THE ANNALS OF "DUNAREA DE JOS" UNIVERSITY OF GALATI
FASCICLE IX. METALLURGY AND MATERIALS SCIENCE
Nº. 2 - 2017, ISSN 1453-083X

ANALYSIS OF THE FLOODS EFFECTS IN JUNE 2016 IN THE VORONET RIVER HYDROGRAPHIC BASIN

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ABSTRACT

The paper presents an analysis of the hydrological risk parameters registered in the Voroneț river basin. The studies and researches took place on the Voroneț River after the June 2016 floods. The research has taken into account the hydrological risk parameters of the last 20 years recorded in the Siret River Basin. The river basin of the Siret River has been affected by multiple floods in recent years. The floods have morphologically modified the minor and the major river Voroneț, a situation that influenced the floodplain areas in the urban environment and outside. The research analyzed the precipitation, the liquid flows (minimum, average and maximum), the way of formation and evolution of the floods, the volume of the damage produced, etc. The investigation of the precipitation volume indicated a number of factors that have prevailed over the last 20 years. The precipitation value was 71.6 l/m^2 in two days. The flow recorded in the downstream section of the river was 118.12 m^3/s (the probability of calculation is 1%). The processing of liquid flow data revealed more flood flows in the same year. The effects of the floods have brought about the excessive degradation of shore defense works (about 2600 m) on the Voroneț River located in the town of Gura Humorului, Voronet neighborhood and outside the city. The county road DJ 177D was degraded on 1600 m and two bridges were destroyed. Floods have resulted in the destruction of some economic and social objectives in the coastal area. The parameters of hydroclimatic risk highlighted by this research require special conditions for the design of works in the riverbed and the riparian area.

KEYWORDS: water scarcity, physical and apparent water losses, non-revenue water, pipe degradation

1. Introduction

Global climate changes are also present in Romania, where they have produced a number of direct influences on the hydrological cycle. The Romanian and Moldovan territories, in particular (the Siret and Prut basins), are situated in a hydroclimatic transition area characterized by more humid and moderately temperate ocean shades running from the western and continental regions with great thermal and pluviometric discontinuities, from the east [1, 2, 7].

At this stage there are changes in the annual distribution of precipitation and flows on hydrographic basins. The high value of the changes determines a significant hydroclimatic risk in the flow and river level evolution. Hydrological changes influence the behavior of existing buildings in the bed and riverine area [3].

The elements of hydrological risk affect the morphology of the minor bed, the stability of the bed constructions (bridges, regularization works) and the shore (shore defense works, dams). Hydrological risk elements affect the existing habitat in the minor and major river bed [1, 3].

Disastrous floods in recent years have caused significant degradation of the social and economic objectives of the riverside. The value of the damages has become very high, which requires large investments to be made for social and economic recovery. The effect of the changes can be immediately noticed or it occurs after a longer time [3].

The restoration of river regularization and river defense works depends directly on hydrological

parameters. The disturbance of the hydrological parameters determines the behavior of the regularization works and, implicitly, the conditions of the river habitat.

2. Material and research method

The research area is situated in the river basin of the Voroneţ River, a tributary to the right of the Moldavian River. The hydrographic basin is located in the relief area of the Oriental Carpathians, in the geomorphological unit of the Stanişoarei Mountains (Figure 1). The altitude is 510-750 m and on average 730 m [10].

In the area there are a series of heights, called obcines, such as Obcina Voroneţ, Obcina Bătrânei, Obcina Brusturosului, Hill of Monastery, etc.

Fig. 1. *Physical map of the Voroneţ study area* [10]

The Voroneţ River has the cadastral code XII-1-40-26. The Voroneţ River presents a series of tributaries such as streams and torrents: on the left there are the streams Maghernita, Brusturos, Slătioara, and on the right the brooks Varniţa, Moara, Râla, Poiana, etc. (Figure 2). The Voroneţ River basin has an oval shape with a surface of 35 km^2. The length of the Voroneţ River is about 10 km and the slope of 3.17% [6, 8].

The research material consists of documentation and field studies, namely:

- Topographic studies to highlight the morphological changes of the river bed and riparian area.
- Hydrological studies for the determination of flood wave parameters and river flow.
- Hydraulic studies for highlighting the forms of motion and the parameters of the hydrodynamic erosion phenomenon.
- Geotechnical studies in the location of destroyed targets to determine the parameters that have affected the degradation phenomenon.
- Safety studies for the construction of buildings in the bed and the riparian area of the Voronet river, etc.

Some of the studies were taken from the literature and others were elaborated for the situation existing in the river basin. Research has been carried out at the site of the degraded areas and has been part of a technical expertise [4].

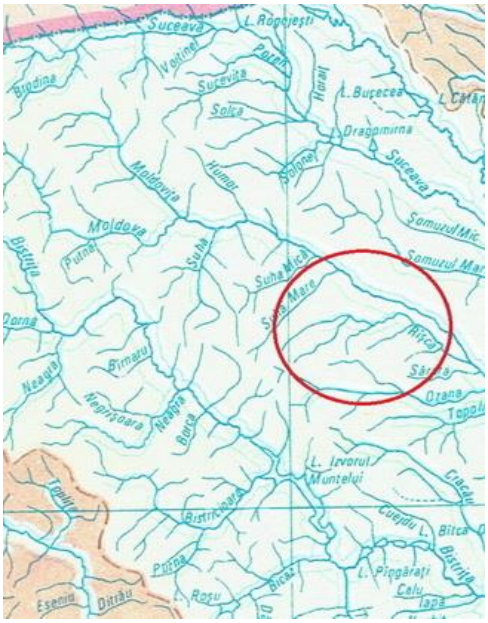

Fig. 2. *Location of Voroneţ river basin in the river hydrographic network of the Moldova river*

The theoretical and experimental research was carried out in the following domains [4]:

1. Research of hydrological parameters on the surface of the hydrographic basin considered in the study. Parameters analyzed are flows (liquid, solid), levels, frequency of floods, flood areas, etc.
2. Investigating the hydraulic parameters on the analyzed river section. Parameters analyzed are flows, levels, speeds, lengths and depths of erosion in the study sections located on the river.
3. Investigation of the hydrological risk parameters on the minor and major river bed morphology on the studied river sector.

4. Effect of risk parameters on structures and riverine habitat.

Primary data has been processed using statistical, hydrological, hydrological, resistance calculation software, applicable in this case study.

3. Results and discussions

The research was carried out on about 60% of the length of the Voroneţ River until it flows into the Moldavian River. The largest degradation of the bed and the riparian environment was recorded at this length. The sectors selected in the research are located in characteristic areas of the river basin as well as along the length of the river (Figure 3) and [4] respectively:

- Sector E1, the confluence of the Voroneţ River and the Slătioara brook (Camp Cristea area);
- Sector E2, the parallel route between the river and the county road DJ 171D;
- Sector E3, the confluence of the Voroneţ River and the Brusturos brook;
- Sector E4, Schit area;
- Sector E5, the parallel route between the river and the county road DJ 171D in the Voronet Monastery area;
- District E6, the urban area with degradation of the bridge and the riparian area;
- District E7, the intravilan area with riparian degradation.

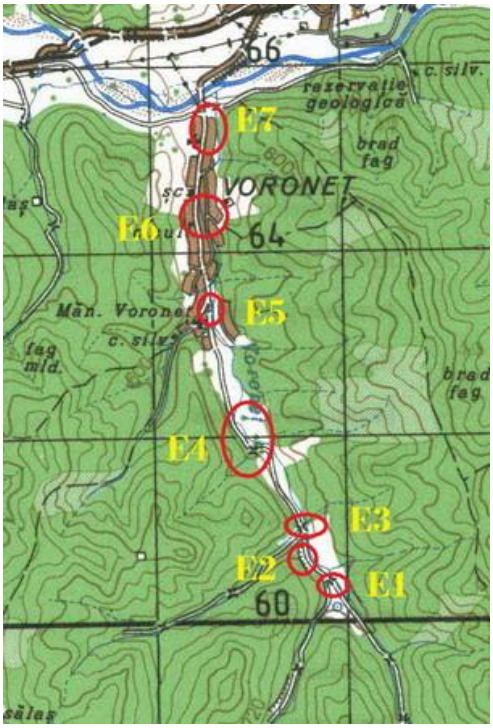

Fig. 3. *The location of the research sectors on the Voroneţ river* [4]

In the research we used climatic data taken from meteorological stations located in the analyzed river basin. Meteorological data were taken over varying time intervals (from 5 years to 45 years). Hydrological data were not collected because of the absence of hydrometric stations located on the Voroneţ River. The data from the hydroclimatic risk periods were analyzed by considering the data over a long period of time.

The Voroneţ River presents an ellipse-shaped river basin, which allows a rapid concentration of the flow (Figure 4). The erosive action of the water has made a minor bed with variable widths, where erosion, meandering and alluvial deposits occur. The river bed is characterized by intense morphological transformation over time.

For collecting data on the Voroneţ River, the meteorological station and the hydrometric station of the city of Gura Humorului were used. In May and June 2016 an abundant precipitation regime was recorded in the Voroneţ River Basin. The precipitations in the area with the highest value occurred during 18-20 of June. The values recorded at the Meteorological Station Gura Humorului were 71.6 l/m^2 [7].

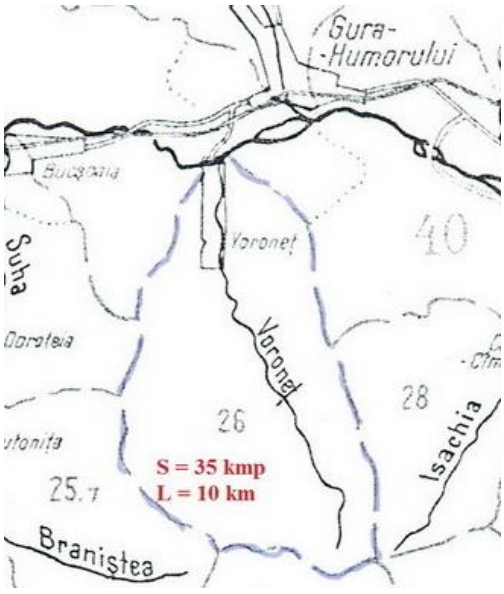

Fig. 4. *The Voroneţ River Basin* [6]

The Voroneţ River does not have a hydrometric station. Maximum flows were analytically determined. The maximum flow rate of 1% for hydrographic basins larger than 10 km^2 was determined by the rational formula [5]:

$$Q_{1\%} = \frac{K \cdot \alpha \cdot I_{60\,1\%} \cdot F}{(F+1)^m} \qquad (1)$$

where: k = 0.28 is a rainfall transformation coefficient of mm / hour in m / s and the area in km^2 in m^2; α - global leakage coefficient; I60 1% - maximum hourly rainfall with 1% probability of exceedance; F - the area of the basin in km^2.

The parameter values in relation (1) were taken from [5] according to river basin characteristics. For the geographic area considered to have a surface area of 32 km^2, the values were: I60, 1% = 125 mm, α = 0.55, m = 0.49. From the calculations, the flow with 1% probability of calculation in the downstream area of the river, respectively Q1% = 118.12 m^3/s [4], was obtained.

The mean altitude of the river basin was 728 m (in the middle section it was 789 m) [4].

The Q1% flow rate was also determined in the middle section of the watercourse (Camp Cristea area), where the first degradations were recorded on the riparian buildings; the resulting value was 71.61 m^3/s. This flow was not fully taken over by the Voroneţ brook, aspect also revealed by the spills on the two banks, but also the important changes of the minor bed. The average multi-annual flow rate is 0.325 m^3/s.

The simulation and verification of flood flows on the Voroneţ River with the probability p = 1% for the flood in June 2016 are presented in Table 2.

Table 1. *Flow Q1% calculated and estimated on the Voroneţ River during the June 2016 flood* [4]

Nr. crt.	S (km^2)	Q_c (m^3/s)	Q_{sp} (m^3/s)	Q_{re}* (m^3/s)
	36.0	118.12	141.74	130.0
	14.6	71.61	85.93	68.0
*- source ABA Bacău 2016				

The precipitations concentrated in a short period of time influenced the water flow in the Voroneţ basin. The floods caused by the Voroneţ River were intensified by the rapid discharge of the water from the slopes by torrential formations (eg. the Brusturosu stream). The concentration time was reduced by the circular / oval shape of the river basin.

The streams have carried alluvial material made of stone (medium and large dimensions), alluvium and forest material. The forest material was variable and even large, so the erosive effect on the bedside, bridges and shores was important. At the confluence and bridge areas there have been bottlenecks and narrowing. The blockages have led to discharges in the coastal area occupied by dwellings, agricultural land, sights, roads, etc. [1, 4].

Fig. 5. *General view of the Voroneţ River shore erosion at the limit of the road DJ 177D in the downstream area after the flood of June 2016 (photo Aug. 2016* [4]*)*

a

b

Fig. 6. *Details of the Voroneţ River's erosive action on the left bank and the road DJ 177D: a - the beginning of the deforestation degradation and the erosion of the road (downstream "Camp Cristea"); b - the end zone of the eroded road section to the slope (upstream of the Brusturos Brook)* [4]

The forestry and stone materials were carried outside the Voroneţ River bed and caused degradation phenomena of the riparian objectives (dwellings, agricultural land, tourist areas, water catchments, etc.). In some areas, the shore was eroded at depths of 2-5 m. A number of citizens' goods were taken by the floods from the bed and transported downstream [1, 4, 9].

The effects of the flood in June 2016 along the Voroneţ River are multiple. The most significant degradations are represented by the following [4]:

- structural degradation of the county road DJ 177D on a length of 1500 m and breaking it on a length of 400 m (Figure 5 and 6);
- partial and total degradation of the bridges (5 bridges), of the footbridges (17 footbridges) and of the pedestrian bridges along the river's length affected by the flood;
- the degradation of shore defense works in urban and out-of-town areas;
- the erosion of the bank in urban and out-of-town areas, a situation that affected individual riverine properties;
- the morphological modification of the river bed by sectors, with the change of flow paths;
- material and human losses.

The river banks were eroded (2600 m of shore) and the bed was morphologically transformed (Figure 5) [4, 9].

The county road DJ 177D was degraded on a route from the Voroneţ district to the "Camp Cristea" area. The county road is parallel to the Voroneţ riverbed on this route at distances of 1.0-45 m. The degradation forms are represented by the erosion of the marshalling with the entrance to the structure and its breaking on the differentiated length [4].

The county road was degraded to a length of 1500 m. High intensity hydrodynamic erosion led to the degradation of the road 177 177D, until its total destruction over a length of 400 m (Figure 6). This situation caused the interruption of traffic over a period of time. The river advanced to the shore, then into the road until it touched the slope (Figure 6.a). The phenomenon has been accelerated by the river's curvature area, the absence of shore defense and the geotechnical constitution of the land.

The reduced dimensions of the Voroneţ River flow section in the degradation area, as well as the absence of shore defense works, were the factors that allowed excessive road erosion. Old shore defense works have been degraded and no longer have a functional role in the transit of floods (Figure 5). The hydrodynamic erosion phenomenon of the bed has led to the lowering of the foundation quota of the shore defense constructions. The absence of rehabilitation works has led to a decrease in the protective capacity of shore defense works [3].

Fig. 7. *Detail regarding the Voroneţ River's erosive action on the river and the road in the Voroneţ Monastery area* [4]

a

b

Fig. 8. *Details of Voroneţ erosive action on the riverbed and its impact on the riparian area: a - bank erosion and damage to a dwelling construction; b - morphological modification of the bedrock with excessive erosion of the left bank* [4]

The reconstruction of the county road must be correlated with the design and execution of shore defense works on the affected river sector.

The section of the riverbed in the area of the Voroneţ Monastery has been affected by erosion phenomena, with an extension in the county road structure. Coastal defense works are degraded and aged without rehabilitation and upgrading. About 2.77 km of coastal defense were degraded by the flood of June 2016 [4].

The alluvial material (large stone, ballast, forest waste, etc.) driven by floods degraded the individual properties located in the river area (tourist hostels, dwellings, pedestrian bridges, agricultural land, etc.).

The degradation of the properties was favored by the non-observance of the law on the distances and the location of the constructions in the riparian area (Figure 8) [4].

The flood from the torrent Brusturos degraded the forest road on about 200 m, and the bridge at the confluence with the river Voroneţ was destroyed. The alluvial transport of the large stone-water mixture eroded the banks and the forest road.

The field analysis has highlighted the blocking of the section of the bridges, footbridges, pedestrian bridges, and small-scale areas. In this context, the transit of water and alluvial material was made over the bridge, the road and the neighboring areas of the minor and major beds.

The destructive phenomena have been of great intensity, over an important length of the river, and the damage is important and requires large investments for remediation.

Floods are a pollutant transport vector that transforms local pollution into regional and trans-regional pollution.

The analysis carried out in the Voroneţ river basin has revealed a number of hydroclimatic risk factors, namely:

- precipitation concentration on short intervals (1-2 days);
- the high frequency of torrential rainfall over short intervals (in the same month);
- reduced river bed capacity for floods with high flows;
- morphological modification of the river bed, erosion of the shore and shore, blocking of the bed, etc.;
- erosion zones adversely affect the stability of buildings and installations in the riverbed;
- increased transport of forestry material to the bedside because of uncontrolled deforestation.

4. Conclusions

1. The territory of the Voroneţ catchment area has been affected in the last 15 years by disastrous hydrological phenomena, which have significantly influenced the morphology of the riverbed, with important influences on the riverine environment. Flood damage has required large investment funds for rehabilitation.

2. During the period 2004-2017, a series of floods with high flow rates but also with high frequency at reduced intervals occurred in the Siret basin which caused morphological changes of the bed and degraded the regularization and shore defense works.

3. The floods produced in June 2016 on the Voroneţ River recorded flows with the probability of 1%, a situation that caused extremely destructive effects on the riparian area.

4. The Voroneţ river flow from June 2016 caused important degradations on the county road in the "Voroneţ Monastery" area, exemplified by the erosion of the bank and the road, as well as the damage of the coastal constructions.

5. The climatic phenomena produced in the Voroneţ river basin over the last 5 years can be characterized as hydroclimatic risk phenomena because of their destructive influence on the coastal area occupied by the dwellings, the county road and the morphology of the riverbed.

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