BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 63 (67), Numărul 1-2, 2017
Secţia
HIDROTEHNICĂ

ANALYSIS OF HYDROLOGICAL RISK PARAMETERS IN TROTUŞ RIVER BASIN

BY

AVRAM MIHAELA and LUCA MIHAIL*

"Gheorghe Asachi" Technical University of Iaşi,
Faculty of Hydrotechnics, Geodesy and Environmental Engineering

Received: February 14, 2017
Accepted for publication: March 22, 2017

Abstract. This paper presents an analysis of the hydrological risk parameters registered in the basin of the Trotuş River. The research took into account the hydrological risk parameters in the last 25 years. The Trotuş River basin was affected by multiple floods in the last 25 years. The floods have changed the minor and major river morphology and have influenced the coastal flood zones. The study was focused on the analysis of the precipitation and liquid flow rates (minimum, mean and maximum) over a period of 50 years. The processing of the rainfall data has indicated some factors that have occurred mostly in the last 20 years. The processing of the hydrological data has highlighted several flood flows in the same year. The effects of floods have resulted in excessive damage to the regularization rivers works studied. The floods caused the destruction of social and economic objectives of the waterside. The hydroclimatic risk parameters highlighted through research are torrential rainfall, flood flows, high flow rates and high speed of riverbed erosion. Hydroclimatic risk parameters impose special conditions on building design regularization of the river.

Keywords: river; rainfall; flow; flood; regulation work.

1. Introduction

A series of global climate changes, with direct impact on the environment have been recorded in the last 30 years. These changes are present

*Corresponding author: *e-mail*: mluca2004@yahoo.com

in Romania and have an influence on the distribution of annual rainfall and flow rates in river basins. The high number of meteorological changes creates an important hydroclimatic risk in the evolution of river flows and water levels. These changes have a direct impact on the river's evolution and the existing buildings located in the riverbed and riparian area. Lately, the hydrological regime of rivers situated in the Siret River basin has been characterised by a high flood frequency. Flash floods in the past few years have produced significant economic damage and human losses.

The hydrological risk factors change the cross section and the longitudinal section of the riverbed morphology, Also, the stability of construction situated in the riverbed (bridges, river works) and on the banks (shore protection, dikes) is affected. The existing habitat in the minor and major riverbed is affected by the hydrological risk factors. The disastrous floods have caused major damages to social and economic structures found in river areas. The value of flood related damages has increased, a situation which requires a significant investment regarding the rehabilitation of the affected areas. The impact of the riverbed changes can be immediately noticed or it can occur after a long period of time. The hydrological parameters evolution has a direct impact on the restoration of river works and shore protections.

2. Study Area and Research Method

The research was conducted in the Trotuş River basin. The research material was collected in the Siret River basin and was customised for the Trotuş River basin. The Trotuş River basin is located in the Eastern Carpathians Mountains relief area and it goes through Ciucului and Tarcăului Mountains and Comăneşti and Tazlău – Caşin Hollows. Trotuş River flows into Siret River downstream from Adjud Town.

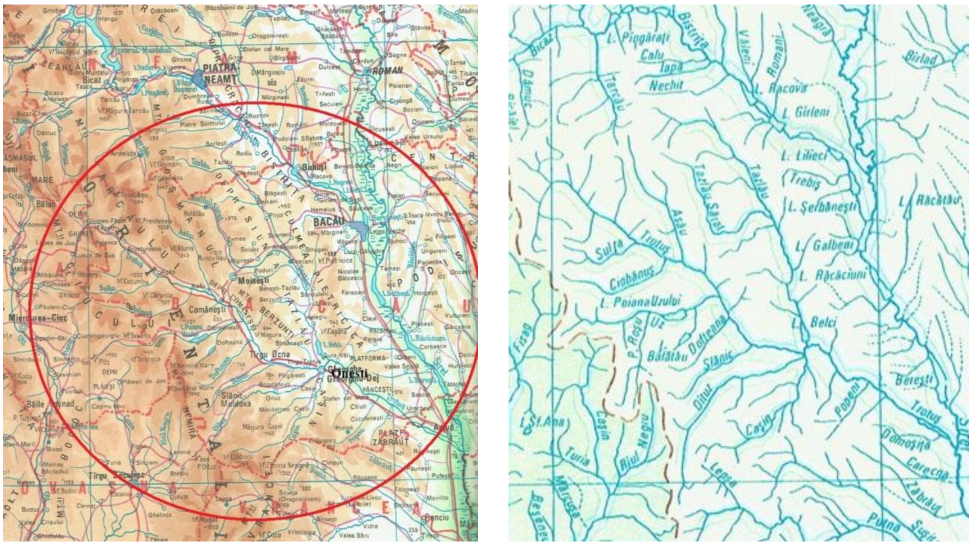
Trotuş River has the cadastral code XII-1-69. Trotuş River springs are located at an altitude of 1360 m in Ciucului Mountains and its main direction is North – South. The Trotuş River tributaries taken into consideration for the analysed sector are (Ujvari, 1972):

a) on the right side: Ciugheş, Cotumba, Grohotiş, Suliţa, Ciobănuţ, Supan, Uz, Dofteana, Slănic, Nicoreşti, Oituz, Caşin, Gutinaş, Căiuţi, Popeni;

b) on the left side: Bolovăniş, Tărhăuţi, Şanţ, Cuchiniş, Brusturoasa, Camenca, Agăş, Seaca, Ciungi, Asău, Urmeniş, Plopul, Cucuieţi, Vâlcele, Tazlău.

The right side tributaries are more numerous and have larger catchment areas (Uz – 469 km^2, Oituz – 337 km^2 and Caşin – 308 km^2) because they drain higher mountain areas and have higher flow rates. The most important left side tributaries are Asăul – 208 km^2 and Tazlăul – 1104 km^2.

The Trotuş River basin has an area of 4,440 km^2. The River's length is 158 km. The average basin elevation varies between 1140 – 734 m. The Trotuş River and its tributaries are monitored through 21 hydrometric stations. This way the flow parameters (liquid and solid flow, water levels, icing, etc.) were determined for a period of 40 – 60 years (Table 1, ABA Bacău).



a *b*

Fig. 1 - Framing of the study area (Trotuş River basin) in the Siret River basin: *a* – the location of the study area in the Eastern Carpathians Mountains; *b* – the location of the area in the Siret River basin.

The data collected consists of hydrological, hydraulic, ground surveillance, geotechnics and operational reliability studies. The studies and research cover a period of 50 years. Some aspects were studied thoroughly for over 25 years. The theoretical and experimental research was conducted on the following areas:

1. Research on meteorological parameters of the catchment area considered in the study. The analysed parameters were: daily, decadal, monthly and annual rainfall and their evolution over time.

2. Research on hydrological parameters of the catchment area. The analysed parameters were: liquid flows, solid flows, water levels, flood frequency, floodplains etc.

3. Research on hydraulic parameters of the river section located in the study area. The following parameters were analysed for each analysis river section: flow rates, water levels, flow velocity (average, minimum, maximum, velocity distribution).

4. Research on hydrological risk parameters on the morphology of the river bed of the river studied.

5. The effect of the hydrological and hydraulic risk parameters on the river and riparian area.

The primary data were processed by using statistical, hydrological and hydraulic computational software.

3. Results and discussion

The hydroclimatic risk phenomenon research is conducted on four rivers situated in the Siret River basin. The rivers selected for the research are found in characteristic areas of the basin:

– from the northern mountain area, Voroneț River;
– from the central mountain area, Tazlăul Sărat River;
– from the piedmont area, Trotuş River;
– from the hills area, Moldova River.

This paper presents the research results only for the Trotuş River basin. Climate data collected from weather stations located in the analysed basin area were used for the research. The meteorological data were collected over variable time intervals (between 5 and 65 years). The analysis was conducted for a number of 65 years for the results to be as realistic as possible. The data were processed and graphically translated for those 65 years and for research required analysis periods (10...20 years) (Avram, 2016). The variation chart of the annual rainfall during 2000-2015 registered at the hydrometric station in Tg. Ocna from Trotuş River basin is represented in Fig. 2.

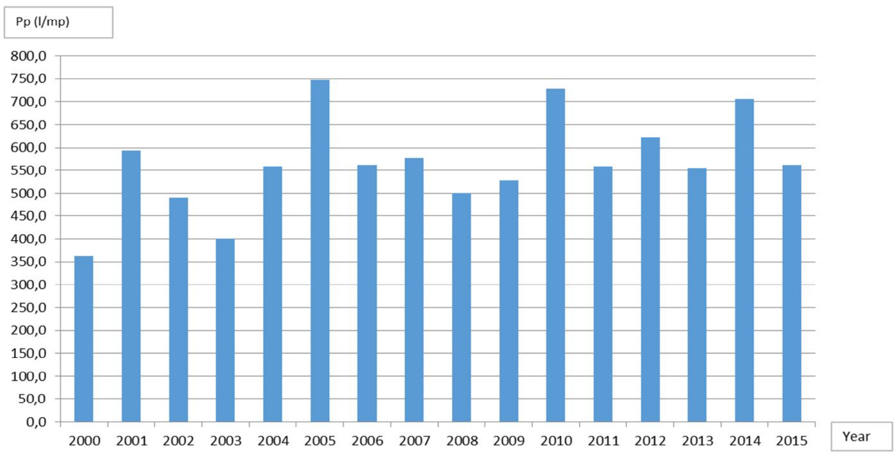


Fig. 2 – Annual rainfall during 2000–2015 variation chart.

The analysis highlights many positive and negative variations, but it can't detect a clear trend towards an increased or reduced value. Under these circumstances it can be said that in recent years, amid global warming, there is not a certain trend of rainfall evolution. The analysis of two extended periods of time (1950-1983 and 1984-2015) shows that, in the first part of the period, the average multiannual rainfall exceeding frequency was higher (20 cases) compared to the second period (only 11 cases).

Hydrological data were collected form hydrometric stations located on the analysed river's characteristic sections (Table 1). Hydroclimatic risk period data were analysed by considering variable periods of time (10,...,65 years). For the analysis were considered mean, maximum and minimum multiannual flows from 1950 to 2015. Flow analysis was also conducted on time intervals determined by the research (Avram, 2016). The research analysed the variation of the mean annual flow compared to the multiannual one and the exceeding of the critical rainfall probability on the rivers considered.

Table 1
Hydrometric Monitoring Network Trotuş River Basin
(A.B.A. Siret, 2015, Avram, 2016)

Nr. crt.	Hydrometric station	Basin area F km^2	Average elevation H_m, [m]	Q_{mean} m^3/s	Q_{max} m^3/s	$Q_{max,\,p}$, [m^3/s]			
						1%	2%	5%	10%
1	Lunca de Sus	88	1,140	0.805	23.2	210	165	113	77.5
2	Ghimeş-Făget	381	1,116	3.65	127	500	410	300	220
3	Goioasa	781	1,052	6.59	**353**[1]	750	625	460	340
4	Tg. Ocna	2,091	924	17.5	**1,490**[2]	1,200	1,025	795	625
5	Oneşti	2,836	830	25.1	**2,294**[3]	1,620	1,390	1,075	840
6	Vrânceni	4,092	734	35.0	**2,845**[4]	2,345	2,095	1,580	1,255
[1] – flood recorded on 29.07.2004; [2] – 12.07.2005; [3] – 12.07.2005; [4] – 13.07.2015									

Seasonal multiannual mean flow analysis shows the following results:

a) the minimum flows occurs during winter and autumn; winter flow amount represents 8.7% to 11.6% of the annual value and between 12% and 15.5% for the autumn flow; the two periods represent more than 1/5 of the annual flow;

b) the maximum flow occurs during spring and summer; spring flow value represents 39.9 to 49.3% of the annual value, respectively 27.1 to 34.7% for summer.

Table 2 shows the transportation of alluvial deposits on Trotuş River and its tributaries.

The Trotuş River basin climatic parameters have shown a high degree of instability in the spring and summer of 2005. The rainfalls have concentrated on short periods of time. Moreover, significant precipitations fell at short time intervals. This led to local flash floods on the Siret River tributaries (A.B.A. Siret, 2005, Luca & Stoenescu, 2007). The most significant flash floods were registered on Siret, Moldova, Suceava, Trotuş, Bistriţa Rivers and their tributaries (A.B.A. Siret, 2005, Luca & Ignat, 2007). Floods with significant flow rates were registered in July 2005 in Trotuş River basin, Vrânceni area, which correlated with those produced on the Lower Siret River. Significant floods have occurred in August 2005 in Suceava and Moldova River basins and on the Middle Siret River.

The flash floods were a result of the high rainfall registered in July and August 2005 in the central – eastern and curvature area of the Eastern Carpathians Mountains and Subcarpathian Hills. The largest volume of rainfall was recorded in Trotuş River basin during 11-14 July 2005 (Table 3, A.B.A. Siret, 2005).

Table 2
The Transportation of Suspended Sediments in Trotuş River Basin (A.B.A. Siret, 2014)

Nr. crt.	River	Hydrometric Station – HS	Catchment area km^2	Average elevation H_m m	Q m^3/s	R kg/s	Tr. gr/l
1	Trotuş	Lunca de Sus	89.2	1,140	0.77	0.11	0.143
2		Goioasa	765	1,052	6.41	4.32	0.674
3		Tg. Ocna	2,084	924	16.3	14.0	0.859
4		Vrânceni	4,077	734	35.2	34.4	0.977
5	Asău	Asău	196	951	2.07	1.28	0.618
6	Uz	Valea Uzului	160	1,070	1.70	0.21	0.124
7		Cremenea	340	1,070	3.95	0.39	0.098
8	Oituz	Ferăstrău	263	810	3.17	1.63	0.514
9	Tazlău	Scorţeni	417	574	3.37	6.07	1.80
10		Helegiu	984	520	6.85	13.0	1.90
R – silt mass flow; Tr. – turbidity							

Table 3
Rainfall Recorded at Ten Hydrometric Stations (HS) During 11 to 14 July 2005
(A.B.A. Siret, 2005)

Nr. crt.	River	Hydrometric station	Rainfall, [l/m^2]			Sum l/m^2
			11-12	12-13	13-14	
1	Trotuş	Lunca de Susşl	30.0	28.0	2.0	60.0
2		Ghimes Faget	31.5	51.0		82.5
3		Tg.Ocna	46.8			46.8
4		Oneşti	39.6	112		151.6
5		Vrânceni	41.4	114	6.7	162.1
6	Ciobănuţ	Ciobănuţ	32.3			32.3
7	Asău	Asău	61.7			61.7
8	Uz	Cremenea	32.3	11.5		44.8
9	Oituz	Ferestrău	54.5	62.5	13.2	155.6
10	Tazlău	Tazlău	23.8	150.0	11.5	185.3
11		Helegiu	40.2	87.5	12.3	140.0

The Flood of July 2005 had a historical character for Trotuş River basin. A significant situation was in the first decade of July, when in the Trotuş River basin weren't registered any major floods (Fig. 3), although the rainfall volume exceeded normal values. Rainfall in the first decade led to increasing soil moisture and high watercourse levels. This determined the appearance of higher leakage coefficients for the second decade of July and favoured flash floods with the critical rainfall probability between 0.5 and 0.1% (p = 0.5,…, 0.1%). Analyzing the data in Table 3 it can be shown that rainfall on the 10th July 2005 was general throughout the Trotuş River basin and the value was extremely high. At Lunca de Sus Hydrometric Station was recorded 80 l/m^2 in 24 h (A.B.A. Siret, 2005).

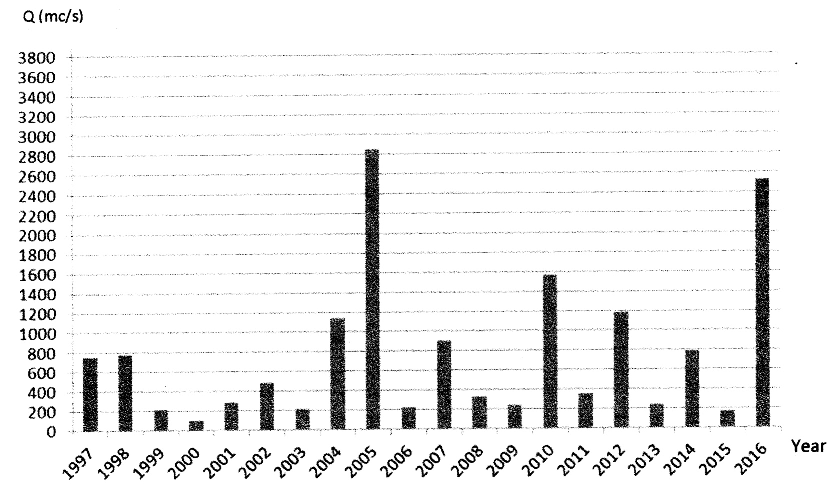


Fig. 3 – Annual maximum flows during 1997-2016 registered at Vrânceni Hydrometric Station.

Trotuş River flow rates were influenced by the hydrological conditions created in the first decade of July, in which case they rose considerably (Table 4). Trotuş River flows have exceeded the critical rainfall probabilities of the flood defence constructions.

The floods produced by this phenomenon have caused extensive economic and social damages and human losses. The most affected river basins were Trotuş, Tazlău, Bicaz, Cracău, Trebeş, Suşiţa, Putna, Rm. Sărat etc. and especially the interior of the Siret River, by collecting floods on the tributaries (the largest contribution being that of Trotuş River).

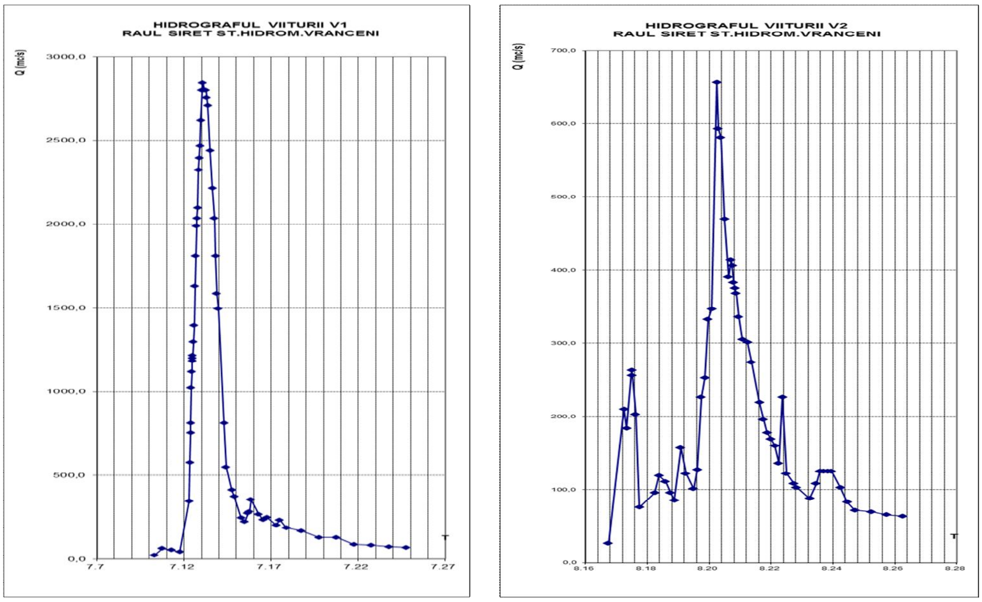
Table 4

Trotuş River Flood Elements Analysis, July 2005 (Avram, 2016, A.B.A. Siret, 2005)

Nr. crt.	Hydrometric station HS	Flood start[1]		Flood peak[2]		Flood end[3]		$T_{cr.}$ hours	T_{tot} hours	Q_{max} m^3/s	P %
		day	hour	day	hour	day	hour				
1	Goioasa	12.07	0.0	12.07	20.00	19.07	18.00			331	10
2	Tg. Ocna	11.07	7.00	12.07	23.00	20.07	12.00	40	221	**1490**	**0.5**
3	Oneşti	11.07	18.00	13.07	0.00	20.07	18.00	37		**2296**	**0.5-0.1**
4	Vrânceni	11.07	18.00	13.07	2.00	21.07	6.00	39		**2845**	**0.5**

[1] – the begining of the flood; [2] – the peak of the flood; [3] – the ending of the food

A hydrograph at the flow measurement hydrometric station was drawn for each flash flood (Avram, 2016). Fig. 4 shows the results of the flow data analysis at the Vrânceni Hydrometric Station for July and August 2005.



a *b*

Fig. 4 – Flood hydrographs for Vrânceni Hydrometric Station on Trotuş River:
a – July 2005 flood; *b* – August 2005 flood.

The cumulative hydrograph for the four hydrometric stations analysed (Vrânceni, Târgu Ocna, Oneşti and Goioasa) reveals the high flow rates and their historic character (Fig. 5). The chart shows the specific way the flood forms, the maximum flow rate propagation from the Trotuş River upstream to the downstream and the flood's ending.

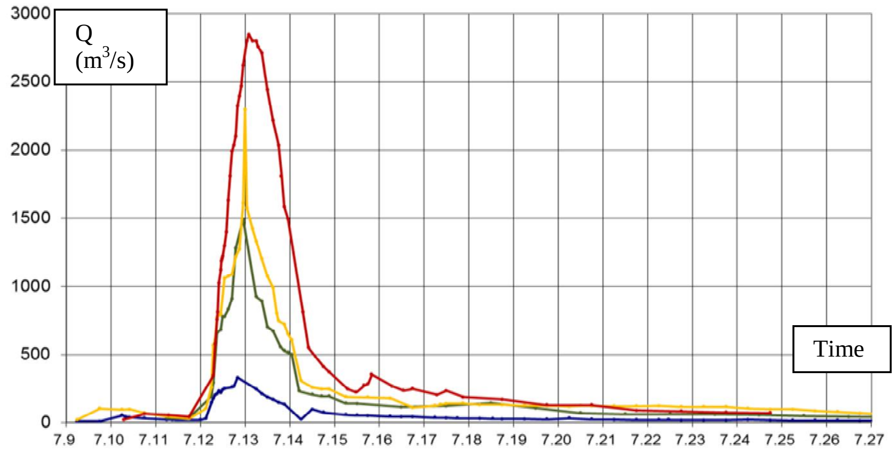


Fig. 5 – The cumulative hydrograph of the Trotuş River in 09-27 July 2005, for the four hydrometric stations: HS Vrânceni – reed; HS Oneşti – yellow; HS Târgu Ocna – green; HS Goioasa – blue.

Data processing and analysis revealed the historic character of the Trotuş River flood from July 2005. It had the highest recorded value and hydrometric monitoring period. The flash flood had a catastrophic flow rate at the hydrometric stations from the middle and lower Trotuş River basin. The analysis of the critical rainfall probabilities (*p*) shows the high values which are exceeding the maximum flood flow rates accepted for the sectors taken into consideration. The proabilities were: 0.5% at Tg. Ocna Hydrometric Station and 0.1% at Vrânceni Hydrometric Station.

The flash floods from 2005 had the highest flow rates ever registered (considered to be historical floods) and the levels produced were above the danger levels, both on Trotuş's main course and its tributaries. These flow rates caused excessive local coastal erosion and riverbed sedimentation which have led to significant riverbed morphological changes.

The Trotuş River flash floods from July has partially and totally degraded housing, household annexes, social and economic constructions, crops, forest lands (Fig. 6). The flood caused extended damages to road infrastructure (national and local roads), railroads, bridges, public interest area access roads etc.

a

b

Fig. 6 – Photo surveys regarding Comăneşti Town from Trotuş River basin in 2005: *a* – coastal area; *b* – town area (A.B.A. Siret, 2005).

The damages produced by the July Trotuş flash flood highlighted the high number of social and economic constructions destroyed. The water-course regulation work and shore defences were partially and totally degraded over great lengths (a summary is shown in Table 5). All major Trotuş River tributaries have multiple degradations. (Avram, 2016, ABA Siret, 2005).

Hydrotechnical works have been strongly affected by the 2005 flash floods in the Trotuş basin, where there were approximately 35.46 km of partially and totally damaged works (ABA Siret, 2005).

The flooding has made significant changes in longitudinal and cross section to the water courses from the analysed area. The alluvial deposits were significant in meander areas, bridges and at sudden riverbed widening. The alluvial layer's thickness varied between 1.50 and 2.0 m. The deposits partially blocked some sectors on the main course of Trotuş River and its tributaries. The stability of shore defences suffered significant changes due to the water's erosive action. The town's shore defence and that of the bridges was totally and partially degraded (Table 5).

Table 5
The effect of the Flood From 11.07 – 14.07.2005 on the Trotuş Riverbed Hydrotechnic Works (selected data, A.B.A. Siret, 2005)

Nr. crt.	Work name	Degraded lengths m	Q_c m³/s	Q_v m³/s	Q_{max} recorded m³/s	Defended settlements	Notes
0	1	2	4	5	6	7	8
1	Left shore defence Trotuş River at Straja	100	490	800	620	Straja	destroyed 100%
2	Water-course regulation work – Trotuş River, Brusturoasa Village	2,500	350	625	320	Brusturoasa Village	destroyed 100%
3	Trotuş water intake	200			2,300	–	– fixed downstream apron destroyed – mobile downstream apron destroyed – right bank concrete slabs revetment damaged L = 60 m – fish ladder destroyed
4	Left, right shore defence Trotuş River, Tg. Ocna	200	795	1,200	1,481	Tg. Ocna Town	Partially degraded
5	Water-course regulation work – Trotuş River at Păgubeni	1,220	585	900	1,350	Păgubeni Village	Totally degraded
6	Trotuş River shore defences, Goioasa Hydrometric Station	50	440	720	440	Hydrometric Station	Totally degraded
7	Casualty						7 people dead

The analysis conducted in the Trotuş River basin for varying time intervals has revealed a number of hydroclimatic risk factors, as follows:

a) high rainfall volume concentration for short time periods (2...4 days);

b) high torrential rainfall frequency for short time periods (in the same month or several months in a row);

c) reduced riverbed transit capacity for major flash floods;

d) river basins configuration, big hill slopes favouring flow concentration;

e) changes in the riverbed morphology consisting of sedimentation zones formation, riverbed and riverbank erosion, riverbed obstructions etc.;

f) biological material transport increase through the riverbed (branches, wood waste, trees etc.), a situation which causes the obstruction of the riverbed and bridges flow section;

g) increased rainfall – water drainage on slopes and river concentration due to the unsupervised deforestation;

h) continuous degradation of the basin regulation works of the non-permanent riverbeds (torrential) flow, a situation which reduces the flow time and increases tributary flow in the main riverbed (Fig.7);

i) change in the river flow coefficients due to human intervention.

a

b

Fig. 7 – Photo surveys regarding Asău Town from Trotuş River basin in 2005: *a* – coastal area; *b* – town area (A.B.A. Siret, 2005).

4. Conclusions

1. In the last 25 years the Siret River basin has been affected by disastrous hydrological phenomena, which have had a great influence on the rivers morphology, with significant influences on coastal environment. The flood related damages have required large investment funds for rehabilitation.

2. During 2000 - 2015 in the Siret River basin have taken place a series of floods characterised by high flow rates and high frequencies in short time intervals, which led to changes in the river bed morphology and the degradation of river works and shore protections.

3. The floods on the Trotuş River from June 2005 have recorded flows rates with a probability of occuring raging from 0.5% to 0.1%, in which case the effects had a highly distructive character on the river bed and coastal area.

4. The Flash Flood registered in the second decade of July 2005 on Trotuş River with the critical rainfall probability of 0.5 % and a value of 2845 m^3/s had the highest flow rate ever recorded at Vrânceni Hydrometric Station (historic flow rate).

5. The clime related phenomena in the Trotuş River basin in the past 15 years can be characterised as hydroclimatic risk phenomena through their destructive influence on the river bed and coastal area.

Acknowledgments. This paper was realized with the support of A.B.A. SIRET in programs of theoretical and experimental research**.**

REFERENCES

Avram M., *Cercetări privind impactul factorilor de risc hidroclimatic asupra proiectării, tehnologiilor de realizare şi exploatării lucrărilor de regularizare a râurilor. Studiu de caz. Raport 2 de cercetare*, Universitatea Tehnică „Gheorghe Asachi” din Iaşi, 2016,.

Băloiu V., *Amenajarea bazinelor hidrografice şi a cururilor de apă*, Edit. Ceres, Bucureşti, 1981.

Băran Gh., Şerban P., *Dezvoltarea durabilă şi managementul resurselor de apă*, Revista Hidrotehnica, **45**, *3-4* (2003).

Biali G., *Methods Used in Romania for Estimating the Agricultural Lands Value Placed in Outside the Cities.* Bul. Inst.Politehnic, Iaşi, **LXI (LXV)**, *1-2,* s. Hidrotehnică, 23-30 (2015).

Diaconu C., Şerban P., *Sinteze şi regionalizări hidrologice*, Edit. Tehnică, Bucureşti, 1994.

Luca M., Ignat A., *Morphological Changes Caused by Floods in 2004-2007 on Soci Area at the Moldova River,* Internat. Conf. „Disaster and Pollution Monitoring – IC.DPM. 3”, Iaşi, Nov. 1-2, 2007, 83-92.

Luca M., Stoenescu I., *L’analyse du comportement de travaux de régularisation dans des conditions de calamité,* Bul. Instit. Politehnic, Iași, **LIV (LVIII)**, *1* (I), s. Hidrotehnică, 25-34 (2008).

Ujvari I., *Geografia apelor României*, Edit. Ştiinţifică, Bucureşti, 1972.

Vamanu E., Olariu P., *Riscuri hidroclimatice în Spaţiul hidrografic Siret în contextul modificărilor geografice. Culegere de lucrări*, Ses. Ştiinţ. INMH Bucureşti, 2002.

* * * *Rapoartele de sinteză privind apărarea împotriva inundaţiilor, fenomenelor hidrometeorologice periculoase, accidentelor la construcţii hidrotehnice şi poluărilor accidentale din judeţul Bacău,* A.B.A. SIRET-Bacău , pentru anii 1991, 2004, 2005, 2010, 2012, 2014, 2015, 2016.

ANALIZA PARAMETRILOR DE RISC HIDROLOGIC ÎN BAZINUL HIDROGRAFIC AL RÂULUI TROTUŞ

(Rezumat)

Este prezintată o analiză a parametrilor de risc hidrologic înregistraţi în bazinul hidrografic al râului Trotuş. Cercetările au luat în consideraţie parametri de risc hidrologic din ultimii 25 de ani. Bazinul hidrografic al râului Trotuş a fost afectat de multiple viituri în ultimii 25 ani. Viiturile au modificat morfologic albia minoră şi majoră a râului, situaţie ce a influenţat zonele de inundaţie riverane. Studiul s-a axat pe analiza precipitaţiilor şi debitelor lichide (minime, medii şi maxime) pe o perioadă de 50 de ani. Prelucrarea volumului de precipitaţii a indicat o serie factori de risc ce au intervenit preponderent în ultimii 20 de ani. Prelucrarea datelor hidrologice a evidenţiat prezenţa mai multor debite de viitură în cursul aceluiaşi an. Efectele inundaţiilor s-au materializat prin degradarea excesivă a lucrărilor de regularizare şi apărare de mal. Inundaţiile au produs distrugerea unui număr mare de obiective economice şi sociale din zona riverană. Parametri de risc hidroclimatic evidenţiaţi prin cercetare au sunt reprezentaţi de precipitaţii torenţiale, debite de viitură, frecvenţa ridicată a debitelor cu valori ridicate şi vitezele mari se eroziune a albiei. Parametri de risc hidroclimatic impun condiţii speciale la proiectarea construcţiilor de regularizare a râului.