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ANALYSIS OF FLASH FLOODS OCCURRED AND REGISTERED AT THE DARMANESTI HYDROMETRIC STATION WITHIN THE UZ HYDROGRAPHIC BASIN

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ABSTRACT

The flash floods and the floods constitute the most dynamic and dangerous hydrological risk phenomena. The floods from the Uz hydrographic basin constitute important threats, having an unpredictable character and a high distribution over time. For the analysis of the occurred flash floods, it was utilized data registered at the Darmanesti hydrometric station for the periods: 1977-1981 and 2001-2005. The data was taken from the Siret-Bacău Water Basin Administration. Among the registered flash floods in these periods were selected the most important, having their frequency and their intensity analyzed. For the periods 1977-1981 and 2001-2005 there have been included exceptional flash floods, more precisely from the years 1978 and 2005. In order to prevent and diminish the negative effects of the flash floods occurrences, it was required the evaluation of the flash floods wave's features: basis flow, peak flow, increasing time, decreasing time, total time, the transited water volume, the drained water volume, the shape coefficient, the specific maximum leakage. The features of the flash floods were studied based on a temporal analysis. It has also been analyzed the oscillation level during the flood, in comparison with the attention elevations, flood elevations and danger elevations. It is noteworthy that during all the years from the studied periods, flash floods have occurred that exceeded the flooding elevation. The danger elevation was exceeded in 57% of the cases for the period 1977-1981 and in 86% of the cases for the period 2001-2005. The rise in frequency of the extreme hydrometeorological phenomena due to climatic changes distinguishes itself through a much larger scale of the flash floods from 2005 in comparison to 1978. In this situation, the local population was exposed to the risk, necessitating protection measures.

Keywords: floods, occurrence frequency, maximum flow, increasing time, decreasing time, defense elevation

1 INTRODUCTION

The Uz hydrographic basin is situated in a hydro-climatic zone of transition, from oceanic nuances to moderate and continental ones, having great thermal and pluviometric discontinuities. The context of the area offers reason to suppose that the eastern part of the country can be more profoundly impacted by the climatic changes.

In our country there are numerous researches concerning the changes occurred in the thermal, pluviometric and hydrologic conditions and their impact on the future hydroclimatic evolution (Arghius, 2007; Mihaila et al., 2009; Mustatea, 2005; Olaru et al., 2010; Romanescu et al., 2011; Rotaru and Kolev, 2010; Stanciu et al., 2005; Teodosiu et al., 2009).

The knowledge of the flash floods is considered to be the representation of major natural risk factors (Affeltranger and Lictorout, 2006; Arduino et al., 2005; Arghius, 2008; Badaluta-Minda and Cretu, 2010; Chiriac et al., 1980; Olang and Fürst, 2010; Romanescu, 2009; Romanescu and Nistor, 2011; Rosu and Cretu, 1998).

In the Siret basin (including Uz), the major flash floods have been recorded in 1970, 1975, 1988, 1991, 2005 (Romanescu and Stoleriu, 2006).

The flash floods often cause floods with negative and even devastating consequences over the natural environment and the human settlements. These are triggered following the fall of very large quantities of precipitations in a relatively short period of time, over the hydrographic basin, due to snow melting, the overlapping of the two phenomena or following the occurring of accidents in the hydrotechnical constructions (especially in the zone of the reservoir lakes dams) (Minea and Romanescu, 2007).

The studied basin is situated in the eastern part of Romania, and belongs to the Trotus basin, a component of the greater Siret basin, The river Uz is one of the important right tributaries of the river Trotus. It springs from the Ciuc mountains from an altitude of 1175.33 m, crosses the hydrographic basin on a length of 46 km and meets the river at Darmanesti confluence point, at an altitude of 320.43 m. The surface of the hydrographic basin is about 475 km^2. From a mathematical standpoint, the basin can be found between 26˚00'16" and 26˚30'56" eastern longitude, and between 46˚08'44" and 46˚23'27" northern latitude (Figure 1).

On the river Uz has been built the Poiana Uzului reservoir lake (1965-1972) and was commissioned in 1974.

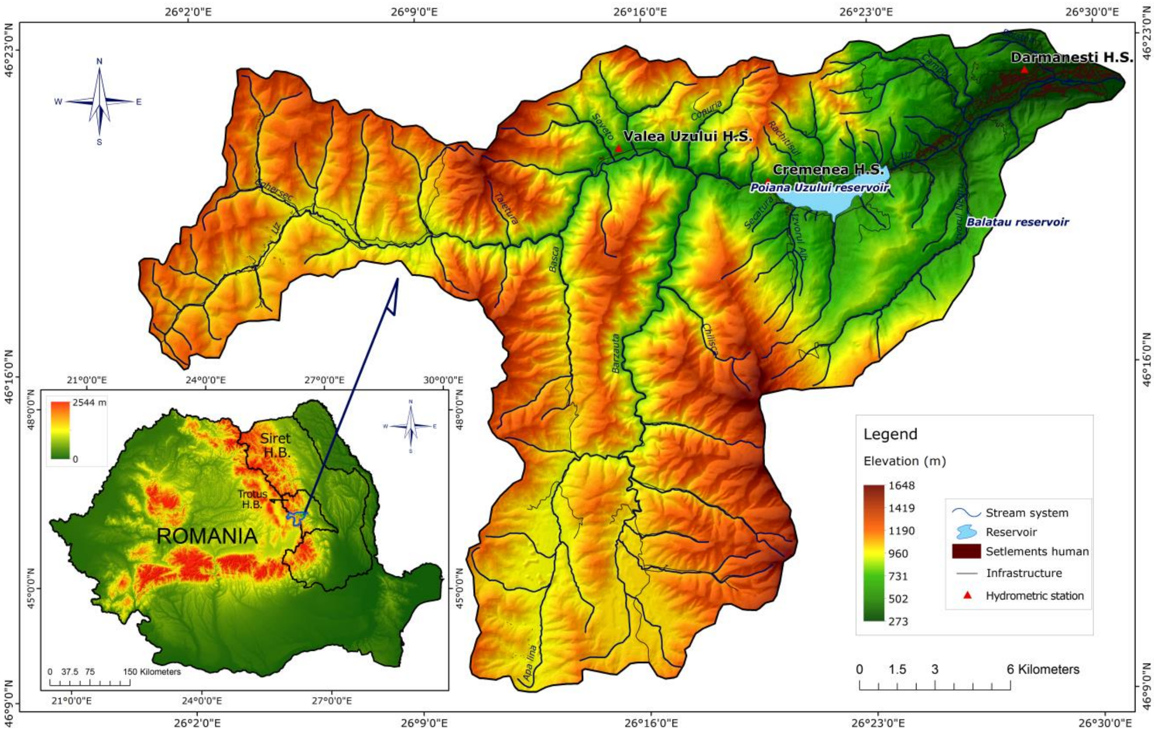

Figure 1. The geographical location and mathematic coordinates of the Uz river basin

The Darmanesti hydrometric station is situated on the river Uz, downstream of the lake. It was commissioned in 1976 and the total area of the drainage basin is around 404 km^2 (Table 1). The average multiannual precipitation quantity is about 623.3 l/m^2, the average multiannual flow is about 4.9 m^3/s and the maximum historical flow recorded at the station was about 132 m^3/s in the summer of 2005.

Table 1. Data from the Darmanesti hydrometric station

River	Hydrometric station	Establishment date	Distance from the spring (km)	Drainage basin	
				Area (km^2)	Altitude (m)
Uz	Darmanesti	1976	43	404	975

2 METHODS

Hydrological, analytical and statistical methods have been used for the elaboration of this study. The data registered at the Darmanesti hydrometric station situated on the river Uz, was taken from the Siret-Bacau Water Basin Administration. For the graphic processing of the database and for the statistical analysis, Microsoft Excel has been used. For the seasonal, monthly and daily frequency analysis, there have been selected annual flash floods for the following periods: 1977-1981 (the period immediately following the commissioning of the Poiana Uzului dam); 2001-2005 (the more recent period during which the historical maximum has been recorded). Due to a lack of data, two period were selected for analysis (1977 – 1981 and 2001-2005) which justify the scope of the study. The characteristics of the flash floods resulted following the analysis of the maximum flows, of the time durations (increase, decrease and total), of the volumes of water (increase, decrease and total) transited on the riverbed during the flash floods, together with the height of the drained water layer, the flash flood shape coefficient, the levels' oscillation during the flash floods depending on the defense elevations (A.S.= 150 cm, F.S.=200 cm, D.S.=300 cm).

3 RESULTS AND DISCUSSION

The current period is confronted with a significant increase in frequency and intensity of the extreme hydro-meteorological events. The rising in intensity of the floods in the recent years is due in part to the large quantities of precipitations fallen in a relatively short period of time, due to deforestation on large mountainous and plain areas, the uncontrolled settlement of people in the extended riverbed, but also the removal of the humid zones from the meadows of some watercourse, thus influencing the overflow phenomenon (Romanescu and Stoleriu, 2006).

In the period 1977-2009 which includes the studied periods, a large oscillation of the average annual precipitations quantities has been recorded. One can notice that in the rainiest years, i.e. 1980, 2001, 2005, followed by 1978, 1979, 1981 and 2002. The decreased precipitations amounts has been recorded in 1977 and 2003 (Figure 2).

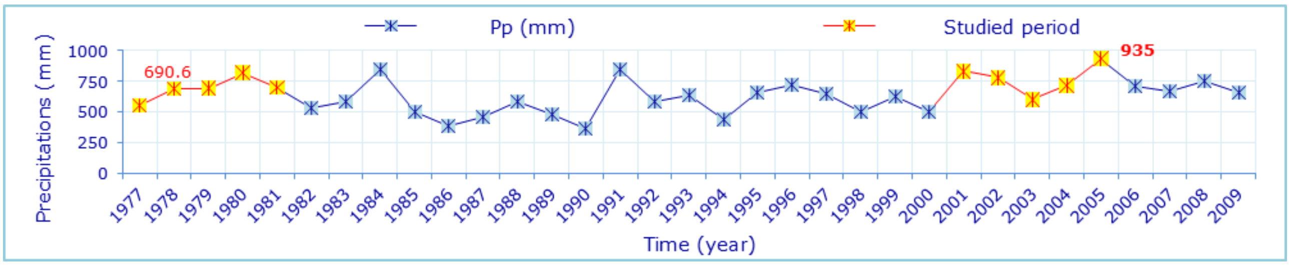

Figure 2. The annual precipitations registered at the Darmanesti station (1977-2009)

For the period 1977-1981, the high values of the maximum flows have been recorded during the years 1977, 1978 and 1981, while for the period 2001-2005, the values have been recorded for the years 2001 and 2005. The highest values of the maximum flows occurred during the flash flood of 1978 (129 m^3/s) and from the year 2005 (132 m^3/s). The amplitude of the flows from the second period (2001-2005) has been much higher than the one from the first studied period (1977-1981). This fact is due to the large quantities of precipitation fallen in a relatively short time interval and due to the anthropic interventions from the late years over the natural environment (deforestation, changes of the watercourse, overpopulation and the settlement of the households in the extended riverbed, hydrotechnical constructions, etc.). During the flash flood of July the 13th 2005, when the maximum historical level has been recorded at Darmanesti station, the level of the water reached 5.2 meters (Figure 3).

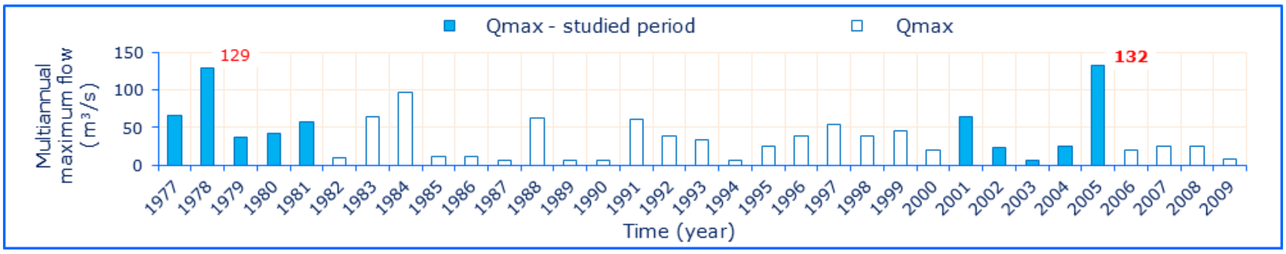

Figure 3. The interannual variability of the maximum annual flows on the river Uz (1977-2009)

For a *temporal analysis of flash floods*, the annual flash floods from 1977-1981 and 2001-2005 have been selected. An analysis of the seasonal, monthly and daily distribution has been performed for the whole 16 flash floods.

By analyzing the monthly distribution of the flash floods from the period 1977-1981, one can notice that during the months of June and August occurred the highest number of flash floods. Between December and April no flash flood has occurred. For the period 2001-2005, the maximum number of flash floods has been recoreded in July. Between October and February, but also in May, a lack of flash floods was noticed (Figure 4a).

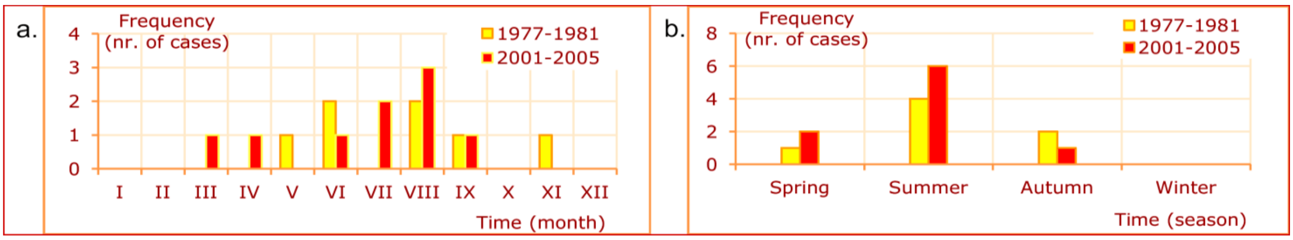

Figure 4. The monthly (a) and seasonal (b) occurrence frequency of the maximum flow occurrence in the Uz hydrographic basin

The analysis of the seasonal distribution from the first studied period (1977-1981) highlights the fact that the frequency of flash floods usually occurs during summer (57%), followed by autumn (29%) and spring (14%) (Figure 4b).

In the second period (2001-2005), the maximum number of flash floods have been recorded in the summer (67%), followed by the spring (22%). In autumn, the flash floods occurred into a small proportion (11%). The winter features a lack of flash floods, for both periods.

By analyzing the percentages of the flash floods for each of the semesters, the first semester of the year from the period 1977-1981 registers 43%, while for the second registers 57%. For the second period 2001-2005, the flash floods registered 33% for the first semester and 67% for the second semester.

By analyzing the daily distribution of the flash floods, one can notice that during the periods 1977-1981, the flash floods are more frequent during the second part of the month. The most critical period during which had occurred even two flash floods per day has been at the end of the month of August between 24th and 29th. For the period 2001-2005, during the days of 5th, 6th and 17th even two flash floods per day did occur (Figure 5).

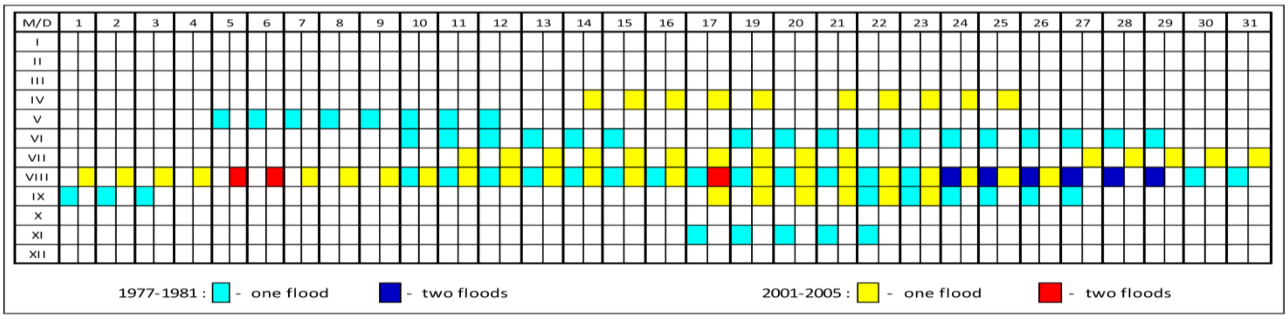

Figure 5. The flood events occurrence at Darmanesti hydrometric station (1977-1981 and 2001-2005)

One can notice that in the period 1977-1981, the number of days with two flash floods (six days) is double than in the period 2001-2005 (three days). The month of August has proven to be the one in which the floods occur almost every day (1-2 flash floods per day).

The flash floods occurred in the warm part of the year. The immediate period following the commissioning of the Poiana Uzului dam has been characterized by a large number of flash floods recorded during summer or autumn, while more recently the flash floods recorded during spring and summer. This may be due to late climatic changes which lead to a sudden and early increase of the temperatures, resulting in the overlapping of the torrential rain from the warm season with the snow melting.

The features of the flash floods. The main characteristic elements of the floods were determined based on the flash floods hydrographs, by selecting the two most significant annual flash floods. The main studied elements were: the initial base flow (Q_{bi}), the peak flow (Q_{max}), the flow at the end of the flood (Q_{bf}), the increase time (T_c), the decrease time (T_d), the total time (Tt), the increase volume (W_c) and the decrease volume (W_d), the total volume (W_t), the height of the drained water layer (h_v), the shape coefficient (γ). The Table 2 renders a more extensive vision over the flash floods elements and provides a more detailed perspective on the values of each flash flood.

Table 2. Statistical data of the floods from the periods 1977-1981 and 2001-2005

Year	Fl. nr.	Q_{max} (m^3/s)	W_c (mil.m^3)	W_d (mil.m^3)	W_t (mil.m^3)	h_v (mm)	γ	T_c (h)	T_d (h)	T_t (h)	Q_{bi} (m^3/s)	Q_{bf} (m^3/s)
1977	1	66.40	1.24	6.51	7.75	19	0.14	26.00	214.00	240.00	24.08/7:00	3.09/7:00
1978	1	129.00	0.26	1.92	2.18	5	0.04	8.42	121.58	130.00	22.09/7:00	27.09/17:00
	2	61.40	0.03	1.88	1.91	5	0.08	0.33	112.00	112.33	17.11/11:40	22.11/7:00
1979	1	37.80	1.62	8.24	9.86	24	0.34	80.67	169.33	250.00	19.06/7:00	29.06/17:00
	2	26.00	2.21	6.42	8.63	21	0.24	123.00	333.00	456.00	10.08/7:00	29.08/7:00
1980	1	43.10	0.58	0.07	0.65	2	0.04	31.5	84.50	116.00	10.06/7:00	15.06/7:00
1981	1	57.00	4.86	0.95	5.81	14	0.22	62.00	96.00	158.00	5.05/17:00	12.05/7:00
2001	1	64.90	0.31	5.51	5.81	14	0.29	16.00	80.00	96.00	21.04/18:00	25.04/18:00
2002	1	22.90	0.88	4.54	5.42	13	0.31	48.00	175.50	223.50	17.08/5:30	26.08/13:00
2003	1	6.20	0.31	0.45	0.76	2	0.46	48.00	108.50	156.50	17.09/5:30	23.09/18:00
2004	1	25.10	0.18	4.52	4.70	12	0.48	5.00	114.5	119.50	14.04/5:30	19.04/10:00
	2	23.00	0.13	2.16	2.30	6	0.67	11.50	40.00	51.50	27.07/5:30	6.08/9:00
2005	1	132.00	6.11	21.62	27.73	69	0.26	42.00	191.50	233.50	11.07/23:00	21.07/16:30
	2	32.80	0.75	6.13	6.88	17	0.23	85.00	216.00	301.00	5.08/5:00	17.08/18:00

For the period 2001-2005, the largest values of the maximum flows, of the volumes, of the height of the drained water layer and of the shape coefficient (γ) are higher for the period 1977 – 1981. For the period 2001-2005, the time durations present low values in comparison with 1977-1981. The amplitude has risen lately (Table 3).

Table 3. Data concerning the floods occurred between 1977-1981 and 2001-2005

	Period		Q_{max} (m^3/s)	W_c (mil.m^3)	W_d (mil.m^3)	W_t (mil.m^3)	h_v (mm)	γ	T_c (h)	T_d (h)	T_t (h)
Maximum	1977-1981	**Value**	**129**	**4.86**	**8.24**	**9.86**	**24**	**0.34**	**123**	**333**	**456**
		Year/ Flow number	1978/1	1981/1	1978/2	1979/1	1979/1	1979/1	1979/2	1979/2	1979/2
	2001-2005	**Value**	**132**	**6.11**	**21.62**	**27.73**	**69**	**0.67**	**85**	**216**	**301**
		Year/ Flow number	2005/1	2005/1	2005/1	2005/1	2005/1	2004/2	2005/2	2005/2	2005/2
Minimum	1977-1981	**Value**	**26**	**0.03**	**0.07**	**0.65**	**2**	**0.04**	**0.33**	**84.5**	**112.33**
		Year/ Flow number	1979/2	1978/2	1980/1	1980/1	1980/1	1980/1	1978/2	1980/1	1978/2
	2001-2005	**Value**	**6.2**	**0.13**	**0.45**	**0.76**	**2**	**0.23**	**5**	**40**	**51.5**
		Year/ Flow number	2003/1	2004/2	2003/1	2003/1	2003/1	2005/2	2004/1	2004/2	2004/2
Average	1977-1981	**Value**	**60.1**	**1.54**	**3.71**	**5.26**	**12.86**	**0.16**	**47.42**	**161.49**	**208.90**
	2001-2005	**Value**	**43.84**	**1.24**	**6.42**	**7.66**	**19.00**	**0.39**	**36.50**	**132.29**	**168.79**

The hydrograph of the flash flood is also called the hydrograph of the drain or of the flash flood wave. According to the hydrograph, the physiographic and climatic features governs the relationship between the rain and the drain from a certain hydrographic basin.

The flash flood shape coefficient (γ) has been obtained as the ratio between the total volume (Wt) and the circumscribed rectangle (Q_{max} * T_t).

$$\gamma = W_t / (Q_{max} \cdot T_t) \quad (1)$$

When the shape coefficient γ=0.5, the flash floods hydrograph has a triangular shape, but when γ>0.5, then the shape is a trapezoidal one. When γ<0.5, the hydrograph takes the form of two parabolic arches (Minea and Romanescu, 2007).

In the Uz hydrographic basin, for the majority of the flash floods, the γ did not exceeded the value of 0.5. The exception being the flash flood from 2004 (γ=0.67), whose hydrograph presents a trapezoidal shape (Figure 6).

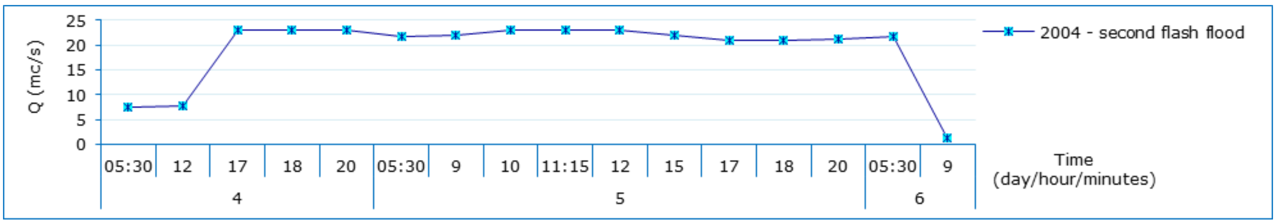

Figure 6. The hydrograph of the secondary flash flood from 2004

Except for the second flash flood in 2004, all the other flash floods have a multi-wave character and occur in a very short time interval, causing major damages. This is due to heavy precipitations occurring at very short time interval which lately and that caused rapid quick drains on the deforested slopes. The multiwave flash flood also represent the effect of the tributaries' spill into the river Uz and of the rains fallen at different intervals during the flash flood itself.

The hydrograph of the flash flood from July 2005 presents an unusual form. The flash flood from 2005 has begun with a large volume of water that preceded the maximum flow. The round shape of the peak, but also the other elements that define the flash flood suggest the pluvial nature of its occurrence. During the flash flood the maximum flow exceeded 27 times the value of the monthly multiannual average flow (4.9 m^3/s). After reaching the maximum flow, in the downward phase, the flash flood becomes again the previous large volume of water for a longer period of time due to precipitations fallen during the deluge.

By comparing the two hydrographs of the most important flash floods from the two studied periods (1977-1981; 2001-2005), one could observe its evolution in time. The hydrographs of the two flash floods can be distinguished by their shape, the hydrograph of the 2005 flash flood, presenting a rather complex shape.

The comparative study of the most important flash floods from the two studied periods confirm the idea that the changes occurred in the thermal, pluviometric and hydrological conditions have a devastating impact over the future hydroclimatic evolution. The flash floods followed by the floods, in the Uz basin, are dynamic and dangerous risky phenomena. Their character is unpredictable and presents a great distribution in time, being real threats to the natural environment and from local population.

The *analysis of the threshold's level*. Once the Darmanesti hydrometric station has been commissioned, it has been established different defense stages against the floods: the attention state (A.S.=150 cm), the flood stage (F.S.=200 cm) and the danger stage (D.S.=300 cm). Depending on how the levels oscillate in relation to these thresholds, different prevention, warning measure are implemented, not to mention the measure for evacuating the population.

The figure 7 highlights the fact that all flash floods exceeded the attention and the flood stage for a while. The flash floods from the years 1977, 1978, 1981, 2001, 2002, 2004 and 2005 have reached and have exceed all the danger stages.

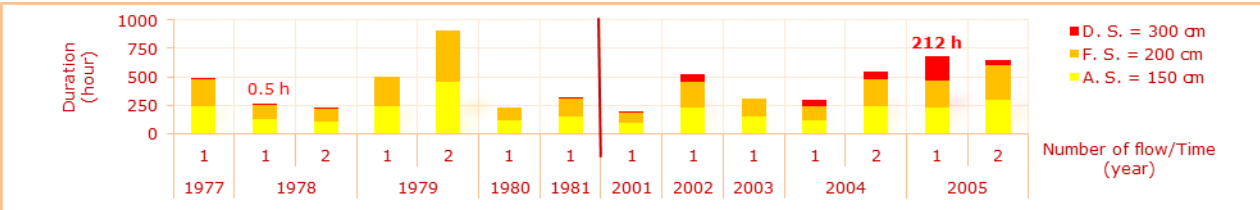

Figure 7. The duration time of the threshold defense levels overpasses at Darmanesti station

In the Table 4, there are highlighted the moments of the flash floods when the levels exceeded the defense stages. The attention stage (A.S.=150 cm) and the flood stage (F.S.=200 cm), was exceeded each time by the flash flood. The maximum duration during which the flood stage was exceeded has been during the period 1977-1981, more precisely in 1979 for about 456 hours, while the one from the period 2001-2005 was about 301 hours in 2005. The minimal duration recorded in the first period has been about 112.33 hours (1978). The second recorded for the second period has been about 96 hours (2001). The highest time durations during which the danger stage has been exceeded (D.S. = 300 cm) was about 6 hours (1981) – for the first period, while for the second period it was about 212 hours in 2005. The lowest time durations during which the danger stage has been exceeded was about 0.28 hours in 1978 for the first period, while for the second period it was about 10 hours.

Table 4. Beginning and ending time moments of flood events against the threshold defence levels at Darmanesti hydrometric station

Year	Fl. nr.	A.S. = 150 cm			F.S. = 200 cm			D.S. = 300 cm		
		Qbi	Qbf	Hr.	Qbi	Qbf	Hr.	Qbi	Qbf	Hr.
1977	1	24.08/7:00	3.09/7:00	240	24.08/7:00	3.09/7:00	240	25.08/8:00	25.08/11:00	3
1978	1	22.09/7:00	27.09/17:00	130	22.09/7:00	27.09/17:00	130	22.09/15:15	22.09/15:45	0.5
	2	17.11/11:40	22.11/7:00	112.33	17.11/11:47	22.11/7:00	112.21	17.11/12:00 17.11/13:13	17.11/12:10 17.11/13:20	0.28
1979	1	19.06/7:00	29.06/17:00	250	19.06/7:00	29.06/17:00	250	-	-	-
	2	10.08/7:00	29.08/7:00	456	10.08/7:00	29.08/7:00	456	-	-	-
1980	1	10.06/7:00	15.06/7:00	116	10.06/7:00	15.06/7:00	116	-	-	-
1981	1	5.05/17:00	12.05/7:00	158	5.05/17:00	12.05/7:00	158	8.05/3:30	8.05/9:30	6
2001	1	21.04/18:00	25.04/18:00	96	21.04/18:00	25.04/18:00	96	22.04/10:00	22.04/20:00	10
2002	1	17.08/5:30	26.08/13:00	231	17.08/5:30	26.08/13:00	231	17.08/18:00	20.08/13:00	67
2003	1	17.09/5:30	23.09/18:00	156.5	17.09/5:30	23.09/18:00	156.5	-	-	-
2004	1	14.04/5:30	19.04/10:00	124.5	14.04/5:30	19.04/10:00	124.5	14.04/8:15	16.04/18:00	57.75
	2	27.07/5:30	6.08/9:00	243.5	27.07/5:30	6.08/9:00	243.5	4.08/17:00	6.08/5:30	59.5
2005	1	11.07/23:00	21.07/16:30	233.5	11.07/23:00	21.07/16:30	233.5	12.07/9:00	21.07/5:00	212
	2	5.08/5:00	17.08/18:00	301	5.08/5:00	17.08/18:00	301	15.08/5:00	16.08/5:00	48

In the year 2005, during the historical flash flood, there was recorded 520 cm, exceeding the attention stage (A.S.) with 370 cm, the flood stage (F.S.) with 320 cm and the danger stage (D.S.) with 220 cm (Figure 8).

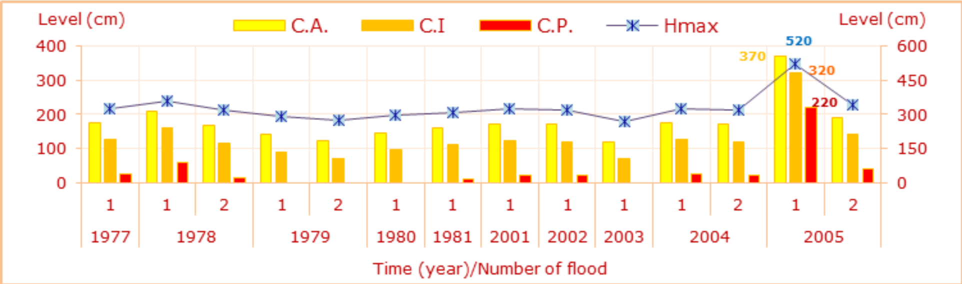

Figure 8. The levels registered during the exceptional maximum flows in the Uz hydrographic basin

In comparison with 1977-1981, the period closer to the current one, 2001-2005, during the flash floods, the water level exceeded the danger stage for a greater period of time. The area corresponding to Darmanesti station and the population situated in the surroundings are permanently threatened by the floods. Besides the climatic factor having a huge contribution, there is also the physical-geographic factor. This one includes the downstream positioning in relation to the lake, the relatively horizontal surface bordered by steep enough hills, which gives the valley the appearance of the letter “U”. The populated area occupies the extended riverbed closer to the minor riverbed of the river Uz. In this area, the river is extremely meandered These issues explain why the water stays for longer periods of time on the flooded surfaces.

The flash flood occurred on the river Uz in July 2005, when were recorded the highest historical maximum flows at Darmanesti station, but also at Cremenea station situated upstream, presented serious issues to the local inhabitants (Figure 9).

Figure 9. Flash flood from July 2005 – Uz river basin

The flash floods from July 2005 were triggered as a result of torrential rains fallen in large quantities in a relatively short period of time for several consecutive days. The large quantities of water favored an exceptional increase of the water level from the Poiana Uzului reservoir situated upstream of the Darmanesti station. The situation has become alarming when the limit of the spillway crest was reached (511.44 mdM) and maintained for a couple of hours. In this situation, the maximum discharged flow was about 133 m^3/s, out of which 100 m^3/s were evacuated through spill. Exceeding the capable flow of the Uzului riverbed downstream of the lake (100-120 m^3/s) would have aggravated the situation. Then there was a real danger for the dam to break, the disaster would have endangered the downstream zones. The disaster was avoided with an adequate water management.

4 CONCLUSION

The current study highlights the fact that, in the Uz hydrographic basin, the flash floods are triggered following the fall of large quantities of water from the warm season precipitation, in a relatively short period of time, being favoured by the physical-geographic factor. The cold season is characterized by a lack of flash floods due to the solid state precipitations. During spring, sometimes the water from the rains overlaps with the water from the snow melting process, causing the large volumes of water and also the flash floods.

Knowing the main elements of the flash floods registered at the Darmanesti hydrometric station for the studied periods (1977–1981; 2001-2005), present a particular technical-scientific and practical importance. One can notice the destructive character of the flash floods in the studied area, all of them exceeding the attention and the flood stage; some of them even the danger stage. This proves the necessity of prevention and protection measures of the population and of the vulnerable elements from the area prone to the danger of flooding.

The study proves the utility by its contribution to the prevention and the halting of the negative effects of such phenomena. The arguments support the reason for performing the study on the flash floods for the periods 1977-1981 and 2001-2005, in the area corresponding to Darmanesti hydrometric station situated in the Uz hydrographic basin.

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