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MANAGEMENT OF MULTIPURPOSE WATER STORAGE RESERVOIR IN FLOOD WATER REGIMES

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As a consequence of climate changes the extreme hydrological phenomena occures, in terms of spatial and temporal variability. In such conditions – of more frequent and extreme high water regimes and reduction of low water – the water storage reservoirs should be used for active flood protection as well as for improving the low water regimes. The possibilities for better flood control in the multipurpose water resources system, including the water storage reservoirs, are analyzed in the paper. Case study described in the paper refers to the Trebišnjica River Hydrosystem (Herzegovina). As a part of the improvement of management process a mathematical simulation model was developed. Model proposes the most favorable operational rules for operation with water gates at the bottom outlet and spillways of the dam, according to the criterion of achieving the best transformation of the flood wave. The main goal is the best possible protection of the Trebinje Town from destructive influence of the flood waves.

Keywords: Flood control, water storage reservoirs, mathematical modeling

1. INTRODUCTION

One of the important purposes of the water storage reservoirs is flood protection. That purpose becomes more important under conditions of climate changes, whose main characteristic is greater irregularity of precipitations, with shorter but more intensive raining periods and longer periods of droughts, especially for rivers with small catchment areas.

In the design phase of water storage reservoirs designers always define some additional volume for flood protection. But full flood control effects of reservoirs (and overall water resource system) can be achieved after implementation of the operative management model, where one of the modules is minimization of water flows in the river downstream of the reservoir. Now days, such management models are usual part of water resources system projects, but 20 or 30 years ago that area was at the infant stage and such parts of projects did not exist [1]. As a consequence, a lot of existing reservoirs in Serbia and the wider region do not have such models, and management in period of high water flows is usually performed on the base of experience, or previous calculations. This management approach limits the management options, and usually all available reservoir capacities are not used [2]. In some cases inadequate management can generate worse flood than it would be in natural conditions. It is especially dangerous in the case of dams with gated spillways.

That is why it is very important to implement operative and flexible water reservoir management models [5], which can calculate the consequences of some management rules or find the optimal management rules for defined goals and limitations.

2. BACKGROUND AND STUDY AREA

The Trebišnjica Hydrosystem (Eastern Herzegovina, Bosnia and Herzegovina) is one of the most complex water resources systems in the region [7]. Construction of the system started 60 years ago and it still lasts. The backbone of the system is Trebišnjica River, the largest sinking river in Europe. Its catchment area is highly karstified with numerous ponors, springs, estaveles and underground connections with different capacity. The population of this area has been struggling with water for centuries. In cold period of the year (period of high precipitation when underground conduits are saturated), local people struggle with floods. Beside high water flows, in that period, all karst poljes are turned into lakes. In summer period, with low or without precipitation, they struggle with droughts.

With the construction of the complex Trebišnjica Hydrosystem in Eastern Herzegovina region, the rechearge of the largest infiltration zones was reduced to specific, short-lasting, hydrological periods or completely bloked. Water is stored in reservoirs and transported through the tunnels and channels from higher elevated parts of catchment areas down to the sea. Along its route water is used for power production, irrigation, water supply and number of secondary benefits. Duration of flood events in karst poljes is limited and locally eliminated.

The Hydrosystem Trebišnjica consists of seven dams, six reservoirs, six tunnels (with total length of 57 km), four channels with total length of 74 km, and seven hydropower plants with total instaled capacity of 1069 MW.

Due to its complexity, the construction of the system has been divided into three phases. The I phase of the system (the most economical part) includes the Grančarevo dam, with HPP Trebinje I and the Gorica dam with HPP Dubrovnik and HPP Trebinje II (Fig. 1). This is the „backbone“ of the entire hydrosystem and it was completed in 1975. The management model described in the article is made for this part of the system.

The main element of the system is Bileća Reservoir, created by 123 m high Grančarevo Dam, with total water storage volume of $1280 \cdot 10^6$ m^3, active volume of $1100 \cdot 10^6$ m^3 and normal operating level 400 m a.s.l. There are two lateral spillways with radial gates for flood discharges, with maximal capacity of 874 m^3/s and two bottom outlets with maximal capacity of 266 m^3/s. HPP Trebinje I, with three Francis turbines of installed flow 3 × 70 m^3/s, and installed power 171 MW, is located in the immediate proximity of the dam body.

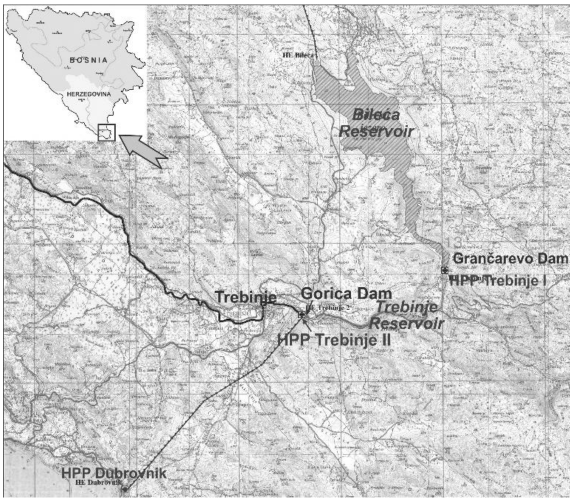

Figure 1. Trebišnjica Hydrosystem (I phase)

The gravity concrete Gorica Dam (33.5 m high) is situated 13.5 km downstream from Grančarevo dam. It formes Trebinje Reservoir, with total storage volume of $15.6 \cdot 10^6$ m^3 and normal operating level 295 m a.s.l. There are two spillways in the centre of the dam, with radial gates, with maximal capacity of 412 m^3/s and two bottom outlets with maximal capacity of 800 m^3/s. Two intakes for the HPP

Dubrovnik are located at the left bank in the immediate proximity upstream of the dam body. The HPP Dubrovnik is underground HPP, with 16.5 km long head race (tunnel and penstock) and two Francis turbines with installed flow 2 × 45 m^3/s and installed power 2 × 108 MW. In the left bank immediately downstream of the dam is HPP Trebinje II, with one Kaplan turbine (installed flow 45 m^3/s, minimal flow 12 m^3/s). Ecological flow [3] that has to be provided downstream of the Gorica Dam is 8 m^3/s. There is also outlet for discharging guarantied flow downstream of the dam.

The Trebinje Town is situated 4 km downstream from the Gorica Dam. One of the important purposes of the system is flood protection of the Trebinje Town. This purpose becomes more important and complex in conditions of climate changes, when flood waves are more frequent and intensive as well as because of uncontroled construction of the area in the immediate vicinity of the river. That is why the Trebinje is now endangered with flows greater than aproximately 400 m^3/s, the flow that occurs once in 1.25 years (80% probability), while earlier that boundary flow was much higher, round 750 m^3/s.

Due to this situation a mathematical simulation model for management in flood periods was developed (Flood wave mitigation model). Model proposes the most favourable management rules the gated spillways and bottom outlets of the dam, according to the criterion of achieving the best mitigation of the flood wave. The main goal is the best possible protection of the Trebinje Town from destructive influence of the flood waves. This model is a part of complex Trebišnjica River Management Model, designed to improve all aspects of the system's effectivity and the operational management capabilities of reservoirs and HPPs on Trebišnjica River. Main task is optimisation of management to achive optimal hydropower production, the best efects of flood protection and the best protection of Trebišnjica river ecosystem in period of low water flows.

3. HYDROLOGICAL REGIME IN THE STUDY AREA

Hydrological regime of the investigated area is very irregular, as a consequence of irregular precipitations (with maximal values in cold period of the year, late autumn and winter) and highly karstified area with numerous underground conduits, that reduces the period of flood wave concentration.

In order to create a flood mitigation model, it was necessary to analyze the flood waves that occur in the reservoirs. It should be mentioned that one of the characteristic of Bileća Reservoir is that the reservoir submerge its own springs aproximately 75 m. That is why it is not posible to measure the inflow into the reservoir, as the inflow is completely underground. That data can be obtained indirectly, by calculations based on data on the change of the reservoir volume and flow that is discharged downstream.

Hydrological analises for Bileća Reservoir for period 1957-2006 indicates that high water flows are frequent in period from 15 October to 15 Mart (Fig. 2), with specially high frequency in the period from 1 November to 31 February. During this period, depending on the water level in Bileća Reservoir, it is highly probable that the priority task of system management will be switched from the energy optimisation regime to the regime of flood protection and mitigation of flood waves.

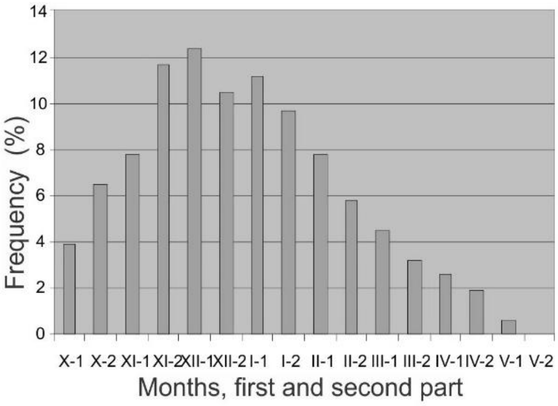

Figure 2. Frequency of flood waves that inflow into the Bileća Reservoir

In its final stage, Trebišnjica River Managament model will have prediction module (part), with task to predict flood waves on the base of different inputs (mainly the precipitation, flows and levels in piezometers). To complete that part of the model it is necessary to equip the entire catchment area with measuring stations with automatical transfer of the measured data to the central database, where necessary calculations will be performed. This is complex task (time and economicaly very demanding). Untill that part of the model is completed, input flows are defined on the base of detailed hydrological analyses of all flood waves (waves with maximal flow over 200 m^3/s) recorded in period 1957-2006. Some general parameters of those waves are:

- period of flood wave concetration is from 1 to 2 days,
- base flow varies from 50 m^3/s to 150 m^3/s,
- maximal gradients of flow increase are over 300 m^3/s in a day,
- recession period usually last 6 to 8 days,
- gradientof flow decrease is 100 – 150 m^3/s in a day.

Also there is a possibility of occurance a few successive waves.

On the base of described analyses flood waves are divided into three groups:

1. small waves, with maximal flow less than 300 m^3/s – those waves can easily be mitigated in Bileća Reservoir without any aditional management measures. This type of waves are not included in the model;

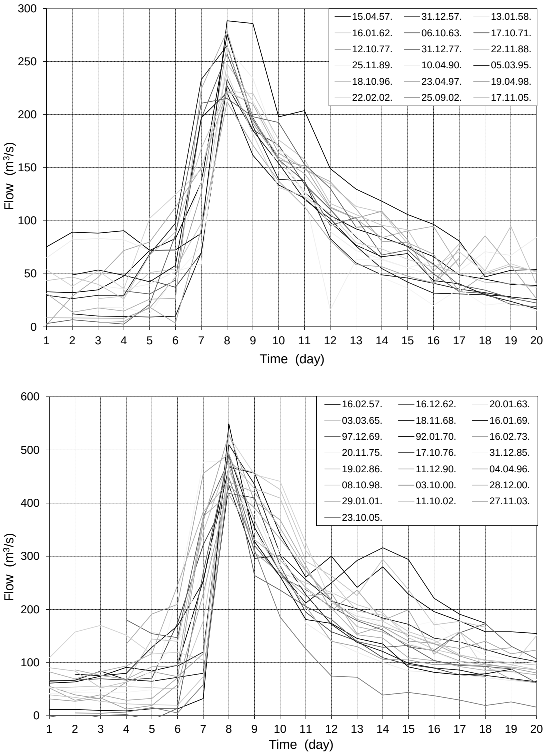

Figure 3. Medium and high flood waves for Bileća Reservoir

2. medium waves, with maximal flows from 300 m^3/s to 400 m^3/s (Fig. 3) – those waves were used to define sinthetic flood waves named 'S' – midium waves in model and has to be tested by the Flood wave mitigation model;
3. high waves, with flows over 400 m^3/s (Fig. 3), used to define sinthetic flood waves named 'V', that has to be tested. If such waves occures the entire system switch into emergency flood protection regime, which implies the obligation of all HPPs to continiously work with it's installed flows, since the flood protection is a prior management requirement.

Inflow into the Trebinje Reservoir (lateral inflow between Grančarevo and Gorica dams) is also mostly underground and cannot be directly measured. Analyses of inflows into the Grančarevo and Trebinje reservoirs indicated that very good correlation between these flows can be established:

$$Q_{mdot} = 0{,}0006485545 \cdot Q_{dot}^2 + \\ + 0{,}0836931 * Q_{dot} + 1{,}159062$$

where

Q_{mdot} – lateral inflow into the Trebinje Reservoir

Q_{dot} – inflow into the Bileća Reservoir

On the base of this equation inflow into the Trebinje Reservoir can be easily calculated.

But, during the exploatation of the system, extremely unfavourable lateral inflows into the Trebinje Reservoir were noticed. The reason is the underground karst catchment area of the Sušica River (the biggest tributary of Trebišnjica River). That is why lateral inflow in model can be also defined using syntethic flood waves, with maksimal flow in the range from 200 to 300 m^3/s (Fig. 6). This is more complex task because Bileća Reservoir has to mitigate flood waves more significantly in order to enable mitigation of such a large wave in the Trebišnjica Reservoir.

4. FLOOD WAVE MITIGATION MODEL

Management model for flood mitigation is simulation model with main task to give the most favourable management solution for Bileća and Trebinje resevoirs in flood periods, satisfying certain management rules, with goal to protect Trebinje Town from flooding (flow should be less than 400 m^3/s) and to achive maximal mitigation of flood wave in reservoirs. Model is based on the calculation of balance equations, first for upstream Bileća Reservoir, and then for the Trebinje Reservoir.

The system management strategy in the conditions of high water inflows completely differs from management strategy in regular operation conditions, when main request for system is optimal production of HPPs as well as satisfying all other users of the system. In flood conditions system management and operation of HPPs have task to mitigate flood waves in the best possible way. It is assumed that HPPs in that period work with their full available capacity. Specialy important is operation of HPP Dubrovnik, as it redirects water from the Trebišnjica River toward the Adriatic Sea.

Schematic view of the system is presented at Fig 4. The system consists of two subsystems: Bileća Reservoir and Trebinje Reservoir.

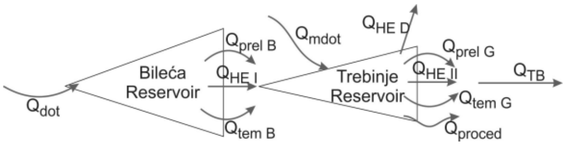

Figure 4. Schematic view of Trebišnjica Hydrosystem (I phase)

Input parametars for model: • inflows into the Bileća Reservoir (Q_{dot}), • lateral inflows into the Trebinje Reservoir (Q_{mdot}), • number of available turbines in HPP Trebinje I, • operation regime of turbines in HPP Trebinje I (optimal or maximal), • water level in Bileća and Trebinje reservoirs at the begining of flood period (H_{B0} and H_{T0}, respectively), • water level in Bileća Reservoir that should be achieved at the end of flood period, • maximal water level in Bileća Reservoir that should not be exceed, • water level in Bileća Reservoir when spillway gates start opening.

Output parametars of the model: • water levels in Bileća and Trebinje reservoirs (H_B and H_T) as time series for flood period, • management of spillway gates at Grančarevo and Gorica dams, • management of Grančarevo and Gorica dams bottom outlets, • water flows downstream of Gorica dam (flows through Trebinje Town) as time series for flood period (Q_{TB}).

Paramerers calculated in the model: • water flow through spillways ($Q_{prel\ B}$) and bottom outlets ($Q_{tem\ B}$) at Grančarevo dam, • turbine flow in HPP Trebinje I ($Q_{HE\ I}$), • water flow through spillways ($Q_{prel\ G}$) and bottom outlets ($Q_{tem\ G}$) at Gorica dam, • turbine flow in HPP Trebinje II ($Q_{HE\ II}$) and HPP Dubrovnik ($Q_{HE\ D}$), • leakage flow from Trebinje Reservoir (Q_{proced}).

As it was earlier mentioned, untill prognostic model for the system is not incorporated into the model, the inflow into the Bileća Reservoir (Q_{dot}) can be defined by selecting flood wave from the synthetic flood wave bases. There are two groups of waves ('S' – medium and 'V' – large) and four types in each group (Fig. 5). Concentration periods of flood waves are 1, 1.5 or 2 days and period of recession 8 ÷ 9 days. Maximal flows are up to 450 m^3/s for medium waves and up to 700 m^3/s for high waves.

Lateral inflow into the Trebinje Reservoir (Q_{mdot}) can be defined in two ways:

1. The automatic procedure (usually applied) - inflow is determined on the base of the correlation dependence described earlier.

2. Choice of a special synthetic wave of lateral inflow - In very rare cases the lateral inflow can be greater than the inflow generated by the correlation dependence. If such a hydrological situation is predicted, lateral inflow can also be selected from another set of synthetic hydrograms named 'MS' (3 types of hydrograms, Fig. 6).

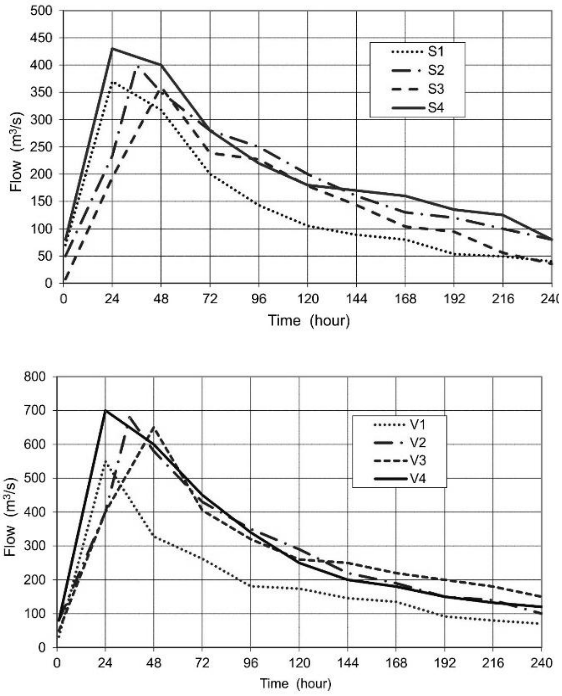

Figure 5. Synthetic flood waves for Bileća Reservoir

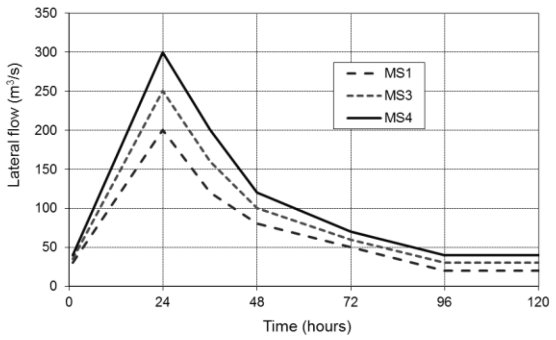

Figure 6. Synthetic flood waves for lateral inflow into the Trebinje Reservoir

4.1 SUBSYSTEM 'BILEĆA RESERVOIR'

The management for Bileća Reservoir is determined using basic balance equation and certain management rules:

$$\frac{\Delta V_{B,i}}{\Delta t} = \overline{Q}_{dot,i} - \overline{Q}_{HE\,I,i}(H_{B,i}) - \overline{Q}_{prel\,\mathrm{B},i}(H_{B,i}) -$$

$$- \overline{Q}_{tem\,\mathrm{B},i}(H_{B,i})$$

$$H_{B,i} = f(V_{B,i})$$

where:

- $\Delta V_{B,i}$ - change of the volume in the i-th interval of time: $\Delta V_{B,i} = V_{B,i} - V_{B,i-1}$

- Δt - time interval, which is constant in the model: $\Delta t = 1$ čas

- $\overline{Q}_{*,i}$ - mean flow value during the time interval. It is assumed that degree of openness of gates is constant during the time interval. The change in the flow depends only on the water level in the reservoir $H_{B,i}$

$$\overline{Q}_{*,i}(H_{B,i}) = \frac{Q_{*,i}(H_{B,i}) + Q_{*,i-1}(H_{B,i-1})}{2}$$

Water flow downstream of the Grančarevo Dam (inflow into the Trebinje Reservoir):

$$Q_{B\_izl}(t) = Q_{HE\,I}(t, H_{B,i}) + Q_{prel\,\mathrm{B}}(t, H_{B,i}) +$$

$$+ Q_{tem\,\mathrm{B}}(t, H_{B,i})$$

Since the flows QHE I, Qprel B and Qtem B depend on the water level in the reservoir, it is necessary to carry out an iterative calculation for determining the flow, that is, the volume and the water level for each time step.

The calculation is performed as iterative procedure until a satisfactory solution is obtained:

- In the first iteration, it is assumed that the spillway gates and bottom outlets are closed, so that entire discharge is equal to turbine flow of HPP Trebinje I. If maximal water level in the Bileća Reservoar does not exceed the input maximal level for a given period of the year, the flood wave can be completely accepted (mitigated/caught) in the reservoar, without any additional discharge.

- If the water level exceeds input maximal value it is necessary to discharge additional quantity of water, first through the spillway, and then if necessary through bottom outlets. The radial spillway gates openes when water level achieves elevation defined as input value/parametar. This water levels are one of the results of this model (Fig. 7) and are described later in the article. The opening step is 10 cm. It is allowed to open one step every hour, and maximal opening is 3m.

- If the flood wave can not be evacuated this way bottom outlets has to be opened. Both outlets open simultaneously, due to the dissipation of energy above the waterfall. The opening step is 10%, and it can be opened once in an hour.

- The calculation continues until such management is achieved that the maximal water level in the reservoir is under defined maximal value.

- Closing of the gates is performed in a similar manner and at the same water levels in the reservoir as opening. First the gates of the bottom outlet are closed, and then the spillway gates. The steps for cloasing are the same as for opening (10% for bottom outlet gates and 10 cm for spillway gates). The gates cloased one step each time when water level in the reservoir falls below the defined water level and it continues until gates completelly cloase.

4.2 SUBSYSTEM 'TREBINJE RESERVOIR'

The schematic view/representation of the subsystem 'Trebinje Reservoir' is shown at figure 4. The management rules for the Gorica Dam (the 'G' in the equations) are determined using basic balance equation and certain management rules, similar as for the Bileća Reservoir:

$$\frac{\Delta V_{G,i}}{\Delta t} = \overline{Q}_{mdot,i} + \overline{Q}_{HE\ I,i} + \overline{Q}_{prel\,\mathrm{B,i}} + \overline{Q}_{tem\,\mathrm{B,i}} - Q_{HE\ D}$$
$$- Q_{HE\ II} - \overline{Q}_{prel\,\mathrm{G,i}}(H_{G,i}) - \overline{Q}_{tem\,\mathrm{G,i}}(H_{G,i}) - \overline{Q}_{proced,i}(H_{G,i})$$

$$H_{G,i} = f(V_G, i)$$

where:

- $\Delta V_{G,i}$ - change of the volume of Trebinje Reservoir in the i-th interval of time:

$$\Delta V_{G,i} = V_{G,i} - V_{G,i-1}$$

- Δt - time interval, which is constant in the model: $\Delta t = 1$ čas

- $\overline{Q}_{*,i}$ - mean flow value during the time interval. It is assumed that degree of openness of gates is constant during the time interval. The change in the flow depends only on the water level in the Trebinje Reservoir $H_{G,i}$.

$$\overline{Q}_{*,i}(H_{G,i}) = \frac{Q_{*,i}(H_{G,i}) + Q_{*,i-1}(H_{G,i-1})}{2}$$

Water flow downstream of the Gorica dam (Q_{TB}):

$$Q_{TB}(t) = Q_{HE\ II} + Q_{prel\,\mathrm{G}}(t, H_{G,i}) +$$
$$+ Q_{tem\,\mathrm{G}}(t, H_{G,i}) + Q_{proced}(t, H_{G,i})$$

These flows has to be determined in iterative calculation for each time step because they depend on the water level in the reservoir.

Since the Bileća Reservoir has the main role/task in flood waves mitigation (because of its large active volume), while the Trebinje Reservoir has the role of compensatory basin, simulation analysis has shown that the recommended water level in the Trebinje Reservoir during the flood protection period is 294 m a.s.l., and in periods of high probability of the appearance of large waves (especially large lateral inflow) recommended water level is 292 m a.s.l.

The iterative calculation is very similar to procedure described for the Bileća Reservoir, but some management rules are different.

- HPP Dubrovnik and HPP Trebinje II operate with constant turbine flow $Q_{HE\ II}$ = 45 m^3/s and $Q_{HE\ D}$ = 90 m^3/s;
- Leakage from the reservoir (Q_{proced}) depends on the water level in the reservoir and can be calculated on the base of functional relation.
- When it is necessary to discharge over 135 m^3/s the radial gates at the bottom outlets open (symmetrically), with opening step of 30 cm, until discharge of 350 m^3/s is achieved. Gates are managed with the condition that the level in the Trebinje Reservoir is maintained constant, at the level equal to level at the begining of flood period (H_{T0}). Such management provides flows through Trebinje less than 400 m^3/s.
- If it is necessary to discharge through bottom outlets over 350 m^3/s, a part of the flood wave is accepted by the free volume of the Trebinje Reservoir, without increasing opening of gates on bottom outlets.
- Further opening of the gates at bottom outlets continues if the level in the Trebinje Reservoir increases over 294 m a.s.l. or some other level recommended for periods of emergency events. Maximal discharge through bottom outlets is 800 m^3/s. In extremely rare cases, if it is not possible to evacuate the entire amount of water through the bottom outlets, opening of the radial spillway gates begins, with opening step of 10 cm every hour.

If the simulations show that the levels in the Trebinje Reservoir will rise above 295 m a.s.l. the user of the program immediately receives information that the flood wave cannot be accepted and mitigated in Trebinje Reservoir. Then, the program 'Flood mitigation' is restarted, in order to examine whether additional emptying of the Bileća Reservoir can further increase its protective function.

On the basis of numerous simulations and analyses of frequency of flood waves (Fig. 2) possibilities of flood wave mitigation in the Bileća Reservoir during the flood period were analysed. As a result dijagram of recomended water levels is proposed (Fig. 7). Purpose of this diagram is to help in defining water levels in the Bileća Reservoir, which are also required as the input data for Flood wave mitigation program.

- Red zone is protected space reserved for the situations which limit the normal functioning of the system (e.g. problems with function on HPP Dubrovnik). If water level gets into red zone all necesary measures should be carried out to reduce it as soon as possible.
- Orange zone is defined as a zone in which flood waves are mitigated and discharge is performed according planned management rules, or management rules deffined by the Flood wave mitigation program.

- Yellow zone is defined as a zone with precautionary measures and enhanced surveillance.

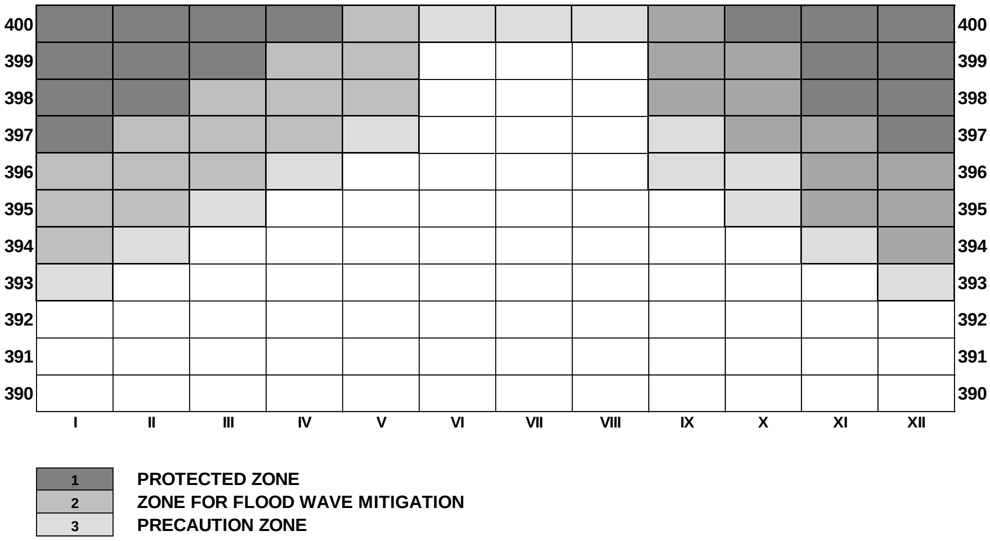

Figure 7. Dijagram of recomended water levels in Bileća Reservoir for flood period

In the normal working period diagram of recommended water levels in Bileća Reservoir differs from recommended levels in flood period. It is defined on the base of optimal management of hydropower plants according to the criteria of maximal energy production of the system. Calculations were performed for period 1956-2005 and one of the results was optimal water levels in Bileća Reservoir. These values were statistically analysed for each month. The probabilities of optimal water levels are presented in the graphical form (Fig. 8). Lower water level boundary connects the optimal levels of 10% probability of occurrence, while upper water level boundary refers to optimal levels of 90% probability of occurrence. This is very important diagram which should help in the management of Trebišnjica Hydrosystem. Water levels in Bileća Reservoir should be maintained within the defined boundaries.

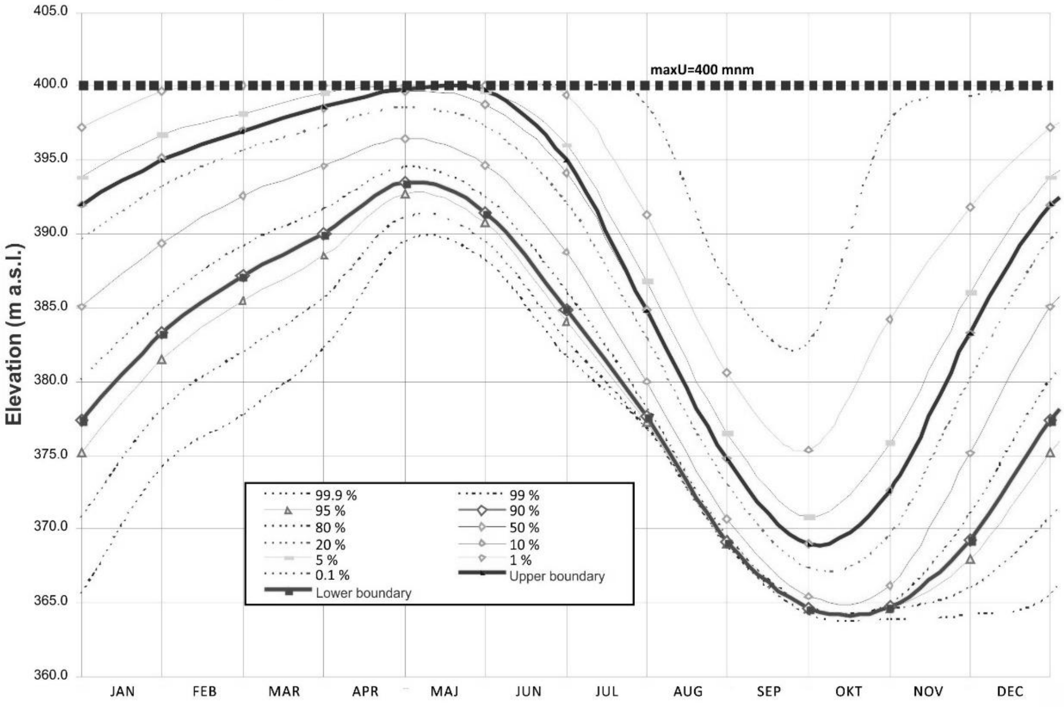

Figure 8. Dijagram of optimal water levels in Bileća Reservoir

5. CONCLUSIONS

Improvement of reservoir management using a real-time model allows significant increase of the effects of multipurpose systems. This improvement refers to:

- increasing the operability of the measuring and information system to be able for real-time management,
- creating the operative mathematical model for defining inputs into the system, and
- improving the decision algorithm.

For the system of two reservoirs and three hydropower plants on the Trebišnjica River, a Trebišnjica River Management Model has been developed. One of the important parts of this model is the Flood wave mitigation model. The model allows the user to obtain the most favourable management based on the data on the current state of the system according to the criterion of minimizing the maximal flows through the Trebinje Town. This is, in fact, a suboptimal solution for the simulated hydrological situation. Results of the model are rules for management of gates at spillways and bottom outlets of dams as well as the diagram of water flows through the Trebinje Town in flood period. The software is adaptive, so that management decisions can be constantly improved in accordance with obtaining new information on the shape and size of the input waves. In this way, the greatest mitigation of flooded waves is achieved, and the most successful active protection of Trebinje is realized in defined hydrological conditions.

In order to allow efficient management during the year, on the base of optimization analyses, diagram of optimal water levels in the Bileća Reservoir have been made. Also, on the base of simulations performed for different flood waves, diagram of recomended water levels in the Bileća Reservoir as well as recomended water levels for Trebinje Reservoirs (both reservoirs) are proposed. Adequate use of these diagrams can successfully compromise demands of different water users.

Further improvement of the model should be directed towards the development of the prognostic model. This is particularly important for the Flood wave mitigation model, because input flood waves would be flood waves predicted on the base of observed (measured) parameters instead of predefined synthetic waves used in current model.

It is very important to develop similar management models for other large water storage reservoirs, especially those situated upstream from settlements and urbanized river valleys. Management performed without previous control of management rules results in cautious management without the full use of all model performance.

REFERENCE

[1] B. Đorđević: „Water resources systems” (in Serbian), Naučna knjiga, Belgrade, 1990, 498p

[2] B. Djordjević: „Cybernetics in Water Resources Management”, WRP, USA, 1993, 619p

[3] B. Đorđević, T. Dašić: „Method for determing the environmental flow downstream of the dams and water intakes” (in Serbian), Journal Vodoprivreda, Vol. 43, No. 252-254, 2011, pp.151-164

[4] B. Đorđević, T. Dašić: „Water storage reservoirs and their role in the development, utilization and protection of catchment”, Spatium International Review, 2011, pp.9-15

[5] B. Đorđević, T. Dašić: „Expert system for operational planning and implementation flood control” (in Serbian), Journal Vodoprivreda, Vol. 47, No. 276-278, 2015, pp.187-202

[6] H. Kaladžisalihović, A. Bibović: „Numerical model of flood wave on river Neretva, FBiH” (in Serbian), Journal Vodoprivreda, Vol. 43, No. 252-254, 2011, pp.189-196

[7] P. Milanović: „Karst of Eastern Herzegovina and Dubrovnik Littoral”, ASOS, Belgrade, 2006, 362p

[8] D. Pavlović, V. Vukmirović: „Statistical analysis of the short duration rainfall by the annual maxima method” (in Serbian), Journal Vodoprivreda, Vol. 42, No. 246-248, 2010, pp.137-148

[9] S. Prohaska, A. Ilić: New method for defining multiple coincidence of flood waves in complex river systems (in Serbian), Journal Vodoprivreda, Vol. 42, No. 246-248, 2010, pp.125-136