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A CASE STUDY ON THE DIAGNOSIS AND CONSEQUENCES OF FLASH FLOODS IN SOUTH – WESTERN ROMANIA: THE UPPER BASIN OF DESNATUI RIVER

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Abstract: The paper examines the flash floods that may appear in a representative river basin occupying the south-western Romania and also feature an example of the most recent flash flood from 2005–2006, more specifically, its causes and consequences. In order to accomplish the objectives, hydrological data were used to identify the characteristics of the floods. Finally, the case study of the flash flood was delivered through the field research, observational method, discussion with the authorities and investigation of the meteorological and hydrological available data. The research offers an insight on the dimension of damages triggered by a flash flood event, based on the statistical data provided by the village hall and the few remaining places preserving the traces of the floods (houses, bridges). Because we could not provide all the necessary data in order to determine the frequency and scale of such risk phenomena, the analysis is assessed on general hydrological statistics of flood events between 1964 to 2011. By leading the research, it resulted that the specific feature of the upper basin of Desnatui River is its temporary drainage and that in the periods of high flow, the capacity of the river channels is diminshed and the floods may occur. The paper succeeds to revive the insufficient scientific concerns on this kind of hydrological risks issued in the space occupied by the upper basin of Desnatui River and eventually, to supply the need for such study in the context of modern hydrological research preoccupations.

Key words: Desnatui River, flash floods, hydrological risks, Romania

Introduction

The Upper Basin of Desnatui River is located in the central-northern part of Dolj County, in south-eastern extremity of the Getic Piedmont, Romania (Figure 1). Desnatui River is a tributary of the Danube River through Bistret lake in southern Oltenia Plain. To the west, it is bordered by Drincea Basin and its subbasin, Baboia (part of full basin of Desnatui) and to the east and northeast, it borders the basin of Jiu River. To the south, it is continued by its lower sector. The analyzed sector of the river basin is vulnerable to flooding phenomena both in its northern, much higher part, through the danger caused by drainage from

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the slopes (effect of rainfall combined with snowmelt in early springs), and in the south, due to the expansion of household up to the minor bed (Stroe, 2003).

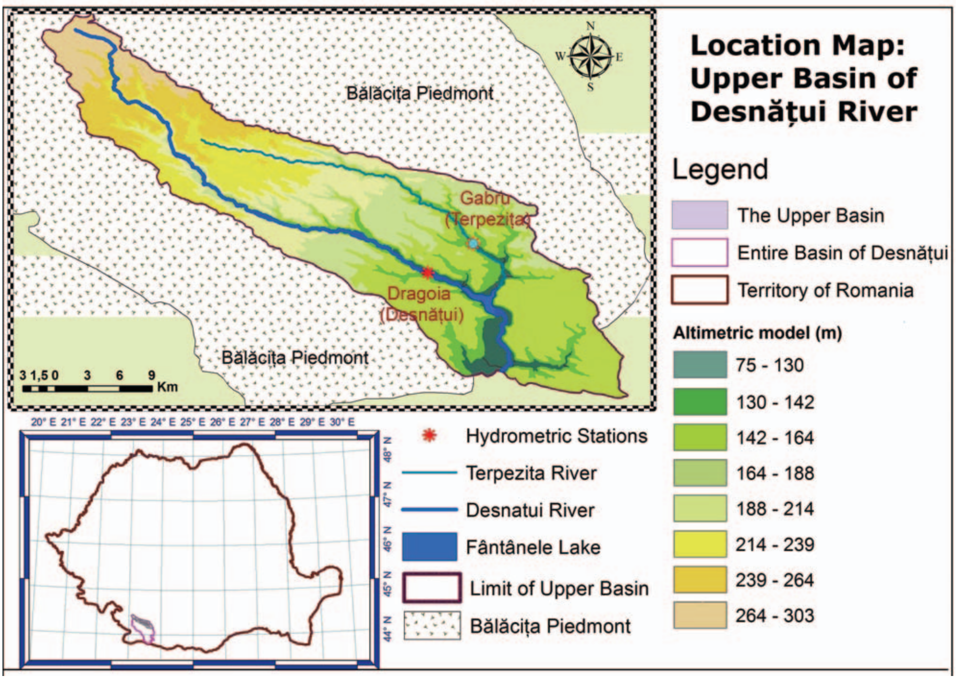

Figure 1. Location map of the upper basin of Desnatui River

Besides the complex analysis of the hydrological elements of the floods, the institutional vulnerability is the second main route towards integrated flood risk assessment (Armas, 2005). Thus, in our area of interest, because of the fact that floods are rare, their power and effects are almost always neglected and the villagers are taken by surprise, turning a seemingly banal flood or high waters episode into a real hazard.

At the regional level, authorities are less aware of the need to adapt the social element to a plausible negative flood event. Knowing from the institutional level to the individual one which are the means to combat the effects of floods, or, even better, to prevent them, could be a way to get closer to the point where the difference between hazard and natural phenomenon is stated.

The study of hydrological risk, however, is a fundamental concern of hydrologists in Romania, justified by the fact that the landscape itself is a research component that supports the development of territorial perspectives over the geographical phenomena. Flood risk, out of a universal definition, identifies the researcher with both his humanistic and physical side, as the features representing the outset of such research come both from the topographic substrate around water bodies, and the social dimension of such phenomena (Trautman & Carlsen, 2004). Thus, the physical-hydrological risks constitute the limiting factors generating the failure of the hydrological and human system of defense against the floods (Toma-Dina, 2011). Flood phenomena are presented in connection with the air, since they are most often caused by manifestation of climatic elements, respectively precipitation (Grecu, 2004).

Every year floods cause material damage all over the country. Hydrological phenomena aspects were not comprehensively treated for the upper basin of Desnatui River, but there have been case studies and articles that were addressed briefly to some risk events in recent years. General studies, however, about the floods risks were soared only in the last two decades. Contributions to their foundation had researchers, as Armas (2005), Grecu (2004), Chendes (2007), Ghioca (2008), Chiaburu (2010), on both the impact evaluation of such phenomena and theoretical appreciations.

Data and methods

In this paper, geomorphological, meteorological and hydrological data went through a process of operationalization for the general theory, followed by the statistical and graphical processing of data, using cartographic and mathematical methods. The effects induced by the discovered sets of risk episodes were confirmed in a simultaneous and subsequent fieldwork, concerning mostly the human dimension of the risks, and then correlated with the numerical data collected from the meteorological and hydrological stations. The methods used in completing the research formed more or less the steps towards the complex assessment of the floods in the study area. To fulfill the purposes of the research, we used a number of methods, such as geographical observation method, the historical method, the method of analysis and synthesis, graphical method, the mapping and statistical methods, or inductive and deductive method.

Direct observation meant a spot interpretation of the risk elements, such as villages, houses and land uses, these allowing us to decode the main components of hydrological extreme phenomena. The geographical and statistical methods have proven useful in analyzing historical phenomena to ascertain the genesis of the current (fluvial topography), enabling knowledge of past conditions that have occurred and have led to the effects of floods.

Inductive and deductive methods were enhanced in linking information from oral historical sources in some locations, statistical records (in this case, of floods and damage agricultural crops), data from linguistics (hydronyms and local names of processes and landforms), oral sources – discussions with villagers, finding housing / areas with vulnerability to risk.

Results and discussions

Hypothesis and preliminary arguments

When a moisture surplus, derived from rainfall, snowmelt runoff, or mixed nature, is attained on a watershed, this generates maximum flow phases, known as high waters (Trautman & Carlsen, 2004). Flash Flood phenomenon occurs when the water from the river exceeds the river channel and flows in the neighboring areas covered by crops, pastures, forests, constructions (Toma, 2011), etc. On the other hand, floods generally come about when the magnitude of extreme hydrological events, as flash floods are, on the communities becomes hazardous to human and agricultural land (Daniel et al., 2012).

The upper basin of Desnatui River basin of presents an extensive vulnerability to flooding both in the north, higher part (effect of rainfall combined with snowmelt in the spring), and in the south, less higher sector, due to the expansion of household up to the minor riverbed. Effects on communities envisage two types of vulnerability: material and social one. The material vulnerability arises when the human settlements are located along the river flood strip, or because of the practice of economic activities, especially agricultural ones, which show social vulnerability depending on the readiness of people face to an extreme natural event.

Most floods occur as a result of heavy rains in the transitional seasons, when receptor substrate bed is saturated, floods then being associated to the flash-flood phenomenon. Therefore, the floods in this area of the basin, compared to those from the lower basin situated in the plain, happen as a result of extreme weather conditions (rains falling in large quantities in a very short time), so each time such phenomena take the residents and the authorities by surprise. Areas exposed to the greatest risk of flooding (Terpezita, Gubaucea, Radovan and Ciutura villages) are monitored by only three hydrometric stations and the alert network is not powerful enough to prevent a state of risk.

Characteristic elements of flash floods

Taking into consideration the data available for more than 40 years for two out of three hydrometric stations, Dragoia (on Desnatui River) and Gabru (on Terpezita tributary), the hydrological analysis will highlight the years when the mean and maximum flow reached the warning or alert levels.

Since the prediction of the hydrological events would require a more complex set of data, which, practically, were not available for a river basin with such a little importance in Romania, in order to reach a diagnosis of floods from Desnatui Upper Basin Administration, we considered some of the most important flood hydrographs at the two above mentioned stations, from 1970, 1995, 1998 and 2005 years. The analysis of the flood hydrograph from February 1970 for Dragoia Hydrometric Station (Figure 2), shows that its rise time is very short, and the decrease takes more than two days.

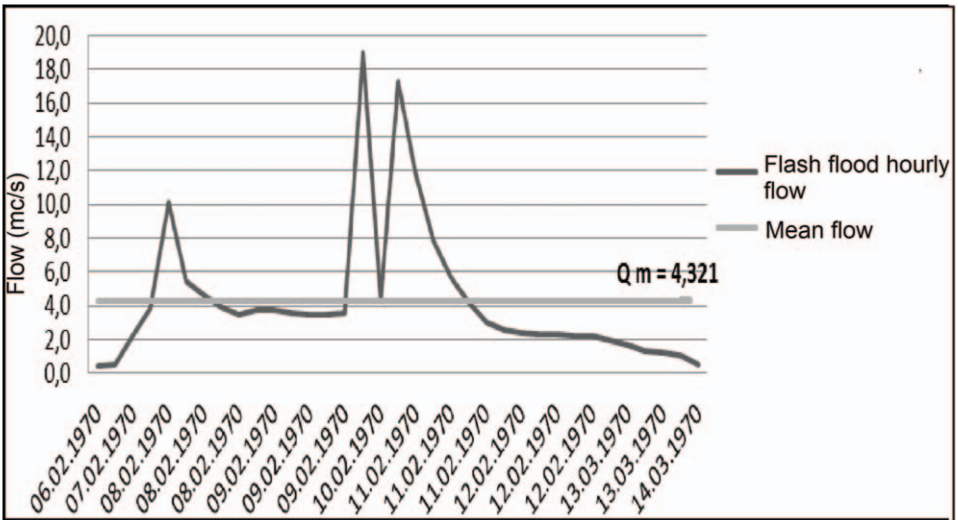

Figure 2. Hydrograph of the flash flood from 6th February to 14th March 1970 at Dragoia Hydrometric Station (Data source: ABA Jiu)

Desnatui River presented three maxima and two minima. However, it was a single flood light, but very strong and fast, when the flow reached almost 20 m^3/s and the increase of the flow was short (from 02/06/70, 17:00 to 07/02/70, 17:00), being followed by a rapid decrease, but gradually to a lower flow rate of 3 m^3/s. On the 10th February 1970, the main maximum of 19 m^3/s was reached, being succeeded by another two peaks of 17.3 m^3/s and 11 m^3/s, so that, since 02/11/70 9:00 flow steadily declined until stabilizing at the value of 0.5 m^3/s

(3/14/70 7:00). The total time of the flood (192 hours) was obtained by summing up the time of increase and decrease and gave us appropriate information about the flood wave propagation speed.

This means that the flood lasted long enough and that there was a fairly large range of wave propagation, flow oscillations, with several increases and decreases, several secondary maximum and minimum values. Figure 3 reveals the characteristics of the second analyzed hydrographs, according to the values registered for the flash flood taking place in December 1995 on Terpezita River, Gabru Hydrometric Station.

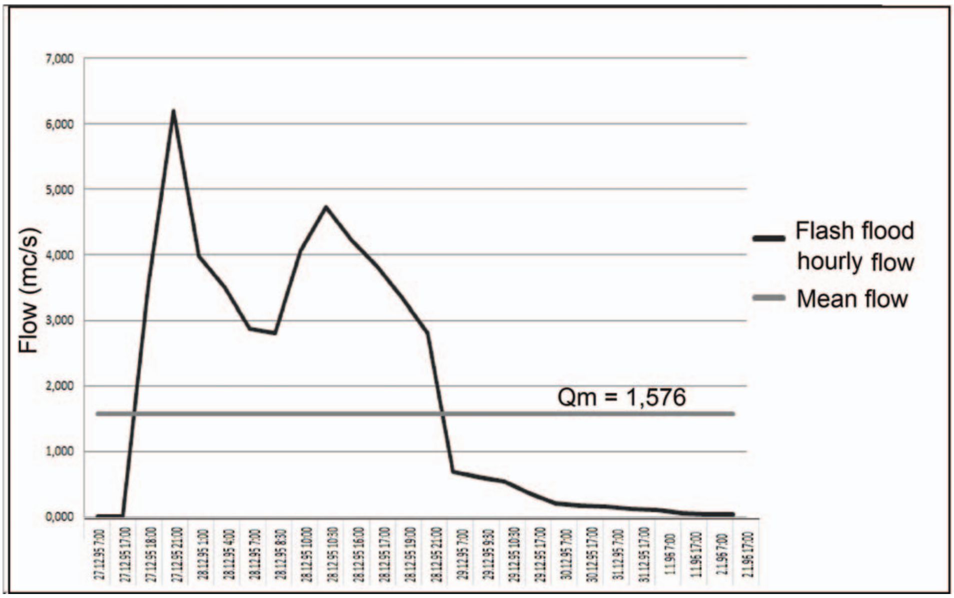

Figure 3. Hydrograph of the flash flood from 27th December 1995 to 2nd January 1996 at Gabru Hydrometric Station (Data source: ABA Jiu)

The total time of the flood is 109 hours and it is composed of two peaks, the first at a flow of 6.2 m^3/s (27.12.1995, 21:00), and the second one with a value of 4.72 m^3/s (28.12.1995, 10.30). The growing time is very short, of about only an hour, and decreasing time is 22 hours and 30 minutes. The flood type is pluvial, showing a composite transect of two peaks and some more minimum values.

This flood from 1998 (Figure 4) is due to heavy rains in the last month of autumn, in a time of low temperatures, an almost zero evaporation and low infiltration capacity in water aquifers. Although it appears that the maximum flow rates were kept for a long period of time, the flood has a total of 7 days, of which only 22 hours are to be maintained at more than 20 m^3/s and the rest of the time, either the flood is on the upside steeper left flank, or backwards flank (about 5 days). It is a flood for which the maximum values have remained stationary, on the same level with peak value recorded for 16 hours, all the values being above 20 m^3/s.

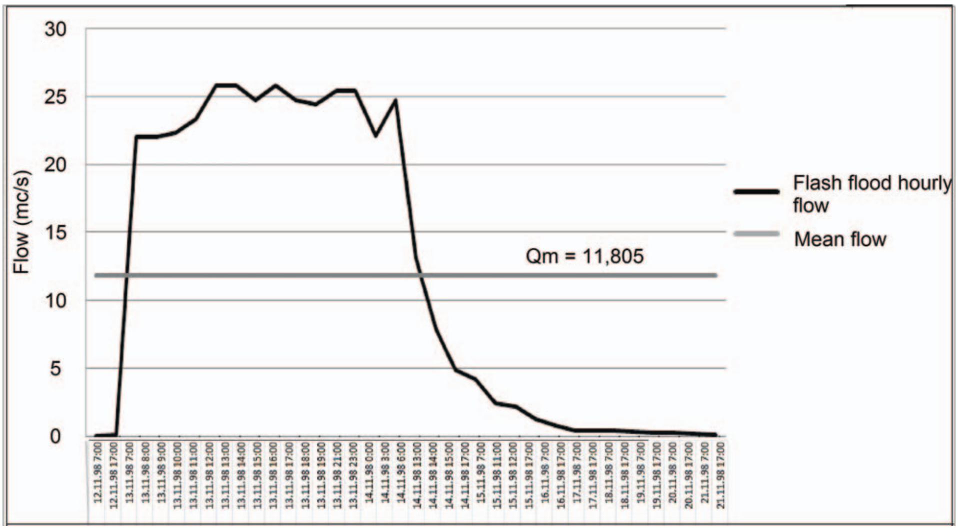

Figure 4. Hydrograph of the flash flood from 11th November 1998 to 19th November 1998 at Dragoia Hydrometric Station (Data source: ABA Jiu)

The most important, as consequences regard, was the flood of September 2005, from Gabru and Dragoia Hydrometric Stations (Figure 5). The second one was characterized by two periods of rise and fall, its complexity being given by the symmetry between the two peaks and their flanks. The second peak however, stayed at the highest value of 28.5 m^3/s for more than 3 hours and this was more than two times higher than the maximum values registered for the first, secondary peak. Since the maximum flow, on the 16th August 2005, 19:00, flow began to decrease gradually until it reached the minimum value of 3.5 m^3/s, registered on the 17th August 2005, at 18.00.

What is more, between the absolute minimum and the absolute maximum flow passed only 14 hours, so that on 18th August.2005, 8.00 the rate of 49.5 m^3/s was recorded and it was maintained for two hours and a half. The total time of the flood is 54 hours, including the rise time of 7 hours, and the decrease of 8 hours. It is also a pluvial flood triggered within a few hours after the rain started.

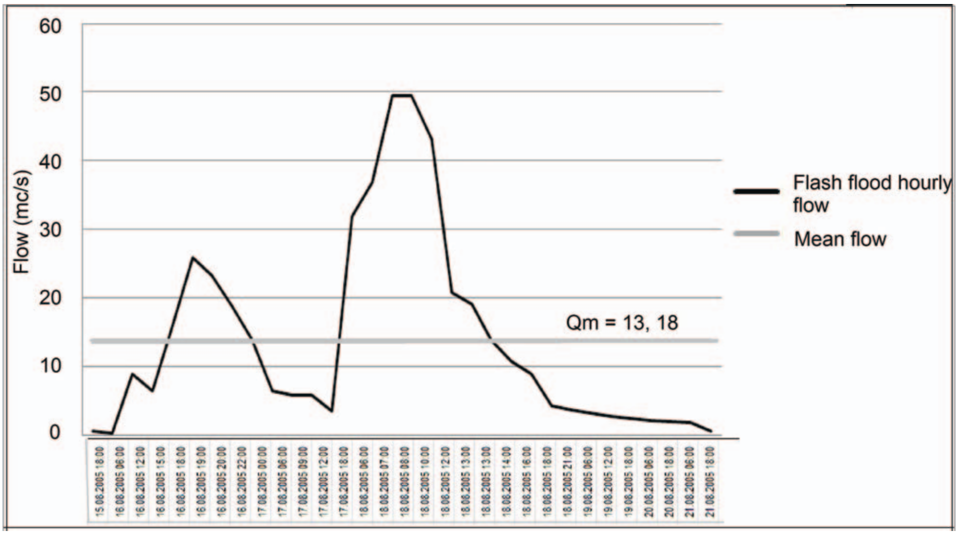

Figure 5. Hydrograph of the flash flood from 15th to 21th August 2005 at Dragoia Hydrometric Station (Data source: ABA Jiu)

The correlation of the episodes characterized by extreme flow of some hours to some days would not have been possible without the calculation of the runoff coefficient. Runoff coefficient introduces the relationship between flow and precipitation (Pisota et al., 2010). This is expressed as a ratio of the amount of drained water (Y) and the amount of rainfall (X) in a certain period of time:

$$\eta = \frac{Y[mm]}{X[mm]} = \frac{1000 * Q * T}{1000000 * F * X}$$

To have a conclusive tableau of the flash floods in the study area, we used data from Dragoia Hydrometric Station, as it is the only mixed post (with recording precipitation, besides the main hydrological function), thus allowing us to interconnect the last three significant flash floods (1998, 2005 and 2006) with the years in which the highest coefficient was registered. The available information was from 1993 to 2011 (Figure 6). Hence, it can be seen that the three years in which the runoff coefficient exceeded the value of 0.15 are also years when flash floods occurred.

To put it plainly, it means that, whenever we talk about flooding episodes with repercussions on society, those phenomena are very rare (given the hazardous character of this kind of floods), but consequential, being frequently the ones responsible for the growing average value of a parameter (mean annual flow, for example), in the whole referential year.

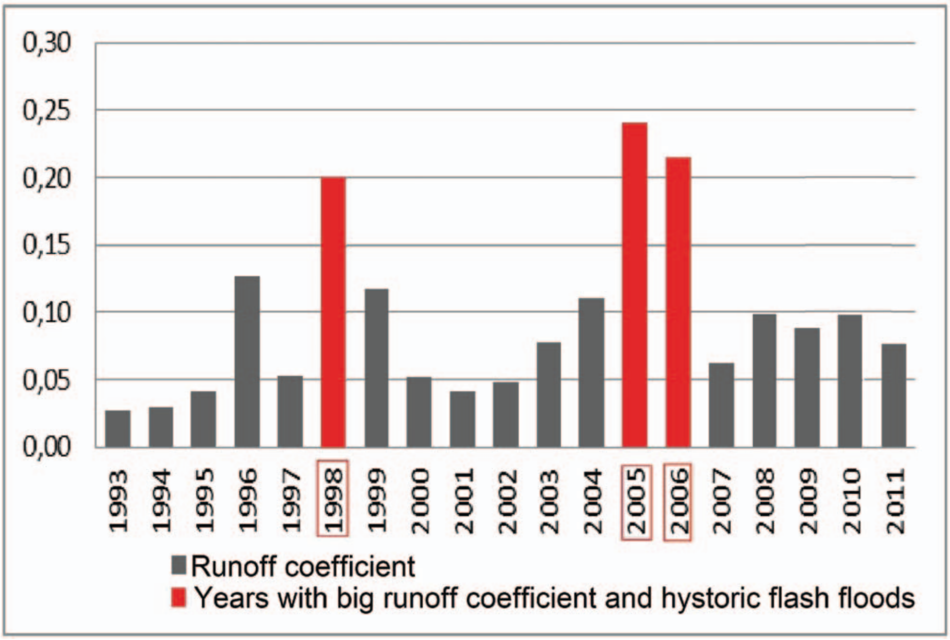

Figure 6. Runoff coefficient (1993-2011) for Dragoia h.s. (Data source: ABA Jiu)

The main features of the most meaningful flash floods in the study area are synthetized in the Table 1. With the support of Microsoft Excel Program, we were able to calculate the most significant parameters pursued in all sorts of hydrographs characterizing floods. In order to calculate the total volume of floods in the catchment analysis was used the sets of data for the hydrographs shown above, identifying the total volume of water drained during the flood. A next step was to delimit base flow and volume of water related to the volumes and to obtain its omission from the calculations (Pisota et al., 2010). By finding out the maximum volume, it was possible to calculate the form factor of the flood hydrograph. The final formulas used were the following: h = W / 1000*F, where FDragoia = 216 km^2 and FGabru = 109 km^2, whereas ɣ = W / (Qmax – Qb) * Tt (Pisota, Zaharia, & Diaconu., 2010). The discussion of this parameter requires a prior shape of flood hydrographs. The analysis led to the conclusion that in most cases hydrographs were simple, unlike the composite ones. Also in this context, the mean stratum was calculated for each hydrograph, ascertaining that higher values of this parameter occur in areas with steeper slope (Dragoia on Desnatui, in comparison to Gabru on Terpezita), which favor runoff, and depending on the degree of vegetation cover and composition and the particular soil type.

Table 1. Flash floods most important parameters (Data source: ABA Jiu)

	Station	River	Year	Tt	Qb	qmax	Wsr	Wb	Wt	ɣ	Hs
1	Dragoia	Desnatui	1970	100	2.6	88	1.766	0.934	2.7	0.39	8.2
2	Gabru	Terpezita	1995	61	1.85	56.9	0.083	0.406	0.49	0.36	0.8
3	Dragoia	Desnatui	1998	16	17.6	236.7	0.34	1.01	1.35	0.91	3.15
4	Dragoia	Desnatui	2005	54	5.35	454.1	2.096	1.04	3.14	0.33	19.2

*Wb = starting volume [mil.mc]; Wtr = total volume [mil.mc]; Wsr = drained volume [mil.mc]; Hs = drained stratum [mm]; Qb = starting flow [m^3/s]; Tt = Total time of the flash flood [h]; q = specific maximum flow [l/s*kmp]; ɣ = flood form coefficient

When interpreting the numerical information from the table, we could clearly notice the strength of the flash floods from the last 15 years, as the record values belong to the flash floods from 1995, respectively 2005. The most voluminous flash flood was the one from 2005, followed by the year 1998 with a value less than half than the first value. In addition, the flood form coefficients have similar values, except for the flood from 1998, when the total time was the shortest one of only 16 hours. It can also be noticed an increase of the maximum flow, from 1970 to 2005, reaching values of more than five times higher (from 88 m^3/s to 454.1 88 m^3/s).

Finally, one can observe that it is a strong correlation between the evolution of the basic flow into maximum flow and the total time of the flood. For the years 1970, 1995 and 2005, when the total time covers more than one day, the ratio between the two values of flow is increased, unlike the ratio corresponding to the year 1998, which hardly exceeds 10.

Case study: Flash floods from 2006 in Terpezita Village

Terpezita Village is located in the north-eastern sector of Balacita Piedmont and approximately in the center of the upper basin of Desnatui River (Figure 7). The topography is individualized by large, tabular floodplains, deepening the river system in asymmetric slopes (the right one is lower and deeper than the one on its left side). Terpezita valley, which crosses the village, has slopes affected by dynamic processes that fragment the piedmont in large and smooth floodplains, which remain suspended from the meadows.

Due to the flash floods occurring in August 2005 and March 2006 on Terpezita, near its Hydrometric Station, Gabru, its tributary, Lazu river, was also affected and it was actually the one responsible for the most consequential floods. The hydrograph corresponding to the flood from 11th to 16th March 2006 at Gabru (Terpezita) Hydrometric Station (Figure 8) is one of mean total time, summing 30 hours of registration. As mentioned in the previous subchapter, the flood duration influences directly the effects on the neighboring land along the rivers. In this case, the time has to be correlated to the type of the flood, which is a simple one, starting with a period of almost 8 hours of high waters (Tc = rising time) and finishing with another period of low waters. This indicates that we deal with a short period of time characterized by maximum values (higher than 80 m^3/s) and that the flanks of the maximum value are very steep. Thus, hydrologically speaking, this flash flood from March 2006 had a huge potential of dangerousness, which was then confirmed by the material damages.

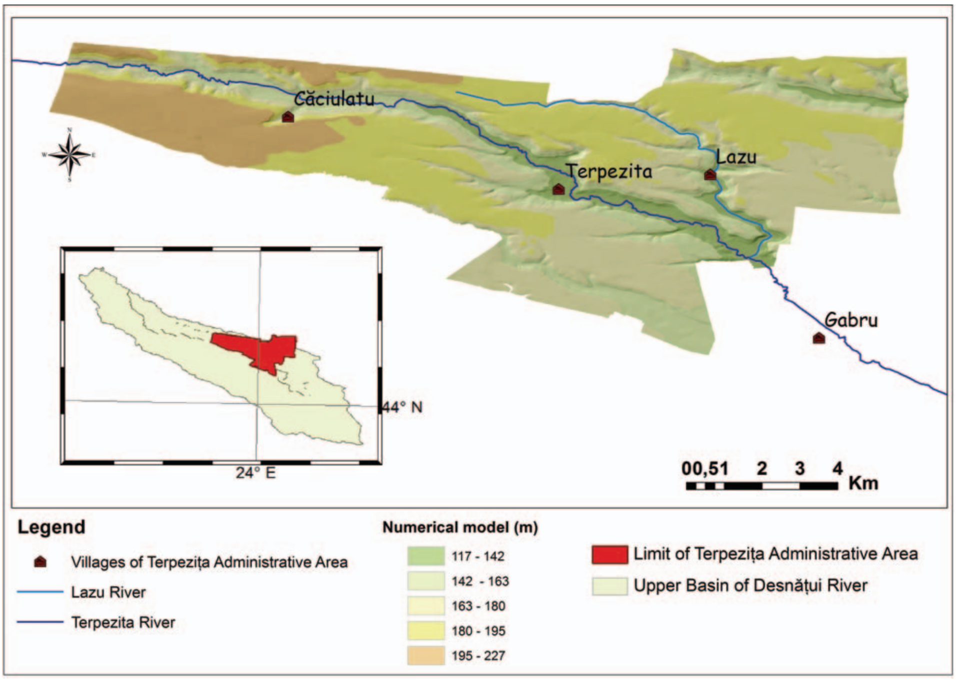

Figure 7. Location Map of Terpezita Administrative Area

Source of data: Military Topographic Map, 1982, Scale 1:25.000

The flood was a mixed one, being caused by spring rains, associated with snowmelt on the slopes. The rains began two days before reaching the maximum flow record.

The cyclonic activity was one of humid air masses moving from south-western and western Europe towards the Black Sea basin and Russian Plain, thus discharging the energy by dint of the torrential rains all over Romania (Figure 9). The piedmont landscape itself causes significant changes in the transformation of air masses and fronts developments, intensifying or weakening the formation of clouds (Bogdan & Marinica, 2007).

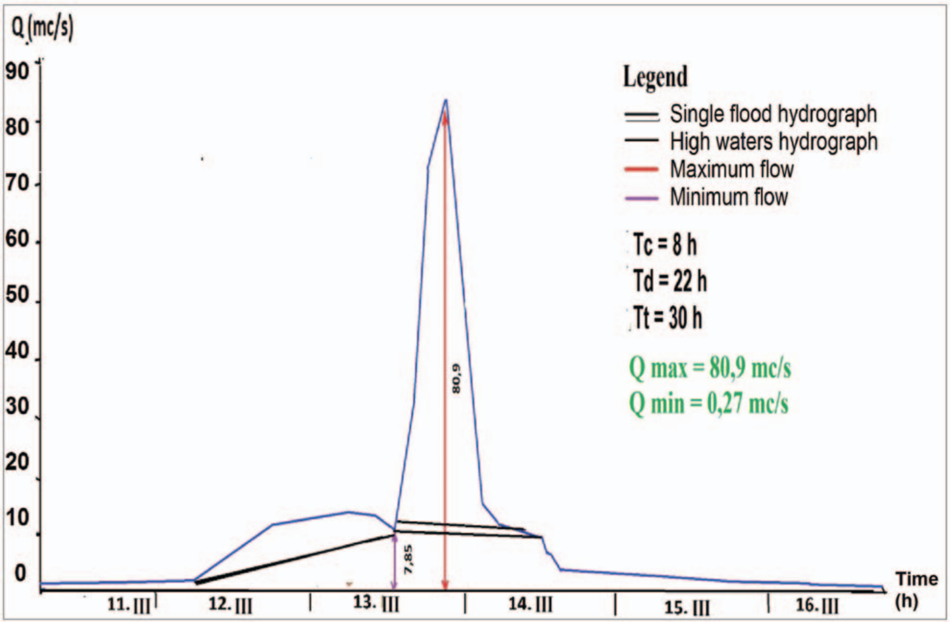

Figure 8. Flash flood hydrograph – 11th to 16h March 2006 at Gabru h.s. (Data source: ABA Jiu)

However understandable it may seem, the main cause (heavy rainfalls and snowmelt) could not be entirely responsible for the apparition of flash flood without taking into account all other conditioning morphological and social factors.

Above all, the length of the two rivers, especially Lazu River, is of great importance in the formation and implicitly in the analysis of the flash flood, because in this piedmont basin, the tributaries of the main river are short and intermittent or semi-permanent (Stroe, 2003). The flash flood surprised the residents and the authorities, affecting both households along the rivers, the infrastructure (insufficient sized bridges) and the agriculture (Figure 10).

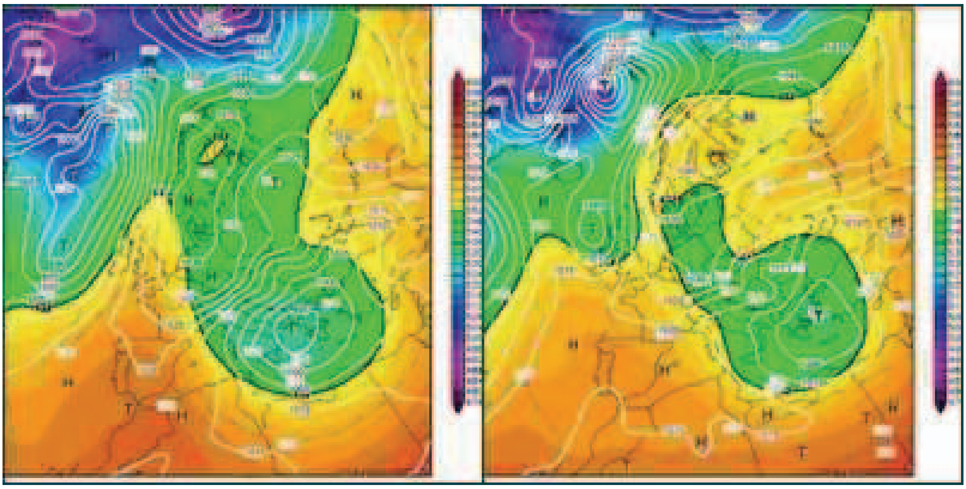

Figure 9. Europe Synoptic Map, geopotential at the level of 500 mb (13th-14th March, 2006)

Source of data: http://www.wetterzentrale.de

Figure 10. Images illustrating the damages after the flash flood in Lazu village (Morosanu, 2012)

It results that, after a long period of lack of flow or low-waters, which can last for several years, the riverbed is quickly filled and swollen waters caused the large amount of rainfall in only a few hours discharge immediately in the floodplains.

Damage assessment (Table 2) emphasizes the consequences of the flash flood for the threatened elements, particularly the infrastructure and the human settlements. Fortunately, the rivers in this type of upper basin have never so much power as to transform the material effects into a national disaster with life losses. In brief, we summed up the following damages in Terpezita and Lazu localities:

Table 2. The impact of the flash flood in Terpezita and Lazu

Locality name	Affected households	Fallen houses	Houses affected by subsequent landslides	Number of distroyed bridges	Dimension (km) of other hydrometric structures (dams, communal roads along the rivers)
Terpezita	79	14	2	2	4.35
Lazu	75	4	3	1	3.2

Source of data: Terpezita Hall and field work

Last but not least, the activity conducted during the research field also divulged some deficiencies in the administration and environmental management of the settlements:

- Lack of municipal waste management, waste being stored sometimes in the local riverbed, making it impermeable to water stagnation or flow high rates;
- Precarious investment in the infrastructure materials that do not fit in case of floods and landslides;
- Poor risk education for the locals and the small percentage of insurance on the properties
- Reduced intervention of the authorities to remedy the adverse effects of flooding and delayed reconstruction of bridges.

Conclusions

After studying the extreme hydrological phenomena in the Upper Basin of Desnatui River, it was revealed that this area is not entirely vulnerable, but that physically based flood evaluations within a watershed and with consequences on human society becomes more and more feasible.

However, the need to reduce the chances of unexpected events likely to produce effects on the environment, involves the integration of both structural and non-structural measures in order to obtain optimal strategies for managing risk phenomena. The hydrological structures in this area (dams and bridges) need a permanent revision and adaptation to the size of a flood wave that can occur as a result of torrential rains.

Due to the fact that the rivers in the study area are usually semi-permanent, riverbeds have to be maintained unobstructed, so that the water collected during the floods will not generate floods. Much of the flood risk is due to a natural potential (periods of precipitation surplus), but human interventions in the environment, by deforestation, usage of groundwater resources, overflow of rivers' meadows by expanding agricultural land in floodplains, are still made.

In the very end, although the other researches have so far been conducted for different separate areas in the entire basin of Desnatui River, analyzing the evolution of flow characteristics of the main rivers in the sections of interest, may provide the possibility of solving the basic problems arising in engineering practice in relation to planning and rational use of water resources.

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