

QUALITATIVE ASSESSMENT OF FLOOD-INDUCED MATERIAL RISK IN CÂMPENI TOWN

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ABSTRACT. - **Qualitative assessment of flood- induced material risk in Câmpeni Town.** In this paper we present the results of a study aiming to make a qualitative assessment of flood- induced material risk on the Arieș River within the Câmpeni built- up area (without the constitutive vilages). In order to achieve our goal, we have used the Swiss assessment method, which 1) quantifies the hazard (in our particular case, the flood danger level) and 2) relates it with the vulnerability of the exposed elements. The results show that close to 1/3 of the build- up area is exposed to extreme floods, that is 532 934 m², out of which 73,8 % is of high risk, as a consequence of the catastrophic effects that an extreme flood (i.e., a flood with a return period smaller than 300 years) could generate. By periodically determine the flood- induced risk for given areas, protective measures can be taken accordingly to it, to insure a better risk management, with both economic and social benefits.

1. Introduction

In this paper we present the results of a study aiming to make a qualitative assessment of flood- induced material risk on the Arieș River within the Câmpeni built- up area (excluding the constitutive vilages).

In order to achieve our goal, we have used the Swiss assessment method (Loat & Petrascheck, within the Office Fédéral des Eaux et de la Géologie, 1997, cited by Stănescu & Drobot, 2002), which 1) quantifies the hazard (in our particular case the flood danger level) and 2) relates it with the vulnerability of the exposed elements.

2. Site description

Câmpeni Town (excluding the constitutive vilages) has a population of 5 238 inhabitants (according to the "Recensământul populației și locuințelor, 2002"), being the largest settlement in the mountain drainage basin of the Arieș river. The population consists mainly in young (0-19 years old) and adult (20-59 years old) persons (29 %, and 58.6 %, respectively).

According to the same source, the town has 962 housing buildings (out of which 50 are blocks of flats), constructed mainly between 1945- 1989 (621), but also before 1945 (189), or after 1989 (152). These buildings contains 1 661 households with 1 896 dwellings that include 4 748 rooms with a constructed area of 76 123 m².

As the potential flooded area includes most of the build-up area which comprised central and industrial zones, including the main socio- economic objectives and highly populated areas, a series of protective measures have been taken, as follows:

- Mihoiești flood detention reservoir, some 5 km upstream on the Arieș River, with a scanty flood retention volume (3,65 mil. m³);
- channelization works (rerouted and enlargement of river channel) and damming up of the Arieș river within the build- up area of Câmpeni Town, the height of the artificial levee's top being close to that of the 1981 spring flood (548,06 m a.s.l.);
- filling in of the lower areas.

In table 1 are given the morphometric characteristics and the annual mean values for the main hydrologic parameters of the Arieș catchment area at Câmpeni gauge station.

Table 1. Morphometric characteristics and annual average values of the main hydrologic parameters of the Arieș basin at Câmpeni gauge station

F (km ²)	Hmed (m)	Cp (%)	Ir (‰)	Qmed (m ³ /s)	Rmed (kg/s)
637	999	47	12,0	12,5	2,13

F- area, Hmed- mean altitude, Cp-forestation coefficient, Ir- mean slope of the river, Qmed- annual mean liquid discharge, Rmed- annual mean suspended load discharge

3. Risk assessment

Flood danger level. In order to assess the flood danger level, according to the Swiss methodology, the first step requires an estimation for the intensity of the flood.

Intensity, which can be rated as low, medium or high, is a function of 1) water depth and 2) output of the multiplication of current velocity and floodwater depth (Table 2).

Table 2. Flood intensity classes, defined by the water depth and/or the output of the multiplication of stream velocity and water depth (BWV, BRP, BUWAL, 1997, cited by Rudolf, 2006)

Intensity	water depth (m)	depth x velocity (m ² /s)
low	smaller than 0.5- practically person are not endangered; limited damages of buildings are possible	smaller than 0.5
medium	between 0.5- 2- persons outside of buildings are endangered; no seriously destructions, damages of buildings are possible	between 0.5 - 2
high	greather than 2 - persons inside and outside of buildings are endangered; seriously destructions of buildings are possible	greather than 2

The values of these two parameters are established in concordance with the level of damages and the danger induce by a flood on a person staying inside (or outside) a building, thus not being influenced by exceedance probability of the event.

The flood danger level is further calculated by combining the intensity of the flood with the return period of the event (Fig.1).

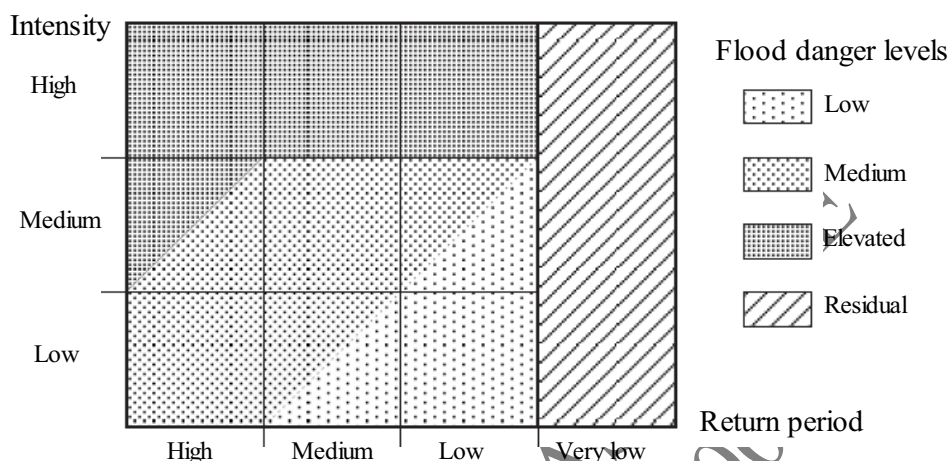


Fig. 1. Matrix for determining flood danger levels
(Loat, R., Petrascheck, A., 1997)

The recurrence period is divided in four main classes, as follows:

- high, for a flood with a return period below 30 years;
- average, with the return period between 30 and 100 years;
- low, with the return period between 100 and 300 years;
- very low, for extreme events, with the return period above 300 years.

To further calculate the flood danger level, we have:

- statistical analysis of the annual peak discharges series in order to establish the annual exceedance probability;
- mapped the area affected by floods in 1995 and 1981, established, in certain key-points, the depth of the floodwater and correlated the field data with the level outputs of statistical analysis. The fieldwork included identification of markers of the flood level (Fig. 2), video and photographic documentation, gathering informations from the local population and authorities.

We mention that the field data refers to present- day topographic situation, as after the floods, some low area were filled in.

In order to determine 30-, 100- and 300-year flood, we have used the "depth" criteria for spaces outside the river channel, and the output of the multiplication of stream velocity and depth water, for the inner sides of the levees (Fig. 3).



Fig. 2. Field identification of watermarks of the most important flood in the Câmpeni town: City hall building (left), private household (right)

To estimate the maximum discharge for each of the three flood scenarios (30-, 100- and 300-year flood), the maximum annual discharges for the 1978- 2005 period were analysed by means of statistics, using the Pearson III distribution. At Câmpeni gauge, the following values were obtained: 530 m³/s, 547,42 m a.s.l. (30-year flood), 752 m³/s, 548,11 m a.s.l. (100-year flood) and 940 m³/s, 548,80 m a.s.l. (300-year flood). As the “0” staff level has changed in time, the values for the corresponding levels to last mentioned discharge were extracted as absolute altitude (meters above sea levels), taking into account the limnimetric keys after the highest floods, the most recent limnimetric key (2007) and the hypsometric data from the hydrometric station’s cross section.

In case of 30-year flood, we have taken into consideration the most plausible scenario: we have assumed that the flood will not surpass the levee’s top, but regardless of that, in the build- up area both inundation (by upsetting of waste waters where the level of the sewerage’s lid is below the level of the floodwater), and outflows of the Caselor, Brătineasa and Joldoaia tributaries would occur as a consequence of the backwater generated at the confluence with the Arieș river. The flood’s intensity can’t have higher rate in condition of the stagnant water developed over more part of affected zone and low waterdepth. This scenario is close to the real situation during the 1995 flood, which had a relatively similar return period.

In the case of flood with return period than 100 years, apart from the above mentioned phenomena, the scenario also considers a slight surpass of the levee’s top, followed by slow filling- in of the precincts outside the levees.

When considering extreme floods (300-year flood) large scale surpass of the levee's top is stipulated, with intense erosive processes and breaches, all leading to rapid infilling of the low areas outside the banks. Under these conditions, in short time, the overflow water will be involved in the generalized flow process over the floodplain, the flood's intensity increasing with water velocity.

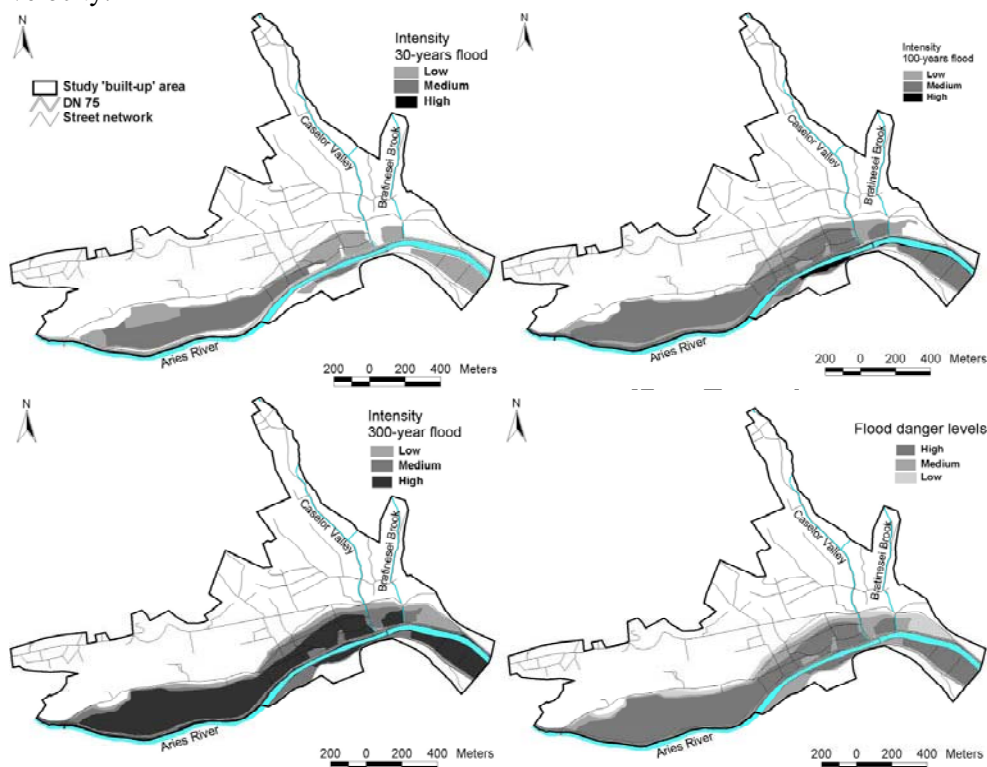


Fig. 3. Intensity classes of floods with a return period of 30, 100 and 300 years, and map of flood danger levels

From the total build-up study area of 1 775 439 m², close to 1/3 (i.e., 30%, equaling 532 934 m²) is susceptible to be affected by floods with a return period of 300 years. This would also be the maxima flooded area, which could only increase by a few percent in case of catastrophic flood events, with return period of 300-1000 years. Out of the 55,3 ha within the flooded area, 82.4 % (44.1 ha) is on the left side of the Arieș. The width of the flooded area is, within the build-up area, around 200 m.

By combining the classes of flood intensity with return period of event, we obtained the flood danger levels map (Fig. 3).

Vulnerability estimate. Difficulties in building a precise methodology to estimate the damages led the experts from CADANAV (CAstastre des DAngers NAturels du canton de Vaud- Suisse) to work out a qualitative- based assessment method, i.e., a simplified evaluation of the vulnerability, that allows the combination of the results with those obtained through the flood danger assessment.

The following steps are included in this method (Stănescu and Drobot, 2002, Table 3.13, p. 136- 137):

- assets analysis, which includes mapping and framing in seven categories (A- G), with the importance increasing from A class (for example: steppe, unexploited forest, mountain tracks etc), to G class (for example: buildings of special importance for emergency situations);
- each above defined categories is designated (according to the nature of effects during a flood event) a potential damage level (Table 3);

Table 3. The potential damages levels, for asset classes (Ronté C., 2003)

Potential damages levels	Material assets
low	A, B
medium	C, D, E
high	F, G

The objectives from Câmpeni Town, as classified in the above mentioned classes, are shown in figure 4.

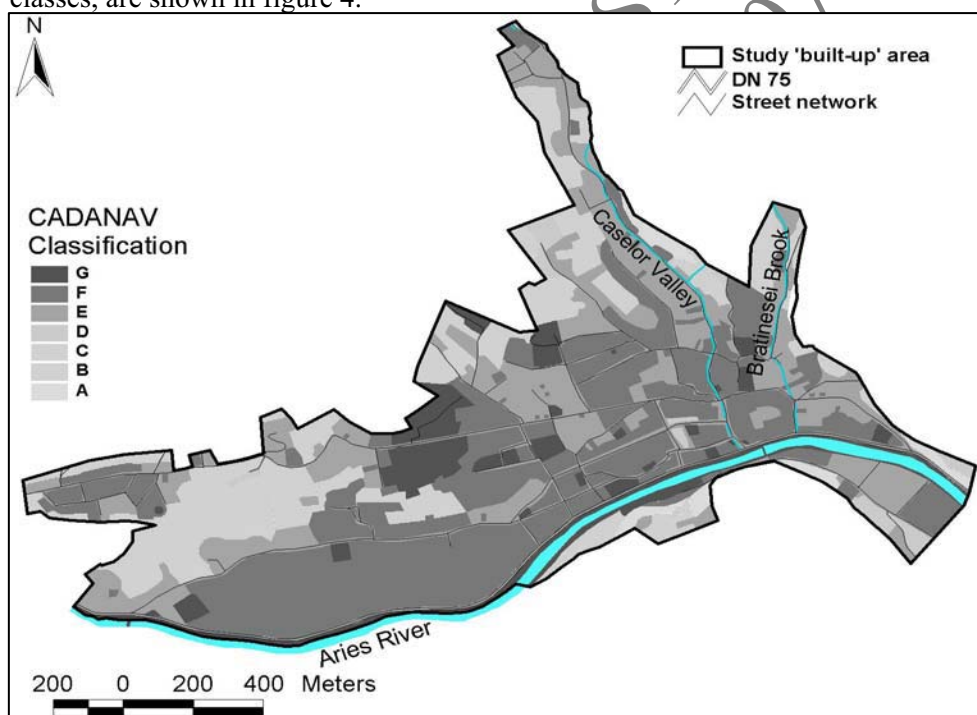


Fig. 4. The map of the types of objectives, according to the CADANAV

Hazardous material deposits, fuel stations, highly populated areas (bus station, schools, super markets) and all-important cultural goods (churches, museums) were considered objectives with high risk, while within the buildings of special importance during emergency situations were included the City Hall, the military base, Police, National Administration Romanian Waters, Sanitary Veterinary Direction, bridges and dams.

We mention that the objectives included in “class G” were considered together with the surrounding land, while in the case of those from classes F and E, the unconstructed areas over 1000 m² were mapped separately (e.g., gardens, orchards, pastures and meadows etc.).

Each category of objectives was designated different degree of potential damages, according to the methodology presented in table 2.

Qualitative assessment of flood risk includes both the flood danger level and the degree of potential damages. The combination of these two elements led to the establishment of six levels of risk (Table 4).

Table 4. Qualitative assessment risk matrix (Widmer, B, 2002)

Flood danger levels	elevated	3	5	6
	medium	2	4	5
	low	1	2	3
		low	medium	high
		Potential damages levels		

Our data shows that 9.63 % of the possibly flooded area has a minor degree of risk, 16.6 % an average one, while 73.8 % has a high risk of being affected by floods (Fig. 5). The large areas exposed to high risk are a consequence of the catastrophic effects which could come out of a 300-year flood that would have a peculiar intensity on areas of special importance (e.g., residential, commercial and industrial areas). The area including Arieșului, Oituz, and Libertății streets, The Forestry High School and the inner sides of the levees (Fig. 6) are the areas with high risk flood, the water level possibly reaching 2.5 m above normal level, while current velocity could overpass 3 m/s in places with reduced roughness close to the Arieș river.

Summarizing the results, solutions to limit the level of risk (and reduced it to a residual risk) can be proposed, as follows:

- maintenance and consolidation of the levees, in order to reduce their erosion and the possibility of breaching;
- reinforcement and raising of the Mihoiesti reservoir dam, in order to attenuate the extraordinary flood (from our perspective, this would be the most efficient solution for the municipality of Câmpeni);

- holding of constructions within the flood area, in order to maintain its initial function (attenuation of floods) and limit the artificial rising of water level;
- improvement of the efficiency of both forecast and warnings regarding floods;
- advertisement campaigns to increase the level of awareness regarding insurances for natural hazards;
- improvement of general education regarding emergency situations;
- acquisition of materials and emergency equipment;
- development of a volunteer team for emergency cases.

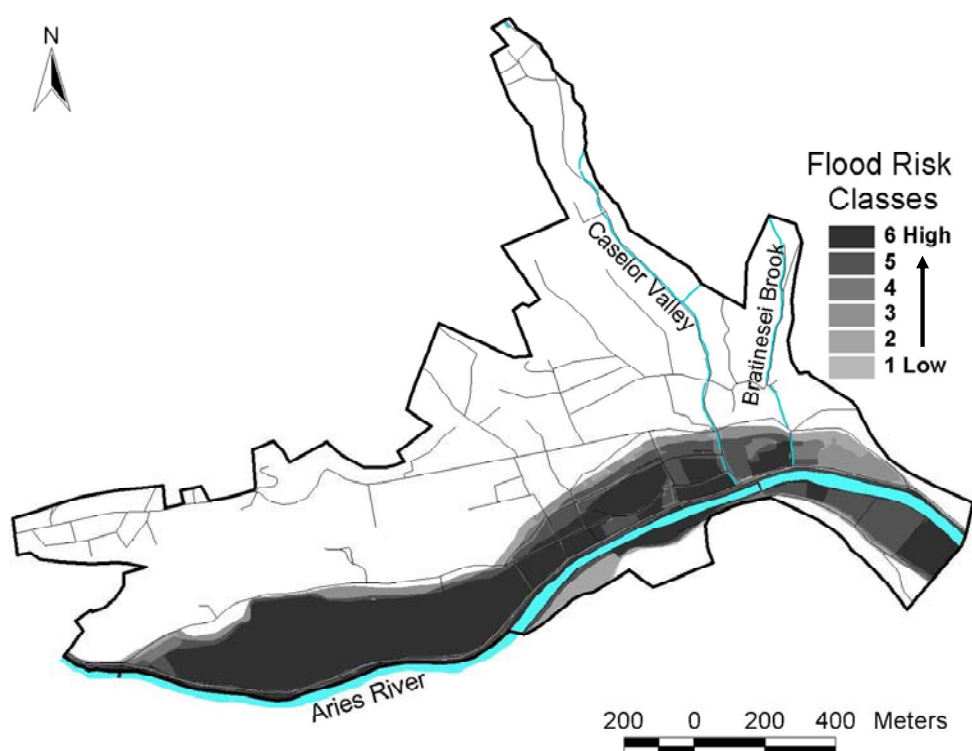


Fig. 5. The map of flood-induced material risk (Arieș river, Câmpeni build-up area)

Recurrent estimation of the flood risk for given areas is an important task, as supplemental safety measures can be adopted, respectively, a better risk management is assured, with both social and economic positive results.



Fig. 6. The areas with high flood risk within the build-up area of Câmpeni Town:
a. objectives on the left bank of the Arieș River: Arieșului, Oituz, Libertății streets;
b. objectives on the right bank of the Arieș River: Forestry High School, mill, slaughter-house

The flood risk map for Câmpeni Town is considered a useful tool for the immediate programming of the risk managing activities. Regardless of that, we consider that the issue of flood in the area can be further investigated in more detail, by increasing the resolution of studied area, periodic actualization of data and, more important, inclusion within the study also the small streams. Moreover, quantitative risk assessment is needed, by establishing a correlation between the intensity of the flood and the real cost of both affected assets/goods and specific losses.

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