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THE STUDY OF HYDROLOGICAL REGIME MODELING USING HEC-RAS MODEL. CASE STUDY RIVER BASIN BAHLUEȚ

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Abstract

This paper presents the results of a hydrological simulation using HEC-RAS model within the Bahlueț river basin. In this study, the basin was modelled from the headwaters to the Târgu Frumos hydrometric station. 6 date profiles were processed between the source and Târgu Frumos hydrometric station. Precipitations were measured directly at the 2 stations considered, Cârjoaia and Târgu Frumos. Data recorded by rainfall stations over 3 days, in May 2021, were taken into account for hydrological modelling. Values reach up to 175 mm/h were recorded during the rain. At the Târgu Frumos station were recorded rainfall values of 12 mm/h, which proves the heterogeneity of the rain. Also, it is observed that the rain starts in Târgu Frumos around 16:00, stopping around 18:00. The rain continues measured at the Cârjoaia rainfall station from 18:40, with values of 175 mm/h being recorded. The data recorded at both rainfall stations shows that the river basin is subject to a variable rainfall in space and time.

***Key words**: hydrological simulation, HEC-RAS, precipitations, runoff.*

INTRODUCTION

Water is one of the fundamental resources for life. The occurrence of extreme events such as droughts and floods, resulting from land use and climate change, has increased in recent decades. Over the years, land use has changed through: expansion of agriculture, increased deforestation, intensive grazing and increased urbanisation. Understanding the associated effects of land use and climate change on water resources is of paramount importance for prevention and mitigation actions.
Many studies have focused on understanding the relevant hydrological processes to create flood risk management plans. Knowledge of the different hydrological variables is an important aspect for the proper management of water resources. In this way, researchers in different fields have improved and implemented several tools related to water resources, including hydrological models.
According to Abbaspour et al. (2015), hydrological models are important for planning water resources to meet various demands by helping in their sustainable use. Hydrological modelling is the mathematical modelling of the rainfall-runoff process on slopes, resulting in a hydrograph of flow in the closing section of a catchment.
Hydrological modelling predicts the runoff from rainfall in a catchment and hydraulic modelling aims to assess the area flooded by rainfall.
Regardless of their degree of complexity, hydrological methods have at least one thing in common: they cannot do without the information provided by measurement networks, and their performance is closely linked to the availability of data (in time and space).
Flood hazard maps provide information on the extent of flooded areas, water depth and, where appropriate, water velocity, for floods that may occur over a given period. These maps are produced using various techniques such as hydrological and hydraulic modelling based on detailed mapping of the river and major riverbed.

MATERIALS AND METHODS

The study was carried out on the Bahlueț catchment which has a cumulative area of 551 km², Figure 1.
The average rainfall in the basin is 502.3 mm at Târgu Frumos and the annual temperature is 9.1°C. Hydrometrically, the basin has a temperate continental climate with cold winters and warm summers with more frequent winds from the NW in winter and from the SE in

spring. This climate is characterised by heavy rainfall in early summer, which generates flooding, but also has periods of dry season.

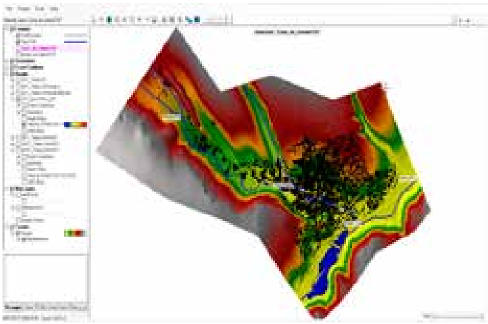

Figure 1. Area of interest under study

Seasonal precipitation losses occur in this area as surface fluxes: winter: 13.96%, spring 48.62%, summer 27.58%, autumn 9.84%.

The city of Târgu Frumos, due to its geographical position, is vulnerable to flooding. The Bahlueț River is the subject of the present study, constituting a potential hazard for the city and its surroundings. It is in this perspective that this study comes to create and manage the database on flood risk in the Bahlueț basin.

The chosen approach involves a hydrological study, the choice of profiles and the construction of a model using the most common free modelling software HEC-RAS (Hydrologic Engineering Center - River Analysis System).

For the catchment under consideration for which recorded flow data were available, the program provides, from local rainfall data, the calculation of rainfall in the catchment and its transformation into flow by HEC-RAS.

In this study, hydrological modelling was performed with the HEC- RAS 6.0 program with two-dimensional version and according to the following methodology:

1. Preparation of topographic data. Topographic data provide a physical description of the area. The DTM for the area of interest was extracted using ARCGIS and Global Mapper software.
2. Preparation of hydrological data. These data include rainfall, input data and boundary conditions.
3. Development of a hydrological model that simulates rainfall-runoff modelling processes and generates results for the study area.
4. Validation of HEC-RAS model results.

In terms of input data, the HEC-RAS model requires a stream of observed data, knowledge of the topography of the catchment using a digital terrain model, a land use map of the study area and other information that will ultimately lead to valuable results.

However, water pathways, from the moment the raindrop meets the land surface to the possible flow in a river, depend on a multitude of factors variable in space and time (HL - hydraulic length, representing the longest path of a water droplet from the point of rainfall to the control section); Tlag - the time between the centre of gravity of the rain and the top of the flow hydrograph; Concentration time - the time it takes for the furthest droplet to reach the control section (equals in principle 1.67 Tlag and represents the duration of the computational rainfall) (Balan, I. et al., 2015).

RESULTS AND DISCUSSIONS

In the case of the study, sub-basin modelling was carried out from the source to the Târgu Frumos hydrometric station within the Bahlueț catchment over an area of 63 km² (Figure 2).

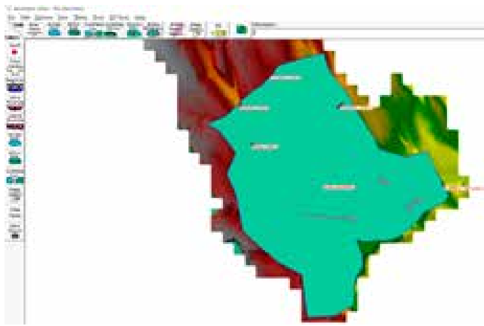

Figure 2. The simulation area considered

The hydrological behaviour of the catchment is governed by all the physical characteristics. Slope, geology, pedology, degree of anthropisation, vegetation cover are all physical factors that can have an impact on runoff velocity, runoff rate, infiltration and flood control (Stătescu et al., 2011).

Characteristic land use layers and information on existing soils within the study catchment were added to determine the CN (Figure 3).

Figure 3. Land use in the Bahlueț catchment area

Land use within the Bahlueț watershed is predominantly agricultural, with cultivated land and pasture (Figure 4).

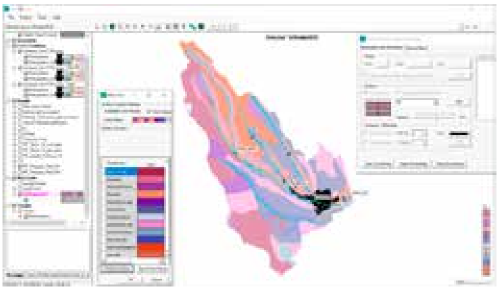

Figure 4. Soils within the Bahlueț catchment area

Physico-chemical characterisation of the initial state of soils is carried out to determine the condition of a site before any work is started.
Research carried out in the Bahlueț catchment revealed a variety of soil cover. According to their characteristics and limitations, soils in the studied area were classified into 5 classes, from II to VI (SRTS 2012) (Dorin G. et al., 2021).
The predominance of soils of the cernoziom type is observed: cambic, clayey but also grey soils, erodic anthrosoil, rocky, pseudoglacial, lacustrine and pseudorendzine. They are soils of different fertility due to their physico-chemical properties (Dorin G. et al., 2021).
Data recorded by rain gauge stations during 3 days from May 1 to May 3, 2021 were taken into account for the hydrological modelling. The two rain gauge stations were chosen because of their favourable position with respect to the whole basin.
Precipitation was measured directly at the two stations considered, at Cârjoaia and Târgu Frumos.
The analysis of the rainfall recorded at the rain gauge stations shows significant differences between the two rain gauge stations Cârjoaia and Târgu Frumos, (Figure 5).

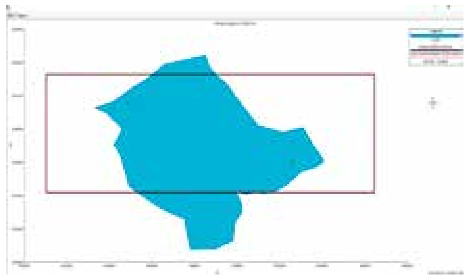

Figure 5. Rain gauge and hydrometric stations

The data of 6 profiles between the top of the basin and the Târgu Frumos hydrometric station were processed (Figure 6).

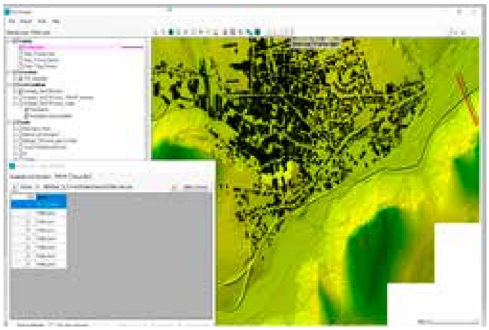

Figure 6. Implementation of line profiles

The selected profiles are perpendicular to the direction of flow, they do not intersect each other, cover the entire floodplain and take into account the geomorphological changes of the major riverbed.
A rain gauge allows only a single measurement which is not always representative of the rainfall received by a catchment. For the selected sub-basin from the top of the catchment to the Târgu Frumos hydrometric station, rainfall was calculated using the Thiessen polygon method (Figures 7 and 8).

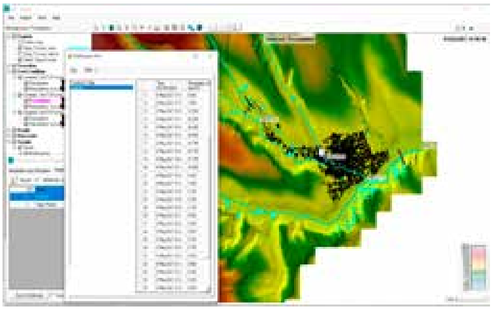

Figure 7. Precipitation calculated by Thiessen method at Cârjoaia rain gauge station

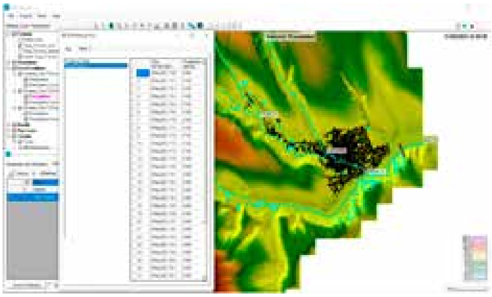

Figure 8. Precipitation calculated by Thiessen method at Târgu Frumos rain gauge station

Based on the entered rainfall data as well as the other parameters, the program was run to simulate the entered rainfall. The run was carried out in several steps and was analysed with great care (Figure 9).

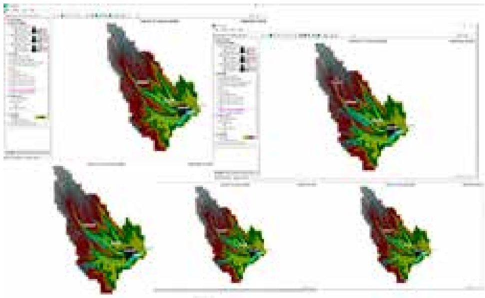

Figure 9. Hydrological rainfall simulation results

It is noted that during the rainfall considered, values of up to 175 mm/h were recorded. At the Târgu Frumos rain gauge station rainfall values of 12 mm/h were recorded, which proves the heterogeneity of the rainfall.
The rain started in Târgu Frumos around 16:00 and stopped around 18:00. The rain continues from 18:40 at the Cârjoaia rain gauge station, recording cumulative rainfall values of 175 mm/h (Figure 10).

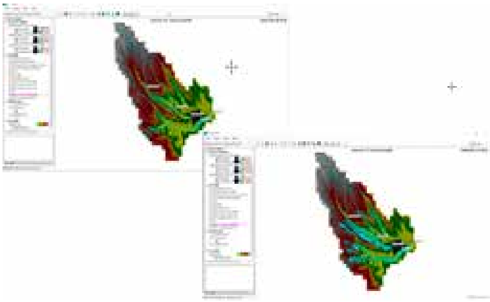

Figure 10. Hydrological rainfall simulation results

Modelling is the basis for identifying and prioritising the right measures. It can flag potential problems/risks before they arise. Modelling answers the "what if" question. Allows modelling of urban areas that usually have complex two-dimensional behaviour, surface runoff and sewerage system (Balan, I. et al., 2016).
The data recorded at the two rain gauge stations show that the catchment is subject to a spatially variable rain field. In order to limit the dispersion of the shape coefficient it is indicated to avoid too large time steps therefore a time step of 10 minutes was chosen in the study.
It is observed that the magnitude is consistent in areas with regular slopes, whether they are steep or not.
Modelling runoff from hydrological precipitation allowed us to both visualise surface runoff and predict it in the studied catchment (Figure 11).

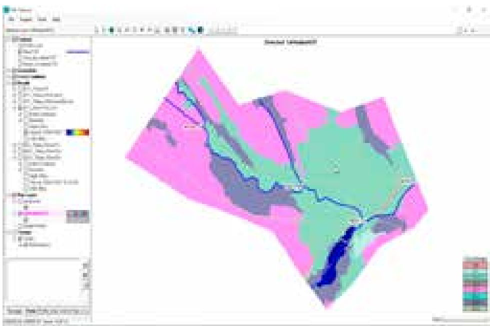

Figure 11. Curve number CN

Forested areas show low surface runoff values due to their excellent infiltration capacity as well as their ability to recycle water back into the atmosphere creating a perfect balance for the environment. These forested areas have flood mitigation potential if they are located upstream of the catchment or if a substantial part of the catchment is occupied by continuous forests.

Grasslands have the most balanced water retention capacity compared to arable and artificial land, and have a high potential for interception, infiltration and storage of rainwater falling on the soil surface.

Arable land shows high values of surface runoff with low water holding capacity compared to other vegetation types especially where the soil through different agricultural practices can be compacted.

Artificial areas, such as housing, industrial and commercial buildings, have a substantial local impact on water runoff, as soil sealing and compaction prevent or drastically decrease the capacity of soils to allow water infiltration and exchange with the atmosphere, favouring the shutdown of the natural circuit and increasing temperatures (Stătescu et al., 2004).

It has been shown that the volumes of water transported by floods and the volumes of runoff generated by rainfall follow the same spatial distribution.

At the same time, flood amplification or attenuation downstream of the basin depends on the amount of rainfall received by the basin, but a flood can be attenuated downstream even if the rainfall amounts are significant.

Rainfall can be evenly distributed over a period or can vary greatly over the same period. The duration can also be long or very short.

The hydrological study is a very important step in the study of flood protection, its objective being to recognise floods by peak flow aspects. This stage is essential for the hydraulic simulation of the Bahlueț River.

CONCLUSIONS

The second half of the 20th century saw considerable advances in the understanding of rainfall-runoff processes, emphasizing the fundamental role of saturated zones in the generation of streamflow. Also, due to increasing resource capacity, hydrological modelling has increased enormously from global to distributed modelling.

Adequate knowledge of rainfall runoff processes is essential to estimate the amount of runoff produced in a basin for planning and management of sustainable water resources projects. Activities for estimating runoff volumes and flood peaks can be easily simplified by adopting a modelling concept and understanding rainfall partitioning and the main factors that trigger runoff.

The process of transforming rainfall into runoff over a basin is complex and exhibits both temporal and spatial variability. However, within a catchment the variability is mainly controlled by the physical and chemical properties of the ground surface.

Runoff occurs when the rainfall rate over a given area exceeds the rate at which water can infiltrate into the soil. Runoff occurs more frequently in areas where rainfall intensities are high and the infiltration capacity of the soil is reduced due to surface sealing.

The generation of runoff is an important factor in both soil loss and the movement of nutrients from the soil surface, resulting in reduced soil productivity and crop yields, especially in agricultural land. Some studies have shown that in areas with fine textured soils, runoff can range from 8% to 49% of annual rainfall depending on prevailing conditions.

The Bahlueț catchment covers an area of 551 km². Within the catchment, lands with slopes ranging from 9-19% dominate, thus showing that slopes create the dominant landscape of the studied area and it is observed that most of the catchment describes a hilly landscape.

The town of Targu Frumos and its surroundings have experienced excessively violent floods over time causing significant damage. Overflows of the Bahlueț River during rainy periods are one of the main sources of flood risk for the city which continues to increase due to human action.

This study presents a simulation of the May 2021 flood event and focuses on the upstream section from the headwaters to the Tg. Frumos. This simulation is performed using the two-dimensional capabilities of the new HEC-RAS version 6.0 program. The simulation provides very useful information for decision makers.

The simulation results are used to estimate and assess flood damage as well as for flood control planning.

A better knowledge of the rainfall amounts during floods, in particular their spatial distribution, will increase model performance.

Estimation of received rainfall at the basin scale could be improved with the enriched network of automatic rain gauge stations.

The importance of soils as well as land use in the rainfall-runoff process has been proven, therefore: analysis of soil properties, detailed analysis of land use in the inundation area, impact of land use changes and further on different scenarios can be analysed to obtain the best results.

Modelling aims to limit flood risks and prevent droughts through better land management. Hydrological modelling can also be complemented by hydraulic modelling to develop flood scenarios for different volumes of water to improve flood risk management. (Stătescu et al., 2010)

Putting modelling to work as a tool for understanding the hydrological functioning of catchments and as a decision aid is one of the best methods recognised as both simple and with high quality results.

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