STUDY REGARDING FLOOD PROPAGATION ANALYSIS THROUGH GOLEŞTI RESERVOIR

Gabriela-Andreea DESPESCU[1], Petrișor MAZILU [2], Răzvan-Dan BOGZIANU[3], Adrian BĂRBIERU[4], Gheorghe LĂZĂROIU[5]

This research aims the investigation of possibilities for applying mathematical models of the floods in order to determinate the optimal flow solutions with minimal impact on the environment.

The study can also demonstrate that using existing data on a dam (expertise, hydrological studies, operating regulations, etc.), it is possible to identify operating rules to avoid emergency situations or diminish their effect (reduce damage, attenuate the peak of the flood etc.)

Keywords: floods, hydraulic modelling, HEC-Ras, flow hydrograph, dams.

1. Introduction

Floods represent peak moments in the evolution of a water flow [5].

Researchers describe them as "the most dramatic episodes of hydrology". They are characterized by very fast increases (talking in hours), sometimes extraordinary, of water levels and thus of the flow, until reaching a maximum, followed by decrease, also fast (but with a speed slightly smaller than growth), returning to normal flow parameters.

Over the next period, due to global warming, there is an assumed imminent flood danger. In this case, it is good to consider as an important function of the catchment, the flood control function [8].

Flood control has as a general objective to limit the discharge of water flows into and around the watercourses so that the level of damage can be reduced. Consideration must be given to the effect due to storage and the effect due to water leakage at the downstream control points.

[1] PhD student, University POLITEHNICA of Bucharest, Romania, e-mail: gabriela.despescu@yahoo.com

[2] National Administration ”Romanian Waters”, Romania, e-mail: petrisor.mazilu@rowater.ro

[3] Eng., National Administration ”Romanian Waters”, Romania, e-mail: razvan.bogzianu@rowater.ro

[4] Eng., National Administration ”Romanian Waters”, Romania, e-mail: adrian.barbieru@rowater.ro

[5] Prof., University POLITEHNICA of Bucharest, glazaroiu@yahoo.com

Dams are special, massive hydropower constructions, built across the rivers, in the riverbed, in order to retain upstream a volume of water in a reservoir (artificial lake) [6], [8]. The water retained in this lake is intended for various uses: irrigation, water supply for localities and industry, fish farming and recreation, the main use mostly being the production of electricity. Making dams and reservoirs on the flowing watercourses have another important goal, namely flood fighting, through the possibility of accumulation of a very large volume of water in the artificial lake, water from the rain and from snow melting [5].

In general, flash floods are a direct consequence of climatic conditions that constitutes, in most cases, the triggering factor of these phenomena [7].

Natural disasters lead not only to economic consequences, by destruction of large infrastructure and goods, but have also a big impact on the social aspects for affected area.

The main causes for floods that lead to important human and material damages in Romania [4] are:

- torrential rainfall type;
- massive deforestation;
- inadequate maintenance of the riverbeds and especially in the localities or near the bridges (the desilting and cutting the vegetation in the minor riverbed, waste removal, etc.);
- placement of unauthorized constructions in the torrential zones and floodplain area;
- the undersized sewer networks.

2. Location of work

Goleşti dam and reservoir are located on the middle Argeş river, 10 km downstream of Piteşti municipality and about 7.3 km downstream of Piteşti dam and reservoir (Fig. 1).

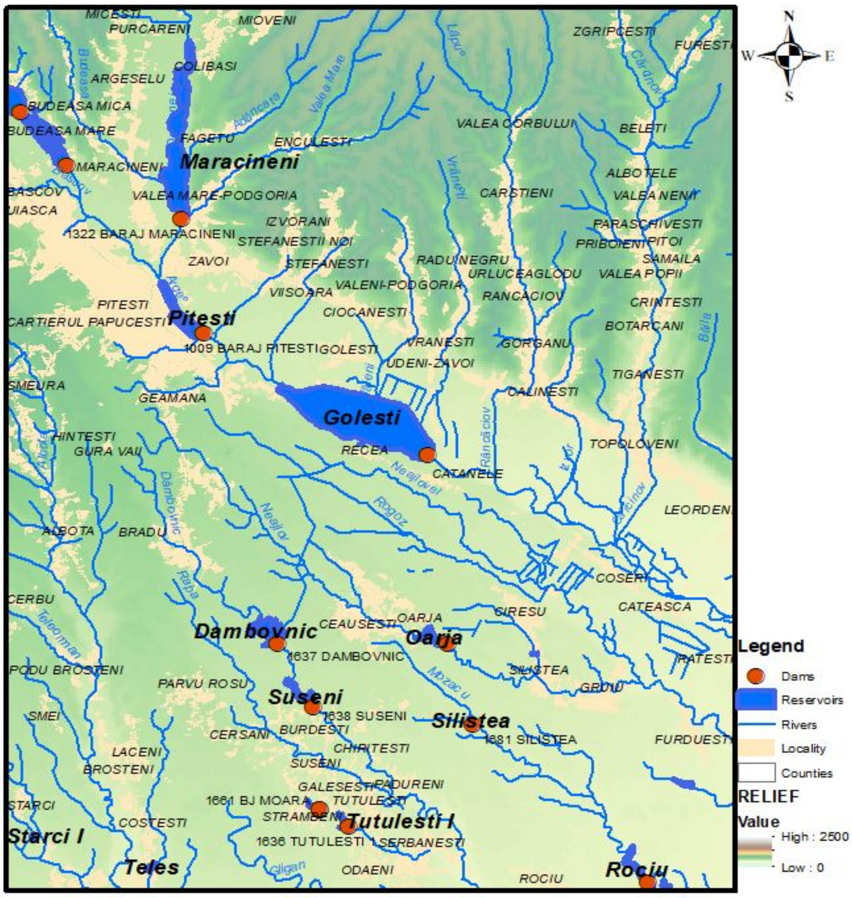

Fig. 1. Map of Goleşti dam [2]

The complex improvement of the Argeş River is at the head of the hydroelectric waterfall, the Vidraru reservoir with a volume of 465 million m³. There is a large number of hydropower plants and complex energetic works. The Goleşti reservoir (Fig. 2) is the next and the last important one on the Argeş River, having the role of flood fighting.

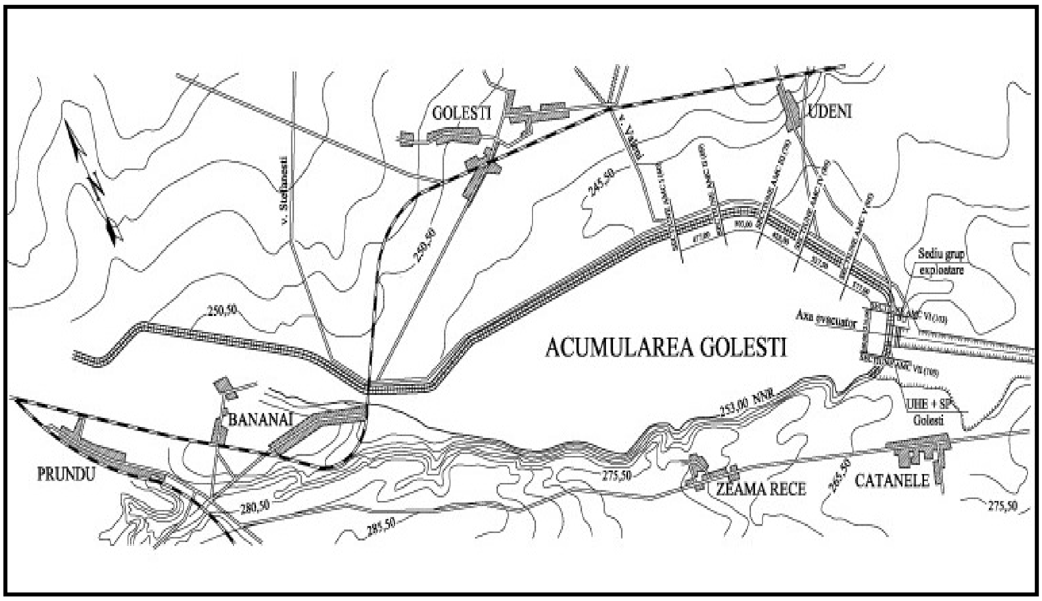

Fig. 2. Golești dam map [10]

3. General Elements for Water Flow Modeling with the HEC-RAS Programme

The hydraulic calculations on the Argeş River, downstream of the Goleşti dam were performed with the HEC-RAS software, which reproduces the propagation of the flood waves in a natural and improved regime, highlighting the hydraulic characteristics of the riverbed.

The calculation model can determine the characteristic flow data of non-permanent and permanent water in a uniform or progressively variable hydraulic regime for rivers [9].

The mathematical model is based on the integration of the equations of non-permanent and permanent movement by finite differences [1].

$$\frac{\partial A}{\partial t} + \frac{\partial (Q)}{\partial x} = Q_{\text{lat}} \tag{1.1}$$

$$\frac{dy}{dx} + \frac{\alpha}{2g}\frac{\partial}{\partial x}\left(\frac{Q^2}{A^2}\right) + \frac{1}{g}\frac{\partial}{\partial t}\frac{Q}{A} = -J_{\text{e}}$$

where A is the cross-sectional area, t is the time, Q is the flow, x is the distance along the flow, y is the free sectional area elevation, Q_{lat} - the inflow and α - the Coriolis coefficient and J_e is the energy slope.

This research uses the HEC-RAS programme to achieve hydraulic modelling in terms of its capabilities in flood risk studies like: availability and accessibility (free of charge), rapidity in calculations, does not require important hardware resources [11], [12].

4. Hydraulic modelling on Argeş River

Determination of the generated hydrographs at the Goleşti dam, as well as their propagation on the Argeş river, were made using the HEC-RAS modelling software.

Goleşti reservoir was scheduled to be carried out in order to:
- the water supply for Bucharest;
- water supply for ARPECHIM Piteşti;
- water supply of the Căteasca - Teiu irrigation system;
- production of electricity through HPP Goleşti;
- Flood waves mitigation on the Argeş River [9].

The profiles were extracted from the land model using the Geographic Information System (GIS) software, some of which were obtained by interpolation using the HEC-RAS program.

The roughness coefficients were estimated, taking into account the literature, at 0.05 for the major riverbed and 0.035 for the minor riverbed.

To achieve this modeling, it was chosen the largest flood that was recorded between 2005 and 2014 at Goleşti dam, with a maximum flow $Q_{afl} = 1236.67\ m^3/s$.

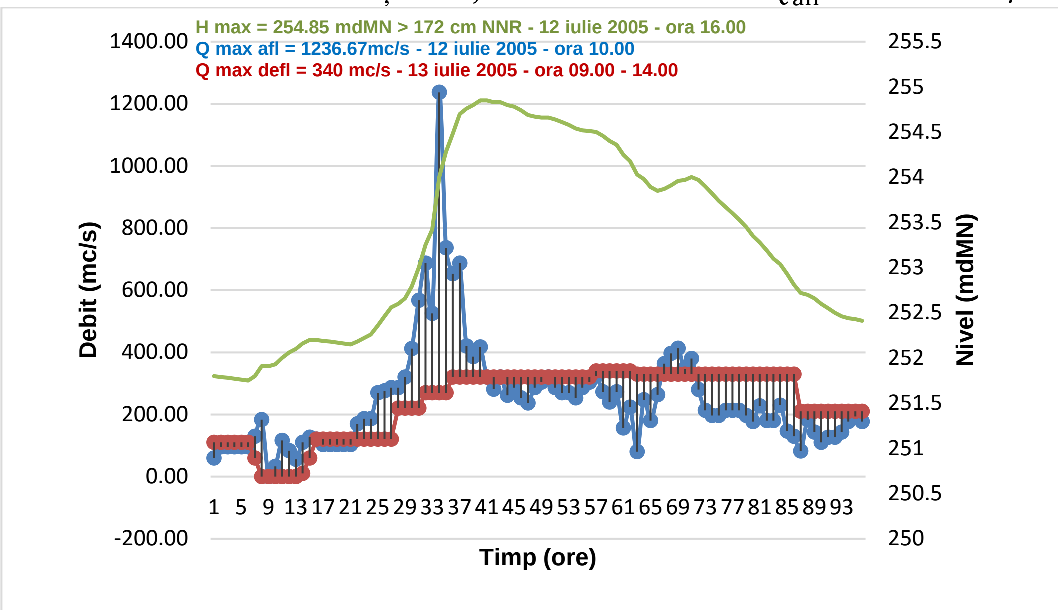

Fig. 3. The flood wave hydrograph recorded at Goleşti between 11-15 July 2005

Fig. 4 presents the profiles made on the analyzed area, highlighting the Goleşti dam position [2].

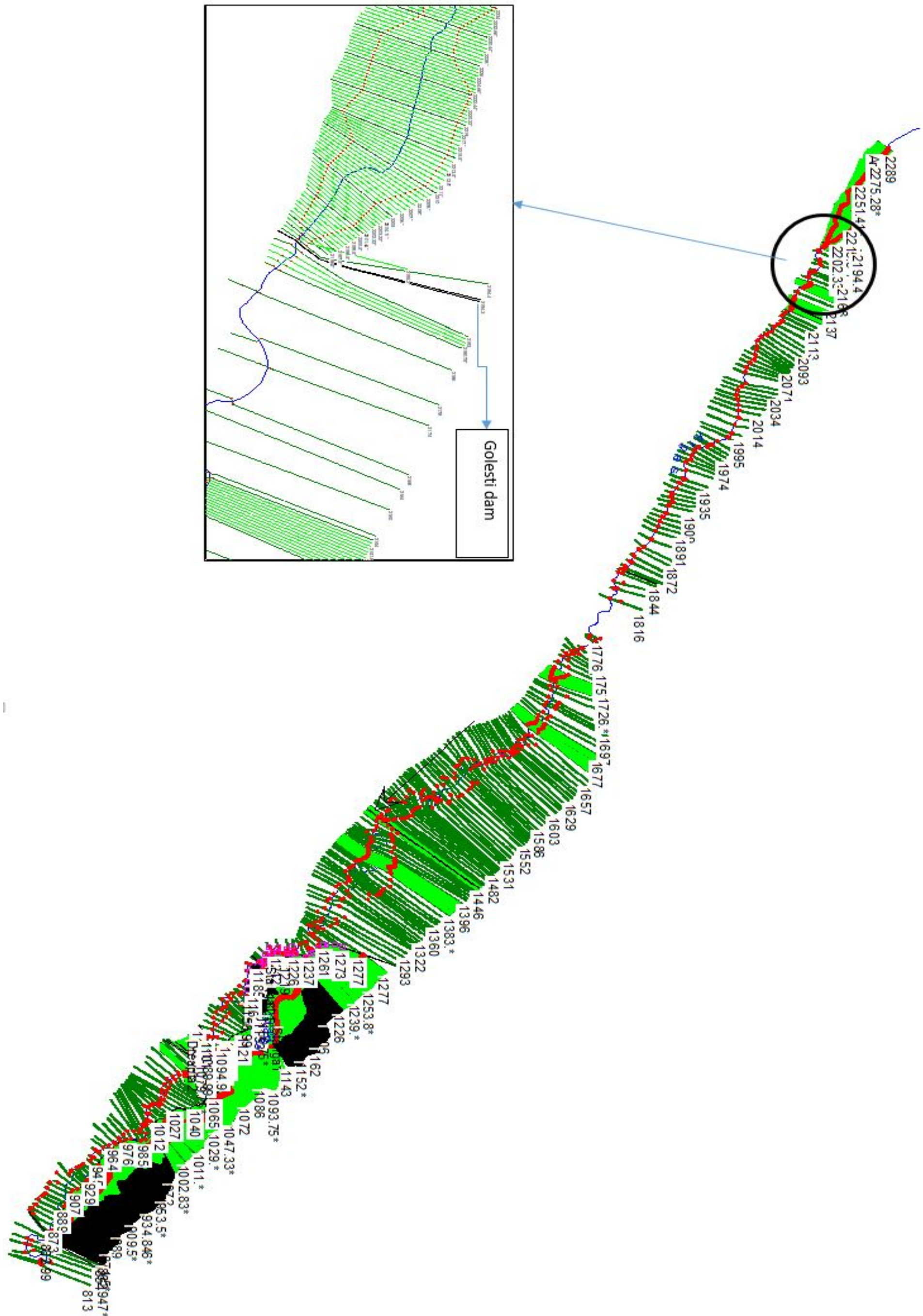

Fig. 4. The studied area on the Argeș River - the Golești sector

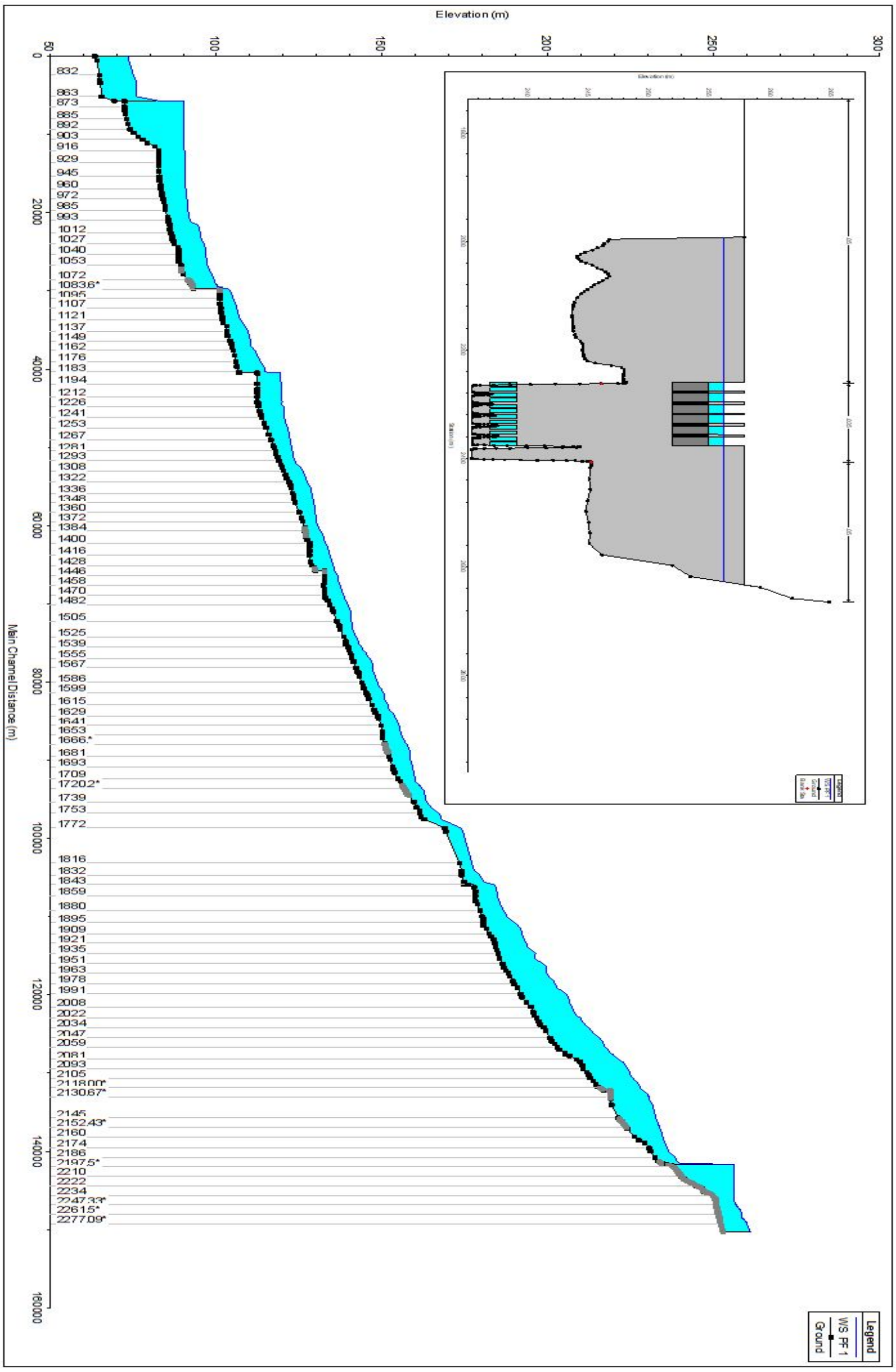

Fig. 5. Longitudinal profile of the Argeş River, downstream Goleşti Dam

Following the results it can be noticed that evacuating a flow using all the evacuators with 2 m, the accumulated water does not discharge over the dam and the lateral defense structures are not exceeded.

5. Hydraulic modelling for $Q_{1\ \%}$ to define Emergency Situation Management at the Goleşti dam

❖ **Hydraulic modelling for $Q_{1\ \%}$, assuming normal exploitation with the continuous hydropower plant operation.**

The hydromecanical equipment of the spillway is composed of:

- 6 open air gate;
- 12 bottom gate;

According to the provisions stipulated in the Goleşti Dam Operating Regulations, the order of handling of the hydromechanical equipment is as follows [10]:

- for the bottom gates: 7, 8, 1, 2, 12, 11, 3, 4, 10, 9, 5, 6;
- for the open air gates: 4, 3, 5, 2, 6, 1.

When closing the overflow dam, the order of handling the equipment is the reverse of the opening.

The calculation rate with the 100 - year probability of exceedance at Goleşti reservoir is $Q_{1\ \%} = 2180\ m^3/s$.

Tabel 1

Synthetic data of natural floods in the Goleşti section

River	Section	F [km²]	Q_{max} [m³/sec]							T_t [hours]	T_{cr} [hours]	γ
			0.01 %	0.1 %	0.5 %	1 %	5 %	10 %	20 %			
Argeş	**Goleşti Dam**	3181	5660	3760	2744	2180	1360	828	570	112	27	0.26

For the hydraulic model of the flood with the calculation flow at the Golesti reservoir, in case of normal exploitation, the manoeuvers for opening/closing of the dischargers were performed according to the provisions of the Operating Manual of the dam, starting from an initial level equal to the normal level of exploitation NNR = 253 mdMN (meters above the Black Sea) and continuous operation of the hydroelectric plant with a flow rate of 90 m³/s.

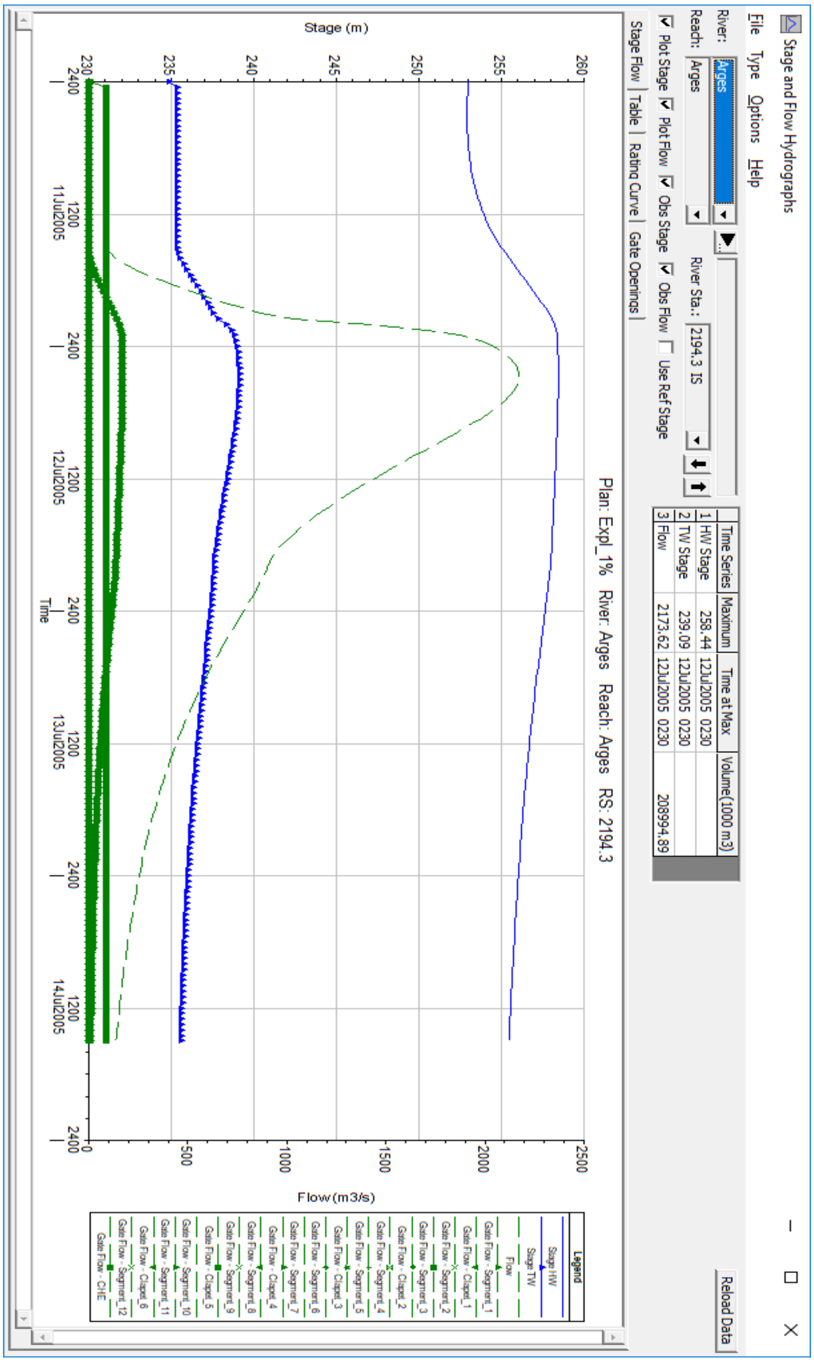

Fig. 6. Initial hydrograph at Goleşti dam for a flood with $Q_{1\,\%}$

The maneuvers were performed so that the level in the lake does not drop by more than 1.5 meters per day, to the provisions of the Operating Manual of the dam.

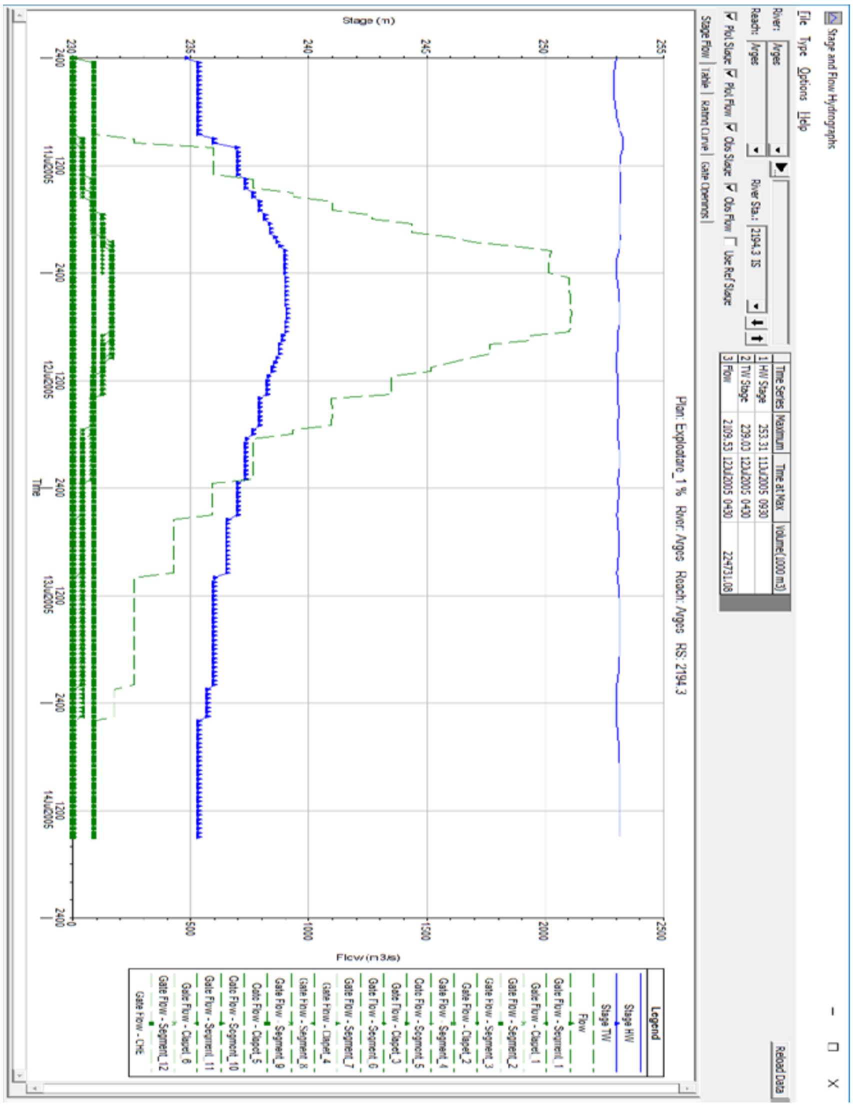

Fig. 7. The resulted hydrograph at Golești dam for a flood with $Q_{1\,\%}$

The maximum flow obtained using the hydraulic modelling is Q = 2109.53 m^3/s.

- **Hydraulic modelling for $Q_{1\,\%}$, assuming pre-emptying manoeuvers with the continuous hydropower plant operation – option 1**

For flood modelling with the calculation flow, in the case of pre emptying, the opening/closing manoeuvers of the dischargers are started according to the provisions of the Operation Manual of the dam, starting from an initial level equal to the minimum level of operation NmE = 244 mdMN (meters above the Black Sea) and continuous operation of the hydroelectric powerplant with a flow rate of 90 m^3/s.

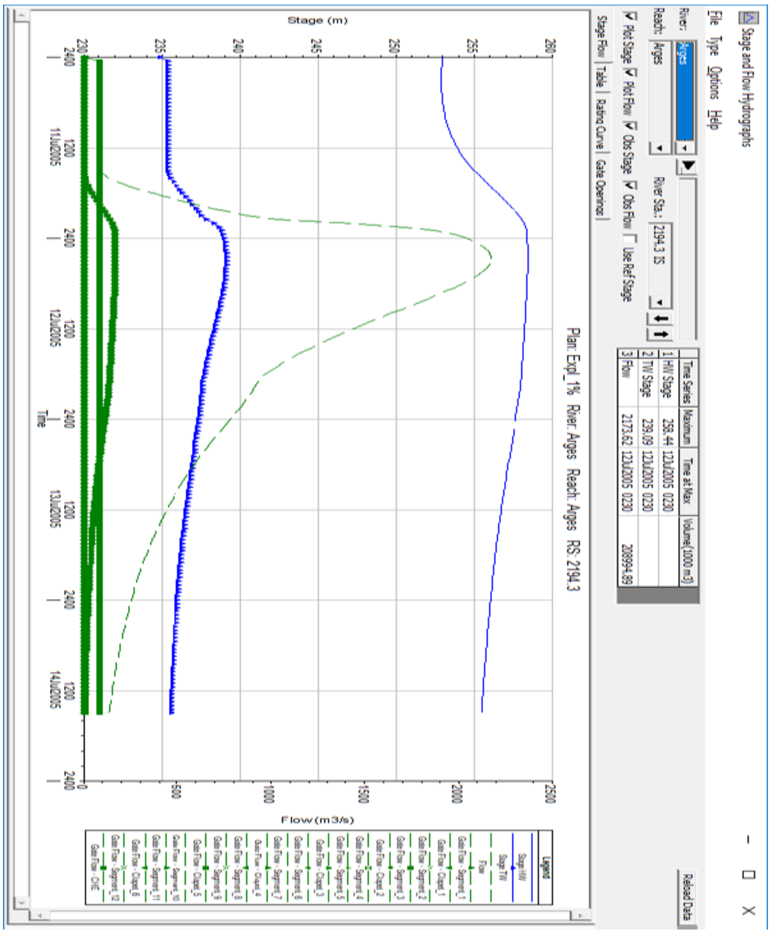

Fig. 8. Initial hydrograph at Goleşti dam for a flood with $Q_{1\,\%}$ and pre-emptying manoeuvers

The maneuvers were performed so that the level in the lake does not drop by more than 1.5 meters per day, to the provisions of the Operating Manual of the dam.

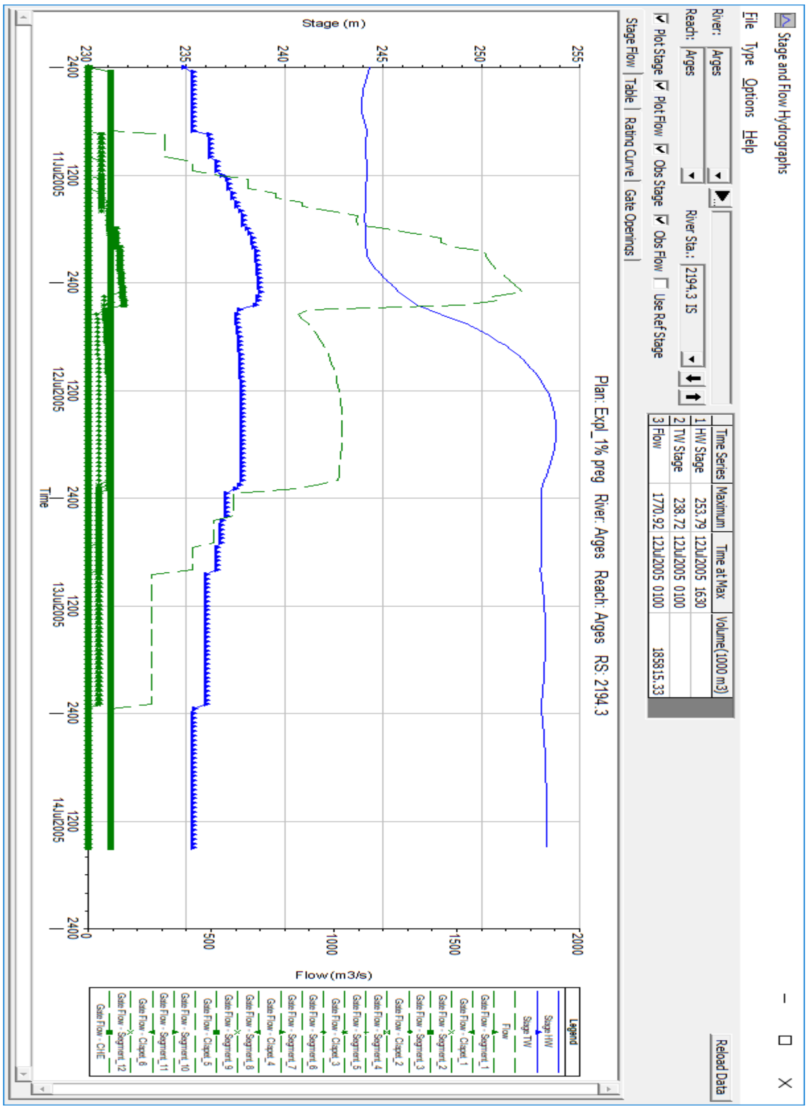

Fig. 9. The resulted hydrograph at Golești dam for a flood with $Q_{1\,\%}$ and pre-emptying manoeuvers – option 1

The degree of attenuation of the maximum discharge rates obtained in this case of exploitation in the Goleşti sector is

$$\beta_{1\,\%\,preg1} = \frac{Q_{\text{max.afl.}} - Q_{\text{max.defl.1}}}{Q_{\text{max.afl.}}} \cdot 100 = \frac{2180 - 1770.92}{2180} \cdot 100 = 18.76\ \%$$

where

$\beta_{1\,\%\,preg1}$ is the degree of mitigation of floods in this case;

$Q_{\text{max.afl.}}$ is the maximum flow ($Q_{1\,\%}$ = 2180 m^3/s);

$Q_{\text{max.defl.1}}$ is the maximum flow obtained by following hydraulic modeling.

The results obtained from the modeling can be seen in Figure 10, by the hydrograph superposition because of the normal manoeuvers during operation in the Goleşti section resulting from the pre-emptying manoeuvers.

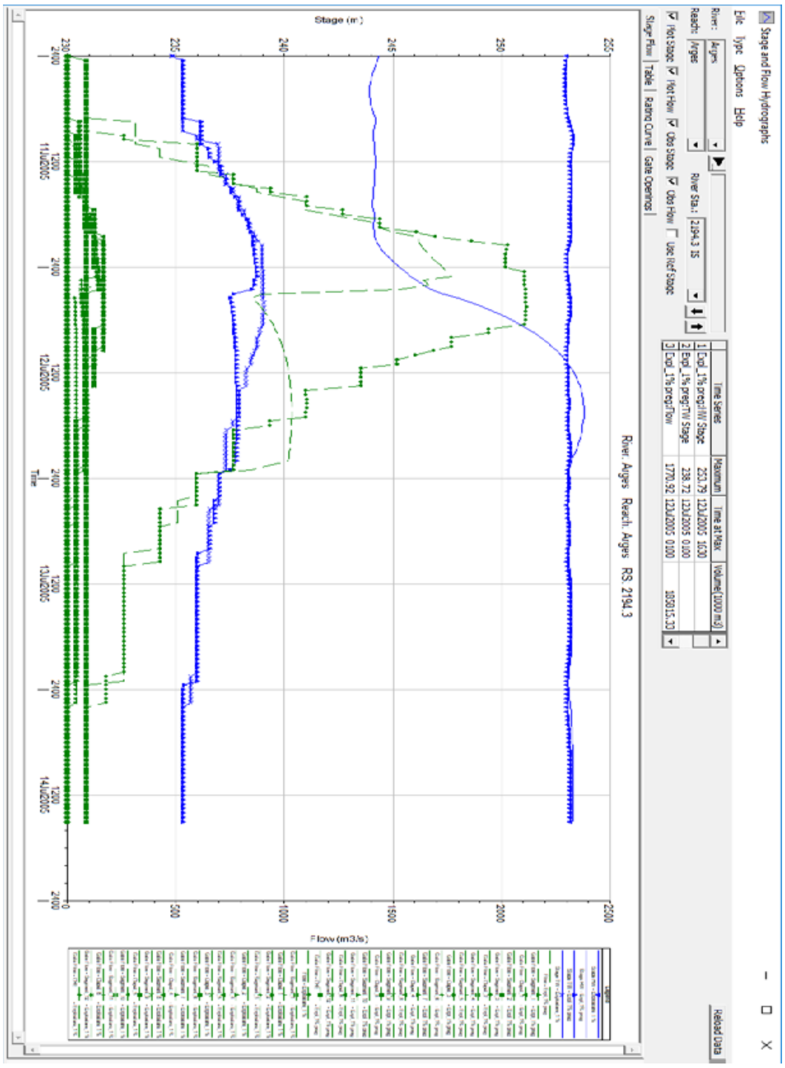

Fig. 10. Influence of the pre-emptying manoeuvers on the maximum flow in the Golești section

The results that following the modeling in the normal exploitation hypothesis, in the case of a flood with the calculation rate $Q_{1\,\%}$ = 2180 m^3/s is a maximum flow with $Q_{max\ 1\ \%}$ = 2109.53 m^3/s and in the case of exploitation with pre-emptying manoeuvers, the maximum flow resulted is $Q_{max.\ defl.1}$ = 1770.92 m^3/s.

- **Hydraulic modelling for $Q_{1\ \%}$, assuming pre-emptying manoeuvers with the continuous hydropower plant operation – option 2**

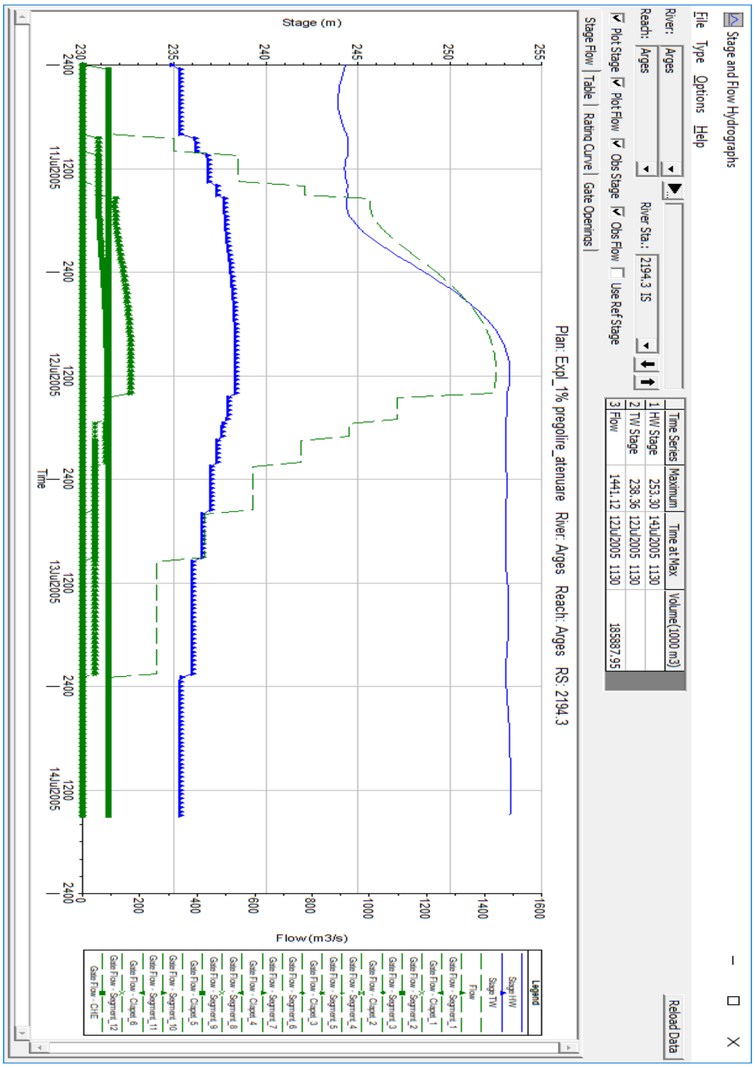

Fig. 11. The resulted hydrograph at Golești dam for a flood with $Q_{1\ \%}$ and pre-emptying manoeuvers – option 2

In this case, the exploitation with pre-emptying manoeuvers of Golești accumulation consists in the different handling of the evacuators at the moment of reaching the maximum level in the lake. This mode of exploitation sought to achieve a higher degree of attenuation.

The maximum flow resulted in this hypothesis is $Q_{\text{max. defl.2}}$ = 1441.12 m^3/s.

Due to the delay of the evacuation opening, according to the option 2 operating, a maximum flow rate from 1770.92 m^3/s to 1441.12 m^3/s it was achieved.

The degree of attenuation of the maximum discharge rates obtained in this case of exploitation in the Goleşti sector is

$$\beta_{1\,\%\,preg\,2} = \frac{Q_{\text{max.afl.}} - Q_{\text{max.defl.2}}}{Q_{\text{max.afl.}}} \cdot 100 = \frac{2180 - 1441{,}12}{2180} \cdot 100 = 33{,}89\,\%$$

where

$\beta_{1\,\%\,preg2}$ is the degree of mitigation of floods in this case;

$Q_{\text{max.afl.}}$ is the maximum flow ($Q_{1\,\%}$ = 2180 m^3/s);

$Q_{\text{max.defl.2}}$ is the maximum flow obtained by following hydraulic modeling in this case.

According to the results of this modeling, the level of the water in the downstream bed is decreasing with 1 m.

5. Conclusions

In this study, the analysis of the flow of water flows to the Golești hydroelectric power plant during periods of high water, the main purpose being to study with the help of mathematical models the possibility of mitigation the negative effects of these phenomena.

Reproduction of the flood wave is performed to calibrate some parameters and to perform mitigation calculations in reservoirs or riverbed propagation on the reproduction of real phenomena in order to be able to achieve synthetic flows.

This work can help in flood control management by establishing rules for operating reservoirs based on predictive information on the characteristics, duration and timing of the flood generation, introducing restrictions on the realization of new constructions in the floodplain and planning adequate land use.

It can also demonstrate that using the existing data on a dam (expertise, hydrological studies, management plans) can identify a rule that avoids the emergency or reduces its effect (to reduce the damage, the peak of the flood).

R E F E R E N C E S

[1] *K. O. Asante, G. A. Arlan, S. Pervez, J. Rowland*, A linear geospatial streamflow modeling system for data sparse environments', International Journal of River Basin Management, Vol. 6, No. 3, 2008.

[2] Gabriela Despescu (Boerosu), Researches on the management of hydropower facilities in emergency situations, PhD thesis (to be published), 2018.

[3] *C. Diaconu, P. Şerban,* Sinteze şi regionalizari hidrologice (Hydrological synthesis and regionalization), Editura Tehnică, (Technical Publishing House), Bucureşti, Bucharest, 1994.

[4] *O. Gabor,* Metode de combatere a inundaţiilor (Methods of flood control), Bucureşti, Bucharest, 2005.

[5] *I. Pisota, Liliana Zaharia*, Hidrologie (Hydrology), Editura Universităţii, (University Publishing House), Bucureşti, Bucharest, 2002.

[6] *D. Stematiu,* St. Ionescu, Siguranta barajelor și managementul riscului (Safety of Dams and risk management), Editura Conpress, (Conpress Publishing House), Bucureşti, Bucharest, 2010.

[7] *M. Şelarescu, M. Podani*, Apărarea împotriva inundaţiilor (Flood defence), Editura Tehnică (Technical Publishing House), Bucureşti, (Bucharest), 1993.

[8] *D. Stematiu*, Accidente și incidente la construcții hidrotehnice (Accidents and incidents in hydraulic infrastructure), Editura AGIR, AGIR Publishing House, București, 2018.

[9] *** A.N.A.R., Plan de acţiune în caz de accident la barajul Goleşti (Action plan in case of accident at Goleşti dam), 2017.

[10] *** A.N.A.R., Regulamentul de exploatare al acumulării Golești (Goleşti reservoir operating manual) 2016-2025.

[11] *** http://www.hec.usace.army.mil/software/hec-ras/.

[12] HEC-RAS User's manual. Version 5, 2016.