ISSN 1453 – 7303 **"HIDRAULICA" (No. 3/2018)**
Magazine *of Hydraulics, Pneumatics, Tribology, Ecology, Sensorics, Mechatronics*

Studying the Influence of River Works on River Flow Regime with 1-D Hydraulic Modelling

As.Prof. PhD. Eng. **Marie-Alice GHIȚESCU[1],** Lect. PhD. Eng. **Albert Titus CONSTATIN[1]**

[1] Politehnica University Timisoara, alice.ghitescu@upt.ro, albert.constantin@upt.ro

Abstract: *The one-dimensional (1-D) hydraulic models are the most adequate for river modelling flow. This case study involves the rehabilitation of the CFR bridge, km 38 + 389, line 116 DII Simeria - Petrosani at Ruşor town, Hunedoara county. Therefore, the Ruşor River is being thought through, with a series of complex river works of the river bed and channel, in order to regulate the flows near CFR Bridge. To prevent future possible damages, a 1D hydrodynamic model of the Ruşor river sector was developed, highlighting the effect of the river regularization works. The hydraulic model was built with HEC-RAS 4.0 software, for two flow simulation scenarios: natural river flow and regulated river flow. Following the simulation of the hydrodynamic modelling, a significant reduction in the flow rates within the calculation reach was observed.*

Keywords: *1-D hydraulic modelling, river works, HEC-RAS.*

1. Introduction

In science, by modelling it understood the simplified reproduction of a real system that preserves the important characteristics and processes that take place in it.
Physical and mathematical models are suitable for research for a wide range of boundary conditions and the development of general design rules. Verification of final results requires field investigations and measurements as well as assessment of experiments and tests. [3]
In river modelling, the most common hydraulic models are the one-dimensional models (1D). Hydraulic computational models are constructed on the basis of conservation laws (mass preservation, energy conservation, moment conservation).
For the description of surface water flow in 1D system, the uniform flow equations and those of uniformly gradual flow are used. The following equations are used for uniform flow:

$$\frac{d_h}{d_x} = \frac{S_0 \cdot S_f}{1 \cdot F_r^2} \tag{1}$$

$$Q = \frac{1}{n} \cdot R^{\frac{1}{6}} \cdot \sqrt{R \cdot S_o} \cdot A \tag{2}$$

$$K = \frac{1}{n} AR^{\frac{2}{3}} \tag{3}$$

Where: -h is water depth (m);
- x is the measured distance along the river channel (m);
- S_o is the river bed slope;
- S_f is the friction slope;
- Q is river flow (m^3/s);
- K is river conveyance (m^3/s);
- A is wet surface (m^2);
- R is hydraulic radius (m);
- n is Manning's roughness coefficient ($s/m^{1/3}$);
- g is gravity acceleration (m/s^2).

2. Case Study

The purpose of the present paper is to show the influence of the proposed complex works on the river flow regime, in comparison with the natural (initial) river flow regime. This is made through hydraulic modelling of both scenarios for the 1 in 100 year return period flood event. The hydraulic modelling tool used for this is HEC-RAS software, for a one-dimensional hydrodynamic river channel model.

2.1 Hec-RAS modelling tool

The HEC-RAS software was developed at the Hydrologic Engineering Center (HEC), which is a division of the Institute for Water Resources (IWR), U.S. Army Corps of Engineers. HEC-RAS is a software that allows to perform one-dimensional steady flow hydraulics, one and two- dimensional unsteady flow river hydraulics computations; quasi unsteady and full unsteady flow sediment transport- mobile bed modelling; water temperature analysis and generalized water quality modelling (nutrient fate and transport). The HEC - RAS program is designed to perform one-dimensional and two-dimensional hydraulic computations for a full network of natural and artificial channels, overbank or floodplain areas, levee or embanked protected areas. And it can model the surface water profile in subcritical, supercritical or mixed flow [3], [4]. Depending on the flow regime (subcritical, supercritical, or mixed), the boundary conditions should be selected for different flow conditions, but also to determine which of these edge conditions can be used upstream or downstream or both.

2.2 Background description

The case study area is in Ruşor town, Hunedoara County, on the railway line CF 116 DII Simeria Petroşani at 38+989km, at the railway metal bridge. At km 38 + 989 there are two independent parallel bridges, each for one CF 116 Simeria-Petrosani line (see Figure 1) [1].

Fig. 1. Case study area of interest, Rusor River

In the bridge area at km 38 + 989, the banks of the Ruşor River bed have suffered due to floods, significant degradations that may endanger the proper behavior of foundations of existing bridges in the area. The current state of the river bed and railway infrastructure motivated the necessity to perform some complex works of regulation of the Ruşor River bed in the area of the railway bridge located on the railway line CF 116 Simeria-Petroşani between Băieşti - Pui stations, in Ruşor locality at km 38 989. The railway bridge has an opening of L = 19.0 m. In Figure 2 is illustrated an overview of the case study railway bridge.

Fig. 2. Bridge overview, Rusor River

2.3 Hydrodynamic modelling and numerical simulation

To assess the transit situation of flows with different probabilities of occurring on the watercourse along the bridge, it was necessary to build two numerical models, in two different flow regime scenarios. A numerical model represents the initial situation, the natural river flow regime, and the second numerical model represents the situation with the proposed works (supporting walls, bottom weir and stabilization river bed works), post-scheme model (regulated river flow regime). For the hydraulic modelling the total river reach length was 164m, with 21 cross sections considered, obtained from topographical survey. The railway bridge is located between cross sections ST13 to ST17. It was appreciated that cross section ST13 is the upstream bridge section, and ST17 is the downstream bridge cross section.
The roughness coefficients adopted for this study range between n=0.02-0.025 for the river bed, and between n=0.03-0.035 for the floodplains.
As modelling boundary condition upstream, a flow hydrograph was used, for the peak flow flood event 1 in 100 year return period $Q_{1\%}$=105m^3/s. The time length of the resulted flood flow hydrograph was 4 to 5hours, with recorded data every 2 minutes. For the downstream boundary condition, the normal depth was used.
In Fig. 3 are presented the river reach plan view for both scenarios: natural flow regime and regulated river flow regime.

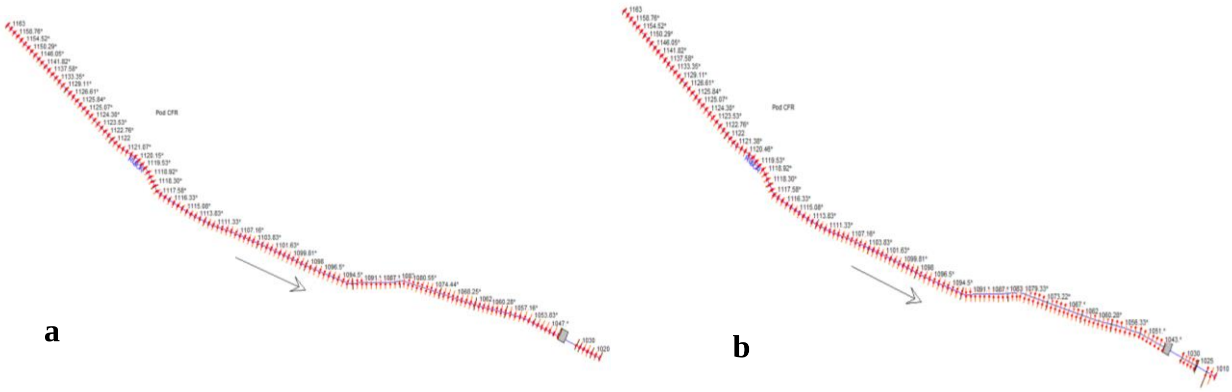

Fig. 3. River reach plan view **a.** Natural river flow regime, **b.** Regularized river flow regime, Rusor River

The ST13 cross section was considered to be the railway bridge cross section, and built accordingly, take into account the survey data and roughness coefficient (see Fig. 4).

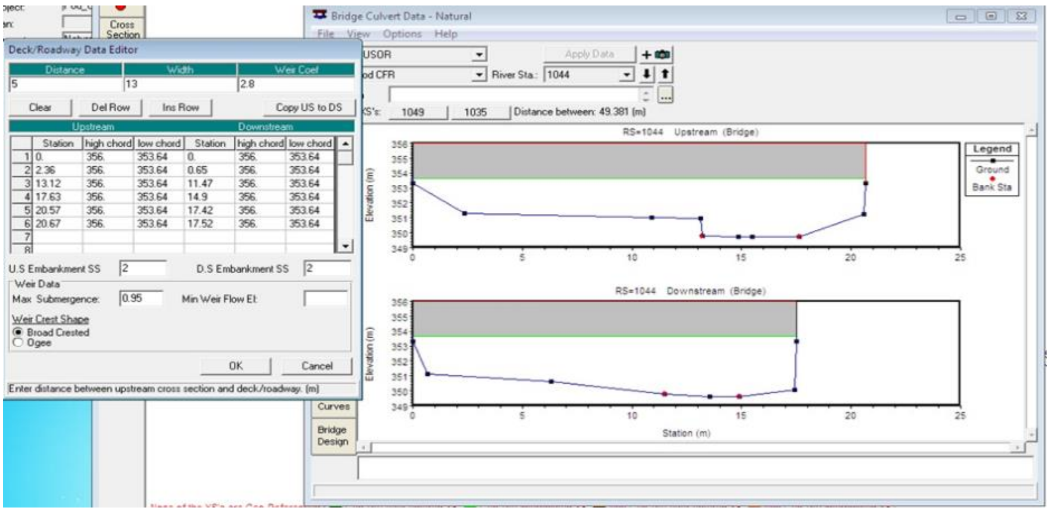

Fig. 4. River cross section at railway bridge, upstream and downstream view, Rusor River

As a change between the two flow regimes, in the regularised scenario, cascade bottom weirs were considered in the correspondingly cross sections (see Fig.5).

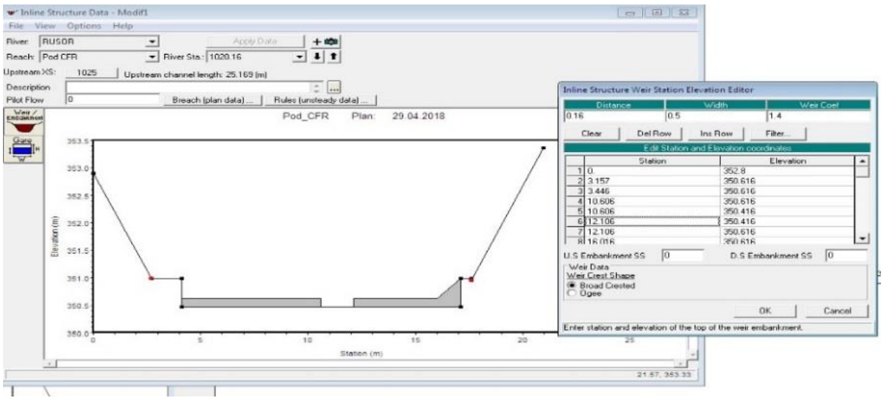

Fig. 5. River cross section at bottom weir, Rusor River

The river bed works were represented in the regularised flow scenario by the change in the roughness coefficient values and cross sections geometry (see Fig.6).

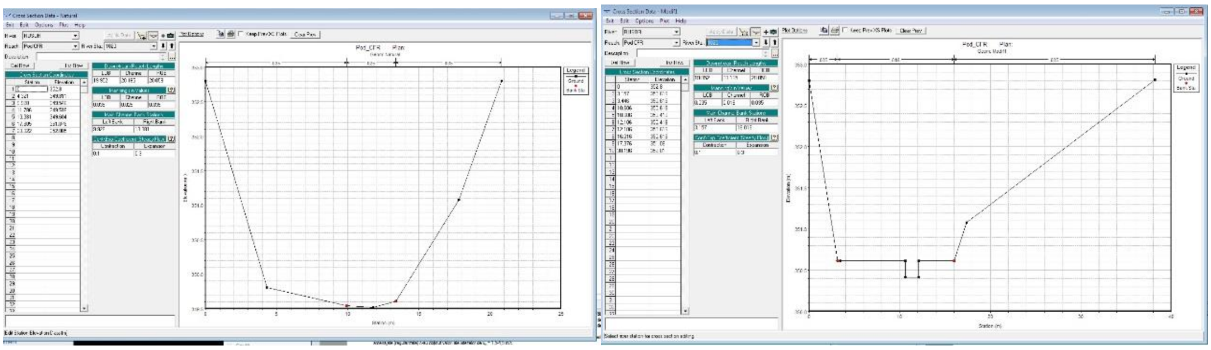

Fig. 6. Cross Section ST20 view **a.** Natural river flow regime, **b.** Regularized river flow regime, Rusor River

3. Results and Discussions

The modelling simulations of both flow regime scenarios outputs are illustrated as water levels in the following figures, Fig.7 to Fig. 12. The roughness coefficient Manning's n proved to be a significant sensitivity parameter. One of the majors constrains for the obtained results was the railway bridge soffit level, at 353.64maBSL. The water levels resulted over the hydraulic simulation in the bridge cross section had to be below the railway bridge by 1.0m, in order to prove the efficiency of the considered river works.

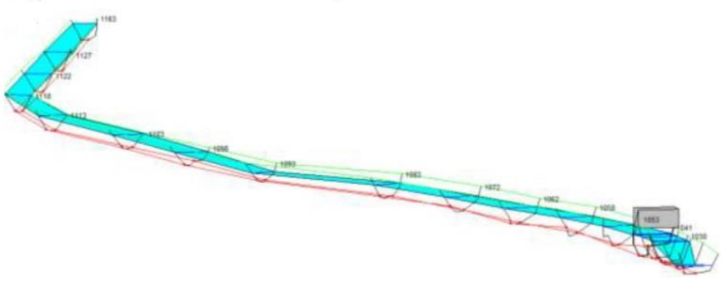

Fig. 7. Long profile view of Rusor River reach, natural river flow regime scenario

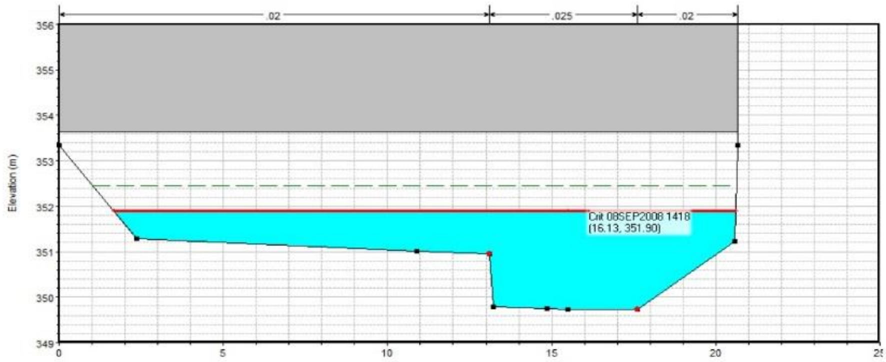

Fig. 8. Upstream Rusor River cross section at railway bridge, natural river flow regime scenario

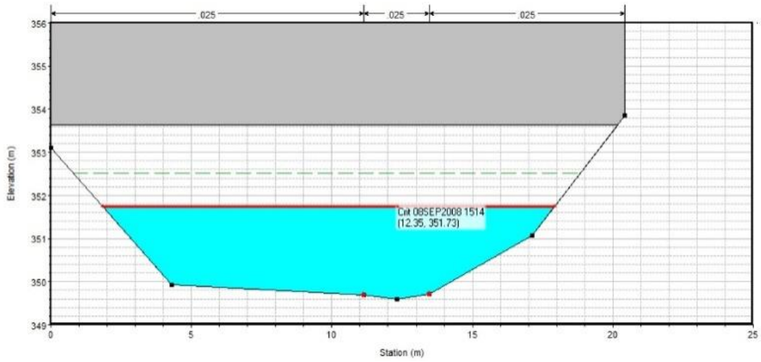

Fig. 9. Downstream Rusor River cross section at railway bridge, natural river flow regime scenario

In the following figures are illustrated the represented results obtained in the regularized river flow regime scenario.

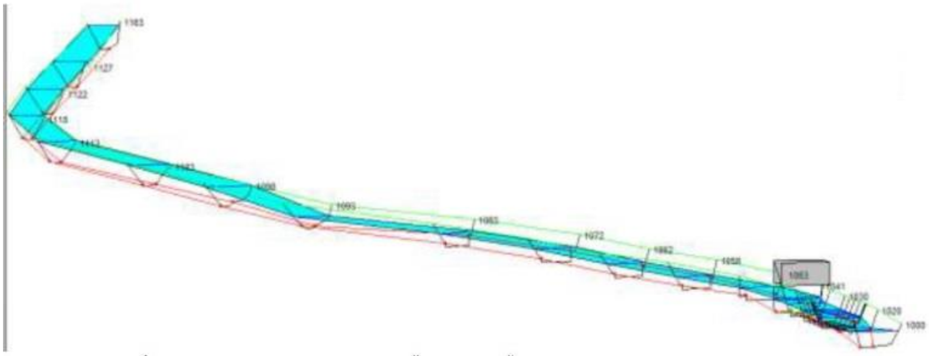

Fig. 10. Long profile view of Rusor River reach, regularised river flow regime scenario

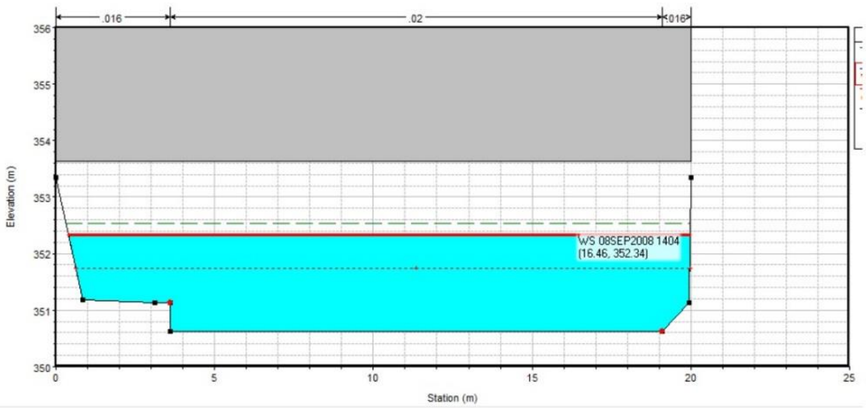

Fig. 11. Upstream Rusor River cross section at railway bridge, regularised river flow regime scenario

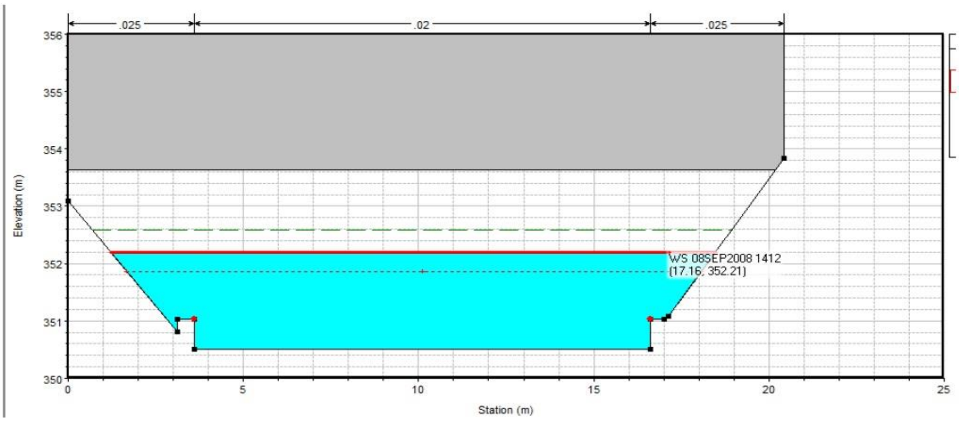

Fig. 12. Downstream Rusor River cross section at railway bridge, natural river flow regime scenario

From the modelling simulation, the results showed that in the natural flow regime scenario, the obtained velocities had range values between v_m = 3.5 - 6.8 m/s, where in the regularised flow regime the velocities vales obtained were in the range of v_m = 1.5 – 4.5 m/s.
Although, the water levels may show a small increase, the velocities which are an important factor in the railway bridge infrastructure stability, showed an overall decrease.

4. Conclusions

This case study presented in this paper illustrated the influence of river works on the natural river flow regime. A one-dimensional hydraulic model was built for this purpose, for two flow regime scenarios: natural flow regime and regulated river flow regime.
In the natural flow regime scenario, the obtained velocities had range values between v_m = 3.5 - 6.8 m/s, where in the regularised flow regime the velocities vales obtained were in the range of v_m = 1.5 – 4.5 m/s.
As a result of the model simulations, the outputs of the two flow regimes scenarios, showed a significant decrease of the flow rates in the computation sections of the regularised flow regime scenario, in comparison with the natural flow regime scenario.
Therefore, the proposed river works proved the expected impact on the river flow regimes, by decreasing the water levels and velocities in the railway bridge vicinity.

Acknowledgments

Acknowledgments to Administrația Bazinală de Apă Mureș for river flow recorded data.

References

[1] S.C. LONGHERSIN SRL Timisoara and Universitatea Politehnica Timișoara, Facultatea de Construcții, Departamentul de Hidrotehnică. *Proiect nr.: BC 104 / 15.11.2017 Reparație radier şi infrastructură albie râu Rușor în zona podului de la km 38+989, Linia 116 D II Simeria – Petroşani*.
[2] Popa, Radu. *Elemente de hidrodinamică a râurilor.* București, Editura Didactică și pedagogică, 1995.
[3] Ghitescu, Marie-Alice. *Analiza posibilităților și limitelor conceptelor de modelare a curgerilor în sistem 1D, 2D și 3D*. Timisoara, Editura Politehnica, 2010.
[4] Brunner, G.W.. HEC–RAS 4.1, *River Analysis System, Hydraulic Reference Manual*. USACE, November 2002.