NEW SOLUTIONS INTO MAINTAINING THE DIKES LIFE BY ESTABLISHING THE RISKS ZONES OF INFILTRATIONS

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Abstract - The present paper has a purpose to estimate the real capacity of transport of natural river beds in permanent correspondence with zone reality especially after repeated floods. The selected area was the Siret basin, confronted into 2005 with repeated floods. A numerical model based on experimental measured local data was elaborated. The proposed subject herein has as principal purpose to minimize the uncontrolled effects and to offer a possible solution of this environmental problem, referring at vicinity of river beds. In establishing of the numerical model have been taking into consideration the geological conditions, the hydrological data collected, of natural or established beds into the selected area, Cracau and Bistrita rivers. Some numerical results and conclusions are finally presented. There are also proposed some solutions to minimize the unwanted effects, uncontrolled erosions in some places or sediments depositions, infiltrations, etc.

Keywords: transport capacity, floods, data base, numerical modelling, erosion, infiltration, sedimentation

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. Not far away, area considered safe (environmental speaking) have been transformed into zone with infiltration, uncontrolled erosions and slides. The numerical model presented intend to solve a recent appeared problem, referring of free surfaces flows in natural beds or critical regimes of high waters after lasting drought in proximity vicinity. By knowing the flow rate, the water level, the sediments structure and the porosity of the underwater flows, by direct reading into a well known, measured section will be possible to establish the risks zone far away on river borders, into populated zones.

Generally, in other countries from European Union the environmental programs laws impose that after every hydrological special event into the affected area rehabilitation should be realized. Unfortunately in 2005 three such events, considered disasters overlapped. As a direct result, secondary phenomena appear, being harder and harder to be controlled in time. In present time an operational program must to be completed as short and medium term plan management, to assure optimal ecological and safety energetic power conditions.

There are zones near analyzed area where meander phenomena, sediment deposals with hard infiltrations, uncontrolled erosion appear. All of them in time lead to landslides, followed by road, house, agricultural terrain, etc. destruction.

In 2005, year considered to have way over the annual average (hydrological speaking) 4 catastrophic floods took place in the Siret and Bistrita basin area, in 12-16.04.2005, 20-24.05.2005, 16-22.06.2005 and 20-22.09.2005. All of them were registered as disasters due humans and animals 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, as international waters.

In present all evaluations and analysis of the capacity of transportation of natural rivers beds are realized 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.

1. EXPERIMENTAL DATA BASE

To accomplish the numerical model it's necessary to make a data base of collected samples from the specific area. The measurements were made in situ, referring at hydrologic capacities, average values of rainfall, type of nature and dimensions of sediments, infiltrations favourable area and compare the obtained results with the existent data base measured during last 50 years. There were collected data for the rate flows of analysed rivers, sediments, quality of waters, etc. Further are mentioned only a part of the effected measurements during 5 months, into 2005, 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; explained by entrance of the cold air from north-east to lower areas,
- average temperature of the month July 20°C; 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
- average values of rainfalls during summer 450 mm
- wind average velocity during the entire year 3.6 m/s, at level of 10 m over the land

Significant variations of rainfalls appear into months July-November; the quantities have been greater even then in higher zones.

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 first realised dam, Dam Mountain Source with a multi-annual surveillance increase the minim flow rate from 0,4xQm registered into drought years till 0,7xQm. 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 Pângărați	SH Vaduri	SH Piatra Neamț	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**

In Tab.2 are mentioned another important parameters necessary into realization of the data base for numerical modeling.

Table 2. Structure of sediments analysed from two different ecosystems

Nr	Parameter	Lake Pângărați	Lake Vaduri	Lake Reconstrucția
1	Humidity (105^{0}C) %	63,46	58,12	53,68
2	pH (up H)	6,72	6,53	7,03
3	Organic Substances (%)	7,05	6.12	9.17
4	Mineral substances	94,15	94,07	92,64
5	NH^+_4 mg/100g	5,93	7,32	8,24
6	NH^+_4 mg/l	107,18	142,29	153,91
7	NO^-_3 mg/100g	0,42	0,47	0,39
8	NO^-_3 mg/l	6,15	7,38	7,21
9	PO^{3-}_4 mg/100g	0,057	0,064	0,096
10	PO^{3-}_4 mg/l	1,23	1,37	1,64
11	$N\text{-}NH^+_4 + N\text{-}NO^-_3$ mg/100g	4,72	5,83	6,78
12	$P\text{-}PO^{3-}_4$ (mg/100g)	0,023	0,027	0,032
13	$N_{dissolved}/P_{dissolved}$	239,14	252,16	232,87

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, Table 3, 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

		LAKES, River and Channels					
Param	Data	Riv	Cha	Pang.	Vad	B.D	Rec
Temprature ^{0}C	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 + 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. subMg $KmnO_4$/l	6.08 1.11	9,10	12,4	12,09 10,62	12,40 10,97	12,9 6,73	9,10 14,1
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	0,04	0,01	0,028 0,020	0,026 0,012	0,01 0,04	0,01 0,02
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	0,01 2	0,01	0,012 0,008	0,012 0,010	0,01 0,03	0,02 0,02
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	12,1	6,51	6,62 7,18	6,88 7,63	6,73 12,2	6,84 8,64
Druitt (^{0}G) 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	64,1	33,6	34,47 36,07	34,47 40,88	35,2 70,5	37,6 49,7
Magnesium mg Mg^{2+}/l	6.08 1.11	9,73	7,78	7,88 9,24	8,07 8,27	7,78 10,2	6,81 7,30
Bicarbon. Mg HCO_3^-/l	6.08 1.11	209	114	115,9 128,1	119,6 134,2	122 214	123 146

Considering from point of vue of chemically's 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 flows with free surface in rivers with sediment transport and infiltrations propagated through dikes. The cross sections have arbitrary shapes. At each analyzed section was considered the entered sediments and the transported sediments to next section, meaning the solid balance for the volume equilibrium. To simulate the real, natural flow it is necessary to know the physics of phenomena, and to establish the significant parameters and relations between them. The mathematical model used in some scheme of calculus the basic equilibrium, based on data base considered basic entrances:

- initial cross-sections profile through rivers beds

- distances between cross sections and the geographic variation of the altitude
- the roughness of river beds during the whole analyzed distance
- the maximum flow rate, how it grows and how it decrease, as time dependence
- sediments variation in time as concentration, dimensions, type, etc

In Fig. 1 is presented a schematic description of the appearance of infiltrations.

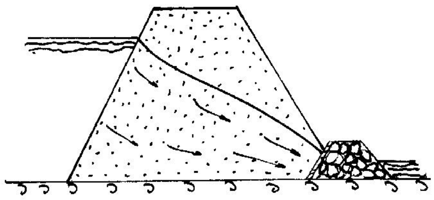


Fig.1. Infiltration through dikes

In Fig.2 a, b are presented images from the analyzed area.

Fig..2-a, b. Images from affected area

Further are presented the obtained results in cross-sections into river Cracau, one of the fourth analyzed rivers. The initials coordinates, determined by in-situ measurements are mentioned into Table 4.

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	491.6	0	490.3	0	489.8	0	488.3	0	487.4
2	490.1	3	489.5	10	489.7	1	487.0	3	486.2
15	490.2	20	489.9	26	489.2	6	487.3	7	486.4
20	490.8	23	489.2	43	489.2	23	487.5	13	486.9
25	490.7	32	489.3	57	489.0	28	487.0	15	486.4
36	490.4	60	489.3	61	488.2	31	487.8	20	486.5
50	490.1	66	489.5	77	488.3	36	487.8	30	486.8
60	490.8	72	490.1	81	488.0	40	488.3	42	487.6
64	492.1	78	490.7	93	488.0				
74		84	490.9	109	488.9				

There were estimated the zones were appears sedimentation and the zones where erosions and infiltrations appear. Into numerical modeling 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 cross-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 zones-erosion. To estimate the infiltration rate were be taken into account

- **Hazen relation**

$K = A \cdot c \cdot \tau \cdot d_e^2$

Where:

- *A* -coefficient depending of measuring system, A=1, if k is considered in m/day;
- *c* represents a coefficient depending of contents of argyle in sand; for cleaned sands c = 1000-700, and for sands with argyle c = 700-500;
- d_e- the effective diameter in mm, definite by ratio compared with the smallest grain sand, only 10% (weigh considered) from total sediment grains
- τ is a correction coefficient taking into account the temperature (t^0 C)

The relation may be used at sands with active diameter between 0.1-3 mm, respective ratio d_0 / d_e smaller then 5.

- **Kozeny relation**

$$k = 7{,}94 \frac{p^2}{\left(1 - p^2\right)} \tau \cdot d_k^2 \qquad [\text{cm/s}]$$

Where:

- p is the porosity coefficient
- d_k is the active diameter in mm
- *τ* is a correction factor for temperature, presented in Table 4, after correction calculation.

Table 4. Correction factor for temperature

T	τ	T	τ	T	τ	T	τ	T	τ
0	0,58	6	0,72	12	0,854	18	1,00	24	1,155
1	0,61	7	0,74	13	0,878	19	1,02	25	1,180
2	0,63	8	0,76	14	0,902	20	1,05	30	1,313
3	0,65	9	0,78	15	0,926	21	1,08	40	1,620
4	0,67	10	0,80	16	0,950	22	1,10	50	1,926
5	0,69	11	0,83	17	0,975	23	1,13	60	2,231

- **E. A. Zamarin relation**

$$k = 8{,}07 \frac{p^2}{\left(1 - p^2\right)} c_p \cdot \tau \cdot d_k^2 \qquad [\text{cm/s}]$$

Where:
- d_k is effective diameter in mm
- c_p is a coefficient depending of earth porosity. The τ coefficient has the same values as mentioned into Table 4 and coefficient c_p, from Table 5.

Table 5. Estimation factor for correction of porosity

p%	c_p	p%	c_p	p%	c_p	p%	c_p
27	0,757	32	0,632	37	0,518	42	0,416
28	0,731	33	0,608	38	0,497	43	0,397
29	0,706	34	0,585	39	0,476	44	0,378
30	0,680	35	0,562	40	0,456	45	0,360
31	0,656	36	0,540	41	0,435	46	0,342

During two years were realised complex measurements on both dikes from the affected area. In Table 6 are presented the obtained results for left size of dams and in Table 7 for the right dike; for both tables the notations have the same meanings.

Table 6. Left dike

Dike left size					
Area affected	Form of presentation				
Profile	BU	BB	RU	TU	G
300.5- 300.6				X	
303.1-303.4			X	XX	X
303.8- 303.9			X	XX	X
303.0- 304.0				X	
303.6- 304.5			X		X
307.1- 307.3	X	X			X
307.5- 307.9	X				X
308.0- 308.2	X				
356.0- 356.2	X	X			

Table 7. Right dike

Dike right size			
Affected area	Form of presentation		
Profile	BU	BB	G
410.0- 413.0	X	X	X
416.7-417.0	X	X	X
429.0- 430.0	X	X	
434.0- 435.5	X		
437.5- 437.9	X	X	X
438.5- 439.5	X	X	X
439.0- 446.3	X	X	
445.0- 445.9	X	X	X
458.0- 460.0	X	X	
462.0- 465.0	X	X	

Where:
- BB - formed ponds
- BU - wed ponds
- TU - wed front
- RU - wed surface
- G - Ice on surface/front
- X - appearance into mentioned areas
- XX - intense appearance

Into numerical modeling were tested around 24 Variants. 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 Table 8 are presented the main values entered as data base for the channel and the natural river bed, for both dikes, as they were registered as risk zones, during floods into selected area.

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

Table 8. The dikes characteristics

Section type	Width dike [m]	Up-stream area	Down-stream area	Applied length [m]	
				Left side	Right side
I - 15m < H < 27m	6,00	1:2,00 1:2,5	1:1,75 1:2,00	2627	1827
II - 7,5m < H < 15m	6,00	1:2,00 1:2,25	1:1,75 1:2,00	2700	3600
III - 2,5m < H < 7,5m	4,00	1:2,00	1:2,00	1850	1050
IV - H < 2.5	4,00	1:2,00	1:2,00	890	546
	Total Lengths			8,067	7,023

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 or 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 cross-sections, represented with a different colour.

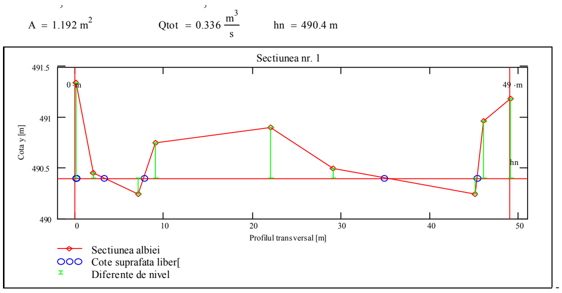
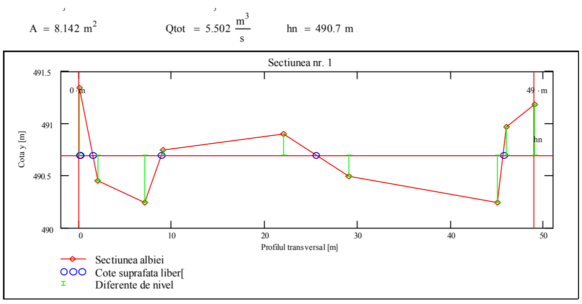
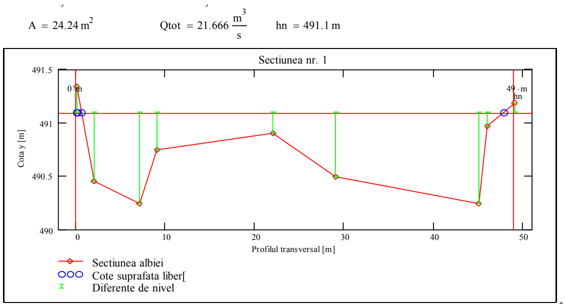


Fig.3 a, b, c Graphic results after numerical modelling in Cross Section 1





Into Fig. 4-a, b, Fig.5-7 are presented some partial results for Sections 2, 4, 5 and 6. It may be observed the risk zones, depending of the flow rate

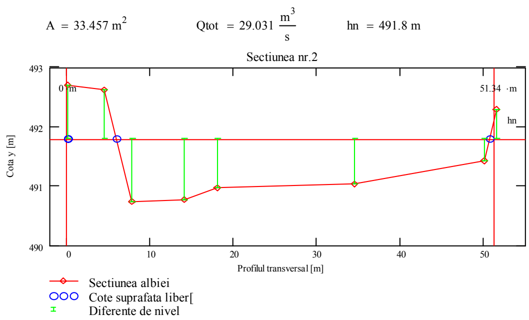
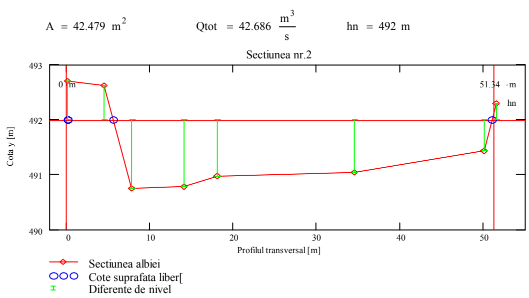


Fig.4 a, b. Results from Cross Section 2



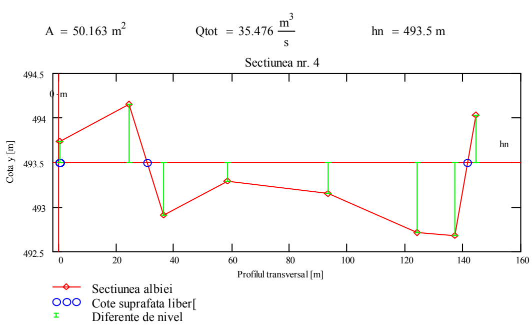


Fig.5. Results from Section 4

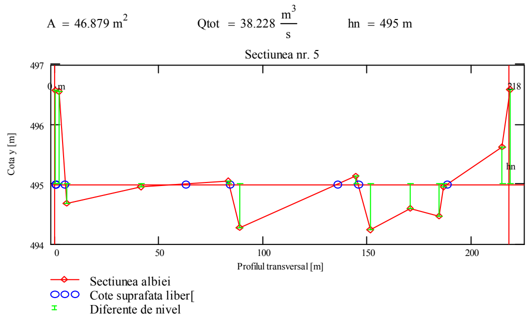


Fig.6. Results from Section 5

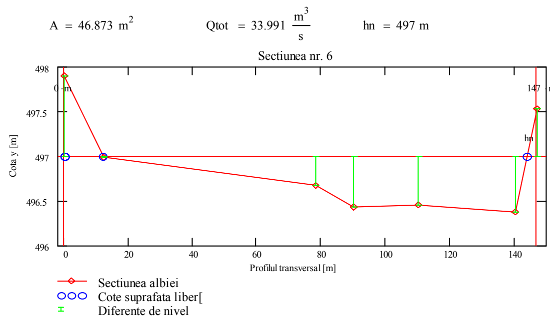


Fig.7. Results from Section 6

As it may be observed from the graphical representations at rate flow over 25-35 m3/s in some cross-sections appear floods. Considering that, tajing into consideration 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.

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 analyzed 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.

After the first conclusions was tested the model for infiltration, into critical sections. The utilisation of different colours into graphic design of the cross section of dike represent the type and dimension of the base of structure: core is realized by local materials, cyan is fine sand, rose a betony zones with solid crushes, etc.

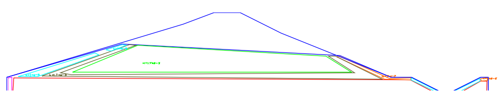


Fig. 8. Dike structure

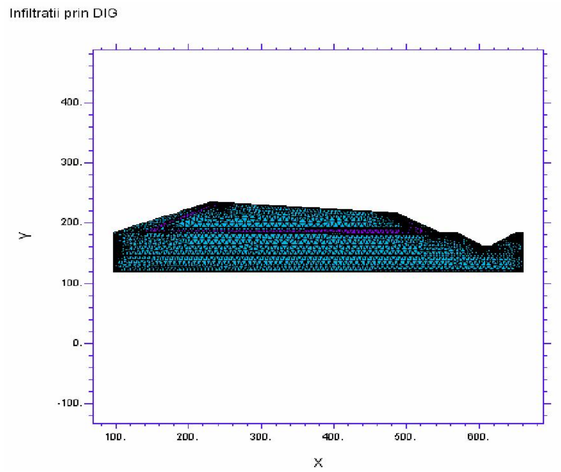
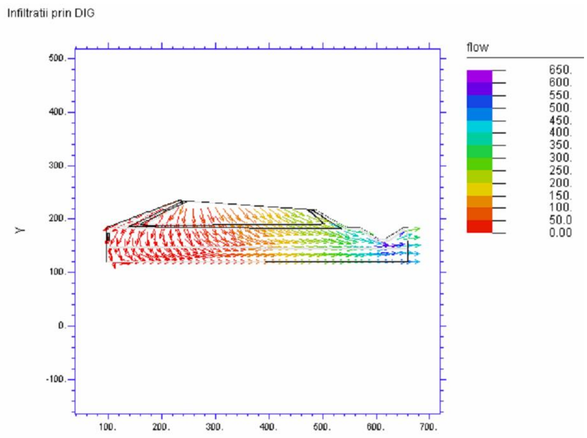


Fig. 9. Element discretisation



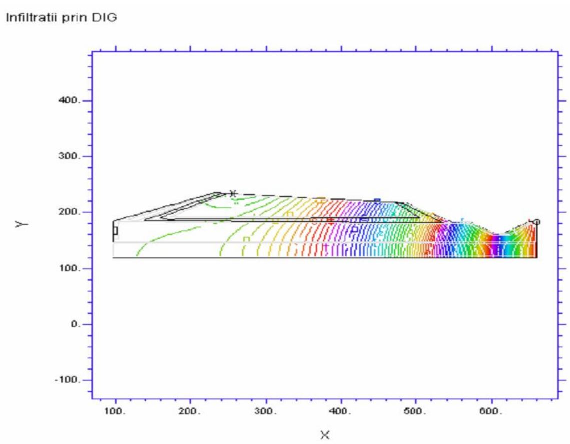


Fig.10. Stream lines due infiltration through dike

5. CONCLUSION

In this paper is presented, elaborated and tested a complex numerical model to simulate the capacity of transport of 4 rivers in natural conditions, for different flow rate. Into the presentation of the obtained results are mentioned only those for the river Cracau. By knowing exactly the zones with real problems into current exploitation, represented by mentioned cross-sections, it's possible to create a plan of surveillance as to avoid future disaster as humans and animals lost, but also for housed agricultural landing, etc.

Now the specialists, the environmental authorities tried to establish another risks zone and to analyse them on-line (permanent) in conformity with actual conditions.

It's recommended that at least at 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.

As finally conclusions, in Romania, in present at 636 hydropower systems find in use,

- 136 have destroyed (or damaged) protections
- 69 dams and dikes are present infiltrations into up-stream current
- 143 dams have mentioned permanent erosions
- 186 dams are system of evacuations well damaged and have no surface possibility of evacuation of high flow rate
- 21 dams are in very bad conditions
- 35 have the utile volume capacity diminishing with more the 55%
- 65 dams are abandoned
- 5 dams are proposed to be send for legal procedures of abandon

Then, there are enough places for environmental protection, for risk analyses, for numerical modeling, sediment transport, free surfaces flows, erosions analyses, infiltrations through dikes and dams.

The obtained results were in conformity with experimental, measured in-situ ones. As it may be observed the risk cross-sections at different water level represents also risk zones for infiltration. The model of infiltration through dams will be developed at dikes also, knowing that there are many such dikes with real problems in our country. By determining the main velocity in cross section of dams it may be established the risk zone of infiltrations and transport of solid material. Knowing the stream lines and the flow rate will be possible to be avoided crucial damages of dikes and dams.

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