Hydrometeorological Conditions Of Low-Water Years In The Mountain Rivers Of Central Asia

Fazliddin Khikmatov, Natalya Frolova, Daniyar Turgunov, Bekzod Khikmatov, Rakhmat Ziyayev

Abstract: In this work special attention is paid to investigation of the process of the low-water year formation with the account of climatic conditions of the basins of Central Asian rivers, including rivers of Fergana valley, Chirchik, Akhangaran, Sanzar, Zaaminsu, Zeravshan, Kashkadarya and Surkhandarya. Interannual fluctuations of the river flow and the influence of meteorological factors on them – in particular, the influence of atmospheric precipitation and air temperature were investigated. The issues of variability of the monthly and annual river flows and their probability are considered. Statistical assessment of the relationship between the flood flow of the extreme (by their water availability) years and atmospheric precipitation is performed. The methods of calculation of basic hydrological quantities applied in investigation of the low-water years on the rivers are improved, and meteorological conditions of their occurrence are investigated. The estimation of the low-water years regarding water safety is made, the disastrous low-water years are defined, and proposals and recommendations on the rational use of hydro-power stations in the low-water years are given.

Index Terms: alimentation sources, catastrophically low-water periods, coefficient of the low-water period, low-water, low-water period, river flow, relative number of the low-water periods, Schults' coefficient, water resources deficit.

1. INTRODUCTION

CURRENTLY, the climate change, and specifically, in the result of its warming, the deficit of the water resources increases in the whole world. In this regard, as it was stated in the report of UN: "...currently, by estimations, 3,6 billion of people live in the regions where the water resources deficit can be observed not rarely than one month a year. Up to 2050 this population will grow, and its number can become 4,8 - 5,7 billion people". Naturally, such unfavorable conditions become crucial during low-water years on the rivers and demonstrate the necessity of more comprehensive investigation of hydrological processes regarding the effect of climatic factors. In the whole world a special attention is paid to the researches of this direction, including also the improvement of quantitative assessment of water resources depending on the climatic factors, to the investigation of the low-water years and peculiar features of their formation, meteorological drought and their possible negative consequences, in particular – relating to hydrological drought in the result of this process. That is why, currently, in the world scale, the issues of estimation of quantitative values of hydrological characteristics applied for investigation of the low-water years on the rivers, assessment of the influence of hydrometeorological factors on their occurrence, and on this base, design, construction and rational management of irrigation systems, hydrotechnical constructions, water storages and hydropower stations are important tasks, and facilitating the development of plans for the step-by-step use of the water-and-land and water-and-power resources and their rational use are of special timeliness.

Currently, in the republic a series of reformations are underway which are directed to more rational use of water resources in different fields of economy. Satisfactory positive results are already achieved. In particular, in "Strategy of actions on the development of the Republic of Uzbekistan" the important tasks are put forward for "... improvement of ameliorative conditions of irrigated lands, and in the first turn, on the introduction of the up-to-date water-economy methods of agricultural technologies...". In this regard, special attention is paid to investigations of the issue of forecast of the low-water years occurrence on the Uzbekistan rivers, and for this purpose, the definition of hydrometeorological conditions which determine them. The assessment of low-water years from the point of view of water safety is an important result. Despite its importance, investigation of low-water periods on the rivers is still one of insufficiently studied problems of the present-day hydrology. In the developed countries of the world, in the framework of this problem, several studies were carried out by scientists of Illinois University of USA (T.Apurov, M.Sivapalan), of the Department of Environment and climate change of Canadian Ontario state (Huaxia Yao), of the National Research Council of Spain (S.Vicente-Serrano, J. Santiago Beguería and J. Lorenzo-Lacruz), Fujian University in China (JiefengWu, Xingwei Chen, Lu Gao, Ying Chen) and others. In their studies they pay special attention to the problems of meteorological drought and its consequences in the form of formation and occurrence of the low-water years on the rivers and resulting water deficit. In the former USSR and CIS countries such scientists as K.P.Voskresenskii, M.N.Bolshakov, A.I.Voiyeikov, B.D.Zaikov, V.G.Andreyanov, L.A.Vladimirov, V.M.Boldarev, N.I.Alekseevskii, N.L.Frolova, A.V.Khristoforov, Zh.Zh.Karamoldoev have studied the problem of low-water periods on the rivers, the causes of their occurrence and their negative aftereffects for water supply. In Uzbekistan such scientists as E.M.Oldekop, L.K.Davydov, V.L.Schults, Z.V.Djordjio and others carried out studies in this direction. At present among the works devoted to this problem the research studies of K.S.Kovalev, A.A.Mavlonov, F.Kh.Khikmatov, N.A.Agaltseva and others are distinguished.

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The problems of the forecasting of low-water periods, their definition with different quantities, hydrological drought, the causes of its occurrence and possible consequences are considered in their research studies. However, in the above-mentioned studies the climatic, in particular, meteorological conditions facilitating the formation of low-water years on rivers, the correlations between occurrence of the low-water years and climatic factors are studied not completely enough. It is also worth to mention in these studies that quantitative values of hydrological quantities which characterize low-water years on rivers are not determined. The presented research work considers the assessment of the low-water years from the point of view of water safety, assessment of their relationship with meteorological factors, more precise definition of the method for calculation of hydrological quantities which are significant for investigation of the low-water years. These aspects differentiate the presented work from the above-mentioned studies.

2 INVESTIGATION METHODOLOGY

2.1 Goal of Investigation
The goal of the investigation is to study the climatic conditions facilitating the formation of the low-water years on the rivers of Central Asia and also to improve the techniques of their assessment with the account of the water safety.

2.2 Objectives of Investigation
The objectives of investigation to investigate natural conditions including also specific climatic features of the basins of mountain rivers of Central Asia from the point of view of the flow formation in the low-water years;

- To assess the influence of climatic factors on the flow distribution within the year and their interannual variability;
- To improve the techniques for distinguishing of low-water years on the rivers and techniques for calculation of quantitative indices of hydrological quantities used for their investigation;
- To find out the frequency of the low-water years occurrence on the rivers and to make statistical estimation of correlation between this process and seasonal precipitation amount and air temperature;
- To group low-water years on the rivers with the account of water safety and to develop scientifically based proposals and recommendations on adaptation to this dangerous phenomenon.

2.3 Object of Investigation
The object of the investigation was selected to be the rivers of mountainous part of Central Asia with natural hydrological regime.

2.4 Subject of Investigation
The subject is the process of the river flow formation in the low-water years depending on climatic factors and assessment of the low-water years from the point of view of water safety, as well as improvement of techniques for calculation of quantitative values of hydrological parameters which determine the low-water years.

2.5 Materials and Methods of Investigation
Up-to-date methods of hydrological calculations and forecasts, of hydrological analogy and geographical generalization, of mathematical statistics and also the techniques developed for statistical estimation of correlated relationships, for regression analysis and the methods of cartographic studies are used in this research study. Reliability of results and conclusions of study are determined with the use of materials of hydrometeorological observations performed according to the uniform methods at hydrometeorological network of the Centre of hydrometeorological service of the Republic of Uzbekistan – Uzhydromet, under the system of the Ministry of Water economy of the Republic of Uzbekistan in the process of execution of the work. Furthermore, in this work the materials of the specialized scientific research institutes – Scientific Research Hydrometeorological Institute (NIGMI), Institute of Irrigation and water problems (NIIIWP), and also the materials of SIC ICWC and personal materials of authors used after their processing with the standard methods are used.

3 MAIN RESULTS OF THIS STUDY
The main results of this study are as follows:
the techniques developed for definition of the low-water on rivers are improved, and the empirical expression for identification of catastrophic low-water period is proposed; genetic relationship between the occurrence of the low-water years and meteorological factors, in particular, with the amount of the seasonal atmospheric precipitation, their type and air temperature are found; statistical assessment of the relationships between hydrological indices which define low-water periods on mountain rivers and physical-and-geographic factors affecting their formation is made, regression equations are derived; the distribution of the relative number, degree of severity of the low-water years and coefficients presenting peculiar features of the low-water periods for the mountain river basins of Uzbekistan are mapped; low-water years on the rivers are grouped regarding the water safety, and scientifically based proposals and recommendations on adaptation of water economy to the low-water phenomenon are developed.

4 RESULTS AND DISCUSSION
The river basins chosen as the object of investigation are located in the eastern, i.e., mountainous part of Central Asia. Almost one fourth part of the territory of Uzbekistan located in the center of Central Asia is occupied with mountains and mountainous slopes. They are situated on the eastern and south-eastern parts and join big mountainous systems which are on the territory of neighbor countries of Kyrgyzstan and Tajikistan. Ugam, Pskem, Chatkal, Fergana, Turkestan, Zeravshan and, particularly, Hissar mountain ranges which reached the territory of Uzbekistan are gradually lowered in north-west and south-west directions. In general, the mountain territory considered in the work belongs to the Western Tien Shan and Hissar-Alai mountain chains. The changes of the main meteorological parameters – atmospheric precipitation and air temperature which affect the formation of the low-water year's formation on the mountain rivers in relation to the area elevation are studied. For this purpose, basing on the data of observations performed at meteorological stations in the basins of investigated rivers the issues of changes of atmospheric precipitation and air temperature values are considered. The regressions of these correlations are equated, and their accuracy is estimated (figs.1 and 2).

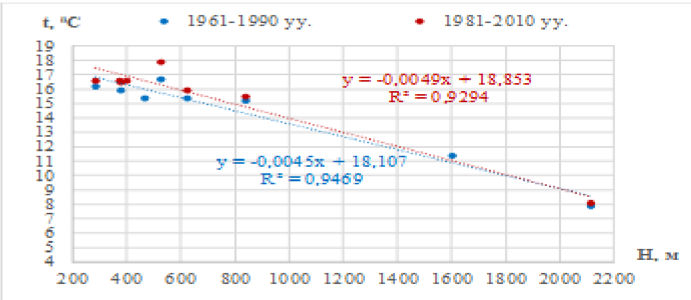

***Fig.1**. Change of the air temperature with elevation in Kashkadarya river basin.*

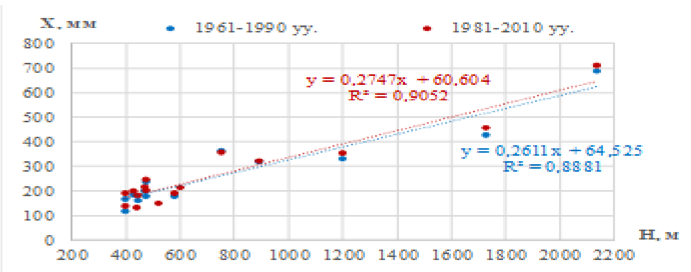

***Fig.2**. Change of atmospheric precipitation amount with elevation in the river basins of Fergana valley.*

These correlation curves demonstrate that elevation patterns of the decrease of the air temperature and increase of atmospheric precipitation turned to be almost the same during two periods. In the work, on the base of results of relevant analysis 38 points of hydrological observations were selected as the reference ones. 23 of these points are in Syrdarya river basin, and 15 – in Amudarya river basin. The closeness of correlations between the mean annual discharge values of the selected reference rivers and the annual values of atmospheric precipitation is estimated, the values of these correlations calculated for the calendar and hydrological (X-IX) years, for the cool period (X-III) are equated (table 1).

***Table 1**. Equations of regression between the river flow and atmospheric precipitation.*

No	River – station	Total atmospheric precipitation	Equations	$r \pm \sigma_r$
1	Chatkal – mouth of Khudaidotsai r.	calendar year	$Q_{\text{сред}} = 0,101\cdot\sum X_{\text{кй}} + 23,2$	0,72 ± 0,046
		hydrological year	$Q_{\text{сред}} = 0,124\cdot\sum X_{\text{гй}} + 4,22$	0,85 ± 0,025
		cool half year	$Q_{\text{сред}}=0,168\cdot\sum X\text{ся} + 11,5$	0,84 ± 0,028
2	Pskem – Mullala vil.	calendar year	$Q_{\text{сред}} = 0,049\cdot\sum X_{\text{кй}} + 35,2$	0,66 ± 0,053
		hydrological year	$Q_{\text{сред}}= 0,063\cdot\sum X_{\text{гг}} + 23,4$	0,83 ± 0,030
		cool half year	$Q_{\text{сред}} = 0,082\cdot\sum X_{\text{хп}} + 28,9$	0,78 ± 0,037
3	Ugam – Khodjikent vil.	calendar year	$Q_{\text{сред}} = 0,022\cdot\sum X_{\text{кг}} +3,72$	0,79 ± 0,035
		hydrological year	$Q_{\text{сред}} = 0,026\cdot\sum X_{\text{гг}} +0,542$	0,90 ± 0,018
		cool half year	$Q_{\text{сред}} = 0,032\cdot\sum X_{\text{хп}} + 4,59$	0,78 ± 0,037
4	Akhangaran – mouth of Irtash r.	calendar year	$Q_{\text{сред}} = 0,020\cdot\sum X_{\text{кг}} + 2,34$	0,59 ± 0,066
		hydrological year	$Q_{\text{сред}} = 0,028\cdot\sum X_{\text{гг}} - 4,45$	0,83 ± 0,031
		cool half year	$Q_{\text{сред}}= 0,033\cdot\sum X_{\text{хп}} + 0,14$	0,71 ± 0,049

Notes: $r \pm \sigma_r$ – correlation coefficient and its error.

On the next stage of investigation, the coefficients of variability of the mean annual discharge values of rivers are calculated. The correlation between these coefficients, i.e. coefficients of variation and Schults' coefficients is estimated (fig.3). With this graph the intervals of variation coefficients variations are identified for each river type distinguished according V.L. Schults' classification [V.L. Schults, 1965] (table 2).

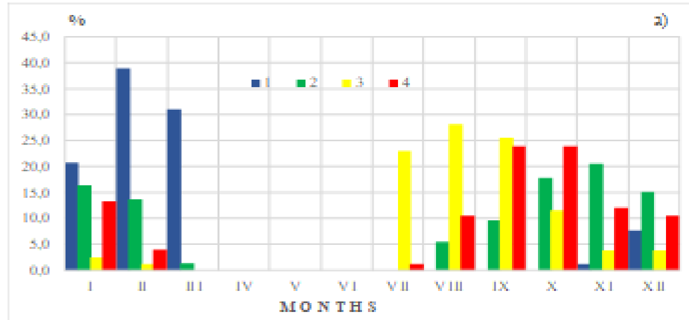

***Fig.3**. Relationship between variability of the annual river flow (Cv) and Schults' coefficient (δ)*

***Table 2**. Intervals of change of variation coefficients (Cv) for rivers with different alimentation type.*

№	Type of alimentation	Cv
1	Glacial-and-snow (δ ≥ 1,0)	0,14 ÷ 0,22
2	Snow-and-glacial (0,99 ≥ δ ≥ 0,26)	0,23 ÷ 0,35
3	Snow (0,25 ≥ δ ≥ 0,18)	0,36 ÷ 0,42
4	Snow-and-rain (0,17 ≥ δ ≥ 0,001)	0,43 ÷ 0,92

The probability of the observed mean monthly discharge values on investigated rivers is estimated. Water resources deficit limited with 90% probability are estimated by the empirical probability graphs. Then, with matching technique, chronological graphs of the annual river flow and normalized integral flow the interannual variability of the water resources deficit was investigated (fig.4).

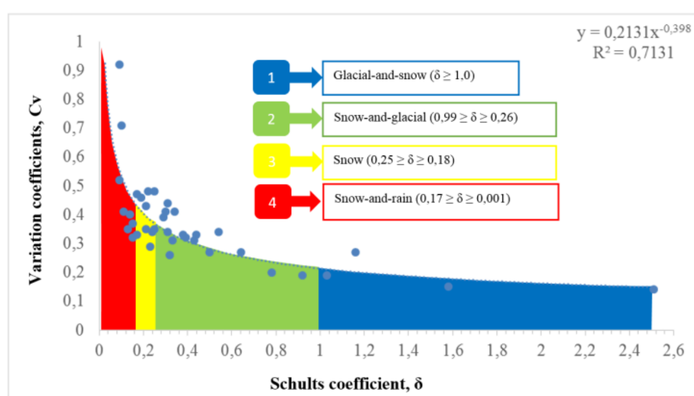

***Fig. 4**. Interannual variability of water resources deficit (1), chronological graphs of the river flow (2) and normalized integral flow curves (3):*

a) Maidantal – river moth (1st type);
b) Tankhazdarya – Kattagan vil. (2nd type);
c) Sanzar – Kirk vil. (3rd type);
d) Khalkadjar – Bazarjoi vil. (4th type).

It is shown that depending on the source of the river alimentation the differences of both the occurrence of water resources deficit within the year, and their total duration are observed. For example, for the rivers with the glacial-and-snow and snow-and-glacial alimentation type (by classification of V.L. Schults) the deficit of water resources is recorded mainly in January - March, while for the rivers with the 3rd and 4th types of alimentation the deficit of water resources is recorded in August - October. However, in the result of increase of severity of the low-water periods on a number of rivers the prolongation of this period is recorded. For example, in low-water year of 1986 the duration of the water resources deficit on Maidantal river was 3 months, while on Tankhyzdarya, Sanzar and Khalkadjar rivers the period of water resources deficit was 6, 4 and 5 months (fig.5), respectively.

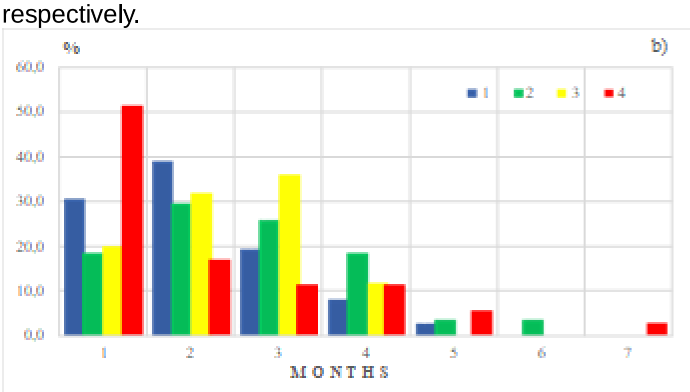

***Fig. 5**. Duration (a) and occurrence (b) of water resources deficit:*
1) Maidantal – mouth (1st type);
2) Tankhazdarya – Kattagan vil. (2nd type);
3) Sanzar – Kirk vil. (3rd type);
4) Khalkadjar –Bazarjoy vil. (4th type).

On the example of the years with extremely low-water the impact of meteorological conditions, in particular, of atmospheric precipitation regime on the flow distribution within a year by months and seasons is studied. Analysis of results of the performed investigation has shown that the years of 1982 and 1983 were low-water ones. One of the main reasons of this is that in the flow formation of that period, during autumn-winter periods (IX-XII) in 1981 and 1982 atmospheric precipitation was much less comparing with their long-term norm. On the example of the concrete tasks the methods of definition of hydrological quantities needed for the investigation of the low-water years are shown. These are the "coefficients of relative water availability" proposed by L.K. Davydov and V.L. Schults, the coefficients recommended by Yu.S. Kovalev and A.A. Mavlonov: "deepness of low-water periods" (gm), "water contrast" (kvk), "relative number of low-water years" (roch), mean "rated-conditional step" of the occurrence of low-water years (rup), "number of the continuous successive low-water years" (rnim), "total amplitude of the degree of change of the river water availability" (aoa), "norm of the low-water period" ( ), "module coefficient of the norm of low-water period" ( ). The methods of definition of the low-water years on mountain rivers proposed by the above-mentioned scientists are improved. For this purpose, the low-water years on the rivers are defined by three methods. With the first method the low-water years are specified with the coefficient of relative water availability (a) proposed by V.L. Schults. With the second method the low-water years are determined by the analysis of the graph of probability curves of the mean annual discharge values for the long-term period. With the second method the low-water years are determined by the analysis of calculated values of the module coefficients of flow (Ki). If $0{,}93 \le K_i \le 1{,}07$ condition is satisfied, then it is accepted that the annual value of the river flow is close to norm. That is why the differentiation of the low-water years to separate groups is made on the base of satisfaction of $K_i \le 0{,}92$ conditions. Results of investigation have shown that regardless the different assessment techniques, the occurrence of the continuous successive low-water years in different river basins follows the definite regularity. For investigation of this issue the analysis of the interannual variability of number of rivers with low-water years was made (fig.6).

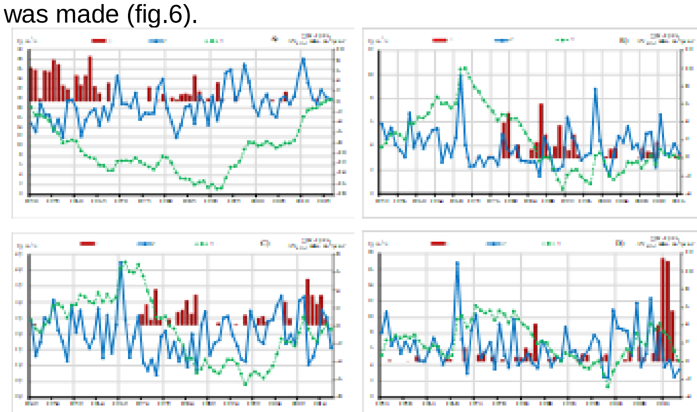

***Fig.6**. Interannual changes of the number (N) of rivers with low-water years.*

Analysis of results has shown that during the period of studies, i.e. from 1950 to 2016 (67 years), in 1974, 1982, 1986, 1989, 2000, 2008 and 2011 almost for all rivers considered in the work, including also Chirchik river basin the low-water was recorded. The reason of this was that in those low-water years the amount of atmospheric precipitation was much lesser than their mean long-term values. For example, by the data of Pskem meteorological station it follows that calculated precipitation norm during the base period (1961-1990) is 842,2 mm. In low-water years of 1982, 1983, 1984 and 1986 the amount of atmospheric precipitation was lesser than norm in 1,55; 1;38; 1,30 and 1,41 times, respectively. As it is known, in Central Asia 15 types of synoptic situations are distinguished, 10 types of which cause the occurrence of atmospheric precipitation (S.I. Inagamova, T.M. Mukhtarov, 2002). The highest amount of atmospheric precipitation is formed due to the air masses intrusion from the west (10th type). This type of synoptic processes (SP) provides for up to 29,3% of the annual atmospheric precipitation (fig. 7). The duration of SP is also very important for the formation of atmospheric precipitation. That is why the duration of SP low-water years is investigated (fig.8).

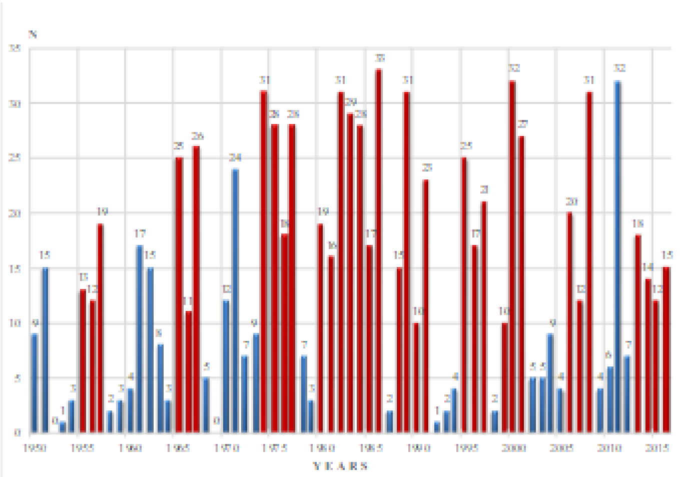

Fig.7. *Atmospheric precipitation distribution by SP types in Central Asia, Oigaing meteostation.*

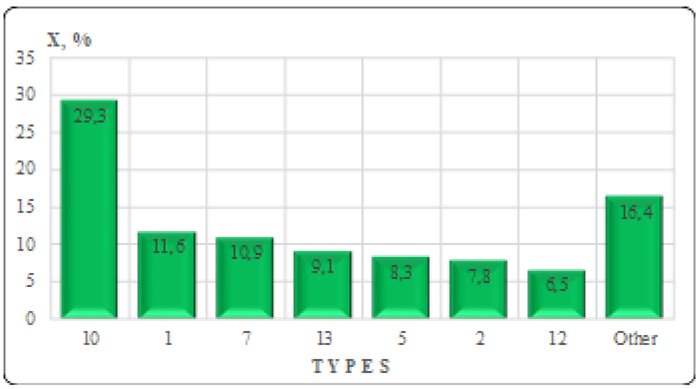

Fig.8. *Changes of duration of SP which determine the formation of precipitation in the low-water years.*

Figure 7 shows that during the low-water years of 1980-1986 on the rivers of Central Asia the total duration of synoptic processes causing precipitation occurrence is less in relation to their mean long-term (181,2 days) values. This circumstance proves the short-time presence of precipitation-forming synoptic processes over Central Asia in this period. Undoubtedly, the above-mentioned conditions determined that atmospheric precipitation amount was less the norm. Taking this into account, in the result of the investigation of 7-year period it turned out that continuous successive period of the low-water years was observed. Regarding this circumstance, the term of "low-water period" was introduced. In the article special attention is paid to the relative number of the low-water years and to the determinant nature factors. For this purpose, the investigated rivers were subdivided to two groups according to classification of V.L. Schults. The rivers with the glacial-snow and snow-glacial alimentation types are included to the first group, while the rivers with snow and snow-rain alimentation type are included to the second group. Calculations were made separately for each group of rivers. Relative number of the low-water years (PRn) is calculated with the expression:

$$P_{Rn} = \frac{N_{мл}}{N} \cdot 100\%, \qquad (1)$$

where: $N_{мл}$ – is the total number of the low-water years; N – is the total number of observation years.

On the base of calculation results the relationships between the relative number of low-water years and annual flow variability (fig.9) were investigated. Distribution of the calculated quantities ($P_{он}$) for P_{Rn}>0,60, 0,59>P_{Rn}>0,50, 0,49>P_{Rn}>0,40 and 0,39>P_{Rn}>0,30 intervals over the mountain river basins (fig.10) is mapped.

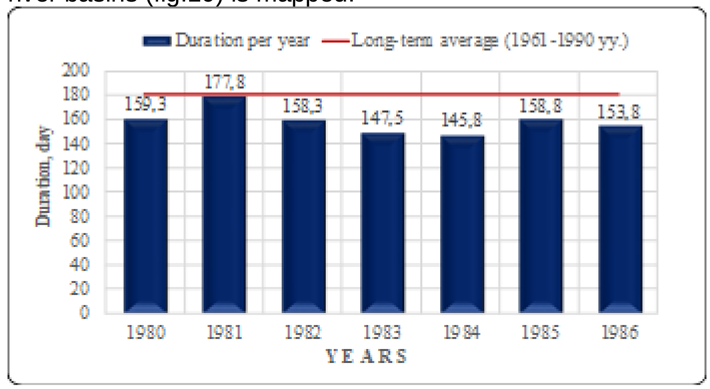

Fig.9. *Graphs of correlation between the relative number of low-water years (roch) and river flow variability (Cv): a) I group; b) II group.*

On the base of calculated values of the module coefficients of the mean annual discharge values, the low-water years are subdivided to 5 following types: 1) 0,92≥Ki≥0,86 – years with decreased flow; 2) 0,85≥Ki≥0,76 – low-water years; 3) 0,75≥Ki≥0,67 – sensitive low-water years; 4) 0,66≥Ki≥0,50 – deeply low-water years; 5) 0,50 >Ki – extremely low-water years.

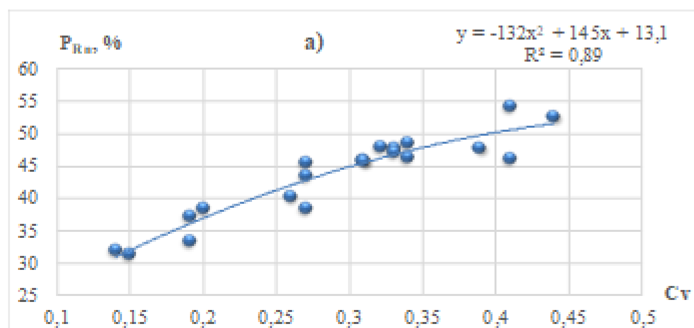

Fig.10. *Distribution of the relative number of low-water years (roch) in the*

mountain river basins

Note: 1. Sokh, 2.Koksu (Kurbankul), 3.Gavasai, 4.Chadaksai, 5.Zaaminsu, 6.Sanzar, 7.Okhangaran, 8.Kyzylcha, 9.Dukentsai, 10.Niyazbashsai, 11.Karabagirsai, 12.Shavazsai, 13.Abdjazsai, 14.Maidantal, 15.Oigaing, 16.Pskem, 17.Chiralma, 18.Chatkal, 19.Akbulak, 20.Ugam, 21.Yangikurgansai, 22.Nauvalisai, 23.Chimgansai, 24.Sangardak, 25.Khalkadjar, 26.Sherabad, 27.Karatagdarya, 28.Aksu, 29.Jinydarya, 30.Tankhazdarya, 31.Uradarya, 32.Kashkadarya, 33.Kichik Uradarya, 34.Yakkabagdarya, 35.Zeravshan, 36.Amankutan, 37.Beglarsai, 38.Akdarya (Agalyk).

The distinguished types of the low-water years are of important practical value for planning of the use of the river water resources. Low-water years, especially of 3, 4 and 5 types can cause a lot of negative consequences for water consumers and water users. Taking these circumstances into account, the above-mentioned types are united to two groups: I. Relatively low-water years, with inclusion of types of years with the decreased flow and low-water years; II. Catastrophic low-water years, with inclusion of sensible low-water years, deeply law-water years and extremely low-water years.
For definition of catastrophic low-water years the coefficient of relative water availability of V.L. Schults (a) is improved as follows:

$$A_d = \left(Q_i - Q_{cp}^{к}\right)/C_v \quad (2)$$

where: A_d – coefficient of relative water availability characterizing its deficit; C_v – variation coefficient; Q_i – mean annual discharge, m^3/sc; $Q_{cp}^{к}$– mean annual discharge in low-water years, m^3/s.
The norm of the low-water value (Q_o^{x}, m^3/s) is calculated by the formula:

$$Q_o^{x} = K_o \cdot Q_i, \quad (3)$$

where K_o – is coefficient of the low-water, and its value is estimated in relation to the type of river alimentation by the following formula:

$$K_o = \frac{Q_{cp}^{x}}{Q_0} \quad (4)$$

where: Q_0 – is mean long-term flow (flow norm), m^3/s.
With the known low-water years on rivers it is possible to get efficient results in the use of the water resources in different sectors of national economy, in particular, in hydropower. In the work the impact of the low-water years on the operation regime of Charvak hydropower station which is the biggest hydropower station in the republic is assessed. For this purpose, the within-year variability of the water balance elements in the extreme years regarding water availability are analyzed (fig.11).

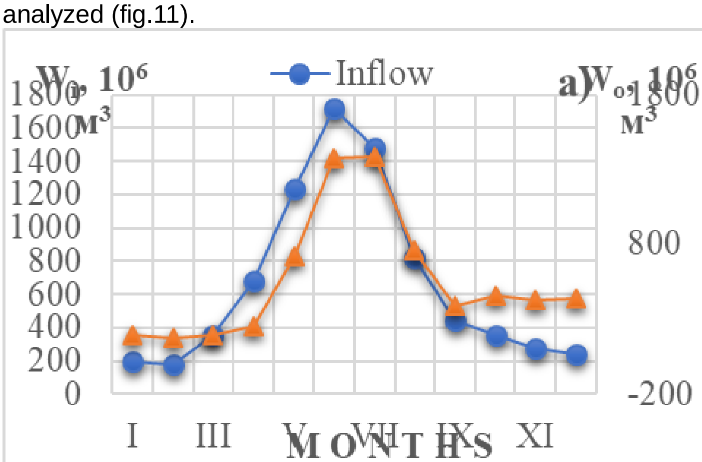

Fig.11. *Within-year variability of the water balance elements of Charvak water storage: a) high-water year of 2009; b) low-water year of 2008.*

The analysis revealed that in the high-water year of 2009 the change of elements of the outflow part of the water balance of water storage is almost similar to the changes of its inflow part. In low-water year of 2008 another situation is observed. For example, in July and August the volumes of released water from water storage were higher than inflow to it. In the result, in 2008 power output was 51% comparing with the mean long-term norm. 1272 mln.kWt/s was lost in the result of low-water situation. Taking the above mentioned into account, for the efficient operation of Charvak hydropower station in the low-water years the relevant proposals and recommendations are made in the work. First, it is required to provide for sustainable operation of the water economy system of Uzbekistan and to pay special attention to the development of the use of alternative energy sources (water, wind, sun). Second, for the efficient operation of Charvak hydropower station it is necessary to take within-year and interannual changes of elements of the inflow and outflow parts of the water balance of Charvak water storage into account. Here it is also necessary to take the decrease of the inflow elements of the water balance of water storage low-water years into account. Third, it is expedient to change the operation of water storage from power-irrigation regime (increase of power output in summer and winter periods) for the irrigation-power regime (decrease of power output in winter period) in low-water years on the rivers inflowing Charvak water storage. This, in its turn will facilitate smoothing the negative consequences of the low-water years in agricultural production
.

5 CONCLUSION

1. Specific features of nature conditions of the mountain river basins are investigated from the point of view of the low-water year's formation. The degree of hydrological investigation of the territory is assessed on the base of analysis of observation materials over more than 200 hydrological gaging stations, while the extent of meteorological investigation is assessed by materials of more than 100 points of meteorological observations. On the base of appropriate criteria, 38 hydrological gaging stations were selected as reference observation points on the rivers with natural flow regime. The area of their catchment varies within 23,3÷10200 km2, while the mean elevation varies in the range of 1340÷3480 meters.
2. Statistical estimation of the relationships between air temperature and atmospheric precipitation recorded at meteorological stations located in river basins with different elevation of the locality is carried out. The values of pair correlation coefficients characterizing these relationships vary in the range of 0,72÷0,98 and 0,78÷0,95, respectively. As it is evident, the values of statistical indices which characterize the closeness of relationship of t=f(H) and X=f(H) types, i.e. coefficients of these relationships' correlation are higher than r≥0,70, and thus, meet the requirements lodged for execution of hydrological calculations.
3. Statistical estimation of the relationship between coefficient of variation of the annual river flow and Schults' coefficient of the within-year distribution was performed. With this relationship the intervals of changes of variation coefficients for each of the river types distinguished by Schultz are determined. According to results, for the first type, i.e., for the rivers with glacial-snow alimentation type the coefficients of variation of the mean annual discharge values vary in the range of 0,14÷0,22, while for rivers related to the second, third and fourth types of alimentation these coefficients vary in the ranges of: 0,23÷0,35, 0,36÷0,42 and 0,43÷0,92, respectively.
4. Probabilities of the mean monthly river flows are

estimated. On the base of 90% threshold values of empirical probability of the mentioned discharge values, the deficits of water resources are calculated. Interannual fluctuations of the values of water resources deficits, their occurrence within a year and total duration period for each of 4 river alimentation types distinguished in classification of Schultz are studied. According to results, for rivers with glacial-snow and snow-glacial alimentation type the deficit of water resources is observed in winter low-water period, while for the rivers of the 3rd and 4th alimentation types the deficit of water resources is observed in summer-autumn period.

5. Mean values of occurrence of “rated-conditional step” (rup) of the low-water years for each investigated river are estimated. According to results of calculations it follows that quantitative values of this index for the investigated 38 rivers vary within 2÷3 years. The number of successively occurred low-water years (rnim) is determined. For simplification of the analysis of calculation results the notion of “low-water period” is introduced in the work. During investigated period, i.e., from 1950 to 2016 the low-water periods were observed 9 times; their occurrence is 3 years in average.

6. Low-water years on rivers are determined using three methods. Low-water years defined on the base of calculated values of the module coefficients of the mean annual discharge values, i.e., with application of the third method and subdivided to 5 types from the point of view of water safety. In its turn, on their base two groups have been established: I. Group of relatively low-water years included years with the flow decrease and low-water years; II. Group of catastrophically low-water years included three types: sensible low-water years, deeply low-water years, and extremely low-water years. For the purpose of definition of catastrophically low-water years the expression proposed by V.L. Schults for calculation of coefficient (a) of the relative water availability is improved.

7. For the first time “coefficient (Ko) of low-water availability” was introduced for characterization of low-water years. Its values were defined for all river types according to classification of V.L. Schults. On its base the expression for calculation of norm of low-water period ($Q_o^к$, m3/s) was proposed. It is recommended to use this expression for assessment of the low-water years from the point of view of safety, in performing calculations related to the organization of efficient operation of in-channel basins in the low-water years for estimation of limit of water intake from irrigation channels, and also in the case of increase of efficiency of irrigation of seeded areas.

8. The distribution of the relative number of low-water years (roch), decrease of the flow norm (kuns) and low-water coefficient (K0) over the basins of mountain rivers of Uzbekistan are mapped. In this mapping the standard Map Info software and Arc GIS software are used. It is recommended to use these maps for development of plans aimed at step-by-step use of the water-and-land and water-and-power resources of the country, their rational use.

9. The issues of the efficient use of hydropower stations in low-water years are considered on the example of Charvak HPS, the biggest hydropower station in the country. The proposals and recommendations for more efficient operation of hydropower stations low-water years on the rivers are developed. These results will put the basis for the development of plans for relevant measures directed to prevention of negative effect of the low-water years on the sectors of national economy related to water resources consumption, in particular, in hydropower sector, and to reduction of the potential damage caused by the low-water phenomenon as much as possible.

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