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WATER FLOW ANALYSIS AT MINTIA DAM ON MURES RIVER IN CASE OF ENDOWING THE RETAINING STRUCTURE WITH A SMALL HYDROPOWER STATION

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Abstract: The paper presents a computer simulation of the accidental water flow on Mureş River in the area of Mintia Dam, considering the running situations for both the existing gates and the supplementary gates from the dissipating basin where the hydropower station is foreseen to be placed. It is aimed to stick to the water levels established for the special running conditions, considering the significant high water wave registered on 1975 (15th June – 15th July) with the maximum reached flow of 2190 m^3/s. The measured water flow values were multiplied with a ratio k = 1.80 in order to reach the maximum statistical possible flow $Q_{0.1\%}$=3942m^3/s.

1. BROAD CONSIDERATIONS

Following the suggestion that came from the Power Studies and Designs Institute, Timisoara Branch, regarding the exploit of the hydropower potential at Mintia hydrotechnical development (photo 1.1) by enriching it with some small hydro turbines in the energy dissipating basin (gaps no. 1 and 2 – left bank and no. 6 and 7 – right bank), a hydraulic study was required in order to verify the water flow transition for both situations, the usual one and the accidental one (special high water wave).

Photo 1.1 Downstream view of Mintia Dam

The following elements were known for drawing the numerical model:

Input data

- the water levels according to the flows of different overrunning probabilities [5] given by the operation conditions:

- corresponding to the flow $Q_{0.1\%}$ = 3942 m^3/s ⇒ the upstream water level at $N_{max\text{-}u,0.1\%}$ =184.19 mBSL (with respect to the Baltic Sea Level) and the downstream water level at $N_{max\text{-}d,0.1\%}$ =182.95 mdMB;

- corresponding to the flow $Q_{1\%}$ = 2660 m^3/s ⇒ the upstream water level at $N_{max\text{-}u,1\%}$ = 181.80 mBSL and the downstream water level at $N_{max\text{-}d,1\%}$ = 181.20 mBSL;

- corresponding to the usual operation flow ⇒ the upstream usual water level at UWL = 179.50 mBSL.

geometry data:

- the site plan view for the analyzed river sector at a scale of 1:5000 (figure 1.1);

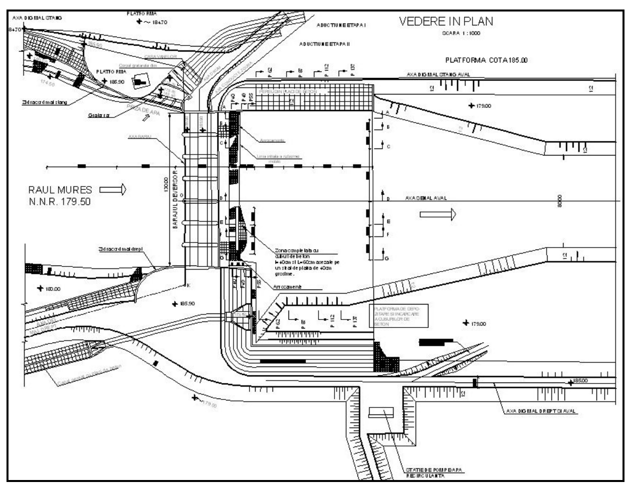

Fig. 1.1 Plan view of Mintia hydrotechnical development

- several cross views on the analyzed sector, covering the riverbed and the flanking flooding plains, and specific considerations regarding the roughness ratios respectively;

- longitudinal view along the analyzed river sector covering the energy dissipating basin (figure 1.2).

- boundary and initial conditions regarding the hydraulic flow:

- the transiting flows for the usual operating

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conditions and the corresponding water levels in several distinct points on the sector;

- the flow-level relationship curve for a given cross view and the hydraulic slope J = 0.0035;

- the water flow behavior in time at the upstream end of the river sector for the accidental operating conditions (the high waters hydrograph registered in 1975, June15–July15).

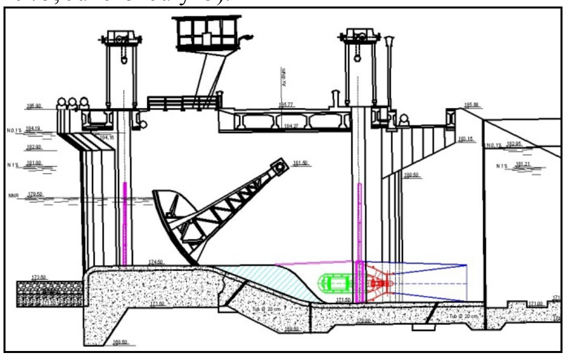

Fig. 1.2 Mintia Dam longitudinal cross view with the proposed hydropower aggregate

2. THE UNSTEADY WATER FLOW MODELING AT MINTIA DAM

2.1 GENERAL MATTERS

In order to study the high water wave possibility of transition through the dam site, a river sector of about 1032m length was modeled by employing HEC-RAS v.4.1 package of programs [1], [2], [3]. The figure 2.1 presents the entire route divided on sections determined by cross views numbered by the river kilometric system. In the part covering the spillway dam and the energy dissipater the model was split on five wires:

- a single wire in the middle zone representing 3 spilling gaps, opened at the dissipating basin and controlled upstream by tainter gates (modeled as plane lifting gates);
- 2 wires on each side, towards the left bank and towards the right bank, having the upstream gates lifted (as the usual operation position for the existing gates) and the hydro-aggregates controlled by lifting plane gates assumed in the downstream cofferdam niche that need to maintain the UWL when running the power plant.

In the same time, 4 other plane lifting gates were considered for these side wires in order to control the water access to the aggregates, gates that are to be opened for the usual running conditions and closed in case of high waters.

Thereby, the numerical model was designed to contain 6 dam type structures, two on the middle wire (the first one being controlled by the 3 upstream gates corresponding to the tainter gates, while the second one represents the dissipating basin, figure 2.2) and one on each of the other four wires (located in the dissipater basin and controlled each by the 2 assumed plane lifting gates aimed to control the water access to the aggregates). In the figures 2.3 and 2.4 one can notice the geometrical characteristics and the position of these structures in some vertical cross-views.

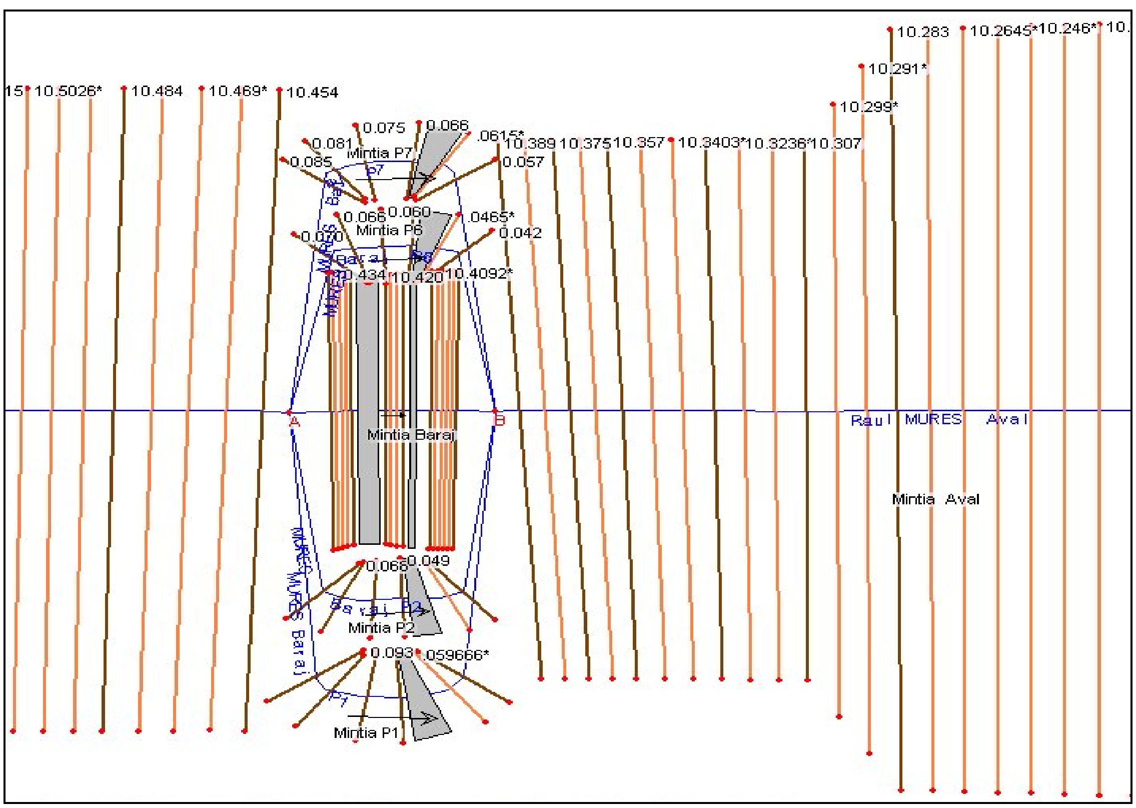

Fig. 2.1 General view of the numerical model (1D) covering the area of the Mintia spilling dam

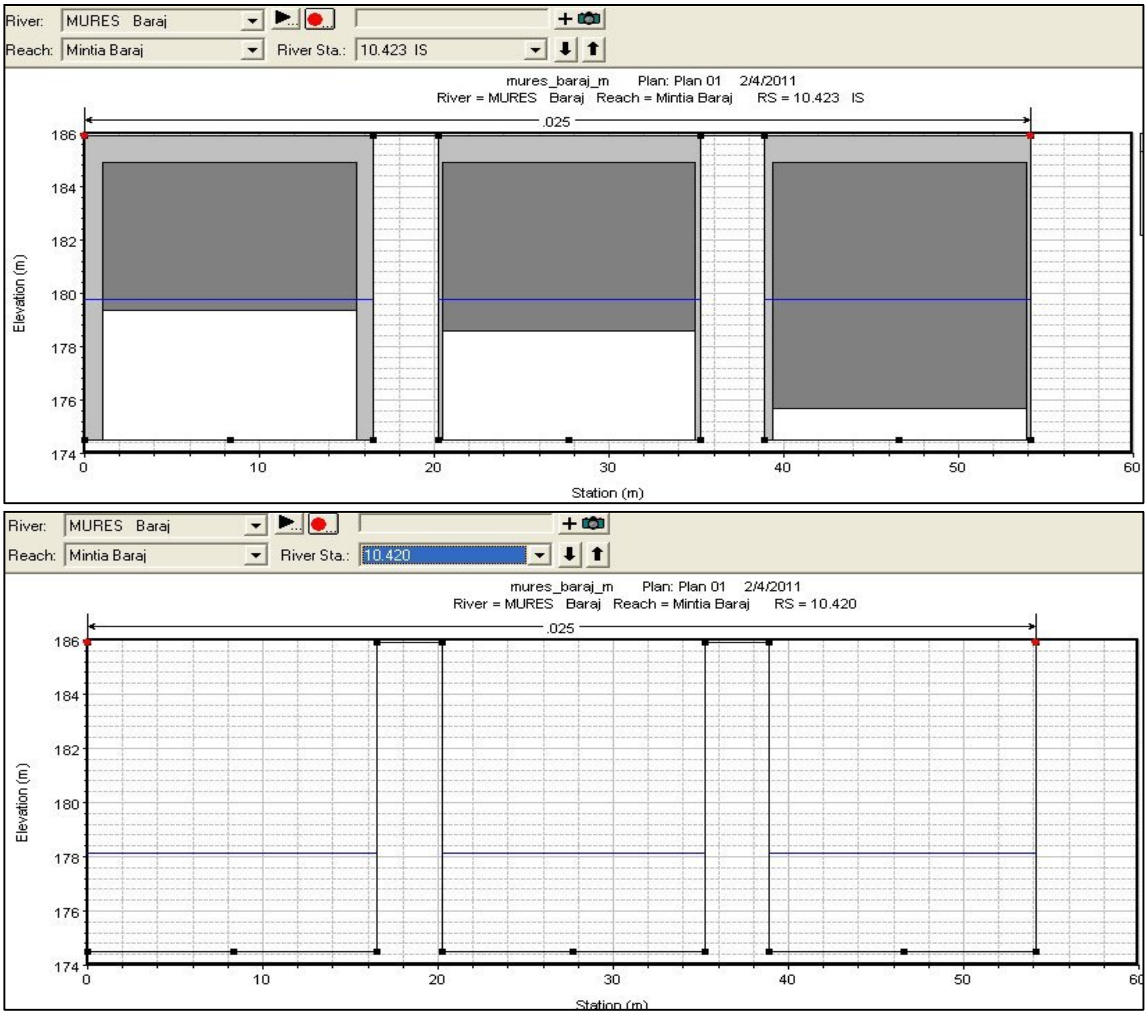

Fig. 2.2 Structures modeling the central wire:
the upstream structure with plane gates (above) and the spilling downstream structure (under)

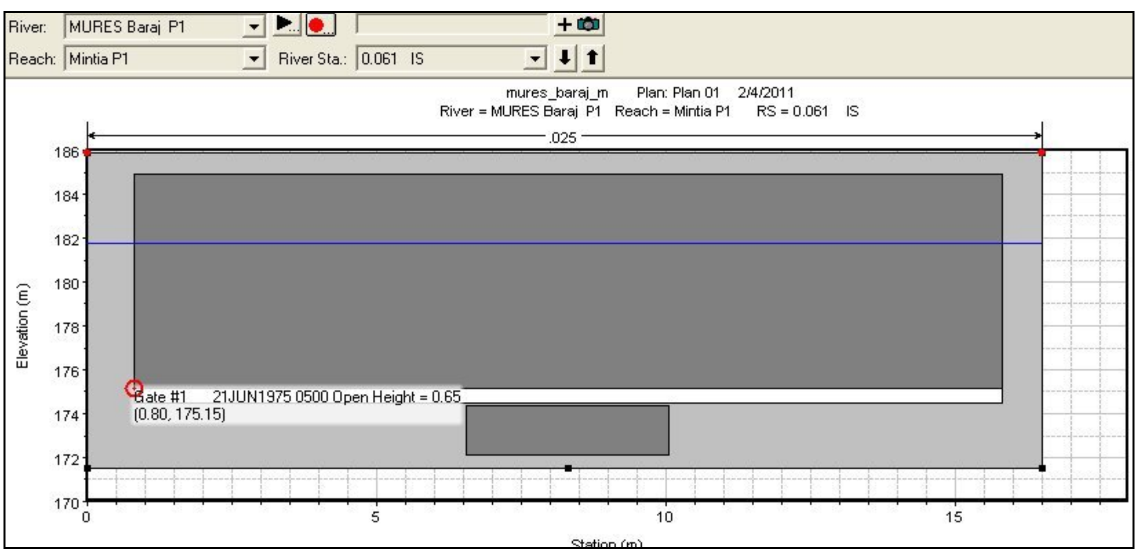

Fig. 2.3 Structure modeling a side wire (P1) with two gates:
the upper one controlling the upstream water level, the lower one controlling the water access to aggregates

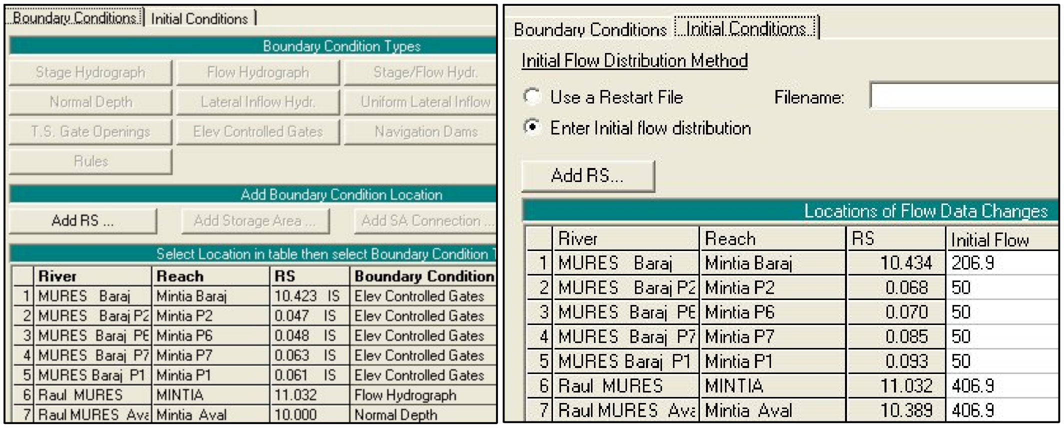

Fig. 2.4 Initial and boundary conditions for the six analyzed structures

2.2 INITIAL AND BOUNDARY CONDITIONS

The running of the numerical model requests to consider specific initial and boundary conditions. These conditions are accessed through graphical windows as shown by the figure 2.5 and refer to:

- the mean hydraulic slope at the downstream end (kilometer 10.000 on Mures River – downstream Mintia, condition no.7) J = 0.0035;

- the high waters hydrograph (registered in 1975) amplified by the ratio k = 1.80 (in order to reach the maximum flow of 3942 m^3/s) and associated to the model entering point (kilometer 11.032 – Mintia, condition no.6);

- the water flows that initially transit through the 6 structures (figure 2.4), with the following values at the start moment: 50 m^3/s through the marginal structures (P1, P2, P6 and P7), 206.90 m^3/s and 406.90 m^3/s (the total entering flow at the km 11.032 and the living flow at the km 10.000) through the middle structures (10.423 and km 10.413);

- specific control elements for the boundary conditions at the structures. For example on wire P1 (the structure at km 0.061, figure 2.1) the control conditions at the plane gate managing the water level for running the aggregate (gate #1, figure 2.6, left) are established by water level criteria applied to an upstream section (i.e. the cross section at km 10.484. If the water level exceeds 181.5 mBSL (due to a high water wave) the gate would be rise with a rate of 0.05 m/minute, while if the water level drops below the reference level of 180.5 mBSL the gate would close with the mentioned rate. The maximum lifting height for gate #1 is 10.40m.

In the same way for gate #2, controlling the entrance to the micro hydropower station (figure 2.6, right), if the reference water level of 180.30 mBSL is over passed than the gate would be lifted at a rate of 0.5m/min. The maximum lifting height for this gate is 2.20m. In case the upstream water level goes below a reference value of 181.50 mBSL, the gate is to be lowered with the same mentioned rate.

Same type of control elements were considered for all dam structures (at kilometer 10.423 on middle wire, figure 2.7; 0.047 – P2; 0.048 – P6; 0.063 – P7) in order to model the lifting / lowering operations of the plane gates.

The water levels considered as initial conditions in all cross sections were obtained by starting the numerical analysis followed by a restart after one hour.

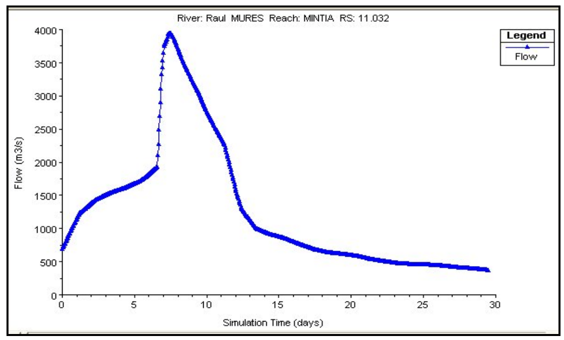

Fig. 2.5 The high waters hydrograph on Mures River at Mintia hydrotechnical development

2.3 MODEL RUNNING AND REACHED RESULTS

The graphical window *Run → Unsteady Flow Analysis* [2] was accessed in order to perform to actual running of the model analysis.

The gates maneuvering lows, the water levels for each model joint at all time steps, the flow variation and velocity variation in all cross sections were obtained by running the numerical simulation. Several temporary positions for the gates at “Mintia P1” structure (kilometer 0.061) and “Mintia Dam” (middle area) respectively are presented by the captures in figures 2.8 and 2.9. The figure 2.10-left presents the opening functions for gates #1 and #2 at “Mintia P1” structure, while figure 2.10-right presents the opening functions for gates #1, #2 and #3 at “Mintia Dam” structure, both reached through model running.

These lows were obtained for the numerical model by following all restrictions defined through the control elements for the entire time period of the analyzed phenomenon.

Figure 2.11 presents the water level and flow variations upstream of “Mintia Dam” structure, on the middle wire of cross section at kilometer 10.434, and on the upstream cross section at kilometer 0.083 of the wire corresponding to “Mintia P1”.

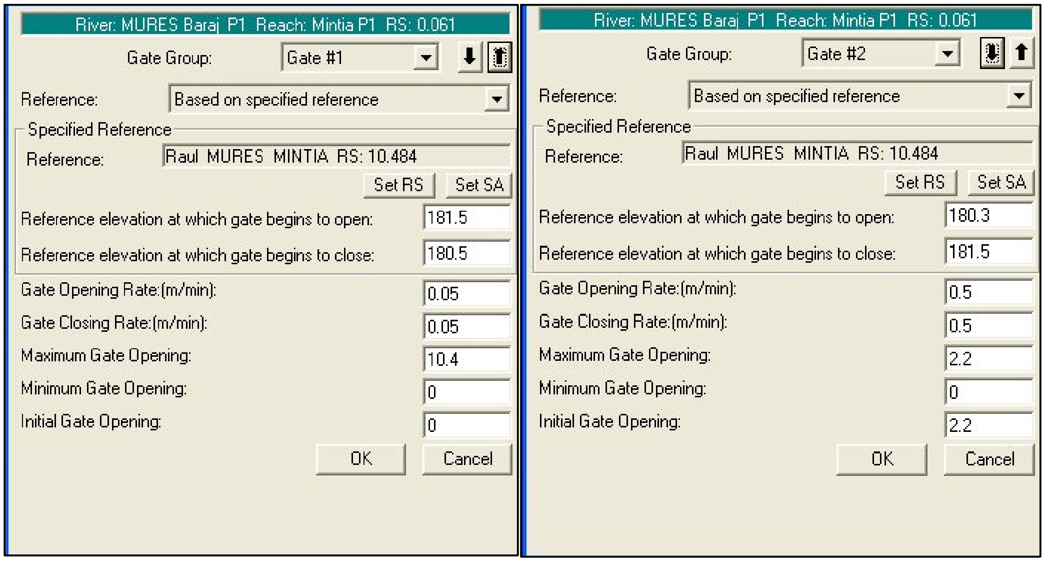

Fig. 2.6 Monitoring conditions for operating the gates: water level control (left) and water access control at aggregates (right)

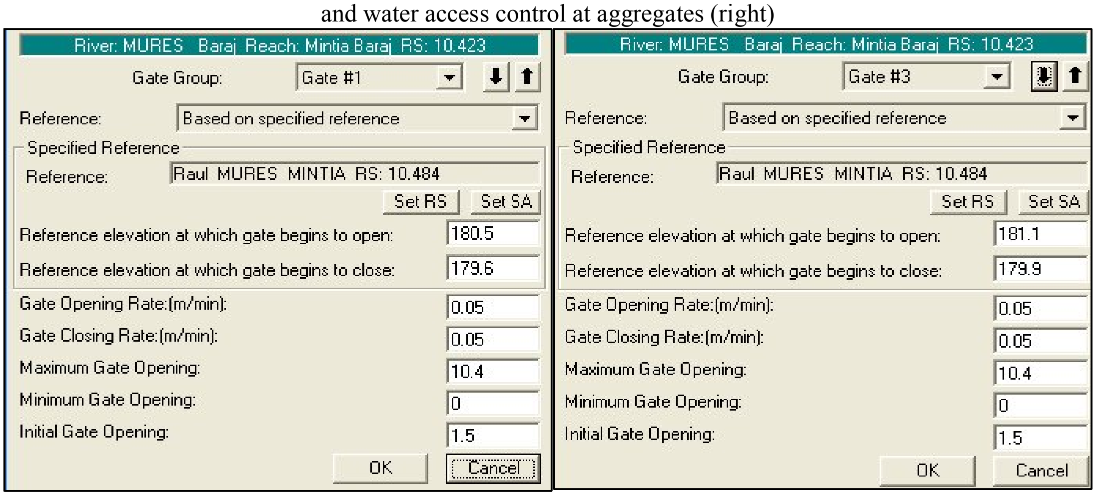

Fig. 2.7 Monitoring conditions for operating the gates: level control of gate #1 (left) and of gate #3 (right)

Figure 2.12 shows two longitudinal profiles through the numerical model at a specific moment, at $02^{\underline{40}}$ on June 17, 1975. On the sector from kilometer 10.606 to kilometer 10.1312* (fig.2.12, above) the profile covers the middle wire overlapped to the side wire (starting at kilometer 0.061 and named Mintia P1), while for the sector from kilometer 10.5969* to kilometer 10.1507* (fig.2.12, below) the profile covers only the side wire.

Velocity distributions in several significant cross sections of the model are presented by figure 2.13. Considering the maximum water discharge through Mintia Development registered at $11^{\underline{10}}$ on June 22, 1975, the following important results can be noticed from these graphical representations:

- the velocity maximum value of 4.50 m/s (first picture of figure 2.13) reached upstream of "Mintia dam" structure (cross section at kilometer 10.434) corresponds to the maximum flow Q = 1684.39 m^3/s (figure 2.11, left) passing through the central gaps;

- the maximum value of 3.16 m/s obtained downstream of Mintia Dam (the second picture of figure 2.13) in the cross section at kilometer 10.389 (near the river left bank at about 25.30m with respect to the reference point) corresponds to the total flow Q = 3942 m^3/s

- the maximum value of 5.01 m/s obtained in the water energy dissipater (the third picture of figure 2.13, cross section at kilometer 10.4183*, at about 28.19 m with respect to the reference point) corresponds to the transited water flow Q = 1684.39 m^3/s;

- in the cross section of kilometer 0.093, upstream of "Mintia P1" structure (placed in the dissipater basin on gap P1), the transition of the flow Q = 566.84 m^3/s (figure 2.11, right) determines the velocity maximum value of 5.18 m/s (the fourth picture in figure 2.13);

- downstream of structure "Mintia P1", on the corresponding wire in the cross section of kilometer 0.057, the transition of the flow Q = 566.84 m^3/s determines the velocity maximum value of 4.58 m/s (the fifth picture in figure 2.13) at about 8.63m with respect to the reference point.

The picture 2.14 shows the water level and discharge variation along the entire modeled period for the studied phenomenon, specifically for the two considered structures:

- at the central structure "Mintia Dam" (fig.2.14, right): the water level presents upstream a maximum value of about 181.32 mBSL (indicated as "HW Stage") and downstream a maximum value of about 180.59 mBSL ("TW Stage"); the variation of the discharge through the three gates presents the maximum visualized value of 559.61 m^3/s (at gate #3) while the total maximum flow is Q = 1684.09 m^3/s;

- at the side structure "Mintia P1" (fig.2.14, left): the water level presents upstream a maximum value of about 182.25 mBSL ("HW Stage") and downstream a maximum value of about 180.25 mBSL ("TW Stage"); the discharge variation presents the maximum values of 566.85 m^3/s through gate #1 and 51.18 m^3/s respectively through gate #2.

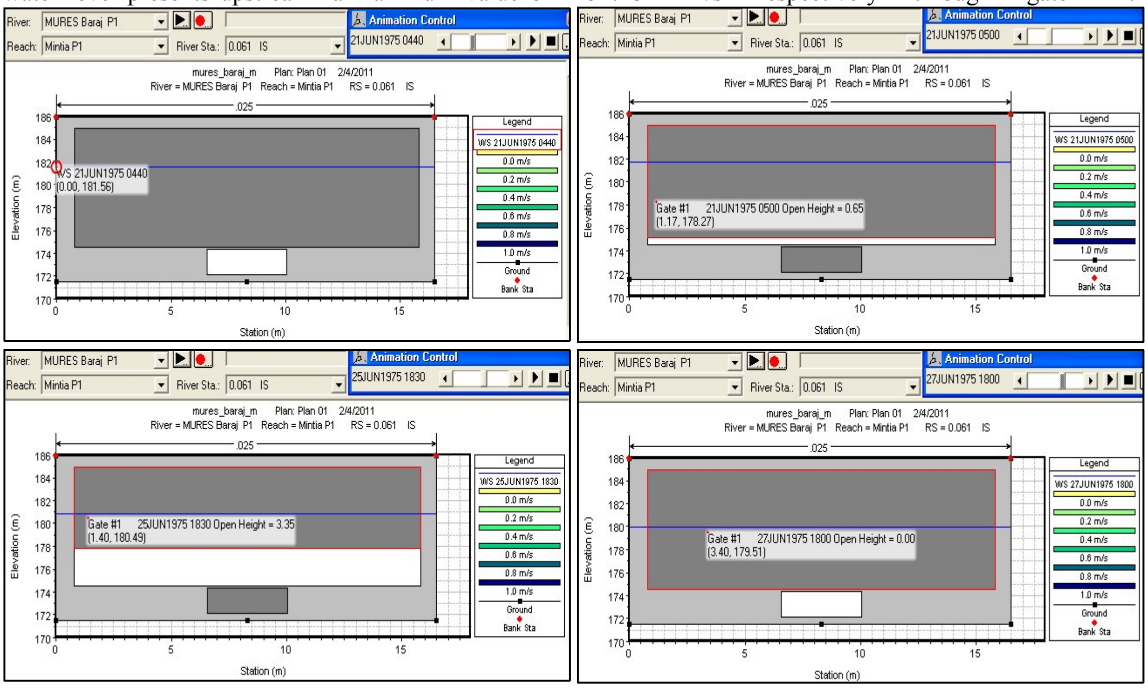

Fig. 2.8 Several positions for "Mintia P1" gates:
above left – gate #1 closed and gate #2 opened at 04^{40} on June 21; above right – gate #1 opened with 0.65m and gate #2 closed at 05^{00} on June 21; below left – gate #1 opened with 3.35m and gate #2 closed at 18^{30} on June 25; below right – gate #1 closed and gate #2 opened at 18^{00} on June 27 (water level upstream at 179.95 mBSL)

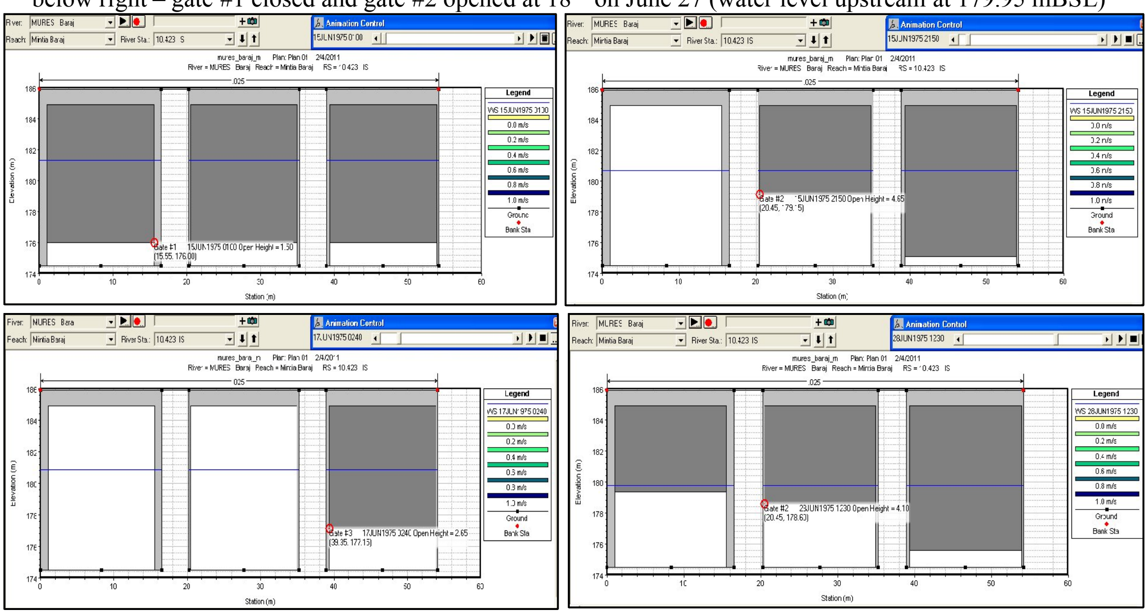

Fig. 2.9 Several positions for the gates on central part of "Mintia Dam":
above left – gates #1, #2 and #3 opened with 1.50m at 01^{00} on June 15; above right – gate #1 fully opened, gate #2 opened with 4.65m and gate #3 opened with 0.60m at 21^{50} on June 15; below left – gates #1 and #2 fully opened and gate #3 opened with 2.65m at 02^{40} on June 17 (water level upstream at 180.79 mBSL; below right – gate #1 opened with 4.85m, gate #2 opened with 4.10m and gate #3 opened with 1.10m at 12^{30} on June 28 (water level upstream at 179.78 mBSL)

3. CONCLUSIONS

The main objective of the presented study of numerical modeling is to test out the possibilities of water flow transition through the hydrotechnical development at Mintia, for both specific situations – the usual running situation and the accidental high water wave situation. In the same time, this study leads to the possibility of drawing the operation laws for the weir gates, following specific restrictions defined by the control elements over the entire modeled period.

Analyzing the gates opening laws at high water wave transition through the structure, it is noticed that the lifting operations start at the central gates of "Mintia Dam" structure (gates #1, #2 and #3) which end up completely opened at the maximum height of 10.20m.

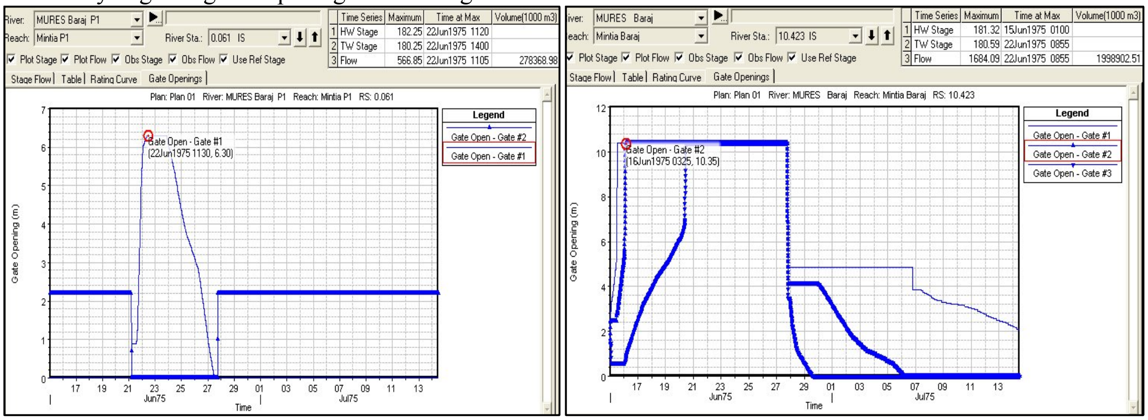

Fig. 2.10 Gates operation laws: left – gates #1 and #2 for "Mintia P1", right – gates #1, #2, #3 for "Mintia Dam"

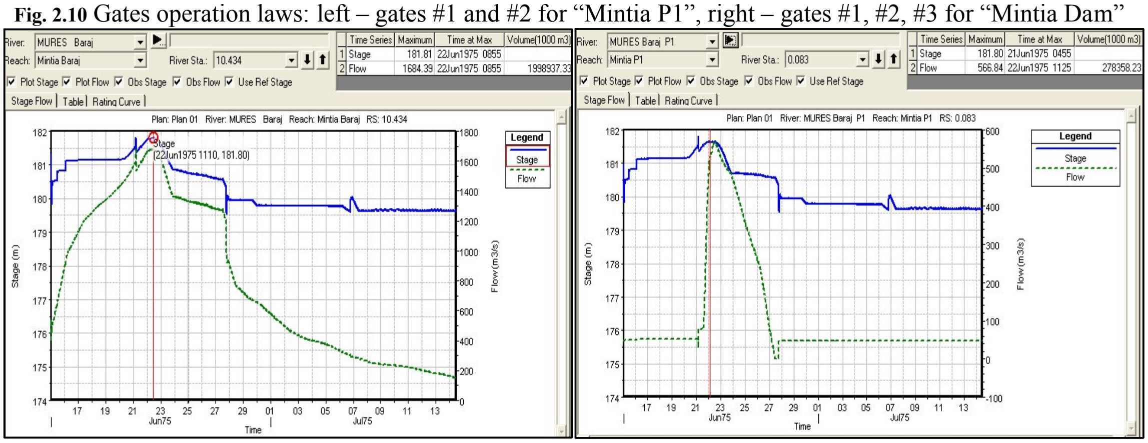

Fig. 2.11 Water level and flow behavior in cross sections at kilometers 10.434 and 0.083

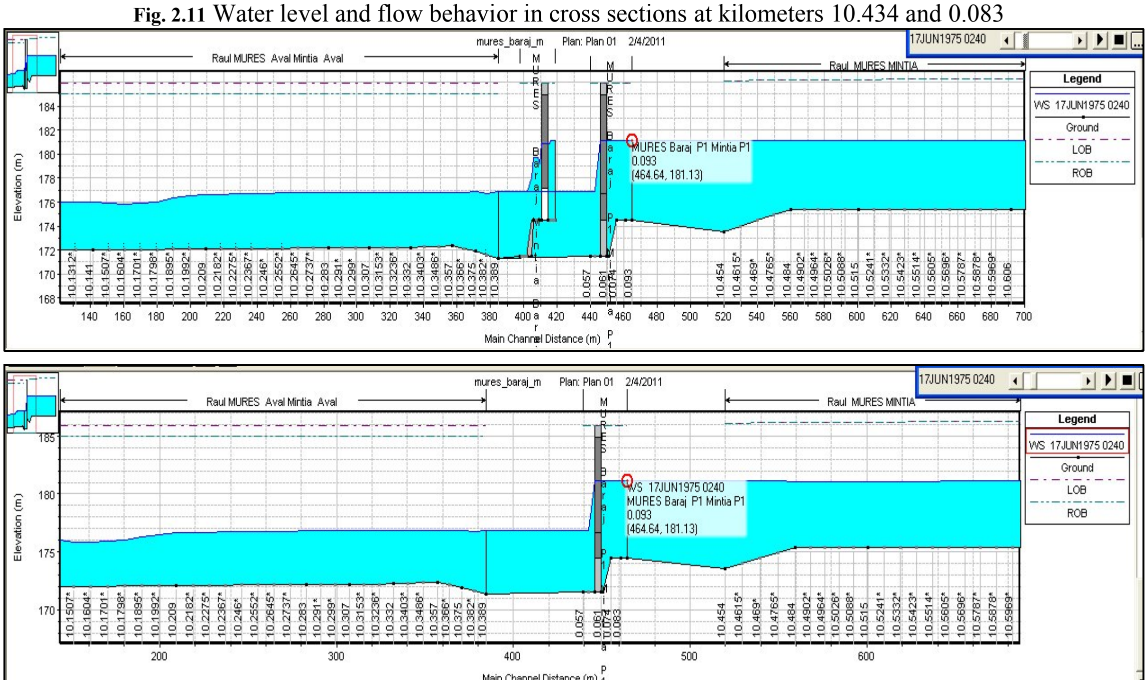

Fig. 2.12 Longitudinal views showing the water level variation (02^{40} on June 17, 1975)

The lifting operations for the gates on sides' wires ("Mintia P1", "Mintia P2", "Mintia P6" and "Mintia P7") start after the complete opening of the three gates of the central structure. The side gates are to be partially lifted, the maximum lifting height being 6.30 m for each.

As about the lowering operations they begin at side gates and after these are completely closed the gates on the central structure start to be lowered.

In case the reference level of 181.50 mBSL (cross section at kilometer 10.484) is over passed, the gates on sides' wires (controlling the access to hydropower aggregates) are to be closed, and when the reference level of 180.30 mBSL is reached again in the mentioned cross section the side gates start to be lifted.

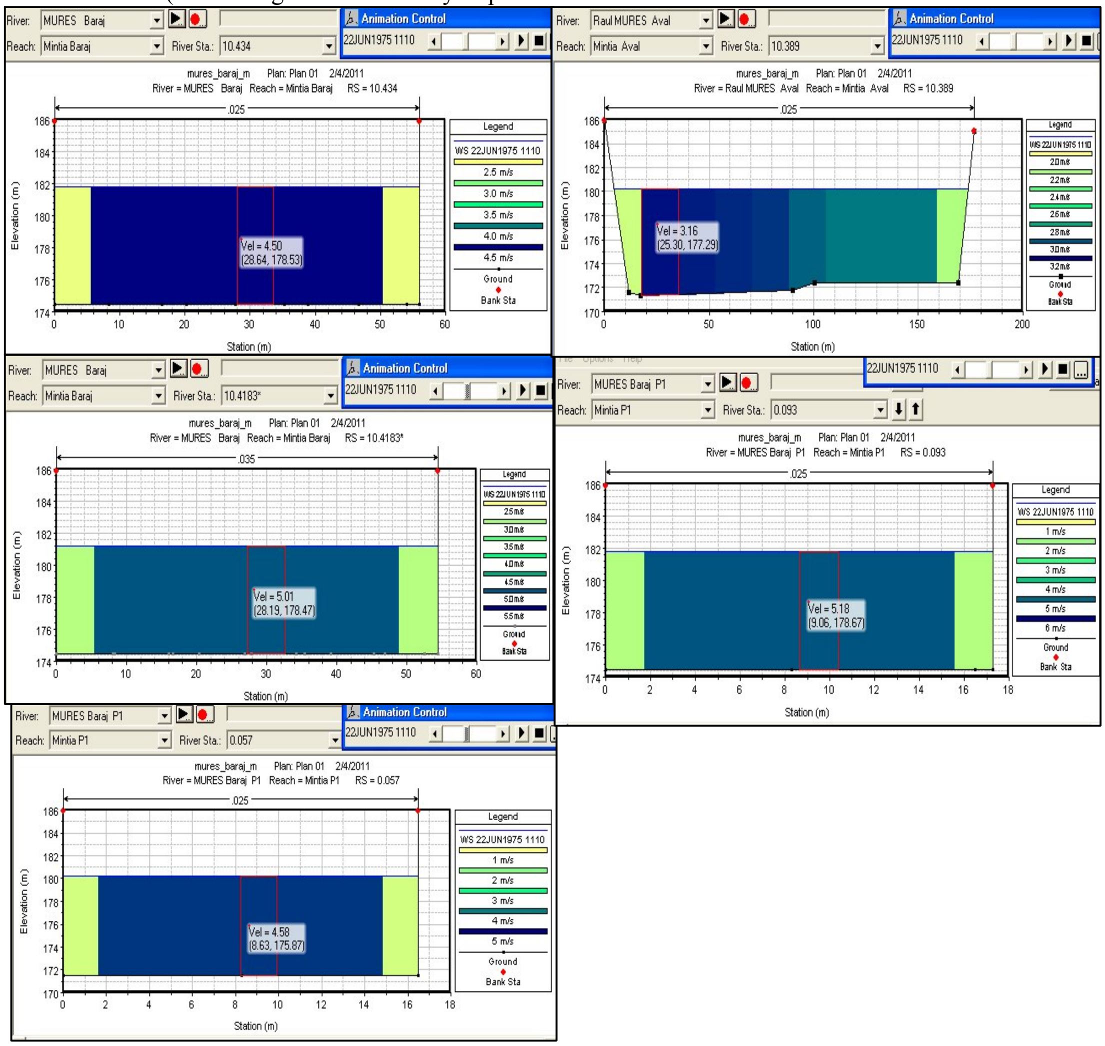

Fig. 2.13 Water velocity behavior for several cross sections

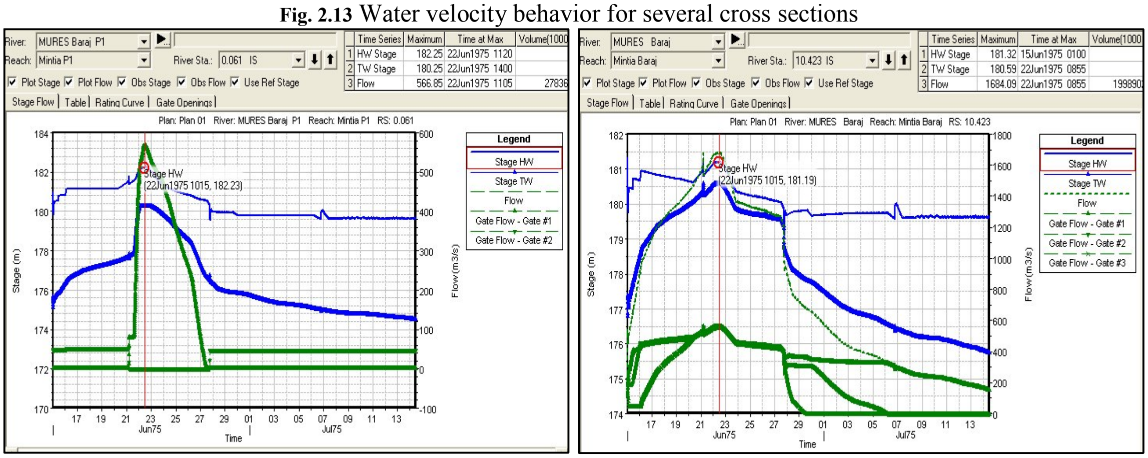

Fig. 2.14 Water level and flow behavior: left – "Mintia P1", kilometer 0.061, right – "Mintia Dam", kilometer10.423

4. BIBLIOGRAPHY

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