FLOOD RISK ASSESSMENT FOR THE PRUT RIVER HYDROGRAPHIC BASIN IN ROMANIA

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Abstract

The eastern part of Romania is frequently affected by floods. The flood regime in the Prut river catchment is characterised by short, high intensity intensity rainfall, coupled with low infiltration in the soil, that lead to flash floodings in the upland areas. The upper cathcment is controlled by the Stanca-Costesti reservoir that grately influences the flow regime and decreseas significantly the flood risk for the downstream areas. Significant floods were recorded during 2005 – 2020, with istoric maximum flows and total volumes. Through successive discharges of different downstream flows, safe transit of volumes was achieved, without endangering downstream objectives. This paper presents a comparative study of the maximum flows registered at the hydrometric stations and flood propagation times between the succesive control sections. In order to maintain the safe operation of the defense lines on the Prut River (the dykes), the personnel of Water Basinal Administration Prut – Barlad carried out immediate interventions at the critical points highlighted on the embankment network (infiltrations, erosions, areas under the projected elevation, under passages), depending on their seriousness and their negative effects. This paper can be used to further improve the existing basinal flood defence plans.

Key words: catchment, high intensity flood, river warning levels, hydrograph

The eastern part of Romania is frequently affected by floods that ravage localities, destroy properties and endanger human lives. Thus, floods are one of the main causes of social and economic loss in the mentioned area.

The National Management Strategy of Risk on Flooding represents the framework of the actions that has to be undertaken by all competent factors able to contribute to risk on flooding management. In present in Romania was adopted the legislative package concerning the prevention and mitigation of disasters (Crenganiș L. *et al*, 2015). Specific and efficient well-coordinated actions are required, according to the new national strategy.

The adverse impacts of floods and droughts include loss of life and property; mass migration of people and animals; environmental degradation; and shortage of food, energy, water and other basic needs. Risk on flooding management means the application of some politics, procedures and practices having as objective the risk identification, its analysis and assessment, monitoring and solutions elaboration for risk on flooding mitigation.

The flood regime in the Prut river catchment is characterised by short, high intensity intensity rainfall, coupled with low infiltration in the soil, that lead to flash floodings in the upland areas. Changing land use patterns during the last 15 – 20 years has increased the frequency and criticality of flooding throughout the catchment.

MATERIAL AND METHOD

Characterisation of the Prut River Hydrographic Basin

The hydrographic catchments of Prut and Bârlad rivers that form the patrimony of Prut - Barlad Water Basinal Administration have a total surface of 20267 km^2 and consists of:

- the middle and inferior catchment of Prut river
- the catchment of Bârlad river
- left tributaries of Siret river

The Prut-Barlad Water Basinal Administration has a complex program of observations and hydro meteorological measurements. Primary data obtained from the observations and measurements are processed and interpreted flood defense purpose and consists of:

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- 73 reservoirs (Total volume = 780,3 millions m^3): 41 reservoirs, 22 non-permanent accumulation, 10 polders
- 877,1 km river regularizations, 1104,8 km levees – 250,52 km for Prut river, 107,2 km river banks consolidations - 39,15 km for Prut river
- 3 derivations – headraces
- 2 hydrotechnical nodes
- 8 pumping stations
- 86 automated stations (DESWAT project)
- 74 automated stations (WATMAN project)
- 110 administrative spaces

The Prut River springs from the Carpathian Mountains on the north-eastern slope of Cernahova, in Ukraine at 2068 m altitude. Up to the Danube confluence, the Prut River flows through Ukraine, the Republic of Moldova and Romania.

In Ukraine, the Prut River has an area of 8300 km^2, in the Republic of Moldova occupies 8250 km^2, and in Romania the Prut catchment occupies 10900 km^2 (about 40% of the total area). Until the entrance to Romania, the Prut River has a length of 251 km. The difference of 695 km to the Danube River is the natural border between Romania and the Republic of Moldova.

To the north of Oroftiana, the Prut River enters the territory of Romania and traverses a distance of 704 km, which receives numerous tributaries: Volovăţ, Baseu, Jijia, Sitna, Miletin, Elan etc (*figure 1*).

Figure 1 **The positioning map with River Prut hydrometric stations**

In Prut River basin, the air temperature presents annual, seasonal, monthly and diurnal variations and also territorial, altitudinal and latitudinal differences, according to the radiative potential, the action of air masses with various sources and the underlying surface characteristics. In Moldavian Plain, the central and southern area are characterized by the average annual isotherm of 9 °C at altitudes below 120 meters above sea level. As the altitude rise above 350 meters above sea level, temperature values fall below 8°C (7.5 °C at Dealul Mare – Hârlău area).

Territorial distribution shows favorable conditions for cold air amassment in the region and also in Suceava Plateau. The mean temperature value of - 4 °C was recorded in January. There were noted instances when in January 2012 the rate was close to – 10 °C, due to the frequent intrusion of cold air masses from Arctic area. Annual average thermal amplitudes were between

23.8 and 24.3°C in Prut River basin on romanian territory (Corduneanu *et al.,* 2015).

The interaction between advection processes and the ones of local circulation, generated by the caloric balance of active surface, air temperature in the summer reach more than 35 °C, while in winter decreases just below – 25 °C. Absolute thermal amplitude exceeds 75°C and highlights continental – excessive features in the area (Vartolomei F., 2012).

Hydrometric Stations

Soon after entering Romania, on the Prut River there are Oroftiana hydrometric station and Rădăuți-Prut hydrometric station, at 68 km downstream, where the water level of the river is measured regularly. 89 km downstream, on the Prut River there was built a large dam that creates the retention for Stanca-Costesti reservoir.

The Stanca – Costesti reservoir is located on the Prut River, at km 576 upstream from the confluence with the Danube River. The dam and the hydro-mechanical equipments are exploited jointly with the Republic of Moldova.

The dam was temporarily put in operation on June 29, 1978, and in the spring of the year 1979, the water level in the lake reached and surpassed for the first time the Normal Level of Retention.

The reservoir has a total volume of 1400 million m^3, of which 665 million m^3 is the volume of attenuation corresponding to the maximum level of probability of exceendance for verification. The reservoir has a major role in flood protection and mittigating the maximum inflow (*figure 2*).

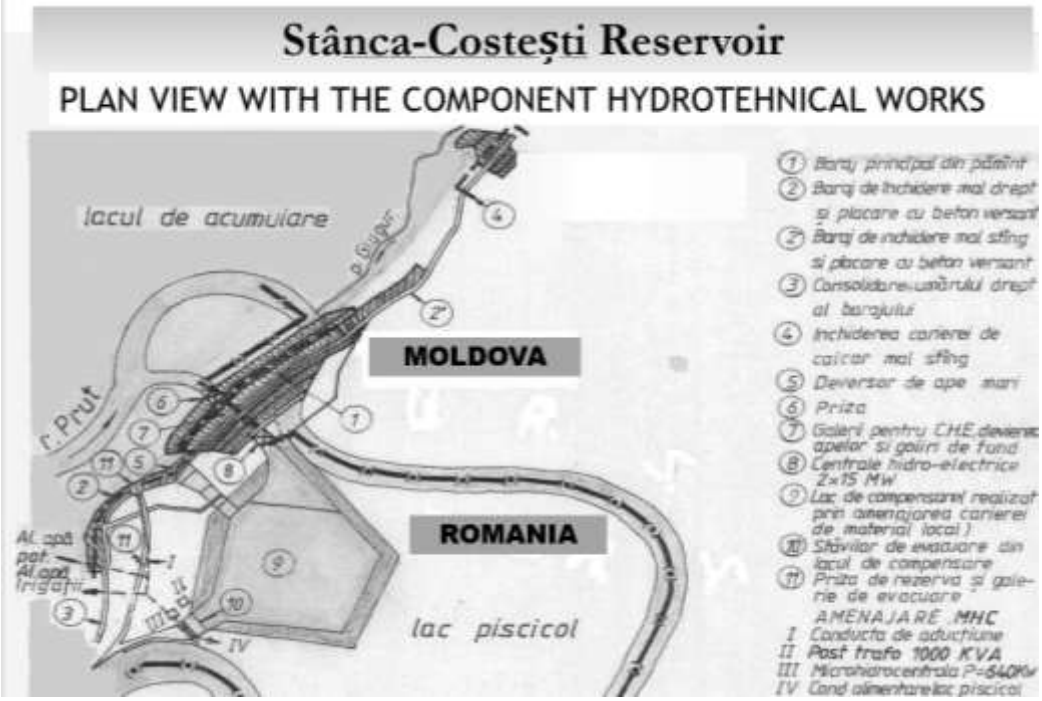

Figure 2 **Plan view with Stanca-Costesti dam and the hydrotechnical works**

At the hydrometric station downstream Stanca-Costesti, the water level of the Prut River is measured and the discharged flow is extracted from the rating curve calculated for the cross section, in correlation with the capacity of the outlets of the dam (Corduneanu *et al,* 2021).

Other important hydrometric stations with rating curves established for the cross sections of the river beds, where flows are calculated, are Ungheni and Prisăcani hydrometric stations, placed at 200 km, repectively 50 km downstream on the Prut River.

Significant floods

Th most significant flods on the Prut River were registered in the years 2005, 2006, 2008, 2010 and 2020.

Figure 3 shows the flows registered in August 2005 at the hydrometric stations Radauti-Prut that were attenuated in Stanca-Costesti reservoir, from a maximum of 2640 m^3/s, to a diminished 568 m^3/s measured downstream (*figure 3*).

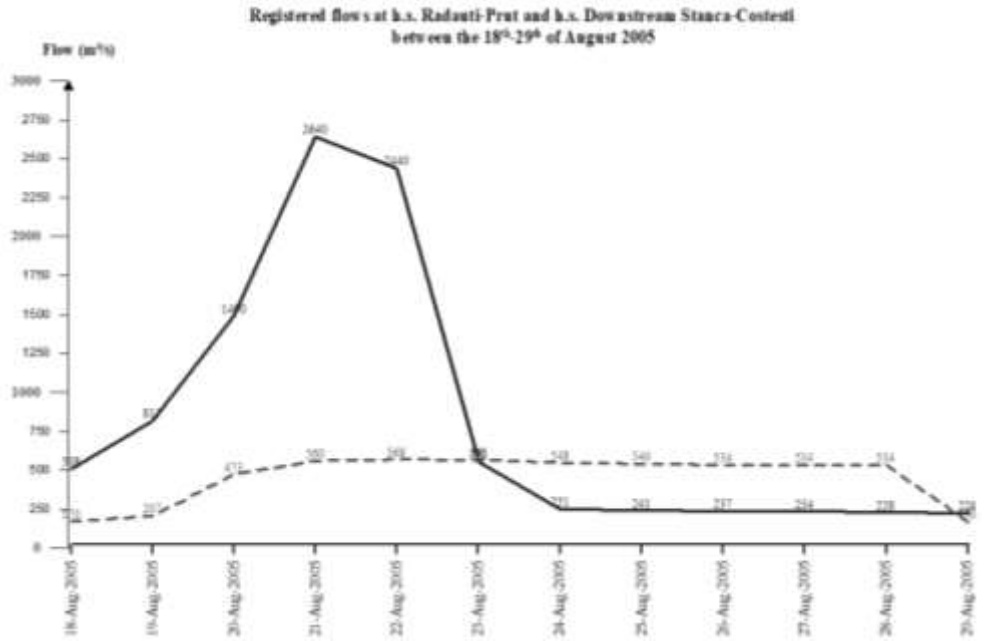

Figure 3 **Registered flows at h.s. Radauti-Prut and h.s. Downstream Stanca-Costesti between the 18th and the 29th of August 2005**

The floods of 2008 were particularly extreme. River warning levels were exceeded during most of the year over many parts of the Prut-Bârlad catchments. The worst floods of 2008 took place in the period from March – April of 2008 and July – December 2008, when the high floods on most of the rivers reached historical limits. Large areas of land were inundated leading to death and severe infrastructure damage (Crenganiș *et al.*, 2018).

During 23rd – 26th July 2008 significant rainfall occurred in Prut River catchment. The total flood volume was 1400000 m^3. Maximum flow registered at Rădăuți – Prut hydrometric station of 4240 m^3/s was superior to the flow of 0,1% probability of exceedance which was 3700 m^3/s. (Corduneanu *et al*, 2014)

The maximum water level of Prut River of 1130 cm exceeded with 530 cm the Danger Level threshold of defense.

Figure 4 shows the flows registered in August 2008 at the hydrometric stations Radauti-Prut that were attenuated in Stanca-Costesti reservoir, from a maximum of 4240 m^3/s, to a diminished 1050 m^3/s measured downstream (*figure 4*).

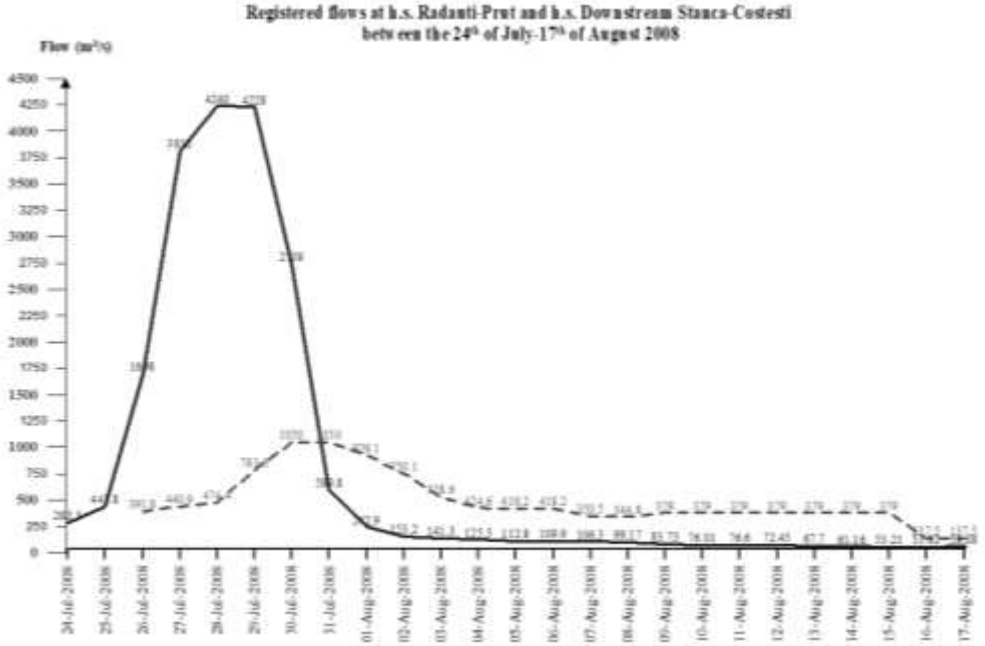

Figure 4 **Registered flows at h.s. Radauti-Prut and h.s. Downstream Stanca-Costesti between the 24th of July and the 17th of August 2008**

For the protection against floods, on the territory of the counties of Iasi, Vaslui and Galati, the right bank of the Prut River was embanked for a length of 250 km. At discharged outflows of about 500 m^3/s, the section of the minor bed of Prut River is full, and on the dilated sections the water penetrates into the floodplain area. In the year 2008, through successive discharges of different downstream flows, safe transit of volumes was achieved without endangering downstream objectives.

For the defense against floods, on the territory of Iași, Vaslui and Galați counties, the right bank of the Prut River was dammed on a length of 250 km. At flows discharged from the Stanca - Costesti reservoir, of about 500 m^3/s, the section of the minor riverbed of the Prut River is full, and on the dammed sections the water enters the dig-shore area.

The maximum discharge from Stanca - Costesti reservoir of 1050 m^3/s diminished downstream of the confluence with Jijia at S.H. Prisacani, recording the flow of 730 m^3/s. The precipitation recorded during the period 23.04.2008 - 30.04.2008 produced the overcoming of the defensive phases at Tutora – Gorban River Prut embankment.

For an entire month, between 23.07.2008 - 22.08.2008, precipitations of over 100 l/m^2 were recorded at most hydrometric stations and pluviometric stations in Iasi County. The recorded precipitations, as well as the propagation of the floods formed on the upper rivers of the Prut and Miletin rivers, led to the overcoming of the defense phases at Prut - Trifesti - Tutora – Gorban River Prut embankment.

The flood on the Prut River caused the entire length of the dykes to be overloaded and the third phase of defense to be exceeded.

As a result of the floods on the Siret and Prut rivers, the state of alert was triggered throughout Iasi County and it was ordered to evacuate the population and animals from the localities situated in the area o Trifesti - Sculeni River Prut embankment.

In order to maintain the safe operation of the defense lines on the Prut River the personnel of Water Basinal Administration Prut – Barlad carried out immediate interventions at the critical points highlighted on the embankment network (infiltrations, erosions, areas under the projected elevation, under passages), depending on their seriousness and their negative effects.

The most important works were those of raising the elevation and filling of the embankments in the areas with saddles and non-conforming transverse profiles of the levees. More losses of human lives and exceptional infrastructure damages were thus avoided.

Figure 5 shows the flows registered in August 2010 at the hydrometric stations Radauti-Prut that were attenuated in Stanca-Costesti reservoir, from a maximum of 2310 m^3/s, to a diminished 885 m^3/s measured downstream (*figure 5*).

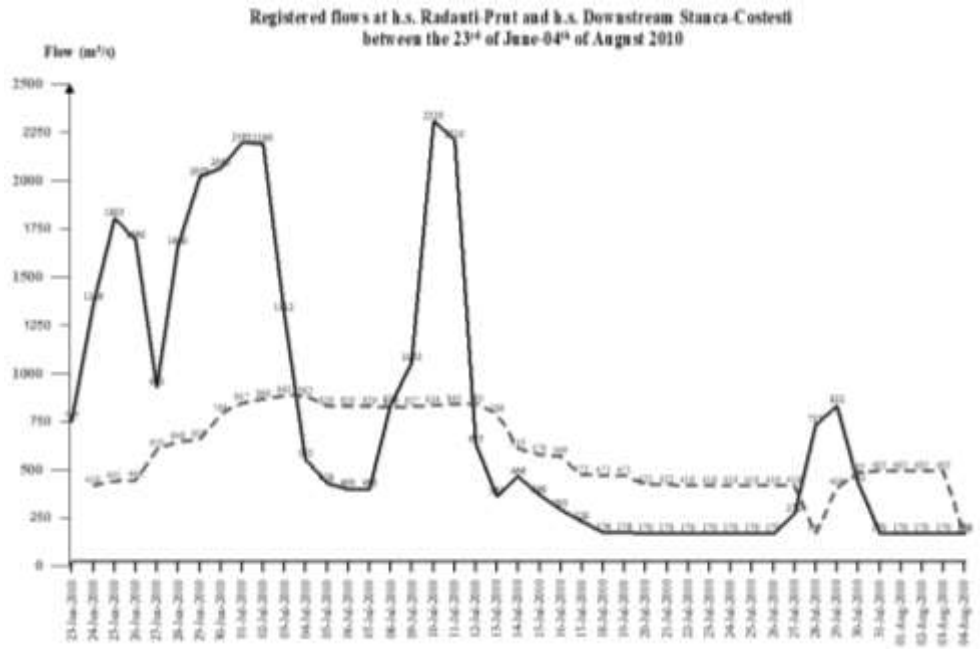

Figure 5 **Registered flows at h.s. Radauti-Prut and h.s. Downstream Stanca-Costesti between the 23rd and the 04th of August 2010**

Figure 6 shows the flows registered in June 2020 at the hydrometric stations Radauti-Prut that were attenuated in Stanca-Costesti reservoir, from a maximum of 2835 m^3/s, to a diminished 820 m^3/s measured downstream (*figure 6*).

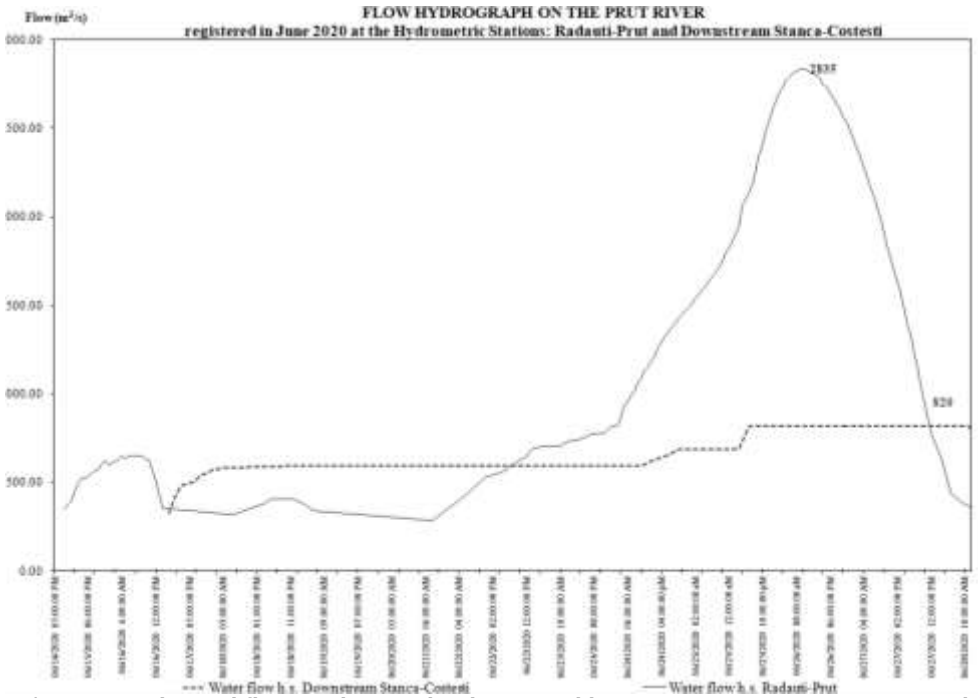

Figure 6 **Registered flows at h.s. Radauti-Prut and h.s. Downstream Stanca-Costesti between the 14th and the 28th of June 2020**

Figure 7 shows the flows registered in June - July2020 at the hydrometric stations Radauti-Prut that were attenuated in Stanca-Costesti reservoir, from a maximum of 2835 m^3/s, to a diminished 820 m^3/s measured downstream (*figure 7*).

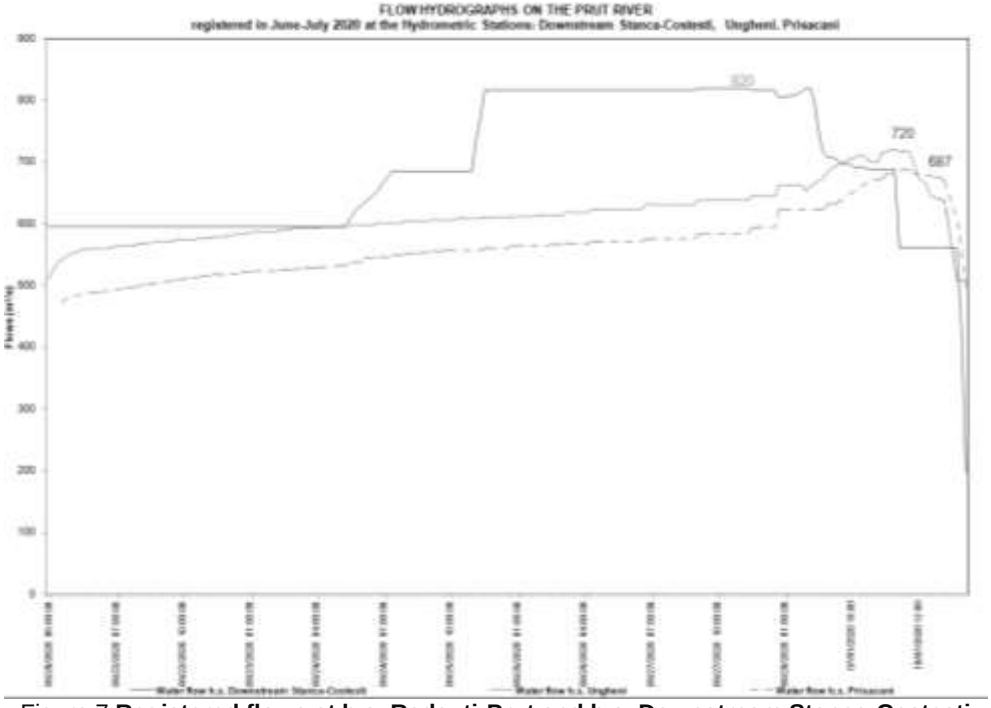

Figure 7 **Registered flows at h.s. Radauti-Prut and h.s. Downstream Stanca-Costesti between the 14th and the 28th of June 2020**

RESULTS AND DISCUSSIONS

The statistical study of the flow and level hydrographs at the hydrometric stations is very important, as it could represent decision support system for the safely exploitation of the Stanca-Costesti reservoir and the longitudinal dykes downstream. Also, it can be used in decisions regarding the population awareness (Crenganiș L. *et al*, 2015).

Figure 8 shows the maximum annual flows registered between 1998 and 2020 at the hydrometric station Radauti-Prut, soon after the River Prut entering this country (*figure 8*).

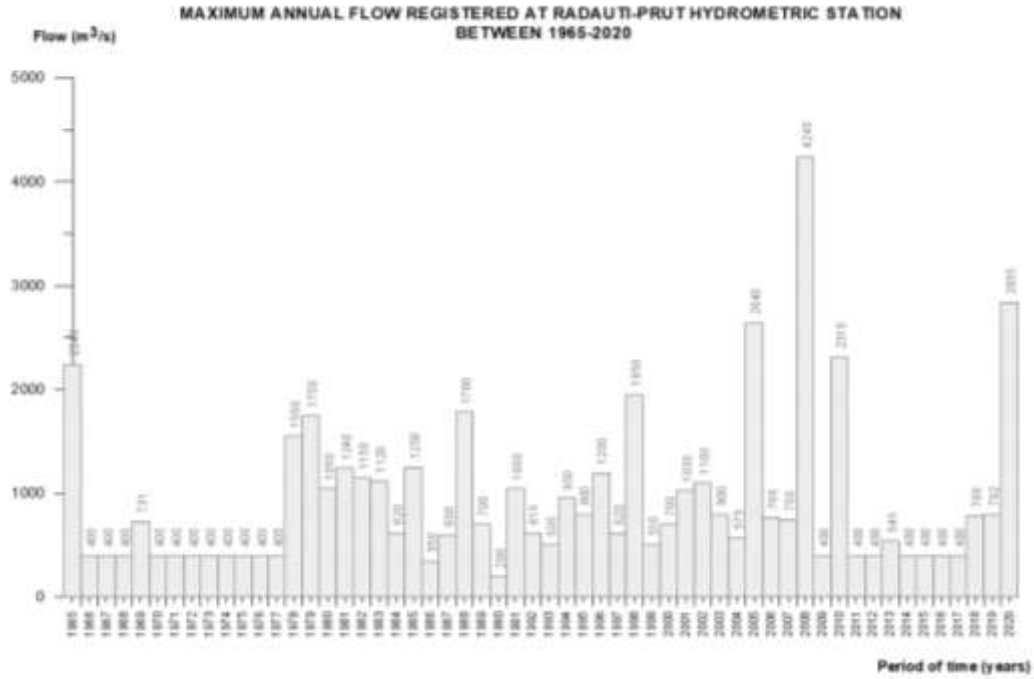

Figure 8 **Maximum annual flows registered between 2004-2020 at the hydrometric station Radauti-Prut**

Figure 9 shows the registered maximum annual flows registered between 2004 and 2020 at the hydrometric station Downstream Stanca-Costesti reservoir (*figure 9*).

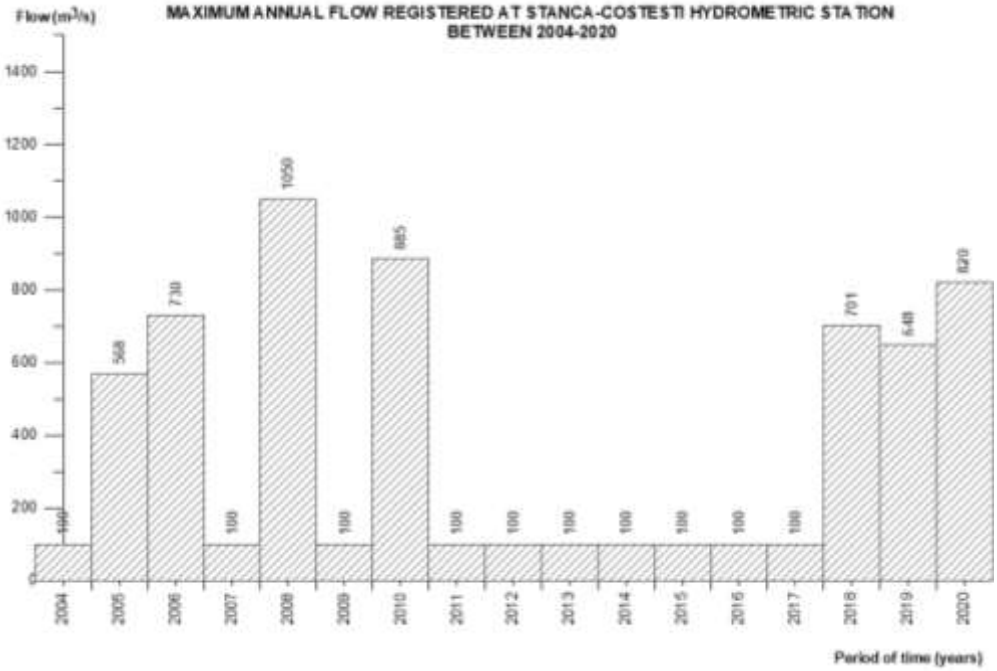

Figure 9 **Maximum annual flows registered between 2004-2020 at the hydrometric station Downstream Stanca-Costesti**

As seen in *table 1*, we have presented the most significant flows registered at the Prut River hydrometric stations in Botoșani and Iași counties.

The most significant flood was registered in the summer of the year 2008, as the flow on the River Prut had a maximum hystorical value of 4240 m^3/s. Also in 2008, the discharge from the Stanca-Costesti reservoir had a maximum hystorical value of 1050 m^3/s (*table 1*).

The discharges evaccuated through the controlled or uncontrolled outlets of the dam are monitored constantly, throughout a flood period and the measurements are completed with rigorously visual observation of the longitudinal dykes.

Table 1

Maximum flows recorded during the years 2005-2020 – m^3/s

No	Hydrometric Stations	2005 Year Flood	2006 Year Flood	2008 Year Flood	2010 Year Flood	2020 Year Flood
1	Rădăuți-Prut	2640	766	4240	2310	2835
2	Downstream Stanca Costesti	568	730	1050	885	820
3	Ungheni	536	478	630	675	720
4	Prisăcani	619	517	731	889	687

The exploitation personnel are constantly monitoring the behaviour of the dykes under the pressure of the floods, so that immediate interventions are made and the flood is transited safely downstream.

After each period of flood, the maximum level of the flood is established along the river, at the hydrometric stations and synthesis reports are written and the conclusions are used in elaborating the following basinal and local flood defence plans.

CONCLUSIONS

The statistical study of the flow and level hydrographs at the hydrometric stations and the existence of flood hazard maps are very important, as the conclusions are designed to increase awareness among the public, local authorities and other organisations of the likelihood of flooding. The population that is living and working in areas of potential significant flood risk is encouraged to obtain more information and take appropriate actions, for a better flood protection.

This work paper can be used to improve the existing basinal flood defence plans.

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