

METHODS FOR ESTIMATING WATER FLOWS FROM STORMS AND MELTING SNOW – CASE STUDY

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ABSTRACT:

The paper presents a case study for the evaluation and comparison of three calculation methods in terms of taking the water flows resulting from storms and after melting snow for a metropolitan area, whose rainwater catchment system is the most often completely over run, with frequent flooding in the area. The study compares the results of three calculation methods by correlating the relationships and values used in the literature with the real situation determined on several calculation sections, on different water courses in the proposed area. Based on comparisons for the obtained results, the paper presents a series of conclusions that could be useful in urban systems projects.

2. INTRODUCTION

Obtaining a flood forecast is generally a difficult and fastidious process due to the complexity of the phenomenon (D. Stephenson, 1981) and for this reason there is no precise model on which to make estimates (Loumagne, C. et al., 1991).

There are many areas where heavy rains and storms during the warm period of the year cause heavy floods that are accompanied by various hazards such as landslides or damage to buildings and in extreme situations can cause psychological trauma and sometimes even death (C. Loumagne et al., 1988).

The snow layer is another important element that can lead to flooding (S. C. Colbeck, 1977), the height of the snow layer that settles in the cold period of the year, the evolution, structure, thickness and water equivalent, duration and melting rate in the spring (V. Ștef, et al., 2009).

Flood forecasting as well as methods of taking over the amount of water spilled also contribute to reduce the risk of floods (Murugesu Sivapalan et al., 2003). In monitoring the quantities of water from heavy rains, the following quantities are involved: rain intensity and frequency (Gu"nter Blo"schl, et al., 2008), length and collecting surface of the torrent, slope, vegetation (Zhang L, Dawes WR, Walker GR., 2001) and soil nature in terms of porosity but also water content, air temperature and soil as well as wind speed (Zhang L, Dawes WR, Walker GR. 2001).

This paper presents the calculation variants of water flows from torrential rains in summer respectively from melting snow in winter, both covered in a case study. The determination of water flows will be performed for an area subject to the risk of floods in case of torrential rains and/or storms. The knowledge of the flow values is necessary when choosing and dimensioning the systems for taking over the water surpluses coming from torrential rains or storms in order to prevent the occurrence of floods.

The main river that drains the area is the Mureș, with its tributary Ampoi and the torrents that descend from the Mamut hill. The surface of the Mureș River up to the objective section is 17421 km², the average altitude is 624 m, the general slope of the river is 2.0 m ‰, the sinuosity coefficient is 2.27.

The average leakage in the area is 0.5 ÷ 1.0 l/s·km² in the corridor area, but increases on the slopes of Mamut hill to 1.0 ÷ 2.5 l/s·km² on the right bank of the Mureș River. In the studied area (see fig. 1) nine torrential formations were inventoried. The hydrological regime of these torrents is characterized by large variations in fluid flows as well as an active transport of alluvium.

1. MATERIALS AND METHODS

1.1 Determination of water flows. Current situation

The studied area is part of the Transylvanian Plateau, being located at its contact with the Trascău Mountains.

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The territory is characterized by a complex structure and a pronounced fragmentation, the slopes extending to the Mureş riverbed, respectively Ampoi, through low terraces and well-developed meadows. The area in question is an integral part of the wide corridor of Mureş, respectively Alba Iulia sector. It is in the vicinity of Alba Iulia Municipality and the right bank of the Ampoi River in the area of Miceşti neighbourhood. The slopes are covered with deciduous forests, grassy meadows, vines and residential buildings. The air temperature in the corridor is maintained around 9°C, as a multiannual average value. In relation to this value, the extremes are between +39,7°C in nearby Alba Iulia and -31,0°C at the same weather

station. Precipitation is deficient in the area, the average multiannual amount being 550 mm / year. The maximum of averages occurs in June, the amount of precipitation is between $80 \div 85 \text{ l/m}^2$. The richest rainfall during 24 hours that occurred in Alba Iulia was 55,3 l/m² on 16.08.1949. In the calculation of the leakage was adopted the value of precipitation with a probability of exceeding 1% which represents 3,9 l/min/m².

The snow layer has heights of 25÷30 cm for a relatively short duration, respectively 5÷15 days/year by melting it contributes to the fulfillment of spring or winter floods (figure 1).

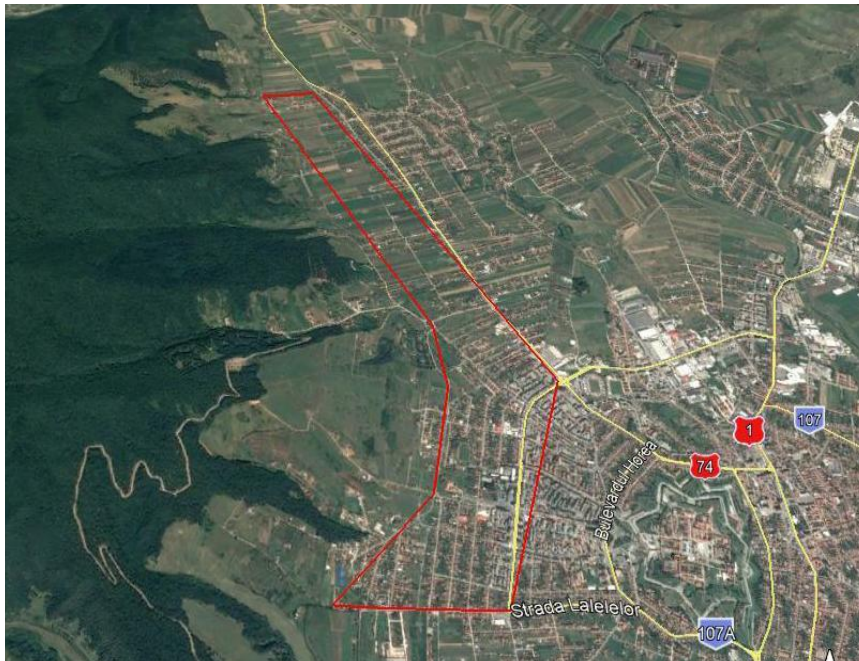


Figure 1. Area affected by floods

2.1 Flow evaluation according to hydro-municipal standards

The highest flows for the nine torrents in the region occur at the melting of spring snows, at their combination with the production of precipitation, at the rich summer rains. The main torrents analyzed in this study are presented in Table 1.

Torrent	Torrent length [m]	Surface [km ²]
T1	1000	0.431
T2	1250	0.795
T3	1000	0.445
T4	250	0.245
T5	2750	2.85
T6	2250	2.56
T7	850	0.427
T8	2000	1.05
T9	850	0.328

Table 1. Characteristic elements of torrents

The STEREO 70 coordinates for each calculation section are centralized in Table 2.

Section	STEREO 70 coordinates in the calculation section	
	X	Y
T1	38 74 68.199	50 82 22.857
T2	38 75 76.420	50 87 30.169
T3	38 77 67.436	50 90 63.604
T4	38 81 96.547	50 95 37.416
T5	38 76 86.461	51 04 22.147
T6	38 75 58.713	51 13 23.330
T7	38 73 64.476	51 19 31.734
T8	38 72 18.898	51 23 05.726
T9	38 71 47.914	51 24 86.239

Table 2. STEREO 70 coordinates in the calculation section

With the help of coordinates, the transverse and longitudinal profiles were drawn.

Transverse profiles

The banks are very sloping without a well-structured major riverbed. The time for collecting water from the slopes is

reduced due to the steep slopes. After leaving the high area, the transversal profile is widely developed, and on it were built residential districts of the city.

Longitudinal profiles

In the longitudinal profile, the upper part of the receiving basin is very inclined, an area where the drainage takes place at high speed, the concentration time in the riverbed being reduced. The lower part of the basin is characterized by relatively low slopes, the drain being already formed and with high speed of movement.

1st Method

Flow rates with flood probabilities of 1%, 3% and 5% were calculated for the STEREO 70 coordinates in table 2 of INHGA Bucharest, the values being presented in table 3.

Taking into account the physical-geographical conditions in the sections presented, the maximum flows with a probability of exceeding 1% were determined by generic calculations. The resulting values were verified using a synthesis relation, of the form:

$$q_{\max 1\%} = f(F) \quad (1)$$

The relationship is valid for the studied area and was obtained by applying the expeditionary method both in the studied basins

and in the neighbouring analogous basins. The generic relation by whom the flow rates with a probability of exceeding 1% were calculated is:

$$Q = K \cdot C \cdot I_{1\%} \cdot F \quad (2)$$

where:

K -transformation coefficient in the metric system, $K = 0.167$ for F in km^2 ;
C - leakage coefficient;
 $I_{1\%}$ -maximum precipitation at 1% probability of production, determined by INHGA's own methods;
F -the surface of the receiving basin in km^2 , (Ștefan Bilașco, 2007).

The obtained results and presented in table 4 that are calculated in natural flow regime at the level of the collector channel at the base of the slope of Mamut hill and at the exit of the torrents from the high area.

2nd Method

The second method use the relation (2) in which the values $I_{1\%}$ and $I_{5\%}$ were determined on the basis of Romania's regionalization maps (figure 2) and pre-calculated tabular values (C. Diaconu, P. Serban, 1994).

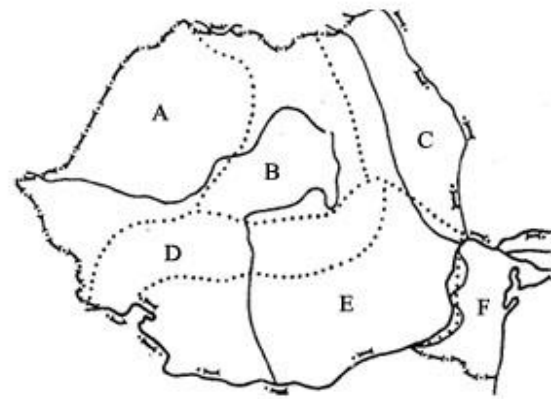
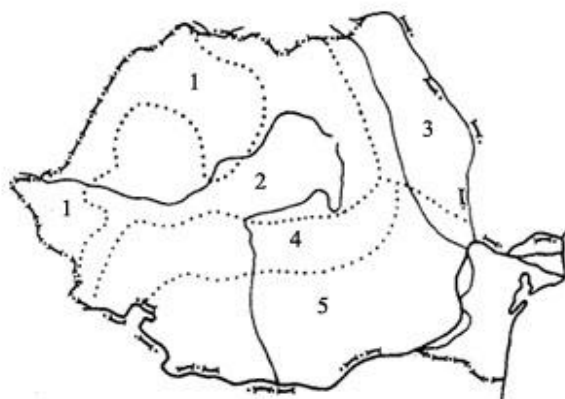


Figure 2. Regionalization of Romania

Alba County is in zone 2A for which the values $I_{1\%}$ and $I_{5\%}$ are shown in Table 3.

$I_{\%}$	t (hours)	Zone 2A
1	1/4	72,4
	1	117
	6	157
	24	201
5	1/4	52,9
	1	85,3
	6	115
	24	147

Table 3. Values for $I_{1\%}$ and $I_{5\%}$ for different periods t

The obtained results are presented in Table 4.

3rd Method

The third method consists in applying the relations from the Romanian Standard SR 1846/2, which is recommended for the design or verification of stormwater drainage systems in known processes: unitary, separative or partially separative.

The studied area, respectively the collection basins of this area were framed in sewerage basins with $S < 10 \text{ km}^2$ (1000 ha) (STAS 1846/2-2007).

The predicted frequency for rains is 1/5 and it was determined according to the location of the studied area (cities without flood control) and the predicted frequency for flooding (1 to "n" years).

In order to determine the flows in the calculation sections for each basin, the importance class of the water use for which the sewerage network is made (STAS 4273-1983), the precipitation regime, relief, drainage conditions, soil permeability, need for

defense were taken into account, in part or all of the channelled area against floods. In case of intensities higher than the intensity of the calculation rain, the establishment of the solutions takes place following some technical-economic analyzes.

$$Q_{\max} = m \cdot S \cdot \phi \cdot i_{p\%} \quad (3)$$

where:

m - flow reduction coefficient, due to the effect of rainwater accumulation in the sewerage network between the time of the onset of rain and the time when the maximum flow in the calculation section is achieved; the flow reaches the maximum value after filling the collectors and establishing a permanent flow regime up to the calculation section, dimensionless;
 S - the surface of the basin from which the water passing through the calculation section is collected [ha];
 ϕ - the surface of the basin from which the water passing through the calculation section is collected POT=30%;
 $i_{p\%}$ - average intensity of rain, with probability of exceeding $p\%$ (curve 18 IDF (STAS 9470-1973), in [l/s/ha].

The duration of the calculation rain for the first section (NP 133-2013) was determined by the relation:

$$t_1 = t_{cs} + \frac{L_1}{V_{a1}} \quad [\text{min}] \quad (4)$$

and for the following sections with the relation:

$$t_i = t_{i-1} + \frac{L_i}{V_{a1}} \quad [\text{min}] \quad (5)$$

where:

t_{cs} - surface concentration time, in minutes;
 L - surface concentration time, in minutes;
 V_a - the estimated speed of water flow in the incipient channel, considered, for a first calculation, between 60 and 120 m/min. If, the speed at full section resulting in the sizing of the channel, differs by more than $\pm 20\%$ of the speed initially adopted, the calculation shall be repeated by appreciating a new speed, equal to the speed at the resulting full section, until the above condition is met;
 t_i - the duration of the calculation rain in section i , located downstream of the sizing section of the canal, in minutes;
 t_{i-1} - the duration of the calculation rainfall in section $i-1$, located downstream of the previously dimensioned channel section, in minutes;
 L - the length of the channel section that is dimensioned, in meters;
 V_{a1} - the estimated speed of water flow in the sizing channel, in meters per minute; it must be chosen in such a way that it does not differ by more than $\pm 20\%$ from the speed of the full section resulting from the sizing of that channel.

Torrent	Surface [km ²]	1 st Method			2 nd Method			3 rd Method	
		1%	3%	5%	1%	3%	5%	1/5 zone 18	1/20 zone 18
T1	0.431	4.91	3.40	2.66	2.60	-	1.90	2.60	2.95
T2	0.795	8.42	5.80	4.57	4.80	-	3.51	4.30	5.44
T3	0.445	5.10	3.50	2.77	2.69	-	1.96	3.50	3.04
T4	0.245	3.22	15.70	12.60	1.48	-	1.08	1.50	1.68
T5	2.850	23.30	15.00	12.00	17.20	-	12.57	4.90	19.49
T6	2.560	22.00	6.60	5.29	15.45	-	11.29	4.30	17.51
T7	0.427	4.78	3.30	2.60	2.58	-	1.88	5.30	2.92
T8	1.050	9.73	2.60	2.10	6.34	-	4.63	2.10	7.18
T9	0.328	3.87	2.20	1.75	1.98	-	1.45	1.90	2.24

Table 4. Maximum flow values

Figure 3 shows graphically the results obtained by the three calculation methods presented above.

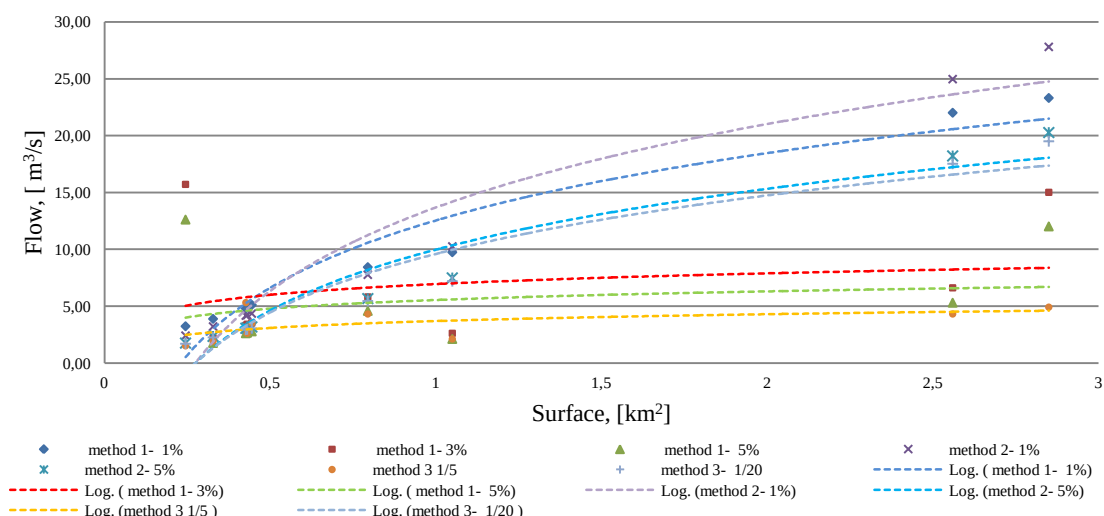


Figure 3. Graphical representation of the calculated values

3. CONCLUSIONS

The following conclusions can be drawn from the analysis of the values obtained:

- The highest values of the maximum flows were obtained with first method;
- The first method has the best accuracy in estimating water flows from storms and melting snow and offers the possibility of determining flows at various probabilities of their production;
- The differences obtained with the second method are due to the values taken from the specialized literature that are not updated; moreover, there is no possibility to determine the flow values for the probability of 3%;
- The third method is the classic method of determining meteoric water flows, in the development of the calculations we use readings from graphs and the adoption of coefficients that have been determined on an experimental basis and are not updated;
- Regarding the development of some localities that is taken place to hilly or mountainous areas, or in their vicinity, the topographic studies carried out in the phase of urbanism and landscaping projects must also include 3D models, which even if are of low design accuracy (10÷20 cm on the Z axis), still provides sufficient information to be used by hydrologists and designers of municipal sewerage and water systems that can assess non-permanent watercourses/torrents in the studied area and the work required to be designed for their takeover;
- Non-permanent watercourses/torrents, if neglected in urban studies, can lead to significant expenses for the implementation of measures to take over and manage them after the start of real estate or industrial projects. After overcoming the stage of elaboration of studies and starting the construction works, the solutions left at the disposal of investors or public administrations are, in most cases, extremely expensive;
- The determination of the torrents flow in various sections, of the floods with the related liquid and solid flows, from the neighboring areas of the construction assemblies of any kind, must be the subject of hydrological studies. Methods available to designers of hydro-urban works and roads should be used only for areas within the locality and with areas less than 0.40 square kilometers;
- The measures that are increasingly required are related to the use of landscaping systems as permeable as possible (pavements, green spaces, areas specially designed for water infiltration into the soil) in newly built complexes in order to reduce stormwater drainage costs;
- Unitary urban sewerage systems, which take in both domestic and rainwater, must be converted to divider systems, where economic and functional solutions cannot be found (while maintaining self-cleaning speeds) and the rainwater intake must be reduced as much as possible;
- Urban sewerage systems, regardless of their type, cannot take water from torrents on hills, hills and mountains in the vicinity of built-up areas due to their heavy loading with alluvium and extremely important flows, with huge differences between flows determined by hydrological methods and those by hydro-urban methods. In these cases, the urban systems, being dimensioned by hydro-urban methods, besides the fact that they will be undersized for the liquid flow, will be clogged in a short time with deposits, most of the times, extremely adherent to the sewer pipes and as a result very difficult to be removed by current operating methods. Ordinary hydro-urban arrangements for separating the solid fraction from rainwater cannot eliminate alluviums specific to the green area, not urbanized, with a strong adherent character. As a result, we

recommend, in these cases, the use of open channels for the discharge of these torrents into emissions.

Based on the comparisons, it was found that the previously reported Maximum Probable Precipitation (PMP) values were significantly underestimated. Moreover, a comparison with the value usually accepted for Romania for rainfall with 1% assurance showed that the proposed values could in turn have been underestimated (STAS 9470-1973).

In conclusion, given the findings presented above and climatic conditions of recent years in which high precipitation is occurring more and more frequently, it is recommended that the estimated values of the flows from precipitation, especially for hills torrents and mountains in the vicinity of built-up areas be calculated on the basis of the relation (2) with values of the updated experimental data and using specialized software tools (Mercado V. et al., 2015).

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