THE STATISTICAL ANALYSIS AND THE QUANTITATIVE ASSESSMENT OF ANNUAL MAXIMUM FLOWS RECORDED IN THE HYDROGRAPHICAL BASIN OF TIMIŞ RIVER

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ABSTRACT. – The statistical analysis and the quantitative assessment of annual maximum flows recorded in the hydrographical basin of Timiş river. We should calculate the frequency of flooding in this part of the country and determine the flow values or maximum levels with certain probabilities of exceedance in order to study the statistical analysis and the quantitative assessment of the annual maximum flows, based on the values related to the annual maximum flows recorded in the hydrometric stations from the basin. The setting of these indicators represents only an early stage in the analytical approach to flood risk of this basin, which should be followed by other complementary stages that include the setting of parameters related to the receptors sensitivity to the action of this risk type, to the exposure of the receiving elements, to the value of the receivers and, finally, to the setting of the flood risk value.

Keywords: hydrographical basin, hydrometric stations, maximum flows, flood risk, statistical analysis, frequency, overflow probability, return period.

1. INTRODUCTION

Recently, the achievement of a deeper analysis of the flood risk in areas of the country that have been severely affected by this type of risk in recent years has proved to be necessary.

These regions include the Timiş river basin, especially its low plains area, which has been hit by the occurrence of major floods for years. We can mention especially the most recent floods from 2000 and 2005, which led to the flooding of several areas of land, to the record of many unfortunate damages and in most cases even loss of life.

Because the flood risk is the combination of the likelihood of flooding and potential adverse effects to human health, environment, cultural heritage and economic activity associated with the occurrence of a flood, a flood risk study for the river basin concept should not be treated separated from the concepts of *frequency*, *probability* and *time* (or period) to return or comeback of this hydrological extreme events (Haidu, 2002).

This study aims to be a comprehensive overview of the mathematical statistics applied in the quantitative analysis and assessment of maximum flows recorded on the basin of Timiş river by applying the calculation methodology of

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frequency and probability of exceeding the maximum flow, important and indispensable steps in the analytical approach of the flood risk.

2. THE WORKING METHODOLOGY

Data referring to the annual largest flow values collected from 13 hydrometric stations, which are very well distributed in the territory, because they are located in different parts of the basin, with a wide variety of physical and geographical conditions (fig. 1), have been used in view of the statistical analysis and quantitative assessment of maximum flows recorded in the basin of Timiş river. The study period is considered long enough and representative, because during those 35 years, from 1975 until 2009, the annual peak flow values present significant variation, including the absolute maximum flow values recorded for the floods from 2000 and 2005 (fig. 2).

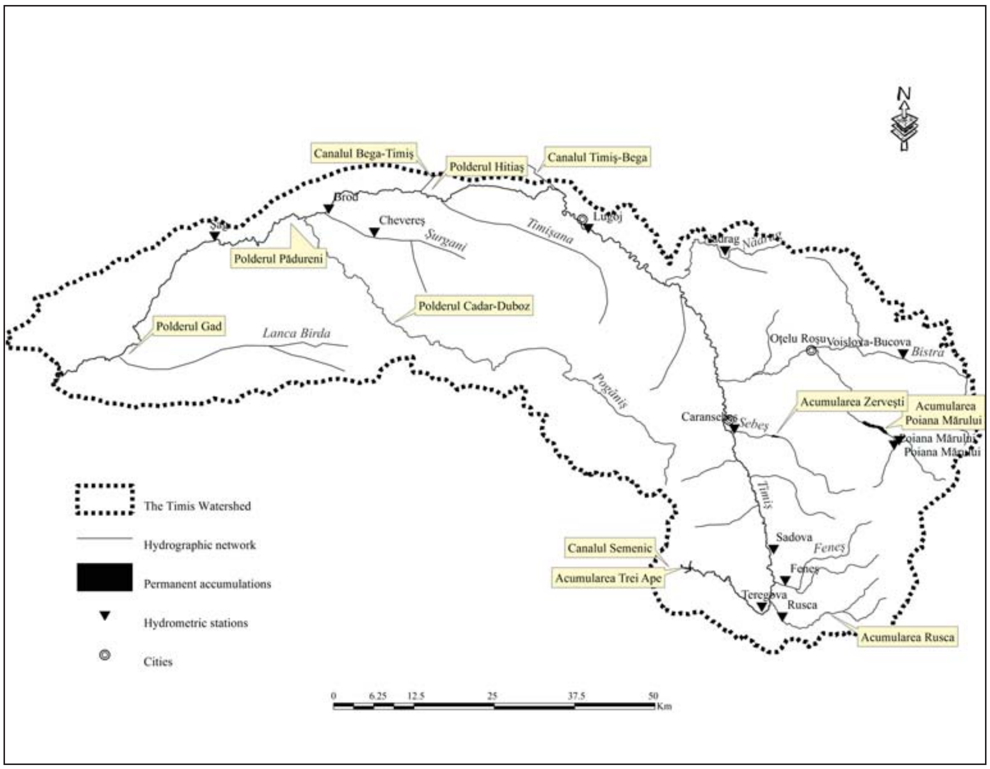

Fig. 1. ***Hydrometric stations and hydrotechnical works in the basin of Timiş river***

In addition to the annual maximum flow values, the records of the largest floods during a year have been taken into account, which have been found at hydrometric stations, containing the extraordinary measurements of flows and levels of the largest flash floods taking place each year.

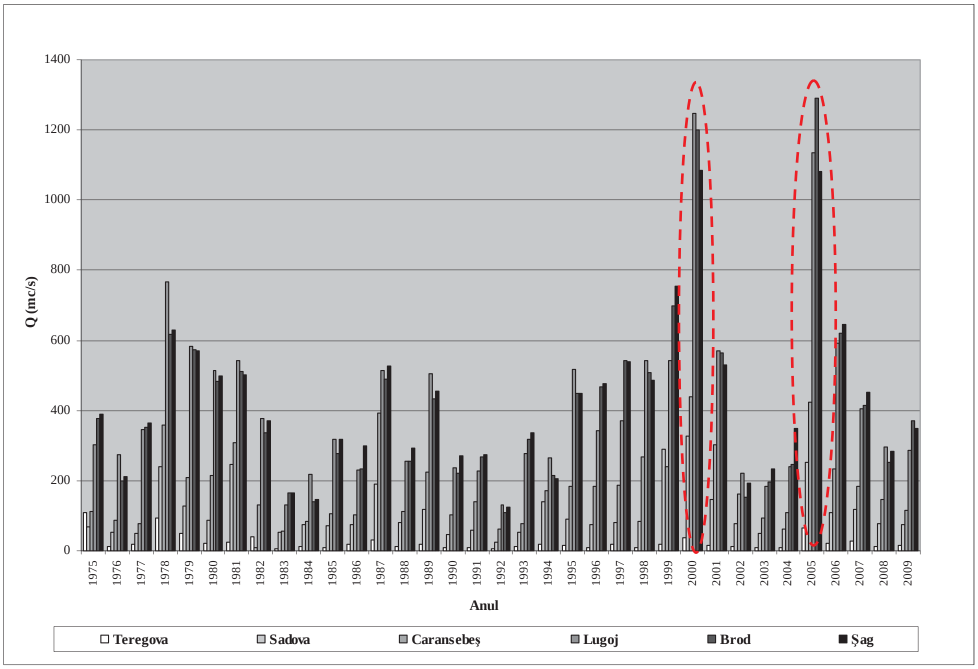

Fig. 2. ***Annual maximum flows (1975-2009) at the main hydrometric stations on Timiş***

Thus, based on the values of the annual maximum flows, the relative and absolute frequencies were calculated primarily for two hydrometric stations located on Timiş river. The frequency analysis is important within the flood risk study because it is a statistical method of prediction, consisting of the study of these events that happened in the past in order to define the probability of occurrence of values in the future (Haidu, 2002).

The absolute frequency (n_x) represents the number of cases in each flow interval, and *the relative frequency* is determined by the ratio of absolute frequency and total number of cases, a ratio that multiplied by 100 helps us find the respective relative frequency percentage (%) (Teodorescu, 2003). Thus, the relative frequency can be determined by the equation:

$$f(x) = \frac{n_x}{n}$$

where: n_x - the absolute frequency
n – the total number of cases

The empirical distribution of curve parameters have been calculated by the method of moments (Arghiuş, 2006) using the formulas for calculating the most important statistical characteristics of a range of data, namely *the arithmetic mean* (Q_{Mmed}), *the coefficient of variation* (C_v) and *the asymmetry coefficient* (C_s). These features of the range of data consisting of the annual values of maximum flow rates have been calculated using the following formulas:

$$Q_{Mmed} = \sum \frac{Q_{Mi}}{n}$$

$$C_v = \sqrt{\frac{\sum (k_i - 1)^2}{n}}, \text{ where } k_i = \frac{Q_{Mi}}{Q_{Mmed}}$$

$$C_s = \frac{\sum (k_i - 1)^3}{n C_v^3}$$

where:

Q_{Mmed} – the arithmetic mean of the maximum flow;

Q_{Mi} – the maximum flow corresponding to the number from the range of terms;

n – the number of terms in the range of data;

C_v – the coefficient of variation;

k_i – the module coefficient;

C_s – the coefficient of asymmetry (Arghiuş, 2006).

A very useful method of hydrometric and hydrological data processing is the calculation of the *probability* of occurrence of certain maximum flow rates (Teodorescu, 2003). Thus, the empirical exceedance probabilities can be calculated using the formula:

$$p = \frac{m - 0,3}{n + 0,4} * 100\%$$

where:

m – the number of the maximum flow from the range of terms in decreasing sequence;

n – the number of terms in the range.

The classical method of determining the probability of exceedance, i.e. the distribution range with three parameters (Pearson III), has been used for the statistical analysis of the range of maximum flows from the 13 hydrometric stations, and the maximum flow values with different probabilities of exceedance have been obtained using the following formula (Arghiuş, 2006):

$$Q_{Mp}=Q_{Mmed} (C_v * øi + 1)$$

The values of the øi coefficient, which vary depending on the value of the coefficient of asymmetry (C_s) and the value of the probability of exceedance, have been extracted from page 14 of document: http://teaching.ust.hk/~civl253/lecture %20notes. files/frequency%20analysis%202.ppt. Based on these values, on the values of the coefficient of variation and on the average values of the maximum flows from each hydrometric station, the peak flow values with different probabilities of exceedance (Q_{MP}) have been obtained and are presented in table 2.

3. THE INTERPRETATION OF RESULTS

The absolute frequency values and relative frequency values for the two hydrometric stations studied, namely Teregova, close to the springs of Timiş, and Şag located on the lower course of Timiş river, where the flood risk is high, are shown in Fig. 3. By analyzing the frequency of the two hydrometric stations, one can note that, as we move away from the source of Timiş river, the frequency curve of annual maximum flows changes greatly increasing the flow rate range with the highest values of flows, within which the rates recorded for the catastrophic floods of 2000 and 2005 are also found.

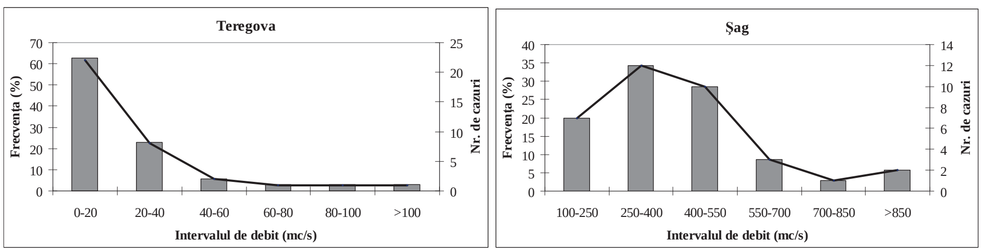

Fig. 3. ***The histogram of frequencies for the hydrometric stations of Teregova and Şag***

The results obtained by calculating the empirical distribution curves parameters and the corresponding maximum flows with different probabilities of exceedance or return period are shown in tables 1 and 2. By analyzing these results, we notice that the values of the coefficient of variation (C_v) vary from a hydrometric station to another, recording the minimum value (0.52) for the hydrometric station located in Şag on Timiş river and the maximum value (1.03) for the hydrometric station located in Nădrag, on Nădrag river, a tributary of Timiş.

The high values of the coefficient of variation, characteristic of the hydrometric station from Nădrag, are due to the range of data referring to peak flows, to some exceptional values, such as the maximum flow recorded in 2000, approximately six times higher than the annual average of maximum flows during 1975-2009.

The lower values of the coefficient of variation are due to the adjustment of the runoff, whether it is a natural adjustment (the high coefficient of forest coverage within the basin and the high value of average altitude of the hydrographical basin) or it is an anthropogenic adjustment (through hydrotechnical works in the basin).

We may include among the hydrotechnical works carried out within the basin the completion of the permanent accumulation of Trei Ape, which strongly modifies the water flow regime in Timiş river, starting with its springs. The influence of this accumulation, as well as the influence of the Semenic Canal, through which water is transferred from Timiş to Bârzava, is felt in the minimum, average and maximum of the water flow on Timiş river throughout its upper and middle course.

Table 1. Hydrological characteristics of the hydrometric stations in the basin

Stream	Hydrom. station	Year of constit.	F (km^2)*	Hmed (m)*	Multian. average Q (m^3/s)	Absolute maxim. Q (m^3/s)	Year	Average maxim. Q (m^3/s)	Cv	Cs
Timiş	Teregova	1907	167	901	2,5	108	1975	23,93	0,95	1,79
Rece	Rusca	1957	163	1184	4,6	180	1999	43,35	0,73	0,37
Feneş	Feneş	1964	125	973	2,8	156	1999	37,78	0,75	0,38
Timiş	Sadova	1951	560	936	10,5	328	2000	108,2	0,70	0,17
Timiş	Caransebeş	1966	1072	765	18,4	441	2000	183,2	0,56	0,03
Bistra	Voislova-Bucova	1958	232	892	3,9	280	2000	51,75	0,85	1,52
Şucu	Poiana Mărului	1958	77	1430	3,0	176	2000	32,16	0,9	1,94
Bistra Mărului	Poiana Mărului	1958	79	1442	2,7	96	2000	27,92	0,73	0,29
Nădrag	Nădrag	1963	36	742	0,7	63,5	2000	10,91	1,03	3,77
Timiş	Lugoj	1950	2706	666	37,9	1247	2000	418,9	0,59	0,07
Şurgani	Cheveres	1964	138	141	0,4	40,3	2005	15,35	0,72	0,06
Timiş	Brod	1971	3682	569	31,1	1290	2005	415,6	0,62	0,1
Timiş	Şag	1961	4493	477	35,4	1084	2000	424,7	0,52	0,03

* Source: (Munteanu Rodica, 1998)

We notice that the maximum flow values with the probability of exceedance of 1% vary quite sharply from one station to another. As we move further away from sources of Timiş, these values increase, except for the last hydrometric station (Şag), where a decrease is recorded.

Table 2. ***Maximum flow rates with different probabilities of exceedance / return period***

No.	Stream	Hydrometric station	Maximum flow rates with different probabilities of exceedance / return period					
			0,5	1	2	4	10	20
			200	100	50	25	10	5
1	Timiş	Teregova	118,2	103,5	88,7	73,8	53,9	38,6
2	Rece	Rusca	136,7	126,1	114,9	102,8	85,0	69,2
3	Feneş	Feneş	121,3	111,9	101,9	91,1	75,1	60,9
4	Timiş	Sadova	317,4	295,4	271,7	245,9	206,7	171,1
5	Timiş	Caransebeş	447,5	421,9	394,0	362,9	314,8	269,6
6	Bistra	Voislova-Bucova	223,7	198,2	172,4	146,2	110,4	82,1
7	Şucu	Poiana Mărului	154,4	135,0	115,6	96,0	70,1	50,3
8	Bistra Mărului	Poiana Mărului	86,1	79,8	73,0	65,6	54,6	44,7
9	Nădrag	Nădrag	72,8	58,0	47,9	36,6	22,8	13,8
10	Timiş	Lugoj	1078,8	1012,0	939,6	860,0	738,2	625,5
11	Şurgani	Cheveres	44,9	41,9	38,6	35,1	29,6	24,6
12	Timiş	Brod	1103,7	1034,1	958,6	875,6	748,6	631,1
13	Timiş	Şag	993,6	938,4	878,3	811,4	707,8	610,7

This reduction in the hydrometric station from Şag of the maximum flow values with the probability of exceedance of 1% is due to the maximum flow values recorded during the floods in 2000 and 2005 which were significantly reduced due to the impermanent accumulation from Pădureni, located between the two hydrometric stations, which stored a volume of flood wave attenuation of 20 million m³. However, at least in 2005, the maximum flow value recorded at the hydrometric station in Şag was an exceptional value in terms of its classification within the statistics, and the probability of exceedance corresponding to this flow rate was 4%.

The peak flows have been influenced by the breaking of dams and the retention of significant volumes of water in the permanent and impermanent reservoirs upstream from it (Fig. 1) for all hydrometric floods recorded at this station from 1975 to 2009.

During the last flash floods, the carrying capacity of the major river beds was exceeded downstream from the hydrometric station from Şag, because the defense dams have been designed to resist a flood with the probability of occurrence once every 20 years (Report on the flood from April 2005 in the hydrographical basin of Banat , INHGA).

Fig. 4 and 5 display the charts referring to the theoretical curves with different probabilities of exceedance from the basin's hydrometric stations, which allow the setting of small intervals of the probability of exceedance, so needed in practice.

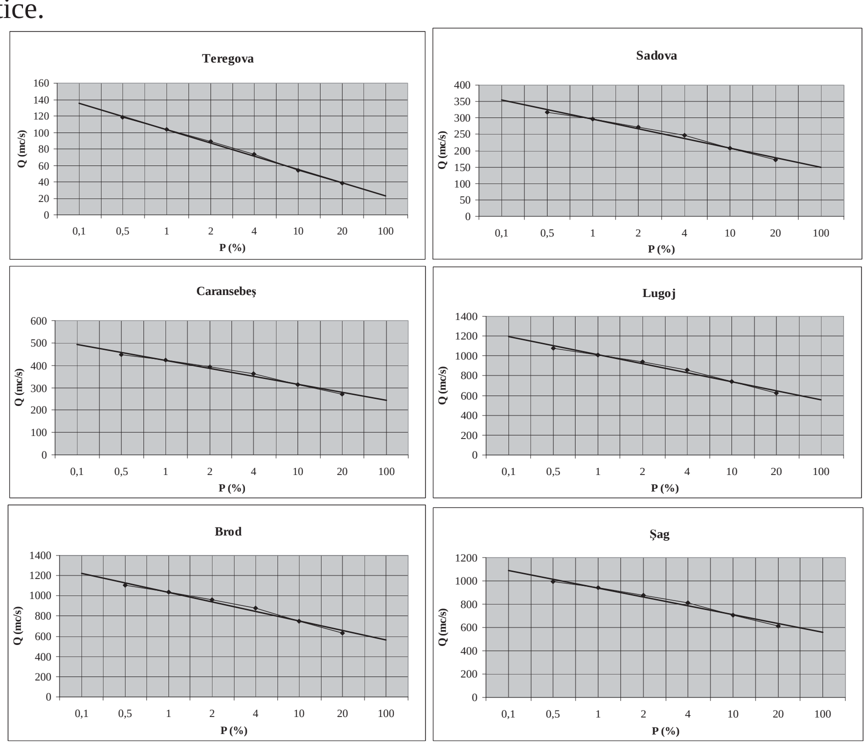

Fig. 4. ***The charts referring to the distribution curves from the hydrometric stations located on Timiş***

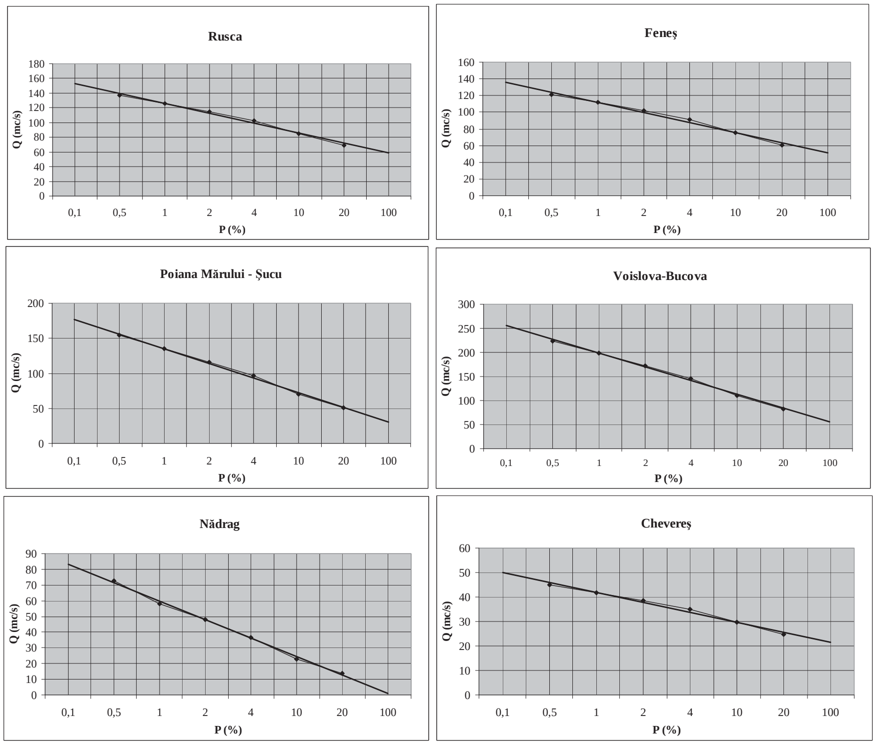

Fig. 5. ***The charts referring to the distribution curves from the hydrometric stations located on the tributaries of Timiş river***

4. CONCLUSIONS

This study of statistical analysis and quantitative assessment of annual maximum flows represents an earlier stage in the analysis of the flood risk in the hydrographical basin of Timiş river. The stage in which we have determined *the frequency, the probability* and *the return period* of such extreme events should be followed by other additional stages, which complete the flood risk analysis and which should be rendered clearly on the flood risk map of the hydrographical basin of Timiş river.

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