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HYDROMETEOROLOGICAL MONITORING IN WEST MORAVA RIVER BASIN (SERBIA)

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Abstract: Due to the unfavorable environment conditions that Serbia, and mainly Čačak, have been experiencing in the last few years (such as frequent floods, droughts and fires), as well to the particularly underdeveloped monitoring system that can't properly envisage and prevent such situations, it is essential for Serbia to get familiar with the application of new and up-to-date technologies in this field. This paper has the aim to analyze the situation in the area of Čačak, in particular in the West Morava river basin, to collect data about the hydrometeorological monitoring standards in Serbia and the methodology of monitoring the main hydrometeorological parameters. The paper shows some climatic trend with the data available for precipitation and runoff in the area of West Morava river basin. The results of the research can contribute to the prevention of floods in the West Morava river basin.
Keywords: hydrometeorological monitoring, West Morava river, rainfall and runoff regime

INTRODUCTION

Streamflow serves man in many ways. It supplies water for domestic, commercial and industrial use; irrigation water for crops; dilution and transport of wastes; energy for hydroelectric power; transport channels for commerce; and a medium for recreation. Records of streamflow are the basic data used in developing reliable surface water supplies because the records provide information on the availability of streamflow and its variability in time and space. The records are therefore used in the planning and design of surface water related projects, and they are also used in the management or operation of such projects after the projects have been completed.

Streamflow records are also used for calibrating hydrological models, which are used for forecasting, such as flood forecasting. Streamflow, when it occurs in excess, can create a hazard and floods caused extensive damage and hardship. Records of flood events obtained at gauging stations serve as the basis for the design of bridges, culverts, dams and flood control reservoirs, and for flood plain delineation and flood warning systems. Likewise, extreme low flow and drought conditions occur in natural streams, and should be documented with reliable streamflow records to provide data for design of water supply systems. It is therefore essential to have valid records of all variations in streamflow. In May 2014 Serbia was hit with floods and as a consequence, the importance of an efficient hydro meteorological and environmental monitoring system in strategic areas, as that close to Čačak, became vital [1-2].

West Morava river basin includes a significant part of the western and southwestern Serbia, and covers an area of 15,805 km2. From a morphological point of view, in the basin stand mountains, plateaus and valleys. The highest point on the mountain basin is Hajle (2400 meters above sea level), while the lowest part of the West Morava river is 127 meters above sea level. Measured from the source West Morava is 208 km long. The average width of the river is about 35 m, with maximum depths of up to 4 meters. The bottom frame is changed depending on the surface of the terrain through which it flows, and can be rocky, gravelly, and sandy to muddy the downstream part of the course. The highest mountains in the basin are Kopaonik (2017 m) and Mokra Gora (2155 m). High mountain formations occupy the western, northern and central parts of the basin, while the lower formations are in the south. A regards valleys and ravines, in the West Morava river basin we found the greatest depression Polje, in Kosovo. In the river basin take place different valleys: Part of the basin around the lower courses of the West Morava has the characteristics of plain hilly terrain. This paper shows the results of hydrometeorological monitoring in West Morava river basin on the basis of available hydrological data as well as forecasts that can be expected in the future [3].

MATERIAL AND METHODS

The rating curve, also known as stage-discharge relation, is the empirical or theoretical relationship existing between the water-surface stage and the simultaneous flow discharge in an open channel. The rating curve is a very important tool in surface hydrology because the reliability of discharge data values is highly dependent on a satisfactory stage-discharge relationship at the gauging station. As regards the determinations of rating curves in different section of West Morava river, it is used the method with flow equations of hydraulics. The stage-discharge relation for open-channel flow at a gauging station is governed by channel conditions downstream from the gauge, referred to as a control. Generally, the flow in this area is controlled by a section control that is a specific cross-section of a stream channel, located downstream from a water level gauge that controls the relation between gauge height and discharge at the gauge [4].

The table 1 shows the Manning's coefficient used to estimate the value of the discharge for each station on West Morava river and rating curve's equations defined by the Ordinary Least Squares method.

Table 1. Manning's coefficient and rating curve's equations in different section of West Morava river

Station name	Manning's coefficient n ($m^{-1/3}s$)	Equation
Jasika	0.036	$Q=63.67(h-136.93)^{1.76}$
Trstenik	0.038	$Q=74.42(h-159.81)^{1.94}$
Miločaj	0.050	$Q=59.53(h-194.89)^{1.58}$
Kratovska Stena	0.038	$Q=20.57(h-292.22)^{1.81}$

For the station in Čačak we have a detailed rating curve and the profile of the control section used to calculate the dependence of the discharge from the stage values. This control section is situated in correspondence of a bridge, not too far from the bridge where the stage instruments are set. Figure 1 shows the rating curve for the station in Čačak.

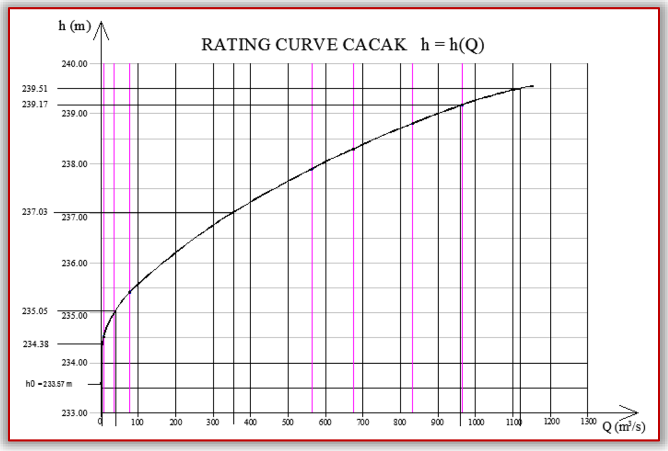

Figure 1. Rating curve for the station in Čačak

The flow duration curve is a plot that shows the percentage of time that flow in a stream is likely to equal or exceed some specified value of interest. Although the flow duration curve does not show the chronological sequence of flows, it is useful for many studies. It can be used to show the percentage of time river flow can be expected to exceed a design flow of some specified value, or to show the discharge of the stream that occurs or is exceeded some percent of the time. A flow duration curve characterizes the ability of the basin to provide flows of various magnitudes. Information concerning the relative amount of time that flows past a site are likely to equal or exceed a specified value of interest is extremely useful for the design of structures on a stream [5].

The shape of a flow-duration curve in its upper and lower regions is particularly significant in evaluating the stream and basin characteristics. The shape of the curve in the high-flow region indicates the type of flood regime the basin is likely to have, whereas, the shape of the low-flow region characterizes the ability of the basin to sustain low flows during dry seasons. A very steep curve (high flows for short periods) would be expected for rain-caused floods on small watersheds. Snowmelt floods, which last for several days, or regulation of floods with reservoir storage, will generally result in a much flatter curve near the upper limit. In the low-flow region, an intermittent stream would exhibit periods of no flow, whereas, a very flat curve indicates that moderate flows are sustained throughout the year due to natural or artificial streamflow regulation, or due to a large groundwater capacity which sustains the base flow to the stream [6].

For the station in Čačak, are available the daily value of discharge for the years 1991, 1992, 1993, 1999, 2002, 2003 and 2005. Figure 2 shows the average duration curves for all the period and the characteristic values for the monitoring stations in Čačak.

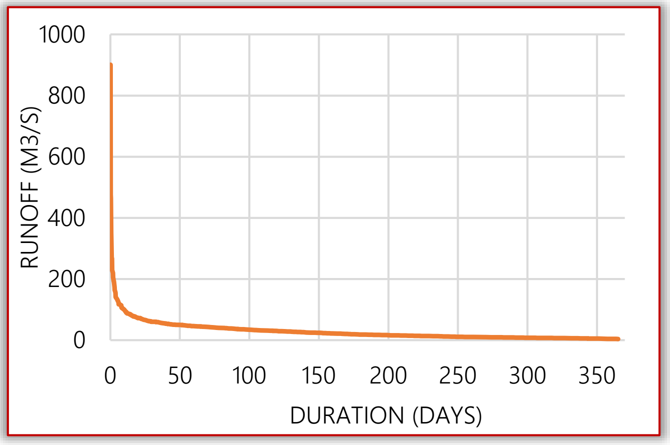

Figure 2. Flow duration curve and characteristic Q values for the station in Čačak

Table 1. The characteristic Q values for the station in Čačak

Discharge	Value (m^3/s)
Q_{max}	901
Q_{min}	3.8
Q_{91}	36.5
Q_{182}	18.4
Q_{247}	9.4

RESULTS AND DISCUSSION

The probability distribution of annual maxima it's a procedure to estimate the maximum water flow for a fixed time return period, starting from hydrometric observations. A series of maximum observed flow forms, on a statistical point of view, a sample of all the possible values that flow can have, so it is the so called population. The probability distribution functions most used in the hydrological practice for fitting the values of extremes, as annual rainfall and runoff maxima, are the lognormal distribution and the Gumbel distribution.

For that purpose we will use the Gumbel distribution, also known as distribution of extreme values type 1 (EV1). For the station in Čačak, the analysis on the annual maxima, is made with a series of 21 data. In some cases there is just the value for river level, so we calculate the discharge with the rating curve. The Figure 3 shows the probability distribution for this station. We calculated also the maximum flow for fixed return period of 5, 10, 20, 50, 100, 200, 250, 300 and 500 years.

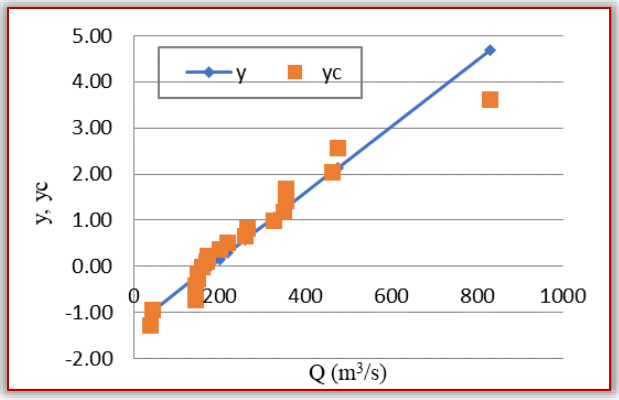

Figure 3. EV1 Gumbel for Čačak station

Table 2. The maximum flow Qc values for Čačak for fixed return periods

T in years	Qc in (m^3/s)
5	386.7
10	491.1
20	591.3
50	720.9
100	818.1
200	914.9
250	946.0
300	971.4
500	1042.6

Figure 4 reports the variability of the flood peaks as a function of the basin area. We can see that the experimental points can be approximated as a linear function.

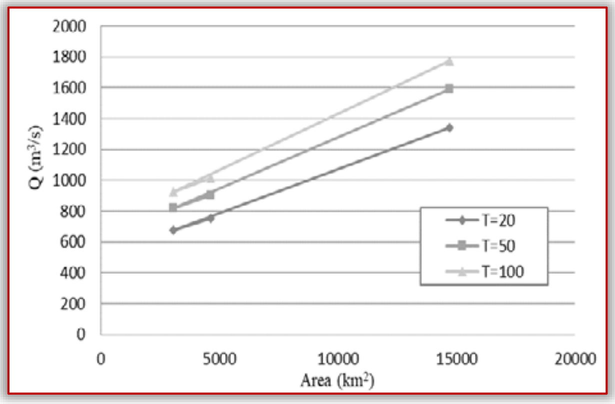

Figure 4. Variability of the T-quantiles of flood peaks as a function of the West Morava river basin

About the characterization of the climatology in this area, we have to discuss some results from specific statistical tests. In order to assess a possible trend in the historical series considered in the analysis, several statistical tests are available in the literature: among them, Mann Kendall (MK) and Spearman's rho tests are widely used. These tests are nonparametric test, one of their primary merits being that they do not assume that the data under analysis were drawn from a given distribution.

MK test was selected in our analysis since it has been extensively used in hydrology; on the other hand the performances of MK and Spearman's rho tests are almost identical in terms of power. To compute a trend slope of the runoff series, we used the Sen Theil test for the estimation of the regression line [7].

From the obtained results for the stations Miločaj and Jasika, the values for both the tests Man Kendall and Spearman are out of the confidence interval. In fact, the values are both less than 1.76 (for Miločaj is -2.153 the Man Kendall and -2.121 the Spearman and for Jasika is -2.296 the Man Kendall and -2.289 the Spearman), so it means that there is a significant decreasing in the runoff regime. For the other station Kratovska Stena, the nearest station to Čačak city, the results of tests and the linear trend show a constant trend with small scraps.

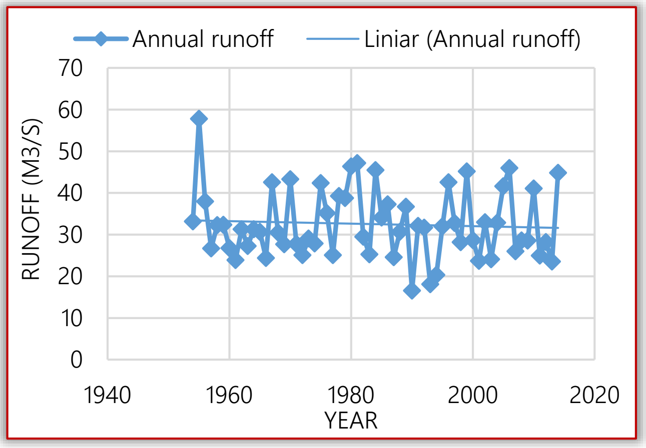

Figure 5. Linear runoff trend for Kratovska Stena station

CONCLUSIONS

Rainfall and runoff regimes in the West Morava basin were investigated to understand the hydrology of this catchment in view of the improvement of its hydrometeorological monitoring system. Monthly rainfall and runoff data were analyzed to detect regimes and trends. It was observed that for two out of five rainfall stations a significant increasing trend results from the application of Mann-Kendall and Spearman statistical tests. Runoff data exhibit that for two of the three runoff station with an enough big range of data, there is a significant decreasing trend results from the application of Mann-Kendall and Spearman statistical tests. To make some conclusions about this work, it is necessary also to underline that the monitoring in the city of Čačak is not exhaustive. This entails that it's very difficult to prevent some dangerous situations. The installation of a meteorological and hydrological station in the city of Čačak will help, in the years, having a more complete perspective of the meteorological and hydrological situation in the area, in particular in the West Morava river basin.

Acknowledgements

This work is part of the HYdrometeorological Modelling for Environmental qUalitycontRol, HYMEUR project. This project takes place thanks to the Central European Initiative (CEI) project connected to Know-how Exchange Programme (KEI), between the University of Brescia and the University of Kragujevac. The project is financed by the CEI found at the European Bank for Reconstruction and Development (EBRD) contributed by Italy.

Note

This paper is based on the paper presented at 7th International Conference Industrial Engineering and Environmental Protection 2017 – IIZS 2017, organized by University of Novi Sad, Technical Faculty "Mihajlo Pupin", in Zrenjanin, SERBIA, 12 – 13 October 2017.

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ISSN: 2067-3809