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HIGH-WATERS FLOW 2D HYDRAULIC MODEL IN CASE OF SIDE EMBANKMENT BREACH ON A RIVER SECTOR

Marie Alice Ghițescu[1] Gheorghe Lazăr[1] Albert Titus Constantin[1] Alina-Ioana Popescu-Bușan[1] Şerban-Vlad Nicoară[1]

ABSTRACT: The paper presents a 2D discrete numerical modeling of a specific framed river sector where an embankment breach development is considered in case of a given significant high-waters phenomenon. The uncertainty parameters of the failing breach development on the river left defense levee are reached by the help of a probabilistic controlling software based on Monte Carlo Method, McBreach, compatible with HEC RAS version 5.0.7. Once the breach time progress sampling parameters are established, the study looks to better estimate the flood phenomenon evolution and spread on the river left side plain. In the end, some practical issues regarding the flood protection measures for an agricultural investment in the area are to be discussed, by considering the revealed unsteady hydraulic characteristics of the 2D model.
Keywords: river engineering, flow numerical simulation, high waters flow, embankment breach, river flood

1. GENERAL CONSIDERATIONS

The discrete numerical modeling is based on the existence of a flood study on the Crasna River, in the area of Craidorolț locality, Satu Mare County, with the establishment of some constructive aspects of flood protection of the technological platform on the left bank, of the company *SC Topagrar SRL* [1]. The numerical model includes the geometry of the Crasna Riverbed (a length of approx. *1872 m*) and the associated areas. The database represents a *situation plan* (a topographical survey in *Stereo 70*), *49 cross-view profiles* (*37 short profiles* highlighting the morphology of the minor and major riverbed framed by the flood defense, respectively, *12 long cross-view profiles* that also reach the location of the mentioned economic objective) [2]. The location of the technological platform is approximately *1 km* away from the bed of the Crasna River (distance from the flood defense embankment, on the left bank of the river). The current natural ground around the technological platform is arable extra-urban, located at an average elevation of approx. *125.50 mSL* and covers a total area of approx. 60000 m^2. The *2D* model of the Crasna River and its adjacent surfaces will represent a *3D polygon network* (with a maximum of 8 sides) as can be seen in the graphic representation of *Figure 1*.

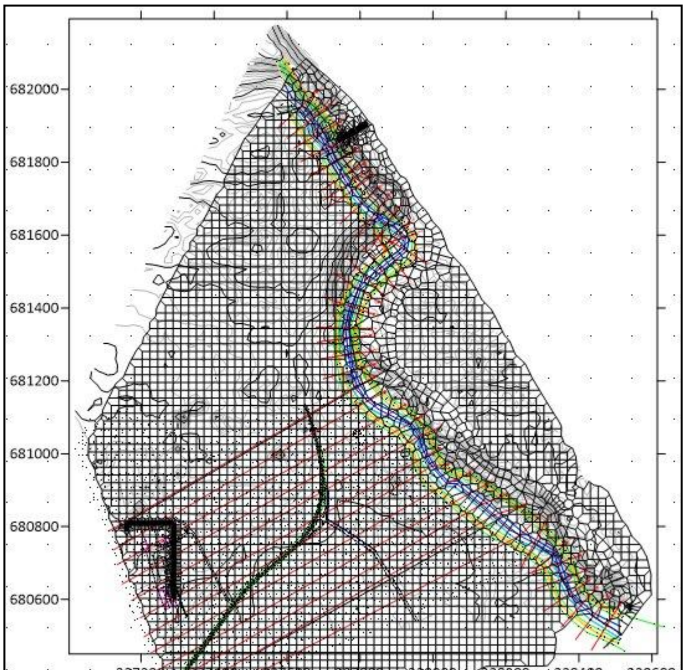

Figure 1. Discrete surface in 3D representation, contour lines obtained by a specialized spatial interpolation program (x, y and z–dimension) for the entire area of the numerical model database

[1] Faculty of Civil Engineering, Department of Hydrotechnical Engineering, Splaiul Spiru Haret No. 1/A, 300022, Timișoara, alice.ghitescu@upt.ro

The current configuration of the natural terrain originates from the spatial points (coordinates: *x, y* and land elevation *z*) resulting from the topographic survey [1], as well as the graphic processing of the geometry in *3D* (*Figure 2*, see also the numerical models in [11/12/13/15]). In addition to the documentation [11], the maximum flow with the 1% exceeding probability on the Crasna River is also known: at *Craidorolț Hydrometric Station*, in the proximity of the river crossing bridge, this water discharge represents approx. $Q_{1\%}$ = 502 m^3/s, as considering the influence of an upstream reservoir (Vârșolț).

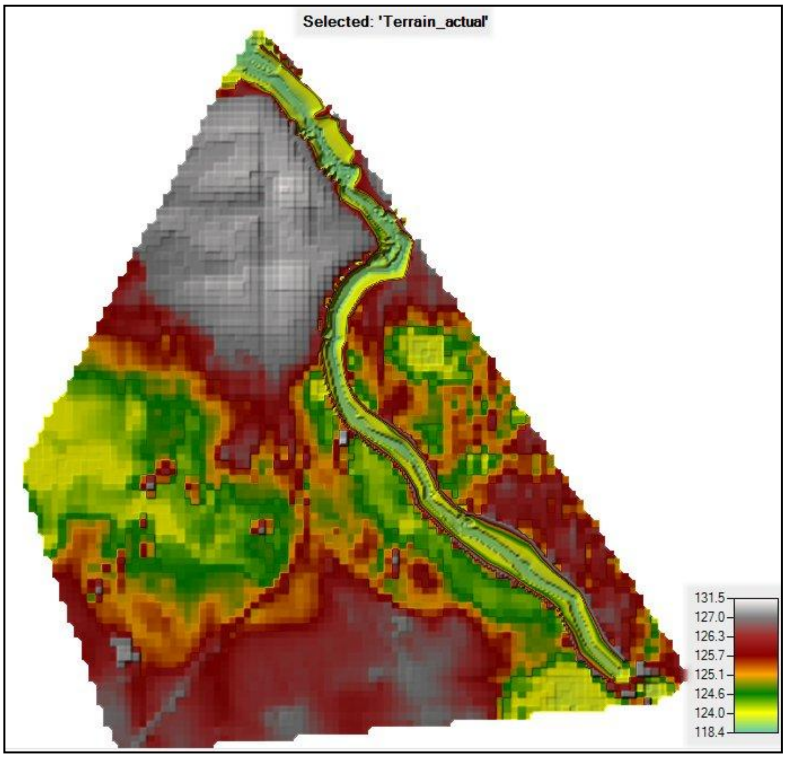

Figure 2. 3D digital surface – Crasna River and river modeled sector adjacent surfaces

If we analyze the configuration of the terrain resulting from the intermediary graphic processing (with the 2D topographic interpolation as a basis and then by interpolation adjustments between the cross-sections on the watercourse route), it is observed that the defense embankments in the major riverbed are not properly modeled. For this reason, additional adjustment corrections are needed upon this structure in the modeled area. These additional corrections can be made within the new adjustment package software (*HEC-RAS version 6.0*) by introducing two longitudinal profiles for the left bank and the right bank, provided with standard sections at the top of the embankments. They will interpolate knowing the embankments allure. A standard section contains information about the topographic crown elevation, the slopes of the faces, as well as the Δx limitation distance in the cross-section of the adjustment, meaning on the interpolation horizontal direction. The adjustments were so performed along the riversides' embankments (see also [15]).

From the carried-out analysis, as described by [10] and [11], it is known that there would be necessary to build a defense embankment to prevent the flooding of the technological platform in the area of the left bank. Therefore, a fictitious connection structure will be introduced on the numerical model, which will contain a protection dike with a maximum height ΔH= *1.2m*; following the processes of results analysis, it is to be established whether the proposed elevation of the canopy ensures the protection of the technological platform enclosure.

2. ACCOMPLISHMENT OF THE 2D DISCRETE NUMERICAL MODEL

2.1 General approach

As to achieve 2D discretization, a simple polygonal surface denoted "***ZONE_S2D"*** was defined and then divided into discrete polygonal elements (a polygon can have a maximum of 8 sides) by simply choosing two distances in the orthogonal directions *Ox* and *Oy*. As a result of this discretization process, by considering $\Delta x=20m$, $\Delta y=20m$ and a surface roughness coefficient of $n=0.055$, a discrete graphical representation was produced. There was defined a central region of the Crasna River, as comprising the area of the minor riverbed, the area of the major riverbed and the defense embankments. A refining discretization was then carried out with a predefined grid of $\Delta x=5m$ and $\Delta y=5m$, as resulted in the graphical representation in *Figure 3*.

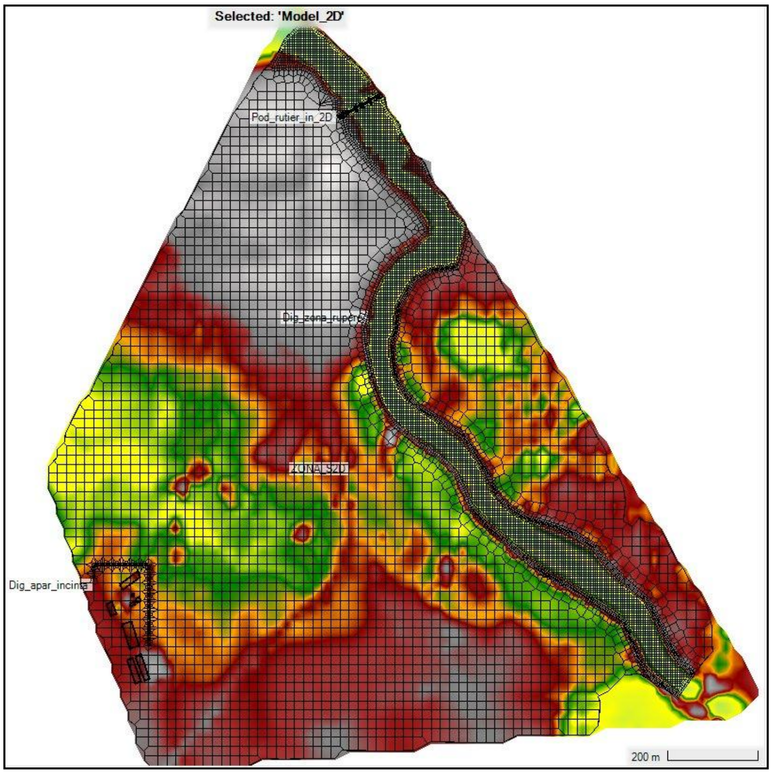

Figure 3. 2D discrete numerical model (Zona_S2D) on the Crasna River, comprising the left bank lateral structure – Dig_zona_rupere, the river-crossing bridge – Pod_rutier_in_2D and the connection structure – Dig_apar_incinta

As the defense embankments in the major riverbed are not properly modeled, additional adjustment corrections were made by introducing two routes at the top of these structures. There was employed the new specific additional facility (the layer →*Terrain ... Modifications*) of the *HEC-RAS software package v.6.0 Beta3*, with which the embankments' actual longitudinal configurations were adjusted by interpolation based on the standard cross-sections (the current standard section contains actual data about the crown topographic elevation, the faces slopes, as well as the distance on the interpolation horizontal direction). The fictitious connection structure (*Dig_zona_rupere*) was additionally introduced on the left bank. Furthermore, a gap is to be inserted as failure breach on this structure, by employing the geometric characteristics given by [11].

By studying previous documentations regarding the area of the technological platform, meaning the current northern area where three new objectives are to be developed, there was noticed the existence of a clogged irrigation canal where the level of the natural land is below 124.50 mSL. Therefore, it may be assumed that it is possible to flood the technological enclosure by this area.

As a result of analyzing the graphic post-processed outcomes of specific simulations, it comes out that the company platform is to be flooded by the northern side. Further improvements were made to the above-described numerical model to achieve proper flood protection. This is the reason for introducing the proposed connection structure *Dig_apar_incinta* in the discrete numerical model, as shown in the graphical representation of *Figure 3*.

The presented 2D numerical model contains two fictitious structures, the *connection structure* (*Dig_apar_incinta)* defining the protection embankment in the northern vicinity of the technological platform, and the *lateral connection structure* (*Dig_zona_rupere*) on the left river bank which will contain the development of a failure breach, as well as the known uncertainty parameters as used in the [11]. The area and the geometric and hydraulic characteristics are visible in the graphical representation in *Figure 4*.

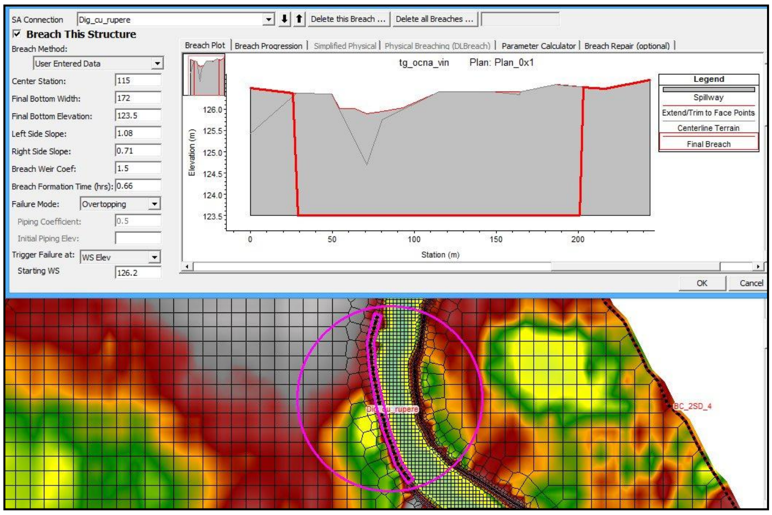

Figure 4. Geometric and hydraulic parameters for the fictitious side connection structure

The new high-performance *HEC-RAS software package vers. 6.0 Beta3* contains important new facilities for the generation of geometric elements in 2D modeling. For example, in the presented model a 2D road overpass structure has been introduced, composed by the following elements: 4 openings for water drainage, 2 side pillars and 4 intermediate pillars, at the location of the Craidorolț Hydrometric Station (*Figure 5*).

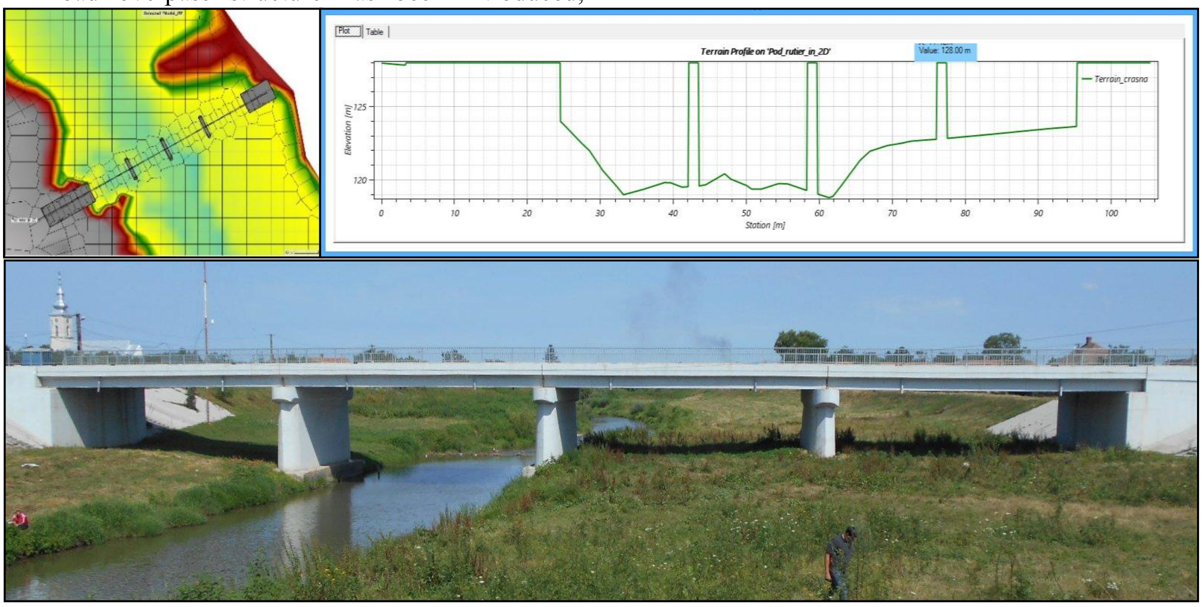

Figure 5. Traffic river-crossing structure – situation plan, structure cross-section and downstream overview

2.2 Initial and boundary conditions

As usual, the boundary conditions in the 2D model ("*ZONA_S2D*") are as follows: the watercourse transit flow of a certain exceeding probability in the associated sector introduced as a high waters hydrograph, values attached to the inlet edge (*"BC_S2D_ 1"*), and the hydrodynamic slope (*i=0.0695‰*) assigned to the outgoing edge ("*BC_S2D_3"*) and the two lateral surfaces on the left and right banks ("*BC_S2D_ 2"* and "*BC_S2D_ 4"*). The high waters hydrograph configuration was given as recorded on the Crasna River (*Craidorolț Hydrometric Station*) and sized by the proper ratio (*3.4451*) to reach the maximum flow value of *502.74*m^3/s.

The actual numerical simulation of the liquid flow transit is carried out as for a given period of time, starting at 9:00 a.m. and ending at 11:00 p.m. on May 26th, 2015, moment known for its special hydrological event. The analysis running was settled with a time step of 1 second, while the storage of the reached results was directed at a time interval of 5 minutes.

3. NUMERICAL SIMULATION AND OUTCOMES PRESENTATION

Following the execution of the specific numerical simulations, all the steady and the time-depending parameters were obtained over the entire 2D domain: *levels*, *flows* and *velocities*. The outcomes presentation as following the post-processing in a graphic form, in the current RasMapper graphic area of the *2D* model, was organized as follows:

- particles trajectories plotted as overlaid to the water surface spread (in *mSL*) at several time moments on May 26th, 2015: 15:10 → Q=240m^3/s, 15:50 →

Q=270m^3/s, 18:00 → Q=344m^3/s and 22:00 → Q=502.74m^3/s (Figure 6);

- water depth distribution (in *m*) over the model area at the specific time moment of 22:00 with the maximum inlet flow Q=502.74m^3/s, aside with the corresponding water velocity distribution (in *m/s*) (Figure 7);
- water level distribution (in *mSL*) and, respectively, its expansion along a longitudinal profile ("*profil_longitudinal_2*") together with the water velocity distribution (in *m/s*), at the specific time moment of 22:00 on May 26th, 2015 (Figure 8);
- detailed area of the crossing bridge showing the flow lines overlaid to the water surface, together with the piezometric line development along the crossing structure, at the same time moment of 22:00 on May 26th, 2015 (*Figure 9*);
- piezometric level (elevations in *mSL*) and water discharge (in *m^3/s*) time developments at the connection structure (*Dig_zona_rupere*) and, respectively, flow and level graphic representation with specific visualization at the random time moment of 03:30 p.m. (Figure 10).

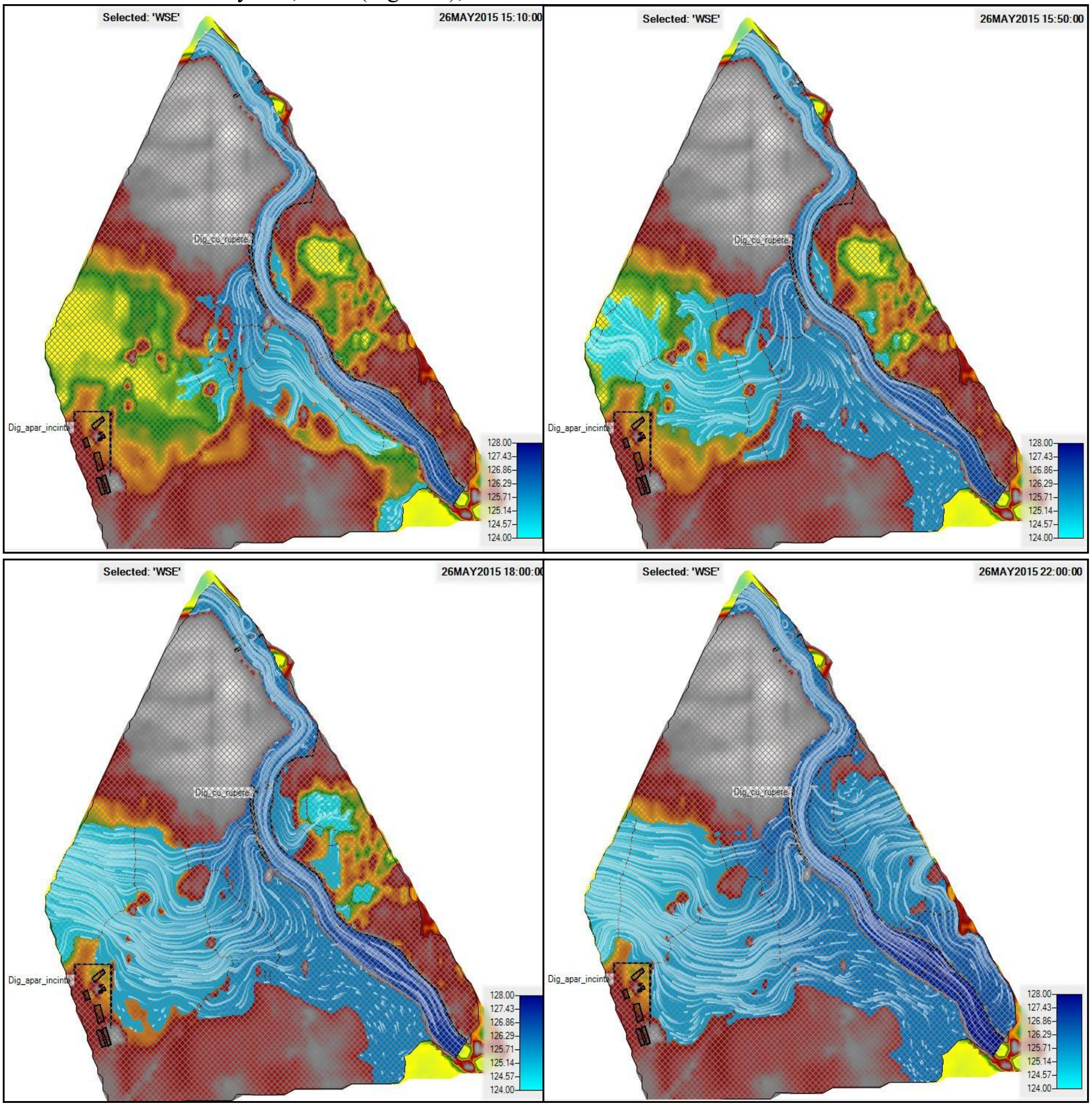

Figure 6. Particles trajectories as overlaid to the water surface development over the 2D model, acquired at several sequential moments of time on May 26th, 2015

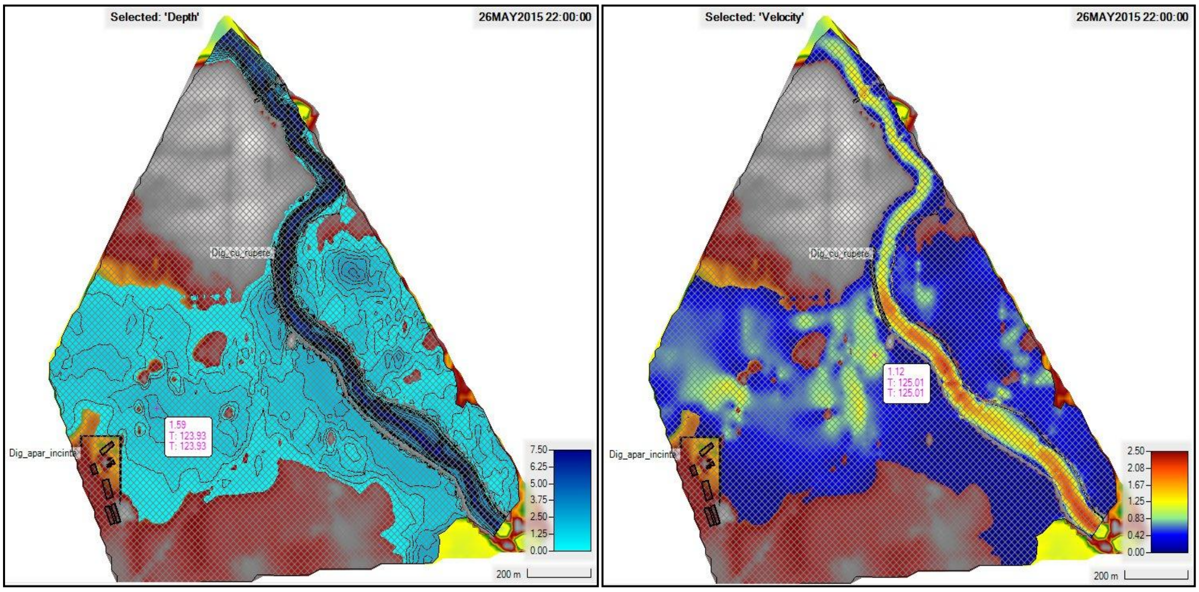

Figure 7. Water depth and water velocity distributions (in m and m/s, respectively) over the 2D model at the specific time moment of maximum inlet flow Q = 502.74 m^3/s, 22:00 on May 26th, 2015

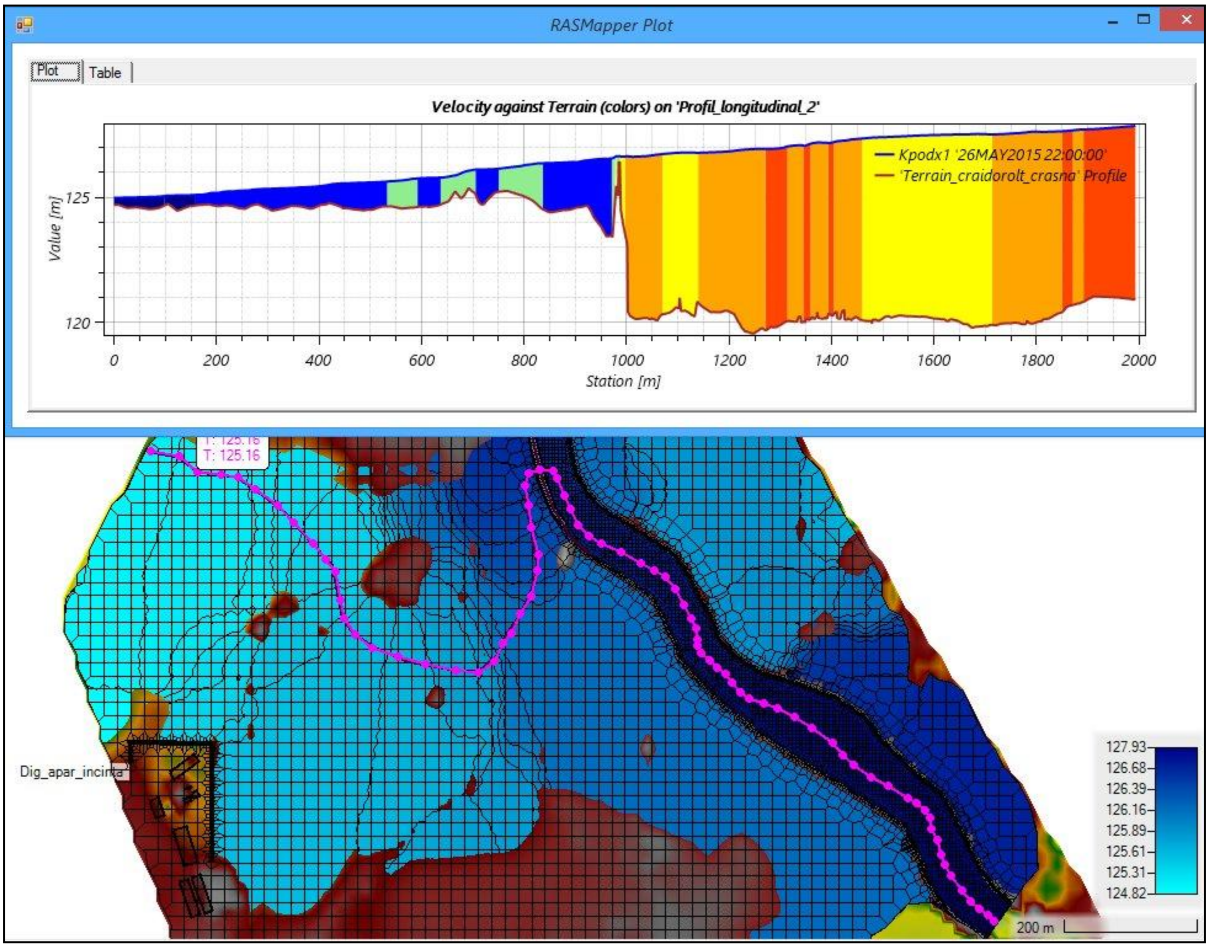

Figure 8. Water level distribution (bottom, in mSL) over the 2D model area and longitudinal level profile with velocity development at time moment of maximum inlet flow, 22:00 on May 26th, 2015

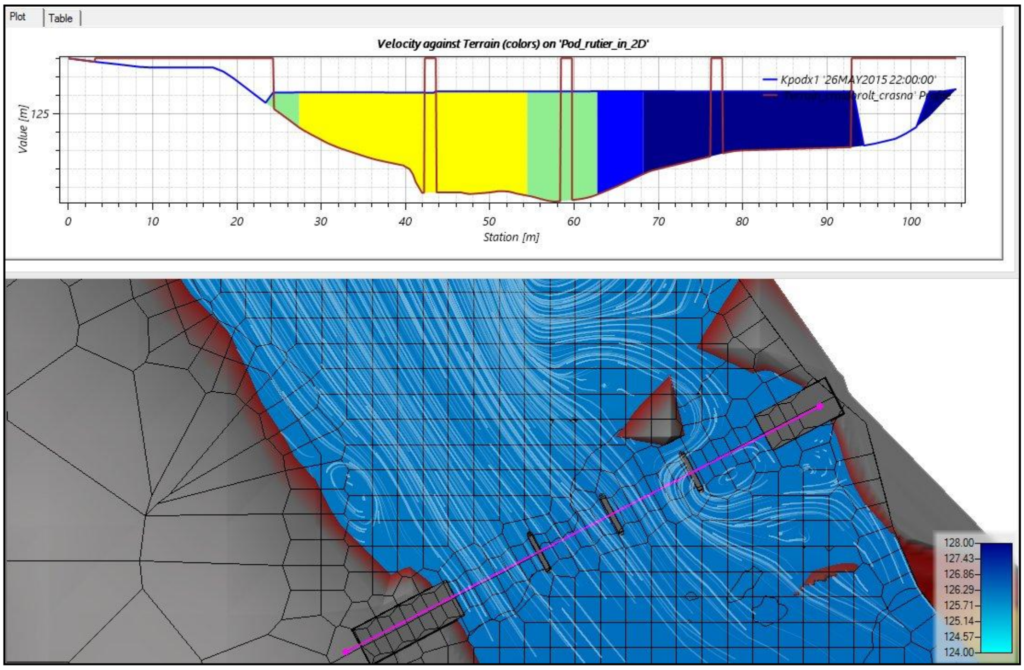

Figure 9. Detailed area by the crossing bridge with flow lines overlaid to the water surface (bottom, in mSL) and the piezometric line development along the crossing structure at time moment of maximum inlet flow, 22:00 on May 26th, 2015

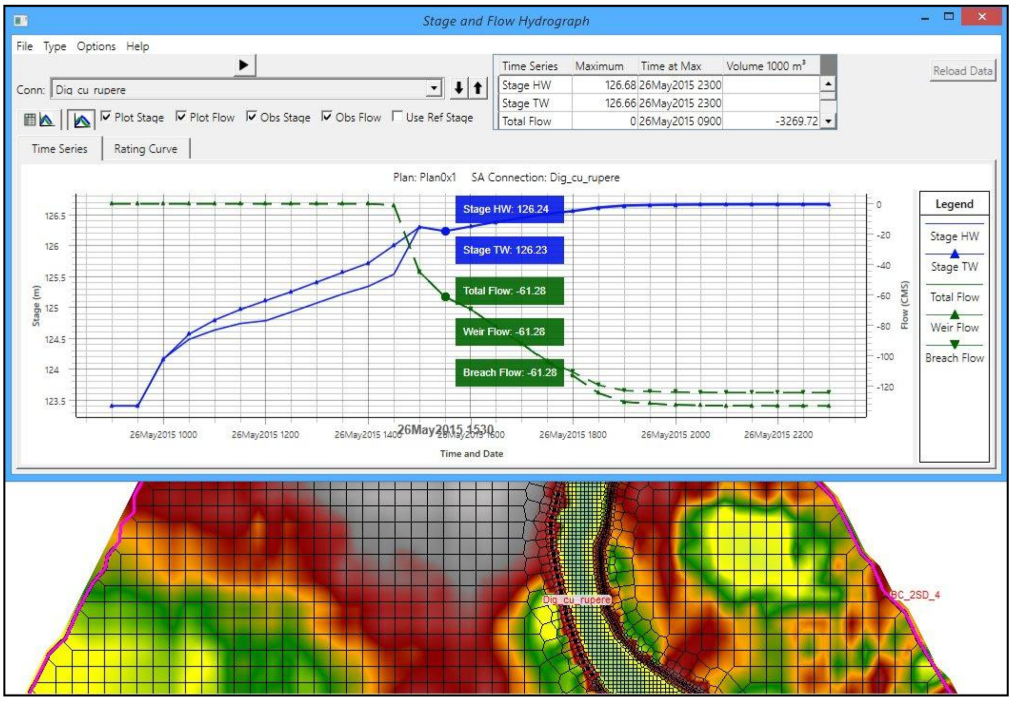

Figure 10. Time developments of piezometric level (elevations in *mSL*) and water discharge (in *m^3/s*) at the connection structure (*Dig_zona_rupere*)

Figure 11 presents some geometric characteristics that should be achieved at the enclosure embankment in the most unfavorable situation, meaning when the maximum transit flow on the Crasna River reaches the value Qmax = 502.74 m^3/s.

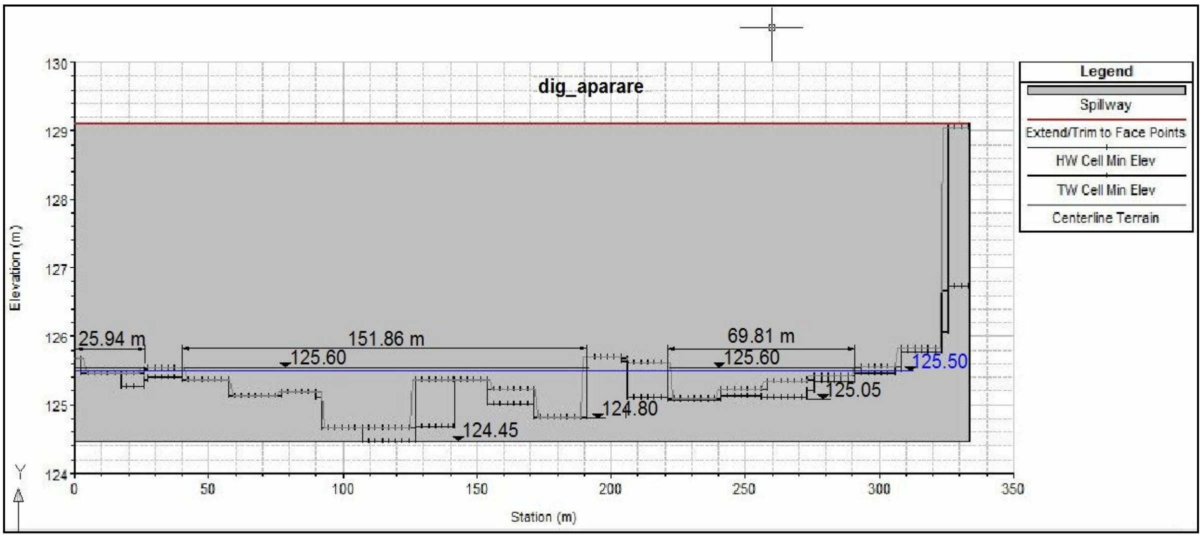

Figure 11. Longitudinal profile by the contour enclosure embankment in the northern side of the technological platform

4. CONCLUSION

By developing the discreet model and running the numerical analysis, there can be noticed that when the transit flow reaches the maximum value Qmax = 502.74 m^3/s (as a discharge arranged regime influenced by the Vârşolţ reservoir), the water transit would take place over the minor and major riverbed, overtopping the defense embankments on the two banks of the Crasna River on a significant length, as well as through the breach developed on the left bank.

In conclusion, even in this variant in which the dam on the left bank gives way and a breach develops with a length at the base of approx. 172.05m, and in the flood zone a protection of the technological enclosure is carried out by placing a defense dam on the contour, it can be said that the technological platform is not floodable when the hydrograph transits from accidental flooding.

Therefore, the variation of the water levels reached in the floodplain area, signaled and obtained by hydraulic calculations in non-permanent regime (HEC-RAS program package vers. 6.0 Beta3), reflects the existing situation on the ground at the present time of topographic surveys.

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