HYDROLOGIC HAZARDS GENERATING EMERGENCY SITUATIONS IN THE MIDDLE MOUNTAINOUS SECTOR OF BISTRIŢA VALLEY

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Abstract: Beginning with the end of the 20th century, with the rise of the mean air temperature by 0.6–0.7°C, a significant increase in the frequency of extreme natural phenomena (mainly thermal and rainfall-related ones, generators of emergency situations) was triggered. The present paper analyzes the most important hydrological risks manifested in the mountainous middle sector of Bistriţa valley, with negative consequences (large material damage and human life losses). The middle mountainous sector of Bistriţa valley is a narrow couloir on whose bottom the river meanders between the abrupt slopes of two mountain areas with maximum altitudes of 1,859 m (Budacu Peak in Bistriţa Mts.) and 1,529 m (Bivolul Peak in Stânişoarei Mts.). Bistriţa is the river with the longest mountainous course in Romania, its length in the eastern Carpathians being of 216 km, over 2/3 of its total. In this sector, but mainly between Vatra Dornei and Poiana Largului, the ice jam phenomena are the most frequent and intense on all Romanian rivers. In the analysis of the main hydrological hazards (floods due to torrential rainfall and winter ice jams), whose frequency has increased significantly during the last three decades, data were used from Piatra Neamţ, Ceahlău - Sat and Ceahlău Toaca meteorological stations as well as from other hydrometric stations and rainfall gauges. There were also used references on the climatic features of the middle basin of Bistriţa or larger areas including it, the factors that may influence the occurrence and evolution of hydrological and climate phenomena with risk potential, or those needed to define some notions (hazard, risk and emergency situation).

Keywords: *hydrologic hazards, rainfall, floods, ice jams, losses*

1. Introduction

Global climate warming, a more and more obvious phenomenon in the last decades, has determined an increase in the vulnerability of many areas in respect of climate and hydrological hazards, which induce significant direct and indirect consequences on global environmental changes (Bogdan and Marinică, 2007).

Analyzing some of the concepts and notions of *hazard*, *natural risk and vulnerability* presented in different papers (Smith, 1992; Bălteanu, 1992; Bălteanu and Rădiţa, 2000; Moldovan, 2003; Goţiu and Surdeanu, 2007; Stângă, 2007; Romaescu, 2009 etc.) it results that the **natural hazard** is the likely interaction between man-made, economic, social, political, cultural entities and a dangerous natural phenomenon, whose attributes (localization, time, intensity, frequency) cannot be determined exactly. **An emergency situation** represents a non-military exceptional phenomenon which by dimension and intensity threatens human life and health, the environment, important material and cultural values; in this case in order to re-establish the normality status there are needed urgent measures and actions, resources and a unitary management of the forces and means involved.

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2. Main climatic elements influencing hydrological risks

The lower sector of the mountainous Bistriţa valley studied here is limited by Suceava County (downstream of Broşteni) and Piatra Neamţ, corresponding to the central-eastern part of the central group of the Eastern Carpathians.

The characteristics of the climatic elements from the analyzed valley sector are representative for the „*temperate climate of medium and low mountains*" in the Eastern Carpathians, moderately cool at lower altitudes and cool at medium ones, with „elements of moderately warm climate in the area of Izvoru Muntelui reservoir and warm mountainous climate downstream of Pângăraţi - Vaduri lakes" (Mihăilescu, 2001). In the analysis of some of the main climate characteristics we took into account those meteorological phenomena (air temperature, winds, rainfall) which present a high potential for the occurrence and manifestation of hydrological hazards, mainly in what regards their maximum and minimum values and durations.

Air temperature. The analysis of mean annual and seasonal values in altitude determined:

- a *warm climate* at altitudes lower than 400 m, with mean annual temperatures of 8-9°C, - 4°C in January and 22-24°C in July;

- a *moderately warm climate* between altitudes of 400-900 m, with a mean annual temperature of 6-8°C, respectively – 4°C in January (with frequent thermal inversions) and 16-19°C in July;

- a *moderately cool climate* between 900-1,300 m altitude, with a mean annual value of 4-6°C, respectively - 4 - -5.5°C in January and 13-16°C in July;

- a *cool climate* between 1,300-1,700 m, with annual means of 2-4°C, respectively - 5.5 - - 7°C in January and 11-13°C in July;

- a *very cool climate* at altitudes over 1,700 m, with a mean annual air temperature of 0-2°C, - 7 - - 9.5°C in January and 9-11°C in July.

Important variations are also registered in the monthly or daily regime of mean air temperatures.

The highest variations of air temperature were recorded, normally, for the absolute minimum and maximum values. The maximum thermal values were recorded in August, being of 39.0°C at Piatra Neamţ (in 1957), 36.5°C at Ceahlău - Sat (in 1946) and of 25°C at Ceahlău - Toaca (in 1988 and 1998). The absolute minimum values were recorded in January and February 1963, when some arctic air invasions determined values of – 27.4°C at Piatra Neamţ, -25.4°C at Ceahlău - Munte and – 29.2°C at Ceahlău - Sat. The cold period of the year is favourable for thermal inversions, with significant effects on the freeze-thaw process. The air thermal and water freeze-thaw regime are highly different in the microclimatic areas of the reservoirs, mainly of Izvoru Muntelui (mean annual water volume of 1.25 million cubic meters and a surface of about 3,200 ha).

Winds. If at higher altitudes wind direction is subordinated to the general atmospheric circulation, as it can be seen at Ceahlău – Toaca station (the dominant winds being the western ones with 50% during summer and 55% in November), at lower altitudes the main circulation is directed along Bistriţa valley, from NW during the night and in the mornings and from SE during the day. This relative periodicity is changed during the year moments when important weather changes occur. Strong winds, even if their occurrence frequency is reduced, can have a climatic risk potential and inflict material losses.

Rainfalls, an important climatic risk factor. The mean annual rainfall quantities were averaged for the analyzed valley sector (Mihăilescu, 2001) at 605 mm at Piatra Neamţ, 664 mm at Pângăraţi, 708 mm at Tarcău and 675 mm at Ceahlău-Sat, but with important annual and seasonal variations. The research contract between Neamţ County Council and SC TOPOPREST SRL certifies the aforementioned, as it can be seen from the map of the distribution of mean annual rainfall quantities on the territory of Neamţ County (Figure 1).

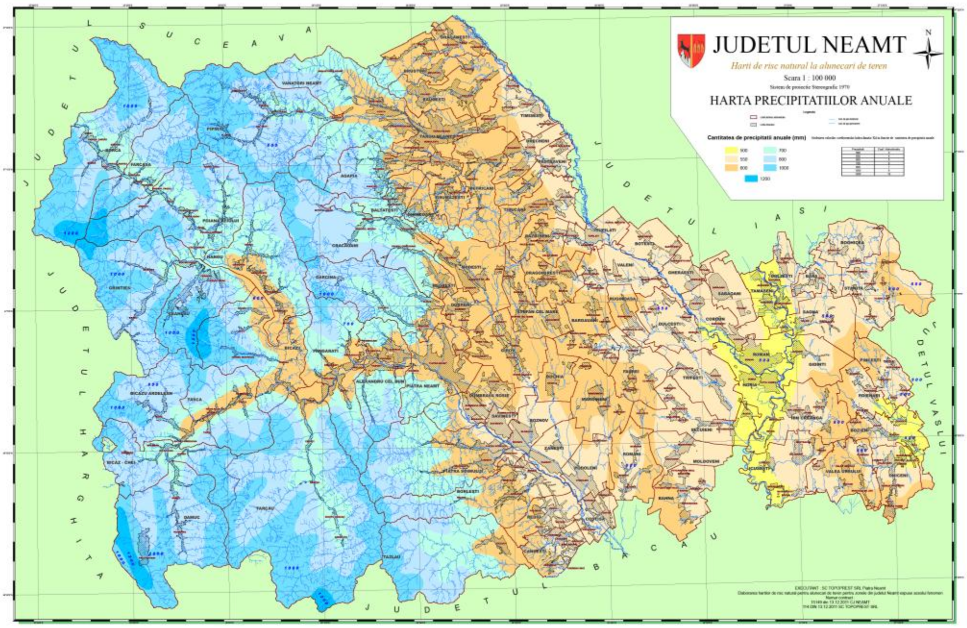

Figure 1. Mean annual rainfall in Neamţ County (S. C. TOPOPREST S.A., 2012)

Memorable years were 1912, when at Piatra Neamţ (the oldest rainfall measurements on Bistriţa valley) were recorded 1,165 mm and the droughty year of 1945, with 448 mm at Piatra Neamţ and 489 mm at Ceahlău - Sat. During the year, the largest rainfall quantities are recorded in the warm season during May-June (Piatra Neamţ - 103 mm, Pângăraţi - 121 mm, Tarcău 114 mm, Ceahlău - Sat - 124 mm, Rugineşti - 124 mm, Frumosu - 275,3 mm in 2013, Ceahlău Schit - 307 mm in 2010 etc.) and July (188.5 mm at Sabasa in 2010). The lowest quantities are recorded in the cold season, respectively December and January (Piatra Neamţ - 20 mm, Pângăraţi - 21 mm, Tarcău - 23 mm, Ceahlău - Sat - 23 mm). The absolute monthly maximum value measured at Piatra Neamţ was of 413 mm in September 1912, rainfall lacking completely in March 1934 and December 1910. At Pângăraţi the maximum monthly rainfall was of 308 mm in May 1971, while at Ceahlău - Sat they registered 1 mm rainfall in April 1948.

The values of the maximum rainfall quantities in 24 hours were of 91 mm at Pângăraţi in July 1969; 87.6 mm at Piatra Neamţ in June 1989; 81.9 mm at Ceahlău - Sat in June 1949 and 84.7 mm in June 2010 at Ceahlău - Schit.

3. Analysis of the main hydrological hazards generating emergency situations

During **2005 - 2010**, the professional, voluntary and private services for emergency situations in Neamţ County took part in **4839** emergency situations (not counting the SMURD[2] ones). The dangerous hydrological and meteorological phenomena occupied the 2nd

[2] Serviciul Mobil de Urgenţă, Reanimare şi Descarcerare (Mobile Service for Emergency, Reanimation and Extrications)

place (26.18%), the rainfall quantities in 2005, 2008 and 2010 generating floods and important material losses (Table 1 and Figure 2).

Table 1. Situation of emergency situations in Neamt County during 2005-2010

Emergency situations (except SMURD interventions)	2005	2006	2007	2008	2009	2010	Total	Total %
Fires	305	368	441	426	488	410	**2,438**	50.38
Extrications	1	12	10	26	1	1	**51**	1.05
Personal assistance	24	40	62	91	64	62	**343**	7.09
Environmental protection	2	1	4	12	13	6	**38**	0.79
Other emergency situations (floods, meteorological phenomena, ammunition destruction)	142	94	171	359	248	253	**1,267**	26.18
Uncontrolled fires	0	0	23	24	119	52	**218**	4.51
Animal rescue	9	11	17	26	22	25	**110**	2.27
Other interventions	4	7	6	42	101	185	**345**	7.13
Area insurance / surveillance	0	0	0	0	0	29	**29**	0.60
Total	**487**	**533**	**734**	**1,006**	**1,056**	**1,023**	**4,839**	100 %

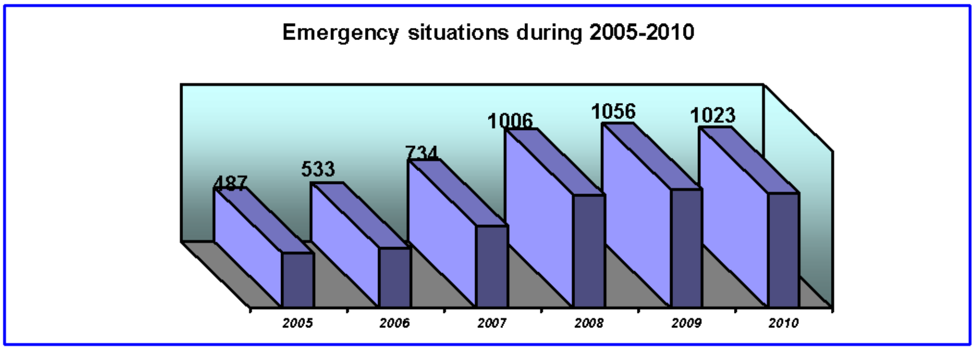

Figure 2 Emergency situations occurred during 2005 – 2010 in Neamţ County

(Inspectorate for Emergency Situations Neamţ)

Floods represent the most frequent natural hazard. In the studied area, they occur frequently on Bistriţa's tributaries, such as Sabasa, Schit, Hangu. The cause is represented by abundant rainfall caused by the accentuated atmospheric instability determined by the succession of frequent atmospheric fronts.

The frequency of flood occurrence and their intensity have increased, mainly due to climatic changes and to the reduction in the river transportation capacity due to buildings constructed in the floodplain. This fact can be seen in the graphic showing the variation of floods during 1974 - 2013 in Hangu township (Figure 3).

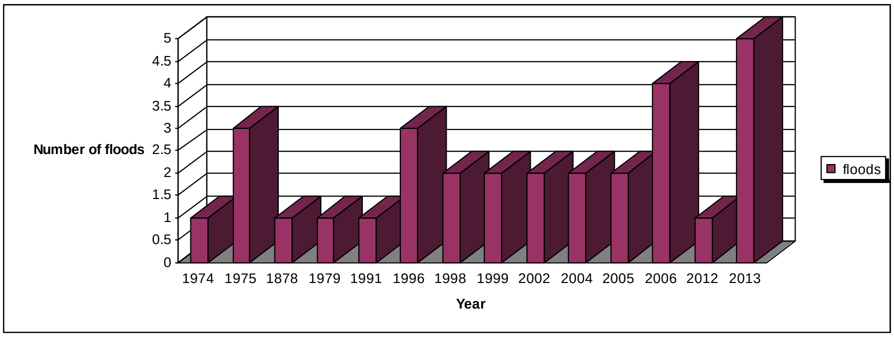

Figure 3. Number of floods during 1974 – 2013 in Hangu Township (Defence plan against floods, ice dams and accidental pollution on water courses from Hangu Township, 2013)

Although the number of floods increased during the analyzed period, after 2005 it was accompanied by a reduction in the losses produced by these dangerous hydrological phenomena. This shows that the structural and non-structural measures taken by the local administrative authorities and institutions responsible for the management of emergency situations were effective (Figure 4).

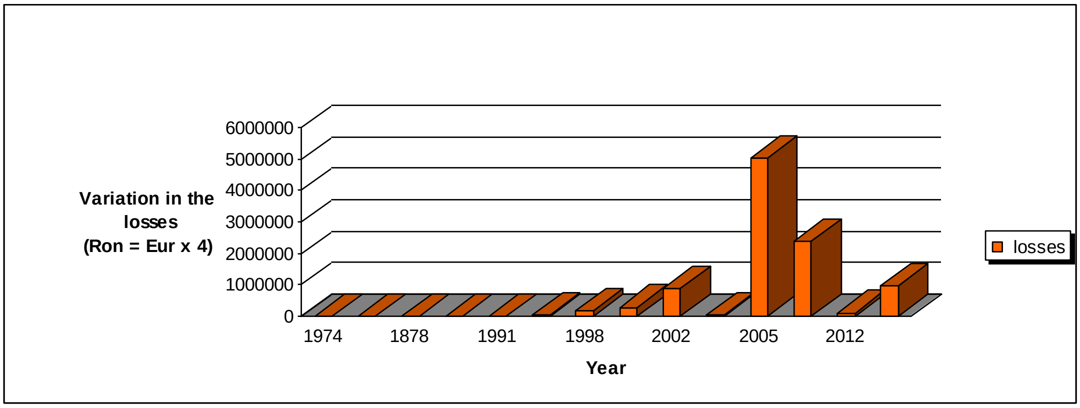

Figure 4. The variation in the losses generated by floods during 1991 – 2013 in Hangu township (no data are available for the 1974 - 1991 period)

Flood intensity was also amplified due to human influence on environmental elements: deforestation, not managing torrents or drains, existence of badly projected and constructed works, buildings constructed in floodplains. Abundant rainfall led to important water level increases in some isolated river sectors, the most affected areas being those from the upper basins of Bistriţa, Tarcău, Bicaz, Bistricioara and Hangu.

The year 2005 represented one of the key moments in what regards the flood intensity in the county, as a consequence of the large volume of rainfall. This was the year when defence levels were exceeded at 14 of the 30 hydrometric stations that record daily the evolution of water levels since 1970 up to present. During July-August 2005, floods also occurred on a series of smaller rivers lacking hydrometric stations and on a series of torrential organisms which recorded important water quantities coming from slopes. These induced important material losses, as it can be seen in figure 4 and table 2.

Table 2. Flood frequency and value of material losses in July-August 2005 (Synthesis reports regarding flood defense - SGA Neamţ).

Locality	**Flood period**	**Losses value (thousands Ron)**	**Hydro-meteorological data**
Ceahlău	11-13.07	5.850	Significant large rainfall quantities accompanied by thunders and lightning. At Ceahlău, Schit brook exceeded the attention level (AL) with 10 cm (H= 10 cm, Q= 18.30 cm/s), with a maximum on 12.07.2005, at 20.00 when the AL was exceeded by 25 cm (H=25 cm, Q= 29.5 cc/s).
Borca		160	
Poiana Teiului		1.604	
Hangu		1.124	
Borca		75	During 03-05.08.2005 they recorded 15.5 l/sqm at Frumosu, Farcaşa in one hour and 40 minutes, with dense hail (mean diameter 1cm) and 18.4 l/sqm in 48 hours; 22.2 l/sqm at Sabasa station, Borca in two and a half hours,

Locality	Flood period	Losses value (thousands Ron)	Hydro-meteorological data
Farcaşa	03-08.08	4.200	with dense hail (mean diameter 2 cm) and 26.8 l/sqm in 48 hours. During 05-07.08.07.2005 were recorded 7.7 l/sqm at Frumosu station and 12.2 l/sqm in 48 ore; 5.2 l/sqm at Bistricioara station, Ceahlău and 9 l/sqm in 48 hours.
Hangu	17-21.08	3.923	On extended areas there were recorded significant rainfalls with lightning and wind intensification, the measured quantities being: During 16.08.2005, 07.00 AM - 18.08.2005, 07.00 Am: At Sabasa station on Sabasa brook, Borca – 11.3 l/sqm in 48 hours; at Poiana Largului station on Bolătău brook – 47.2 l/sqm in 24 ore / 49.7 l/sqm in 48 ore; at Frumosu station on Bistriţa – 34.8 l/sqm in 24 hours / 37.9 l/sqm in 48 hours. During 18.08.2005, 07.00 AM - 20.08.2005, 07.00 Am at Sabasa station on Sabasa – 8.5 l/sqm in 24 hours / 64.8 l/sqm in 48 hours; at Poiana Largului on Bolătău – 2.9 l/sqm in 24 hours / 78.9 l/sqm in 48 hours; at Ceahlău on Schitu brook – 8.1 l/sqm in 24 hours / 73.2 l/sqm in 48 hours. The levels on all river courses rose.

The years 2008 and 2010 were also referential for the floods occurring in Neamţ County, due to the torrential rainfall recorded during June and July. This situation can be seen in the statistical analysis of the emergency situations occurred on the territory of Neamţ County in 2010, dangerous hydrological and meteorological phenomena occupying the 2nd place (7.5%) after fires (Fig. 5).

During these years' floods, rainfalls fell almost daily, in their regime significant periods that produced floods and torrential discharge being identified. In this context, all rainfall quantities fallen were important for maintaining an accentuated soil humidity, contributing to reduced infiltrations and an effective participation to discharge formation.

In 2013 also, torrential rainfall during June (06-08.06 and 22-30.06, as it can be seen from the national radar map from 24.06.2013) generated important slope, brooks and rivers discharge as well as level increases on some rivers from the basins of Siret, Moldova and Bistriţa. Floods also occurred in the middle mountainous basin of Bistriţa (Figure 6 a and b), where cumulated rainfall in June determined the exceeding of the mean monthly value with 100 up to 200% (275.3 mm at Frumosu, 343.8 mm at Sabasa, 266.1 mm at P. Largului).

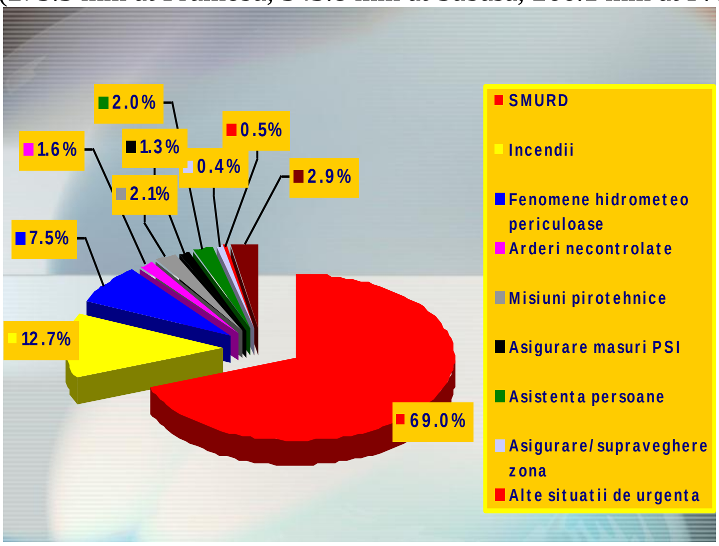

Figure 5 Percentage of emergency situations occurred in 2010
(Inspectorate for Emergency Situations Neamţ)

Figure 6a National radar map on 24.06.2013


Figure 6b Damages induced by the hydrological and meteorological phenomena on 06 – 08 and 22 – 23 June 2013 in the townships of Farcaşa, Hangu and Borca

Floods in middle Bistriţa valley on 06 – 08 June 2013

On 6th June, 2013, I.S.U. Neamţ received a meteorological warning, yellow code for the 06 th -07th June between 18^{00}-18^{00} and a yellow code hydrological warning for 6-8th June between 20 and 10 o'clock. The torrential rainfall on 6-7th of June cumulated 83.4 l/sqm at Sabasa hydrometric station on Sabasa river; 75.8 l/sqm at Ceahlău on Schit brook, 28.2 l/sqm at Frumosu; 21.2 at P. Largului on Bolătău brook; 21.2 at Sabasa and generated important discharge from slopes, torrential brooks, as well as level increases on some rivers in Bistriţa basin. The mentioned hydrological and meteorological phenomena affected 5 localities, the losses being presented in the table below.

Table 3. Losses due to the hydrological and climatic phenomena occurred on June 6-8, 2013

Nr.	Basin, town, township	Water courses	Affected objectives	Causes	Losses value (RON)
1. Hangu township					
1.	Hangu village	Hangu, Audia, Sasu and Mitrofan brooks	- 2 bridges; - 0.6 km of roads; - 25 m of mattress gabions; - 4 bridges.	- torrential rainfall, torrential discharge from slopes, increases in water levels, discharge and speed on the mentioned brooks.	125,700
2.	Buhalniţa village	Buhalniţa brook	50 m of concrete channel on Buhalniţa brook destroyed	increases in water levels, discharge and speed on Buhalniţa brook	21,400
2. Farcaşa township					
3.	Farcaşa village	Farcaşa brook	- 1 wooden bridge destroyed; -120 m of river bank defence walls destroyed; -0.3 km of road affected; -3 households affected and 0.13 km destroyed; - 2 bridges affected.	increases in water levels, discharge and speed on Farcaşa brook	8,020
4.	Stejaru village	Stejaru brook	- 1 km of road affected; - 3 bridges affected;	increases in water levels, discharge and speed on Stejaru brook	3,240
5.	Buşmei village	Buşmei brook	- 3 km of roads affected; - 0.012 m of gabions on the right bank destroyed; - 0.34 m of Buşmei channel affected.	increases in water levels, discharge and speed on Buşmei brook	29,800

Ice jams, complex hydrological and meteorological phenomena specific to the cold season and determined by river water freeze-thaw processes, are common for temperate area rivers and represent an important risk factor in flood occurrence. On Bistriţa and some of its tributaries, the phenomenon is the most frequent and intense in the country.

Ice jams (*zator*, Russian; *embâcle*, French; *eisbarre*, German; *zăpor*, Romanian) are the names given to ice dams that form on rivers during the winter periods. The consequence of ice jams formation is the blockage of river waters that leads to a decrease in the water level downstream of the jam and a sometimes sudden increase upstream, where important floods may occur. The destructive effects of ice jams determined Ashton (1986) to consider them the largest hazard of winter phenomena.

According to the moment of occurrence, there are freeze and thaw ice jams. Freeze ice jams occur during the period of river water freezing at the beginning of the winter phenomenon and are caused by the accumulation of frazil ice under the ice bridge.

Thaw ice jams are caused by the accumulation of ice floes on the river in certain sectors, resulted from the breaking of ice jams due to increases in air temperature. In Bistriţa basin (upstream of Izvoru Muntelui – Bicaz reservoir) the phenomenon has a larger frequency in the upper course (Dornelor Depression up to Zugreni) and a lower one in Zugreni – Crucea sector (Ştefãnache, 2003, 2007; Surdeanu et al, 2005; Rădoane M. et al 2009; Giurma and Ştefãnache D., 2010). In the Crucea – Borca sector these types of ice jams have a lower frequency, while downstream of Borca they were not signaled.

After the emplacement of Izvoru Muntelui – Bicaz reservoir, downstream of Borca there has occurred another type of ice jam, which blocks the floodplain on a 27 -28 km length, for 14 – 35 days, and which has an annual frequency and sometimes occurs 2-3 times per year (Fig. 7).

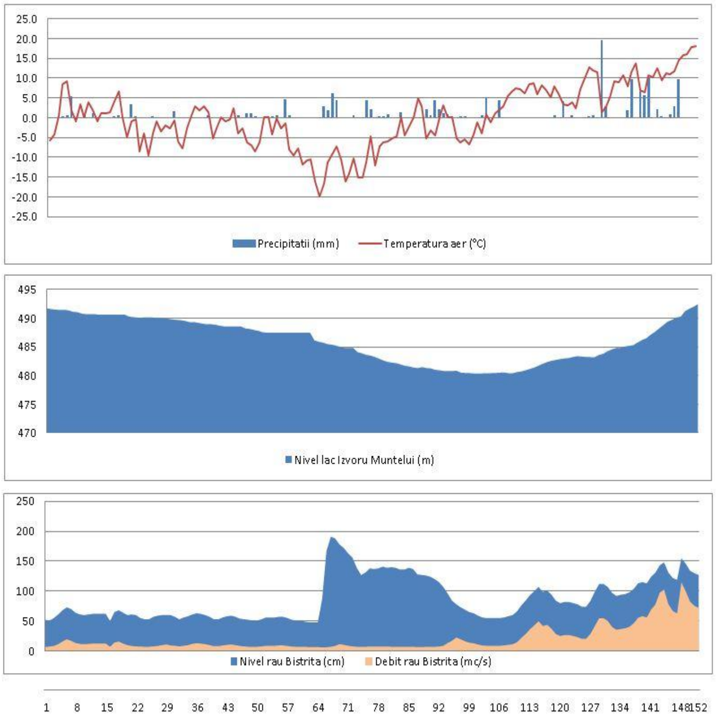

Fig. 7 Variation of the hydrological and meteorological factors that influenced the occurrence of ice dams at Frumosu station on Bistriţa, December 2011 – April 2012

This type of ice jam was first signalled by Ciaglic et. al (1975). The authors mention that the phenomenon has two phases: the first – a submerged phase when the ice floe brought by the river enters under the ice bridge on a certain distance. The blocking of the river section is done by the deposition of the ice floe on the bottom of the old floodplain and not by "sticking" to the lower base of the ice bridge (as it is usual on rivers), from where it extends slowly in the floodplain, sometimes filling it and overflowing (Figure 8).

Fig. 8 Ice jams on Bistriţa in 2009-2010

The authors consider the phenomenon to be human-influenced, because the flows of ice floes and packs have occurred in the area long ago before the creation of the reservoir. At the same time, the phenomenon is also considered atypical, because the ice floes agglomerations occur in the absence of an ice bridge (Rădoane et al, 2009).

To avoid losses, Ştefănache (2007) and Giurma and Ştefănache (2010) propose as solution the careful monitoring of the phenomenon. Ciaglic (2008, 2009) considers that, in order to substantially diminish the effects of ice jams, there is a need to act against the causes, respectively the ice floes that manifest almost continuously during the winter along the whole river sector between the confluence with Crucea and Bistriţa's entrance into the reservoir. He proposes two solutions:

1. diminishing the formation of ice needles and as a consequence of bottom ice that generated the ice floes;
2. at the beginning of winter, when the first winter phenomena occur on the river, and on the reservoir ice bridges of up to 15 cm occupy a small surface at the bottom of the lake, it should be maintained a free water channel, whose side should be wider than the river's underwater floodplain and which should follow the old river course. Thus, the ice floes would flow towards the reservoir area lacking ice bridge where it would dissipate and melt into the mass of water due to temperatures of 4 - 5 ^{o}C.

The idea of diminishing ice floes occurred during the research conducted in the extremely cold winter of 1963 – 1964 on Bistricioara, right side tributary of Bistriţa, close to the reservoir entrance.

Although the climatic, geological and morphological conditions were identical, the river basin being smaller, in its upper part, upstream of the confluence with Azod brook, the ice bridge with a thicknesses of 35 - 40 cm covered, with very small exceptions, the entire river surface, while downstream of the ice bridge suddenly it disappeared even if air temperature was the same. The conducted measurements led to the conclusion that the phenomenon is caused by the nature of the hydraulic relationships established between the river and the underground waters (Ciaglic, 1965; Ciaglic and Vornicu, 1973). This phenomenon was also observed during our field research in March 2012, when water temperature measurements were done in different areas (Figure 9).

Figure 9 Ice bridges on Bistricioara downstream Azod brook and on Azod brook at the confluence with Bistricioara, 2012

By re-conducting research after the damages inflicted by ice jams in 2003, the conclusion was that, besides the hydraulic exchange relations, the phenomenon also involves the latent heat liberated during the disintegration reactions of the radioactive elements from the underground, the areas where ice jams don't occur or are weakly manifested being those where uranium deposits exist (the exploitation from Lesu Ursului on Bistriţa, Bradu and Putna Întunecoasă on Bistricioara).

Taking into account the fact that the effect of the attenuation in the intensity of ice formations on Bistricioara is very strong (up to disappearance) due to the high water losses through infiltration (> 40 %) in the Capul Corbului area and that then it reappears in the left bank upstream of the confluence with Azod brook at Sângeroasa – Tulgheş, we might conclude that the same effect might be obtained on Bistriţa.

In this respect, we propose that in the many points that Bistriţa has water losses (areas identified together with Ciaglic in the field in the winters of 2011–2012 and 2012-2013) small transversal submerged rapids, with heights of 40–50 cm, should be constructed. Thus, there would occur a level increase upstream, increasing the discharge lost through infiltration, which on Bistriţa are smaller than on Bistricioara. The effect would be a substantial increase in the temperature of waters downstream, where the underground waters would come back to the river, diminishing the occurrence of ice needles, bottom river ice and ice floes.

The most important floods occurred due to ice jams and other favourable factors (the existence of bridges that reduce the dimensions of the floodplain, unfinished waterworks, irrational extension into the floodplain of households), with human casualties and important material losses, occurred on December 24th 1995 and January 1st 2003. The comparative data of the two floods are presented in table 4.

Table 4. The characteristics of the ice dams on 24.12.1995 and 01.01.2003

Flood date	River length with ice jams (Km)	Ice thickness (m)	Maximum rainfall in the basin (l/sqm)	Human casualties	Dead animals	Losses (thousands RON)
24.12.1995	21	5-7	38,1	-	-	612
01.01.2003	21	5-7	13,4	3	845	1.550

Evolution and effects of the dangerous hydrological and climate phenomena on December 24th 1995

Starting with November 23rd 1995, ice bridges were formed on Bistriţa upstream of its entrance into Izvoru Muntelui reservoir on a length of 15 km, due to decreased temperatures of up to -13°C. The level fluctuations of Bistriţa due to temperature oscillations from day to night and from a period to another (from -13°C to +12°C) led to the formation of ice dams. Up to December 15th, the ice dams from the sector between the entrance into Izvoru Muntelui reservoir and Săvineşti did not arise major problems, only local blockings being registered. Beginning with December 15th the phenomenon amplified, culminating with high levels of the ice jams during December 19th-22nd (248 cm, with 2 cm under the attention level).

The high temperatures in the period after (December 22-25 - max.+14°C) combined with rainfall in the upper basin (23 l/sqm in 24 hours at Dorna Candreni, Suceava County) determined a level increase on Bistriţa, which led itself to the mobilization of ice formations from the floodplain and the banks, agglomerating them over those already created around the access bridge towards Ruseni village and the Zahorna bridge from Poiana Teiului, as well as in the meanders downstream. The lack of possibilities to reach Izvorul Muntelui reservoir, due to the large blockage led to an increase in the water level upstream (220 cm at Frumosu, with over 20 cm above the attention level on December 24th at 16.30), respectively a flood which engaged ice blocks over the river banks. This affected the villages of Poiana Teiului, Poiana Răchiţii, Topoliceni, the social and technologic platforms of the hydro-power unit from Poiana Teiului and partially the works being executed at the moment.

The variation in the river levels, rainfall and ice jams at Frumosu section on Bistriţa in the 1995-1996 winter is presented in figure 10.

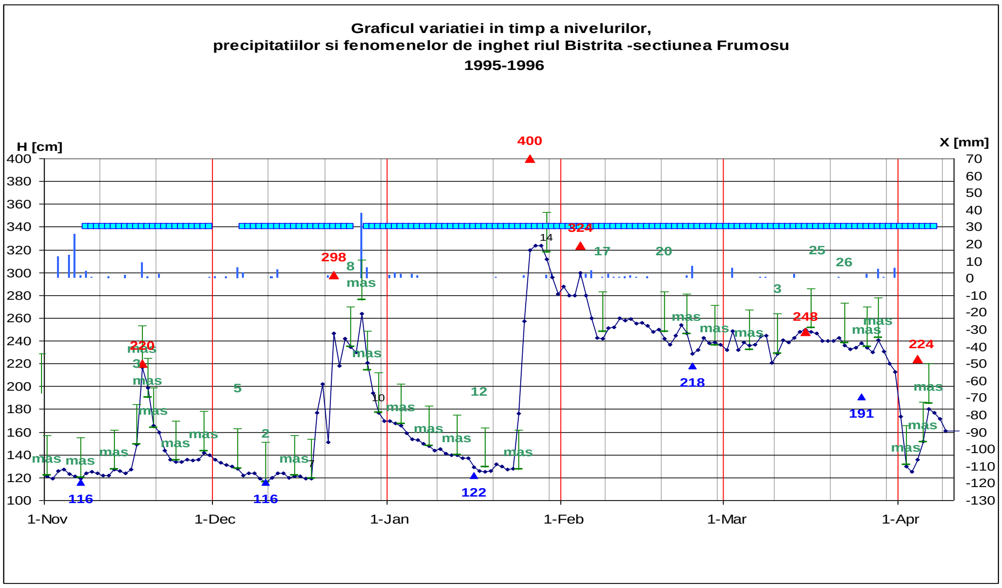

Figure 10 Variation of river levels, rainfall and ice phenomena on Bistriţa in Frumosu section (winter of 1995-1996), Ştefănache D. (2007)

The value of the material losses was of 822 million ROL, according to the synthesis reports regarding defence against floods belonging to Neamt County Comission of Defence against Distasters.

The floodplain unblocking was conducted on December 24th at 20.30, when water started retreating towards the floodplain.

The evolution and effects of the dangerous hydro-meteorological phenomena on January 1st 2003

On December 31st 2002, ice jams from the end of the reservoir extended up to Pântei brook, on a length of 21 km, with a depth of the stabilized ice packs of 1 to 6 m. After a long period with negative temperatures between -23° C and -15° C, during 30.12.2002 - 01.01.2003 there occurred sudden increases in temperatures, up to +5° C. Winds were weak to moderate, with intensifications in the mountain area. Maximum temperatures were between -2° C at Ceahlău Toaca and +11° C at Piatra Neamţ, while the minimum were of -7° C at Ceahlău Toaca and +1° C at Piatra Neamţ. The snow measured 12 cm at Ceahlău Toaca. In these conditions, in the upstream depressions there occurred a warmer microclimate due to solar radiations and higher temperatures. The ice from the blockings upstream detached and cumulated while floating downstream, increasing the pressure on the ice dams from Fărcaşa (Stejaru, Buşmei, Fărcaşa and Frumosu villages) and Poiana Teiului (Galu and Săvineşti) townships, producing a flood on Bistriţa. At Frumosu hydrometric station, between 21.30 - 01.30 in the New Year's Eve, the levels have risen from 189 to 470 cm.

The floods produced by the ice dams had as consequences (according to ISU Neamţ) three human deaths, one damaged house, 35 affected houses (foundations etc), 11 destroyed households, 68 damaged households, 20 damaged stables, one bridge and two wood bridges destroyed, 39 tons of forage destroyed, 10,500 m of fences destroyed, 20 flooded basements, 845 dead animals. The damage was estimated at 15,454.45 million ROL according to the synthesis reports regarding defence against floods belonging to Neamt County Comission of Defence against Disasters.

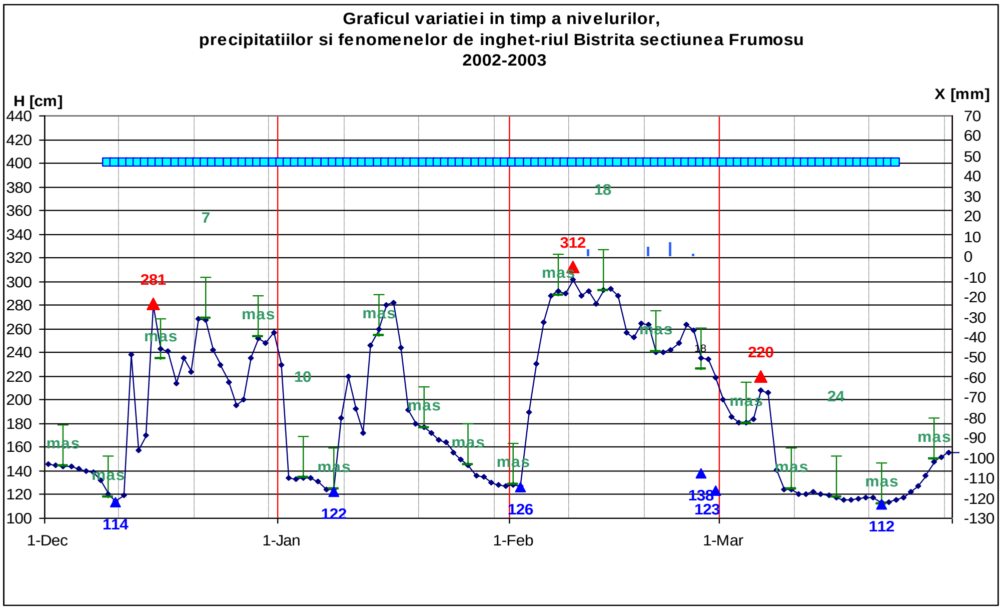

Figure 11 Variation of river levels, rainfall and ice phenomena on Bistriţa in Frumosu section (winter of 2002-2003), Ştefănache D. (2007)

4. Conclusions

Dangerous hydrological and meteorological phenomena that have occurred during the last years in the middle Bistriţa valley have strongly affected the human settlements, defence structures, infrastructure, agricultural terrains etc. The causes that influence the occurrence of these hazards are natural and anthropic.

To prevent floods due to heavy rainfall and winter ice dams on the Bistriţa valley (especially upstream of Izvoru Muntelui reservoir), an efficient risk management is needed, taking the following measures:

- *structural measures*: a corresponding management of floodplains, slope forestation and mitigating soil erosion, conducting works to correct torrential organisms, continuing works needed to energetically manage Bistriţa river, re-dimensioning bridges (Romanescu, 2005);

- building transversal submerged rapids in certain points where Bistrita river has water losses, so as to diminish the occurrence of ice needles, bottom river ice or ice floes;

- *non-structural measures*: **education** through mass-media for preventing and alleviating extreme phenomena, **improving means of alerting population**, **improving means of synoptic surveillance of regions vulnerable to risks** so as to prevent population, **strengthening legislation and administrative measures** to ensure an efficient activity of all organisms involved and of population in case of disasters, **creating concrete plans of managing natural risks**, **involving non-governmental and ecological organizations and people in mitigation activities of extreme natural phenomena** (strategies of managing mesteo-climatic risks, according to the conferences from Rio, 1992 and Yokohama, 1994).

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