SOME ASPECTS REGARDING THE MAXIMUM FLOW THE COLD SEASON IN THE UPPER PART OF THE BUZĂU RIVER CATCHMENT

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ABSTRACT. - Some aspects regarding the maximum flow during the cold season in the upper part of the Buzău River Catchment. This article aims to analyze the maximum flow during the cold season (November 1st to April 30th), in the upper part of the Buzău River Catchment. The research took into account only those floods whose maximum discharges exceeded twice the multiannual medium level. The analyzed period covers 46 years (1965-2010) for Nehoiu and Sita Buzăului hydrometric stations (hs) and the Bâsca Roziliei hs on the Bâsca River. The dynamics of hydrological processes during the cold season is strongly influenced by winter phenomena. They have high occurrence over the sectors of rivers from depressions and valleys, especially over those in Comandău Depression. The months mostly affected by winter phenomena (ice cover) were: January, February and December. The floods with the highest discharges were recorded in April, both on the Buzău River at Nehoiu hs (44%) and on the Bâsca at Comandău hs (79%) and Bâsca Roziliei hs (53%). The changing of the shape and position of the waves of floods in time, on the Buzău and Bâsca Rivers are caused by the effects of the attenuation phenomena (Siriu Reservoir) and subsidence (the lower part of Bâsca River, downstream of the confluence with Păltiniş River).

Keywords: maximum flow, flood, cold season, Buzău River Catchment

1. INTRODUCTION

In the hydrological regime of rivers, the maximum flow generally corresponds to the periods of high waters, when discharges have high values for a longer period of time (days, weeks, even months), either as a result of long-term rains, of reduced-intensity rains, or of slowly melting snow (Diaconu, 1988). The high waters are specific to spring in Romania (as a result of high pluvial and nival - snow-melt - supplies) and to the second part of autumn (a consequence of frontal rains). The highest values of the maximum flow are usually recorded during floods. These, unlike high waters occur in a relatively short time (from a few hours- flash floods, up to a few days) and sometimes they have spectacular peak discharges, being generated by heavy rains or by the suddenly melting snow. Floods may occur in any season, but they have a higher frequency in spring and summer, when up to 50% and 40% of the overall floods occur within a year in Romania (***, 1971).

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Annual floods in the country are of pluvial origin. Annual maximum discharges caused exclusively by the snow melting hold only 3-4% of the overall annual maximum discharges (***, 1971; Diaconu & Şerban, 1994). During the cold season, the transited volumes of water in the mountain areas are *"up to 50-60% of the annual reserve"* (Şerban *et al.*, 1989). Information on the maximum flow in the researched area is to be found in some previous studies conducted at national level, such as: *Râurile României - Monografie hidrologică* (***, 1971), *Geografia apelor României* (Ujvári, 1972), *Viituri excepţionale pe teritoriul României. Geneza şi efecte* (Mustăţea, 2005). At a regional scale, analyses on the maximum flow can be found in the papers published by Zaharia (2004), Diaconu (2005), Chendeş (2011), Minea (2012).

This paper aims to analyze the maximum flow during the cold season (from November 1st to April 30th), in the upper part of the Buzău River Catchment, for the purpose of establishing its features.

2. DATA AND METHODS

The main types of data were the hydrological ones (the discharges of floods, average monthly and multiannual discharges) those related to climate (temperatures and precipitation) and geospatial datasets. Hydrological data were received from two hydrometric stations (sh), located on the Buzău River (Sita Buzăului and Nehoiu) and one on the main tributary, Bâsca (Bâsca Roziliei). The reference period covers 46 years (1965-2010), with an interval for investigation from November 1st to April 30th. Complementary, depending on the production year of floods, discharges belonging to Vama Buzăului sh (1989-2010), located on the upper course of Buzău River and on the Bâsca River of Comandău sh, were also used (1974-2010). The hydrological data (discharges) and spatial data (vector and raster), were provided by the National Institute of Hydrology and Water Management (NIHWM), Bucharest. Climate data (temperature and precipitation) were received from National Meteorological Administration (NMA) Bucharest.

The specific features related to the floods study are caused by the ambiguity of the methods for determining the underground contribution, against the pluvial/nival contribution and by the criterion of establishing the level of the discharge from which floods are taken into account. This level can be considered as a multiple (from 2 up to 5) of the annual average discharge (Réménieras, 1999; Diaconu & Şerban, 1994; Pişota & Zaharia, 2002). Musy & Laglaine (1992), regarding the delimitation of the base flow compared to the surface flow, believed that the delimitation methods are quite empirical, the easiest one being the drawing on the floods hydrograph of a line that joins the starting point of the growth of the discharge with the point of inflection/breaking of a decreasing curve. Pandi (2010), points out for the individual floods hydrographs, several manual methods (e.g. by a straight line with 3 positions: ascending, parallel and descending). The variation of the main discharge of floods under the CAVIS software (Corbuş, 2010), is determined complexly, by different methods (continuously, with a constant slope, concave, recursive and generalized).

Within this paper, the selection of floods was based on the level of twice exceeding the medium and multiannual discharge (Diaconu şi Şerban, 1994; Pişota şi Zaharia, 2002). The value of the average multiannual discharge was calculated using the average monthly multiannual discharges. The determination of the characteristic elements of the flood waves was realized with the constant model of the CAVIS program. The main methods were represented by spatial analyzes using GIS techniques (ArcGis Desktop 9.3) and statistical analyze of hydrologic data.

2.1. Area of study

The study area corresponds to the upper Buzău River Catchment. This area is located in the external region of Curvature Carpathians and includes mountains and intra-mountain depressions (Întorsura Buzăului and Comandău). It lies between 1,954 m a.s.l. (Ciucaş Peak) and 350 m a.s.l. at Nehoiu hs (Fig. 1), with an average altitude of 1,020 m.

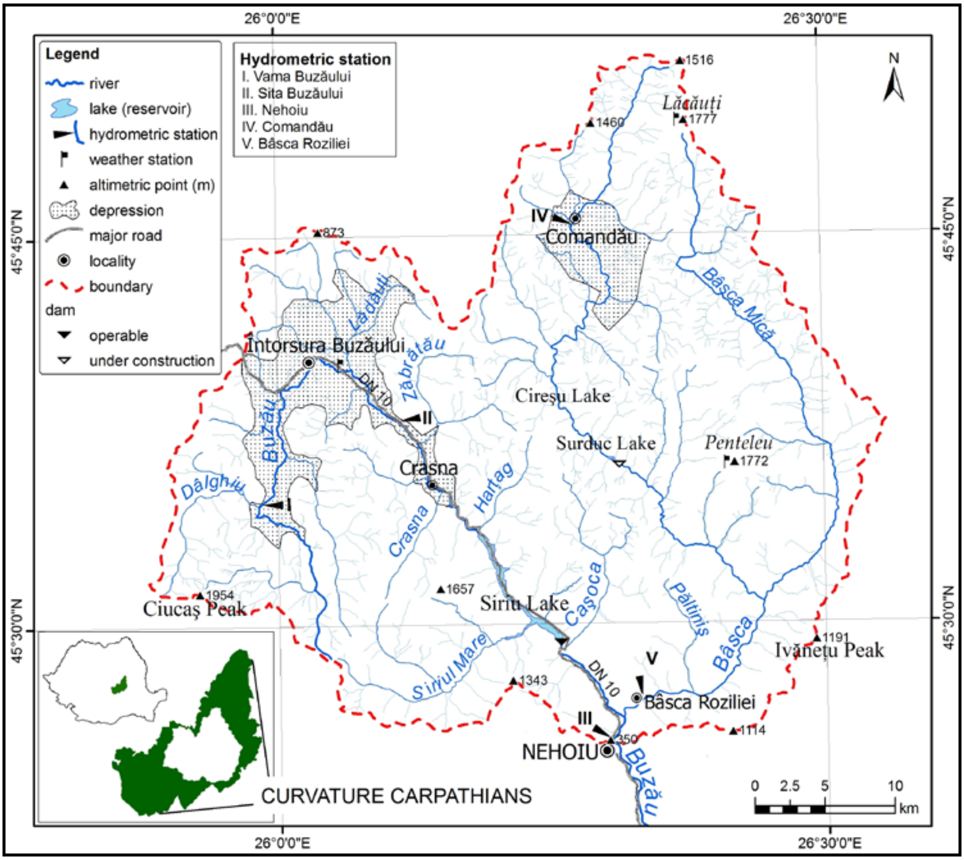


Fig. 1. ***Localization of the upper sector of Buzău River Catchment***

The hydrographic stream of Buzău River (Strâmbul, Dâlghiu, Lădăuţi, Zăbrătău, Crasna, Siriul Mare and Bâsca) drainage the basin area of 1,572 km^2 (Fig. 1), and has a medium density of 1.07 km/km^2. The discharges specific to the annual average have values between *"10 and 16l/s/km²"* (Zaharia, 2004). Within the monthly studied interval are transited ~ 45% from the medium annual volume. The hydrologic regime, after 1983 was partly influenced by the site corresponding to Siriu Dam, and after 1989, it was entirely influenced by the commissioning of the Siriu Lake (reservoir). Thus, floods waves on the River Buzău are diminished – by changing the volumes and shapes – in the Siriu Lake. There are in addition to be built dams of Cireşu and Surduc – in execution, on the river Bâsca River.

The maximum recorded discharges at the hydrometric stations used within this study and within the analyzed period, did not outrun the empirical probability (P), P = 10%. Specific cases are the exceedance of the warning stage (attention stage, inundation and danger). One such case was recorded in the spring 2007, when the flood discharge of 23.III, on Buzău River had higher values than those belonging to the warning stages at Sita Buzăului sh (Tab. 1) and because of geomorphological conditions of the riverbed, many households were flooded, including road (DN 10), between Sita Buzăului and Crasna.

Table 1. ***Morphometric and hydrological characteristics of studied hydrometric stations (1965-2010) in the upper part of the Buzău River Catchment***

River	Hydrometric station	A (km^2)	H_{med} (m)	L (km)	Q_{med} (m^3/s)	Q_{max} (m^3/s)/ 1.X. - 4.IV.	Q (m^3/s)		
							AS	FS	DS
Bâsca	Comandău*	105	1,252	24	2.54	32,3/ 22.III.1989	43.3	112	212
	Bâsca Roziliei	778	1,108	66	12.5	299/ 23.III.2007	638	828	1,023
Buzău	Vama Buzăului**	113	1,120	20	2.95	83/ 12.XII.1990	47.5	66.2	87.7
	Sita Buzăului	360	939	39	5.78	215/ 23.III.2007	68.5	96.1	152
	Nehoiu	1,572	1,020	66	22.4	508/ 20.I.1965	534	938	1,160

Data source: according to NIHWM, 2012. * - the analyzed period of Comandău sh is between1974 and 2010; ** - the analyzed period of Vama Buzăului sh is between 1989 and 2010; A = Catchment's area (upstream the hydrometric station); H = Catchment's mean altitude (upstream the hydrometric station); L = river length; Q = discharge; Q_{med} = mean discharge; Q_{max} = maximum discharge; AS = attention stage; FS = flooding stage; DS = danger stage.

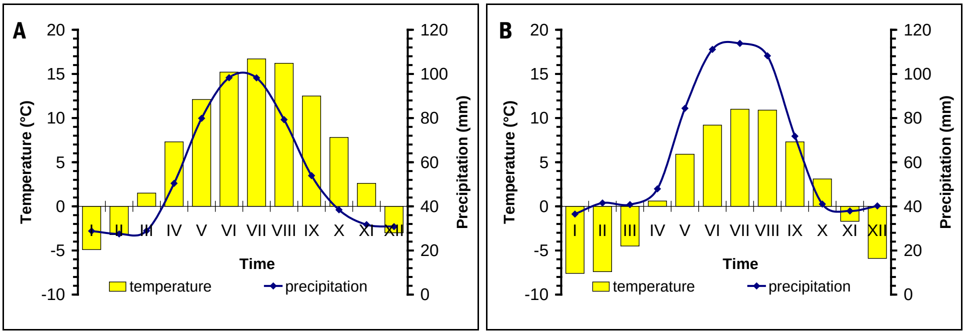
3. REZULTS

Within the studied area the maximum flow during winter is the result of the pluvial input – more important quantitatively combined, with that originating in the snow melting.

The phases of maximum flow (floods and high waters) are influenced naturally (the temporal variability of the climatic parameters) and artificial (Siriu Lake). These show the temporal dynamics (seasonal and monthly) and special (compound and propagation).

3.1. Climatic conditions

The climatic parameters are affected by the foehn phenomenon in the context of a western atmospheric circulation. The atmospheric average multiannual temperatures (1965-2010), range between below 6.7 °C at Întorsura Buzăului weather stations (ws) (707 m a.s.l.) and 1.7 °C at Lăcăuţi ws (1,776 m a.s.l.). The annual precipitation amounts to 646 mm at Întorsura Buzăului ws and 775 mm at Lăcăuţi ws (according to NMA, 2013). The lowest monthly precipitation amounts belong to winter months (~14%) with minimal temperatures in January. The large supply of rivers (pluvial - nival) is carried out between March and April, when temperatures become positive and when there is a snow disposal, overlaid with the increasing quantities of liquid precipitation (Fig. 2).



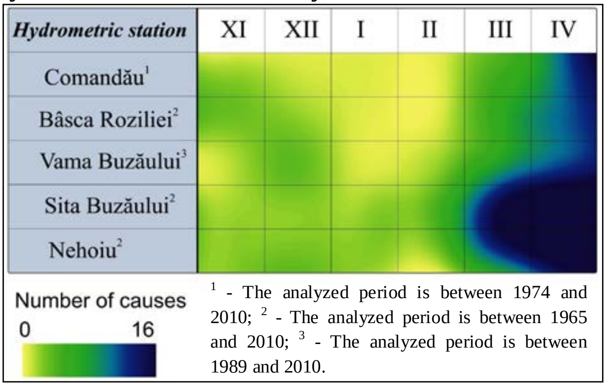
Data source: NMA, 2013.

Fig. 2. ***Variability of mean temperature and precipitation at Întorsura Buzăului ws (a) and Lăcăuţi ws (b) (1965-2010)***

The negative thermal averages are specific to the winter months, and at Lăcăuţi ws the interval is of 5 months (November - March). The hydrologic impact of low atmospheric temperatures on the river flows is generated by the winter phenomena (ice needles, ice on shore, ice cover, frazil pans, ice floes and ice blocks known as ice jams). During the cold season these lead to both the diminishing of flow as a result of the production of ice formations, and to the production of floods caused by the breakage of ice covers. On Bâsca River, in Comandău Depression, these phenomena usually appear in the second half of November and disappear in March. These have a moderate intensity on Buzău River, on the Întorsura Buzăului Depression, on the inferior part of the upper part of the hydrological Buzău River Catchment. The effects associated with the production of *ice cover* causes a partial or total blockage of the river flow, but the frequency and the duration on the same river varies from year to year and from one sector to another. Significant durations (2-3 months) occur on the upper course of Bâsca River (e.g. at Comandău sh the ice cover last from the beginning of December to late March). Unfavourable circumstances to the emergence of the ice cover (positive temperatures, sectors with high downhill slope and speed; underground supply; the execution of the evacuation methods of the discharges of Siriu Lake) are specific to Buzău River at Vama Buzău sh and downstream of Siriu Lake and lower part of Bâsca River. As a result, favourable conditions for the emergence of floods and inundation are being created (e.g. the surrounding human area of Întorsura Buzăului - Sita Buzăului).

3.2. Temporal dynamics

The frequency of monthly incidence of floods at hydrometric station in the Carpathian part of the Buzău River Catchment, in the analyzed period shows the high potential in April (79% at Comandău sh; 53% at Bâsca Roziliei hs; 44% at Nehoiu hs), followed by the one in March. Low to zero frequency months are the winter ones (Fig. 3).



Data source: according to NIHWM, 2012

Fig. 3. ***The number of floods in the upper sector of the Buzău River Catchment***

The floods duration is an important element because the magnitude of the effects generated by the flood depends upon it. The demonstration periods of floods generally covers large measures of unfolding, on the rising part, as well as on the decrease part. Certain floods contain specific features, but through large measures and volumes, transform into *"high waters"* (e.g. the 5.IV.1992 flood from Nehoiu hs on the Buzău River). The durations of floods on the Buzău River to Nehoiu sh were studied, in a natural regime as well as in an artificial one.

The highest volume and unfolding volume flood was recorded, in a natural regime in the year 1981 (7.III - 8.IV). This highest flood in Nehoiu sh recorded Q_{max}= 447 m^3/s (13.III) and lasted 446 hours out of which the rising period was 110 hours and the decreasing period was 336 hours and recorded the highest total volume of the flood in the observation period (185×10^6 m^3). In an artificial regime, the duration of the floods and high waters transited on the Buzău River is controlled in the Siriu Lake, but conditioned by the water volume contained within the lake, before the event occurred. Simultaneously, the flood duration depends on the intensity of the genetic factor, and this is also influenced by the content of the Bâsca River (≥ 50%) in the lower part of the Siriu Lake. As an example, the compound flood of March 2007, at Nehoiu sh Q_{max} = 438 m^3/s (23.III; 22:00 h) recorded the total duration of 132 hours, out of which 64 hours belonged to the rising limb and 68 hours to the decreasing limb (Table 2).

The following values resulted from the study of the average measures of the largest floods from the cold season, which numbered 5 floods, at the Nehoiu hs: the total measure of transit towards a flood wave is one week; the rising measure, depending on which the character of the flood is being established, may vary from 11 to 65 hours; the decreasing measure is 6 days (between 68 to 274 hours).

Table 2. ***Characteristics of the flood from 23 March 2007***

River	Hidrometric station	Q_{max} (m^3/s)	RT (hh:mm)	Time (hours)		
				total	increase	decrease
Bâsca	Comandău	21.8	18:30	264	74	190
	Bâsca Roziliei	299	16:00	213	71	142
Buzău	Vama Buzăului	60.4	17:00	216	83	133
	Sita Buzăului	215	20:00	408	75	333

Data source: according to NIHWM, 2012; Q_{max} = peak discharge; RT = recording time.

3.3. Spatial dynamics

As much as the *compound and propagation of floods* is concerned, the following particularities were noticed from the carried out analysis: a) the hydrographs show the form of a singular flood as well as of *"high waters"*; the complex significant floods are the result of the lateral inflow contribution, on the lower part of the Siriu Lake, the contribution of the Bâsca River being significant; b) the propagation of the flood waves is conditioned by the synergism of geomorphologic factors (the alternation of channel contraction and broadening sectors of the Bâsca River and Buzău River Valleys); morphometric factors (the area of catchment; the length of the main river); climatic factors (the effect of rains and/or the yielding water from the snow layer that affects the whole upper part of the basin from upstream to the lower part of the river) and anthropogenic (hydraulic artificialities).

The change of shape and position of flood waves, as time passes, on the Buzău and Bâsca Rivers is caused by the effects of *attenuation and subsidence* phenomena. *Attenuation* is also influenced by geomorphologic features of the valleys, which contain sectors that allow the infiltration, retention and inundation of floodplains and fluvial terraces (e.g. Buzău River, in the Întorsura Buzăului Depression). Artificially, the attenuation is achieved in the Siriu Lake – through the retention of a part of the affluent discharge (Q_{afl}); for example the conveyance of the complex flood from 20 to 31.III.2007, was attenuated through the Siriu Lake by 47% (Q_{afl} = 243 m^3/s and Q_{defl} = 142 m^3/s). *Subsidence* in generally is a phenomenon oftenly overlapped to natural attenuation (Şerban et *al.*, 1989), and consists on the reduction of maximum discharge, following the river sectors with low slopes transit (the inferior part of the River Bâsca, downstream of the confluence with the Păltiniş River).

4. CONCLUSIONS

The analysis of the corresponding flood wave flow hydrographs from the period of 1965 to 2010 in the upper part of the Buzău River has led to the following conclusions:

a) the floods that happened in the cold season, most commonly in early spring, due to the climatic conditions are mono wave and compound (as a result of the lateral inflow and depending on how they spread) and that overlapped *"high waters"*;

b) the floods are not characterized by ample values of maximum discharges, but by large volumes and duration of transit;

c) the hydrologic effect of attenuation of the flood wave in the Siriu Lake, at Nehoiu hs is reduced, because through compounds, the Bâsca River doubles the flood discharges.

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