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NUMERICAL MODEL OF MINIMIZATION OF UNCONTROLLED EFFECTS DUE TO REPEATED FLOODS NEAR VICINITY OF RIVERS

Victorita RADULESCU[1], Dana Roxana HORHOIANU[2], Z. ZETENYI[3], Alexandra RADULESCU[4]

The present paper is dedicated to estimate the real capacity of transport of natural river beds in permanent correspondence with zone reality after repeated floods. A numerical model based on experimental measured local data was elaborated. The proposed subject herein has as purpose to minimise the uncontrolled effects and to offer a solution of a maximum actuality problem, referring at vicinity of river beds. In establishing of the numerical model have been taking into consideration the environmental real conditions of natural or established beds in selected area, Cracau and Bistrita rivers, Siret basin, well known for the local problems which appear during and after floods. Some conclusions are presented and some solutions to minimise the unwanted effects, uncontrolled erosions in some places or sediments depositions.

Keywords: transport capacity, floods, data base, numerical modelling.

1. Introduction

In the past 20-25 years no real complex plan regarding the ecological and power energetic rehabilitations for the interior and near vicinity of river beds have ever been made. During the last 5-6 years, after floods from 2004 and 2005, have been recorded apparitions of uncontrolled deposit of sediments in some places or in a contrary of some erosion zones, uncontrolled costal slides, having as immediate effect turning that zones into risks areas. The numerical model presented in this paper solves a recent appeared problem, due to the actual conditions regarding flows in natural or critical regimes or high waters or lasting drought in proximity vicinity of areas affected by repeated floods. By knowing the flow rate, the level by direct reading into known, measured section will be possible to establish the risks zone far away on river borders.

The European Union laws concerning environmental protection imposes that after every hydrological special event into the affected area should be realised

[1] Prof., Power Engineering Faculty, University “Politehnica” of Bucharest, Romania
[2] Eng., Environmental Protection Division, SC Hidroelectrica SA of Bucharest, Romania
[3] Prof., Power Engineering Faculty, University of Oradea, Romania
[4] Master Student, University “Politehnica” of Bucharest, eng. SC ELCEN SA, Bucharest, Romania

a rehabilitation of the entire zone. As a direct result, secondary phenomena appear, being harder and harder to be controlled in time, if it will be not completed an actual short or medium term management plan, to assure optimal ecological and safety energetic power conditions.

There are zones near analysed area in which meander phenomena, sediment deposals, or uncontrolled coastal erosion appear, which in time lead to landslides, followed by road, house, agricultural terrain, etc. destruction.

In 2005, year considered to have way over the annual average from hydrological point of view, 4 catastrophic floods took place in the Siret and Bistrita basin area. All these floods from 12-16.04.2005, 20-24.05.2005, 16-22.06.2005 and 20-22.09.2005 have been followed by human and animal losses and severe material damages: houses, bridges, agricultural lands and forests. In 2006 two severe ecological accidents have been recorded, due to the cyanide leak from the decantation basins in cleaning stations of waters, followed by long term environmental perturbations (appeared due to the over-border pollution), in approximately 2 months reaching until the Danube Delta. We must not omit the fact that most rivers are part of Siret and finally Danube's hydrographical basins, waters that cross many adjacent countries.

In present all evaluations and analysis of the capacity of transportation of natural rivers beds are realised only in areas with massive destruction and in areas where serious damages ware made. There hasn't been made an ecological and technical research of an entire area, which analyses the phenomena in the whole basin. Nowadays the international commitments impose complex analysis and arrangements for the entire hydrological basins.

2. Experimental data base

To realise the numerical model for the analysed areas were made experimental measurements in situ, referring at hydrologic capacities, average values of rainfall, comparing with values obtained during last 50 years from literature, rate flows of analysed rivers, sediments, quality of waters, etc. Next are mentioned part of the effected measurements during 5 months, considered significant for further environmental analysis.

In these conditions the principal characteristics of the analysed microclimate are: average annual temperature 8.5°C, medium temperature of the month January – 4.5 °C (it is explained by entrance of the cold air from north-east to lower areas), average temperature of the month July 20°C (it may be explained by the possibility of circulation of continental very warm air, especially from south), relative humidity 80 %, average rainfall during a year 500-600 mm and average values of rainfalls during summer months being 450 mm.

Variations of rainfalls appear into months July - November, the quantities being greater then in higher zones. The wind average velocity during the entire year is 3 m/s, at level of 10 m over the land.

The Bistrita river has a medium rate flow of 45 m^3/s, during 125 km, having a difference of 372 m and a potential of 1200 kW/km. Due tot the fact that the rate flow has been controlled by the dam Mountain Source with a multi-annual surveillance increase the minim flow rate from $0{,}4xQ_m$ registered into drought years till $0{,}7xQ_m$. In Table 1 are mentioned some average flow rate.

Table 1

Average value of monthly flow rate in some sections crossing Bistrita river

Section	SH Cârnu	SH Pângăraţi	SH Vaduri	SH Piatra Neamţ	SH Bacau
X	27,96	33,25	33,52	33,85	37,99
XI	26,42	30,99	31,23	31,50	40,40
XII	21,48	25,36	25,57	25,81	33,83
I	17,96	21,25	21,38	21,59	28,49
II	18,13	21,46	21,63	21,85	27,05
III	32,11	38,41	38,77	39,19	44,61
IV	80,30	97,35	98,11	99,28	107,17
V	92,21	109,53	110,47	111,55	118,18
VI	73,15	87,65	88,41	89,34	96,22
VII	59,37	70,91	71,49	72,22	76,38
VIII	43,96	52,56	53,02	53,56	57,15
IX	33,10	39,51	39,85	40,29	41,87
Annual average	43,85	52,35	52,79	53,34	59,11

Another important parameter taking into account in numerical modelling

Table 2

Structure of sediments analysed from two different ecosystems

Nr.	Parameter	Lake Pângăraţi	Lake Vaduri	Lake Reconstrucţia
1	Humidity (105^0C) %	55,46	53,38	55,66
2	pH (upH)	6,80	6,65	7,04
3	Organic substances (%)	6,95	5,93	8,36
4	Mineral substances (%)	93,05	94,07	91,64
5	$NH_4^+(mg/100g)$	5,85	7,27	8,01
6	$NH_4^+(mg/l)$	105,48	136,19	143,91
7	$NO_3^-(mg/100g)$	0,33	0,41	0,19
8	$NO_3^-(mg/l)$	5,95	7,68	3,41
9	$PO_4^{3-}(mg/100g)$	0,068	0,072	0,086
10	$PO_4^{3-}(mg/l)$	1,22	1,34	1,54
11	$N-NH_4^+ + N-NO_3^-(mg/100g)$	4,61	5,74	6,27
12	$P-PO_4^{3-}(mg/100g)$	0,022	0,023	0,028
13	$N_{included}/P_{included}$	209,54	249,56	223,93

was the type, nature, dimensions and structure of sediments. From the analysis of the sediments taken from those two ecosystems analysed we obtained the results mentioned into Table 2 and Table 3.

The analysis were accomplished on measured in-situ probes, taking from more then 60 places crossing the rivers Cracau, Bistrita, Siret, on both sides, during years 2006-2007-2008. The obtained data from the chemistry and hydro-chemical analysis prove the fact that sediments are moved more then 45 km during a flood as those one from 2005.

Table 3

Chemical and hydro-chemical structure of sediments and water

Parameter	Data	River	Chanel	Lake			
				Pang.	Vaduri	B.Doamnei	Reconstructia
Temperature ^0C	6.08 1.11	12,0	15,0	15,5 9,2	15,5 6,8	15,0 6,2	14,0 9,3
pH (u.pH)	6.08 1.11	7,6	7,5	7,5 7,4	7,5 7,3	7,5 7,2	7,5 7,3
Oxygen incl. Mg O_2/l	6.08 1.11	8,28	7,07	10,11 9,30	8,74 10,53	8,44 7,93	9,04 9,20
Org. subst. Mg $KmnO_4$/l	6.08 1.11	9,10	12,40	12,09 10,62	12,40 10,97	12,09 6,73	9,10 14,16
Azoth Mg NO_3^-/l	6.08 1.11	1,53	1,94	1,63 1,94	2,41 1,90	2,28 3,03	2,51 1,15
Nitrates Mg NO_2^-/l	6.08 1.11	0,040	0,013	0,028 0,020	0,026 0,012	0,013 0,014	0,014 0,020
Ammonium Mg NH_4^+/l	6.08 1.11	0,32	0,15	0,27 0,57	0,21 0,31	0,15 0,24	0,19 0,28
Phosphate Mg PO_4^{3-}/l	6.08 1.11	0,012	0,010	0,012 0,008	0,012 0,010	0,010 0,030	0,014 0,016
Alkalinity total m val/l	6.08 1.11	3,44	1,88	1,90 2,10	1,96 2,20	2,00 5,52	2,02 2,40
Druitt total gr germane	6.08 1.11	12,12	6,51	6,62 7,18	6,88 7,63	6,73 12,23	6,84 8,64
Druitt (^0G) temporary	6.08 1.11	9,63	5,26	5,32 5,88	5,49 6,16	5,60 9,85	5,66 6,72
Calcium Mg Ca^{2+}/l	6.08 1.11	64,13	33,66	34,47 36,07	34,47 40,88	35,27 70,54	37,67 49,70
Magnesium mg Mg^{2+}/l	6.08 1.11	9,73	7,78	7,88 9,24	8,07 8,27	7,78 10,21	6,81 7,30
Bicarbonates Mg HCO_3^-/l	6.08 1.11	209,8	114,7	115,9 128,1	119,6 134,2	122,0 214,7	123,2 146,4

Considering chemically water lakes Pangarati, Vaduri, Lady Batca and Reconstruction are from category I of surfaces waters in conformity of STAS 4706/88). A special situation refers at wasted waters from river Cracau and the nature and concentration of sediments in this river during floods.

3. Numerical modelling

The numerical model is dedicated to unsteady flow with free surface in rivers with sediment transport. The cross sections have arbitrary shapes. At each analysed section was considered the entered sediments and the transported sediments to next section. To simulate the real, natural flow it is necessary to know the physics of phenomena, to establish the significant parameters and relations between them. The mathematical model used in some scheme of calculus the basic equilibrium based on some data base considered as entrances:

- initial cross-sections profile through rivers beds
- distances between sections and the geographic variation of altitude
- the roughness of river beds during the whole analysed distance
- the maximum flow rate, how it grows and how it decrease, as time dependence
- Sediments variation in time as concentration, dimensions, etc.

Further are presented the obtained results in cross-sections into river Cracau, one of the fourth analysed rivers; the initials coordinates are mentioned into Table 4. There were estimated the zones were appears sedimentation and the zones where erosion appears. There were considered 7 cross-sections. It was determined the free surface of flow during 4 cases of transported flow rate with assurance 10%, 5%, 2% and 1%.

For each section was determined the sediments balance. For each flow rate were considered 4 cases of roughness. For 3 cases it may be observed a further developing of sedimentation on left side of the river, especially in sections 5-7.

It must be mentioned once again the importance of knowing exactly the dimensions of sediments. Due to them it is possible that into the same flood in some cross- sections to appear sedimentation and into other errosions.

Table 3

The coordinates in five cross-sections on Cracau river

Profil 1av		Profil 2av		Profil 3av		Profil 4av		Profil 5av	
x	y	x	y	x	y	x	y	x	y
0	491.06	0	490.33	0	489.88	0	488.31	0	487.43
2	490.14	3	489.53	10	489.78	1	487.02	3	486.25
15	490.25	20	489.93	26	489.23	6	487.32	7	486.45
20	490.86	23	489.27	43	489.27	23	487.52	13	486.95
25	490.73	32	489.38	57	489.08	28	487.09	15	486.45
36	490.46	60	489.3	61	488.24	31	487.82	20	486.51
50	490.14	66	489.58	77	488.37	36	487.87	30	486.81
60	490.87	72	490.1	81	488.04	40	488.31	42	487.65
64	492.1	78	490.07	93	488.09				
		84	490.92	109	488.98				

Into Variant 1 and Variant 2 due to selected dimensions of sediments and roughness of soil was obtained sedimentation in all cross-sections selected. From global balance into selected areas appear sedimentations after any floods from those four selected.

Into Variant 3 and 4 it may be observed an alternative of sections where sedimentations appear and where erosions appear.

4. Numerical results

Further are presented some results from numerical modelling. For each time step is mentioned the number of cross-section and the situation concerning sedimentation/erosion at that time, the average value of movement velocity, the Froude number attached to flow at the moment, the cross-section during flowing and effective area for fluid flow. Finally are estimated the new coordinates for the river sections, represented with a different colour.

Further are presented only a part of the obtained results.

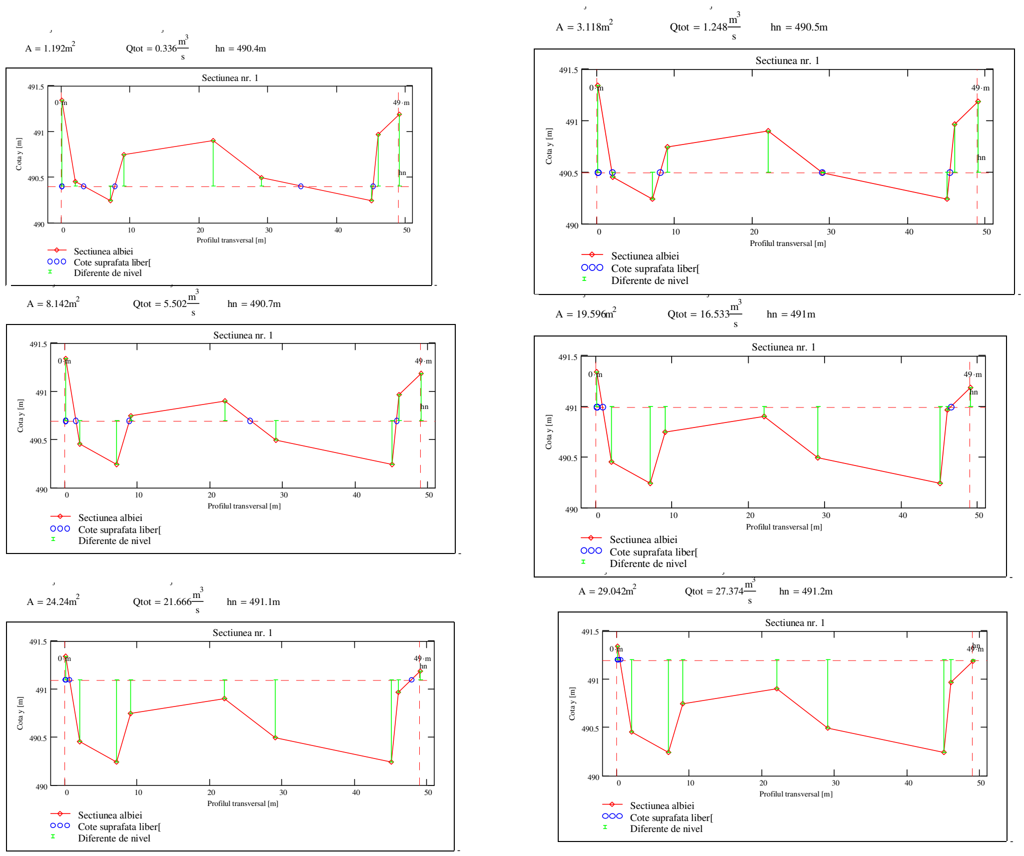
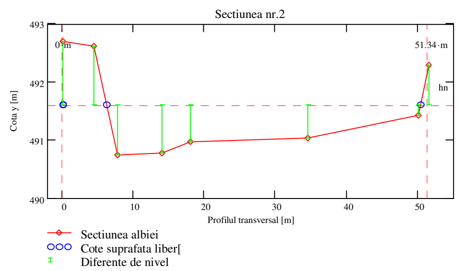
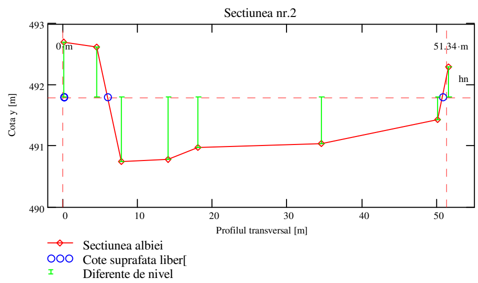


Fig. 1. Partial results from Section 1

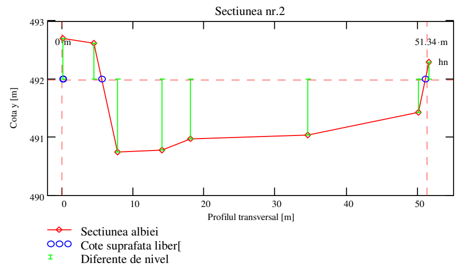
$A = 24.574 m^2$ $Qtot = 17.614 \frac{m^3}{s}$ $hn = 491.6 m$



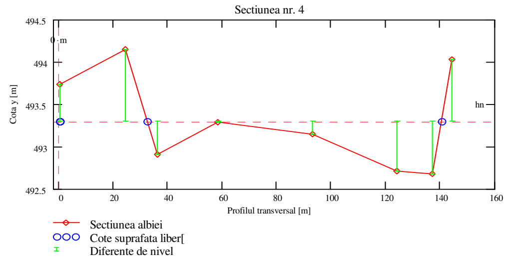
$A = 33.457 m^2$ $Qtot = 29.031 \frac{m^3}{s}$ $hn = 491.8 m$



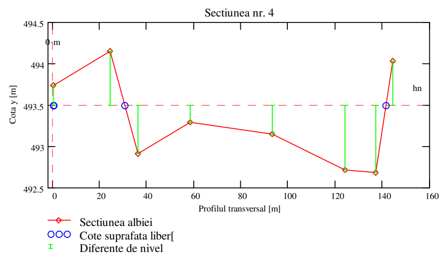
$A = 42.479 m^2$ $Qtot = 42.686 \frac{m^3}{s}$ $hn = 492 m$



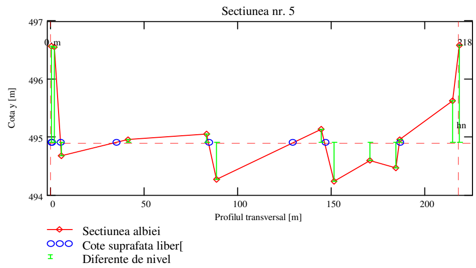
$A = 28.268 m^2$ $Qtot = 16.992 \frac{m^3}{s}$ $hn = 493.3 m$



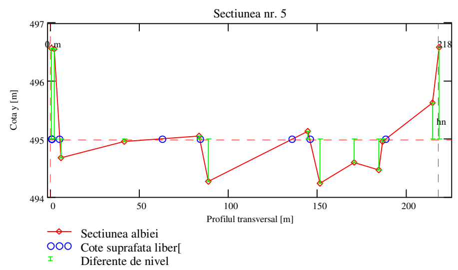
$A = 50.163 m^2$ $Qtot = 35.476 \frac{m^3}{s}$ $hn = 493.5 m$



$A = 33.966 m^2$ $Qtot = 25.372 \frac{m^3}{s}$ $hn = 494.9 m$



$A = 46.879 m^2$ $Qtot = 38.228 \frac{m^3}{s}$ $hn = 495 m$



$A = 46.873 m^2$ $Qtot = 33.991 \frac{m^3}{s}$ $hn = 497 m$

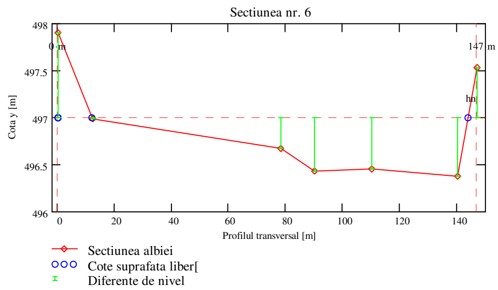


Fig. 1. Partial results from Section 1

As it may be observed from graphical representations at rate flow over 25-35 m^3/s in some cross-sections appear floods. Considering that in twice cases into year 2005 the rate flow was over 100 m^3/s it's obviously necessary to be created zones where will be realised local deposits of sediments. From time to time this places will be systematically cleaned and the deposits (sediments) used in constructions or other applications. To obtain more accurate precision in each sections where introduced two supplementary points at altitude 530 mdm.

5. Conclusions

In this paper is presented, elaborated and tested a complex numerical model to simulate the capacity of transport of 4 rivers beds: Cracau, Bistrita, Siret and Jiu. Into the numerical results are mentioned only for the river Cracau. By knowing exactly the zones with problems into current exploitation, represented by cross-sections, by reading far away of zones with villages, houses the level of water during floods it's possible to create a plan of surveillance and to avoid further humans, animals and materials lost during floods.

As it may be observed for Cracau river, for assurance 10% on left side in section 6 at rate flow over 35 $m^3/$ will be over-border and floods. For rate flow with assurance 5% the analysed zone is not capable to transport the all amount of water. In this case on left side in section 5, 6 and 7 will be registered over-borders and on the right side in sections 1, 5, 6 and 7 also, and so on.

Now the specialists the engineers from local authorities are capable to analyse permanent the situations in conformity with actual conditions and to avoid further damages.

Even so, it is recommended that at least 2 years, even if there where not recorded great amount of waters the mentioned cross-sections to be verified, considering any uncontrolled deposition of sediments.

R E F E R E N C E S

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