Universidad de Cádiz

FEATURES OF THE HYDROLOGICAL REGIME OF THE CHATKAL RIVER

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MASTER THESIS IN WATER AND COASTAL MANAGEMENT

WACOMA (2015-2017)

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STATEMENT

I hereby declare that this work has been carried out by me and this thesis has been composed by me and has not been submitted for any other degree or professional qualification.

This work is presented to obtain a master's degree in water and coastal management.

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HACEN CONSTAR:

Que esta Memoria, titulada **“Features of the hydrological regime of the Chatkal River”**, presentada por D. Kodirov S.M., resume su trabajo de Tesis de Master y, considerando que reúne todos los requisitos legales, autorizan su presentación y defensa para optar al grado de Master Erasmus Mundus in Water and Coastal Management (WACOMA).

Cádiz, (July, 19)

Dr. Plink N.L. **Dr. Sikan A.V.**

I dedicate this master thesis to my parents.

May Allah bless them…

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ABSTRACT

The Charvak Reservoir is the largest reservoir in the territory of the Republic of Uzbekistan. It is surrounded by The Tien Shan Mountains. From the dam of the reservoir begins The Chirchik River (mean annual flow rate 208 m^3/s) and it is one of the biggest right tributaries of The Syr Darya River. The Chatkal River (mean annual flow rate 108 m^3/s) is the biggest tributary of The Chirchik River. On the basis of long-term data from 8 hydrological and meteorological stations, intra-annual surface runoff distribution was evaluated. Major hydrologic features of The Chatkal River, detection and removing of linear trends, test for homogeneity, long-term fluctuations of the time series, calculation of annual stream flow under different frequency distributions were estimated.

The data set of statistical characteristics and their standard errors are estimated, for average flow rates the error does not exceed 10%, for the coefficient of variation; the error does not exceed 15%. To describe frequency distribution The Gumbel Distribution was applied.

(KEY TERMS: The Chatkal River; The Charvak Reservoir; hydrology; intra-annual runoff distribution; average flow rate.)

1. INTRODUCTION AND OBJECTIVES

1.1 GENERAL INFORMATION

The Republic of Uzbekistan is a country in the central part of the Central Asia, territory – 447 400 km². Population – 32,121 million (January, 2017). The capital city of Uzbekistan is Tashkent. Figure 1.1 presents national emblem and flag of Uzbekistan.

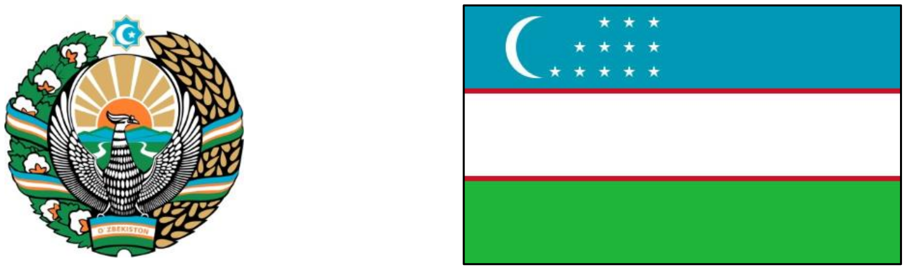

Figure 1.1 – National emblem and flag of Uzbekistan [7].

The Republic of Uzbekistan is bordered by Kazakhstan to the north and northeast, with Turkmenistan in the southwest, Afghanistan in the south, Tajikistan in the southeast and Kyrgyzstan in the north-east (see fig. 1.2). The official language – is Uzbek (from October 21, 1989). Additionally, Russian and Tajik languages are also widely spoken. The composition of the population by nationality as of January 1, 2013 - Uzbeks - 82%, Tajiks - 4.8%, Russians - 2.6%, Kyrgyz - 1.4%, Tatars - 0.7%, Koreans - 0.6% and the rest - 7.9% [7]. Administratively Uzbekistan divides into 12 regions (Vilayat), the Republic of Karakalpakstan (capital city is Nukus) and Tashkent city.

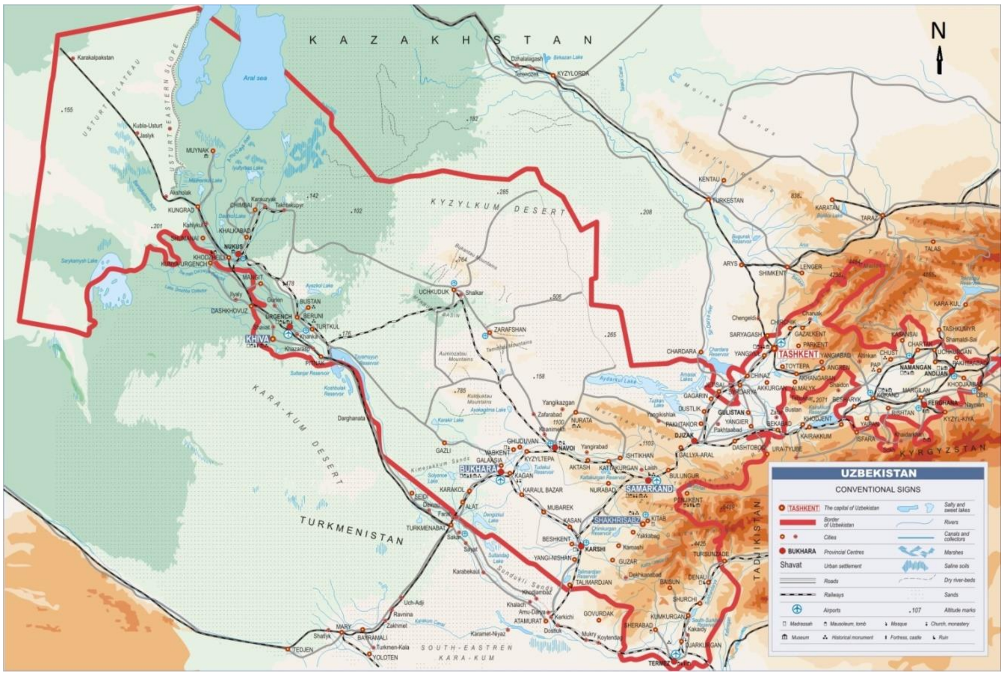

Figure 1.2 – The Republic of Uzbekistan [13].

In Uzbekistan, the following sectors of the economy play key roles: hydrocarbon resources (mainly natural gas - 11th in terms of extraction in the world, 60-70 billion m^3), gold mining (4th in the world in reserves and 7th in mining, approximately 92 tons annually), agricultural products - mainly cotton, vegetables, fruits, and melons [7].

Uzbekistan ranks sixth in the world in the production of cotton and the fifth in exporting it as a raw material [3]. First and foremost, very comfortable climatic conditions (arid, long and cloudless hot days) and fertile irrigated lands contribute to a high yield of cotton cultivation. In order to get the whole picture in terms of cotton production, only water is needed. This was the main reason for the beginning of the large-scale developing of new lands in Central Asia and particularly in Uzbekistan (from the 1950s). And relatively in short time in Uzbekistan alone, more than 50 medium and small reservoirs were built. The Chatkal River, which we are focusing on, flows into the Charvak Reservoir which is the product of above-mentioned activity. It was built during 1963-1978 years. [2]. The reservoir is used mainly for energy, drinking, fishery and recreational purposes. The Chirchik River begins from the dam of the Charvak Reservoir, and it is the main right tributary of the river Syr Darya in the territory of Uzbekistan.

1.2 Physical and Geographical Characteristics of the Republic of Uzbekistan

This dissertation deals with features of the hydrological regime of the Chatkal River which are located in the territory of Uzbekistan and Kyrgyzstan. Chatkal – is a mountain river and it begins from a nameless moraine lake in the territory of Kyrgyzstan [1]. It flows mainly to the west along the westernmost part of The Tien Shan Mountains. Near to the Burchmulla village (Tashkent region, Uzbekistan), it flows into the Charvak reservoir. The length of the river is 217 km (223 km until 1965) and catchment area is 6580 Km^2 (7110 km^2 until 1965) [10]. The study of the hydrological regime of the Chatkal River is necessary for effective regulation of water resources. The main objective of the research is to study the hydrological regime of the Chatkal River and to evaluate the main characteristics of the intra-annual distribution of river surface runoff.

As initial data, we used a series of meteorological and hydrological characteristics for 8 stations and we set up hydrological series of the average monthly, daily annual water discharge data set. All meteorological stations which are located in the study area considered being high mountain stations in terms of altitude and all rivers of the study area flow into Charvak reservoir. The nearest meteorological station to the Charvak reservoir is Chimgan and it is located on 1265 m above the sea level, the farthest station Oigaing, on the other hand, located on 2175 m above the sea level.

All hydrological stations along the Chatkal River had been opened during the 1970s. After filling the Charvak reservoir The Chatkal River – station at Charvak village turned up to be under the water. At present, the nearest hydrological station of The Chatkal River is located just before the mouth of The Khudoydodsay River [11].

1.3 Relief and Geological Structure of Uzbekistan

The particularity of the nature of Uzbekistan is determined by its location in long distance from the world ocean. Considering the geological structure of the relief, the country's territory can be divided into two main parts: 1) plains - occupy a significant part of Uzbekistan (78.7%), and it is mostly the Turan Lowland; 2) mountains and intermountain depressions draw up the rest (21.3%) of territory of the country. From the west and northwest to the east and southeast the country's territory gradually turns from the plains into the mountains. The Ustyurt Plateau, within Turanian lowland, is distinguished with its steep cliffs; in some places, the height of cliffs reach 300 m. The Turanian lowlands extend far to the east, forming flat places: in the north, the Hunger Steppe, in the central part - the Carnab and Karshi Steppes, slowly passing into the foothill plains and mountain ranges. In the south and east, many mountain ranges of the Tien Shan and Gissar-Alai mountains and intermountain depressions isolate them

(Fergana, Zeravshan, Chirchik-Akhangaran, etc.). In those mountains, a number of peaks with a height of more than 4 thousand meters above the sea level, (peak Hazrat Sultan of the Hissar Mountains, 4643 m., Peak Beshtor Pskem Ridge, 4299 m.).

Uzbekistan is located in the zone of seismic activity; therefore, tectonic movements often occur on his territory. Sometimes the impact forces reach 8-10 points on the Richter scale. Historical data indicate earthquakes of the past centuries. For instance, in 1240 in Urgench, in 1797 in Urgut, 1818, 1821 in Bukhara, in 1868 in Samarkand, in 1966 in Tashkent strong earthquakes have been observed [6].

1.4 SOIL COVER AND VEGETATION OF UZBEKISTAN

In the plains of Uzbekistan, the following types of soil are most often encountered: gray-brown, sandy, takyr, meadow-marsh and sierozem (gray soil). On the plateau of Ustyurt, in the low mountains of Kyzyl-Kum and at the foot of the Nurata Mountains, gray-brown soils are widespread. These soils contain only 0.3-1.0% of humus and hence little vegetation [10].

In sandy plains of Kyzyl-Kum, Central Fergana, Mirzachul (Hunger Steppe) desert sandy soils are widespread, the proportion of humus is 0.3-0.6%. In the deserts, Takyr soils also often observed. They are the composition of clay rocks and contain approximately 0.5-1.0% humus. In places with Takyr soil almost no vegetation; the surface of the ground is covered by a hard crust, strongly cracked. Solonchaks (salt marsh) and saline soils formed in places close to groundwater table (Mirzachul, Fergana Valley, Karshi steppe, Lower Amu Darya).

In large river valleys of Uzbekistan, meadow and bog soils are widespread. Light eastern gray soils predominate on the eastern and southern foothill flat parts of the country. The humus content in them is small - up to 1.0-1.5%.

In the Zeravshan, Chirchik, Akhangaran, Kashkadarya and Surkhandarya valleys, as well as in the lower reaches of the River Amu Darya since ancient times, irrigated agriculture and irrigation network are well-developed. As a result of prolonged artificial processing, sierozem changed their initial abilities and became cultivated.

Complicated relief of the Republic defines the diversity of the vegetation cover. Flora of Uzbekistan has more than 3700 plant species. At least 20% of the species are endemic, i.e. indigenous to a place; most of them grow in the mountains. The interesting feature of the vegetation of the steppes and deserts is the existence of a few, but particular shrubs. They are scattered along barkhans (sand dune) and been half-covered with sand, gnarled, knotted curved and broken by the wind, with small leaves or completely leafless. In summer months they create specific steppe coolness [5].

1.5 HYDROGRAPHIC NETWORK OF UZBEKISTAN

All rivers of Uzbekistan originate in the mountains of the Tien Shan, Gissar-Alai, where a large amount of snow and ice accumulated. In the mountains of Central Asia up to 12,000 water courses are formed. Sais (small rivers with a permanent or temporary watercourse or creeks) among them are very often can be found. In the territory of Uzbekistan, more than 600 such sources formed [13]. The main hydrographic network of Uzbekistan is the Amu Darya, the the Syr Darya and their tributaries that enter the Aral Sea basin (see Fig. 1.3). The biggest between them in terms of water content is The Amu Darya River. Figure 1.3 shows the whole hydrographic network, with average annual runoff of inflow and outflow of the Central Asia Rivers.

Figure 1.3 – Hydrographic network of Uzbekistan [4].

The Syr Darya is the second largest in terms of water volume and the first in Length River of The Central Asia. With a headspring of The Naryn River, its length is 3019 km, and the catchment area is 219 thousand km square. The beginning of The Syr Darya River lies in the Central (Inner) Tien Shan Mountains. After the merger of The Naryn River with The Karadarya River it is called The Syr Darya River. The River has snow and glacial nourishment types. The water regime is characterized by spring-summer high water periods, which begins in April. The largest runoff observes in June. About 75.2% of the streamflow of Syr Darya River formed in the mountains of the Kyrgyz Republic. Afterward, The Syr Darya River crosses Tajikistan, Uzbekistan and flows into the Aral Sea in the territory of Kazakhstan. About 15.2% of the streamflow of The Syr Darya River is formed in the territory of Uzbekistan (the Chirchik River, the Akhangaran River and the rivers of Fergana Valley), 6.9% in Kazakhstan and 2.7% in Tajikistan [8].

The length of The Amy Darya River with headspring of The Pajn River is 2,540 km, and the catchment area is 309 thousand km square, the annual stream flow near Kerki city is 61.8 km^3 [5] or 2160 m^3 / s (1926-1973). After the merger of Panj with Vakhsh River in the mountains of Tajikistan, the river becomes The Amu Darya River. From Uzbekistan three large right tributaries flow into The Amy Darya River (The Kafirnigan River, The Surkhandarya River, and The Sherabad River) and one left tributary (The Kunduz River) flows from Afghanistan. Further to The Aral Sea, the river receives no inflow stream. The nourishing of the river is mainly made up of thawed waters, thus the maximum flow rate is observed in the summer months, and the smallest in January-February. Such intra-annual distribution of streamflow contributes use of river water for irrigation purposes. Flowing through the plain, from Kerki to Nukus city (Karakalpakstan), The Amy Darya River loses most of its water to evaporation, infiltration mainly via irrigation. In terms of turbidity, the Amu Darya ranks first in the Central Asia and one of the first places in the world. The main streamflow of The Amy Darya River is formed in the territory of Tajikistan (about 74%). Then the river flows along the border of Afghanistan with Uzbekistan, then crosses Turkmenistan and again returns Uzbekistan and flows into The Aral Sea. About 13.9% of The Amy Darya River streamflow is formed in the territory of Afghanistan and Iran and only 8.5% in the territory of Uzbekistan [9].

1.6 GLACIERS OF THE STUDY AREA

In the basin of The Chatkal River, more than 120 glaciers concentrated with a total area of 51.2 km^2 (see Fig. 1.4). They are located in the upstream of The Sandalash River. In the basin of The Sandalash River itself, 58 glaciers located, with area 20.1 km^2 in sum [1]. Morphological types of glaciers are various. The main mass is occupied by corries and hanging valley glaciers (60.3%). A characteristic feature in the distribution of morphological types of glaciers in the basin of The Chatkal River is the valley of The Sandalash River is dominated by corries glaciers, while in the Valley of The Chatkal River concentrated most of the hanging and other kinds of valley glaciers.

By the size of the glacier of the basin belong to small glaciers (from 0.1 to 0.6 km in length); glaciers with an area of bigger than 1.0 km^2 are seven. The largest glacier of the basin is called Karotoko Vostochny (East), its area is 2.3 km^2, and the maximum length is 2.4 km. In general, for the basin of The Chatkal River, the average area of the glacier is 0.4 km^2, the length is 0.9 km.

Figure 1.4 depicts the schematic distribution of glaciers of the Chatkal River basin.

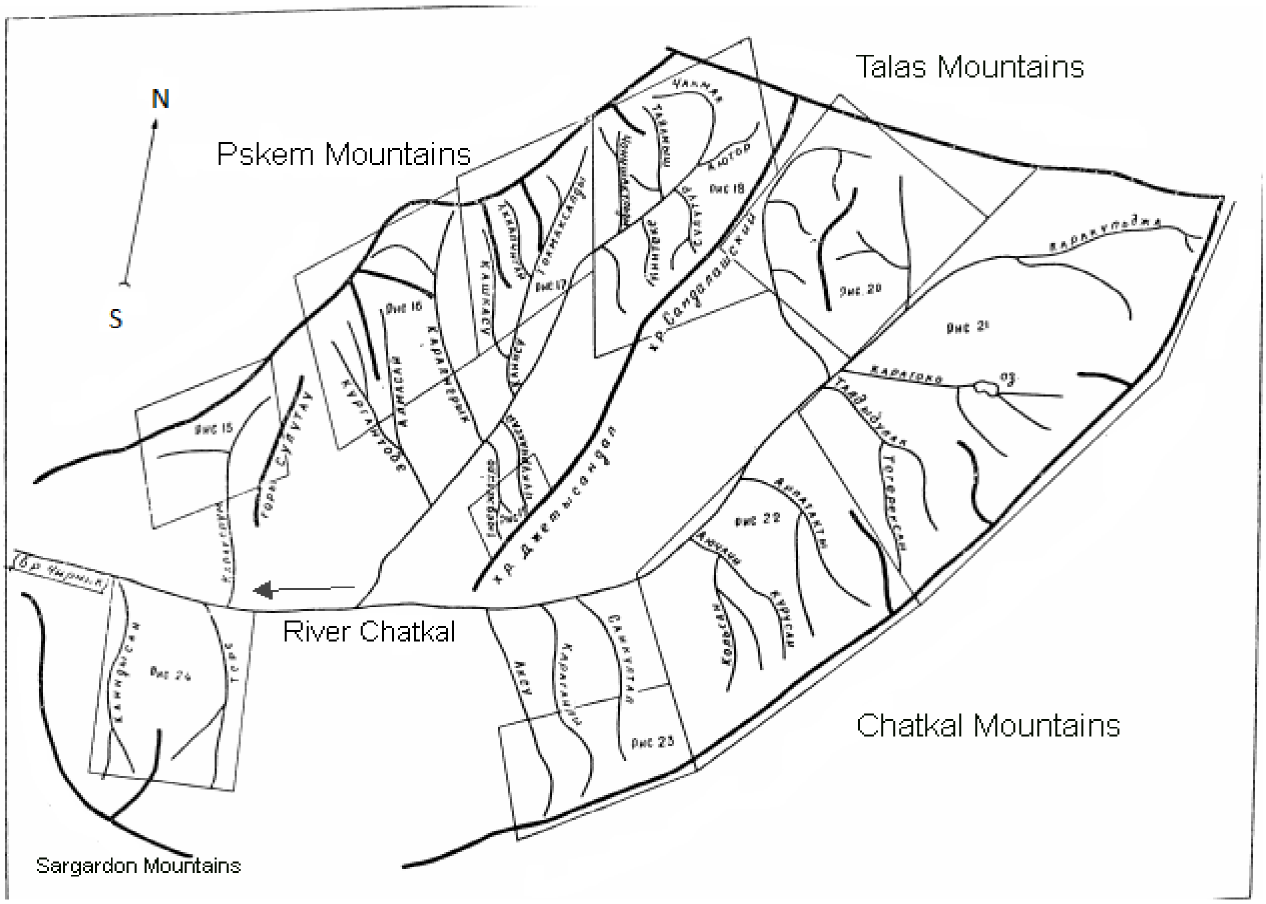

Figure 1.4 – Map-scheme of glaciers of the Chatkal River basin [1].

The majority of glaciers of the basin are concentrated in the interval of altitude 3300-4100 m, noteworthy, 24% of the ice area lying in the 3500-3600 m zone. The average height of the neve (firn) line is 3650 m. In some places of the basin, the height amplitude ranges up to 430 m. The basin of The Chatkal River is twice less glacier than the basin of The Pskem River, where 250 glaciers with a total area of 127.8 km^2 located. The orographic orientation of both basins contributes to the penetration of air masses into them; however the Sargardon ridge, which lies at the beginning of The Chatkal River valley and located *perpendicular* to the Chatkal ranges, is an important obstacle in the movement of air masses. Consequently, in the upper reaches of The Chatkal River, the total amount of precipitation is 800 mm, whereas in the basin of The Pskem River this amount reaches 1500-2000 mm per year. The coldest month is January; mean air temperature of this month in the 3000 m height reaches minus 29-30°.

In most cases, thawed water from glaciers first filtered in the thickness of moraine deposits and passes a definite section of the valley and only then becomes surface runoff. It was also noted when the river stream forms directly from the glacier, a distinctly expressed daily course of the water level is observed; Peak comes in the afternoon. When the meltwater passes through loamy deposits, the peak of the daily high water is smoothed, and thus the river stream is detained [1]. The value of the detention of the runoff depends on the length of the section and on the characteristics of the material and the existence of lakes. Due to glaciers of this area, lakes in the upstream of The Chatkal River are widely distributed. A study of the hydrograph of daily flow rates for three different years in terms of water content shows that the first spring flood peak of expenditures from the thawing of seasonal snow cover in the low mountainous region takes place in April. The second peak, which is formed from the melting of high mountain snows and glaciers, takes place in late June early July. Afterward, a decline of flow rate almost by the end of November takes place. In some years, the April flood peak may exceed the summer flood peak (see Fig. 1.5).

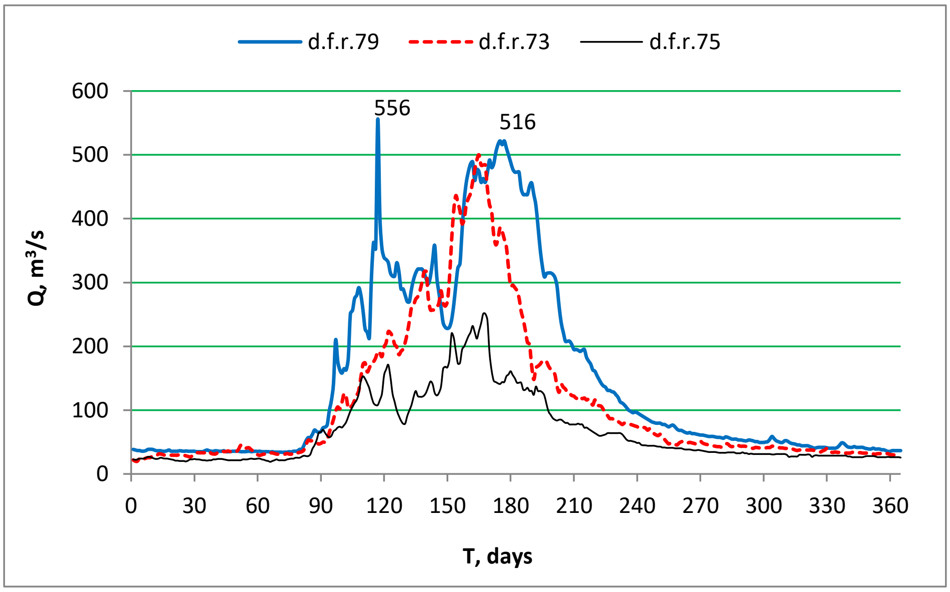

Figure 1.5 – hydrograph of the daily mean flow rate for three different watery years, The Chatkal River – at Khudoydodsay station.

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2. MATERIALS AND METHODS

2.1 THE CLIMATE OF THE STUDY AREA

As noted earlier Uzbekistan's highly variable and continental climate the location relative to the world ocean plays a key role. The peculiarity of climate is expressed in cloudless and long days in most periods of the year, and in a few precipitations, especially in the plain areas. The climate is sharply continental and hence the amplitude of daily and annual air temperatures is high [5].

In general, warm air masses come from the Atlantic Ocean. Air masses reach territory of Uzbekistan warmed, "dried up", and tropical air mass carries only a hot air stream and therefore on the plains rarely falls more than 200 mm of precipitation annually, and in some places, their amount do not even exceeds 70-80 mm. Only in the mountains, they increase up to 600-800 mm. In the southeast, on the windward slopes, even more amount of precipitation falls, which creates favorable conditions for the development of rain-fed farming. Furthermore it contributes the growth of appropriate forms of plants and agricultural crops. By the seasons of a year, the precipitation is unevenly distributed and therefore main part fall in the winter and spring months [2].

In winter, the cold air masses invade from the Arctic Ocean and Siberia, the weather changes rapidly, the air temperature drops dramatically. At Ustyurt (Karakalpakstan) plateau, for example, the temperature drops to minus 40ºC. In the mountains, winter is even severe and lasts 4-5 months [16].

To analyze the climate of the study area we used data from four meteorological stations (Fig. 2.1, Table 2.1) [8].

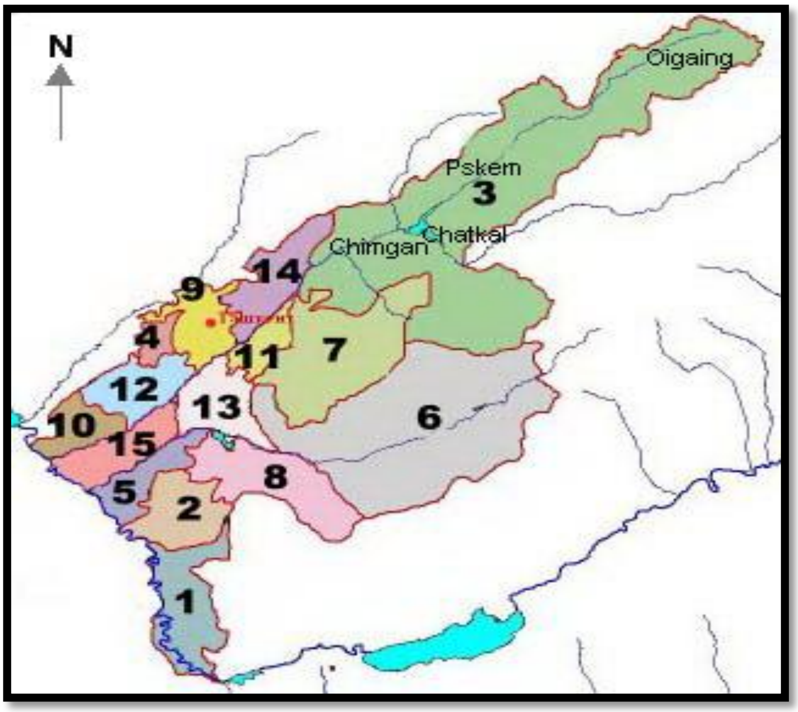

Figure 2.1 – Map-scheme location of the meteorological stations in the study area.

Table 2.1 – the information about meteorological stations of the focusing area

Name of station	International code of station	Latitude	Longitude	Elevation above the sea level, m	Location
Oigaing	38339	42º10′	70º52′	2175	Uzbekistan
Pskem	38462	41º54′	70º22′	1265	Uzbekistan
Chatkal	38471	41º54′	71º21′	1421	Uzbekistan
Chimgan	38706	41º31′	70º01′	1675	Uzbekistan

2.2 AIR TEMPERATURE

For better understanding, the weather stations were divided into two groups in terms of elevation above sea level: 1) meteorological stations located within 1300-1700 m (Chimgan, Chatkal, and Pskem); 2) upper than 2000 m above sea level (Oigaing). As it can be seen in Figures 2.2, 2.3, 2.4, for the first group, the average temperature of the hottest month (July) varies between 18-25 °C. The average temperature of the coldest month (January) is minus 4-9 ° C. The maximum monthly air temperature is 25-32 °C; the minimum temperature is minus 8-15°C.

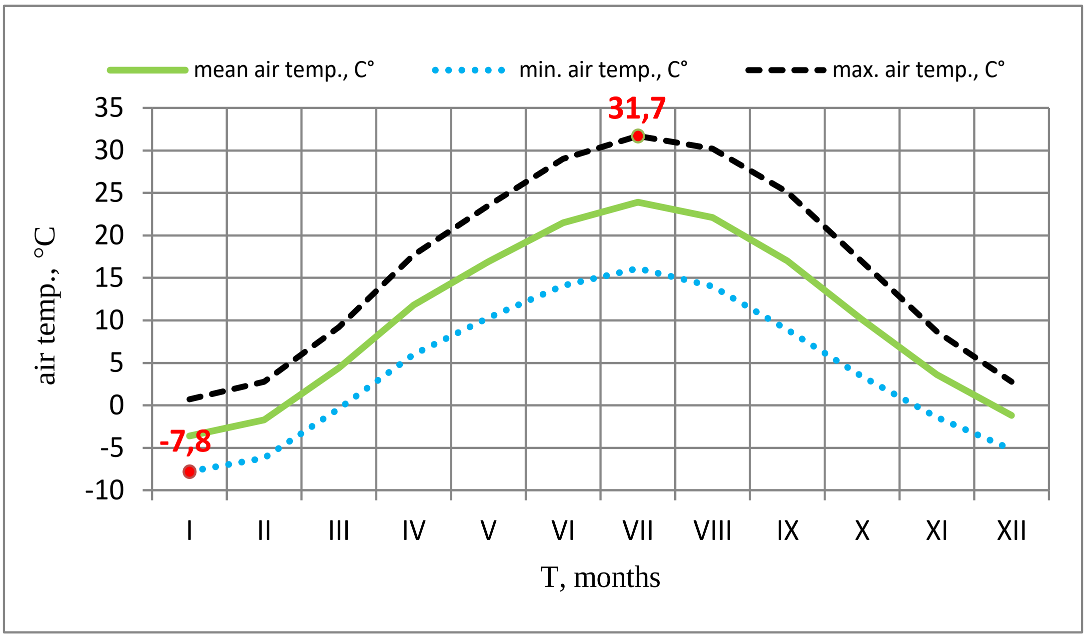

Figure 2.2 – Mean, maximum and minimum air temperatures at meteorological station Chatkal, 1980-2015.

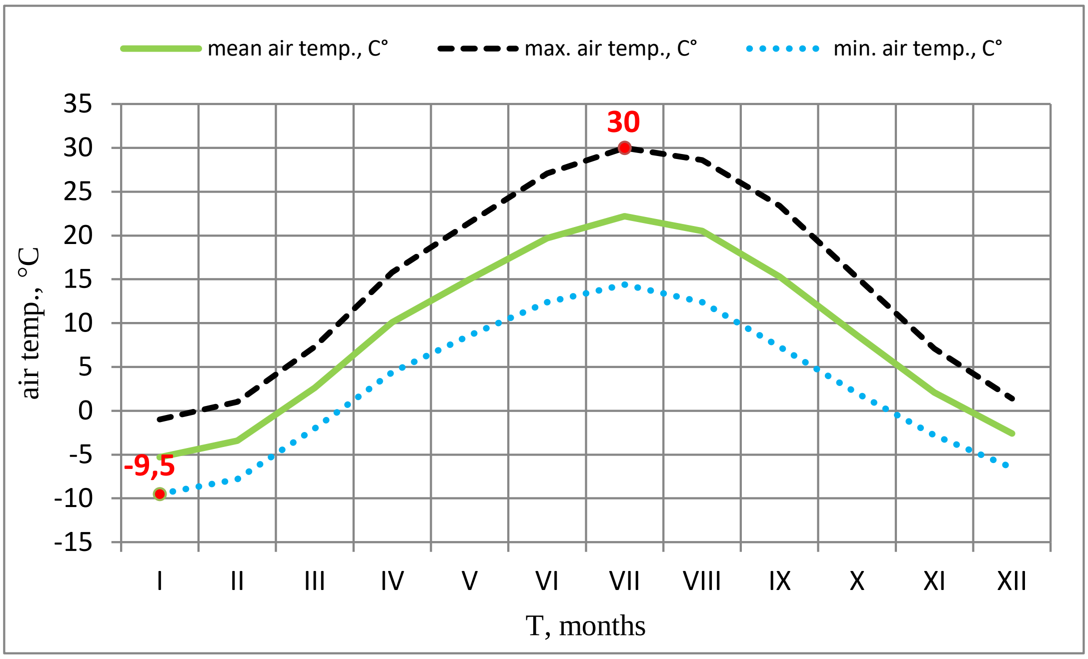

Figure 2.3 – Mean, maximum and minimum air temperatures at meteorological station Chimgan, 1980-2015

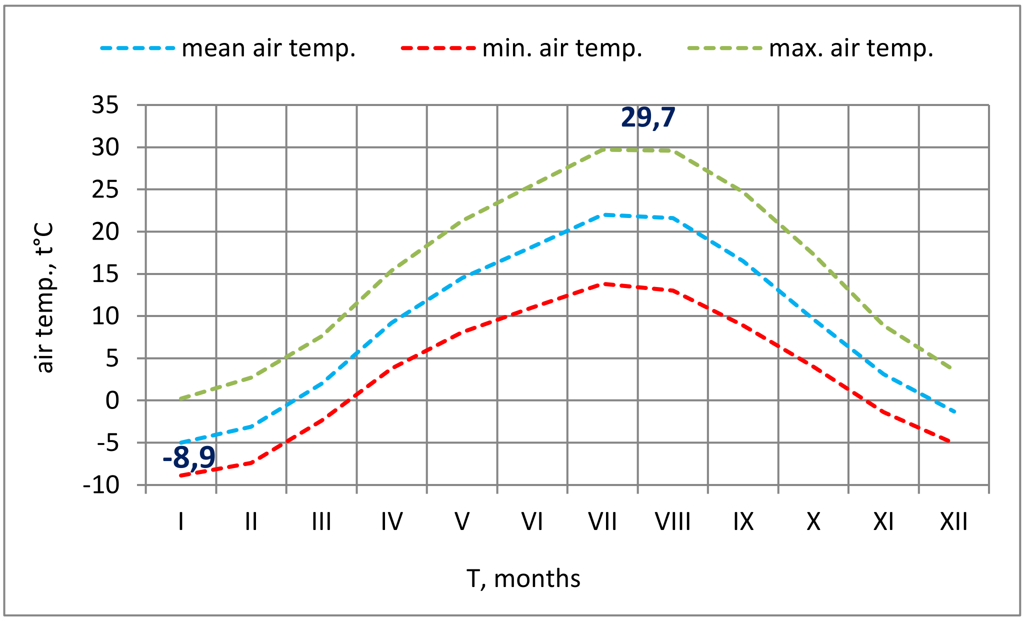

Figure 2.4 – Mean, maximum and minimum air temperatures of meteorological station Pskem, 1980-2015 [4].

For the second group (Fig. 2.5), the average temperature of the hottest month (July) varies between 20-23 °C. The average temperature in January, within the range of minus 12-13°C, the maximum monthly air temperature 23 °C, the minimum temperature - minus 17°, which means with increasing altitude the air temperature drops significantly.

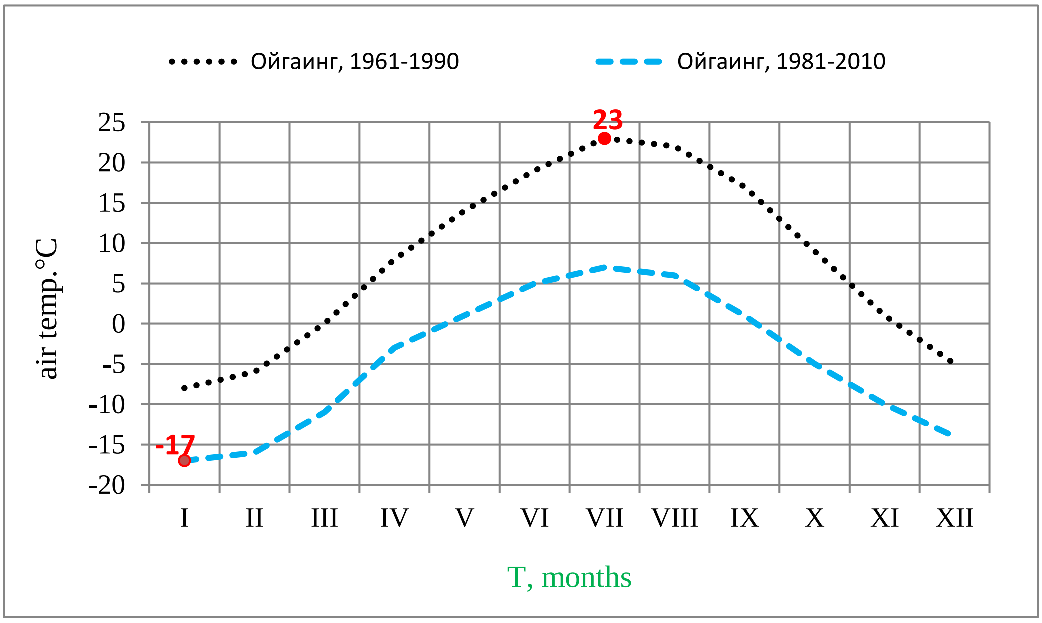

Figure 2.5 – Maximum and minimum air temperatures of meteorological station Oigaing, 1980-2015.

2.3 PRECIPITATION

The intra-annual distribution of precipitation is shown in Figures 2.6 and 2.7. As can be seen from these figures, 64-65% of the annual amount of precipitation falls from January to May, the smallest part (5-6%) falls during the period of June-September months [10].

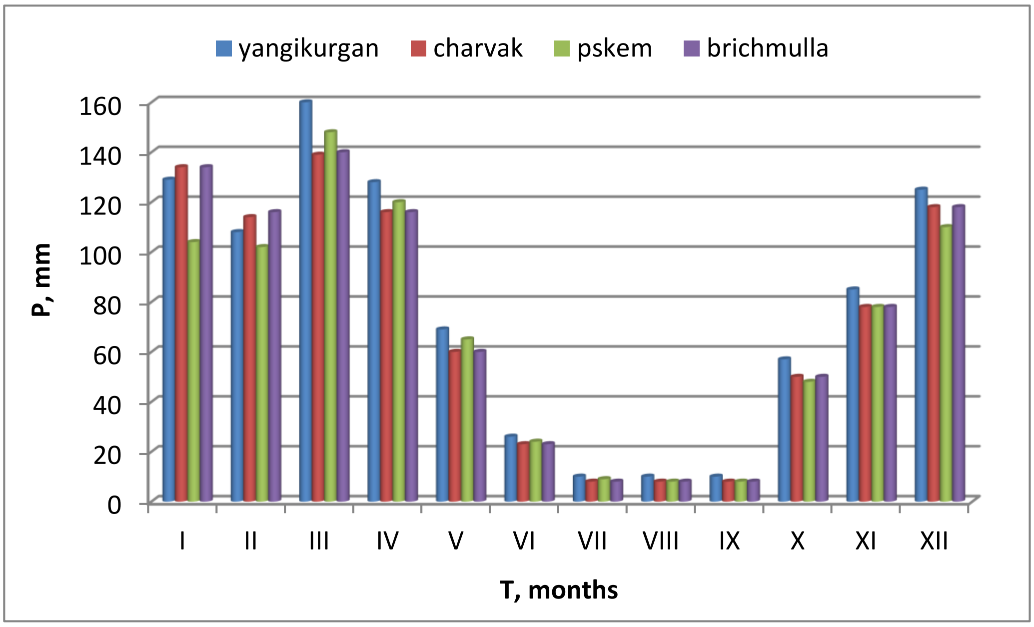

Figure 2.6 – Average long-term monthly precipitation at Pskem meteorological station.

The average long-term amount of annual precipitation for each meteorological station is presented in the table - 2.2.

Table 2.2 – average long-term annual precipitation, mm [4].

№	Meteorological station	Precipitation, mm	
		For a period of 1961- 1990	For a period of 1981- 2010
1	Chatkal	555	574
2	Chimgan	533	559
3	Pskem	546	572
4	Oigaing	523	538

For all the stations during 1981-2010 precipitation is increasing in the hot season (May-August). But this growth is within 3-5%, which does not exceed 9% statistical error. It was also found about 44% of the annual amount of precipitation falls in liquid form, 26% mixed precipitation and 30% in the form of snow [9].

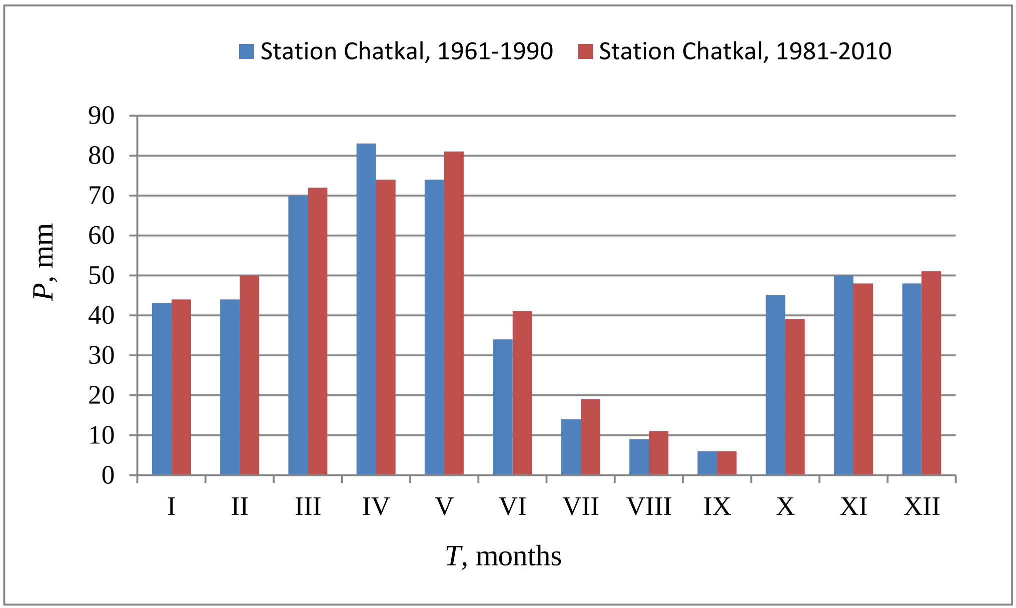

Figure 2.7 – The average monthly sum of precipitation for the long term at Chatkal meteorological station with a two different period of observations.

2.4 HYDROLOGICAL CHARACTERISTICS OF THE STUDY AREA

The Chatkal River with the name Karakuldzha originates from the southwestern slopes of the Talas Alatau ridge of Kyrgyzstan. The river got the name Chatkal River - after the merger of right tributaries Karakasmak River and The Karakuldzha River. From the *source* to the *mouth* The Karateka River, The Chatkal River flows (left tributary) in a valley with a deep, narrow gorge [11]. The slopes of the valley are almost vertical, sometimes even overhanging (Figure 2.8). Their surface is strongly dissected by gorges of tributaries of the river and ravines. The floodplain is found only in the places of the basins of the hollow-like expansions of the valley. The width of the floodplain reaches 200 meters and in some places 300 meters.

Figure 2.8 – The Chatkal River. View from cradled crossing about 6-7 km before the mouth of The Charvak Reservoir.

The Chatkal River has four main tributaries: Ters and Akbulak - left tributaries; Koksu and Sandalash - right tributaries and plenty of little tributaries (more than 100).

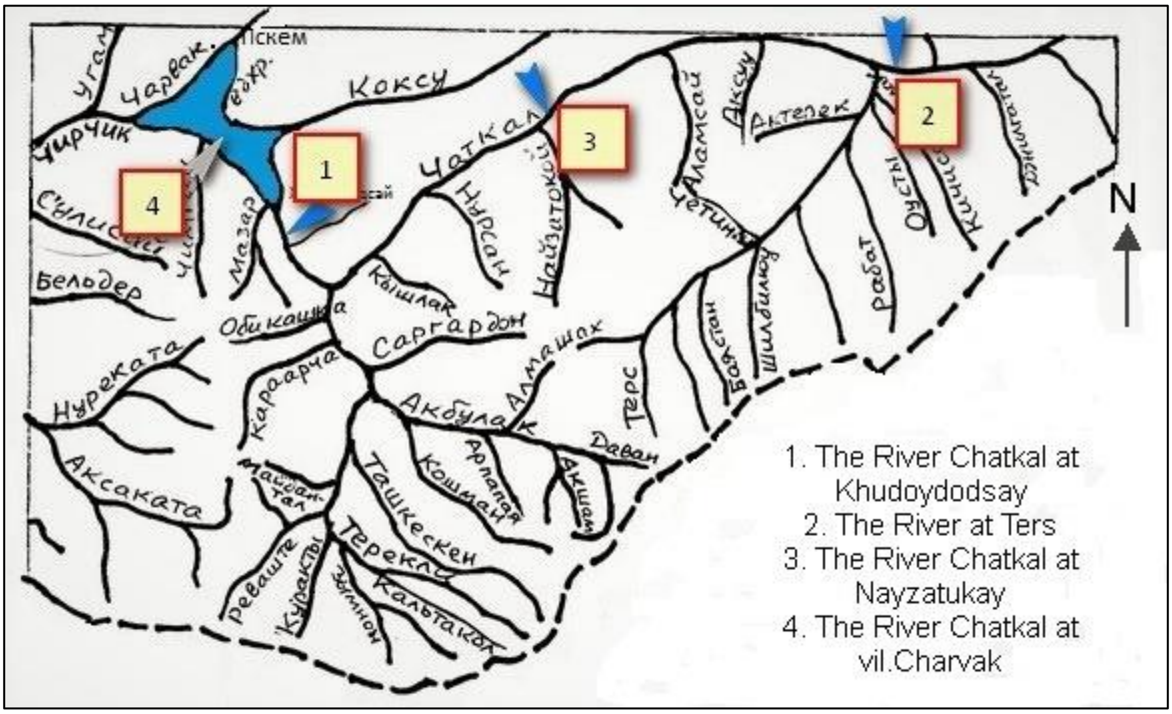

Figure 2.9 – Map-scheme of main tributaries and hydrological stations of the Chatkal River, green arrow points to the North.

From listed Chatkal's tributaries with a catchment area of 1157 km^2 Sandalash is the largest one, and this is 16,8% of the total catchment area of The Chatkal River. And catchment area of the rest tributaries as follows Ters River is 561 km^2, Akbulak River – 818 km^2 and Koksu – 405 km^2 respectively. Shultz V.L. [11] proposed the classification of the rivers of Central Asia by the type of their nourishment (see Table 3.1). Even nowadays, this classification is widely used in the field of hydrology in the countries of Central Asia.

Table 2.3 – The classification of Shultz V.L.

Rivers, by their types of nourishment	Criteria for assigning of rivers to a particular type of nourishing		
	$\delta = \frac{W(VII-IX)}{W(III-VI)}$	$W_{VII\text{-}IX}$, in % of annual stream	The month with a maximum stream
The rivers of glacial snow nourishing	≥ 1.00	≥ 38	VII, VIII
The rivers of snow-glacial nourishing	0.99-0.27	40-17	V, VI
The rivers of snow nourishing	0.27-0.18	16-12	IV, V
The rivers of snow-rain nourishing	0.17-0.00	13-0	III, IV, V
W- annual surface runoff, δ-runoff relationship between the period of July-September and March-June			

According to this classification for the Chatkal River, this criterion is equal to 0.50, which corresponds to the type of the rivers of snow-glacier nourishment. As in the previous chapter, it was noted that the Chatkal River flows into the Charvak reservoir. Charvak HES (hydroelectric station) with a capacity of 600 MW (four with a 150 MW hydro electric units each) is one of the largest hydroelectric power plants in The Central Asia (see Fig. 2.9.1). The Charvak hydrologic junction has crucial integrated importance for the development of the national economy sectors in the region, first of all, hydropower energy, regulation of river stream and irrigation of fertile lands [15]. The coastline of the reservoir is almost 100 km and at half these lengths there are occupied by many recreation areas, boarding houses and children's camps [16]. The gate of the watercourse is located in the upstream of The Chirchik River – that is a right tributary of The Syr Darya River. Figure 2.9.1 shows the location of the Charvak reservoir and the Charvak hydroelectric power station.

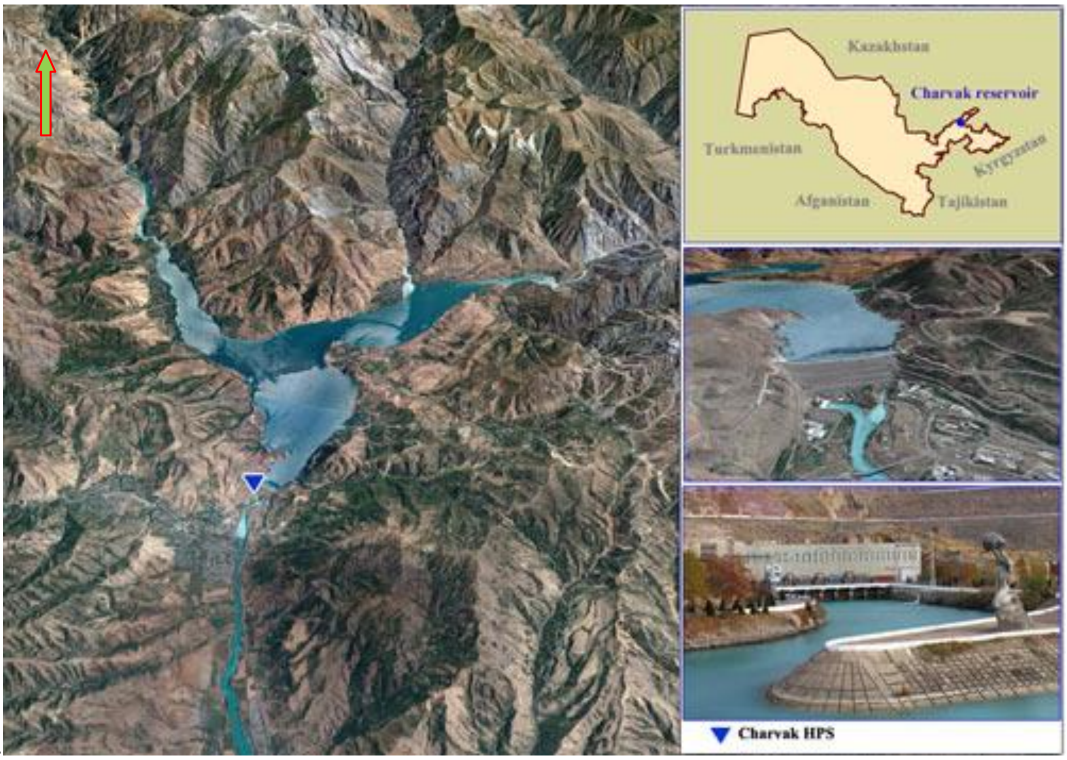

Figure 2.9.1 – The Charvak Reservoir and Charvak HES in Google Earth, green arrow points to the North.

The average annual discharge of the Chirchik River at the hydrological station near to HES is 208 m^3/s; the maximum observed flow rate is 1600 m^3/s; the average annual storage 6.6 km^3. The Rivers Pskem, Koksuv, Chatkal, Nauvalaysai, Mazarsai and Yangikurgansai flow into the reservoir as well as drains of many small springs.
In Table 2.4, the main characteristics of the reservoir and HES are given [15].

Length of the Dam, m	**770**
Maximum depth at the Dam, m	**148**
Maximum discharge through construction (*P* = 0,01%), m^3/s	**2400**
Discharge through HES building, m^3/s	**500**
Total volume of the reservoir, million m^3	**2006**
Active volume of the reservoir, million m^3	**1580**
Maximum projected height of the Dam, m	**168**

The Charvak reservoir provides seasonal stream regulation in accordance with irrigation necessities, keeping summer flood peaks and rainfall waters for further use of water during periods of low water availability (in August - September). By regulating the runoff during the winter season, Charvak Reservoir also contributes to an increase the efficiency of the downstream Chirchik-Bozsu water cascade.

2.5 INITIAL DATA

Usually, hydrometeorological data are collected in hydrological yearbooks. In this dissertation, we used the average monthly and average annual water discharge data from four hydrological stations of the focusing area (Table 2.5). The disposition of the stations is shown in Figure 2.9. The data of annual flow rates received from the department of water cadaster and meteorological measurements, Centre of Hydrometeorological Service at Ministry of Emergency Situations of The Republic of Uzbekistan [8] and hydrologic yearbooks of the library of Russian State Hydrometeorological University.

Table 2.5 – Hydrological stations of the Chatkal River.

№	River – station	*F*, km	The period of observation	observations, year
1	Chatkal River – at Khudoydodsay station	6580	1965-2014	50
2	Chatkal River – at Nayzatukay station	5520	1933-1963	26
3	Chatkal River – at Ters station	4090	1933-1975	39
4	Chatkal River – at Charvak village station	7110	1932-1963	35

2.6 EXTENSION OF THE RECORDS AND OBSERVATIONS

In hydrology, for filling in missing data and extension of records of the annual stream flow, corresponding to the availability and the length of data the following methods are commonly used: 1) for a long period of observations, the calculation is carried out directly from the observation data; the time period from this dataset is used in computations if its duration is 50-60 years and more; 2) if observation is short it has to be filled relatively to a longer period of observation by applying the method of hydrological analogy (river analog); 3) in the case of a series of observations very short or no data at all, annual runoff is determined by generalizations of the results of studied river or the water balance equations are used [12].

In this research, we used the method of *hydrological analogy*. For hydrological stations, where it is necessary to fill the gaps of records of The Chatkal River, the parameters of the linear regression equation for the connection of average annual discharge is calculated. Low-flows gauged in the Khudoydodsay station are related to contemporaneous data for the Charvak village station, enabling low-flow characteristics for the Charvak village station to be transferred through the relation to the Khudoydodsay station (Figure 2.9.2).

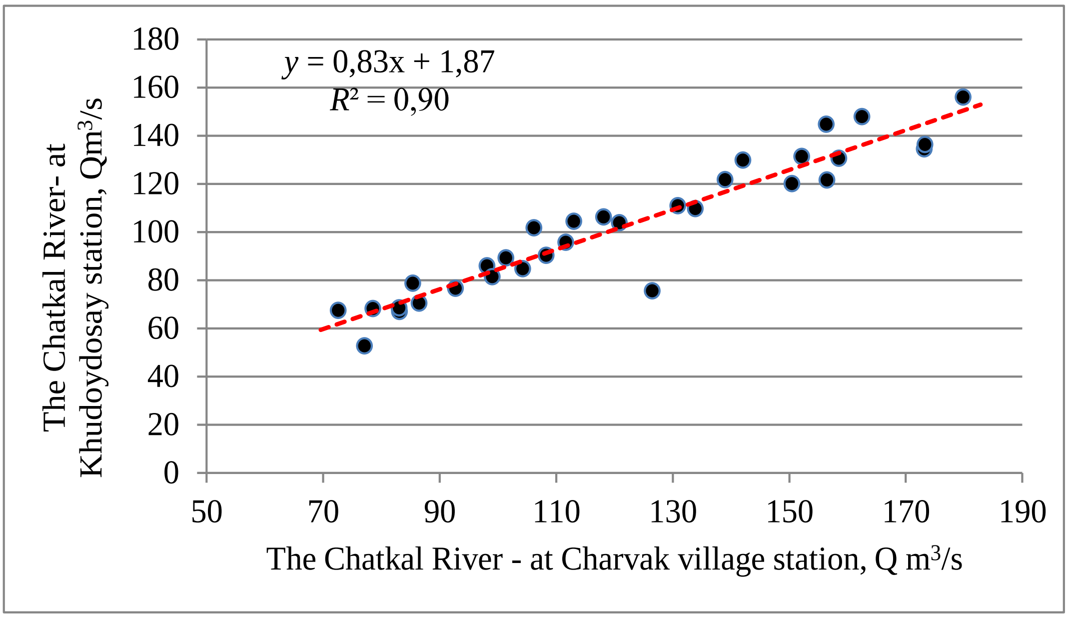

Figure 2.9.2 - Low-flow correlations between two The Chatkal River streams, Khudoydodsay station and Charvak village station, 1933-1966.

Table 2.6 – the parameters of the low-flow correlations plot of the annual discharge values between two stations of The Chatkal River – at Khudoydodsay station and The Chatkal River – at Charvak village station.

Characteristics	Value
estimated river (*Y*)	Chatkal River – at Khudoydodsay station
analog-river (*X*)	Chatkal River – at Charvak village station
Observations (*n*)	32
The correlation coefficient (*R*)	0,95

Standard error of R (σ_R)	0,04
R/σ_R	23,3
the coefficient of regression (a)	0,83
Standard error a (σ_a)	0,05
a/σ_a	16,65
Independent member (b)	1,87
Regression Equation	$Y = 0,83 * x + 1,87$

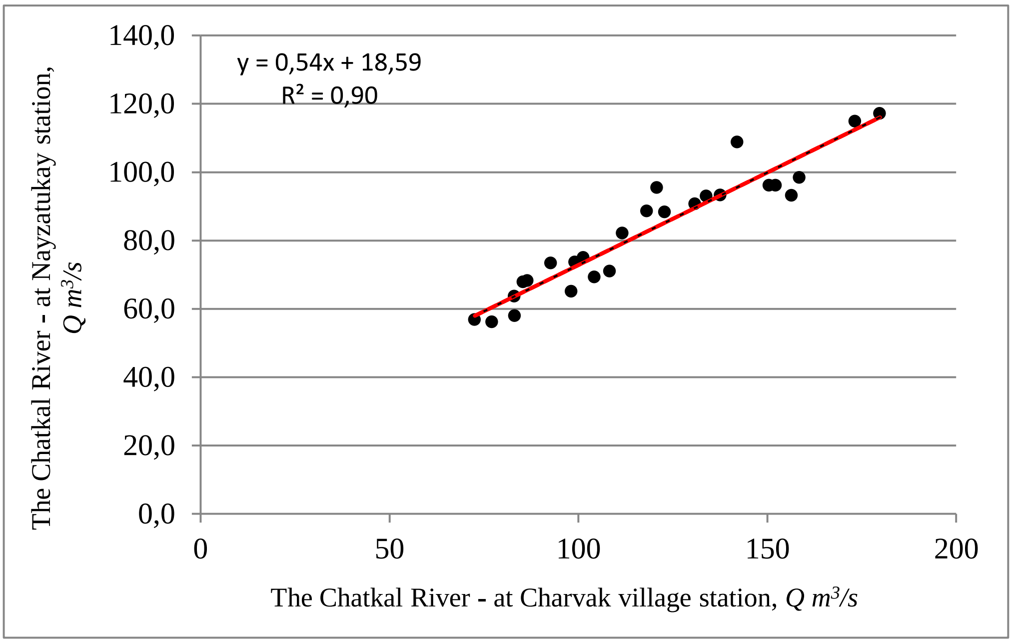

Figure 2.9.3 - Low-flow correlations between two The Chatkal River streams Nayzatukay station and Charvak village station, 1933-1963.

Table 2.7 – The parameters of the low-flow correlations plot of the annual discharge values between two stations of The Chatkal River – at Nayzatukay station and at Charvak village station.

Characteristics	Value
estimated river (Y)	Chatkal River – at Nayzatukay station
analog-river (X)	Chatkal River – at Charvak village station
Observations (n)	26
The correlation coefficient (R)	0.95
Standard error of R (σ_R)	0.064
R/σ_R	14.90
the coefficient of regression (a)	0.542
Standard error of a (σ_a)	0.04
a/σ_a	14.89
Independent member (b)	18.6
Regression Equation	Y=0.54*x+18.59

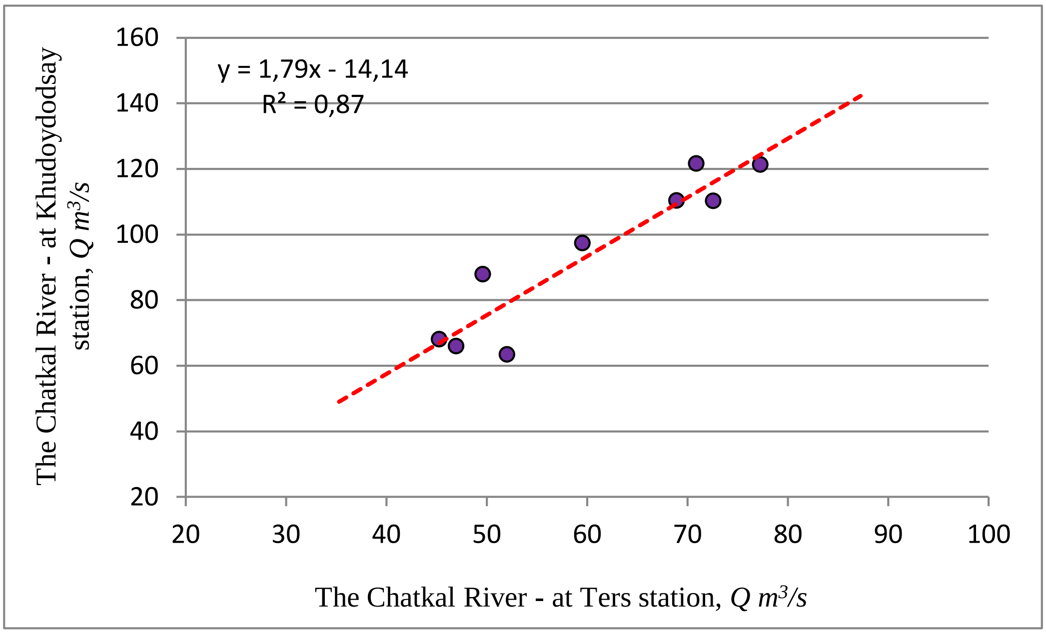

Figure 2.9.4 - Low-flow correlations between two The Chatkal River streams Khudoydodsay station and Ters station, 1965-1975.

Table 2.8 – the parameters of the low-flow correlations plot of the annual discharge values between two stations of The Chatkal River – at Khudoydodsay and at Ters stations.

Characteristics	Values
estimated river (*Y*)	Chatkal River – at Khudoydodsay station
analog-river (*X*)	Chatkal River – at Ters station
Observations (*n*)	9
The correlation coefficient (*R*)	0,93
Standard error of R (σ_R)	0,025
R/σ_R	36,7
the coefficient of regression (*a*)	1,79
Standard error of *a* (σ_a)	0,094
a/σ_a	18,96
Independent member (*b*)	14,14
Regression Equation	Y=1,79*x-14,14

2.7 DETECTION AND ESTIMATION OF LINEAR TRENDS

In order to prove the hypothesis of absence of a monotonic linear trend in the dataset, a criterion of the significance of the correlation coefficient for the dependence *x = f (t),* where *t* – time, was applied. The coefficient of paired correlation and its standard error calculated by using the following formula (2.1, 2.2):

$$R = \frac{\sum_{i=1}^{n}\left[(x_i - \bar{x})(t_i - \bar{t})\right]}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2 \sum_{i=1}^{n}(t_i - \bar{t})^2}}, \qquad (2.1)$$

$$\sigma_R = \sqrt{\frac{1 - R^2}{n - 2}}. \qquad (2.2)$$

The null hypothesis of absence of linear trend not rejected if:

$$|R| / \sigma_R < t_{1-\alpha} \qquad (2.3)$$

Where $t_{1-\alpha}$ – quartile of the Student *t* distribution with $\nu = (n - 2)$; 2α - two tails of the level of significance, *n* – sample size.

The significance level was taken as $2\alpha = 5\%$. In this situation $t_{1-\alpha} = t_{0,975} \sim 2$. Outcomes of the Test are presented in Table 3.1.

2.8 HOMOGENEITY TEST OF THE DATASET

In hydrology, in the most analyses of homogeneity test of the data set Fisher's and Student's criterion applies. To estimate the stationarity of variances (Fisher's test) and mean values (Student's test), the time series (data set) divided into two or more samples. It is desirable to connect the boundaries of the partition with observation dates of the assumed disturbance of the stationarity. In our case, it was not possible. Thus we divided into two equal parts. Furthermore for both samples separately empirical values of Fisher's statistic were calculated:

$$F^* = \frac{D_1^*}{D_2^*} \qquad (2.4)$$

Where D_1^* and D_2^* – are variances of the both parts of analyzing sample, whereas numerator normally bigger part of the variance is taken ($D_1^* > D_2^*$).

Critical values of the Fisher's F Test Two sample variances ($F_{2\alpha}$) for a level of significance 2α = 5 % (n_1 and n_2 – the number of observations) depending on freedom two tails of $\nu_1 = n_1 - 1$, $\nu_2 = n_2 - 1$ defined from the table. The hypothesis of the homogeneity is not rejected if it fits the following condition:

$$F^* < F_{2\alpha}. \quad (2.5)$$

Student's criterion allows the estimation of the homogeneity by using the mean value of the sample. The empirical value of Student's statistic calculated by applying the formula:

$$t^* = \frac{\bar{x}_1 - \bar{x}_2}{S}\sqrt{\frac{n_1 n_2}{n_1 + n_2}} \quad (2.6)$$

Where $\bar{x}_1$ and $\bar{x}_2$ – are average values of the first and second part of the analyzing sample; σ_1 and σ_2 – are standard deviations of the first and second part of the analyzing sample. S –defined by using the following formula:

$$S = \sqrt{\frac{(n_1 - 1)\sigma_1^2 + (n_2 - 1)\sigma_2^2}{n_1 + n_2 - 2}} \quad (2.7)$$

The critical values of Student's statistic t-test: Two-sample Assuming equal variances ($t_{2\alpha}$) depending on freedom two tails are identified from a table, $\nu = n_1 + n_2 - 2$ with a level of significance 2α = 5 %.

The hypothesis of the homogeneity is not rejected if it fits the following condition:

$$|t^*| < t_{2\alpha} \quad (2.8)$$

2.9 THE ASSESSMENT OF THE MAIN HYDROLOGICAL CHARACTERISTICS

It is the primary concern of hydrologist to picking up of a reasonable method for evaluation of the basic parameters of river flow for determining the hydrological features and because it could significantly influence the result obtained. The paragraph discusses three methods for estimating of parameters, which often used in modern hydrological computations: the method of Moments, the method of maximum likelihood and the method of L (linear combinations) moments.

The maximum likelihood method leads to efficient computation with small random scattering and estimations of likelihood method are practically not biased. Nevertheless, there are disadvantages of the method: cumbersome calculations and the dependence of the formulas for estimating the statistical parameters from the distribution law, which in turn creates bondage on the statistical characteristics [1].

There are a number of advantages with *L-moments* method in defining the parameters, especially in the zone of extreme values. In our dataset we did not observe extreme values thus we decided not to use this method [3].

The method of moments means in equating the expressions for the distribution moments to the corresponding sample estimates. The required assessments can be derived by considering the number of moments of the distribution equal to the number of parameters to be estimated and solving the equations obtained with respect to these parameters [6]. The disadvantage of the method concludes in solving practical hydrological problems: the bias of the estimates at high asymmetry (C_s = 3 - 4C_v) and at high values of the coefficient of variation C_v. 1. In this research *the method of moments* is applied to calculate the main statistical characteristics of the average annual runoff and their errors for the following reasons:

1. Evaluations of the parameters are derived in an explicit form, i.e., by formulas (which are simple enough).
2. Estimations of the parameters do not depend on which families of distributions will be used in further calculations.
3. The hydrologic datasets which we worked with have a small (or moderate) coefficient of variation and skewness (C_v < 0, 6; C_v/C_s not more than 3). In this case, bias is insignificant.

The calculation of the mean value, which depends on the number of years of hydrologic observations, was carried out by using the formula:

$$m_x = \overline{X} = \frac{1}{n}\sum_{1}^{n} X_i \qquad (2.9)$$

The following formula is used for assessment of the coefficient of variation and skewness:

$$C_V = \sqrt{\frac{\sum_{1}^{n}(K_i - 1)^2}{n-1}} \qquad (2.9.1)$$

$$C_S = \frac{n\sum_{1}^{n}(K_i - 1)^3}{(n-1)(n-2)C_V^3} \qquad (2.9.2)$$

Where $k_i = x_i / \bar{x}$ – the coefficient of the ratio between sample and sample means;

The standard error of the sample mean:

$$\varepsilon_X = \frac{C_V}{\sqrt{n}} * 100\% \qquad (2.9.3)$$

Where C_v – coefficient of variation of the sample;

To estimate the standard error of the coefficient of variation of the sample the following formula is used:

$$\varepsilon_{C_V} = \frac{\sqrt{1 + C_V^2}}{\sqrt{2n}} * 100\% \qquad (2.9.4)$$

For the evaluation of the error of skewness formula of S.N. Kritskiy and M.F. Menkel was applied [7]:

$$\varepsilon_{C_S} = \frac{\sqrt{\frac{6}{n}\left(1 + 6C_V^2 + 5C_V^4\right)}}{C_S} * 100 \qquad (2.9.5)$$

2.9.1 INTRA-ANNUAL RUNOFF DISTRIBUTION OF THE CHATKAL RIVER

The observations of average monthly water discharge are used to estimate the inter-annual distribution of The Chatkal River runoff. The evaluations of the intra-annual distribution of runoff were implemented not for hydrological years which generally starts from October 1st, but for water management years because the beginning of the water management year and hydrological year practically never coincide. In ex-USSR countries, for the beginning of the water management year, the earliest date of the onset of the high water phase is normally taken [17].

In this section, to determine the intra-annual distribution of runoff the method "average distribution of runoff over years of a featured gradation of water content or runoff" was used.

When calculating the annual distribution runoff by the applying "average distribution of runoff over years of a featured water content graduation," average annual water flow data set was generated. The resulting hydrological data set was ranked in descending order, and its empirical probability was determined by using the following formula:

$$P = \frac{m}{(n+1)} * 100\% \qquad (2.9.6)$$

Where m – is the sequence number of data set and n – is a number of samples.

In accordance with the calculated supply curve, the water management year of the corresponding water group was selected: 1. High watery year; 2. Average watery year; 3. Low watery year [14]. In turn, water managements year also divided into two periods of watery, low watery period *(IV-IX months)* and high watery period *(X-III months)* respectively.

3. RESULTS AND DISCUSSIONS

3.1 EXTENSION OF DATA SET

The initial dataset for The Chatkal River – at Khudoydodsay station was from 1965 to 2014. However, the dataset was extended to 32 years (Figure 3.1).

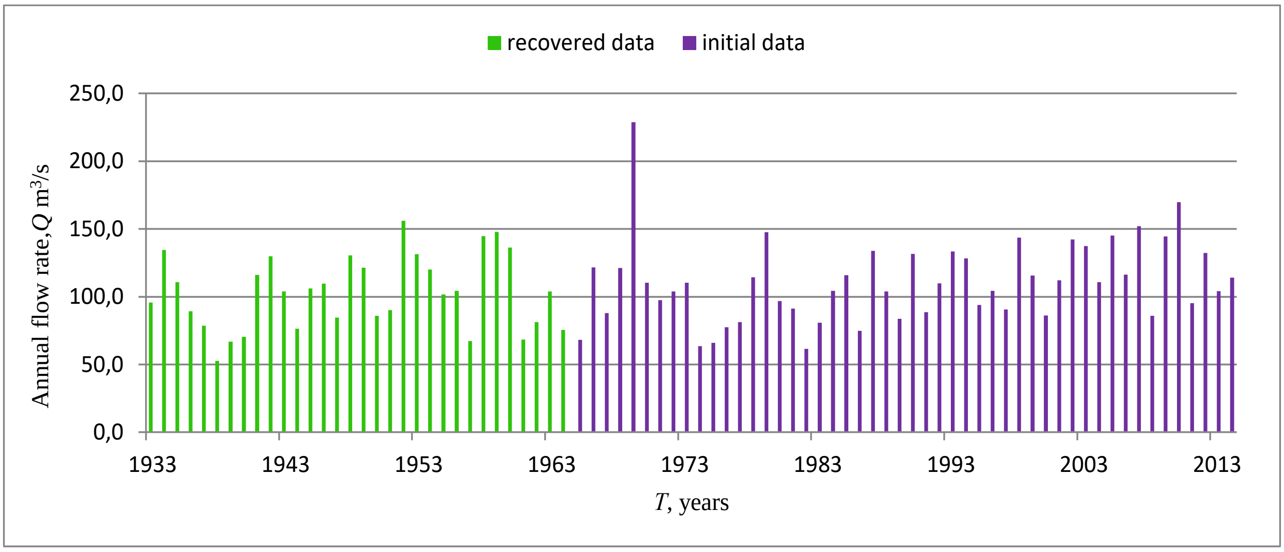

Figure 3.1 - Histogram of annual stream flow for the Chatkal River – at Khudoydodsay station, initial with the recovered data set.

Table 3.1 –Test results of the hypothesis of absence of a monotonic linear trend in the dataset of the annual flow rate of 4 hydrological stations.

№	River, station	R	σ_R	R/σ_R	H_0: $R = 0$
1	The Chatkal River – at Nayzatukay	0.004	0.204	0.326	Do not reject
2	The Chatkal River – at Ters	0.000	0.164	0.029	Do not reject
3	The Chatkal River – at Khudoydodsay	0.243	0.141	1.717	Do not reject
4	The Chatkal River – at village Charvak	0.327	0.155	1.988	Do not reject

From the results in Table 3.1, it can be seen for all hydrological stations of The Chatkal River linear trends are statistically insignificant.

Figures 3.2 and 3.3 illustrate the time series of the annual water discharge for different periods according to the dataset of the hydrological stations of The Chatkal River at Khudoydodsay station and The Chatkal River – at Charvak village station.

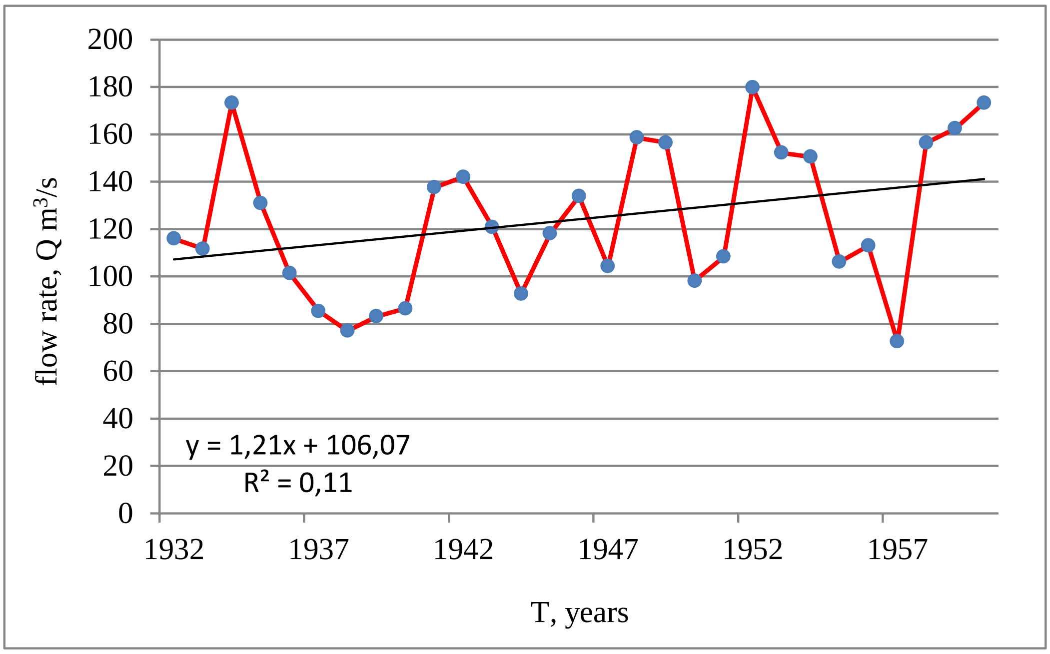

Figure 3.2 - Time series of annual flow rates of The Chatkal River at Charvak village station for the period 1932-1966, the linear trend is not detected.

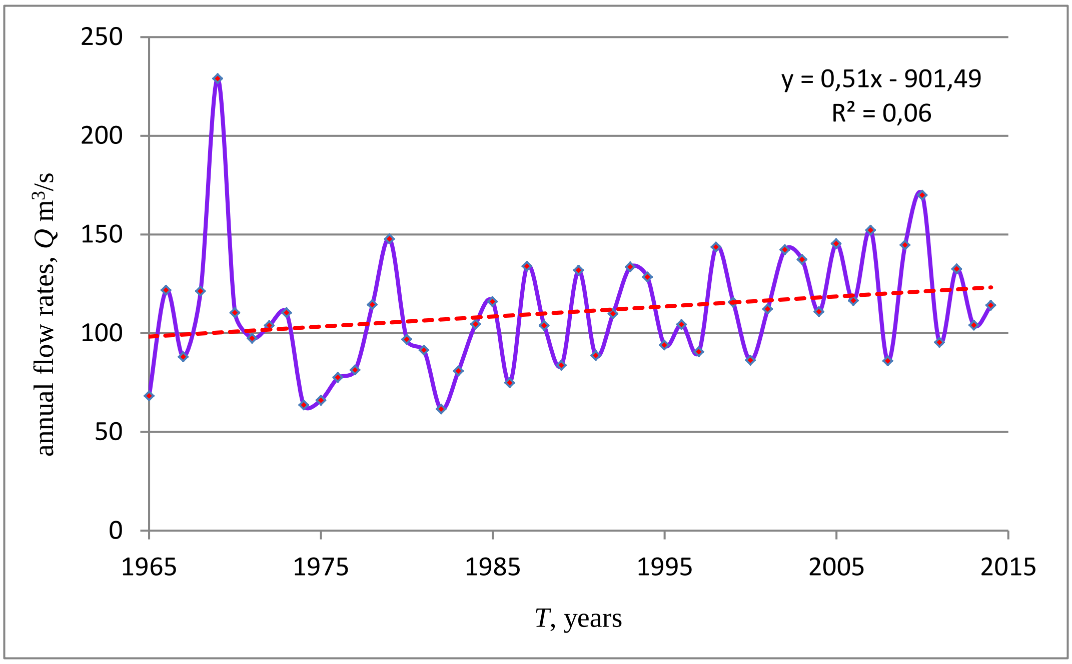

Figure 3.3 - Time series of annual flow rates of The Chatkal River at Khudoydodsay station for the period 1965-2014, the linear trend is not detected.

3.2 RESULTS OF THE HOMOGENEITY TEST

Table 3.2 presents the results of homogeneity test of annual flow rates for all gauging stations of the focusing area.

Table 3.2 – results of homogeneity test of the dataset.

№	Hydrological station	N, years	$\lvert t^* \rvert$	$t_{2a=5\%}$	$H_0 : Q_1 = Q_2$	F^*	$F_{2a=5\%}$	$H_0 : D_1 = D_2$
1	The Chatkal River – at Nayza	26	-0.10	2.06	don't reject	1.06	3.28	don't reject
2	The Chatkal River – at Ters	39	0.19	2.03	don't reject	1.02	2.55	don't reject
3	The Chatkal River – at Khudoydodsay	82	-0.87	1.99	don't reject	1.50	1.88	don't reject
4	The Chatkal River – at vil. Charvak	35	-1.01	2.03	don't reject	1.48	2.74	don't reject

Test for homogeneity using Student's method is not rejected because the value within the range of critical two tails. The second test for homogeneity using Fisher's method is not rejected because the value within the range of critical one tail. And this implies that our data set is homoscedastic. In other words, the conditions of runoff formation of The Chatkal River are not changed.

3.3 THE STUDY OF THE LONG-TERM FLUCTUATIONS OF TIME SERIES

To estimate long-term fluctuations of the annual flow rates of analyzing rivers, the difference integral curves are plotted (DIC).

DIC is always starts with zero and end at zero. For example, assuming for a certain year, the annual stream flow is higher than the expected value, then the DIC rises. If lower than the average value, then it decreases respectively [13].

Figure 3.4 shows the DIC of the average annual water discharge of The Chatkal River- at Khudoydodsay hydrological station, which has the longest data set of observations among the stations of The Chatkal River.

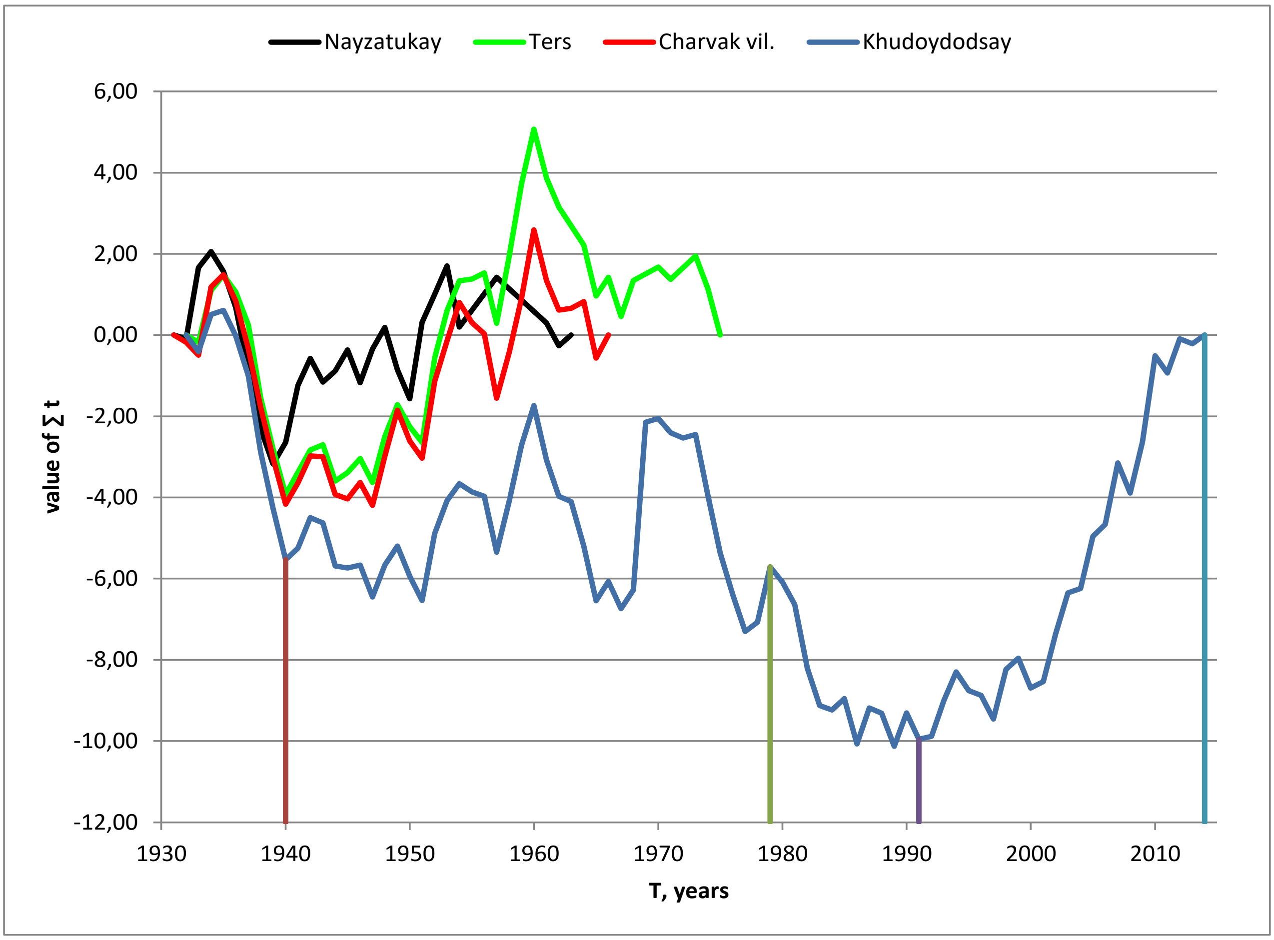

Figure 3.4 - Difference integral curves of annual flow rates of The Chatkal River- at Khudoydodsay hydrological station.

As Figure 3.4 depicts, , the average annual flow rate from 1940 to 1979 remains close to the average value, though during 1980-1991, the DIC was going down, which means this period is low water (annual flow rates are relatively less than the expected value). And from 1992 till present, the average annual water discharge rises in relation to the average. And, consequently, this considered as a high water period.

Joint analyses of the DIC (see Fig. - 3.4) for all hydrological stations of the study area shows that the long-term runoff of The Chatkal River changes almost simultaneously or synchronically.

3.4 RESULTS OF THE ESTIMATION OF MAIN HYDROLOGICAL CHARACTERISTICS

Table 3.3 presents the results of evaluations of the main hydrological characteristics and their errors of the analyzed dataset.

Hydrological Station	Catchment area, km^2	Q_m, м^3/c	Q_m, l /s km^2	C_v	C_s	C_s/C_v	Relative error, %		
							Q_m	C_v	C_s
The Chatkal River-Nayzatukay	**5520** (1932-1964)	82,8	15,0	0,21	0,22	1,03	4,2	14,2	108
The Chatkal River-Ters	**4090** (1915-1962, 4290)	64,0	15,6	0,23	0,26	1,12	4	12	61
The Chatkal River-Khudoydodsay	**6580** (1965-2015)	108	16,4	0,27	0,87	3,21	8,7	8,1	32
The Chatkal River-village Charvak	**7110** (1933-1967)	121	17,0	0,25	0,22	0,85	4	12	85
Average value	–	–	16	0,24	0,39	1,53	5,15	11,5	71,5

As can be seen from Table 3.3, for all analyzed hydrological stations of The Chatkal River modulus of flow (amount of water that is originating from unit area per second in liters) varies within 15-17 l / s km^2, the coefficient of variation - C_v varies within the of 0.21-0.27. At the same time, the statistical error of the average annual water flow is in the ranges within 8-9% and the error of C_v does not exceed 15%.

3.5 THE PROBABILISTIC METHODS OF CALCULATION OF THE AVERAGE ANNUAL STREAMFLOW

This section provides computations of several families of distributions which are widely used in hydrology. Based on recovered data set of The Chatkal River near Khudoydodsay Station, mean annual stream flow is estimated and exceedance probability distribution plotted for the following families of distributions: Normal, Lognormal, Gumbel and Kritskiy-Menkel [7]. For a selected return period annual mean flow rate can be derived from Fig. 4.6.

Figure 3.5 represents a comparative illustration of the average annual water flow of the exceedance probability distributions Normal, Lognormal, Gumbel and Kritskiy-Menkel.

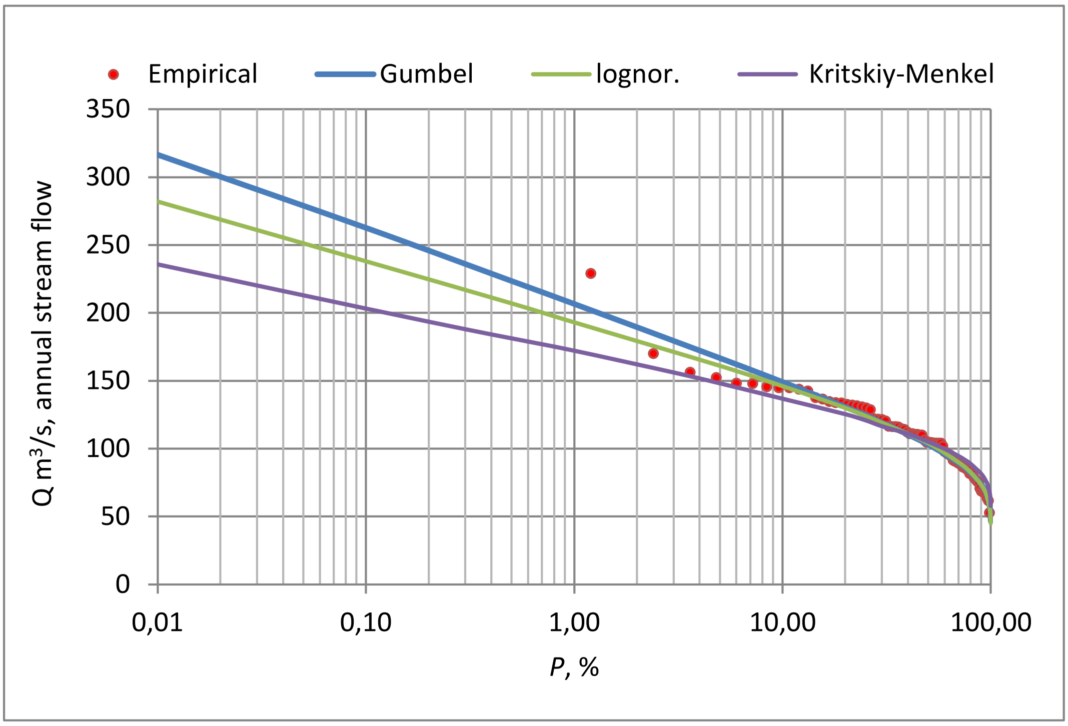

Figure 3.5 – Exceedance probability distribution plot of the average annual water flow for Normal, Lognormal, Gumbel and Kritskiy-Menkel distributions, The Chatkal River-at Khudoydodsay, with C_v – 0.27, C_s – 0.87, Q_m- 108 m^3/s.

As figure 3.5 illustrates for a given 0.01% of security (return period of 10,000 years), the average annual flow rate with the lognormal probability distribution is equal 280-285 m^3/s, according to Kritskiy-Menkel, the flow rate is equal to 230-240 m^3/s, while in the Gumbel distribution shows 315 -320 m^3/s.

As an example, it was the Gumbel (Generalized Extreme Value Distribution Type-I) was chosen (see Fig. 3.5 and Fig. 3.6). In the empirical distribution plot, one sample strongly deviates from the others.

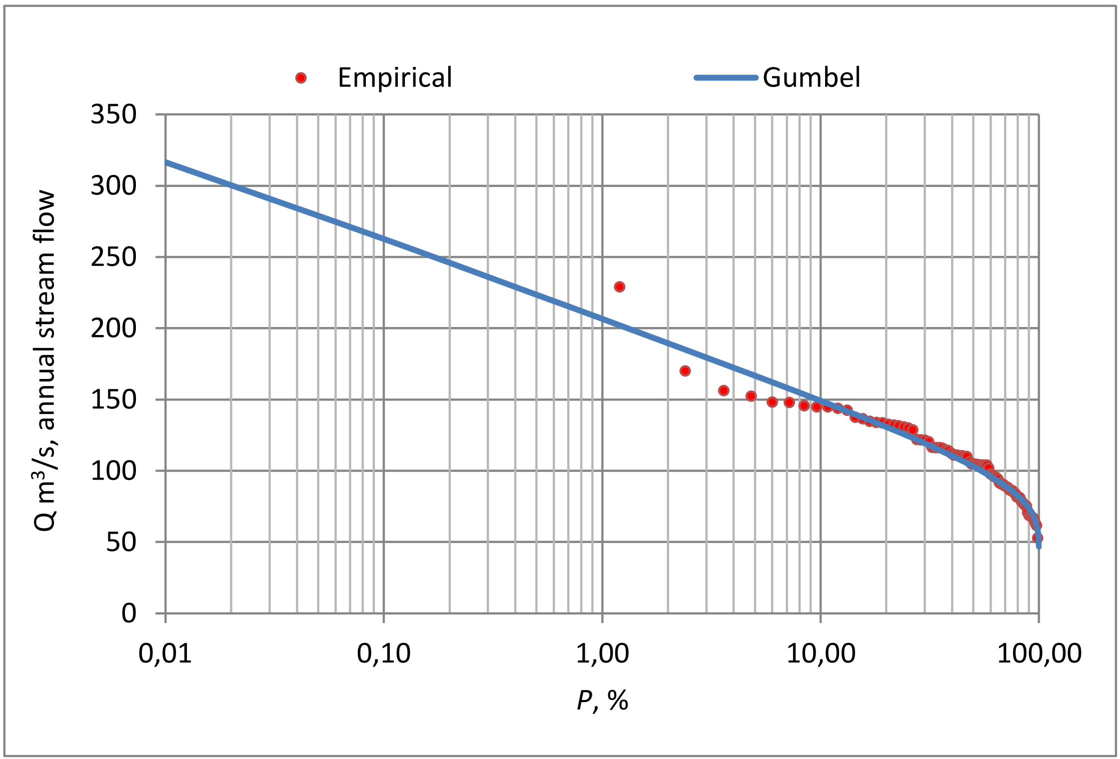

Figure 3.6 – Exceedance probability distribution plot of the average annual water flow for Empirical, Gumbel distributions, The Chatkal River-at Khudoydodsay, with C_v – 0.27, C_s – 0.87, Q_m- 108 m^3/s.

This is the average annual water discharge for 1969, which was extremely high due to heavy snowfall and relatively long winter. The Gumbel distribution best fits because it lays more close among others to this sample, since it best fits the maximum average annual flow rate.

Figure 3.7 – expresses the histogram of the average annual water discharge by the empirical and by the Gumbel distribution obtained with the application of the software *Statistica*.

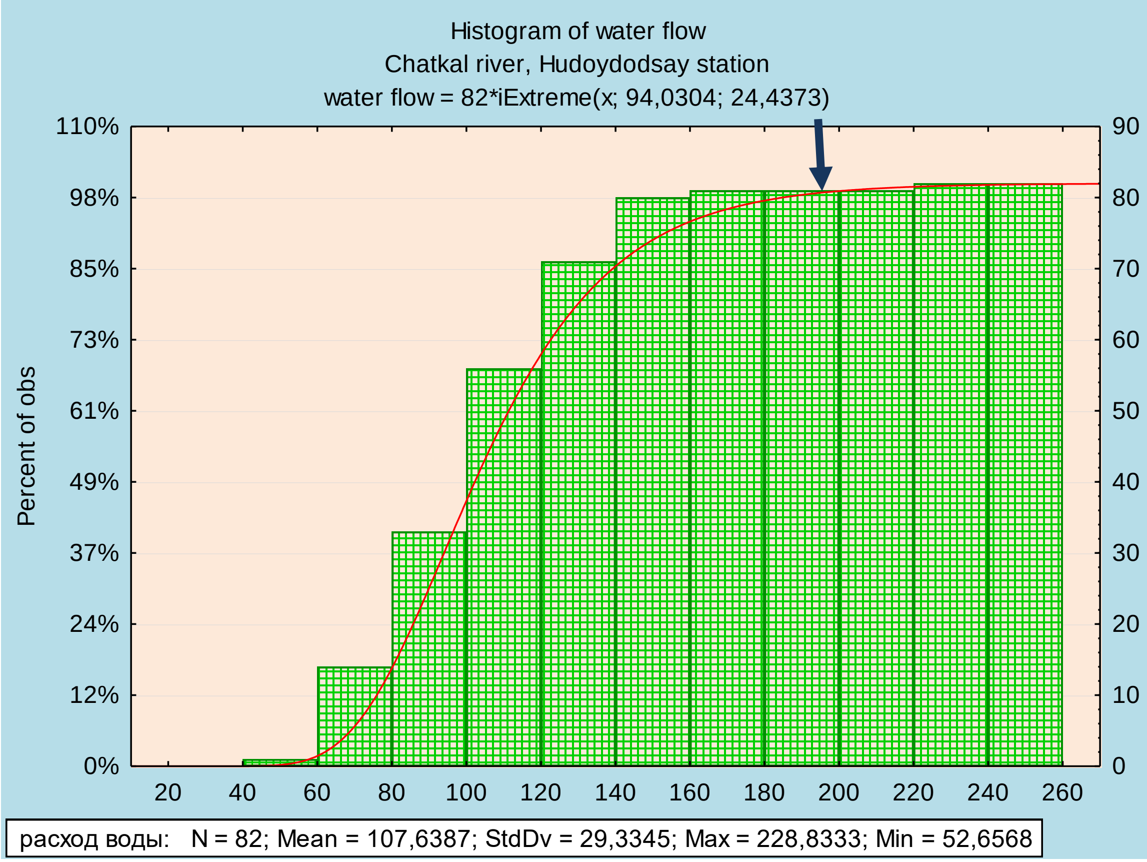

Figure 3.7 – Histogram plot of the cumulative probability of annual flow rate, The Chatkal River at Khudoydodsay station.

The results of calculations of the empirical and analytical (Gumbel) probability distributions of the average annual water discharge are compared. The outcomes show that the estimations made using *Microsoft Excel2010* and the software *Statistica* are almost identical: for a given 1% security curve, 100 years return period (see Fig 3.6, when applied Excel), the Gumbel curve gives Q = 210 m^3/s, and when the Statistica program was used (Figure 3.7, see arrow) Q is also equal to 210 m^3/s.

3.6 INTRA-ANNUAL RUNOFF DISTRIBUTION

Table 3.4 – Results of the evaluation of intra-annual runoff distribution of The Chatkal River.

№	Hydrological station and observations in years	Intra-annual runoff distribution (average in **low watery year** group)		Intra-annual runoff distribution (average in **average watery year** group)		Intra-annual runoff distribution (average in **high watery year** group)	
		high water period, % *(IV-IX)*	low water period, % *(X-III)*	high water period, % *(IV-IX)*	low water period, % *(X-III)*	high water period, % *(IV-IX)*	low water period, % *(X-III)*

1	**The Chatkal River at Nayzatukay, 30**	76	24	81	19	83	17
2	**The Chatkal River at Ters, 38**	75	25	79	21	82	18
3	**The Chatkal River at Khudoydod say, 48**	77	23	80	20	83	17
4	**The Chatkal River at village Charvak,40**	77	23	79	21	83	17
Mean by periods:		76	24	80	20	83	17

Table 3.4 depicts that depending on how much rainfall in a year the intra-annual distribution of the runoff of the Chatkal River for high-water periods (IV-IX months) ranges 76-83%, in low-water periods (X-III months) varies within the range of 17-25%. This means regardless of water management year group, for the high water period about 80% of the runoff formed and rest 20% of runoff is formed in the second phase respectively (see Fig. 3.8).

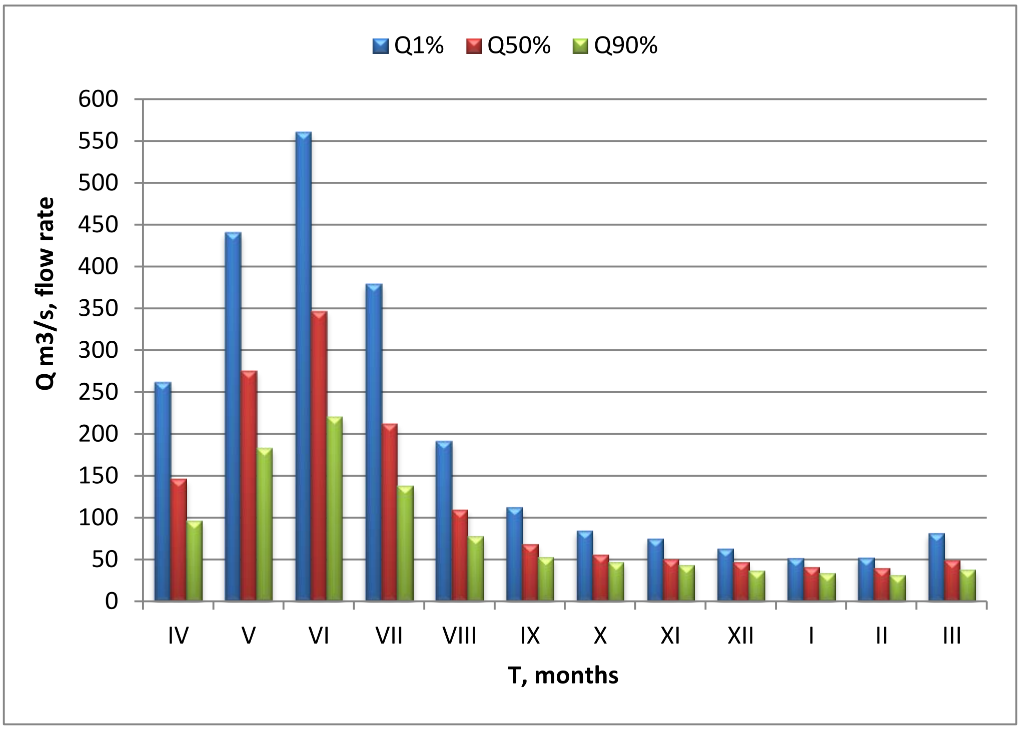

Figure 3.8 – Histogram intra-annual runoff distribution of The Chatkal River at Khudoydodsay station, with 1%, 50%, and 90% exceedance probability, Pearson 3 type family.

As Figure 3.8 shows, that for a given 1% of the exceedance probability in the high-water group for The River Chatkal at Khudoydodsay hydrological station the highest average annual flow of water in June 561 m^3/ s, the smallest average annual flow is 52 m^3 / s in January-February. For a given 90% exceedance probability in the low-water group, these values are equal to 220 m^3 / s in June and 31.5 m^3 / s in January-February of.

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4. CONCLUSIONS

As a result of the work done, the following conclusions can be drawn:

1. Filling in missing observations and extension of records were fulfilled.
2. Detection of the presence of absence of linear trend showed the absence of linear trends in analyzed hydrologic series.
3. The data set is homogeneous and stationary, this leads to the source of generating river stream is not changing.
4. Analysis of the difference integral curve exhibited since 90's of the last century to the present time, a high water period has been observed on The Chatkal River and its tributaries. This is mainly due to the increase of annual precipitation.

5. The hydrograph of daily flow rates demonstrated there are two flood peaks during a year: in April and in June. The first is related with the melting of seasonal snow and the second with the melting of perennial snow and glaciers.
6. For all data set, statistical characteristics and their errors are estimated, for average flow rates the error does not exceed 10%, for the coefficient of variation, the error does not exceed 15%.
7. The empirical and Gumbel security curves were plotted. As an analytic Gumbel curve was chosen for analysis.
8. The computation of intra-annual runoff distribution for three different years of watery and for two distinguished periods of watery was carried out.
9. It is derived that independently from the watery of year 80% of runoff originates in high water period and 20% in the low water period.

5. APPLICATION OF THE WORK

Taking into account that the water of the Charvak reservoir was built for diverse uses (hydropower, irrigation, drinking water, recreation, and fishing) the conclusions that we obtained as a result of the research can be useful for the following purposes:

1. The outcomes of this research may contribute significantly to the efficient use of the Charvak reservoir.

2. The information about evaluation of linear trend analysis will be valuable for specialists who are concerned about the effects of global climate change on The Chatkal River basin and its tributaries.

3. The results of the DIC analysis gave the possibility of estimating the long-term fluctuations in the time series of the Chatkal River and provided a background prediction for the near future. This study can be useful in solving problems of rational use of water resources in the region.

4. The obtained statistical characteristics of the series of Hydrometeorological elements can be used in further research projects.

5. The analysis performed on the intra-annual distribution of the stream flow allows the identification of the periods of high and low water on the Chatkal River. This information can be very useful for tourists and sportsmen since the river is located in the active recreation area and it has been used for rafting since the times of the USSR.

ANNEXES

List of annexes

Annex 1.	Annual streamflow of The Chatkal River (initial and reduction data).
Annex 2.	The evaluation of linear trends.
Annex 3.	Inter-annual distribution of runoff.

ANNEX 1

Annual streamflow of The Chatkal River at four different stations, m^3/s (The recovered data are given in parentheses)

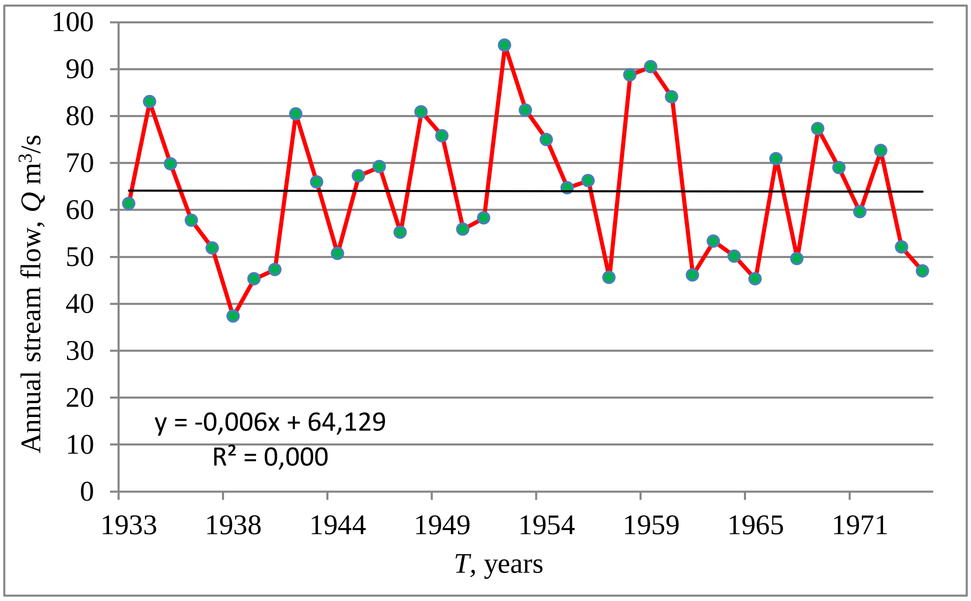
Year	Hydrological Station			
	The Chatkal River – at Nayzatukay station	The Chatkal River – at Charvak village station	The Chatkal River – at Khudoydodsay station	The Chatkal River – at Ters station
1933	82,1	112	(95,6)	61,3
1934	115	173	(134)	83,0
1935	90,7	131	(111)	69,8
1936	75,0	101	(89,2)	57,8
1937	67,9	85,4	(78,7)	51,8
1938	56,1	77,1	(52,7)	37,3

Year	Hydrological Station			
	The Chatkal River – at Nayzatukay station	The Chatkal River – at Charvak village station	The Chatkal River – at Khudoydodsay station	The Chatkal River – at Ters station
1939	57,9	83,1	(66,9)	45,3
1940	68,2	86,5	(70,4)	47,3
1941	93,2	138	(116)	(71,6)
1942	109	142	(130)	80,4
1943	95,5	121	(104)	65,9
1944	73,3	92,7	(76,5)	50,6
1945	88,5	118	(106)	67,2
1946	92,9	134	(110)	69,2
1947	69,3	104	(84,6)	55,2
1948	98,4	159	(131)	80,9
1949	93,1	156	(121)	75,8
1950	65,1	98,2	(85,9)	55,9
1951	70,9	108	(90,2)	58,3
1952	117	180	(156)	95,1
1953	96,1	152	(131)	81,2
1954	96,1	150	(120)	75,0
1955	(75,9)	106	(102)	64,7
1956	(79,6)	113	(104)	66,2
1957	56,8	72,6	(67,4)	45,5
1958	(103)	156	(145)	88,7
1959	(106)	162	(148)	90,5
1960	(112)	173	(136)	84,0
1961	63,6	83,1	(68,4)	46,1
1962	73,7	99,1	(81,3)	53,3
1963	88,3	123	(104)	(67,8)
1964	(86,9)	127	(75,5)	50,1
1965	(61,0)	78,6	68,1	45,3
1966	(93,7)	139	122	70,9
1967			87,9	49,6
1968			121	77,3
1969			229	(127)
1970			110	68,9
1971			97,4	59,5
1972			104	(66)
1973			110	72,6
1974			63,5	52,0
1975			66,0	47,0
1976			77,4	
1977			81,3	
1978			114	
1979			148	
1980			96,7	
1981			91,3	

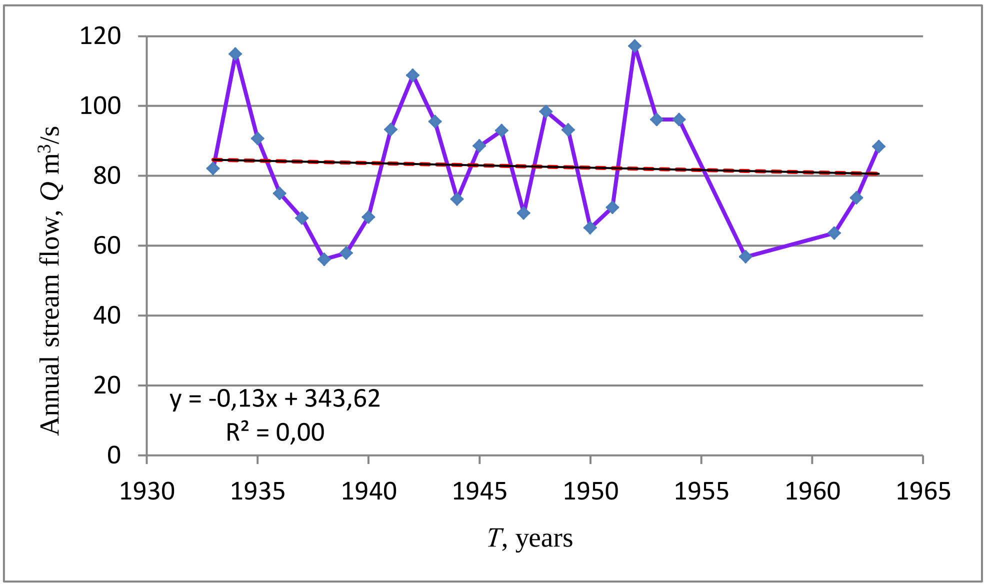
Year	Hydrological Station			
	The Chatkal River – at Nayzatukay station	The Chatkal River – at Charvak village station	The Chatkal River – at Khudoydodsay station	The Chatkal River – at Ters station
1982			61,5	
1983			80,8	
1984			104	
1985			116	
1986			74,9	
1987			134	
1988			104	
1989			83,7	
1990			132	
1991			88,6	
1992			110	
1993			133	
1994			128	
1995			93,9	
1996			104	
1997			90,6	
1998			144	
1999			116	
2000			86,2	
2001			112	
2002			142	
2003			137	
2004			111	
2005			145	
2006			116	
2007			152	
2008			85,9	
2009			145	
2010			170	
2011			95,2	
2012			132	
2013			104	
2014			114	

ANNEX 2

Detection and evaluation of linear trends



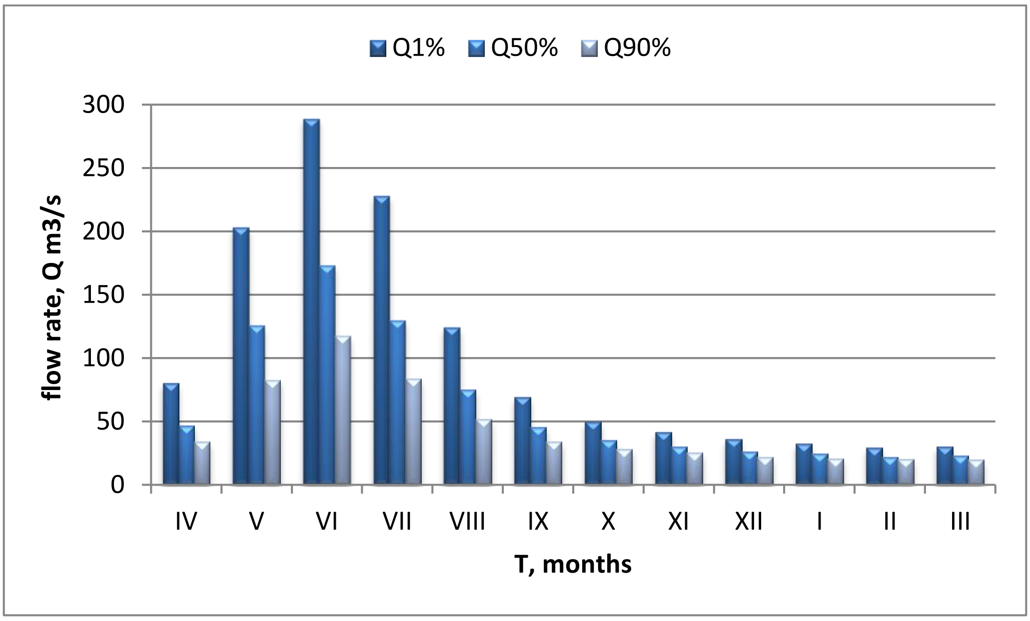
Chronologic graph of annual flow rates of The Chatkal River – at Ters station, 1933-1975 years, and the linear trend is not detected.



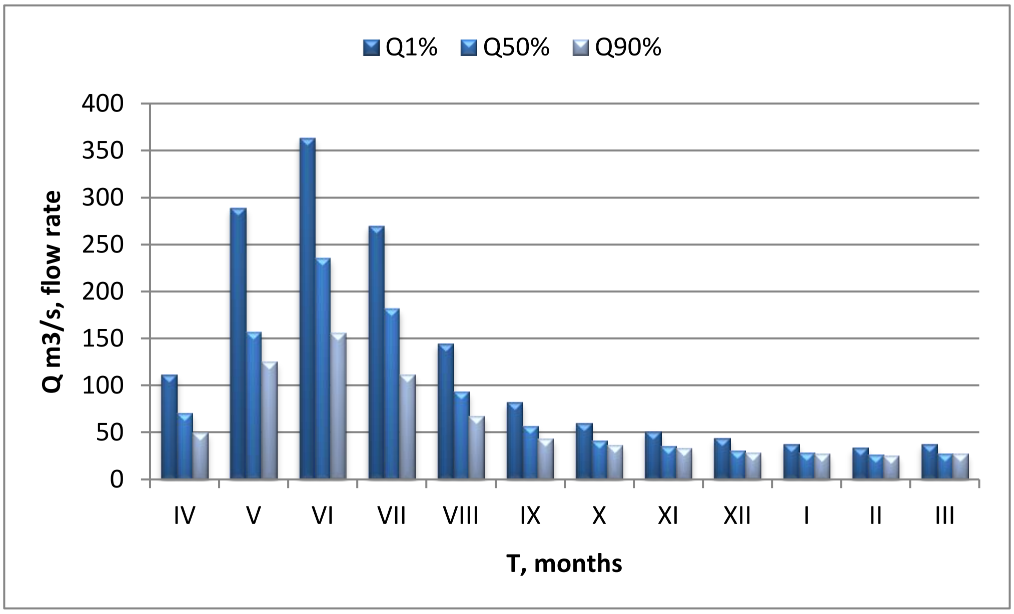
Chronologic graph of annual flow rates of The Chatkal River – at Nayzatukay station, 1933-1963 years, and the linear trend is not detected.

ANNEX 3

Intra-annual runoff distribution



Histogram of intra-annual runoff distribution of The Chatkal River at Ters station, with 1%, 50%, and 90% exceedance probability, Pearson 3 type family.



Histogram of intra-annual runoff distribution of The Chatkal River at Nayzatukay station, with 1%, 50%, and 90% exceedance probability, Pearson 3 type family.