RESEARCH ARTICLE

Flood Frequency Analysis With Gumbel's Extreme Value Distribution

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Funding: No specific funding was received for this work.

Potential competing interests: No potential competing interests to declare.

Abstract

This paper presents the results of a study aimed at analysing the flood frequency of the Nera River using the Gumbel distribution. One of the major problems faced by water resources engineering design specialists is the estimation of peak flows. The instantaneous peak flow data over a period of 30 water years (1993-2022) were collected from National Water Authority. For this analysis the return period (T) used is 2 years, 10 years, 50 years, 100 years, 150 years.

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Keywords: flood peak, Gumbel's frequency distribution, probability, return period.

1. Introduction

Flood frequency analysis is most used by specialists in estimating peak flood amounts for a set of non-exceedance probabilities. Flood frequency analysis is used for the design of hydrotechnical works (dams, bridges, spillways, dykes, etc.) and for risk assessment in flood zones[1].

Flood frequency analysis involves fitting a probability model to the sample of maximum flows recorded over an observation period, for a watershed. The established model parameters can then be used to predict extreme events with a large recurrence interval (Pegram and Parak, 2004).

These frequency estimates are vital to floodplain management; to protect the public, to minimize flood-related costs, to design and locate hydraulic structures, and to assess the hazards of floodplain development[2]. The Gumbel distribution is a statistical method used to forecast extreme hydrological events such as floods[3](Shaw, 1983).

2. Materials and Methods

2.1. Study Area

The Banat hydrographic area is located in the southwestern part of Romania and occupies an area of 18,320 km^2. The Nera River originates from the Semenic Mountains, with a length of 124 km. The Banat hydrographic area has a moderate temperate continental climate with sub-Mediterranean influences, and the multiannual average temperature is 6°C. Regarding precipitation, they have values of 500 mm in the lowland areas, and 1,000 - 1,430 mm are recorded in the highlands. The total area of the hydrographic basin of the Nera River is 1240 km^2 (Fig.1).

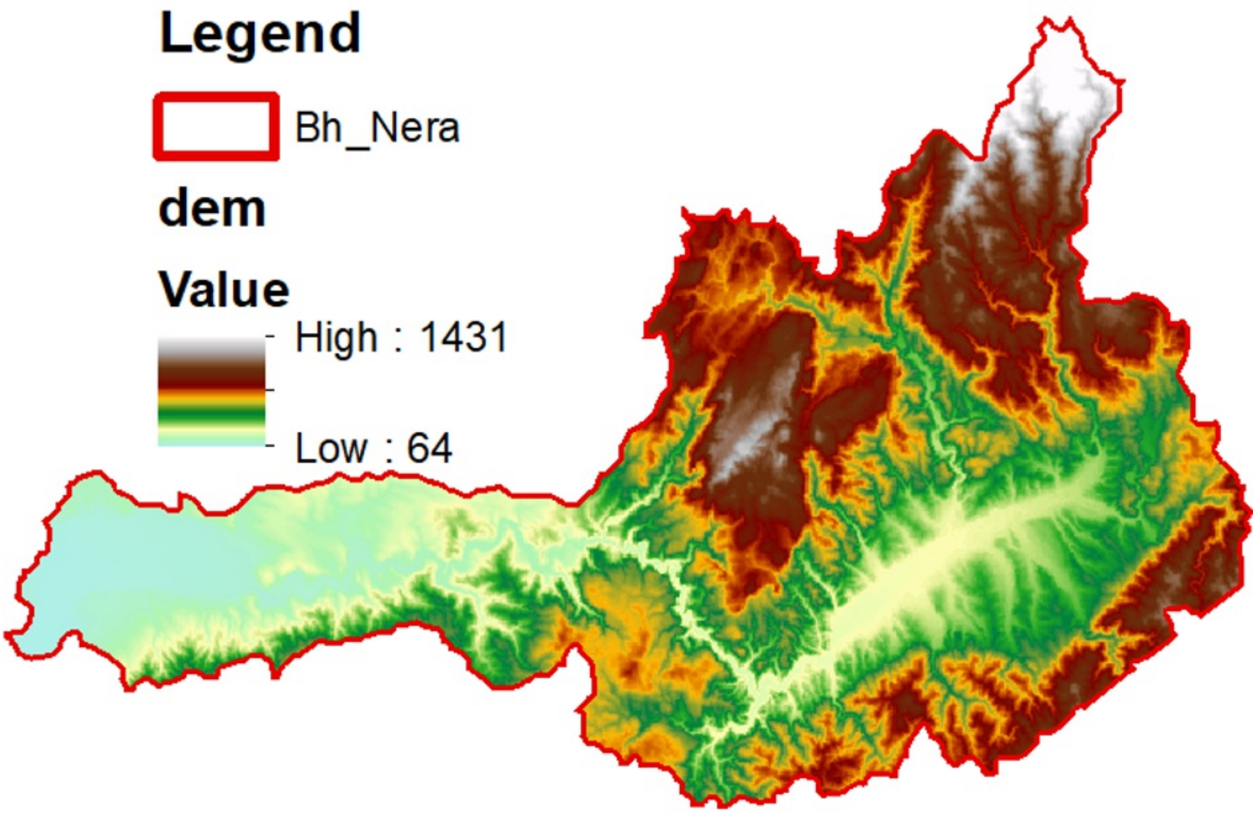

Figure 1. The study area map

2.2. Methods

The Gumbel distribution method, of frequency analysis requires a minimum of ten years of peak historical data to determine the future probabilistic prediction.

In this study, the Gumbel frequency distribution method (Eq. 1) was applied to predict the flood frequency in the Timis river basin [4].

$$F_x(x) = \exp[-exp(-\frac{x-u}{\alpha})] = p \qquad (1)$$

The mean value is calculated by summing all the individual values and dividing by the number of individual data values (Eq. 2).

$$\bar{x} = \sum_{i=1}^{n} \frac{x_i}{n} \qquad (2)$$

$$\tau = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{(n-1)}} \qquad (3)$$

The Gumbel's Distribution time dependent probability frequency analysis equation is (4)

$$X_T = \bar{x} + K \cdot \tau \qquad (4)$$

Where: X_T is Gumbel's Distribution in reference to return period; $\bar{x}$ is the mean value; σ is the standard deviation; K is the factor of frequency

3. Discussion and Conclusions

To estimate the design flood for different return periods with the Gumbel method, from the series of maximum annual floods (table 1) for n years, the average‾ and τ is calculated.

The average value is calculated by the ratio between the summation of all values of the maximum annual flows and the total number of values of the string. The most widely used measure of dispersion is the standard deviation (τ), defined as the square root of the mean square of the deviations from the average value. To calculate the estimates of exceedance probabilities associated with the peak flows in Table 1, Gringorten's position representation formula is used:

$$q_i = \frac{i-a}{N+1-2a} \qquad (5)$$

Where,

- qi - Exceedance probability associated with a specific observation.
- N - Number of annual maxima observations.

- i - Rank of specific observation
- a = 0.44, constant for estimation using Gringorten's method

Next, the probability p_i, reduced variate (Y) was calculated, respectively T_p - represents the estimated distribution of the 30 years of data.

	Anul	Q(mc/s)	qi	pi	Reduced Variate	t
1	1993	105	0.0186	0.9814	3.9756	53.786
2	1994	63.5	0.0518	0.9482	2.9340	19.308
3	1995	103	0.0850	0.9150	2.4211	11.766
4	1996	124	0.1182	0.8818	2.0732	8.461
5	1997	171	0.1514	0.8486	1.8069	6.605
6	1998	101	0.1846	0.8154	1.5893	5.417
7	1999	171	0.2178	0.7822	1.4039	4.591
8	2000	362	0.2510	0.7490	1.2413	3.984
9	2001	135	0.2842	0.7158	1.0956	3.519
10	2002	138	0.3174	0.6826	0.9627	3.151
11	2003	88	0.3506	0.6494	0.8400	2.852
12	2004	127	0.3838	0.6162	0.7253	2.606
13	2005	480	0.4170	0.5830	0.6170	2.398
14	2006	352	0.4502	0.5498	0.5138	2.221
15	2007	268	0.4834	0.5166	0.4148	2.069
16	2008	154	0.5166	0.4834	0.3190	1.936
17	2009	160	0.5498	0.4502	0.2256	1.819
18	2010	319	0.5830	0.4170	0.1339	1.715
19	2011	77.7	0.6162	0.3838	0.0433	1.623
20	2012	203	0.6494	0.3506	-0.0470	1.540
21	2013	213	0.6826	0.3174	-0.1377	1.465
22	2014	428	0.7158	0.2842	-0.2296	1.397
23	2015	264	0.7490	0.2510	-0.3238	1.335
24	2016	129	0.7822	0.2178	-0.4215	1.278
25	2017	41.8	0.8154	0.1846	-0.5245	1.226
26	2018	196	0.8486	0.1514	-0.6354	1.178
27	2019	226	0.8818	0.1182	-0.7587	1.134
28	2020	267	0.9150	0.0850	-0.9023	1.093
29	2021	135	0.9482	0.0518	-1.0854	1.055
30	2022	309	0.9814	0.0186	-1.3825	1.019

Table 1. The annual maximum at Naidas hydrometric station

N=	30	ani
mean=	197.0333	m3/s
std.dev=	110.301	m3/s

The average of 30 years is of 197.033 mc/sand the computation of annual peak discharge for return period of 5 years, 10 years, 50 years, 100 years, 150 years are presented in table 2.

T	YT	K	XT
5	1.49994	-0.0326	193.4379
10	2.250367	0.642006	267.8472
50	3.901939	2.126698	431.6101
100	4.600149	2.754359	500.8418
150	5.007293	3.120364	541.2125

Table 2. The parameters for flood frequency analysis

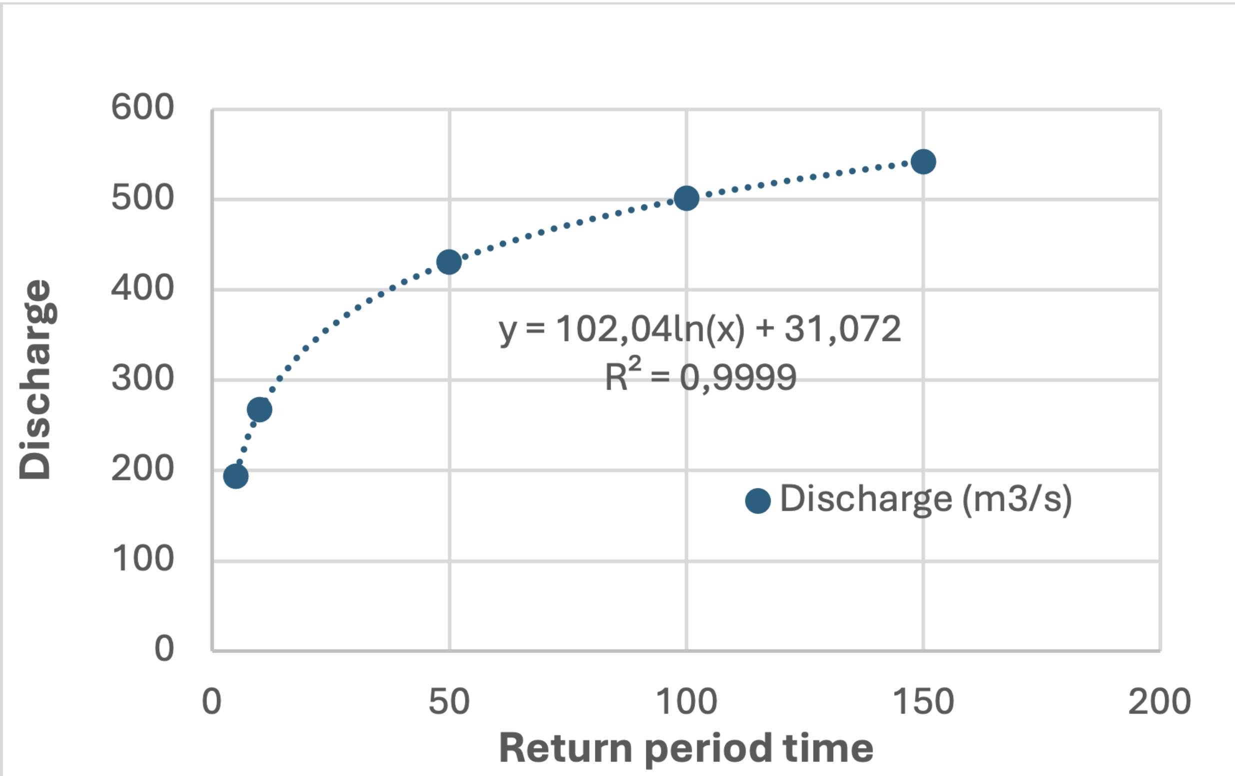

Figure 2. Flood Frequency Analysis Graph

The results illustrate the flows analysed for a return period of 5 years, 10 years, 50 years, 100 years, 150 years are: 267.84 mc/s, 431.51 mc/s, 500.84 mc/s, 541.21 mc /s. From the regression analysis equation, R^2 gives a value of 0.9 which shows that Gumbel's distribution is suitable for predicting the expected discharge in the river.

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