evaporation and filtration losses from the reservoir | 2,63 |
| 4 | Discharge from the reservoir | 182,29 |
| | including for: | |
| | Irrigation | 37,33 |
| | Sanitary releases and losses along the channel | 144,96 |
| 5 | Reservoir volume at the end of the period | 18,345 |
| | Total | ± ΔV=18,2 |

The analysis of the water balance of the Koshkurgan reservoir for 2016 shows that the main part of the reservoir filling (99-100%) depends on the inflow to the reservoir 164.09 mln $m^3$, and in the discharge part of the flow is the release from the reservoir, namely irrigation and sanitary releases and losses along the channel 182.29 mln $m^3$ (110%), which reduces the accumulation of the reservoir, and of these losses on evaporation and filtration is 2.63 mln $m^3$ (1.6%), reservoir accumulation (drawdown) ± ΔV=18.2 mln $m^3$. Disconnect - 18.2 mln. $m^3$

**Table 12 -** Water balance of Kapshagai reservoir for 2016 full volume-34.0 mln $m^3$

| № | Components of balance | mln. m3 |
|---|---|---|
| 1 | Reservoir volume at the beginning of the period | 22,390 |
| 2 | Inflow to the reservoir | 129,477 |
| 3 | Evaporation and filtration losses from the reservoir | 2,006 |
| 4 | Discharge from the reservoir | 125,201 |
| | including: | |
| | Shayanov water supply | 2,655 |
| | Irrigation | 27,967 |
| 5 | Sanitary releases and losses along the channel | 94,579 |
| | Reservoir volume at the end of the period | 22,58 |
| | Total | ± ΔV=4,276 |

Analysis of water balance of Kapshagai reservoir for 2016 shows that the main part of filling (99-100%) of the reservoir depends on inflow to the reservoir 129.477 mln $m^3$, and in the discharge part of the flow is the release from the reservoir, namely irrigation and sanitary releases and losses along the channel 125.201 mln $m^3$ (96%), which exceeds the reservoir drawdown, and of these losses on evaporation and filtration is 2.006 mln $m^3$ (1.5%), reservoir accumulation (drawdown) ± ΔV=4.276 mln $m^3$. Disconnect -+4.276 mln $m^3$

***Conclusion***

Runoff rate is one of the indicators that reflects soil moisture and water availability for vegetation. Low runoff rates may indicate a lack of moisture, which may increase the risk of desertification.

The flow rate is associated with seasonal and prolonged droughts. Reduced flow rates during drought periods can have an adverse effect on agricultural conditions and water supply.

As a result of the above calculations on water balance of reservoirs, shows increasing accumulation of the following reservoirs as Shardara reservoir (+ ΔV=141), Badam reservoir (+ ΔV=15.137), Bugun reservoir (+ΔV=82.12), Kapshagay reservoir (+ΔV=4.276). But decrease of reservoir accumulation shows in Koshkurgan reservoir for 2016, where accumulation is (ΔV=- 18.2 mln $m^3$), which shows large discharge for irrigation, sanitary releases and losses along the channel.

The land fund of the planned zone allows increasing the area of irrigated lands to a great extent, but the chronic deficit of water resources in the Syrdarya basin is a constraining factor. In turn, the results of the water balance of the Aral-Syrdarya river basin for the period 2010 - 2018, where taking into account the above data was drawn up water balance and analysed that the runoff decreased by 755.66 mln $m^3$, which naturally reflected in the lowering of the Aral Sea level.

Prospects for the development of irrigated agriculture in the region urgently require its scientific support, since the associated disruption of the existing ecological balance of natural systems necessitates the development of a comprehensive set of measures for the directed formation of ecological balance of a certain type, which serves as a prerequisite for the creation of agrolandscapes (and as a part of them - agrocenoses) with given properties.

It is also necessary to keep in mind that the solution of the whole set of issues of this complex problem is closely connected with the results of transboundary water allocation of the Syrdarya river flow between the Republic of Kazakhstan and the Republic of Uzbekistan. This is important not only within the framework of national interests, but also under the conditions of regional planning of optimal nature use.

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**References**

1. Bissenbayeva S., Abuduwaili J., Saparova A., Ahmed T. Long-term variations in runoff of the Syr Darya River Basin under climate change and human activities. Journal of Arid Land volume 13, (2021) P. 56–70 .

2. Deng H J, Chen Y N. Influences of recent climate change and human activities on water storage variations in Central Asia. Journal of Hydrology, (2017) 544: P. 46–57.

3. Sambaev N.S. Otsenka gidrologicheskogo sostoyaniya r.Syrdar'iya v predelakh Kyzylordinskoj oblasti. Vektor GeoNauk/Vector of Geosciences 1(3) 2018, S. 95-100

4. Burlibaev M.ZH., Dostaj ZH.D., Tursunov A.A. Aralo-Syrdar'inskij bassejn: gidrologicheskie problemy, voprosy vododeleniya. – Almaty: Dauir, 2001.- 180 s.

5. Otsenka vodnykh resursov i ruslovogo balansa r. Syrdar'ya v predelakh Respubliki Kazakhstan. Tashkent i Almaty: Nauchno-informatsionnyj tsentr MKVK, 2011. – 52s.

6. Sambaev N.S. Sovremennoe gidroehkologicheskoe sostoyanie nizhnego techeniya reki Syrdar'ya i ispol'zovanie ee resursov stoka // Astrakhanskij vestnik ehkologicheskogo obrazovaniya, № 2 (40) 2017. s. 50-55.

7. Vodnye resursy Kazakhstana: otsenka, prognoz, upravlenie. Tom IX. Vnutrennie i okrainnie vodoemy Kazakhstana (Aral, Balkash, Kaspij). Kniga 1 – Almaty, 2012 g. – 456 s.

8. Metodicheskie rekomendatsii po opredeleniyu raschetnykh gidrologicheskikh kharakteristik pri nalichii dannykh gidrometricheskikh nablyudenij. Federal'naya sluzhba Rossii po gidrometeorologii i monitoringu okruzhayushhej sredy. Sankt-Peterburg. 2005.- 123 s.

9. Metodicheskie rekomendatsii po opredeleniyu raschetnykh gidrologicheskikh kharakteristik pri otsutsvii dannykh gidrometricheskikh nablyudenij. Federal'naya sluzhba Rossii po gidrometeorologii i monitoringu okruzhayushhej sredy. Sankt-Peterburg. 2009.- 193 s.

10. Sikan A.V. Veroyatnostnye raspredeleniya v gidrologii. Spetsial'nye glavy teorii i praktiki gidrologicheskikh raschetov: uchebnik. – SPb.: RGGMU, 2020. – 286 s.

11. A. V. Zvyagintseva, S. A. Sazonova, O. I. Marar and L. V. Koval. Environmental approaches when determining the calculated hydrological characteristics. IOP Conference Series: IOP Conf. Series: Earth and Environmental Science 839 (2021) 042079 DOI 10.1088/1755-1315/839/4/042079.

12. Zaurbek A.K. Ispol'zovanie vodnykh resursov bassejna reki Syrdariya i vozmozhnost' formirovaniya bolee blagopriyatnoj ehkologicheskoj obstanovki v ee nizov'yakh. Voprosy geografii i geoehkologii. № 1. 2016. S. 64-74.

13. Otchet. Aralo-Syrdar'inskoj bassejnovoj inspektsii po regulirovaniyu ispol'zovaniya i okhrane vodnykh resursov za 2016 god.

14. F. A. Gapparov, M. F. Gafforova, Q.SH. Eshquvatov. Operating regime of water reservoirs for safe transportation of floods. June 2022AIP Conference Proceedings 2432(1):030017. DOI: 10.1063/5.0090192.

15. Narbayev, T., Zauerbek, A.K., Narbayev, M., Narbayeva, K. Improvement of the methodology and scientific-technical basis of the adjustment parameters of reservoirs in the pool of undrained rivers (case study of Ile river basin). News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences, 2017, 3(423), pp. 100–113.

16. Skhema kompleksnogo ispol'zovaniya i okhrany vodnykh resursov bassejna r. Syrdariya (Obnovlenie SKIOVRa 2008 g.), Kniga 1, chast' 1., 2018 g.

17. SP-33-101-2003. Opredelenie osnovnykh raschetnykh kharakteristik –M.: Gosstroj Rossii. – 2004-71s.

18. V.A. Bakhtiyarov. Vodnoe khozyajstvo i vodokhozyajstvennyj raschety. Gidrometeorologicheskoe izdatel'stvo, Leningrad 1961. – 432 s.

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## ОЦЕНКА ИЗМЕНЕНИЙ И ИСПОЛЬЗОВАНИЯ ВОДНЫХ РЕСУРСОВ РЕКИ СЫРДАРЬИ

***Аннотация***

Рациональное использование водных ресурсов имеет актуальное значение в комплексном использовании и регулировании стока. Поэтому, необходим водохозяйственный расчет, который позволит эффективно и неприемлемо распределять водные ресурсы, не допуская их перерасхода. В статье рассмотрены вопросы об оценке водных ресурсов Арало-Сырдаринского водохозяйственного бассейна. Для анализа гидрологических характеристик изучаемого бассейна были восстановлены ряды годовых расходов воды и построены хронологические графики годового стока. При расчете параметров годового стока построены суммарные и разностные интегральные кривые, определены значения годового стока с использованием всех совокупностей данных гидрологических постов исследуемого бассейна реки Сырдария. Оценены основные статистические параметры годового стока рек, случайные ошибки математического ожидания и коэффициента вариации.

Для водохозяйственного расчета были использованы данные отчета Арало-Сырдарьинской бассейновой инспекции по регулированию использования и охране водных ресурсов за 2016 год, а также Схема комплексного использования и охраны водных ресурсов бассейна р. Сырдария за 2018 год.

Анализ водохозяйственного баланса за периоды 2010-2018 г.г. учитывает, что приходная часть водохозяйственного баланса Арало-Сырдаринского речного бассейна составлял 81690,69 млн м$^3$, расходная часть 82 446,35 млн м$^3$. По данным составлен водохозяйственный баланс и сделан анализ что сток уменьшился на 755,66 млн м$^3$, что естественным образом отразился на понижение уровня Аральского моря. Также по водному балансу Шардаринского, Бадамского, Бугуньского и Капшагайского водохранилища аккумуляция была положительна. Но в Кошкурганском водохранилище аккумуляция была отрицательной.

***Ключевые слова:*** расход воды, годовой сток, статистические методы, водохозяйственные расчеты, водный баланс водохранилищ.

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## СЫРДАРИЯ ӨЗЕНІНІҢ СУ РЕСУРСТАРЫНЫҢ ӨЗГЕРУІ МЕН ПАЙДАЛАНЫЛУЫН БАҒАЛАУ

***Аңдатпа***

Су ресурстарын ұтымды пайдалану ағындыны кешенді пайдалану мен реттеуде өзекті мәнге ие. Сондықтан су ресурстарын артық шығындамай, тиімді және қолайлы үлестіруге мүмкіндік беретін су шаруашылық есептеулер қажет. Мақалада Арал-Сырдария су шаруашылық алабында су ресурстарды бағалау мәселелері қарастырылған. Зерттеліп отырған алапта гидрологиялық сипаттамаларды талдау үшін жылдық су өтімдері қатарлары қалпына келтірілді және жылдық ағындының хронологиялық графиктері тұрғызылды. Жылдық ағынды қатарлары параметрлерін есептеу кезінде жиынтық және айырымдық интеграл қисықтары

тұрғызылды. Сырдария өзені алабындағы барлық гидрологиялық бекеттердегі барлық мәліметтерін пайдалана отырып жылдық ағынды шамалары анықталды. Өзендер ағындысының негізгі статистикалық параметрлері, математикалық күтімнің кездейсоқ қателіктері, вариация коэффициенттері бағаланды.

Су шаруашылық есептеулер үшін 2016 жылға су ресурстарын пайдалануды реттеу мен қорғау бойынша Арал-Сырдария алаптық инспекциясының мәліметтері және 2018 жылға Сырдария өзені алабының су ресурстарын кешенді пайдалану мен қорғау сұлбасы пайдаланылды.

2010-2018 жылдарға су шаруашылық балансты талдау Арал-Сырдария өзен алабының су теңдестігінің кіріс бөлігі 81690,69 млн м3, ал шығыс бөлігі 82 446,35 млн м3 құрайды. Жиналған мәліметтер бойынша су шаруашылық баланс жасалды және нәтижесінде ағынды 755,66 млн м3 азайған, бұл Арал теңізі деңгейінің төмендеуіне әкелді. Шардара, Бадам, Бөген және Қапшағай су қоймалардың су теңдестігі бойынша оң аккумуляцияға ие. Бірақ Кошкурган су қоймасында теріс аккумуляция байқалды.

***Кілт сөздер:*** су өтімі, жылдық ағынды, статистикалық әдістер, су шаруашылық есептеулер, су қоймалардың су теңдестігі

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# ОЦЕНКА ЭКОЛОГИЧЕСКОГО СОСТОЯНИЯ ПОЙМЕННЫХ ЛЕСОВ РЕКИ ШАРЫН И НЕОБХОДИМЫЕ МЕРЫ ПО ИХ ВОСПРОИЗВОДСТВУ

*Аннотация*

Река Шарын – крупнейший приток р. Иле. Площадь бассейна реки 7720 км$^2$, длина 427 км. Истоки реки и ее правобережные притоки расположены на южном склоне Кетменского хребта. Наиболее многоводный ее левобережний приток (река Каркара) формирует сток с северо-восточных отрогов Терскей-Алатау и Кунгей-Алатау. Шарын относится к рекам смешанного типа питания (с преобладанием снегового), с растянутым периодом весенне-летнего половодья (апрель- июль) из-за разновременного таяния снега в различных высотных зонах. Формирование стока происходит в основном в высокогорной и среднегорной зонах бассейна.

Мойнакская ГЭС была введена в эксплуатацию в 2012 году в верхней части реки Шарын. Создание гидроэлектростанции изменило поток реки Шарын, ниже по течению от объекта произрастает ясеновая роща на площади 5014 га. Ясеновая роща имеет статус памятника природы республиканского значения. Здесь кроме ясеня согдианского растут туранга сизолистый, вяз перистоветвистый, барбарис илийский, облепиха и другие.

Хотя была проведена некоторая работа по управлению водными ресурсами, до сих пор не разработан План управления водными ресурсами реки Шарын. В рамках исследований проведена оценка современного состояния пойменных лесов, степени покрытия растительностью и уровня увлажненности поймы в динамике за 2000-2018 гг.