Modelling hydraulic behaviour of Buna River

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ABSTRACT

River Buna is one of the largest rivers in our country, which flow into the Adriatic Sea with a total length of around 44 km. Buna River 1.5 km after flowing out of Shkodra Lake joins Drini River creating a very complex water system. Buna River is considered a plain river flowing in a plain territory, but it collects the waters from a mountainous watershed. It is the only discharge of Shkodra Lake. Through its river bed the waters of Shkodra Lake, Kiri and Drini are discharged into Adriatic Sea. The main altitude of its catchment's area is 909m above the sea level.

The water regime of Buna River after flowing out of Shkodra Lake is not only influenced from the lake but also from the Drini river flow, the biggest River in Albanian territory with a large catchment area of 14173 km^2.

To study the hydraulic behaviour of Buna River, a hydraulic model using HEC-RAS software is set- up based on the digital terrain model in WGS-84 coordinate system developed from the topographic survey made from both countries Albania and Montenegro in their national coordinate systems.

The hydraulic regime of Buna River it is analysed by using the mathematical model built in HEC-RAS software. Different scenarios are taken into consideration based on different inflow hydrographs to evaluate the effect on water level variation along Buna river from the outflow from Lake Shkodra to the Adriatic sea.

Keywords: *Buna River, mathematical model, hydraulic regime, inflow hydrographs*

INTRODUCTION

Buna River is part of the water system of Shkodra Lake-Drini and Buna River. These three water bodies represent a unique hydrographical system collecting water from a watershed with a total area of 19582 km^2 (the Lake Shkodra itself has a catchment area of 5180 km^2) [1]. From Shkoder Lake water flowed into the Adriatic Sea through River Buna and Drini River flows its water just few km (1.5km) after Buna River comes out from Shkodra Lake (figure 1).

Buna River is considered a plain river flowing in a plain territory, but it collects the waters from a mountainous watershed. It is the only discharge of Shkodra Lake. Through its river bed the waters of Shkodra Lake, Kiri and Drini are discharged into Adriatic Sea. The main altitude of its catchment's area is 909m above the sea level.

Figure 1. Location of the study area of Shkodra Lake, Buna and Drini River water system.

This water system Shkodra Lake-Drini and Buna River- is a complicated one from its hydrological and the hydraulics considerations as well.

The climate in the Study Area is Mediterranean subtropical, characterized by a dry and warm long summer and humid winter. The number of days with high temperature (Tmax _ 25oC) varies from 110 to 130 per year. The hydraulic behaviour of Buna River it is analysed based on the mathematical model built in HEC-RAS software (applied also in [2]).

METHODOLOGY

The mathematical model for Buna River it is built using HEC-RAS software, which is created by the Hydrological Engineering Center in USA. This software it is designed to perform one-dimensional hydraulic calculations for a full network of natural or constructed channels [3]. The HEC-RAS software solves the Saint Venant equations of unstedy flow [4]: equation of conservation of mass (1) and the equation of conseravation of momentum (2). These partial differential eqations, which schematic representation is shown in figure 2, are solved through the use of implicit finite difference scheme of Preissmann.

Equation of conservation of mass

$$\frac{\partial A}{\partial t} + \frac{\partial Q}{\partial x} = q_{lat} \qquad (1)$$

Equation of conservation of momentum

(2)

$$\frac{\partial Q}{\partial t}+\frac{\partial}{\partial x}\left(\frac{Q^2}{A}\right)+gA\frac{\partial h}{\partial x}+\frac{gQ|Q|}{C^2RA}=0$$

where:
A - Wetted area [m2]
Q - Discharge [m3/s]
qlat - Lateral discharge per unit length
x - Distance [m]
t - Time [s]
g - Acceleration due to gravity [m/s2]
h - Water level [m] (with respect to the reference level)
C - Shezi coefficient
R - hydraulic radius [m]

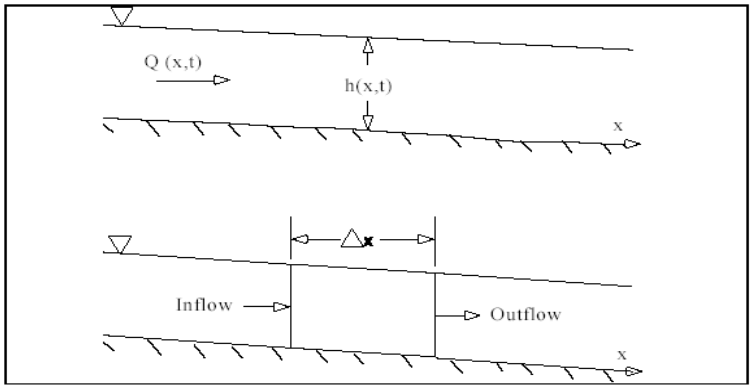

Figure 2. Skematic representation of Saint Venant equation in HEC-RAS

Hydraulic Model in HEC-RAS

The data necessary to build the mathematical model in HEC-RAS are: the geometric data of the terrain and hydrological data of the study area.

***Geometric** Data*
The main geometric data consist of defining the River System Schematic, river confluences data, river flow split and bifurcation data, River Cross- sections, downstream reach lengths, coefficients of energy losses, etc.

River System Schematic
The river system schematic consist of establishing the connectivity of the river system. The connection of branches with each other is very important for the model in order to understand how the calculations should be continued from one branch to another. In the case of the Lake Shkodra, Drin and Buna River water system in addition to Buna River flow, is taken into consideration also the flow from the River Drin (the tributary of Buna River).

The geometric data are based on digital model of terrain [5] for an area that includes the region of Shkodra Lake and the areas affected by the flow from Drin River downstream Vau Dejes and Buna River. For the construction of the digital terrain model were used the information of

topographic survey [6] carried out in the study area in 2005-2006, from the Albanian Academy of Sciences and Academy of Sciences and Arts of Montenegro.

Cross Section data

Cross section data represent the geometric boundary of the stream. Cross sections are located at relatively short intervals along the stream to characterize the flow carrying capacity of the stream. For the water system of Lake Shkodra, Drin and Buna River were used 395 cross sections of whom 15 cross sections in the Shkodra Lake, 9 cross sections in the Drin River before joining the River Buna, 14 cross sections describing the mouth of Buna River in Montenegro, and 12 cross sections describing the mouth of Buna River in Albania. In figure 3, it is presented a cross section in Buna River obtained from HEC-RAS hydraulic software, which is located near the village of Zus.

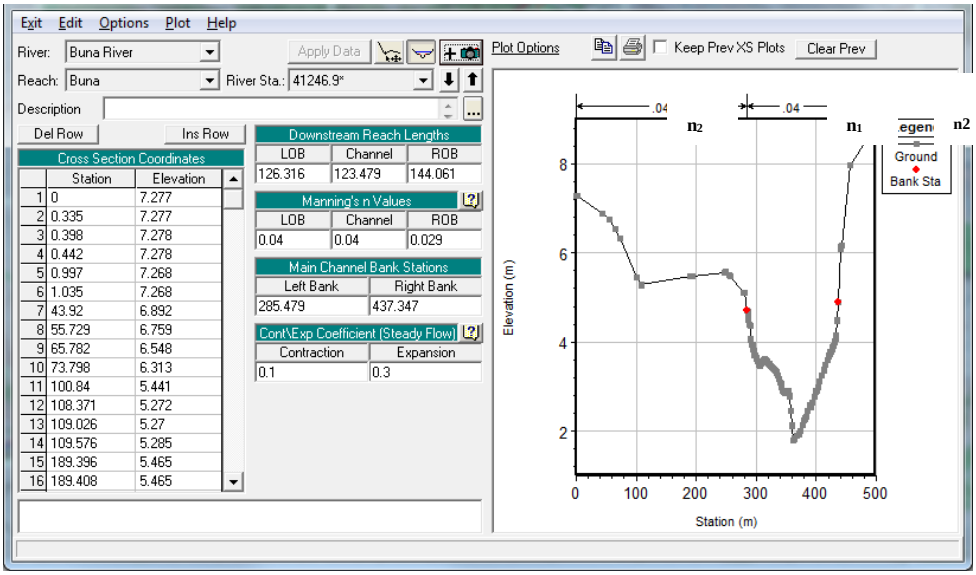

Figure 3. Cross section of Buna River near the village of Zus

An important element in describing the cross sections, is the bed flow resistance coefficient, in our case it was used the Manning's n values. For the river profiles which are Y-Z profiles are used different friction values of Manning's n for the left overbank, main channel, and the right overbank. For the estimation of Manning's n values, the tables compiled by Ven Te Chow [7] were used, then more precise values for this coefficients are calculated after the calibration of the model.

The hydraulic model built in HEC-RAS appears in the figure 4, where can be distinguished the river profiles that are taken in Shkodra Lake as well as river profiles that were taken in River Drin at about 1 km in length, which make possible the consideration of flows entering into Buna River from the Drin. Drini River inflow has a great influence in the water regime of Buna River.

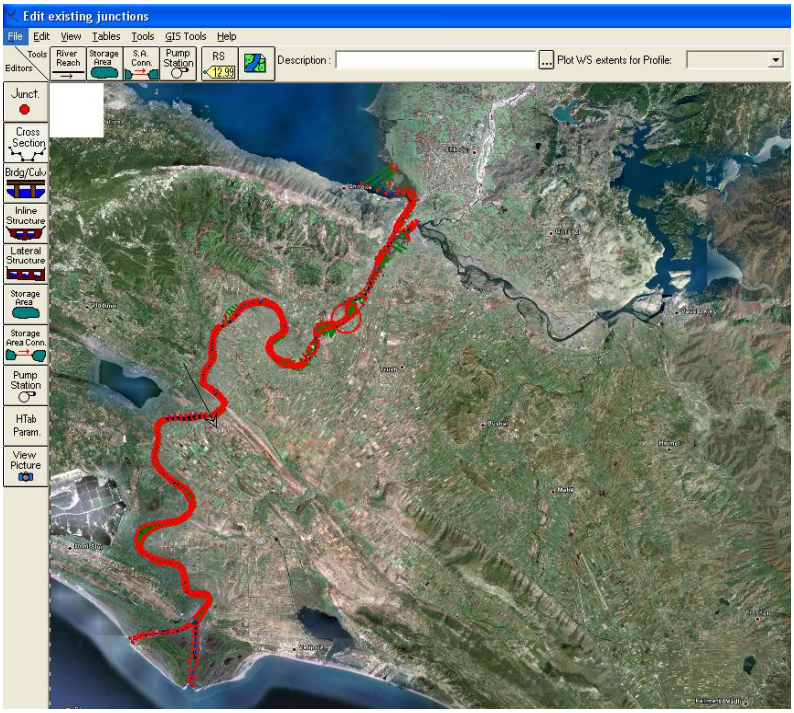

Figure 4. View of the hydraulic model built in HEC- RAS software

Hydrological data

Buna River is the only discharge of the Shkodra Lake and its water regime is strongly linked with this Lake. But in the same time in its river bed, Drini River discharges its water. The flows joining the Drini/Buna River system below Vau Dejes are shown in Figure 5. The principal inputs are from the Gjadri River, which joins the left bank of the Drini just above Spathara, and the Kiri River, which joins the right bank of the Drini close to Shkodra Town. These tributaries have small catchments (combined area less than 500 km2). The Buna River (from Shkodra Lake) joins on the right bank side 1km downstream of the Kiri [8].

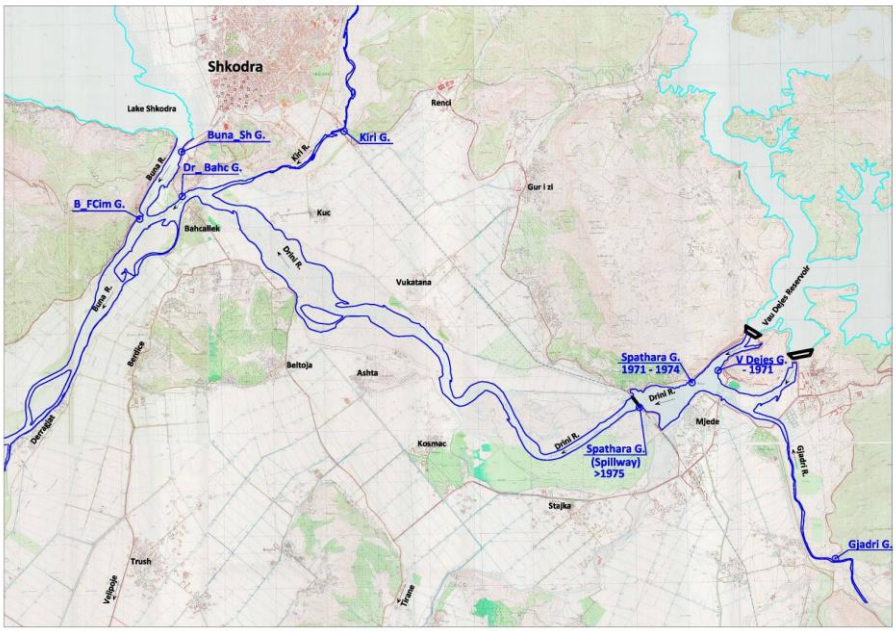

Figure 5. The flows joining the Drini/Buna River Water System (Source [8])

The inflows from Kiri and Gjadri are small compared to the peak releases from Vau Dejes and outflows from the Shkodra Lake. Also, in a major flood the peaks on these tributaries are likely to pass well before the peaks from the larger catchments [9]. The contribution of flow from the Kiri and Gjadri has been incorporated in the inflow hydrograph of Drini River at Bahcallek station. The Buna River water flow after it flows from Shkodra Lake it is incorporated in the inflow hydrograph at Buna Bridge station. These two discharge hydrographs, used as upstream boundary condition of the mathematical model, are presented in figure 6. As downstream boundary condition it is used constant water level of the Adriatic Sea at Buna River mouth in Albania and Montenegro.

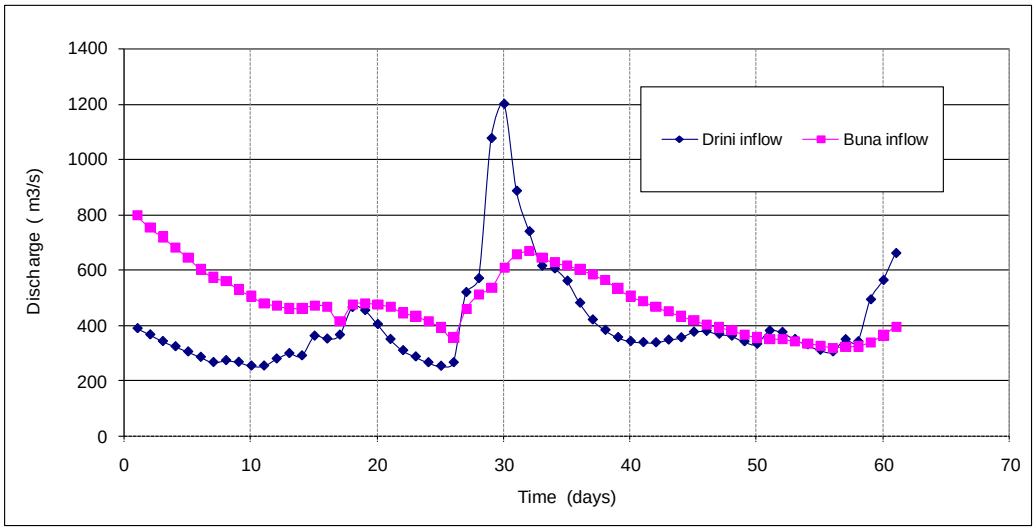

Figure 6. Inflow hydrographs from Shkodra Lake and Drini River for the characteristic event

ANALYSIS OF RESULTS

The hydraulic behaviour of water system of Shkodra Lake - Buna and Drini River it is analysed by using the hydraulic model built in HEC- RAS software. After the calibration of the model, a characteristic flood event for Buna River based on daily discharges, starting from 1 March until 30 April it is analysed. Figure 7 represents the Buna River water flow after it flows out from Shkodra Lake, Drini water flow before it joints Buna River, and Buna water flow after the junction with Drini River calculated from the mathematical model built in HEC-RAS.

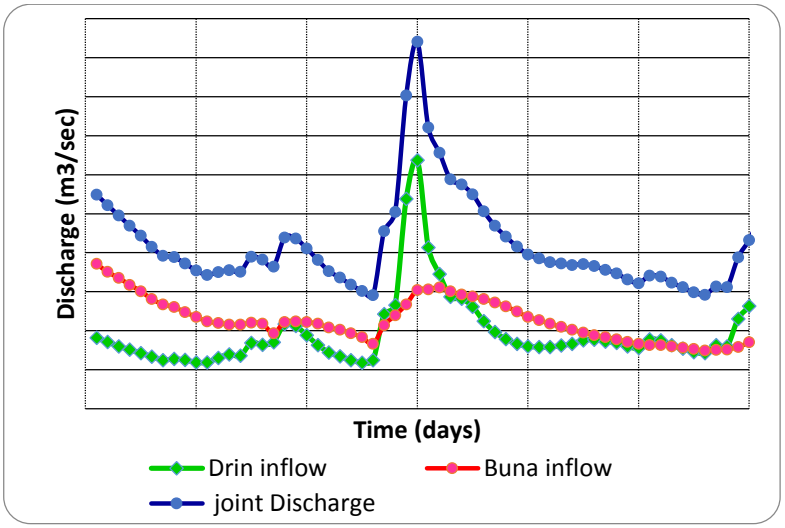

Figure 7. Discharge hydrographs for the characteristic event for Buna River

Important results of the hydraulic model are the water level variation for the charachteristic flood event in all the cross sections along Buna River. In figure 8, it is presented the maximal water level for the cross section near Obot village, whereas figure 9 represents stage hydrographs for the simulation period for the selected river profiles at the junction of Buna River with Drini River, near Obot village, and at the bifurcation of Buna River in the vicinity of Buna River mouth.

Figure 10 shows maximum water levels along Buna River in all the cross sections for the characteristic event. In order to identify areas where the river may overflow its banks, the highest elevation of the terrain are chossen on both sides of the river flow and are compared to the maximum water levels, to determine the area at risk of flooding. Figure 11 represent maximum water levels along Buna River from the outflow from Lake Shkodra to the sea for the characteristic flood event compared to the highest level of embankment. From this figures can be seen than, there is some overtopping of the Buna River banks especially in the vicinity of the Obot village. The flood depth goes from 0.5m untill 1m in this area.

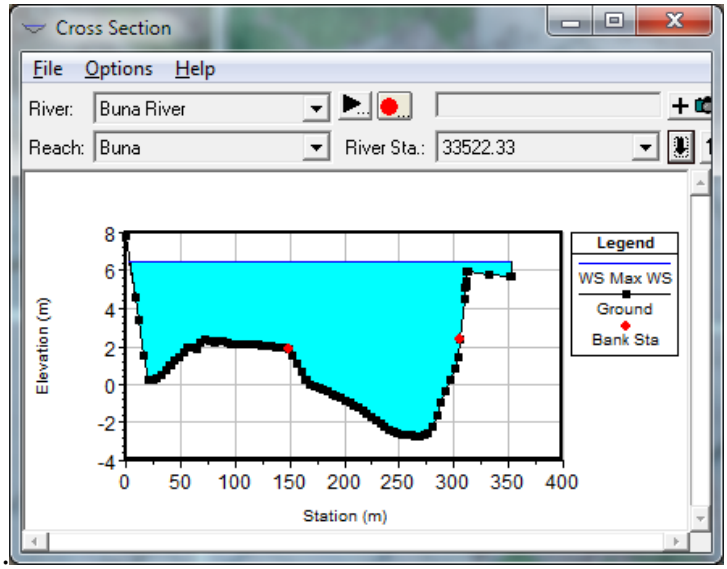

Figure 8. Maximum water level near Obot village for the characteristic event

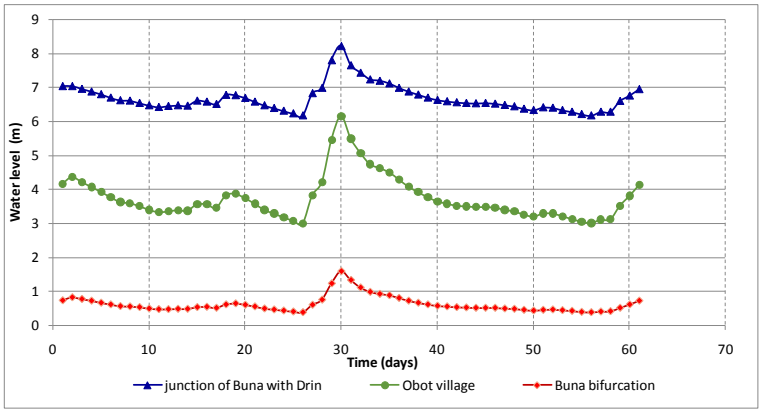

Figure 9. Predicted water levels for the characteristic event at some representative locations

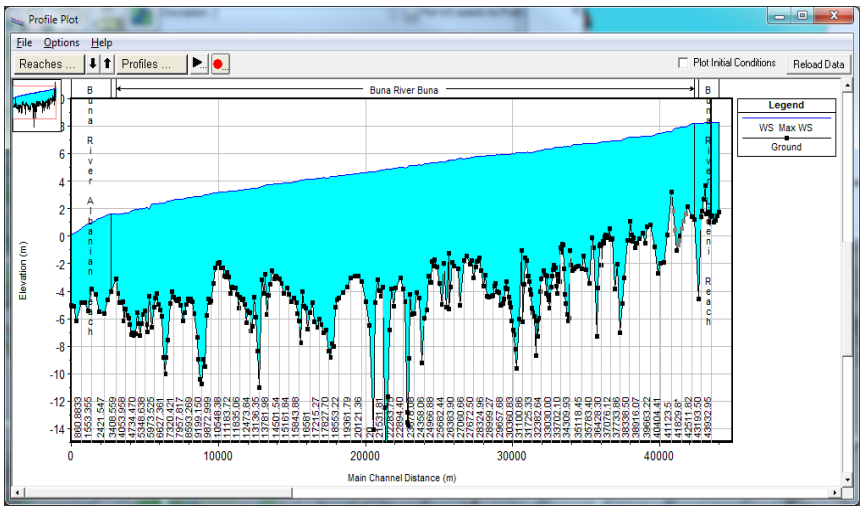

Figure 10. Maximum water levels along Buna River for the characteristic event

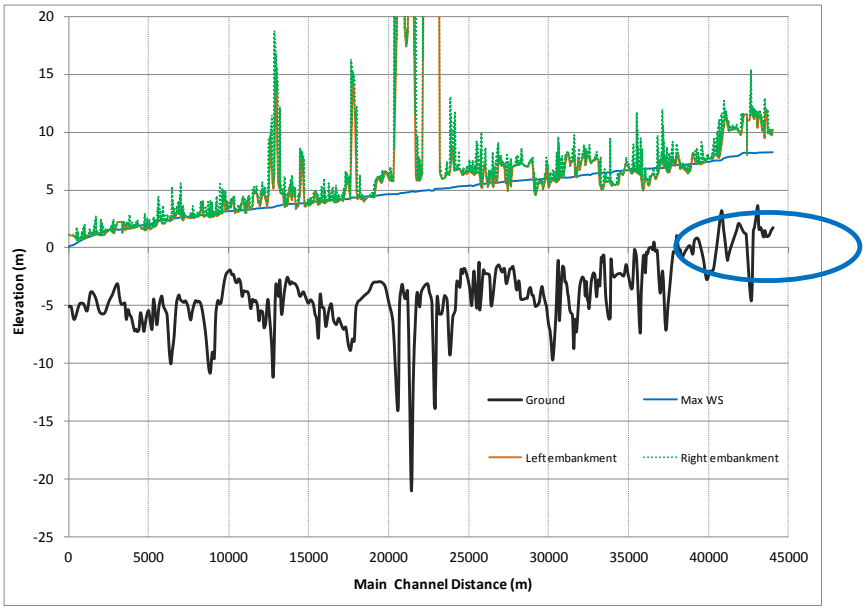

Figure11. Maximum water levels along Buna River for the characteristic event compared to the embankment level

CONCLUSIONS

Buna River is part of the water system of Shkodra Lake-Drini and Buna River, which is the most complicated hydrological complexes in Albania. Buna River is the only discharge of Shkodra Lake, and through its river bed the waters of Shkodra Lake, Kiri and Drini are discharged into Adriatic Sea.

To study the hydraulic behavior of Shkodra Lake, Drini and Buna River water system a mathematical model was set-up in HEC-RAS hydraulic software, based on the digital terrain model in WGS-84 coordinate system developed from the topographic survey made from both countries Albania and Monetnegro in their national coordinate sytems in 2005-2006. A considerable amount of cross sections were used to represent the bathimetry of Buna River, which makes this a reliable model. Some cross sections were used to represent the downstream part of Drini River before the junction with Buna River, which make possible taking into account the influence of Drini River flow into Buna River.

A characheristic flood event from Buna River and Drini River was analysed, where water levels and discharge hydrographs were generated in all the cross sections used to represent Buna River bathimetry, and some of them were presented in this paper. Model results shows some overtopping of the Buna River banks especially in the vicinity of Obot village where the flood depth varies from 0.5 m until 1 m.

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