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ASPECTS REGARDING SOME HYDROCLIMATIC PHENOMENA WITH RISK CHARACTER FROM SIRET HIDROGRAPHIC AREA. STRUCTURAL AND NONSTRUCTURAL MEASURES OF PREVENTION AND EMERGENCY

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Key words: fast intervention systems for floods control, drought

Abstract. In this paperwork, we analyze the hydroclimatic phenomena with risk character, (floods, droughts) of the Siret Hydrographic Area. After an overview of geographic features of the analyzed area, in the writing we refer to:

- drought phenomena in the last years;
- the increase of torrential rains degree;
- aspects regarding special floods to 1991, 2004, 2005 and 2006;
- structural and nonstructural measures of prevention and fast intervention for the defense against floods in the Siret Hydrographic Area;
- fast intervention systems for floods control;

The paper deals with some aspects of risk management, which regard the prevention and the decrease of the effects of these events.

1. The hydroclimatic context of Siret river hidrographic area

The Siret Hydrographical Area represents that part of the hydrographical basin that is administrated by Siret Water Directorate. The relevant hydrographical network of Siret Hydrographical Area includes the main course of this river, from Ukraine border till the junction Dunarea and the hydrographical subbasins Suceava, Moldova, Bistrita, Trotus, Putna si Ramnicu Sarat, also the small affluent from the left side, ill the junction with Barlad River. Barlad subbasin, the left affluent from Barlad downstream and Buzau subbasin are not included in Siret Hydrographical Area. Some of the main elements of this area are presented in the Table no.1

The main elements of the geographic area that determine the hydroclimatic conditions of Siret Hydrographical Area occur from the territory position in the temperate area (with high thermal and rainfall variations) east of the Oriental Carpathians and next to Black Sea space (this fact emphasizes the climatic discontinuities), high fragmentation and the main relief orientations, anthropic influences from historic times and others (Olariu, Vamanu, 2003).

In these general conditions, the hydroclimatic processes and phenomena present daily, monthly, yearly and multiannual variations, which are included in the general conditions of the moderate temperate-continental climate, with a lot of local influences.

Tab. 1 - General data regarding Siret Hydrographical Area

Total surface	47.610 km^2
- In Romania	42.890 km^2
- In SWD administration	27.402 km^2
Total hydrographical network length	15.836 km
-în România	15.157 km
- In SWD administration	10.280 km
Total length	726 km
-în România	559 km
Multiannual medium flow (to the confluence with Dunărea)	240 m^3/s

The main hydroclimatic drainage elements of Siret Hydrographical Area are presented in the Tables 2 and 3.

If we follow the data regarding the multiannual mean temperatures and rainfall, we see that the values are harmonized with the geographical context in which Siret Hydrographical Area is located. The tendency to continentalism and the increase of the rainfall (and also of the drainage regime) results from the absolute thermal and rainfall amplitude extremely big.

2. Present hydroclimatic tendencies

In the last years, there are more theories regarding the global heating and the climatic aridity of some large fields, in the context of the complex impact of the anthropic factors, but also with connotation of some natural phenomena.

For small areas like Siret Hydrographical Area, this kind of situation can be monitored and demonstrated with difficulty, because the climatic and hydrologic elements present a great variability in time and space and is very difficult to distinguish some tendencies. Though, the conducted analyses on the rainfall regime, on a long period of time, can reveal the increase amount of torrents. Also, the tendencies of climatic heating were revealed in several papers.

Starting from analyses at 120 rainfall measuring points from our studied area, in 100 years (Apavaloaie si colab., 1997; Olariu, Vamanu, 2003), were revealed some aspects regarding the increase of the torrential rainfalls. Due to the fact that the homogeneity of the data is missing, it is proposed that some correction of representatively are made with + or – for period of 20 years. (Olariu, Vamanu, 2003).

Tab. no. 2: - Multiannual characteristic values of the air temperature and precipitations in the Siret Hydrographical Area

Nr crt	Weather station	Air temperature (°C)						Rainfall (l/mp)					Max 24 ore
		Medium	Max	Data	Min	Data	Thermal amplitude	Medium	Maxima	Year	Minima	Annual	Data
1	Rădăuţi	7.2	37.2	8/24/1997	-34.2	12/28/1996	71.4	627	1214	1955	346.5	1986	100/05.1955
2	Suceava	7.7	37.8	7/15/1957	-29.8	12/28/1996	67.6	576.4	833.7	1974	330	1946	90/10.06.1951
3	Calimani	-0.3	24.2	8/14/1998	-25	1/31/1990	49.2	610.5	1190	1998	381	1994	61.6/11.08.2001
4	Poiana Stampei	4.3	31.1	8/20/1987	-30.7	31.01/1987	61.8	658.4	1015	1955	439.3	1994	85.6/03.10.1950
5	Vatra Domei	4.2	33.2	8/3/1998	-31.4	12/28/1996	64.6	690.4	1007	1970	477	1987	47.8/21.08.1992
6	Rarau	2.3	29	7/13/1984	-28	1/22/1963	57	893.9	1346	1981	444.1	1953	110.6/06.06.1978
7	Campulung Moldovenesc	6.5	36	8/15/1954	-31.7	12/28/1996	67.7	693	696.7	1955	436.2	1994	79/21.07.1986
8	Falticeni	8.2	37.5	5/10/1905	-27	1/27/1954	64.5	601.5	921.7	1955	366.4	1950	86.5/07.08.1972
9	Dolhasca	8	36.4	7/8/1988	-30.6	1/16/1985	67	562	768.2	1991	299.3	1986	85/06.09.1989
10	Pascani	8.3	36.4	8/11/1994	-27.5	31.01/1987	63.9	534.2	757.2	2001	326.4	1986	71.8/14.06/1998
11	Tҁîrgu Neamţ	8.3	37.2	8/20/1966	-27.5	1/27/1954	64.7	599.8	1041	1991	339.1	1986	111.3/06.09.1989
12	Vf.toaca	0.6	25	8/4/1998	-30.4	2/19/1985	55.4	673.6	929.7	1975	360.7	1986	85.4/18.08.1972
13	Ceahlau sat	7.1	35	7/15/1952	-30.5	1/27/1954	65.5	620.2	893.5	1972	298.9	1986	79.2/12/06.1974
14	Piatra Neamţ	8.7	37.5	7/6/1986	-28	2/20/1954	616.1	616.1	869.3	1991	356.8	1986	1032/29.07.1991
15	Roman	8.7	38.2	8/25/1957	-32.7	1/18/1963	70.9	507.7	938.2	1991	318,9	1973	95.6/29.07.1991
16	Bacau	9	39.6	7/6/1988	-32.5	2/20/1954	72.1	548.3	932.5	1897	294.5	1954	112.8/20.07.2002
17	Brusturoasa	6.9	35	8/4/1998	-28.4	12/28/1996	63.4	571.6	776	1984	440.6	1990	66.6/28.07/1991
18	Tg. Ocna	9.6	38.8	7/15/2000	-26.7	1/14/1985	65.5	591.5	958.5	1954	322.7	1990	110/11.07.1935
19	Adjud	9.6	40	7/5/2000	-29	1/14/1985	69	525.1	907.6	1972	252.4	1994	100/25.10.1944
20	Odobesti	10.2	39.2	8/7/1954	-23.2	2/11/1954	62.4	613.6	1017	1969	352.5	1994	101/14.06.1992
21	Tulnici	8.5	38	7/5/2000	-22.7	1/23/1963	60.7	659.7	1038	1991	376	1990	81.6/29.07.1976
22	Focsani	10.6	39.5	7/5/2000	-28	1/13/1965	67.5	549.3	818	1972	293.8	1994	112.5/25/10/1944
23	Rîmnicu Sărat	10.7	41	7/5/2000	-21	1/14/1985	62	537.5	849.8	1972	322	1986	95.2/28/06/1982
27	Maicanesti	10.2	39	7/25/1987	-26.1	1/18/1983	65.1	440.8	759.9	1966	249.8	1985	90.7/02/07.1971

Table no. 3: - Main drainage elements of the Siret Hydrographical Area

Nr. crt	River	Hydrologic station	F (km^2)	H med (m)	Q (m^3/s)	q ($l/s/km^2$)	Q max (m^3/s)	Q min (m^3/s)	Coef. Torent.
1	Siret	Siret	1637	572	13	7.94	1193	0.698	1709
2	Siret	Hutanu	2152	515	15.2	7.06	866	0.700	1234
3	Siret	Lespezi	5899	513	36.7	7.22	1133	3.4	333
4	Siret	Dragesti	11899	525	77.1	646	1948	5.04	386
5	Siret	Ad.vechi	20355	647	144	7.07	2320	22.3	104
6	Siret	Lungoci	36095	539	211	5.85	4650	32.7	142
7	Suceava	H.canu	2299	629	16.5	7.18	1354	1.3	1042
8	Moldova	Pr.domnei	666	1087	7.31	11	304	1.01	301
9	Moldova	Tupilati	4016	703	32.6	8.12	1416	2.86	495
10	Moldovita	Dragoasa	462	934	5.05	10.9	463	0.35	1257
11	Bistrita	D.giumalau	742	1255	12	16.2	310	1.45	214
12	Bistrita	D.arinu	1690	1206	24.3	14.4	580	2.6	223
13	Bistrita	Frumosu	2880	1172	37.8	13.2	772	4.5	172
14	Dorna	D.candreni	566	1138	7.44	13.1	180	0.45	400
15	Bistricioara	Bistricioara	780	1041	6.22	8.18	85	0.6	142
16	Trotus	Goioasa	765	1052	6.46	8.44	353	0.85	415
17	Trotus	Tg.ocna	2091	924	17.4	8.32	1490	1.4	1064
18	Trotus	Vranceni	4077	734	34.9	8.56	2845	2.45	1161
19	Uz	Cemenea	340	1070	3.99	11.7	229	0.3	763
20	Tazlău	Helegiu	999	520	6.81	6.82	1556	0.5	3112
21	Putna	Botârlău	2460	554	16.2	6.58	1598	2.38	671
22	Milcov	Grozesti	395	410	1.45	3.67	696	seacă	-
23	Râvna	Jiliste	334	315	0.83	2.49	600	seacă	-
24	Rm. Sărat	Tătaru	1060	295	2.53	2.39	282	0.01	28200

We saw that the frequency of maxim precipitations occurring in 24 hours increases meaningfully after 1960, because of the role of the anthropic factor. Regarding the maximum quantities of precipitations occurred in 24 hours, we can draw some important conclusions from table no.4. (Olariu, Vamanu, 2003).

Tab. 4 - Repartition of maximum rainfall in 24 hours on value levels on time intervals

Steps by precipitations (l/m^2)	Number of cases and frequent (%), to time intervals											
	before 1901		1901-1920		1921-1940		1941-1960		1961-1980		1981-2000	
	No. cases	%	No. cases	%	No. cases	%	No. cases	%	No. cases	%	No. cases	%
< 100							1	0,8				
101-120	1	0,8			2	1,7	3	2,5	26	22	32	27
121-140	1	0,8			5	4,2	5	4,2	4	3,3	8	6,7
141-160					3	2,5			4	3,3	10	8,3
161-180									2	1,7	2	1,7
181-200			1	0,8	1	0,8	1	0,8	1	0,8	4	3,3
> 200			1	0,8	1	0,8					1	0,8
TOTAL	2		2		12		10		37		57	50

a. In the hydrographic space of Siret, maximum rainfalls in 24 hours, with values over 100 l/mp occurred after 1960 (78% of cases);
b. Most values are between 101-120 l/mp during the considered period – 48.5% after 1960;
c. After 1980 rainfalls of 121-140 l/mp (6.7%) and 141-160 l/mp (8.3%) in 24 hours (total of 15%) reached an important level;
d. There are many situations when maximum rainfalls in 24 hours have gone over 200 l/mp.

The tendency towards climatic drought can be seen through the analysis of years with drought (rainfall under 450 l/mp) and very dry years (rainfall under 350 l/mp). The frequency of dry years (with drought phenomena) in the northern part of the territory is 10-20% and in the southern part 35%, and that of very dry years is in north/center 5-7% and in south 10%.

In conclusion, in the last decades (ten-years period), climatic phenomena present extreme values, which reflect directly on the water flow regime, and so the expression “rivers from drought to overflow” (Diaconu, 1993) has a real base, so present and future hydrographic phenomena are a major risk factor.

3. Case study

There are numerous situations in the hydrographic space of Siret territory when hydro-climatic phenomena presented major risk character. We can talk about late frost during spring, soil freezing during unexpected periods, wind, storm, hail,

local or general rainfalls, and exaggerated flows on the mountains, floods and overflows with catastrophic character.

3.1. The overflow from July 28th - August 10th in eastern Pericarpathic area.

The most important elements analyzed refer to dense rainfalls fallen in the hours before the overflow, to the extraordinary flows on most river courses in Moldavian Subcarpathic area (Tazlau basin) and to the damages it produced.

The rainfalls between 28-29th of July 1991 had exceeded over 150 l/mp in 24 hours in many places: 234.5l/mp at Dumbrava/ Ozana river, 160.8 l/mp at Petricani/ Toplita river, 153.6 l/mp at Frunzeni/ Bistrita river, 193.6 l/mp at Solont/ Tazlau river, 186.2 l/mp at Orasa/ Tazlau river, 160.8 l/mp at Lucacesti/ Tazlau Sarat river, 156.7 l/mp at Moinesti/ Tazlau Sarat river, 158.6 l/mp at Berzunti/ Tazlau river, 180.2 l/mp at Helegiu/ Tazlau river, 196.3 l/mp at Orbeni/ Orbeni river. These exceptional overflows have appeared after a long period without extreme hydro-climatic phenomena. The big flows produced on the water courses in the affected areas have reached in many cases, the real transit capacities of small river beds, many of these being blocked with garbage, branches, trees, bushes and under poorly dimensioned bridges.

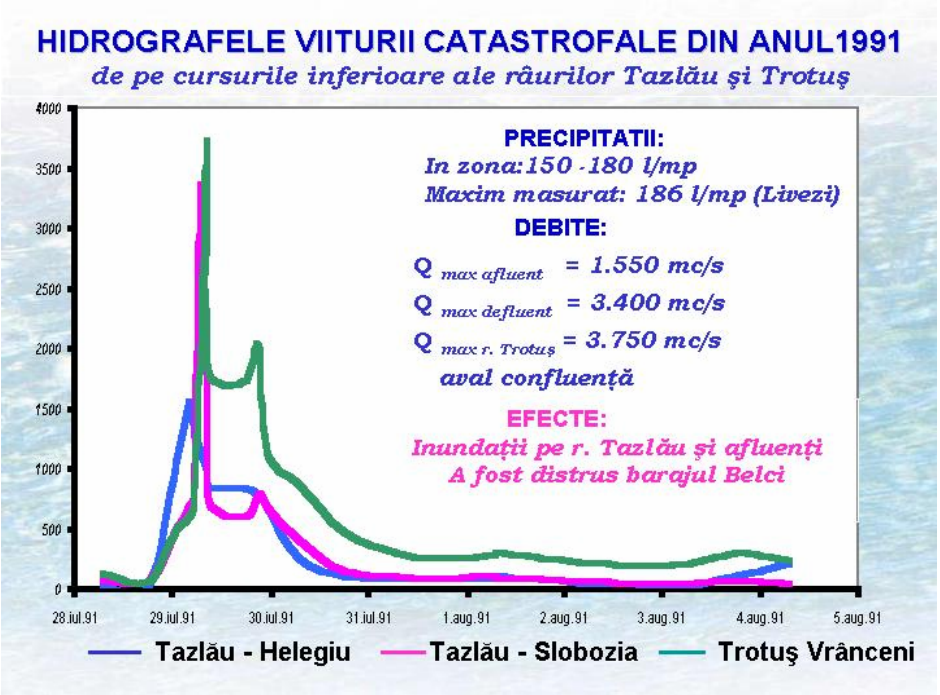
The worst phenomena took place in Tazlau basin (when Belci lake dam was destroyed) and on the eastern slope of Pietricica Bacaului water courses (Fig. 1).

The overflow on Tazlau followed the torrential rains in its hydrographic area. Maximum flows on this river and on its major effluents (Solont, Tazlaul Sarat, Cernu, Berzunti, Valea Rea, Helegiu, Belci) are over the values corresponding to the probability of 1% overpass. The flows produced catastrophic overflows with human victims and huge material damages. The maximum flow recorded in the Belci Lake of 1550 m^3/s couldn't be passed in safety conditions the lake being 90% at that date. In consequence, the dam was destroyed and downstream, a maximum flow of 3400 m^3/s was recorded. After the confluence with Trotus, 2 km downstream the dam, the maximum recorded flow was of 3750 m^3/s (the probability of 1% overpass).

As well, on the eastern slope of Pietricica, on Cleja, Racaciuni, Orbeni and Draguseni rivers, high flow were recorded. These produced overflows, material damages and human victims.

In table 5, we present the damages produced during the 1991 overflows in the county of Bacau (most affected) and in the whole hydrographic space of Siret River.

Fig. 1 - Floods hydrographs for Tazlău and Trotuş rivers for July 28th – August 5th, 1991



Tab. 5 - Damages recorded during the overflow in 1991 in Bacau County and in the hydrographic space of Siret.

Recorded damages 1991	**Bacău county**	**Total basin**
Dead people	91	108
Affected houses : Flooded	5305	11336
Affected houses : Destroyed	1235	2186
Dead animals	5057	5950
Affected soil areas (ha): Totally	10518	19388
Affected soil areas (ha): Partially	12065	77164
DN, DJ, DC (km)	261	954
Bridges (buc)	326	1112
Railways (km)	6	6,2
Affected water management works	5,64	32,66

3.2.The overflow in 2004 in the middle hydrographic space of Trotus River

Although it affected a small area this overflow is interesting because of its destructive effects as geo-morphological processes and as damages and victims. (Radoane et al., 2007). The flows on some effluents were over the 0, 1% probability of overpass (Table 6). The damages were huge (Table 7).

Tab. 6 - The overflow in 2004 in the middle hydrographic space of Trotus river

Nr. crt.	River	Section	F (km^2)	Hm (m)	Q max (mc/s)	Date	Prob. %	Observation
1	Trotuş	Goioasa	765	1062	358	28.07.2004	5-10	
2	Trotuş	Tg. Ocna	2091	924	682	28.07.2004	5-10	
3	Agăş	Agăş	16	970	195	28.07.2004	0,2	Informative values
4	Beleghet	Beleghet	2.2	850	69.8	28.07.2004	<0,1	
5	V. Tijanila	Goioasa	0,75	700	17	28.07.2004	0,2	
6	Goioasa	Goioasa	4,5	870	80,5	28.07.2004	0,1	
7	Ieduş	Goioasa	2,8	900	127	28.07.2004	<0,1	
8	Ciobănuş	Ciobănuş	132	1152	67,2	28.07.2004	20	

Tab. 7 - Registered damages in Bacau County.

Dead people	3	Railway (km)	0,5
Destroyed house (pieces)	25	Forest roads (km)	111,7
Flooded houses (pieces)	762	Electric lines (km)	11
Anexe (pieces)	1225	Telephone lines (km)	15
Tillable areas (km)	280	Water network (km)	10
Bridges (pieces)	279	Social economic objectives (pieces)	9
Streets (km)	57,7	Fountain	881
DN DJ DC (km)	105,6	Hidrotechnical works	13,4

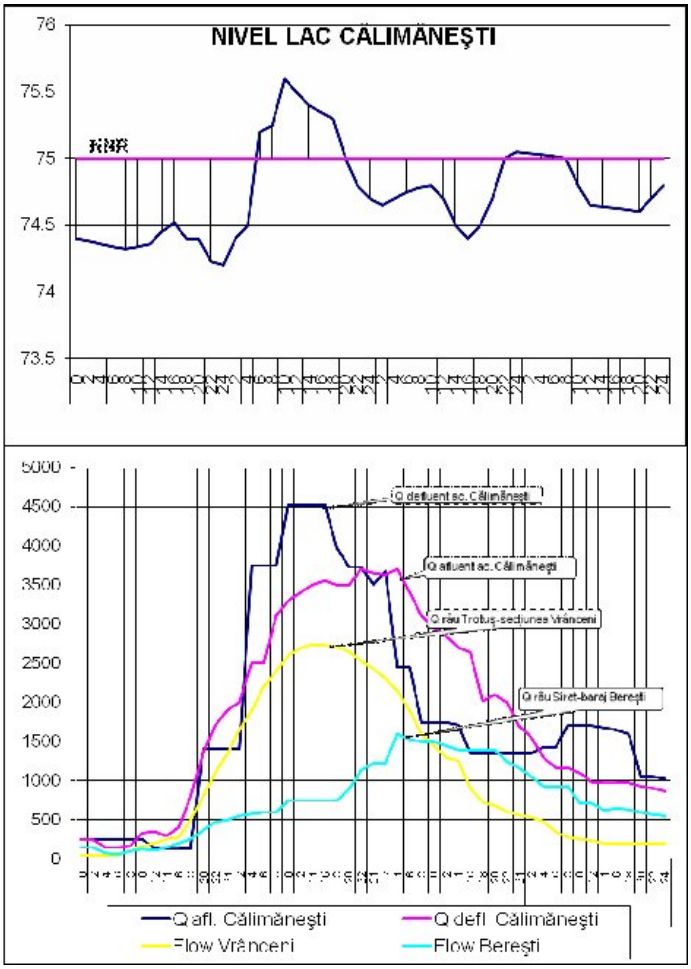
3.3. The overflow during 11-14th of July 2005 in the hydrographic space of Trotus and on the inferior course of Siret River.

This overflow appeared after strong storm in a period with excessive rainfalls in the first half of 2005.

The largest water quantity (150 l/mp in 24 hours) was registered in the hydrographic spaces of Trotus, Putna and Ramnicu Sarat. Also high flows on the middle course of Bistrita River, down Izvoru Muntelui dam were recorded and this complicated measures of transiting the water through the accumulation complex on the middle area of Siret.

The highest quantities of rain fell in the hydrographic space of Trotus: Tazlău/ r. Tazlău – 185,3 l/m^2; Dărmăneşti / r. Uz – 154,9 l/m^2; Dofteana / r. Dofteana – 184,5 l/m^2; Ferăstrău/ r. Oituz – 155,6 l/m^2; Haloş / r. Caşin – 218,2 l/m^2; Scorţeni / Tazlău – 162.4 l/m^2; Oneşti / r. Trotuş – 154.6 l/m^2; Helegiu / r. Tazlău – 140 l/m^2; Vrânceni / r. Trotuş – 162.1 l/m^2.

Fig. 2 - Hydrographs of the overflow in 12-15th July 2005 at the Calimanesti dam (affluent and diffluent flows)



Also in the hydrographic spaces if Putna and Ramnicu Sarat dense rains have fallen: Lepşa/ r. Putna – 175 l/m^2; Colacu/ r. Putna – 199 l/m^2;

Herăstrău/ r. Năruja – 220.4 l/m^2; Tulburea/ r. Râmnicu Sărat – 146.2 l/m^2. As followed, big overflows produced huge material damages. The maximum flow on the inferior course of Trotus River reached 3800 m3/s which combined with over 1700 m^3/s on Siret created a growth of the level of the Calimanesti Lake over the acceptable limits.

In consequence, flows of 4500 m^3/s had to be evacuated through the dam and these caused important overflows downstream and broke in many areas the dams on Siret. At Lungoci, the maximum estimated flow was of 4650 m^3/s, but this value doesn't represent the natural debit because until here important debits were lost by breaking the dyke on Siret, Putna and its effluents.

In Fig. 2, we present the evolution of flows in Calimanesti dam where important fluctuations of the lake level can be seen, under the conditions of taking out 3500 m^3/s.

The damages produced by this overflow in Bacau and Vrancea (most affected) are presented in Table 8.

Tab. 8 - Damages recorded during the overflow in 12-15th of July 2005 in Bacau and Vrancea Counties.

Damages in 2005	Bacău county	Vrancea couny
Dead people	5	15
Destroyed houses (pieces)	1030	1126
Broken houses (pieces)	1080	1968
Flooded houses (pieces)	4114	3094
Social economic objectifs (pieces)	51	26
bridges (pieces)	354	58
DN, DJ, DC (km)	401,7	347
Streets (km)	70	-
Hydrotechnical works (km)	35,46	2,4
Water network (km)	9,07	13,1
Sewerage system (km)	11,07	3,13
Gas network (km)	3,24	
Tillable areas (km)	10931,5	25315
Fountains and overfowable pits (nr.)	1050	2245

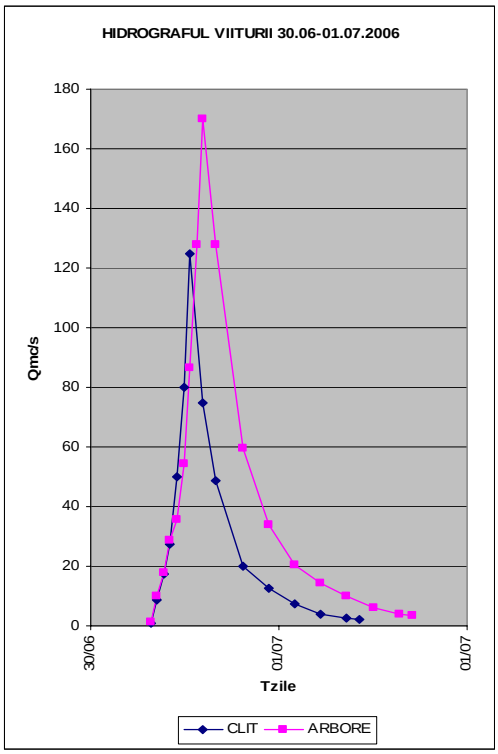
3.4. The overflow in 30 June – 3 July 2006 in Arbore, Suceava County

This overflow represents a local situation that generated huge material damages and killed 12 people (Table 9). This overflow's hydrographs on Clit and Saca rivers are presented in fig. 3.

Tab. 9 - Registered damages in Suceava County (30 June – 3 July 2006)

Persoane decedate	12
Locuințe afectate (buc)	487
Obiective socio-economice (buc)	5
Poduri şi podețe (buc)	207
DN, DJ, DC (km)	302,5
Drumuri forestiere (km)	6,5
Căi ferate (km)	1,4
Lucrări hidrotehnice	5,51
Fântâni inundate	1360

Fig. 3 - Hydrographs of the overflow between 30.06/3.07.2006 on Clit and Saca River



4. Measures of prevention and fast intervention.

From the few examples, as from many other situations, results the high potential of hydro-climatic risks in the hydrographic space of Siret. In this context complex measures of prevention and fast intervention are imposed. Taking into account some situations when houses must be defended, especially in the areas where no major hydro-technical works exist, some fast intervention technologies have been successfully used lately. Such technology is AQUASTOP. These systems of protection against floods used for many years now have been successfully used in Europe (Dăscălița D., 2006).

Given the easy use if this system, its cheapness and the possibility of using them in other activity domain, we recommend using them to defend the houses against overflows. A more complex system against floods are the water structures.

They are especially created to insure a stable barrier that contains and controls the water destructive course. All the materials used in water structures are flexible and allow the structure to adept itself to the land. Two water structures can be put together to form long structures. Although they are more expensive, we recommend them for their high security level, in defending small and middle houses against floods.

An economic and efficient technological solution is using a flexible screen thrust, fixed in the river shore or dyke with the help of a mechanical equipment lead by a vehicle. The maximum height of the superior part of the screen is 100 cm (over terrain part) and for the underground part is 50 cm, but these can be different due to the constructive technical limits imposed by the mechanical equipment and to the necessary height to avoid the overflows. To insure the success in applying this type of technology previous script and specialized stuff are required (Dăscălița D., 2007).

Until the last years there was a special attention for the defense structural measures that defend important objectives against floods. In time it was proved that although it was very expensive the measures didn't work as they were expected. The major structural measures in the hydrographic space of Siret were:

4.1. Works that reduce the highest flows of overflows

- 13750 ha forest areas, from which 8400 ha as forest base;
- 274000 ha CES works;
- 22650 km improved torrential river beds;
- 35 de energetic accumulation and with complex functions, with a total volume of 1,933 mild. mc;
- 104 agrarian accumulations with a total surface of 3863 ha;

4.2. Works that reduce the maximum levels in river beds

- 529 km lakeside consolidations;
- 591 km river beds regularization, rectification, recalibration;

4.3. Decreasing the flow duration through draining works

- 169440 ha hydro-amelioration;
- 151116 ha irrigation arrangements;

4.4.Defending threatened people and important objectives through dams and defense walls

- 325 km dams;

Lately, defense problems against floods can be approached from other points of view, to reduce costs and to be environment friendly. These are called unstructural methods and refer to:

1. ***Splitting into ares the major river beds and meadows***
   - On going works. These splits will be possible after drawing the risk maps; however, the laws stipulate this measure.

2. ***Improving forecasts' quality***
   - Continuous action, based on performing technologies, including automatic stations. Warning codes categories have been implanted.
3. ***Accumulations and hydrological works together exploitation***
   - Exploitation regulations decided at D.A. Siret.
   - Continuous consultations on matters of exploitation in special situations
   - Ex: the passing of the flow on Siret and Bistrita Rivers in 2005 through the accumulation lakes on the middle Siret, under restrictive conditions, downstream.
4. ***Planning the use of agricultural land properly, to retain soil water***
   - In discussion
5. ***Institutional reform: forming a legal framework.***
   - In process
6. ***Economic instruments: insurances, involving people.***

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