

# The Sediment Transport of the Siret River during the Floods from 2010

Florin OBREJA<sup>1\*</sup>

<sup>1</sup> Department of Geography, "STEFAN CEL MARE" University of Suceava

\* Corresponding author: [obreja.florin@usv.ro](mailto:obreja.florin@usv.ro)

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## Abstract

Beginning with 2004 in the Siret River Catchment there occurred exceptional flash floods that exceeded the maximum historical values recorded, on the main river and on its tributaries (2004, the Trotuș River; 2005, the Siret River, the Trotuș River, the Bistrița River, the Putna River; 2006 - the Clit River from the Suceava River Catchment; 2008, the Siret River, the Suceava River). The 2010 summer flood from the Siret River also falls in this category. This paper uses hydrological data (water discharge, suspended sediment discharge) between the 20<sup>th</sup> of June and 10<sup>th</sup> of July 2010 from 5 gauging stations located on the Siret River: Siret, Hutani, Lespezi, Dragești, Lungoci, and also meteorological data (rainfall) measured at different gauging stations from the Siret River Catchment. The rainfall recorded in this time of the year in the catchment was very high, with values up to 210 l/m<sup>2</sup> in approximately 10 days. The hydrographs of the flash flood indicate the fact that the transit of the water through the reservoirs system from the Siret River (Rogojești - Bucecea and Răcăciuni - Berești - Călimănești - Movileni) reduced the maximum water discharge with values between 7-27%. The values of the maximum sediment discharge also recorded a reduction while transiting this reservoirs system with approximately 60%. The evolution of the Siret river bed channel during this flood (aggradations with values between 15-100 cm and degradations starting from 65 cm until 200 cm, in different moments of the flood) is influenced by the high values of the water and sediment discharge and by anthropogenic interventions on the river bed (pit-ballast, regularization of the river bed, reservoirs). Processing the hydrological and meteorological data recorded during the flood (20<sup>th</sup> of June - 10<sup>th</sup> of July 2010) indicates two important features of this event: the climatic variability - exemplified by the big values of precipitations from the catchment and the anthropogenic impact revealed by the transit of the flood wave and the evolution of the river bed.

**Keywords:** flash flood, suspended sediment, human impact, reservoir, gauging station

## Rezumat. Transportul de aluviuni al râului Siret în timpul viiturii din anul 2010

Începând cu anul 2004 în bazinul hidrografic Siret s-au produs viituri excepționale cu depășiri ale valorilor maxime istorice înregistrate, atât pe râul principal cât și pe mai toți afluenții (2004 râul Trotuș; 2005 râurile Siret, Trotuș, Bistrița, Putna; 2006- râul Clit - bazinul hidrografic Suceava; 2008 râurile Siret, Suceava). Tot în această categorie se încadrează și viitura din vara anului 2010 de pe râul Siret. Lucrarea de față utilizează date hidrologice (debite lichide și solide-aluviuni în suspensie) din perioada 20 iunie-10 iulie 2010 de la 5 stații hidrometrice situate pe râul Siret: s.h.Siret, s.h.Hutani, s.h.Lespezi, s.h.Drăgești și s.h.Lungoci, precum și date meteorologice (precipitații) măsurate de asemenea la stații hidrometrice din bazinul hidrografic Siret. Precipitațiile înregistrate în această perioadă în bazinul de recepție au fost destul de ridicate, cu valori de până la 210 l/m<sup>2</sup> în aproximativ 10 zile. Hidrografele unei de viitură indică faptul că tranzitarea acesteia prin sistemelor lacustre existente pe acest râu (Rogojești-Bucecea și Răcăciuni-Berești-Călimănești-Movileni) a redus scurgerea lichidă maximă cu valori cuprinse între 7-27%. De asemenea și valorile maxime ale transportului de aluviuni s-au redus a cantităților în urma tranzitării acestor sisteme lacustre cu aproximativ 60%. Analiza evoluției talvegului râului Siret în timpul viiturii (agradări cu valori cuprinse între 15-100 cm și degradări de la 65 cm până la 200 cm, în diferite faze ale scurgerii) este influențată atât de valorile mari ale scurgerii lichide și solide cât și de componenta antropică de la nivelul albiei majore și minore (balastiere, regularizări de albie, lacurile de acumulare). Prelucrarea materialelor hidrologice și meteorologice din perioada viiturii (20 iunie - 10 iulie 2010) indică două trăsături caracteristice ale acestei viituri: variabilitatea climatică - exemplificată prin valori mari ale precipitațiilor înregistrate în bazin și impactul antropic evidențiat atât prin propagarea unei de viitură cât și prin comportamentul albiei minore.

**Cuvinte-cheie:** viitură, aluviuni în suspensie, impact antropic, lac de acumulare, stație hidrometrică

## Introduction

The problem of the flash floods and also of the sediment transport during these events in Romania was a very important research topic for many scientific papers (Diaconu, Serban, Lăzărescu, Platagea, Mustață, Miță, et.al. in Hydrological Studies and Research, 1961-1998; Diaconu, 1970; Ichim, Rădoane M, Rădoane N, Olariu, Urziceanu-Roșca, Bătucă, Duma et.al. în "P.E.A." Conferences, 1986, 1988, 1990, 1992; Olariu, 1997; Olariu et.al., 1998; Mustața, 2005; Rădoane M. et.al., 2005; Rădoane N. et.al., 2007; the scientific papers of the "Hidrotehnica" Journal, 1964-present day).

The papers of the authors mentioned above approach the manner of flash floods forming, the causes and their effects, propagation times, types of hydrographs, discharge coefficients, methods of forecasting and calculating the maximum discharge and the runoff, estimating the volume of the water and the sediment load transported through the channel, the efficiency of the reservoir in trapping sediments, evolution of the river bed during the floods.

The Siret has also been the subject of some detailed studies on the manner of flood forming and evolution (Diaconu et.al., 1970; Podani, Zăvoianu, 1992; Mustața, 2005; Olariu et.al., 2009, 2010), on the sediment transport during these events (Diaconu et.al., 1970; Rădoane N. et.al., 2007; Olariu et.al., 2010; Romanescu, 2006), on the evolution of the river bed and concerning the anthropogenic impact (Ichim et.al., 1990; Rădoane M. et.al., 2005, 2008; Popa-Burdulea, 2007).

The Siret River is the biggest river from Romania. It springs from the Paleogene flysch of the Wooded Carpathians (in Ukraine) at an altitude of approximately 1238 m and drains, within its catchment the central-eastern part of the Eastern Carpathians and a part of the South-Eastern Carpathians, the Moldavian Sub-Carpathians and the northern part of South-Eastern Sub-Carpathians, the Moldavian Plateau and the Lower Siret Plain. The catchment area of the Siret River covers an area of 44 871 sq km from which 42 890 sq km in Romania. The total length of this river in Romania is 548 km, while there are another 110 km from its springs to the point it enters Romania.

The main relief lines decrease in height from west to east and from north to south. The morphographical and morphometrical features depend on lithology. This way in the Carpathians

area, from west to east, there align the main morphological units:

-*Volcanic mountains*, with massive forms and hard rocks. In this area the runoff is high (15 – 20 l/s/km<sup>2</sup>) and the sediment yield is low (0,5 – 0,7 t/ha/yr).

-*Crystalline mountains*, also with massive forms, and very high, because of the hard rocks, and with limestone intrusion. The runoff is still high (12 – 16 l/s/km<sup>2</sup>) while the sediment yield is low (0,8 – 1,2 t/ha/yr).

-*Flysch mountains* are characterized by a great lithological variability, because of the overthrust layers. Here the runoff has values between 8-14 l/s/km<sup>2</sup>, and the sediment yield become high (20 – 25 t/ha/yr in the South-Eastern Carpathians).

-*Sub-Carpathians* are located on the eastern part of the Carpathians, characterised by the presence of some depressions bounded by anticline hills. In this area the runoff is between 8 – 10 l/s/km<sup>2</sup>, and the sediment yield between 5 – 15 t/ha/an, but there are a lot of variations.

The main relief units from the platform region are the Moldavian Plateau, the Lower Siret Plain and the north-east part of the Baragan Plain. In the plateau, the runoff has values between 2 – 6 l/s/km<sup>2</sup>, and the sediment yield between, de 2 –5 t/ha/yr. In the plain area the values of the runoff and the sediment yield are much smaller.

Olariu P. et.al. (2009) mention for the geography of the Siret River Catchment a few hydro-climatic features which influence the rainfall and runoff regime:

a) The location of the Siret River Catchment in the temperate continental climate, with frequent thermal and rainfall discontinuity.

b) The location on the eastern part of the Carpathians, which represents a complex barrier for the air mass movement from west, more humid and heat moderate.

c) The presence in the vicinity of the space around the Black Sea, which is characterized through an excessive temperate climate.

d) Landscape fragmentations, the local relief and the general orientation of the relief forms, of the valleys and depressions.

e) The early human impact in this river catchment with big influences in modifying the landscape.

The human impact from the Siret River Catchment present a few aspects that need to be mentioned:

-the existence of big reservoirs (Rogojești, Bucecea, Galbeni-nonfunctional at the moment of

the flood from 2010, Răcăciuni, Berești, Cosmești, Movileni) that have a big impact in the annual regime of sediment transport (Fig. 4).

-the presence of a big number of pit-ballast in the Siret flood-plain (approximately 150, with an annual extracted quantity of gravel around 3 mil. tones in 2009, source: "Siret" Water Branch, Bacău).

-numerous hydrotechnical projects (channel regularization, river bank consolidation, damming).

-deforestation and irrational utilization of the agricultural land from the river catchment. Giurgiu V. (2010) presents an evolution of the forest area in Romania, indicating for the present a surface of 27% from Romanian territory. After analyzing the **CORINE Land Cover data set**, it can also be said that between 1990-2006 the forest area was reduced with approximately 15 000 ha and the arable land increased for the same period with almost 5700 ha for the entire catchment.

This study analyzes the flood routing (water and suspended sediment discharge) from the 20<sup>th</sup> of June – 10<sup>th</sup> of July 2010 on the Siret River and the efficiency of the reservoirs in attenuating the flood wave and trapping the sediments. The study area covers the Siret River from the border of Ukraine (Siret Town) until the last gauging station located on the lower course of this river, with suspended sediment measurements, Lungoci, in the Vrancea County, downstream the confluence with the Putna River.

## Data base and methods

In this paper, there were analysed the time series of hydrological data and instant dates from the gauging stations of the Siret River and from the closing sections of the main – tributaries on the right bank (the Suceava, the Moldova, the Bistrița, the Trotuș, the Putna Rivers) before the confluence.

The data base is from the archive of the Hydrological Service of the Siret Water Branch Bacău and consist of: water discharge during the flood; suspended sediment discharge during the flood; annual maximum water and suspended sediment discharge; recorded runoff during the study period, that contributed to the intensity of the flood.

The gauging stations that provided materials for this study are: for the Siret River – Siret, Huțani, Lespezi, Drăgești, Lungoci, and for the main tributaries: Ițcani – for the Suceava River, Roman – for the Moldova, Bacău (Albia veche, Canal UHE) –

for the Bistrița River, Vrânceni – for the Trotuș and Boțârlău – for Putna (Table 1, Fig. 4).

**Table 1. Morphometrical data**

River	Gauging station	The distance from the confluence with the main river (km)	River catchment	
			Area (km <sup>2</sup> )	Mean height (m)
Siret	Siret	559	1637	572
Siret	Huțani	483	2115	515
Siret	Lespezi	410	5888	513
Siret	Drăgești	282	11846	525
Siret	Lungoci	77	36098	539
Suceava	Ițcani	44	2334	629
Moldova	Roman	5	4274	678
Bistrița	Bacău	7	7029	919
Trotuș	Vrânceni	37	4092	734
Putna	Botârlău	11	2450	554

Source: Romanian's Water Cadastre – „Siret” Water Branch, Bacău

The instant data are obtained by measurements during the flood (the 22<sup>th</sup> of June – 10<sup>th</sup> of July 2010) with water discharge measurement tools and by taking samples of water with some special containers for detecting the suspended sediment concentration.

For the situation when the measurements weren't possible, in different moments of the flood, the values of the water and sediment discharge were obtained by using different correlations for each gauging station and by comparison with other flood events similar with the one in 2010 (e.g. at Dragesti station after the 5<sup>th</sup> of June 2010, because of some technical problems, measurements have not been made anymore, making impossible a full analysis of the phenomenon in this section).

In the data gathered were processed in Microsoft Excel and there resulted 2 types of graphics that show very well the main features of the flood from the 20<sup>th</sup> of June-10<sup>th</sup> of July 2010: the hydrographs of water and sediment discharge (Fig. 2, 3) and the diagrams of the evolution of the river bed channel in the sections of measurements, during 2010 and especially during the study flash flood (Fig. 5).

Creating the flood hydrographs required only the preparation of the table and drawing the graphs. The other type of method is a little bit different. To obtain the tendency of the river bed evolution we need some data recorded in the so-called "Water discharge summary" for each gauging station ("0 level" of the staff gauge, maximum depth of the river-Hmax, water level at the staff gauge –H, dates obtained after measuring the water discharge with current meter).

The method to obtain the needed data is presented in figure 1 and consists of decreasing the maximum depth of the river (H max) from the water level at the staff gauge (H), considering the absolute value of the "0 level". The difference between these two parameters is the river bed channel evolution from a measurement to another (normally during a hydrological year at a gauging station there are made 40 to 60 measurements).

Beside the graphical materials of this paper, a comparative analysis of the rainfall recorded in the river catchment, of the maximum values of the water and sediment discharge was also done. Comparisons were made relative to the values of the control sections of main tributaries and to the average annual values.

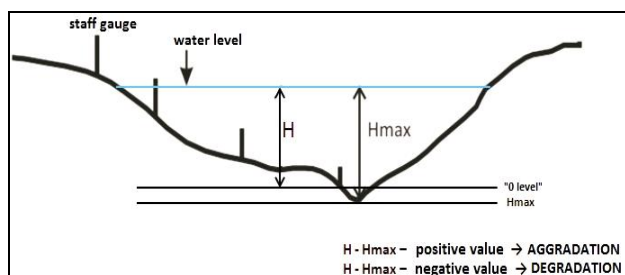


Fig. 1: Method of calculating the height of the river bed

## Results and discussions

The data base that we possessed and the methods applied to process these data have allowed the analysis of the flood from different points of view: the evolution of the precipitation, flood routing and river bed channel evolution. This way, the results and the discussions around them were structured by the topics mentioned above.

### 1. Rainfall variability

The flood occurred in 2010 on the Siret River was a big flood for the hydrological regime of this river and was determined by the rainfalls from the 20<sup>th</sup> of June-1<sup>st</sup> of July. This flood and the precipitations that generate it were very well monitored. Table 2 features the most representative values of rainfall from the period mentioned above comparing to the mean multiannual values from the month of June.

Table 2 presents only the gauging stations considered representative for the study area and where there were recorded important values of rainfall for the study period.

The analysis of the data from this table indicates that the quantity of the precipitation from 20<sup>th</sup> of June-1<sup>st</sup> of July is higher or equal with the mean multiannual

value of the month of June for most of the stations (Siret, Zvoriștea, Țibeni, Horodnic, Părâuți, Lunguleț) or significant compared to the mean value (Brodina, Fd. Moldovei, Pr. Dornei). The big amount of rainfall during the flood compared with the mean value were also mention by other authors, referring to similar events from the Siret River Catchment (Diaconu et al, 1970; Zăvoianu and Podani, 1992; Mustățeș, 2005; Rădoane N. et al, 2007; Olariu et al, 2010).

Table 2. Rainfall from the Siret River Catchment, June-July 2010

River	Gauging station	Rainfall 20.6-01.07 (l/m <sup>2</sup> )	Mean multiannual rainfall – June (l/m <sup>2</sup> )
Siret	Siret	133,4	95,0
	Zvoriștea	202,5	81,8
Suceava	Brodina	109,1	140,8
	Țibeni	209,7	110,8
	Ițcani	32,8	96,8
Pozen	Horodnic	115,2	97,2
Soloneț	Părâuți	120,3	90,6
Moldova	Fd. Moldovei	79,8	95,6
	Pr. Dornei	94,8	115,8
Moldovița	Lunguleț	125,6	130,3

Source: „Siret” Water Branch, Bacău

Considering all these values, it is clear that the excessive nature of the rainfall was also present in other areas from the northern part of the Siret River Catchment, unmonitored unfortunately, but with an important effect in producing and intensifying the flood. The main rivers affected by floods were the Siret, the Suceava, the Moldova, the Bistrita (downstream Izvorul Muntelui Reservoir) and their tributaries. This flood has flowed – with maximum values of the water discharge – downstream of the Siret River. The maximum water discharge recorded is mentioned in table 3.

### 2. Water discharge

The water discharge during the studied flood is presented presented in the graphics from figure 2. These hydrographs were made for all the gauging stations from the Siret river with suspended sediment measurements.

The gauging stations were grouped by the reservoirs system that influences their discharge: Siret, Hutani, Lespezi for Rogojesti and Bucecea reservoirs and Dragești, Lungoci for the group of reservoirs: Răcăciuni, Berești, Călimănești, Movileni (Fig. 2). Galbeni reservoir at the moment of the flood it was drained and nonfunctional for catching and transiting the wave of flood. This reservoir had no influence for the water and sediment discharge.



The graph for the first group of stations indicates very well the attenuation of the wave flood while passing through the mentioned reservoirs (Rogojești, Bucecea) between Siret and Hutani and also the significant contribution of the Suceava River for Lespezi station. The maximum water discharge between these 2 gauging stations (Siret, Hutani) decreased with 27 percent (Table 3). Taking into consideration the other two gauging stations, Dragești and Lungoci, it also can be observed an attenuation of the flood wave after transiting the 4 reservoirs, but smaller that in the north of the basin. For this area the water discharge decreased only with 7 percent from Dragești downstream to Lungoci even if the tributaries inflow was quite small (Bistrita, Trotus, Putna). This situation can be explained only by using some maneuvers to transit big quantity of water through the 4 reservoirs mentioned above.

Table 3. Maximum water discharge from the study area

River	Gauging station	Qmax 2010 (m <sup>3</sup> /s)	Qmax hystorical (m <sup>3</sup> /s)	Observations
Siret	Siret	1115	1193/1969	
Siret	Huțani	815	866/1969	After passing through Rogojești and Bucecea reservoirs Qmax decreased with 27%
Suceava	Ițcani	1050	1710/2008	
Siret	Lespezi	2049	2414/2008	
Moldova	Roman	990	1415/1991	
Siret	Drăgești	2850	2930/2008	
Bistrița	Bacău (Albia veche + Canal UHE)	915	-	
Trotuș	Vrânceni	1280	2845/2005	
Putna	Boțârlău	284	1598/2005	
Siret	Lungoci	2643	4650/2005	After passing through Răcăciuni, Berești, Călimănești, Movileni, Qmax decreased with 7%

Source: „Siret” Water Branch, Bacău – Hydrological Service

According to “SIRET” Water Branch, Bacău, for the middle and lower sector of the Siret River, at Racaciuni, Beresti, Calimanesti and Movileni reservoirs, took place correlated maneuvers took place for transiting important quantities of water in such a way that downstream the Movileni reservoir the maximum water discharge to be around 2300 – 2500 m<sup>3</sup>/s, which really happened (Qmax Lungoci – 2643 m<sup>3</sup>/s). The Siret river channel downstream Lungoci station has a capacity of transiting such amount of water without causing any floods for the localities downstream until the inflow to the Danube.

Normally this type of evolution happens almost every time such a big flash flood occurs – attenuation between Siret and Hutani stations and between Dragești and Lungoci stations. The only situation that can be different is the percentage reduction of the maximum discharge which can be influenced by the tributary inflow.

The type of water discharge evolution is due to the reservoirs that gives a certain mode of flood wave propagation from upstream to downstream. This situation was also observed and mentioned by other authors for the floods occurred in 1991 (Podani, Zăvoianu, 1992) and 2008 (Olariu et.al., 2010).

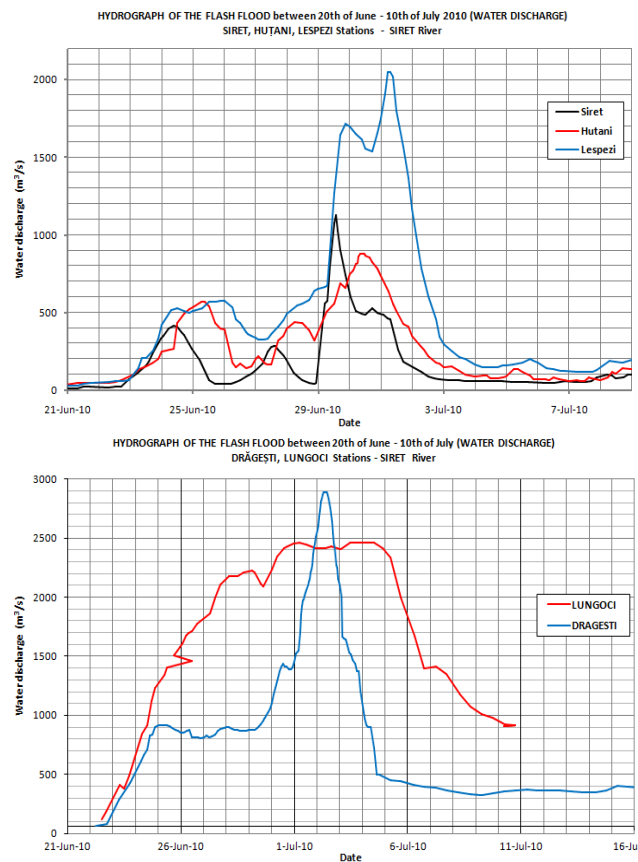


Fig. 2: The attenuation of the flash flood by the reservoir on the Siret River

### 3. Sediment transport

The water discharge of the flood transported important quantities of sediments (Table 4, Fig. 4). Because this study focuses mainly on the sediment transport during the flash flood, we will analyze the recorded values and their evolution during the flood.

Table 4 presents a comparative situation of the suspended sediment discharge (R) and the loads transported during the flood and for the entire year. The values indicate certain features for each station and are arranged in the table from upstream to downstream.

The hydrographs of the suspended sediment discharge also indicate some patterns of the sediment transport of Siret River (Fig. 3).

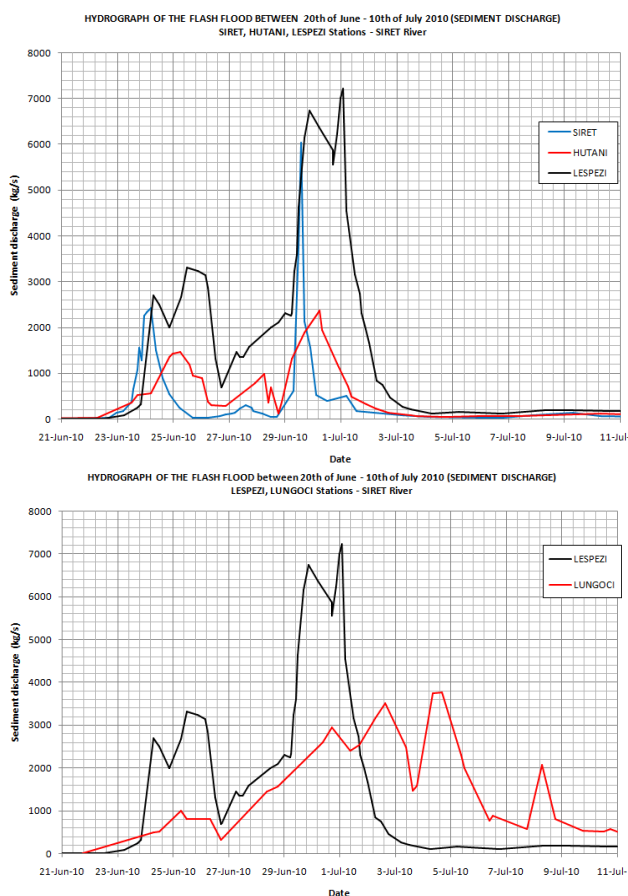


Fig. 3: Hydrographs of the sediment discharge during the flood on the Siret River

The maximum suspended sediment discharge recorded at Hutani station is 60% lower than that registered at Siret station (Fig. 4). Even so the sediment load transported during the flood is much bigger at Hutani (almost 0.3 mil t). This indicates very well the sediment trap efficiency of the two

reservoirs – Rogojesti and Bucecea. These reservoirs reduce the maximum sediment discharge by silting an important amount of sediments at the inflow the reservoir. In the same time, through the outflow of the reservoir there is evacuated important quantities of sediments which influence the sediment load of the flood event downstream.

It should also be mentioned the existence of a big pit-ballast upstream Hutani station, where that with the machinery activity from the channel, disturb the alluvial material, thus facilitating its transport.

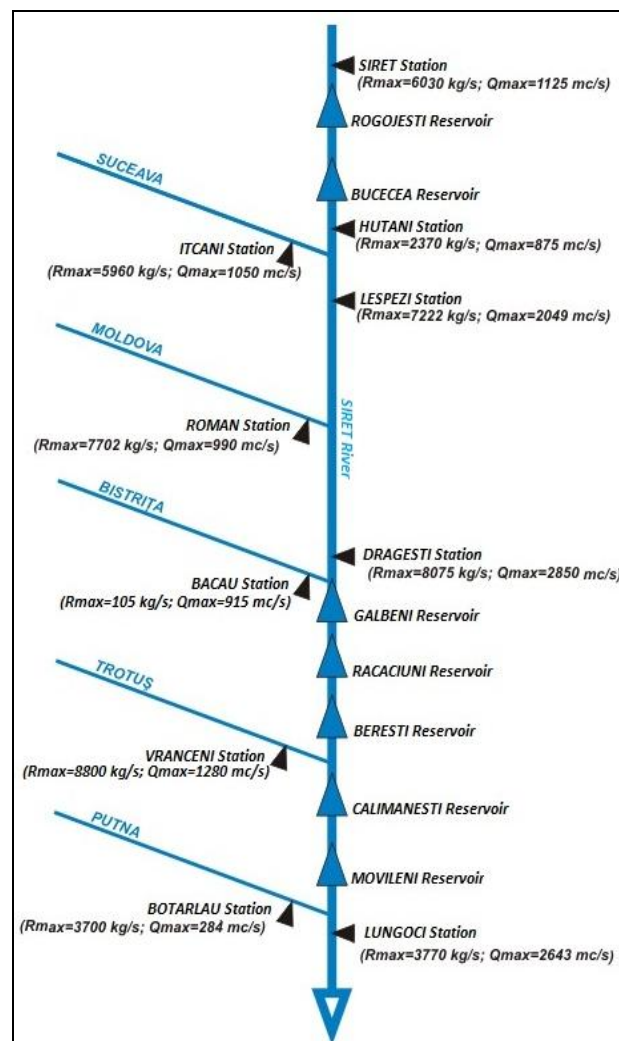


Fig. 4: The location of the reservoirs and the gauging stations on the Siret River and its tributaries

The contribution of the Suceava River to the sediment transport is also important as it can be seen from table 4. The maximum suspended sediment discharge at Lespezi station is significant comparing to the one at Hutani station and the sediment load is much bigger than at the station upstream (Fig. 3).

The data from table 4 regarding Lespezi, Roman and Dragesti stations indicate an important silting of the sediments between Lespezi and Dragesti. The discharge of the Moldova river does not cause any significant increase in the maximum sediment discharge and not even the sediment loads doesn't show an important increase compared to Lespezi station. The sediment discharge and the sediment loads of the Bistrita are very small because of the upstream reservoirs system, starting from Izvorul Muntelui up to Bacau. This indicates the insignificant contribution of this river to the Siret sediment transport.

Even if the Trotus River sediment load has big values, all the quantities are trapped in the reservoirs located downstream the confluence with the Siret. This is why at Lungoci station, the sediment transport

is almost entirely the result of the Putna River contribution, which that year wasn't very important because of a small flash flood. Comparing the maximum sediment discharge from Lungoci with the one at Dragesti station, it can be easily observed that it decreased by 53 percent (Fig. 5).

The impact of the reservoir from the Siret river on the sediment transport was also studied by Olariu et.al. (1998) and Rădoane et.al. (2005). These authors indicate also the sediment trap efficiency of these reservoirs.

Regarding the annual sediment load of the Siret River compared with the one during the flood, the data in table 4 indicate the fact that the biggest part of the sediments are transported during the major floods (between 50 and 89%).

**Table 4. Sediment discharge and sediment loads for the study area**

River	Gauging station	Rmean 2010 (kg/s)	Rmax 2010 (kg/s)	Sediment load 2010 (mil.t/yr)	Sediment load during the flood (mil.t)	Percent from the annual sediment load (%)
Siret	Siret	16,8	6030	0,843	0,450	53
Siret	Huțani	32,6	2370	1,028	0,744	72
Suceava	Ițcani	38,4	5960	1,210	1,083	89
Siret	Lespezi	89	7220	2,807	2,242	79
Moldova	Roman	84,5	7702	2,665	1,648	62
Siret	Drăgești	-	8075*	4,645*	3,021 *	65
Bistrița	Bacău (Albia veche + Canal UHE)	4,9	105	0,154	0,053	34
Trotuș	Vrânceni	68,9	8800	2,172	1,833	84
Putna	Boțârlău	39,9	3700	1,258	0,460	37
Siret	Lungoci	147	3770	4,636	2,372	51

*\*because there are no measurements form the flood, the values presented in the table were obtained from correlations with floods from the previous years (e.g.2008). Source: „Siret” Water Branch, Bacău – Hydrological Service*

The low values indicate a certain type of hydrological regime: for the Bistrita River (34%), the low percentage is influenced by the upstream hydropower improvement of this river, while for Putna River at Botarlau station, (37%) is determined by the small-scale flash flood from 2010 summer.

The ratio between sediment load during the flood and the annual values was also studied and indicated by C. Diaconu (1970). The big percentages during the flash floods are characteristic for almost all the rivers in Romania.

#### 4. Evolution of the river bed channel

For the analysis of the Siret sediment transport, it is also important to observe the evolution of the river bed channel in the monitoring sections during

the floods in order to indicate the moments of erosions and silting.

The method to calculate the river bed channel height is presented in the methods section (Fig.1) and can be achieved by using “Water discharge summaries” for each gauging station, where there are recorded the values of the maximum depth of water, water level, flow velocities, etc.

By processing the data from these “Water discharge summaries” we create the graphs from fig. 5 that point to a few aspects:

-at Siret station it can be observed a stationary situation of the river bed channel during the flash flood, followed by an aggradation (approximately 20 cm) during the decreasing of the water discharge.

This tendency is determined by the location of the Siret station very close to the inflow of Rogojesti reservoir, that attenuates the flood wave through the afflux, causing also the sedimentation at the entrance into this reservoir.

-at Hutani station, the evolution of the river bed channel is a typical one a river bed channel during a major flood – degradation (65-70 cm) during the discharge increase and aggradation (80 cm) during the discharge decrease. At this station, the powerful aggradation is also the result of pit ballast located upstream that exploits big quantities of gravel.

-at Lespezi station, there can be observed a decreasing tendency (approximately 200 cm). This atypical situation is due to the fact that in the vicinity of the measuring section regularization works take place in the river bed channel for the Pascani reservoir that will be put in use in 2013. This way the alluvial material from the river bed channel is disturbed and during the 2010 flood this disturbed material was washed away.

-at Lungoci station, there can be seen an aggradation (100 cm) on the discharge increase and a mild degradation (50 cm) during the discharge decrease. This situation is the result of the controlled regime of the discharge upstream this station and to the contribution of Putna River ( $R_{\max}$  Boțârlău = 3700 kg/s,  $R_{\max}$  Lungoci = 3770 kg/s) during the increasing of the water discharge on the Siret.

For the entire 2010, there can be observed a stability of the river bed channel of the Siret River in the monitoring sections of gauging stations, except for Siret station where there appears a slight aggradation, influenced probably by the land use conditions from upstream, in Ukraine, not calculated yet (deforestation, percent of arable land from the catchment area, sheet and rill erosion, gullies and landslides).

Most of the scientific papers (Brânduș, 1984; Rădoane et.al., 1991; Olariu, 2004; Popa-Burdulea, 2007; Rădoane et.al., 2010) indicates for Siret River and for its Carpathian tributaries a general tendency of degradation of the river bed channel, evolution given to the availability of the sediments from the catchments (deficit or surplus) caused by the human impact (reservoirs, pit-ballast, measurements for reduction soil erosion) and by the hydrological regime. Still, for the 2010 flood and for entire annual evolution, this tendency is not clear, mainly because this sort of evolution takes place and can be observed in a much longer time.

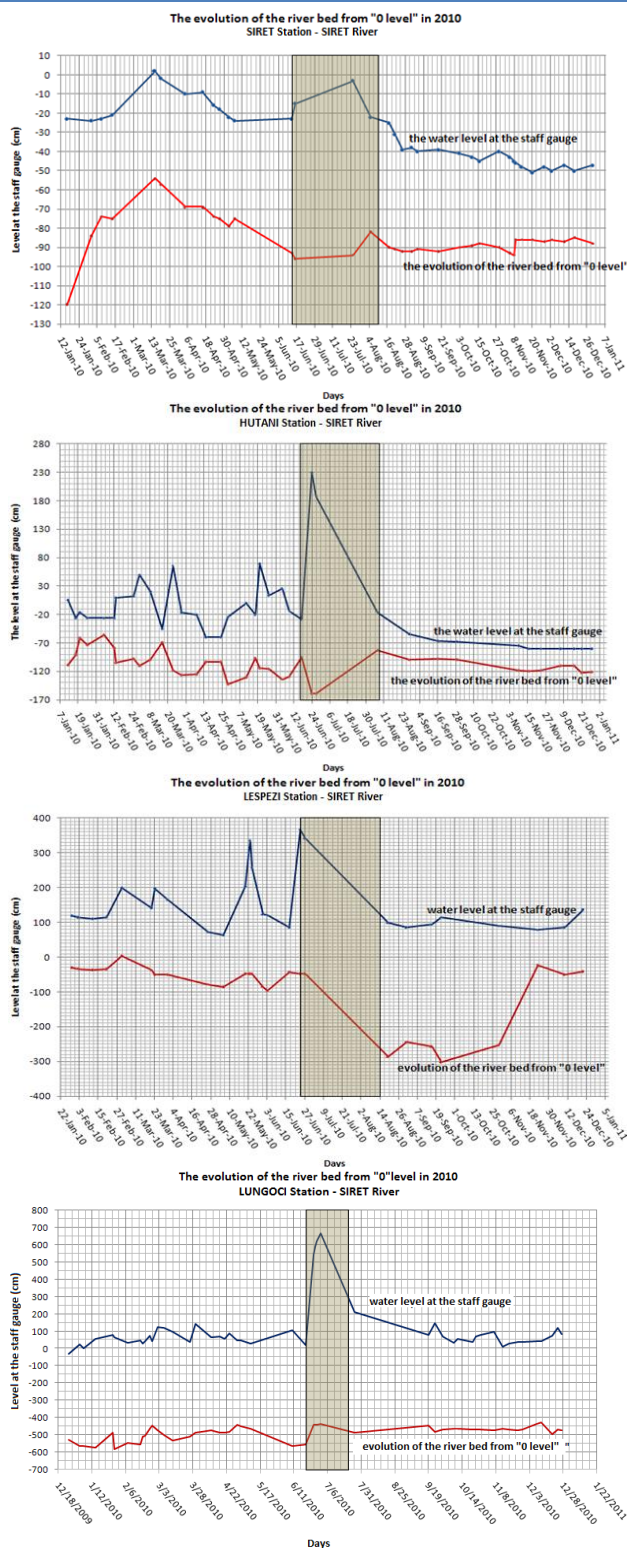


Fig. 5: Evolution of the river bed channel in 2010 in relation with the water level

## Conclusions

The 2010 flood from the Siret River was a significant one, evidenced by high values of water discharge (Table 3) and suspended sediment transport (Table 4).



The discontinuity frequency of the rainfall during the summer season contributed decisively, with important quantities to the water discharge of the flash flood. In general, as it was indicated by other authors (Diaconu et al, 1970; Podani, Zăvoianu, 1992; Mustăţea, 2005; Rădoane et al, 2007; Olariu et al, 2010) the amount of rainfall that generate a flash flood in the Siret River catchment are most of the time higher or closer to the mean monthly values for the occurring month (table 2- for 2010 flash flood). This increase of the climate modifications, influence the water discharge regime and also the sediment transport, causing a more torrential character of the hydrological regime.

The transiting of the flood wave was directly influenced by the reservoirs located between the border of Romania with Ukraine and upstream the confluence of the Siret River with the Putna River. This occurs during every flash flood on the Siret River as it was also mentioned by Podani, Zăvoianu (1992), Olariu et al (2010).

The influence of the reservoirs caused the reduction of the maximum water discharge of 27% and of 60% for the maximum suspended sediment discharge. Still, these percentages can vary due to the scale of the discharge and to the tributaries contribution.

The response of the river bed channel during the 2010 flood was a dynamical one and in general different from a gauging station to another. For Siret station, the evolution during the flood was of a slight degradation (20 cm). At Hutani station the evolution was of aggradation (70 cm) on the discharge increase and degradation (80 cm) during the discharge decrease. The evolution of Lespezi station river bed channel indicates a powerful degradation (200 cm) during the entire flood. The last station that we analyzed, Lespezi, showed an aggradation (100 cm) during the discharge increase and of discharge and a degradation (50 cm) on the moment when the discharge decreased.

The causes for this types of evolution are numerous and are mainly determined by anthropogenic component from the studied catchment: the afflux phenomenon at the inflow in Rogojesti reservoir for Siret station; the impact of the pit-ballast and the regularization working on the river channels for Hutani and Lespezi stations; the contribution of tributaries with sediments during the increasing of discharge on the main river for Lungoci station.

The evolution of the 2010 flash flood indicates the importance of the reservoirs on the Siret River in attenuating the flood wave when the spilling maneuvers are well coordinate.

For the study area must be taken in consideration the importance of the reservoirs, especially because the rates of silting are very high (Rădoane, Rădoane, 2005), which will have a negative effect in the future on the capacity of these reservoirs to retain the flood waves.

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