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Hydroelectric Production using Ab-Terki River Flow Specific Energy

Saeid Eslamian[1], Nicolas R. Dalezios[2], Mahboubeh Amoushahi-Khouzani[3], Maryam Marani-Barzani[4], Amir Gandomkar[5], Morteza Khodagholi[6], Foroozan Rajaei-Rizi[7], Vijay P. Singh[8], Shahide Dehghan[5],Mohsen Ghane[9], Kaveh Ostad-Ali-Askari[10*], Morteza Soltani[11], Yohannes Yihdego[12], Hossein Norouzi[13], Hamid-Reza Shirvani-Dastgerdi[14]

[1]Department of Water Engineering, Isfahan University of Technology, Isfahan, Iran.

[2]Laboratory of Hydrology, Department of Civil Engineering, University of Thessaly, Volos, Greece & Department of Natural Resources Development and Agricultural Engineering, Agricultural University of Athens, Athens, Greece.

[3]Water Engineering Department, Science and Research Branch, Islamic Azad University, Tehran, Iran

[4]Department of Geography, University of Malaya (UM) ,50603 Kuala Lumpur, Malaysia.

[5]Department of Geography, Najafabad Branch, Islamic Azad University, Najafabad, Iran

[6]Isfahan Center for Research of Agricultural Science and Natural Resources, Department of Climate Change & Drought, Isfahan, Iran.

[7]Water Engineering Department, Shahrekord University, Shahrekord, Iran

[8]Department of Biological and Agricultural Engineering & Zachry Department of Civil Engineering, Texas A and M University, 321 Scoates Hall, 2117 TAMU, College Station, Texas 77843-2117, U.S.A.

[9]Department of Civil Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran

[10]Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran*

[11]Department of Architectural Engineering, Shahinshahr Branch, Islamic Azad University, Shahinshahr, Iran

[12]Snowy Mountains Engineering Corporation (SMEC), Sydney, New South Wales 2060, Australia. GeoInformation Science and Earth Observation (ITC), University of Twente, the Netherlands

[13]Department of Civil Engineering, Maybod Branch, Islamic Azad University, Maybod, Yazd, Iran

[14]Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran

***Corresponding Author:** **Dr. Kaveh Ostad-Ali-Askari**, *Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran. Email: Koa.askari@khuisf.ac.ir*

Abstract: *The flow duration curve (FDC) of a riveris one of the important parameters for the hydrological investigation of hydroelectric plants. Computation of the hydroelectric plant capacity and power production requires the determination of relative and cumulative frequenciesof different river discharges. Ab-Terki is one of the sub-basins of Bazoft River, located in Chaharmahal and Bakhtiari province, Iran, next to Koohrang basin. It is located between eastern longitudes of 49°54' to 50° 5' and northern latitudes of 32° 19' to 32° 24'. Morphological conditions, sloping limestone structures, and characteristics of karstic cracks in the basin have led to the formation of large springs in the eastern and western foothills of Zardkooh Mountain. In order to determine the FDCs of Ab-Terki River,3-year daily discharge and 24-year mean monthly discharge of Gooshe-pol station were used. Then, the probabilities of discharges were analyzed using Hyfa and Rank Plot numerical codes and finally, the discharge of Ab-Terki River corresponding to 95% probability was determined.*

Keywords: *Hydroelectric, Ab-Terki, Bazoft, duration curve, mean daily discharge, mean monthly discharge, flow frequency analysis*

1. INTRODUCTION

Ab-Terki River basin covers Ab-Terki River and its tributaries and is limited to Koohrang basin from the East, Bazoft basin from the West and South and Tashnavi basin from the North. The basin with an area of about 90.4 square kilometers is located between eastern longitudes of 49° 54' to 50° 5' and northern latitudes of 32° 19' to 32° 24'. Ab-Terki River has a relatively wide basin, limited by Zardkooh and Koohgerd mountains. The geomorphology and geology governing the flow regime of Koohrang, Ab-Terki and Bazoft riversis such that micro and macro porous limestone serves as a reservoir interfacing between snow and rain input and springs output. The flows form the base discharge or the underground element of the total river flow. The impact of this element in the basin under study is significant in comparison to the net surface flow due to flood generating rainfall. Considering the river flow potential for power production, this study determined the flow duration curves(FDCs) of Ab-Terki River in order to estimate the hydroelectric power that the river can produce[1-2]**.**

2. MATERIALS AND METHODS

Bazoft is a mountainous basin located in Zagros Mountains and is limited to Zardkooh, Chehel khesht, Cherie, Meyli, Haft CHeshmeh, Gandomkar from the Northeast; Sheshbar mountain from the Southeast; Ateh, Lapeh, Sefid, Foolad, Darre Deli, Manazon, Foogeh, Tarazof Lalar, Maqar in the Southwest; and the rest of Zardkooh in the Northwest. The area of the basin to the Morghak hydrometric station, i.e., about three kilometers to its intersection with Karun River, is 2169 square kilometers with a quite long shape located between the eastern longitudes of 34° 49' and 31°50' and northern latitudes of 31°37' and 32°39'.Due to its long shape, the river, which is the only main drain of the basin, starts from the highest point in the northwest at an altitude of 3700 m and elongates to the southeast in a relatively straight line on a distance of 160 km. It joins the Karun River at an altitude of 860 meters at the southeastern end of the basin. The headwater stream consists of a number of important and full of water branches, along which several additional branches are added. The headwater stream of these branches and around the river mostly consists of permanent water springs. The Morghak hydrometric station, located near the junction of Bazoft and Karun Rivers, was established in 1335. Statistics of 21-year discharge record from 1340 to 1361 were analyzed. Evaluation of rainfall in the mountains requires a dense network of barometric and snow measuring devices that can monitor the amount and spatial variation of snow and rainfall on different slopes and altitudes. Unfortunately, such areas not only do not have such a network but even the existing systems do not perform efficiently. However, rainfall statistics of six stations were available in the study area and around it. These stations and their statistical period were:

- Gooshe pol rain gaugestation located in the Ab-Terki Riverbas in with a 9-year statistical period
- Morghakrain gauge station located in the Bazoft River basin with a 27-year statistical period
- Chelgerd rain gauge station located in the Koohrang basin with a 29-year statistical period
- Shahrekord synoptic station with a 14-year statistical period
- Koohrang synoptic station with a 7-year statistical period
- Borujen synoptic stations with a 6-year statistical period

Given the lack of accurate statistics in the basin, statistics of other weather stations were used. It should be noted that except 3-year daily discharge and 9-year monthly rainfall statistics of Gooshepol station located on the Ab-Terki River, no other information was available and thus, analysis of the necessary parameters was done using the statistics of other three rain gauge and three hydrometric stations in the area. These stations provided acceptable statistics of annual and monthly rainfall amounts and therefore, rainfall and its temporal variations were evaluated considering this data [3-9].

The water budget of the Ab-Terki basindid not balance in most months and years with available statistics. Therefore, the output runoff obtained from direct measurements at the hydrometric stations was more than input value (acceptable precipitation in the basin). Thus, the hydrologic budget relation could not be used for determining discharge for the years that had no statistics.

Using the annual rainfall statistics of the Morghak and Chelgerd stations, which had the longest statistical period as well as Gooshepol station located within the study basin, annual changes of rainfall were evaluated and analyzed for the three mentioned stations.

Given the lack of temperature values at the Gooshepol station, the statistics of Koohrang synoptic station, the nearest weather station to the study area, were used.

Climate is the most important environmental parameter that plays a vital role in the life of organisms. Different parameters such as latitude, altitude, topography, distance and proximity to the sea and the location with regard to the regional and continental flows will form different climates in a region. Various methods have been proposed for the determination of climate among which are Demarton, Emberger, and Coupon methods in which temperature and rainfall play a major role.

2.1. The Demartini Method

In this method, the climate is classified as follows:

$$I = \frac{P}{T + 10} \tag{1}$$

P: the average annual precipitation (mm)

T: the average annual temperature (°C)

I: the drought coefficient

The climate classification is shown in Table 2.

Table1. *Physiographic characteristics of the Ab-Terki River basin*

Parameter	Index	Value	Unit
Area	A	90.4	Km^2
Perimeter	P	54.75	Km
Basin length along the main channel	1	16.75	Km
The longest basin axis	L'	17.7	Km
The main channel length	L	91	Km
The total length of the stream	Σ_L	23.69	Km
Equivalent rectangle length	LO	3.816	Km
Equivalent rectangle width	BO	10.73	Km
Equivalent circle diameter	D	1.62	Km
Gravilious coefficient	C	1.62	——-
Skewness (Kurtosis) coefficient	Re	0.606	——
Circular ratio	Rc	.38	——
Shape coefficient	Ff	.161	——
Density of the river network	µ	1.02	Km/Km^2
Average slope of the main channel	S	7.44	%
Maximum height gradient of the main channel	H	2380	meter
Output point elevation	Hmin	1570	meter
The highest elevation of the main channel	Hmax	3950	meter
Center of gravity distance to the basin outlet	Lca	3.3	Km

Table2.*Climate classification based on Demarton method*

Climate	Demarton coefficient range
Arid	Less than 10
Semi-arid	10 – 19.9
Mediterranean	20 – 23.9
Semi-wet	24 – 27.9
Wet	28 – 34.9
Very wet	Great than 35

2.2. The Emberger Method

In this method, the climate is classified as:

$$Q_2 = \frac{2000\,p}{M^2 - m^2} \tag{2}$$

P: the average annual precipitation (mm)

M: the average of maximum temperatures in the hottest month of the year (ºKelvin)

m: the average of minimum temperatures in the coldest month of the year (ºKelvin)

Q_2: The Emberger coefficient

By obtaining the Emberger coefficient and using Fig. 1, the climate of the region can be determined.

The climate of the Ab-Terki River basin is affected by the climate of the adjacent Koohrang basin. According to observations, high parts of the Ab-Terki basin have a cold and wet mountain climate and low parts and Bazoft River bank areas have a moderate and wet climate. In this study, the climate of the area was determined using two methods [10-19].

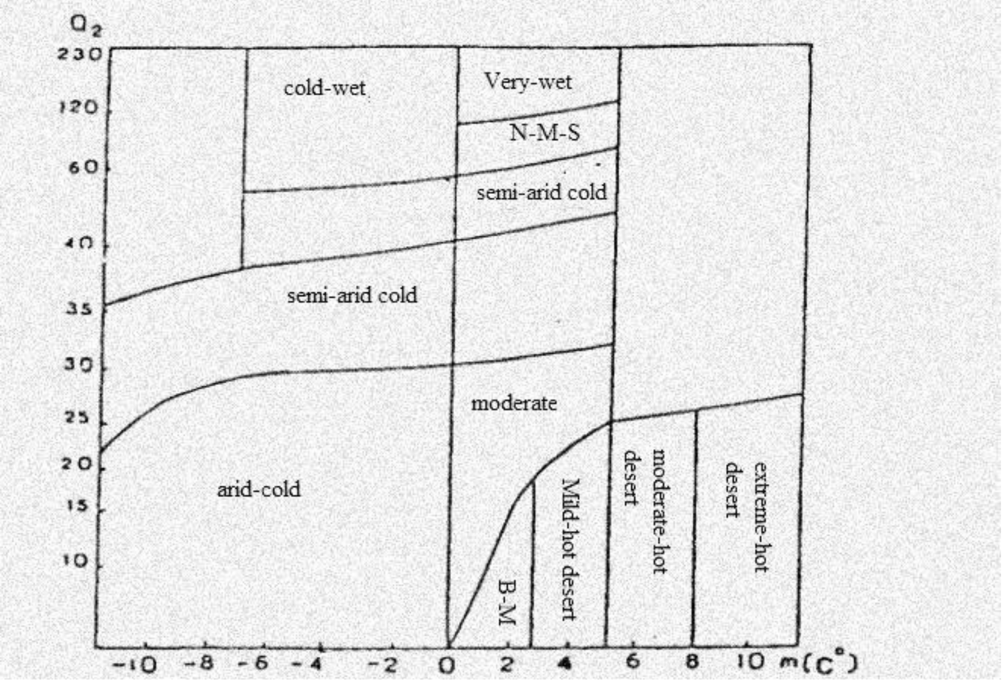


Figure1. *Climate classification using the Emberger method*

Due to the high altitude of the Ab-Terki basin, many frosty days occur in the basin and considering the lack of statistics in the area, available statistics of the nearest Koohrang station were analyzed.

Wind is one of the climatic parameters and was available at Koohrang, Borujen (5-year data), and Shahrekord (9-year data) stations. At these three stations, the average monthly and annual wind speeds were calculated for their statistical periods using weighting average of the wind speed in 8 directions of the north, northeast, east, southeast, south, southwest, west, and northwest. The wind speed at 10 m height was calculated using the following formula:

$$\frac{U}{U_0} = \left(\frac{Z}{Z_0}\right)^{0.15} \tag{3}$$

U_0: the wind speed at the height of $Z_0$from the ground surface

U: the wind speed at the height of Z from the ground surface

In the presence of detailed discharge data at the outlet or a certain point in the basin, the volume of flow at monthly or annual scale can beestimatedusinghydrologicbudget methods. There is no doubt that the estimated value is close to the real value in such a condition that an accurate evaluation of all the involved parameters can be done at the desired timescale. This condition is fulfilled when, first, the basin topography and geology are known, or any flow exchange with adjacent basins, whether in the form of surface flow or underground flow, can be controlled and determined. Second, complete data of input and output climate parameters, either in the form of rainfall or evapotranspiration, would be available in the form of long-term reliable statistics. Third, basin response to the interaction, either in the form of water penetration and deep percolation or feeding surface flows from underground resources or in short, its storage characteristics in the selected parts would be known for determining the water budget [20-39].

The concentration time of a basin is the time that a drop of water travels from the farthest point (on a temporal basis) of the basin to the basin outlet. the concentration time of the Ab-Terki basin was estimated using different formulae [40-54].

- **Pacini[check] method**

$$t_c = 0.108\frac{(AL)^{\frac{1}{3}}}{\sqrt{S}} \qquad (4)$$

L: the length of the main channel (km)

A: the basin area (square kilometers)

S: the average slope of the main channel (m/m)

- **Chow method**

$$t_c = 0.00032\frac{L^{1.15}}{H^{0.385}} \qquad (5)$$

L: the length of the main channel (m)

H: the maximum height difference of the main channel (m)

- **Branzli-Williams method**

$$t_c = \frac{L}{1.5D}\sqrt[5]{\frac{A^2}{S}} \qquad (6)$$

L: the length of main channel (km)

D: the diameter of the equivalent circle(km)

A: the basin area (in square kilometers)

S: the average slope of the main channel (%)

- **Kirpich method-type I**

$$t_c = 0.0003L^{0.77}S^{-0.385} \qquad (7)$$

L: the length of main channel (m)

S: the average slope of the main channel (m/m)

- **Kirpich method-type II**

$$t_c = 0.949(\frac{L^3}{H})^{0.385} \qquad (8)$$

L: the length of the main channel (km)

H: the maximum elevation difference of the main channel (m)

Flood evaluation of a basin without discharge data was performed using the following methods:

1. Using the available maximum annual instantaneous discharge data for the maximum average daily discharge

2. Regional analysis for the determination of flood specific peak discharge

3. The area-discharge method

The third method was used based on the following formula:

$$Q_{Ter} = Q_{Baz} \times \frac{A_{Ter}}{A_{Baz}} \qquad (9)$$

where Q_{Ter} and Q_{Baz} indicate the Ab-Terki and Bazoft River peak discharges, respectively, and A_{Ter} and A_{Baz} indicate the areas of the Ab-Terki and Bazoft basins.

3. RESULTS AND DISCUSSION

In order to determine the study area climate, Demarton and Emberger methods were used. Using Do marten method, I=69.19 was obtained and thus, Ab-Terki basin was classified as a very wet area. Using Emberger method and considering Fig. 1, the basin climate was classified as a cold and mountainous one.

The prevailing wind at Shahrekord, Borujen and Koohrang stations was equal to20 m/son the 1st of February, 1985, 18 m/s on the 20thof May, 1992and 30 m/s on the 9thof December, 1991, respectively.

The concentration time of the study basin was calculated using Pacini, Chow, Kirpich Type-I, Kirpich Type-II and Branzli-Williams formulas and results are shown in Table 3.

Table3. *Concentration time of the study basin using different methods*

Method	Concentration time (hour)
Pacini	0.45
Chow	1.23
Kirpich Type-I	4.44
Kirpich Type-II	1.51
Branzli-Williams	1.31

Because of significant differences between the results obtained from the Pacini and Branzli-Williams formulas and other methods, two methods were discarded and the average concentration time, using the other three methods, was found as 1.51 h.

Table4. *Annual and maximum daily and instantaneous discharges of the Bazoft River at Morghak station in the desired statistical period 1961-1982*

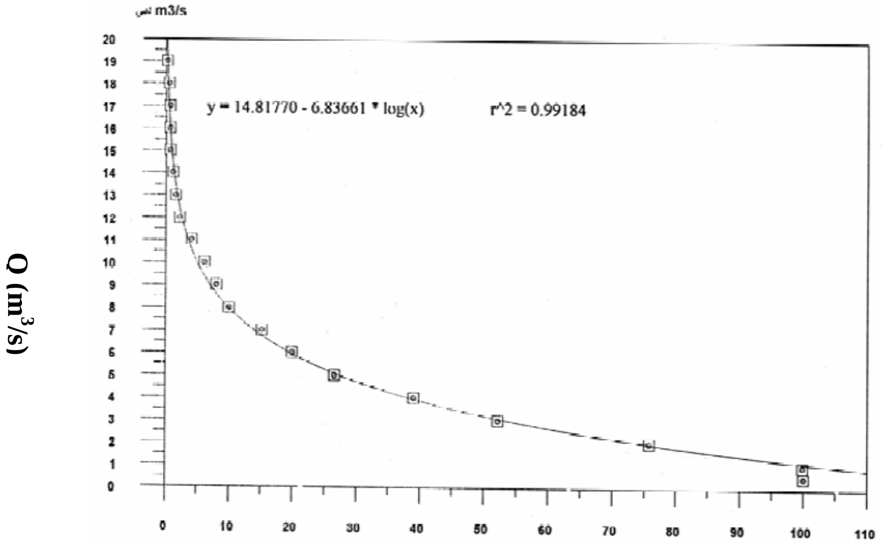
Water year	Annual discharge	Daily discharge		Instant discharge	
		Occurrence date	Maximum	Maximum	Probability
1962-1963	55.3	22/04/1962	311	815	54.5
1963-1964	48.3	11/04/1963	246	591	81.8
1964-1965	43.1	13/03/1964	532	870	45.5
1965-1966	55.6	1965/02/14	459	797	59.1
1966-1967	57.3	1966/03/14	735	917	40.9
1967-1968	42.5	---	---	402	95.9
1968-1969	54.5	1968/04/24	432	1115	27.3
1969-1970	109	---	---	2240	4.55
1970-1971	45.2	1970/03/20	421	459	90.9
1971-1972	46.2	1971/04/13	432	760	68.2
1972-1973	85.1	1972/03/23	700	1136	22.7
1973-1974	57.1	1973/02/22	444	608	77.3
1974-1975	62.2	---	---	1040	36.4
1975-1976	60.6	1975/01/04	287	467	86.4
1976-1977	119	1976/02/11	964	1836	13.6
1977-1978	47.6	1977/03/04	353	635	72.7
1979-1980	81.4	1977/12/13	844	1362	18.2
1980-1981	53.5	1978/12/06	719	1053	31.8
1981-1982	109	1980/04/15	1116	2081	9.1
1982-1983	66	1981/02/21	473	867	50
1983-1984	76.2	1982/03/26	585	772	63.6

Table 4shows the annual discharge (annual average of monthly discharge), the maximum of mean daily discharge and the maximum annual instantaneous discharge of the Bazoft River at the Morghak station for the period of 1340 to 1361. The Weibull formula was used to calculate the probabilities of extreme events. The largest flood of 2240 m^3/s occurred in the water year of 1347-1348. Table 5 shows the average monthly discharge. As can be seen, April and October were the wet months and least watery months of the year for the Bazoft River at the Morghak station. The average annual discharge and annual flood volume of the Bazoft River at Morghak station were estimated for different return periods, based on the log-normal distribution. For a 100-year return period (1% probability of occurrence), average annual discharges of the drought and wet periods were estimated as 34.5 m^3/s and 245 m^3/s, respectively. The volumes of extracted water in this return period were determined as 1088 MCM and 7726 MCM, respectively.

Table5. *Occurrence probability of the average monthly discharge of the Bazoft River at the Morghak station1961-1982*

Aug	July	June	May	Apr	Mar	Feb	Jan	Dec	Nov	Oct	sep	Probability
60	72	110	191	283	432	221	221	120	114	86.5	37	Maximum discharge
38.8	61.4	94.4	137	224	284	172	135	82.8	84.1	34.6	25.7	10 %
27.8	32.9	56.4	90.9	170	214	140	93.9	42.4	43.9	27.5	23.3	25%
22.5	28.4	40.2	64.4	109	137	110	56.1	31.7	32.6	22.5	21	50%
20	24.5	33.9	52.3	82.6	107	93.6	38.1	26.2	22.1	19.2	19.1	75%
19.2	22.8	29.1	47.7	74.4	82.5	76.1	23.4	19.5	18.8	17	15	100%
16	19.8	28.4	45.9	69	75.8	68.3	21.4	18.9	17.3	14.1	14.8	minimum discharge

Due to the lack of statistical years, the results of Bazoft River data were fitted with the Log-Pearson type III distribution. From this distribution, the peak discharge of the BazoftRiver at the Morghak station for a 1000-year return period was estimated as 5418 m^3/s. Then, using three years of daily statistics and 24 years of average monthly discharge measured at Gooshepol station (prolonged statistics),results were obtained as shown in Tables 6 and 7, and an average of the two methods is shown in Fig. 2. The river continuity curve was drawn so that the number of days with the minimum necessary flow in order to produce electricity could be estimated.



(Percent of the year)

Figure2. *Flow duration curve of Ab-Terki River*

Table6. *Discharge, relative and cumulative frequencies of the Gooshepol station based on three years of daily statistics*

Cumulative frequency (%)	Cumulative frequency (day)	Discharge limit	Relative frequency (day)	Discharge classification (m^3/s)
0.36	4	>19.01	4	≥19.01
0.63	7	>18.01	3	18.01-19
0.63	7	>17.01	0	17.01-18
0.63	7	>16.01	0	16.01-17

0.73	8	>15.01	1	15.01-16
0.91	10	>14.01	2	14.01-15
1.09	12	>13.01	2	13.01-14
2	22	>12.01	10	12.01-13
4.19	46	>11.01	24	11.01-12
5.47	60	>10.01	14	10.01-11
6.74	74	>9.01	14	9.01-10
9.94	109	>8.01	35	8.01-9
14.32	157	>7.01	48	7.01-8
18.06	198	>6.01	41	6.01-7
25.09	275	>5.01	77	5.01-6
37.40	410	>4.01	135	4.01-5
53.19	583	>3.01	173	3.01-4
67.24	737	>2.01	154	2.01-3
99.73	1093	>1.01	356	1.01-2
100	1096	>0.5	3	0.5-1

Table7. *Discharge and relative and cumulative frequencies of the Gooshepol station based on 24yearsof average monthly discharges (prolonged statistics)*

Cumulativefrequency (%)	Cumulativefrequency (day)	Discharge limit	Relative frequency (day)	Discharge classification (m^3/s)
0	0	>19.01	0	≥19.01
0.34	1	>18.01	1	18.01-19
0.69	2	>17.01	1	17.01-18
0.69	2	>16.01	0	16.01-17
0.69	2	>15.01	0	15.01-16
1.38	4	>14.01	2	14.01-15
2.08	6	>13.01	2	13.01-14
2.42	7	>12.01	1	12.01-13
4.16	12	>11.01	5	11.01-12
6.94	20	>10.01	8	10.01-11
9.37	27	>9.01	7	9.01-10
10.06	29	>8.01	2	8.01-9
15.97	46	>7.01	17	7.01-8
21.87	63	>6.01	17	6.01-7
28.12	81	>5.01	18	5.01-6
40.62	117	>4.01	36	4.01-5
54.16	156	>3.01	39	3.01-4
84.37	243	>2.01	87	2.01-3
100	288	>1.01	45	1.01-2
100	288	>0.5	0	0.5-1

According to flow duration curve obtained for the river, river discharge exceeded 1.9 m^3/s, 2.2 m^3/s,3 m^3/s,and 3.5 m^3/sat 90%,80%,70% and 50% of the year, respectively. Thus, by changing the discharge occurrence probability from 90% to 80%,80% to 70%, and70% to 50% the minimum discharge increased by 15.7%, 36.4% and 16.6%, respectively.

For the purpose of flood control and water delivery to a hydroelectric plant, flood maximum discharge should be estimated. For flood estimation in the area, the following two methods were used:

1. Using the available data of maximum annual instantaneous discharge. Because of the lack of daily discharge data during three water years of 69-70, 73-74, and 75-76 and the lack of the maximum annual instantaneous discharge data, this method was not used.
2. Regional evaluation for determining the specific maximum flood discharge. After evaluation and using flood data of the Bazoft River, the statistical period of 1335-71 was analyzed. Results of floods with different return periods in the Bazoft and Ab-Terki Rivers are shown in Table 8. The logarithmic Gumbel distribution was the most appropriate distribution fitting the flood data (Table 9). Therefore, the average annual discharge and flood volume of the Bazoft River at Morghak station were estimated for different return periods using the log-normal distribution. It should be

noted that the flood maximum discharge of the Ab-Terki River was obtained using the flood maximum discharge of the Bazoft River.

Table8. *Results of flood analysis for the Bazoft and Ab-Terki Rivers at the Morghak and Gooshepol stations, respectively (using logarithmic Gumbel distribution)*

Maximum flood discharge of the Ab-Terki River (m^3/s)	Maximum flood discharge of the Bazoft River (m^3/s)	Return period (T)
32.82	787.56	2
46.28	1110.62	5
58.12	1394.44	10
77.48	1858.99	25
95.9	2301.02	50
118.52	2843.67	100
146.35	3511.57	200
193.32	4638.5	500
214.64	5150	750
238.58	5724.51	1000
295.91	7100	10000

Table9. *Results of flood analysis in the Bazoft River at the Morghak station (m^3/s)*

1000	500	200	100	50	25	20	10	5	2	Return Period (Year)	Number
										Statistical distribution	
3931	3551	3065	2718	2382	2059	1955	1640	1326	883	Two-parameter Log-normal distribution (probability factor)	1
37983	3441	2983	2653	2334	2024	1926	1624	1320	889	Two-parameter Log-normal distribution (normal variable)	2
3505	3230	2865	2589	2312	2033	1942	1656	1358	908	Gumble	3
9052	7019	5014	3885	3008	2324	2137	1642	1247	823	Logarithmic Gumble	4
3580	3301	2925	2641	2354	2064	1968	1667	1352	885	Pearson type III	5
4837	4222	3485	2991	2542	2134	2010	1645	1305	864	Logarithmic Pearson type III	6
5418	4659	3770	3189	2672	2212	2073	1675	1312	857	Adjusted Logarithmic Pearson type III	7
3373	3134	2818	2579	2340	2101	2024	1786	1547	1231	Fooler	8

3. Area-discharge method. Myer experimental method was used and results are shown in Table 10.

Table10. *Estimation of probable maximum flood discharge in Ab-Terki River basin using Myer method*

Coefficient	Maximum flood discharge of the Ab-Terki River (m^3/s)	Return period (year)
4.4	65.63	2
6.0	89.5	5
7.1	105.91	10
9.4	140.22	50
10.4	155.14	100
13.6	202.88	1000
16.8	250.61	10000

Comparison of results obtained using the regional and Myer methods showed that the estimated values of the maximum flood discharge in the long return periods were close to each other [11-12]. Finally, possible discharges were analyzed using Hyfa and Rank Plot numerical codes, and the discharge of the Ab-Terki River for a 95% probability was determined, and results are shown in Table 11.

Table11. *Possible discharges of the Ab-Terki River*

Aug	July	June	May	Apr	Mar	Feb	Jan	Dec	Nov	Oct	Sep	Probability 1%
3.573	4.935	6.868	9.875	15.618	12.681	9.875	7.726	5.86	9.76	5.35	3.24	5
3.184	4.334	5.922	8.566	13.606	11.61	8.566	6.357	4.62	7.61	4.09	2.78	10
2.953	3.974	5.355	7.763	12.33	10.896	7.763	5.553	4.0	6.38	3.49	2.55	15
2.784	3.709	4.937	7.16	11.354	10.328	7.16	4.972	3.59	5.506	3.11	2.4	20
2.652	3.501	4.61	6.681	10.562	9.85	6.681	4.524	3.29	4.843	2.84	2.29	25
2.543	3.328	4.337	6.274	9.878	9.427	6.274	4.156	3.06	4.305	2.63	2.2	30
2.449	3.178	4.102	5.918	9.268	9.037	5.918	3.842	2.87	3.853	2.46	2.14	35
2.367	3.047	3.894	5.613	8.715	8.672	5.6	3.569	2.71	3.467	2.32	2.08	40
2.293	2.928	3.707	5.31	8.2	8.323	5.31	3.327	2.57	3.127	2.2	2.03	45
2.226	2.82	8.538	5.03	7.717	7.991	5.042	3.109	2.45	2.827	2.1	1.99	50
2.166	2.722	3.383	4.794	7.261	7.657	4.794	2.914	2.34	2.561	2.01	1.95	55
2.109	2.629	3.236	4.555	6.814	7.323	4.555	2.731	2.24	2.317	1.92	1.92	60
2.056	2.542	3.099	4.328	6.381	6.989	4.328	2.546	2.14	2.096	1.84	1.88	65
2.006	2.46	2.97	4.111	5.956	6.648	4.111	2.409	2.05	1.896	1.77	1.86	70
1.959	2.381	2.846	3.896	5.526	6.288	3.896	2.262	1.96	1.709	1.7	1.83	75
1.914	2.305	2.726	3.685	5.091	5.905	3.685	2.124	1.87	1.539	1.64	1.81	80
1.87	2.231	52.61	3.474	4.64	5.482	3.474	1.994	1.79	1.382	1.58	1.79	85
1.828	2.158	2.495	3.256	4.152	4.987	3.256	1.869	1.69	1.237	1.51	1.77	90

4. CONCLUSION

Evaluation of the duration curve showed that the Ab-Terki River has an acceptable potential for the construction of a hydroelectric power. Considering the rugged topography of the area, transferring the water to the plants from other areas is impossible. In addition, construction of hydrometric stations with suitable spatial distribution in the study area is therefore necessary.

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AUTHORS' BIOGRAPHY

Professor Saeid Eslamian, is a full professor of water system engineering in the Department of Water Engineering at Isfahan University of Technology, Iran, where he has been since 1995. He received his PhD from Civil and Environmental Engineering School, University of New South Wales, Sydney, Australia, under the supervision of Professor David Pilgrim. His research focuses mainly on water resources planning, management, and sustainability and statistical and environmental hydrology in a changing climate. Formerly, he was a visiting professor at Princeton University, New Jersey, and University of ETH Zurich, Switzerland. On the research side, he started a research partnership in 2014 with McGill University, Montreal, Quebec, Canada. He has contributed to more than 650 publications in journals, books, or as technical reports. He is the founder and chief editor of both the International Journal of Hydrology Science and Technology (Scopus, Inderscience) and the Journal of Flood Engineering. Professor Eslamian is also associate editor of the Journal of Hydrology (Elsevier) and Ecohydrology and Hydrobiology (Elsevier). He has authored more than 150 book chapters and books. Recently, Professor Eslamian published eight handbooks with Taylor & Francis Group (CRC Press) as chief editor: a three-volume Handbook of Engineering Hydrology (2014), Urban Water Reuse Handbook (2015), a three-volume Handbook of Drought and Water Scarcity (2017), and Underground Aqueducts Handbook (2016).

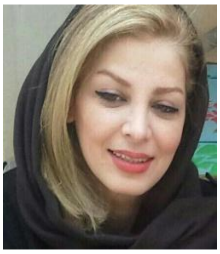
Professor NicolasR. Dalezios, is a professor of agro-meteorology and remote sensing, University of Thessaly, Volos Hellas; president of the Council of the Agricultural University of Athens, Hellas; and professor and founding director of the Laboratory of Agro-meteorology, University of Thessaly, Volos Hellas (1991–2011). He has done his postgraduate studies in meteorology (Athens, 1972) and hydrological engineering (University of Delft, 1974) and his PhD in civil engineering (University of Waterloo, Canada, 1982). He has a longstanding research record in agro-meteorology, agro-hydrology, remote sensing, modeling, environmental hazards, risk assessment, climate variability/change. He is the author or co-author in over 280 refereed publications and technical and scientific publications, member of editorial boards and reviewer in international scientific journals, editor or co-editor in over 20 edited publications, and co-author in about 35 book chapters.

Mahboubeh Amoushahi-Khouzani, Water Engineering Department, Science and Research Branch, Islamic Azad University, Tehran, Iran

Maryam Marani-Barzani, Department of Geography, University of Malaya (UM),50603 Kuala Lumpur, Malaysia.Member of Suggestion Committee in Ministerial of Education in Iran(2002-2007). Member of Research on Heat Sink Capability of Inland Water Resources for Thermal Power Plants in Peninsular Malaysiaproject (TNBR)(2014-2015). Member of Board Trustees at Consultant Engineering Company (SharsazanZendeh Rood) in Iran.(2015-peresent).

Dr. Amir Gandomkar, Department of Geography, Najafabad Branch, Islamic Azad University, Najafabad, Iran.

Dr. Morteza Khodagholi, Isfahan Center for Research of Agricultural Science and Natural Resources, Department of Climate Change & Drought, Isfahan, Iran.



Foroozan Rajaei-Rizi, Water Engineering Department, Shahrekord University, Shahrekord, Iran

Professor VijayP. Singh, Ph.D., D.Sc., D. Eng. (Hon.), Ph.D. (Hon.), D.Sc. (Hon.), P.E., P.H., Hon. D. WRE, Academician (GFA), Distinguished Professor, Regents Professor, Caroline and William N. Lehrer Distinguished Chair in Water Engineering

President, FARA, President, G.B.S. Board, Editor-in-Chief, Water Science and Technology Library Bookseries, Editor, Global Water Resources Book Series, Editor-in-Chief, Journal of Ground Water Research, Editor-in-Chief, Open Agriculture, Editor, Journal of Agricultural Research, Department of Biological and Agricultural Engineering &Zachry Department of Civil Engineering, Texas A and M University. is a professor of agro-meteorology and remote sensing, University of Thessaly, Volos Hellas; president of the Council of the Agricultural University of Athens, Hellas; and professor and founding director of the Laboratory of Agro-meteorology, University of Thessaly, Volos Hellas (1991–2011). He has done his postgraduate studies in meteorology (Athens, 1972) and hydrological engineering (University of Delft, 1974) and his PhD in civil engineering (University of Waterloo, Canada, 1982). He has a longstanding research record in agro-meteorology, agro-hydrology, remote sensing, modeling, environmental hazards, risk assessment, climate variability/change. He is the author or co-author in over 290 refereed publications and technical and scientific publications, member of editorial boards and reviewer in international scientific journals, editor or co-editor in over 20 edited publications, and co-author in about 35 book chapters.

Shahide Dehghan, Department of Geography, Najafabad Branch, Islamic Azad University, Najafabad, Iran.

Mohsen Ghane, Department of Civil Engineering, South Tehran Branch, Islamic Azad University, Tehran, Iran.

Dr. Kaveh Ostad-Ali-Askari, is a PhD of civil engineering, Department of Water Resources Engineering, Faculty of Civil Engineering. He collaborates as Editorial Board Membership in more than 45 Journals and as reviewers in more than 35 Journals. Currently, Associate, Editor-in-Chief of IJREH. He has contributed to more than 125 publications in Journals, Books and Technical Reports. He was a Visiting Assistant Professor at Canadian University Dubai, and American University in Dubai. On the research side, he started a research partnership in 2017 with Concordia University in Montreal, Quebec, Canada. His topics of interest include Groundwater Hydrology, Irrigation and Drainage Engineering, Sustainable Development and Environmental Assessment, Climate and Integrated and Sustainable Water Resource Management, Water System Engineering, Water Resources Planning, Artificial Neural Network, and Genetic Algorithm. Currently, he is a Faculty Member of the Department of Civil Engineering, Isfahan(Khorasgan) Branch, Islamic Azad University, Iran

Morteza Soltani, Department of Architectural Engineering, Shahinshahr Branch, Islamic Azad University, Shahinshahr, Iran.

Dr. Yohannes Yihdego, Snowy Mountains Engineering Corporation (SMEC), Sydney, New South Wales 2060, Australia. GeoInformation Science and Earth Observation (ITC), University of Twente, the Netherlands. Working at Global Engineering consulting firm in Hydro-Geo-Engineering across Australia, Middle East, Asia, Africa in water, resource, mining, infrastructure, transport, energy, agriculture, landfill, contamination/pollution/remediation, environmental assessments, flood/urban drainage design/modelling, drought, climate change Produced hundreds' of Engineering technical -feasibility/ detail design reports & Published several articles & book chapters Serving as peer Reviewer & Editor board member.

Hossein Norouzi, Department of Civil Engineering, Maybod Branch, Islamic Azad University, Maybod, Yazd, Iran.

Hamid-Reza Shirvani-Dastgerdi, Department of Civil Engineering, Isfahan (Khorasgan) Branch, Islamic Azad University, Isfahan, Iran.

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