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# Structural and Non-Structural Measures for Flood Risk Mitigation in the Bâsca River Catchment (Romania)

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**Abstract**

The most common natural hazards affecting the Bâsca River Catchment (extended over a surface of 785 .1 sq. km in the Curvature Carpathians) are floods and flooding. The purpose of this paper is to investigate and analyze structural and non-structural measures for flood risk mitigating in this catchment.

The study focuses on the main factors which generate and favour floods, as well as on flood characteristics (frequency, the largest floods and its consequences).

The main methods are the statistical analyze hydrologic and climatic data, field observations, expeditionary mapping and spatial analyses using Geographic Information Systems (GIS).

In order to analyse flood potential, there were processes processed maximum instantaneous monthly and annual discharges of the Bâsca River at the Bâsca Roziliei hydrometric station (1953 - 2007), Varlaam I (1956-2005), Comandău h.s. (1968-2005) and of the Bâsca Mică River at the Brebu h.s. (1959-1974) and Varlaam II h.s. (1973-2005).

Considerations on structural and non-structural measures for protection against floods are presented in the last part of the paper. An inventory of structural works in the middle and lower part of the catchment (hydrotechnical and erosion control works) and their condition was made.

**Keywords**: *floods, structural and non-structural measures, the Bâsca River Catchment*

**Rezumat. Măsuri structurale şi nestructurale de diminuare a riscului inundaţiilor în bazinul hidrografic al râului Bâsca (România)**

Cele mai frecvente hazarduri naturale care afectează bazinul hidrografic al râului Bâsca (extins pe suprafaţa de 785,1 km$^2$ în Carpaţii de Curbură) sunt viiturile şi inundaţiile. Prezenta lucrare are drept scop investigarea şi analiza măsurilor structurale şi nestructurale cu rol de diminuare a riscului indus de inundaţii în bazinul menţionat.

Studiul se concentrează pe principalii factori care generează şi favorizează viiturile şi caracteristicile acestora (frecvenţa, cele mai mari viituri şi consecinţe).

Principala metodă este reprezentată de analiza statistică a datelor hidrologice şi climatice, observaţia de teren, cartarea expediţionară şi analiza spaţială utilizând Sisteme Informatice Geografice (SIG).

În analiza potenţialului de producere a viiturilor au fost prelucrate debitele maxime instantanee, lunare şi anuale ale râului Bâsca de la staţiile hidrometrice Bâsca Roziliei (1953 - 2007), Varlaam I (1956-2005), Comandău (1968-2005) şi de pe râul Bâsca Mică de la Brebu (1959-1974) şi Varlaam II (1973-2005).

În ultima parte a lucrării sunt prezentate consideraţii asupra masurilor structurale şi nestructurale de protecţie împotriva inundaţiilor. Este realizat un inventar al lucrărilor structurale din sectorul mijlociu şi inferior al bazinului (lucrări hidrotehnice şi antierozionale) şi este analizată starea acestora.

**Cuvinte cheie:** *viituri, măsuri structurale şi nestructurale, bazinul hidrografic al râului Bâsca*

## INTRODUCTION

Floods are natural hazards with complex consequences, both direct and indirect: geomorphological, economic, social and ecological. They hold about one third (34%) of the total number of natural disasters produced worldwide in the 1900-2007 period (Magdelaine, 2010).

Knowing that in the future flood risk is estimated to raise, due, on the one hand, to increasing frequency and amplitude of flooding, in the context of climate changes, and on the other hand to an increased vulnerability determined by the expansion of socio-economic activities in floodplains (Şerban and Gălie, 2006), measures and actions to limit and reduce floods negative impacts on society and the environment need to be effective. At the Union European level, the management of the floods risk is expected to be completed within a common framework for action set by the 2007/60/EC

 

respectively 1632 m a.s.l; these data were provided by the Regional Meteorological Center Muntenia, Buzău and *Clima României*, 2008;

- hydrological data: maximum instantaneous monthly and annual discharges of the Bâsca River at the Bâsca Roziliei hydrometric station (h.s.) (1953 - 2007), Varlaam I h.s. (1956-2005), Comandău h.s. (1968-2005) and of the Bâsca Mică River at the Brebu h.s. (1959-1974) and Varlaam II h.s. (1973-2005) (Table 1); discharges during the main floods; the hydrological data were provided by the "Romanian Waters" National Administration, Buzău – Ialomiţa Water Basin Administration (BI BWA), and the National Institute of Hydrology and Water Management (NIHWM);
- qualitative data: physical status of hydrotechnical works (from the Forest Research and Management Institute - FRMI) and
- quantitative data: number of hydrotechnical works (by the Aquaproiect and FRMI).

**Table 1 Data about the hydrometric stations from the Bâsca River Catchment**

| River | Hydrometric station | A* ($km^2$) | $H_B$** (m) | Stream length (km) | Analysed period |
|---|---|---|---|---|---|
| Bâsca Mică | Brebu*** | 185 | 1240 | 36 | 1959-1974 |
| | Varlaam II | 235 | 1171 | 43,7 | 1973-2005 |
| Bâsca | Comandău | 111 | 1252 | 24 | 1968-2005 |
| | Varlaam I | 440 | 1142 | 53,5 | 1956-2005 |
| | Bâsca Roziliei | 759 | 1110 | 72 | 1953-2007 |

* - Catchment's area (upstream the hydrometric station),
** - Catchment's mean altitude (upstream the hydrometric station)
***- Hydrometric station was out of service in the years 1974.
Morphometrical data are according to Diaconu, 2005.

The main methods were represented by statistical analysis of the hydrologic and climatic data, field observations, expeditionary mapping and spatial analyzes using Geographic Information Systems (trial software, extensions of the ArcGis 10).

## Factors generating and favouring floods

Floods generation is a highly non-linear process that depends on genetic and favourable factors such as the pluviometric regime, geological and morphometrical features (e.g. elevation, slopes, energy relief and drainage density), vegetation, soils and antecedent conditions of the catchment (e.g. land use) (Minea and Zaharia, 2010).

### Precipitations

Precipitations represent the main factor generating floods in the Bâsca River Catchment.

Although in the catchment region, the mean annual amount of precipitation are relatively low (827.3 mm at Lăcăuţi w.s. and 664.3 mm at Penteleu w.s.), rainfalls can trigger floods especially during summer, when the rains have a torrential character. In the morphological features of the catchment, these rains can generate flash-floods.

At annual time scale, the highest average amount of annual precipitation was recorded in June at Lăcăuţi w.s. (130.2 mm in the period 1961-2000) (Fig. 2) and in July at the Penteleu w.s. (117.4 mm, in the period 1988-2007).

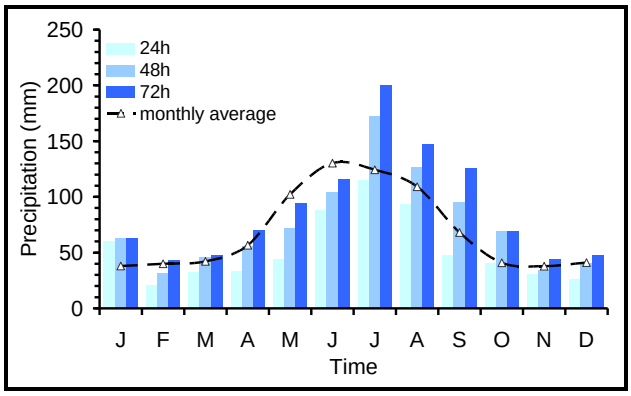


**Fig. 2 Maximum precipitations (rain and snow) in short periods reached at Lăcăuţi w.s. (1961–2000)**
Data source: *Clima României*, 2008

The maximum amounts of precipitation fallen in 24, 48 and 72 hours, at Lăcăuţi were recorded in July (Fig. 2). On July 12th 1969, at Lăcăuţi w.s. it was recorded: 115.4 mm in 24h (88.6% of monthly multiannual average), 172.8 mm in 48h (132.7% of the monthly multiannual average) and 200.7 mm in 72h (154.1% of monthly multiannual average) (Fig. 2).

At Penteleu w.s., on July 18th 1991, there were registered 155.5 mm in 24h (132.4% of monthly multiannual average), and notably 145.3 mm fell in only 6 hours, as it is mentioned in the "Special phenomena" rubric, of the Penteleu w.s. registry.

### Morphometrical factors

Bâsca River catchment is drained by a network of torrential organisms, channels and valleys, with an average drainage density of 3.69 $km/km^2$.

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Basic morphometrical characteristics of the Bâsca River catchment and its main sub-catchments inventoried in the Bâsca Catchment are synthetically exposed in Table 2.

**Table 2 Morphometrical features of the Bâsca River Catchment and its main sub-catchments**

| River | River | Sub-catchment | |
|---|---|---|---|
| | Length (km) | Surface ($km^2$) | Shape |
| Ruginosul | 5.14 | 11.8 | C |
| Corongoş | 5.32 | 12.8 | |
| Slobod | 6.18 | 9.22 | Qc |
| Milei | 6.43 | 15.8 | C |
| Giurgiu | 6.48 | 16.2 | |
| Brebu | 6.55 | 11.1 | |
| Şapte Izvoare | 6.62 | 15.6 | Qc |
| Cernat | 6.69 | 11.1 | |
| Delușor | 6.88 | 20.9 | C |
| Saroş | 7.84 | 14.9 | Qc |
| Poplița | 9.29 | 22.4 | C |
| Ghiurca Mare | 9.59 | 23.3 | Qc |
| Păltiniş | 9.69 | 25.1 | |
| Pătac | 10.0 | 18.5 | E |
| Dârnăul Mare | 10.6 | 21.5 | |
| Cireş | 11.1 | 19.6 | Qc |
| Bâsculița | 11.5 | 40.0 | |
| Bâsca Mică | 46.5 | 238 | E |
| Bâsca Mare | 64.2 | 440 | |
| **Bâsca** | **81.0** | **785.1** | **E** |

E= Elongation; Qc= Quasi-circular and C= Circular
Data source: Morphometrical data are obtained from processed GIS after Romanian Topographic Map, MTD, 1982 (scale 1:25,000).

The catchment's elongation degree was calculated with the shape ratio (Formula 1) proposed by Diaconu and Lazărescu (1965) quoted by Zăvoianu (1985). Transformation of the numeric ratio in qualitative estimation was made after the method specified by Diaconu (2005).

$$F_r = \frac{\sqrt{A}}{L_b} \qquad (1) \quad F_r =$$

where: A is catchment area and

$L_b$ is the mean catchment length.

Considering the qualitative aspect, 35% from sub-catchments have a shape tending to circular (e.g. Brebu, Păltiniş), 35% a circular shape (e.g. Giurgiu, Corongoş) and 26% are elongated (e.g. Bâsculița, Pătac).

The shape of the catchments can have a profound effect on the stream behaviour, especially in relation to the direction of storm movements, e.g. time of concentration (Black, 1991).

Orientation of sub-catchments with quasi-circular and circular shape to the main drainage axis of the Bâsca and the Bâsca Mică River is predominantly transverse. But the elongated shape and large area of sub-catchments (e.g. the Bâsca Mică), determine *"a diminution of floods because tributaries flow into the main stream at greater intervals in time and space"* (Zăvoianu, 1985).

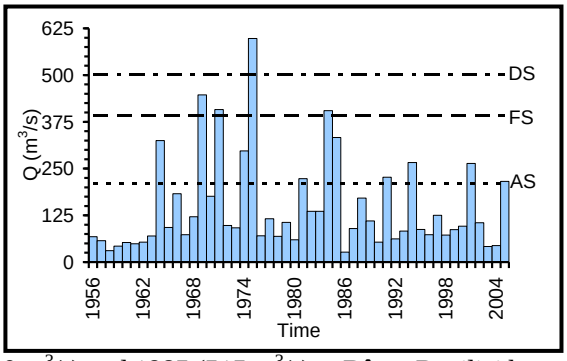
## Maximum flow and floods. Their consequences

We know that particularities of maximum flow present a major socio-economic interest, because they allow the identification and establishment of appropriate measures for flood risk mitigation.

### General features

In the Bâsca River catchment, maximum instantaneous discharges have exceeded in many years the alert stages. Fig. 3 exemplifies the situation from Varlaam II h.s. on the Bâsca Mică River, where maximum annual discharge exceeded in 12 years the discharge corresponding to the attention stage[2].

Maximum instantaneous discharge ($Q_{max}$), on the Bâsca River, which caused major floods and flooding, occurred in the years: 1994 (212 $m^3/s$) and 1975 (204 $m^3/s$) at Comandău h.s.; 1975 (598 $m^3/s$) and 1969 (447 $m^3/s$) at Varlaam I h.s., and 1975 (960 $m^3/s$), 1969 (697 $m^3/s$), 1971 (586 $m^3/s$), 1991




(530 $m^3/s$) and 1985 (515 $m^3/s$) at Bâsca Roziliei h.s.

**Fig. 3 Variability of the maximum annual discharge and alert thresholds (AS = 209 $m^3/s$; FS = 392 $m^3/s$; DS = 502 $m^3/s$) at Varlaam I h.s (1956-2005)**
(Data source: BI BWA, 2009 and NIHWM, 2010

On the Bâsca Mică River, due to the small reception area, there were lower values of annual maximum instantaneous discharges. Thus, at the Brebu h.s., the highest annual maximum discharges were recorded in 1960 (150 $m^3/s$), 1961 and in years 1962 (87.2 $m^3/s$) and 1975 (392 $m^3/s$) 1991 (359

[2]Alert stages are gradual avertization forms, with local defence caracteristics. They are three stages of alert in Romania: attention stage (AS), flooding stage (FS) and danger stage (DS).

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which generated a severe flood in the Păltiniş River Catchment, causing:

- total destruction of works for torrents correcting from the Păltiniş;
- damage to the forest roads and settlements (FRMI, 1994).

After the hydrotechnical works restoration in 1995, a new strong flood was occurred on Saturday 20th of July 2002, with important geomorphological and socio-economic effects:

- landslide reactivatation and destabilization of slopes;
- destruction of some hydrotechnical works (Photo 1);
- affecting sections of the local road DC75;
- homes flooded in the area of the confluence with the Bâsca River and
- one human death.


**Photo 1 Hydrotechnical work destroyed by the flood from July 20th 2002 (near the confluence of the Păltiniş with the Bâsca River)**

These consequences are probably due also to the fact that the works were in most cases hydrologically (exceeded by flood values and channel shifting) and lithologically (alternating layers with hard resistance with friable rocks), limited.

*River channel training (correction) works*

Channel correction aim to the reduce land flooding (Podani and Şelărescu, 1993).

Hydrotechnical works for channel training (frequent on the Bâsca River and in smaller proportion on the Bâsca Mică River) are:

- dry-stone pitching/riverbanks (such works have been identified on the left bank of the Bâsca River, in Varlaam and Gura Teghii villages and in Vadu Oii village, on the Bâsca Mică River);
- embankments made by gabions on the right riverbank of the Bâsca River, between Păltiniş and Furtuneşti villages;
- groynes, on the Bâsca Mică River in Vadu Oii village and on the Bâsca Mare River, upstream of Varlaam I h.s.;
- bridges crossings the river they have the drawback that the pier from the river's channel may generate riverbed jams with wood materials and determine inundations).

The analysis of the physical state of the engineering works indicates that some are degradated by destructuration (groynes) and erosion at the base (brick riverbanks).

In the middle and lower part of the Bâsca river catchment, hydrotechnical works for protection against flooding have degraded in a percent of 65%, requiring rehabilitation, and development of new hydrotechnical works (Minea and Zaharia, 2010).

After 2007, in the lower sector of the Bâsca River, new longitudinal hydrotechnical works (dykes from gabion mattress) are started (Photo 2). On the Bâsca River the project "Hydropower Siriu – Surduc Development", has been developed (being now in construction stage). This project includes a permanent water reservoir "Cireşu" on the upper part of the Bâsca River and an underground derivation "Surduc - Nehoiaşu", from Cireşu Accumulation, The Bâsca River towards the „CHE Nehoiaşu II" hydroelectric power station. This reservoir will mitigate the water volumes contributing to flood effects diminution.


**Photo 2 New hydrotechnical arrangements (gabion baskets) on the Bâsca River (august 10th 2010)**

## Non-structural measures

Non-structural measures are an alternative complementary to structural measures that may reduce the loss of human life and economics. These include: legislation, catchment managements, land and administrative urban planning, education, insurances, hydrologic forecasting and warning.

*Legislation*

Romania is currently in the process of implementing the existing UE legal framework on

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*Catchment management*

For water resources management, BI ABA establishes the *Management Plan of River Basin* (APRB) part of *The scheme for water settling and management.*

The APRB concerns quantitative management of water resources by reducing negative effects of extreme hydric phenomena (floods, drought, excess moisture, soil erosion). In the Bâsca Catchment APRB foresees hydrotechnical works for channel correction and Cireşu Dam Reservoir. In addition BI ABA elaborates the *Plan of defence against floods*[8]. It details the warning phases according to alert thresholds.

Warnings are successive started for h.s. from the river catchments, in relation to the alert stages and to precipitation thresholds for the sites without hydrometric stations.

*Land and urban administrative planning*

One of the reasons amplifying the negative effects of floods is human settlements exposure due to their location in the floodplains (Photo 3).


**Photo 3. Houses located in the floodplain on the right river bank of Bâsca, downstream Păltiniş Village (August 10th 2010)**

Urban planning policy, as an instrument for reducing associated effects of hydric risk is expressed by:

- zoning flooding areas and discouraging constructions in floodplains and
- technical advices regarding the land use.

The role of local public administration is to restrict approvals of new construction[9] in flooding areas and resettlement.

*Insurances*

An important factor for reducing the financial risk for individuals, enterprises, and even whole societies in case of natural hazards is the insurance (Kron, 2005).

In Romania, compulsory insurance of *dwellings* against the negative effects of *earthquakes, landslides or flooding* is a mandatory financial instrument binding from July 1st 2010. Insurance - stipulated by Law no. 260/2008 *regarding compulsory insurance of dwellings against earthquakes, landslides or flooding* (amended) - covers for obligatory insurance of € 10 or €20, depending on the type of construction and on the type of natural hazards (earthquakes, landslides and flooding). Cover limit is € 10,000 or € 20,000.

In the rural space, specifically to the Bâsca River Catchment, the basic problem in flood insurance is low financial power, underestimation and floods traditional cohabitation (a divine premonition).

*Forecasting and hydrologic warning*

Forecasting and warning systems must advance information allowing the population preparedness for the flood occurrence.

Monitoring of the Bâsca River flow regime is provided by 3 h.s. and of Bâsca Mică River by 1 h.s. Nowadays (2010), they are automated and integrated into the DESWAT (Destructive Water) project[10]. Thanks to flood forecasting and warning systems, it is possible to save human lives (Kundzewicz, 2002).

Hydrological warning at national scale is done through mass-media announcements. Informative Bulletins, Hydrologic newsletters (daily and monthly) and Warnings are elaborated by the NIHWM.

Pre-warning local systems and population warning in case of floods requiring evacuation consist of the audible alarm and church bells acting.

## CONCLUSIONS

Floods are the most common natural hazard in the Bâsca River Catchment. Their genesis is mainly pluvial and it is favoured by geographical physical features of the catchment, mainly by the morphometrical parameters.

The lithological structure, consisting predominantly of impermeable rocks, plays an important role. Flooding risk is magnified by anthropogenic intervention (construction in floodplains, improper land use etc.).

In order to reduce the flood risk in the Bâsca River Catchment, especially in its lower and middle

[8] Posted on the website of the "Romanian Waters" National Administration (http://www.rowater.ro).

[9] For a new construction *is mandatory* to obtain the *Construction Authorisation* according to Law No. 50/1991 (amended and supplemented), regarding the authorising and measures for construction.

[10] DESWAT aims diminishing the flood impact by assuring permanent hydrologic monitoring and floods prognosis.

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part, where there is the most concentrated population, both structural and non-structural measures have been initiated.

Structural measures include anti-erosion and hydrotechnical works. Due to their relatively advanced status of degradation, many of them require rehabilitation and extending works.

Non-structural measures represent a complementary support to the structural ones. They need to be developed so as to allow the population's adaptation to the flood risk and *living with them.*

For this, an increased attention should be given to: extending insurances, proper use of floodplains, training and educating of the population, improving hydro-meteorological monitoring and alert systems.

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