Water Flow Transition on a Hydropower Virtually Developed Sector of Bârzava River in the Town of Reșița

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Abstract: *A water flow numerical modelling is developed on the paper for a given sector on Bârzava River where a hydropower associated deviation is assumed, in case of accidental high waters in the Town of Reșița. The model includes two gate-controlled overflowing steps, two water catchments, a headrace pipe of 3052 m in length and 1.10 m in diameter, two energy dissipaters and one micro-hydropower station endowed with two hydroelectric turbines. The flow simulation by the designed numerical model looks to establish the special water levels along the covered sector on the river course and to discuss with respect to the gross head and installed power at an afforded micro-hydropower arrangement. Two specific running situations were assumed, the common running status when the upstream entering section receives the medium multiannual flow and the accidental running status when the entering section is to receive a specified time related flow along the entire considered analysis period of 59 hours.*

Keywords: *River flow, micro-hydropower, numerical model.*

1. General considerations; specific topographical and hydrological data

Bârzava River originates in the Semenic Mountains, Caraș-Severin County, a formation in the Banat Mountains that belong with the Western Carpathians. The river has a receiving basin of 1190 km^2 and a length of 166 km, which from 127 km lay on Romanian territory. Arising in Caraș-Severin County, Bârzava crosses the south of Timiș County and the Province of Vojvodina in The Republic of Serbia where finally reaches the Danube-Tisa Channel. For a length of 3.8 km the river establishes the Romanian-Serbian border. Țerova Rivulet is a right-side tributary of Bârzava River with the joining point in Reșița Town.
The river modelled sector and the hydropower deviation lays on the administrative territory of Reșița Municipality [1], the site being bordered at south (upstream) by the Railway Iron Bridge and at north by the road bridge on Calea Timișoarei Boulevard. Thus, the considered sector spreads over a length of about 6040 m (figure 1).

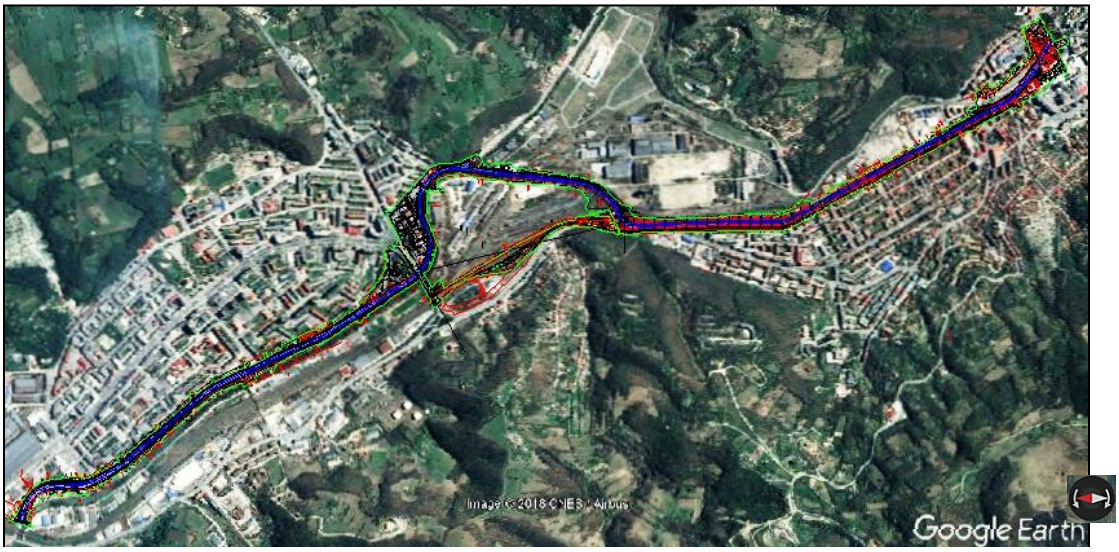


Fig. 1. Aerial view of the modelled sector on Bârzava River in the Town of Reșița with the overlaid topographic measurements plan

Based on the supplied topographical specialized information (Stereo 70 measurements) a specific geometry database (of 6394 distinct geographic coordinates points) was created for the considered river sector, representing the terrain plan view and 121 watercourse cross sections that properly points out the minor and major streambed.
In order to estimate a specific flow transition – water levels and velocity developments in time for any cross section – along the sector related to Reșița Town, the following data had to be obtained: maximum flow values of the particular occurrence probabilities 5% and 1% (according to national regulations with respect to the water arrangement importance and location); high-waters phenomenon development (hydrographer); terrain roughness coefficients for the streambed; flow hydro-energy gradient or flow-level curve corresponding to the downstream ending cross section. The water flow values for different occurrence probabilities together with the high-water development curves possible to happen on the modelled sector were supplied by the "Romanian Waters" National Administration, Banat Water Basin Administration, as presented in table 1. As about the high-waters hydrographer that is to be considered in Reșița, its development and maximum value (corresponding to the 1% probability of occurrence, 142 m^3/s) can be observed in figure 2, given by curve d. The water flow value of 20 m^3/s is to be added as the contribution of Țerova Rivulet, assuming the possible overlapping of its particular hydrographer.

Table 1: Hydrological data

River		Bârzava
Referring point		Traian Vuia Square in Reșița Town
Receiving basin (km^2)		218
Controlled flow	1 %	142
	5 %	78

The main foreseen hydraulic structures related to the model – two gate-controlled overflowing steps, two water catchments, a headrace pipe of 3052 m in length and 1.10 m in diameter, two energy dissipaters and one micro-hydropower station endowed with two hydroelectric turbines [1] – are considered of the IV[th] importance class (constructions of low importance) as stipulated by the national regulations given their dimensions and capacity.
Consequently, the dimensioning and verification water flow occurring probabilities are to be considered of 5% and 1%.

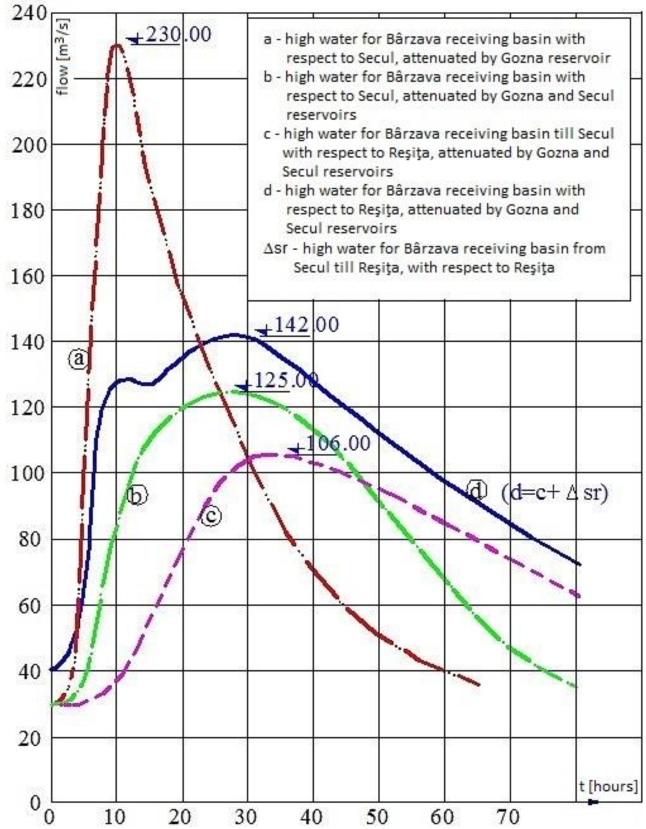


Fig. 2. High-waters hydrographers developments on the modelled river sector in the Town of Reșița, as determined under the conditions of existing upstream water arrangements

The geometrical development d supplied by figure 2 was assigned as transiting the entering upstream section of Bârzava River studied sector, while the additional flow brought by Țerova Rivulet was assigned on the route to the joining section.
The numerical model developed by the help of the performant software package HEC-RAS v.5.03 [2, …, 5] considers thus a possible transiting high-waters wave that eventually reaches the maximum flow value of 162 m^3/s on the downstream section at the road bridge on Calea Timișoarei Boulevard.

2. Numerical modelling, revealed results

The Bârzava River streambed geometry in the Town of Reșița was modelled for a sector length of 6042 m, considering a succession of 155 straight segments delimitated by 156 cross section (121 of which as according to the actual topographic measurements, while the rest of 35 being considered by linear interpolation). The entire path of the numerical model was organized in 5 sectors marked as one can find in the general scheme on bottom part of figure 3.

Fig. 3. General plan scheme (bottom) with marked cross sections (as developed by HEC-RASv.5.03) from the upstream entering position "6042.80*" to the outgoing one "0.00"; the detailed positions PT106 (upper left, "57.43") and PT44 (upper right, "3842.40") of the main hydraulic structures

The cross sections cut up to the major streambed, both sides of the river, their geometry being referred to a start point on the outside edge of the left bank top. The profiles location (identification) is performed by the help of a metric counter (a real number) with respect to the downstream end of the modelled river sector [2, 3].

The discretized path involves 11 bridges and foot-bridges, 2 overflowing steps (with the positions PT44 and PT106) with their accompanying constructions (water catchments and energy dissipaters), a headrace side pipe (with its entering section near the PT44 position) and a micro-hydropower station (MHC-3 in the vicinity of position PT106). This last structure is furnished with two hydro-electric outfits of Axial/Propeller type (bulb turbine, figure 4) of the following designed parameters: group1 (as fuelled by the 3052 m length headrace pipe) – $H_{gross-31}$ = 14.39 m, $Q_{inst-31}$ = 2 m^3/s, $P_{gross-31}$ = 282.33 KW and group2 – $H_{gross-31}$ = 1.76 m, $Q_{inst-31}$ = 2m^3/s, $P_{gross-31}$ = 34.53 KW.

There are also considered a couple of virtual structures, a side type structure at position PT44 (metric location "3842.40" and furthermore associated to the entrance in the headrace pipe on "3052.03") to control and monitor the running regimes and transit flow, and an overflowing retaining (barrage) structure type in the vicinity of position PT106 (metric location "57.43") to model some local and longitudinal head losses.

A transitory hydraulic regime correlated to the required high-waters development phenomenon (hydrographer d in figure 2) was engaged by the designed model and the followed analysis results reflect two specific running situations: the common running status when the upstream entering section PT0 (metric location "6042,80*") receives the medium multiannual flow Q_m = 3.63 m^3/s and the Țerova tributary brings the adding flow $Q_{mȚ}$ = 0.30 m^3/s (infused along the particular time interval between 00:00 and 02:50 of the day "23OCT2017"), and respectively the accidental running status when the entering section is to receive the specified time related flow along the entire considered analysis period of 59 hours (from 00:00 on 23OCT2017 to 11:00 on 25OCT2017).

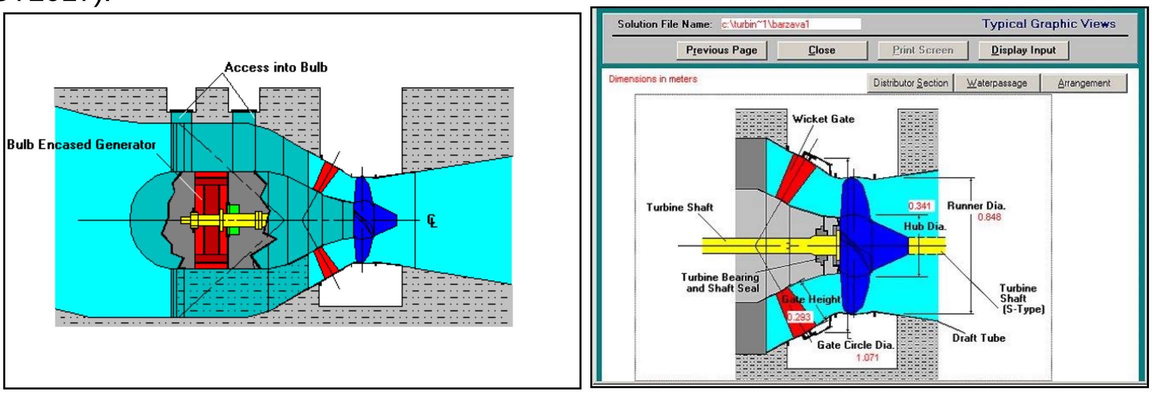


Fig. 4. Characteristic elements a the considered Axial/Propeller hydroelectric turbine

A flap gate covering a rectangular gap of 19.48m width and 2.00m height is modelled on the ridge of each overflowing step, by the help of which the water retention height can be controlled (during a common running status) or that can be completely opened to allow the accidental nigh-waters passing away (during the accidental running status). The alluvia settled in time upstream of the steps/catchments (positions PT44 and PT106) is to be washed by the help of uprising flat gates of 0.80m width and 1.00m height each.
Figure 5 presents the cross sections corresponding upstream and downstream the overflowing step at the position PT44 during the common running status, showing the obtained water level (metric location "3846.03" for upstream and respectively "3831.74*", "3824.60*" and "3796.02" for downstream). The cross sections associated to the structures at position PT106 – overflow step, water catchment and micro-hydropower station – for the common running status are presented by figure 6 (metric locations "760.66*" and "754.43" for upstream and "740.73*" for downstream).
As regarding the accidental running status, conventional results corresponding to the cross sections associated to the structures at position PT44 are presented by figure 7 for the specific time moments 00:10, 04:50 and 06:00 on 23OCT2017 and 11:00 on 25OCT2017 (the end of the given time period). Similarly, figure 8 present the results on cross sections associated to the structures at PT106 for the time moments 00:10, 04:40 and 06:00 on 23OCT2017 and 11:10 on 25OCT2017.
The longitudinal profiles along the 5 analysed sectors of the numerical model, showing the water level development, are presented by figure 9 – common running status at 00:10 on 23OCT2017 and figure 10 – accidental running status at 04:40 and 06:00 on 23OCT2017 and 11:00 on 25OCT2017.

3. Conclusions

Looking to analyse the water levels development under required conditions with respect to the flow transition and a virtual accomplishment of a micro-hydropower arrangement on a particular sector of Bârzava River in the Town of Reșița a thorough numerical model was developed by the help of HEC-RAS v.5.03 dedicated software. Based on this result two aspects regarding this specific arrangement can be judged, meaning the basic parameters and running procedure for the foreseen hydropower development and the transit capacity of the virtual endowed streambed under accidental flow. Therefore, two fundamental running situations were considered for the studied refurbished river sector, one reflecting the common running status of transiting the medium multiannual flow and the other one that covers an accidental running status of transiting the 1% apparition probability high-waters flow wave.

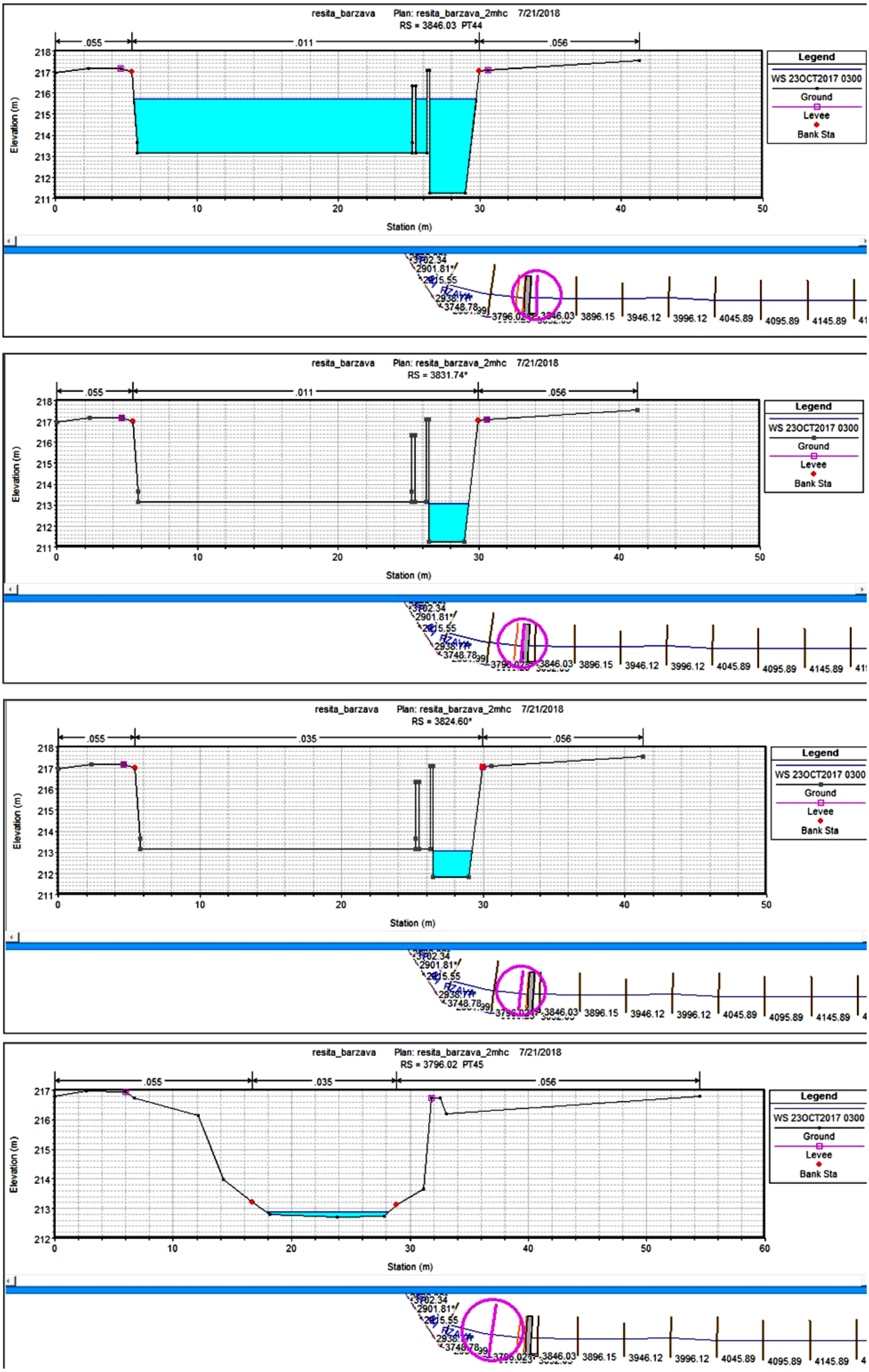


Fig. 5. Cross sections associated upstream (upper) and downstream to structures at PT44 showing the water level produced by the common running status

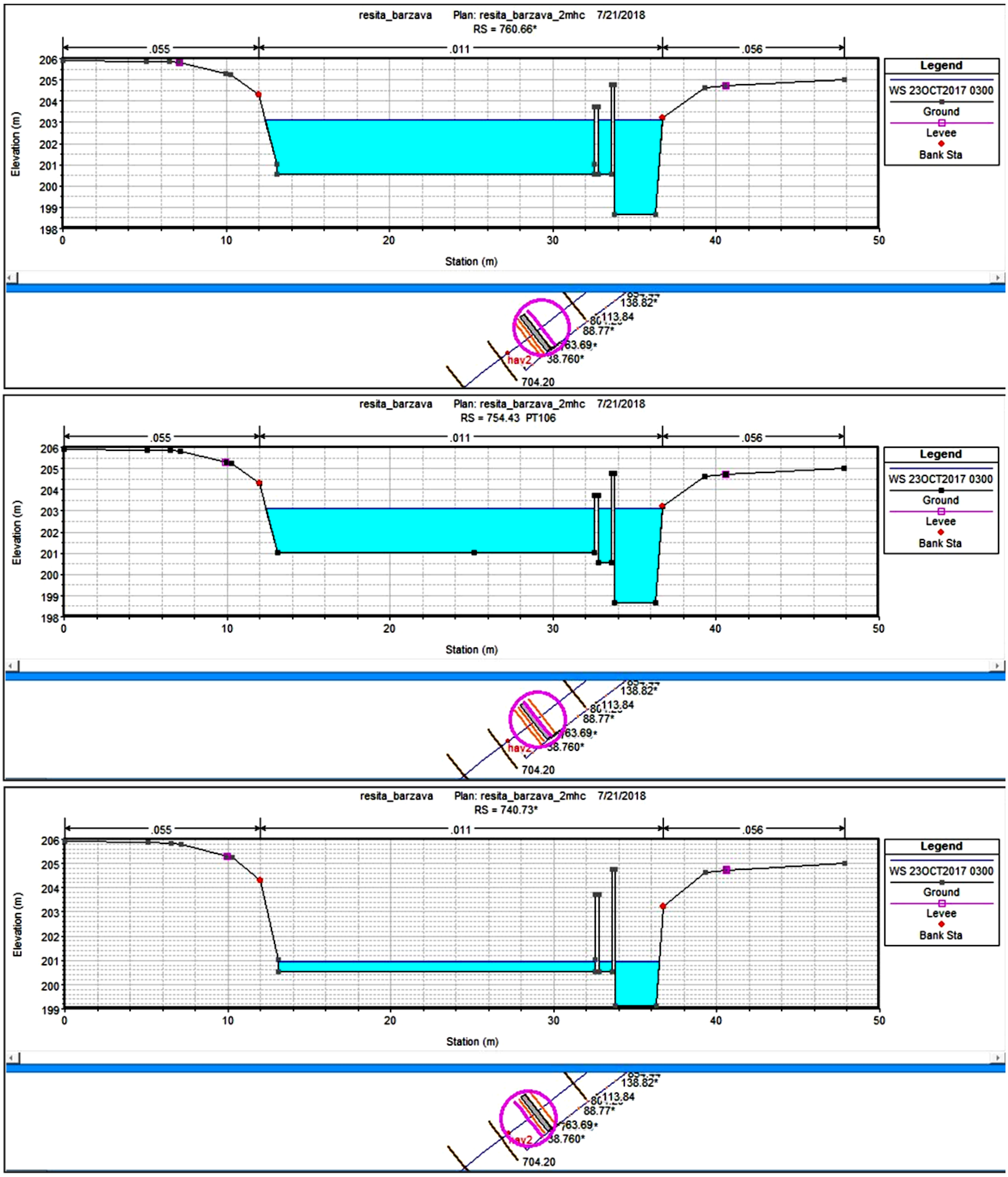


Fig. 6. Cross sections associated upstream and downstream (lower) to structures at PT106 (overflow step, catchment and micro-hydropower station) showing the water level produced by the common running status

Going through the reached results (see the moment 00:10 on 23OCT2017) one can engage the numerical values that define the running parameters for the usual running status of the two power groups designed for the MHC-3 micro-hydropower station:

- the gross head of the first group, as fuelled with the installed discharge $Q_{inst-31}$ = 2 m^3/s by a 3052 m long headrace pipe, results as the level difference $H_{gross-31}$ = 215.73 – 201.34 = 14.39 m, which leads to the gross installed power $P_{gross-31} = 9.81 \times Q_{inst-31} \times H_{gross-31} = 9.81 \times 2 \times 14.39 = 282.33$ kW;
- the gross head for the second group, designed as at an on-step power station supplied with an installed discharge $Q_{inst-32}$ = 2 m^3/s, results as $H_{gross-32}$ = 203.10 – 201.34 = 1.76 m, which may allow a gross installed power $P_{gross-32} = 9.81 \times Q_{inst-32} \times H_{gross-32} = 9.81 \times 2 \times 1.76 = 34.53$ kW.

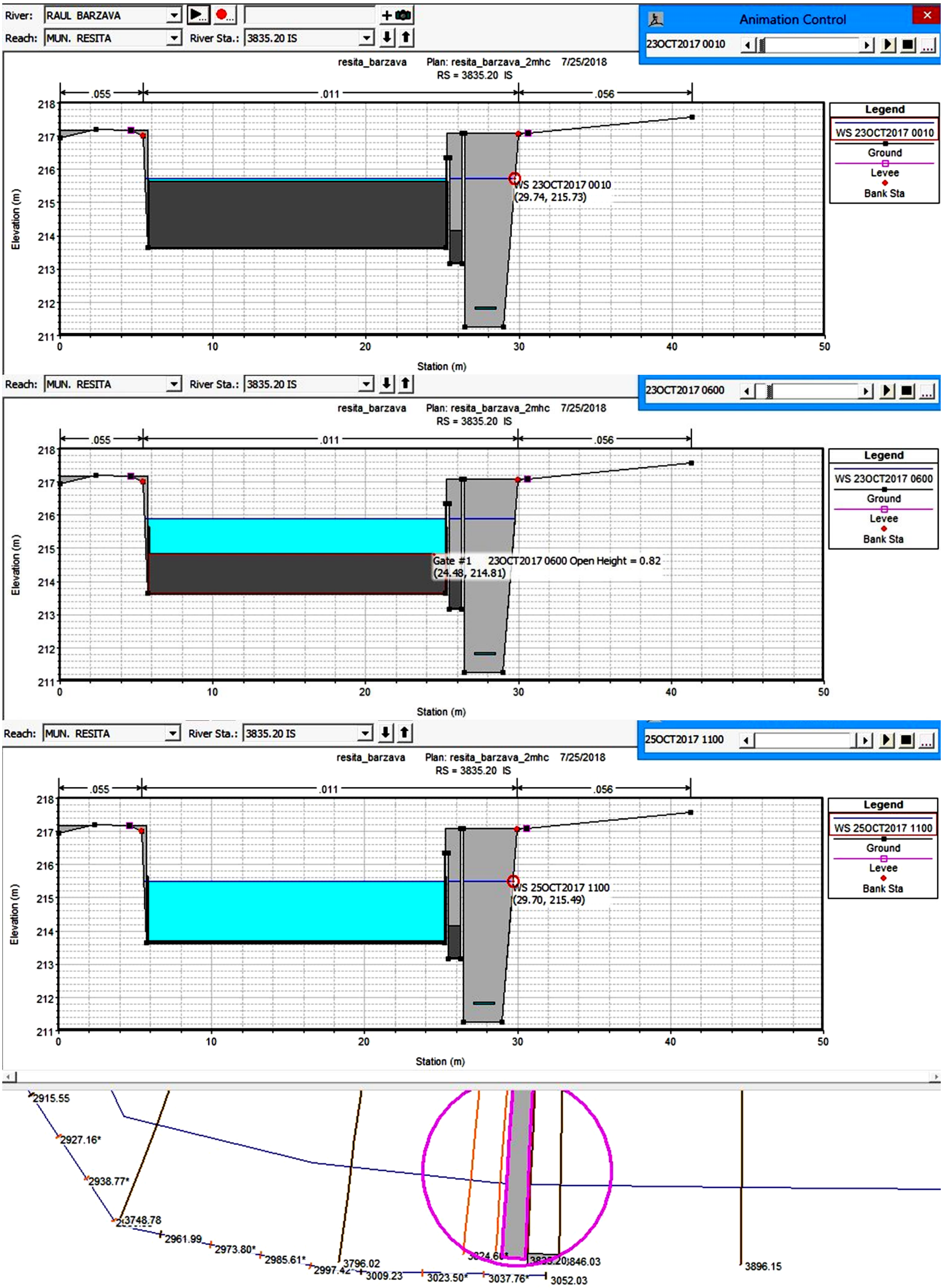


Fig. 7. Cross section associated to structures at PT44 showing the water level produced by the accidental running status for some specific operation conditions and moment of time: flap gate in closed position at 00:10 on 23OCT2017 (upper), flap gate in partially opened position (0.82m) at 06:00 on 23OCT2017 and flap gate in completely opened position at 11:00 on 25OCT2017 (lower)

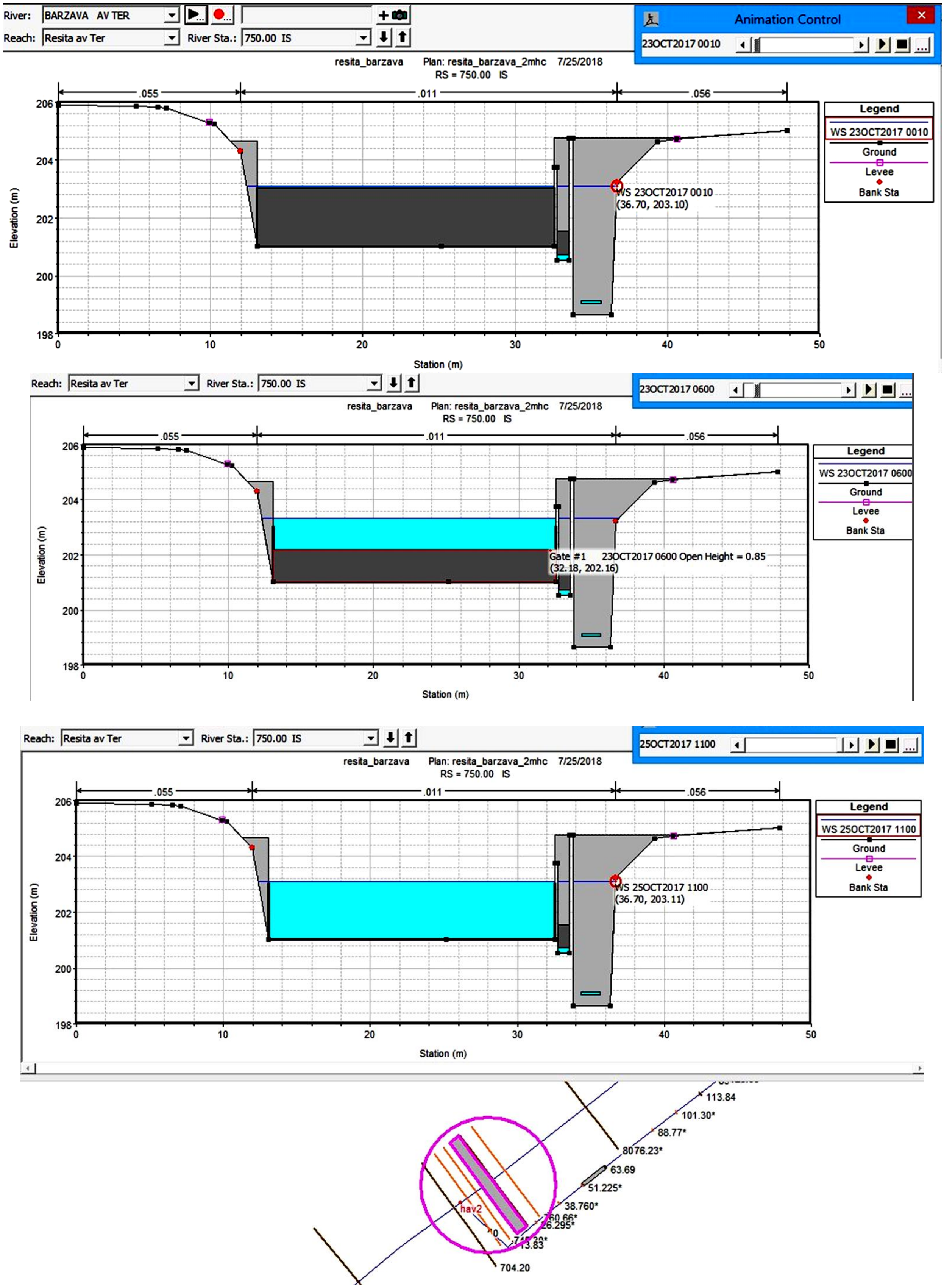


Fig. 8. Cross section associated to structures at PT106 showing the water level produced by the accidental running status for some specific operation conditions and moment of time: flap gate in closed position at 00:10 on 23OCT2017 (upper), flap gate in partially opened position (0.85m) at 06:00 on 23OCT2017 (middle) and flap gate in completely opened position at 11:00 on 25OCT2017 (lower)

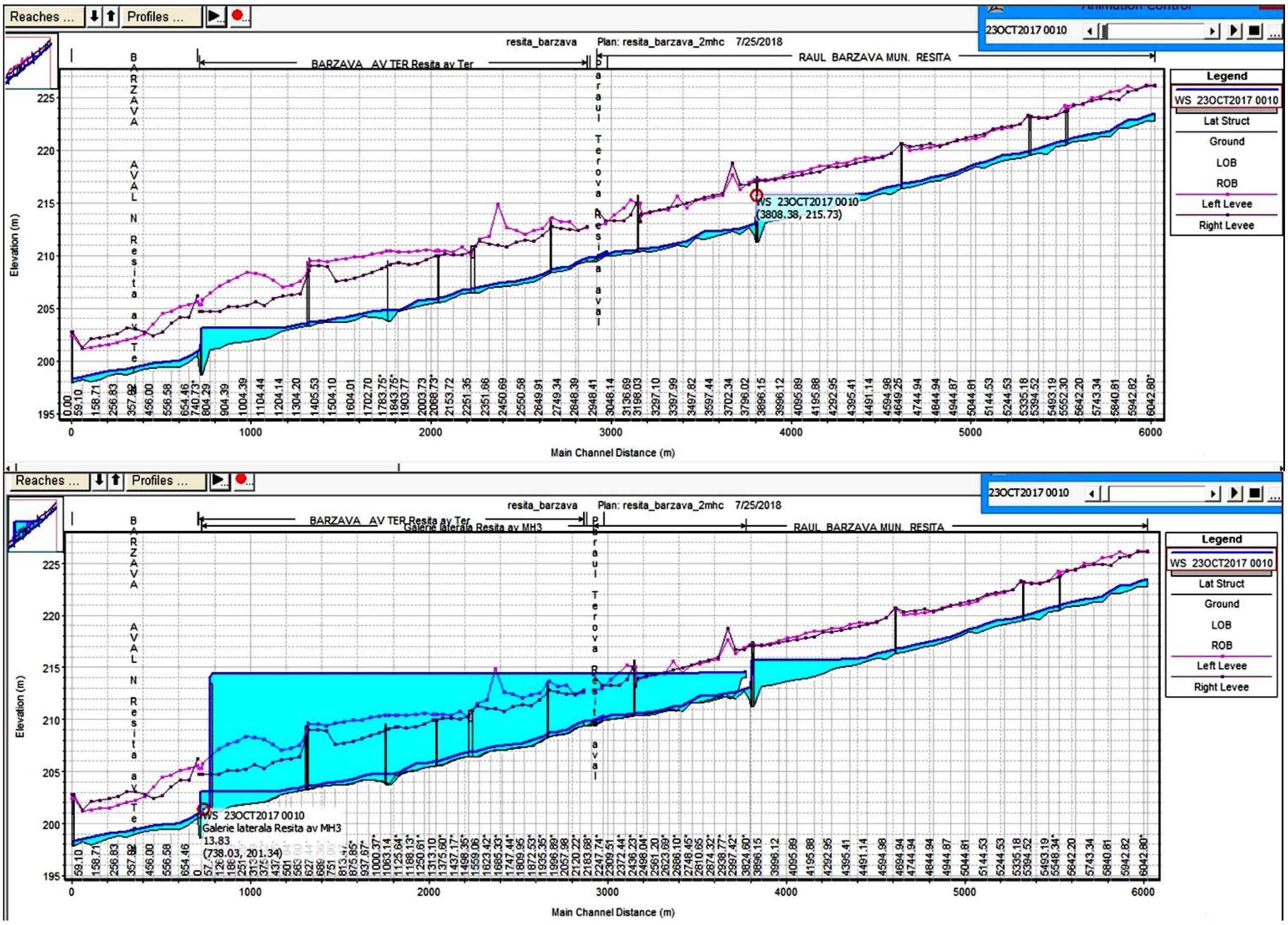
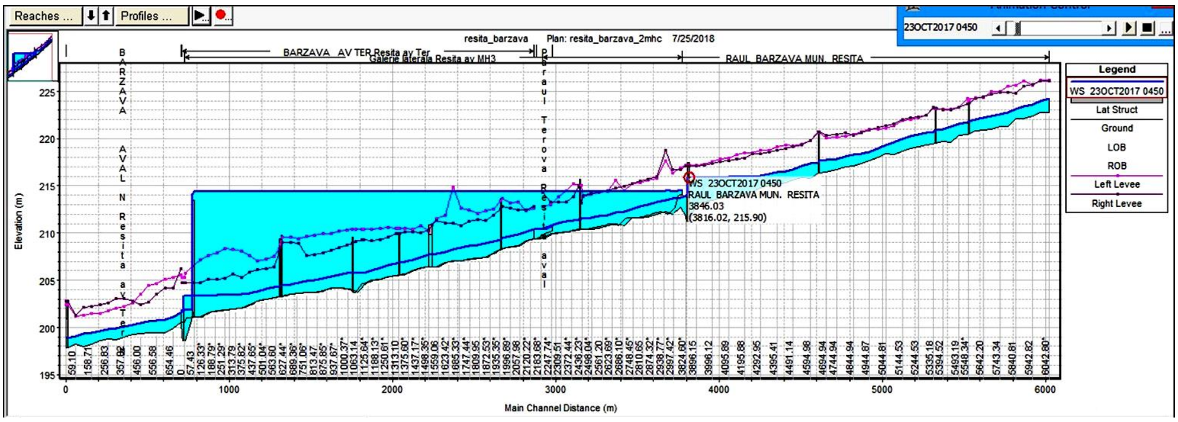


Fig. 9. Longitudinal profiles showing the water level development along the studied sector on Bârzava River in the Town of Reșița, corresponding to the common running status of transiting the multiannual flow Q_m = 3.63m^3/s (moment of time 00:10 on 23OCT2017), displaying only the river-course hydraulic profile (upper) and displaying the overlaid hydraulic profile of the side headrace pipe (lower)

It can be so estimated that the total gross installed power for the presented micro-hydropower development would reach about 316.86 kW under usual running regime given by the mean multiannual flow.

As about the situation produced by the accidental high-waters wave, there can be noticed from the longitudinal water levels time development with respect to the side framing bank levels that the already regulated river valley cross section would still be able to discharge the required maximum flow of 1% apparition probability, obviously under the circumstances of manoeuvring the flap gates on the overflowing steps down to the complete opening of the flow section. There can be concluded that the stipulated high-waters flow can transit the furbished river sector along the populated area under mandatory safety conditions.



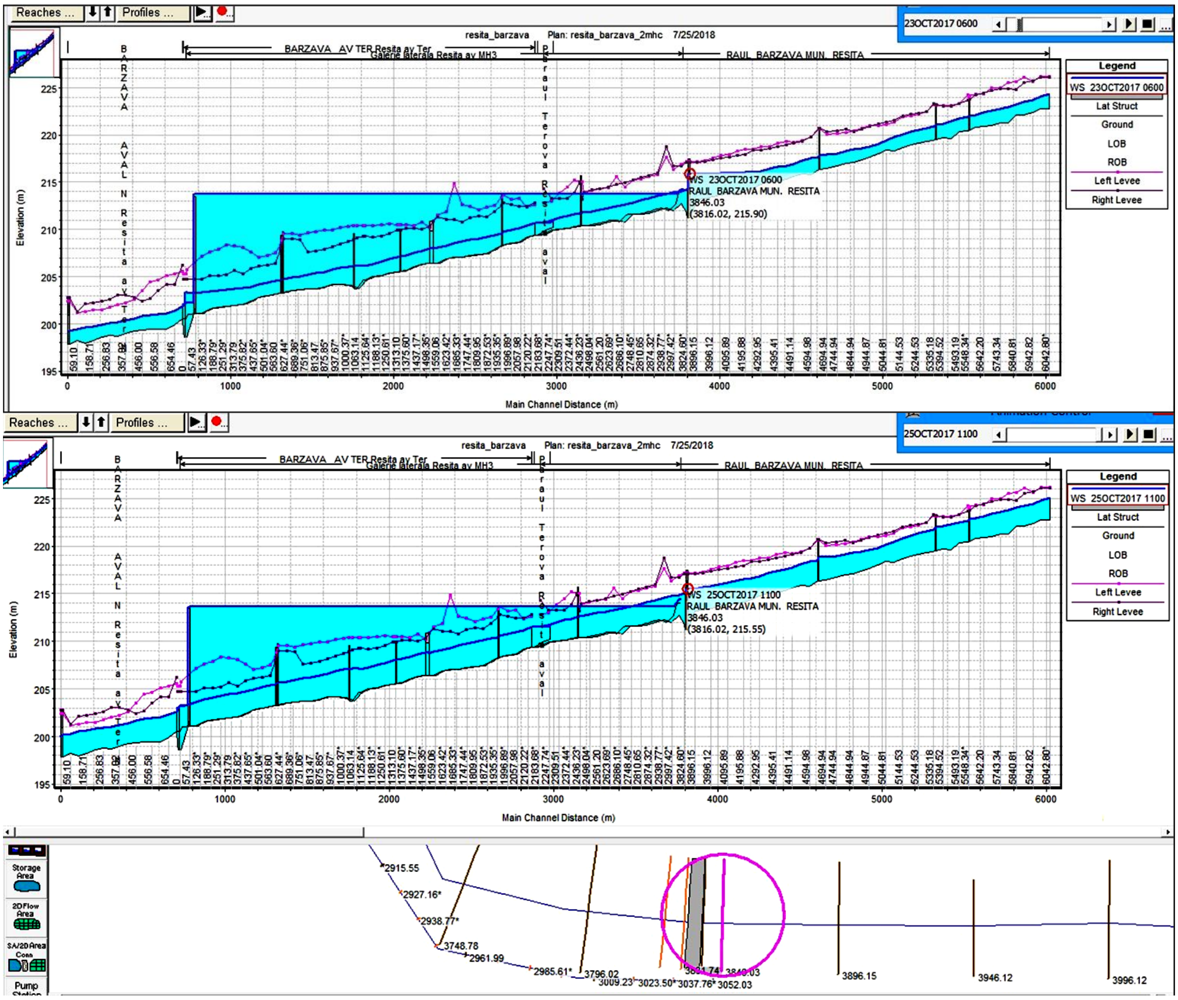


Fig. 10. Longitudinal profiles showing the water level development along the studied sector on Bârzava River in the Town of Reșița (overlaying the hydraulic profile of the side headrace pipe), corresponding to the accidental running status of high-waters flow $Q_{1\%}$ at some given moments of time: 04:50 (previous page) and 06:00 (middle) on 23OCT2017 and 11:00 on 25OCT2017 (lower)

References

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