FORECAST OF THE AFFLUENT DISCHARGES IN THE IRON GATES I LAKE USING A MULTIMODEL PROCEDURE

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Abstract: To forecast the discharges affluent in the Iron Gates I lake, three mathematic models are used, namely: the non-linear PROGRES model concerning the propagation of the discharges, yielded following the application of the theory of the systems to the study of the propagation process, the VMEDZI model based on multiple discharge linear correlation and the PDF model based on multiple discharge and level-linear correlation.

The multimodel elaborated procedure solves the issue of decision-making in real time in the case of using the three forecasting models. It consists in automatically searching the best combination of the results supplied by all the operational models so that the variances of the forecasting errors are minimised.

Validation of the multimodel procedure was performed through simulating the discharge affluent in the “Iron Gates I” reservoir over the 1 January 1997 - 31 December 1998 period.

From statistically analysing the errors and from comparing the measured and simulated hydrographs, certain conclusions are displayed in the end of the article concerning the operational application of the elaborated multimodel procedure.

Keywords: hydrological forecast, hydrological model, multiple linear correlation, multimodel procedure.

VORAUSSAGE DES NEBENFLUSSES LÄDT IN DEN EISENTOREN I SEE AUS, DER EIN MULTIMUSTERVERFAHREN GEBRAUCHT(BENUTZT)

Auszug: um Den Entladungsnebenfluß in den Eisentoren vorauszusagen, wird I See, drei Mathematic-Modelle verwendet, nämlich: das nichtlineare PROGRES-Modell bezüglich der Ausbreitung der Entladungen, ergab nach der Anwendung der Theorie der Systeme zur Studie des Ausbreitungsprozesses, das VMEDZI-Modell gegründet auf mehrfacher Entladung Zungenwechselbeziehung und das PDF-Modell gegründet auf mehrfacher Entladung und Niveau-Zungenwechselbeziehung.

Das Multimodell verbreitete sich Verfahren löst die Ausgabe der Beschlussfassung in Echtzeit im Fall, die drei voraussagenden Modelle zu gebrauchen. Es besteht in automatisch Suchen der besten Verbindung der durch alle Arbeitsmodelle gelieferten Resultate, so daß die Abweichungen von voraussagenden Fehlern minimiert werden.

Gültigkeitserklärung des Multimusterverfahrens wurde durch Simulieren des Entladungsnebenflusses in den " Eisentoren I " Lagerungssee über am 1. Januar 1997 - am 31. Dezember 1998 Periode durchgeführt.

Davon, die Fehler und davon statistisch zu analysieren, sich abgemessen und vorgetäuscht hydrographs zu vergleichen, werden gewisse Zusammenfassungen am Ende des Artikels bezüglich der Arbeitsanwendung des ausgearbeiteten Multimusterverfahrens gezeigt.

Schlüsselwörter: hydrological Voraussage, hydrological Modell, modelliert mehrfache Zungenwechselbeziehung, Verfahren multi.

1. Introduction

Generally, in order to perform hydrological forecast at one hydrometric station, one model is selected and some explicative variables. But, the criteria used to judge the model performances are not sufficient in real time. In this case, three types of disturbances can appear, which are not considerate in the phase of the model calibration. These three types of disturbances are:

- absence of the necessary data of the model (data transmission problems);
- measurement errors due to the apparatus problem or the apart meteorological conditions;

- a particular situation that cannot be simulated with good results by the model.

Because of these disturbances, the forecaster must take some decisions more or less hazardous, which have not be studied before (to estimate the missing or doubtful data). Some of the activities of the forecaster in real time can be eliminated or simplified using some decision automatic procedures and performed software package (hydrological forecast model and one decision procedure). In this case, the forecaster will have much time to look for supplementary data and to better analyse the real situation, which will results in a better-forecast precision.

2. Forecast models

For the forecast of the inflow discharges in the Iron Gates I reservoir three mathematical models are used, namely: the non-linear model PROGRES, obtained from the application of the system theory at the propagation process, VMEDZI model based on discharge multiple linear correlation and PDF model based on discharge and level linear correlation.

2.1. PROGRES model

The mathematical model, elaborated for the daily forecast of the inflow in the Iron Gates reservoir, with a 1-7 days anticipation, is made up of a *simulation model* and a *updating procedure* of the simulated discharges (Figure 1).

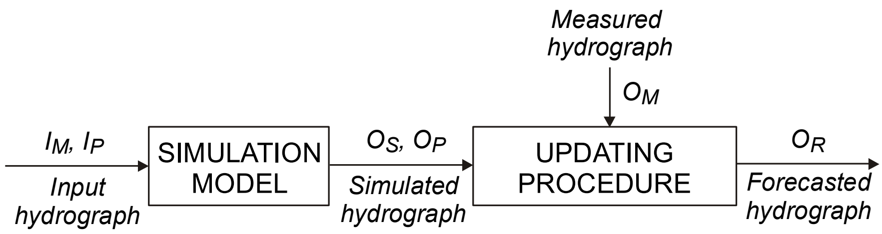

Figure 1. The bloc scheme of the non-linear model (Şerban and Corbuş, 1989).

The input hydrograph on a river sector is represented, for the period before the elaboration of the forecast, by the measured discharges I_M and for the period of the elaboration of the forecast by the forecasted discharges I_P. The resulted vector of the input discharges is propagated on the river reach resulting the simulated hydrograph. Its values are noted with O_S on the anterior period and with O_P for the forecast period. Continuing, by applying the updating procedure we obtain, taking into account the measured discharges O_M, the values O_R that represent in fact the elaborated forecast.

<u>*2.1.1. The simulation model*</u>

For the simulation of the flood routing on specific river sectors an non-linear model is used, resulted from the application of the system theory at the propagation process study (Dooge, 1973; Şerban and Corbuş, 1987; Şerban and Corbuş, 1989):

$$O_S(m\,\Delta t) = \Delta t \sum_{i=p}^{m} I(i\,\Delta t) U_i[(m-i+1)\Delta t],\; m = 1,2,\dots, \qquad (1)$$

$$U_i(j\,\Delta t) = \begin{cases} 1 - \dfrac{K}{\Delta t}\left[1 - e^{-\frac{\Delta t}{K(1-X)}}\right], \text{for } j = 1 \\ \dfrac{K}{\Delta t}\left[1 - e^{\frac{\Delta t}{K(1-X)}}\right]^2 e^{-\frac{j\,\Delta t}{K(1-X)}}, \text{for } j = 2,3,\dots, \end{cases} \qquad p = \begin{cases} 1 \text{ if } m \le n \\ m - n + 1 \text{ if } m > n \end{cases} \qquad (2)$$

where: $O_S(m\,\Delta t)$ is the ordinate at time $m\,\Delta t$ of the output (simulated) hydrograph from the river sector; $I(i\,\Delta t)$ - the mean input discharge in the time interval $[(i-1)\Delta t, i\,\Delta t]$; $U_i[(m-i+1)\Delta t]$ - the ordinate at time $(m-i+1)\Delta t$ of the transfer function (nucleus) of the system at unitary impulse $I(i\,\Delta t)$ uniformly distributed over the time interval Δt; *n* - the number of ordinates of transfer function.

The nucleus function $U_i(j\,\Delta t)$ of a system of Muskingum type has two parameters *K* and *X*. The first parameter represents the travel time of the discharges in permanent regime and it is variable depending on the input discharge in the river sector and the second one indicates the degree of attenuation of discharges.

2.1.2. Updating procedure

The model previously described represents a *simulation* model because the determination of the discharges is entirely based upon the upstream discharges (measured and/or estimated), without taking into account the recorded discharges at the downstream hydrometrical station, where the forecast is elaborated. For the use of this model in real time, a updating procedure is required that, based on the errors between the simulated discharges and the recorded ones up to the forecast elaboration moment at the downstream hydrometrical station, allows a correction of the simulated discharges on the entire period of forecast.

The difference between the simulated discharges hydrograph and the measured discharges hydrograph is due to the imperfect structure of the model, the errors of the input data in the model, the calibration of the model on a limited number of data, the change in time of some characteristics of the river bed.

The used updating procedure (Ferral, 1983) that is applied differently for the increasing limb than for the decreasing one of the simulated discharges hydrograph at the downstream hydrometrical station, takes into account the errors between the simulated hydrograph and the recorded one and also the relation between the slopes of these hydrographs.

For the increase of the discharges hydrograph the following relations are used:

$$\begin{aligned} O_R(t+1) &= O_M(t) + [O_P(t+1) - O_S(t)]CF(t) \\ O_R(t+2) &= O_R(t+1) + [O_P(t+2) - O_P(t+1)]CF(t+1) \end{aligned} \tag{3}$$

where:

$$CF(t) = \left[\frac{O_M(t) - O_M(t-2)}{O_S(t) - O_S(t-2)}\right]^{0,7} \qquad CF(t+1) = [CF(t)]^{0,7} \tag{4}$$

and

$$0,5 \le CF \le 2 \tag{5}$$

For the decrease the relation (3) is used, but in these case the correction factors *CF* are calculated like this:

$$CF(t) = \frac{O_M(t)}{O_S(t)},\ CF(t+1) = \frac{O_R(t+1)}{O_P(t+1)} \tag{6}$$

where: $O_M(t-2)$, $O_M(t)$ are the measured discharges at the moments *t*-2 and *t*; $O_S(t-2)$, $O_S(t)$ - the simulated discharges at the moments *t*-2 and *t*; $O_P(t+1)$, $O_P(t+2)$ - the forecasted discharges at the moments *t*+1 and *t*+2; $O_R(t+1)$, $O_R(t+2)$ - the updating discharges at the moments *t*+1 and *t*+2; *CF*(*t*), *CF*(*t*+1) - the correction factors at the moments *t* and *t*+1; *t* - the moment of the forecast elaboration.

2.1.3. Runoff topological scheme

The general strategy of the runoff modelling in large watersheds in view to elaboration of the hydrological forecasts require double modelling, i. e. both topological modelling of the watershed and rainfall-runoff process modelling.

Runoff in a watershed is generated through a successive integration process over the valley-side, sub-surface and riverbed, of the inlet precipitation amounts.

The mathematical modelling of the runoff requires the achievement of a sketchy representation of the way waters flow and gather in a watershed. This sketchy representation, called topological modelling of the watershed - involves division of the watershed into homogeneous sub-basins and of the river network into characteristic reaches.

When modelling the river network it is necessary to take in consideration the following:

♦ the hydrotehnical structures that modify the maximum runoff;

♦ the socio-economic objectives that can be flooded;

♦ the morphometric characteristics of the riverbed that must be as homogeneous as possible;

♦ the stability and convergence conditions of the mathematical model used.

Taking into account the configuration of the Danube River network and of its main tributaries, a sketch of the runoff was carried out. The routing of the discharge hydrograph is done successively from one river reach to another, on the Danube and its tributaries. The river reaches are delimited by nodes (hydrometric stations or confluences). In each node where there is one hydrometric station, the measured and computed hydrographs are compared. In Figure 2 it is mentioned the length of each river reach and the surface of each catchment is marked in each node.

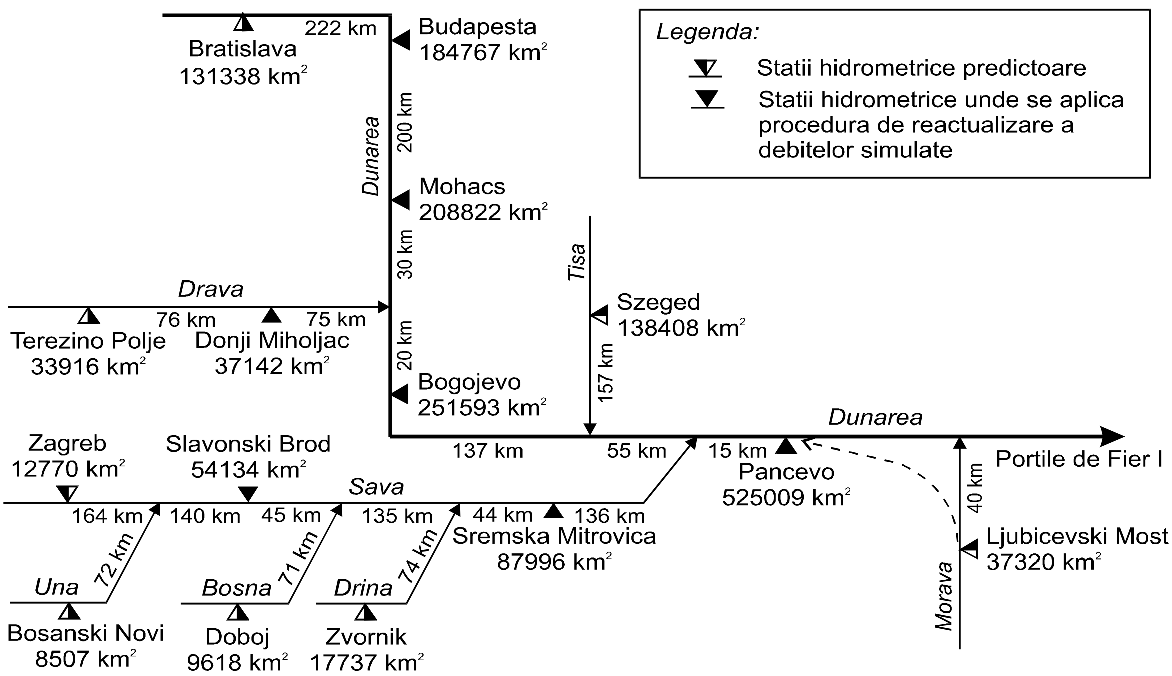

Figure 2. Computational scheme for the Danube affluent discharges forecast in the Iron Gates I reservoir, using the PROGRES model

2.1.4. Parameters calibration

The *K* and *X* parameters of the non-linear model used for the flood routing was determined for the characteristic river reaches, based on the data from the hydrometric stations and of the morphologic characteristic of the riverbed.

The pre-determination of the *K* parameter, representing the routing duration of the discharges between two hydrometric stations, has been done on the basis of the characteristic period of the runoff regime (maximum and minimum) for which have been determined the runoff mean duration of the discharges on the considered river reaches.

The pre-determination of the attenuation parameter *X* has been done function of the morphometric characteristic of the river reaches.

With the pre-determinated values of *K* and *X* parameters and considering the daily discharges recorded in the period 1992-1996, the outflows from the river reach are simulated and compared with the measured ones. If the two sets of hydrographs agree within the limits of an error by ±5% then the parameters are considered to be correctly determined; otherwise the *X* parameter is modified so that the error should get lower. If the error does not decrease when *X* parameter modifies then the computation is resumed considering *K* parameter variable function of the discharge being routed along the river reach under consideration.

2.1.5. Validation of the parameters and conclusions

The validation of the model parameters achieved by the simulation of the flow over the period 1997 - 1998.

After the analysis of the results obtained through the application of the non-linear model to the forecast of the inflow discharges in the Iron Gates I reservoir, with the 1 - 7 days anticipation, the following major conclusions can be drawn:

- The proposed forecast model made up of a *simulation model* and an *updating procedure* gives very good results at its real time application and the forecast errors are in many cases into the adopted hydrological limits (±20%);
- The updating procedure leads to substantial improvement of the simulated discharges, especially in the first 1÷4 forecast days, where practically the errors are situated up to 10%.
- The auto-correlation coefficients of the residuals of the model are about 0.6 what impose to continue the research in view to improve the forecast procedure.

2.2. VMEDZI model

2.2.1. Model Description

As a result of the analysis of the flow formation mode, of the existing hydrometric network, of watersheds with hydraulic structures and of the runoff times for the Danube catchment, up to the inlet into the "Portile de Fier I" (Iron Gates I) reservoir, for the mean daily discharges forecast with a 1-7 days anticipation, there was chosen a mathematical model, based on the multiple linear regression.

The mathematical model, based on discharge multiple linear co-relations, for the mean daily discharges forecast (Serban P., Ungureanu V., 1982), uses a multiple linear co-relation of the form:

$$V_{SP}^{i} = \sum_{j=1}^{NS(i)} \sum_{k=1}^{NA(i,j)} CR(i,j,k) \times V_{S_i}^{DEC(i,j,k)}(i) + TL(i) \qquad (7)$$

where: V_{SP}^{i} represents the forecast value for the *SP* forecast station, with i anticipation days; $NS(i)$ - number of stations, in multiple linear co-relation for *i* anticipation day; $NA(i,j)$ - number of the S_j station inputs in co-relation; $CR(i,j,k)$ - co-relation coefficients (k values for each S_j station); $V_{S_j}^{DEC(i,j,k)}$ - value recorded at the S_j station at the $DEC(i,j,k)$ moment; $TL(i)$ - intercept of co-relation.

2.2.2. Topological scheme

In order to apply this mathematical model for the mean daily discharges forecast in the Danube catchment, up to the inlet into the Portile de Fier I (Iron Gates I) reservoir, first of all, there were analysed the existing hydrometric network, the flow formation mode, the flowing conditions specific to the Danube catchment, up to the section of interest and also the propagation times. On the basis of this analysis, there were established the gauging stations with different delay intervals, making independent variables. There was carried out the schematic representation of the Danube catchment, up to the inlet into the Portile de Fier I (Iron Gates I) reservoir (Fig. 3), including all the selected gauging stations.

It is mentioned the fact that for the affluent discharges forecast in the Portile de Fier I (Iron Gates I) reservoir, with a 1-7 day anticipation, using the model based on discharge multiple linear co-relations, it is necessary to transform levels into discharges at all the gauging stations in the model computation scheme. This transformation is made on the basis of the rating curve corresponding to the computation sections.

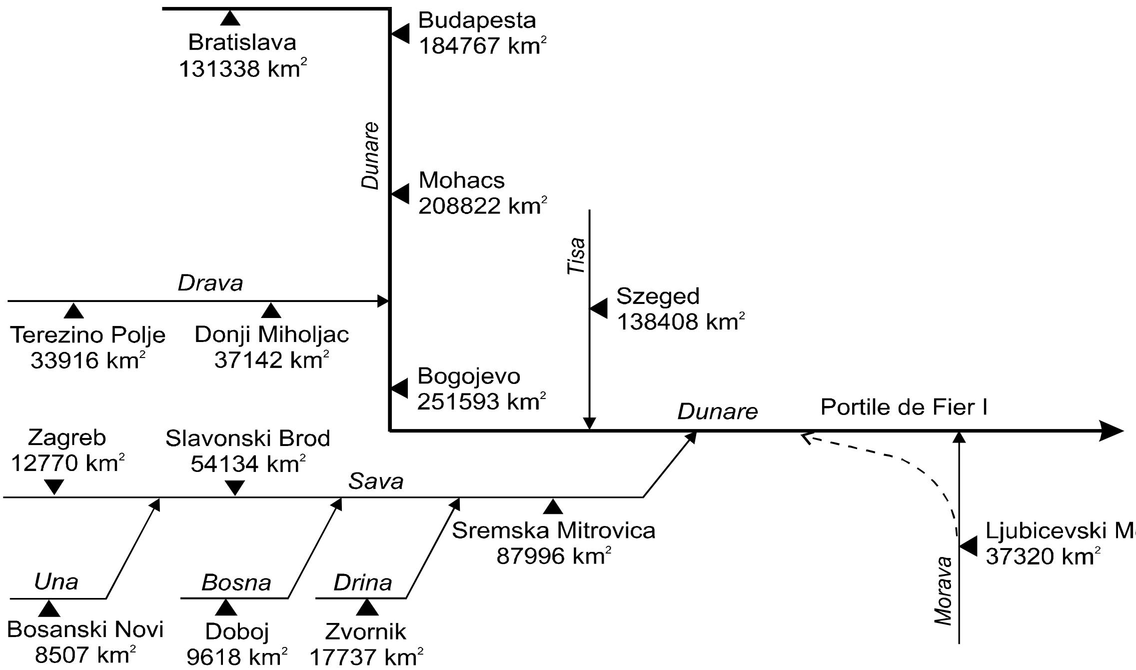

Figure 3. Computational scheme for the Danube affluent discharges forecast in the Iron Gates I reservoir, using the VMEDZI model

2.2.3. Parameters calibration

As a result of the analysis of the existing hydrometric network, of the flow formation mode, of the flowing conditions specific to the Danube catchment, up to the inlet into the Portile de Fier I (Iron Gates I) reservoir and of the propagation times, there were chosen many gauging stations and the delays with respect to the *t* moment (forecast elaboration moment) at which these ones are to be considered and which will represent independent variables of the multiple linear co-relations.

After having performed the computations, for each day of anticipation, there were obtained many multiple linear co-relations, function of the considered variables and delays, by choosing that one with the best co-relation coefficient and which have provided the best discharges estimate with the given anticipation. In Table 1, there are presented the gauging stations of the selected co-relations and the delays at which these ones are considered.

To determine the multiple linear co-relation coefficients, there were used the discharges recorded at the gauging stations selected in the period 1994-1996, except for some particular short periods of time in which data were not available at one or many stations.

2.2.4. Parameters validation and conclusions

The validation of the model based on discharge multiple linear co-relations was performed through the simulation of the affluent discharges in the Portile de Fier I (Iron Gates I) reservoir in the period 1997-1998.

Table 1. Gauging stations of the multiple linear co-relations selected for the Danube affluent discharges forecast in the Portile de Fier I (Iron Gates I) reservoir, using the VMEDZI model and the delays at which these ones are considered

No. crt.	Hydrometric station	River	Anticipation (days)						
			1	2	3	4	5	6	7
1	Bratislava	Dunărea	-	-	-	-	t-1	t	t
2	Budapesta		-	-	t-1	t	-	-	
3	Mohacs		-	t	-	-	-	-	
4	Bogojevo		t-1	-	-	-	-	-	
5	Donji Miholjac	Drava	-	t	t	t	t	t	t
6	Szeged	Tisa	t-1	t	t	t	t	t	t
7	Zagreb	Sava	-	-	-	t	t	t	t
8	Brod		-	-	t	-	-	-	
9	Sremska Mitrovica		t	t	-	-	-	-	
10	Bosanski Novi	Una	-	-	-	t	t	t	t
11	Doboj	Bosna	-	-	t	t	t	t	t
12	Zvornik	Drina	-	-	t	t	t	t	t
13	Ljubicevki Most	Morava	t	t	t	t	t	t	t

By comparing the forecast and measured hydrographs and analysing the errors, it can be noticed that for a 1-3 days of anticipation and particularly for one day of anticipation, when the measured hydrograph and the forecast one almost overlap each other, the forecast model yields excellent results. Although the errors increase at the same time with the anticipation increase, they situate themselves, in most of the cases, within the hydrologically accepted limits (+/- 20%).

2.3. PDF model

2.3.1. Model description

The PDF mathematical model of the affluent discharges forecast in the Portile de Fier I (Iron Gates I) reservoir, the Pancevo section, with a 1-5 day anticipation period, is based on discharge and level multiple linear co-relations.

The computation relations are similar to (7), with the mention that discharge or level variations are used as independent variables.

2.3.2. Topological scheme

The schematic representation of the Danube catchment up to the inlet into the Portile de Fier I (Iron Gates I) reservoir, the Pancevo section, including all the selected gauging stations, is presented in Fig. 4.

2.3.3. Parameters determination

After having performed simulations over the period 1991-1996, for each day of anticipation, there were obtained many multiple linear co-relations, function of the considered variables and delays, by choosing that one with the best co-relation coefficient and which have provided the best discharges estimate with the given anticipation period. In Table 2, there are presented the gauging stations of the selected co-relations and the delays at which these ones are considered.

2.2.4. Parameters validation and conclusions

The validation of the model based on discharge and level multiple linear co-relations was performed by simulating the affluent discharges in the Portile de Fier I (Iron Gates I) reservoir in the period 1997-1998.

By comparing the measured and forecast hydrographs and also analysing the errors, it can be noticed that for 1-2 anticipation days, the forecast model yields good results. Although the errors increase at the same time with the anticipation increase, they situate themselves, in most of the cases, within the hydrologically accepted limits (+/- 20%).

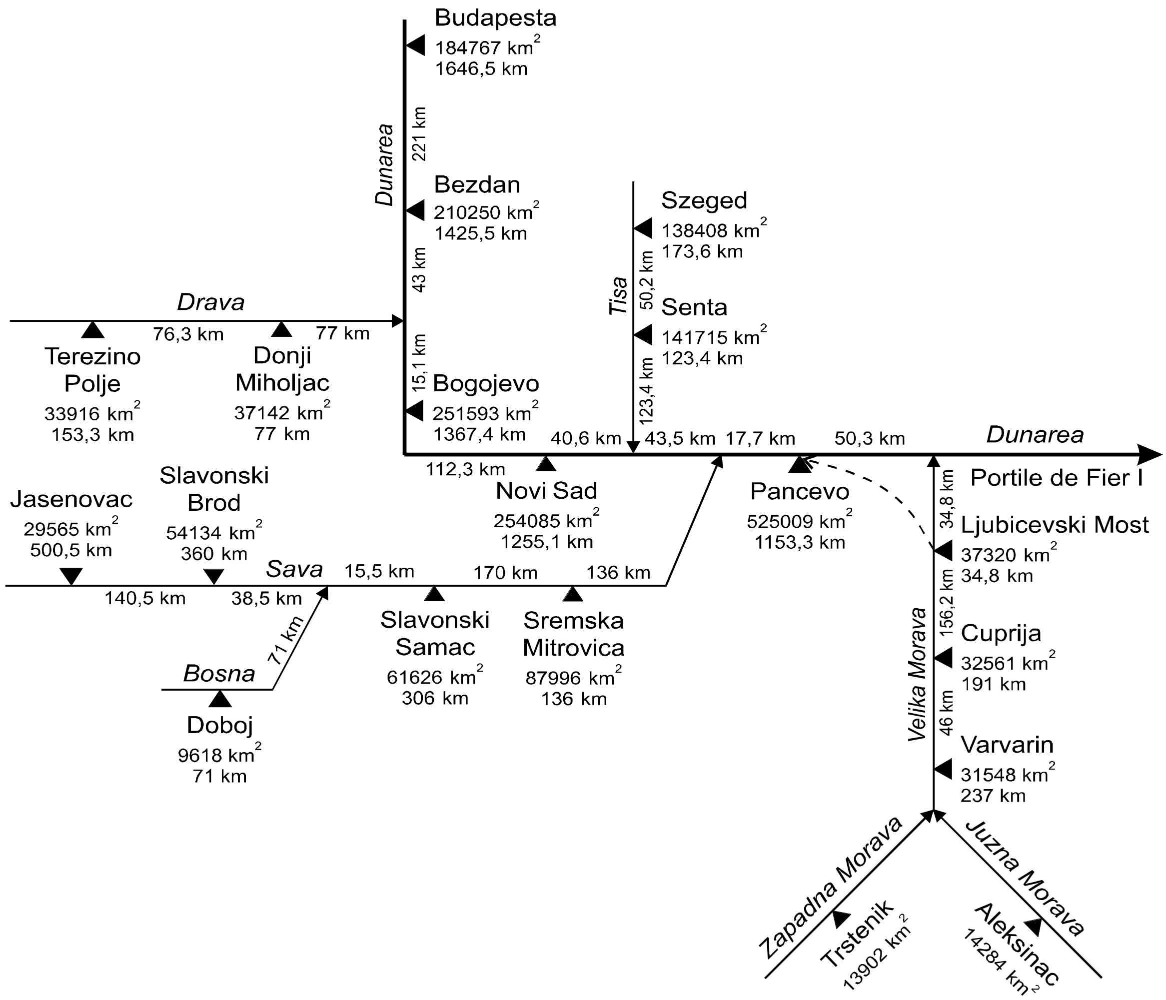

Figure 4. Computational scheme for the Danube affluent discharges forecast in the Iron Gates I reservoir, using the PDF model

Table 2. Gauging stations of the multiple linear co-relations selected for the Danube affluent discharges forecast in the Portle de Fier I (Iron Gates I) reservoir, using the PDF model and the delays at which these ones are considered

No. crt.	Hydrometric station	River	Anticipation (days)				
			1	2	3	4	5
1	Budapesta	Dunărea	-	-	-	-	ΔH(t-1,t-2)
2	Bezdan	Dunărea	-	-	-	ΔH(t,t-1)	-
3	Bogojevo	Dunărea	-	-	ΔH(t,t-1)	-	-
4	Novi Sad	Dunărea	ΔQ(t,t-1)	ΔH(t,t-1)	-	-	-
5	Terezino Polje	Drava	-	-	-	-	ΔH(t,t-1)
6	Donji Miholjac	Drava	-	-	-	ΔH(t,t-1)	-
7	Szeged	Tisa	-	-	-	-	ΔH(t,t-1)
8	Senta	Tisa	ΔQ(t,t-1)	ΔH(t-1,t-2)	ΔH(t,t-1)	ΔH(t,t-1)	-
9	Jasenovac	Sava	-	-	-	-	ΔH(t,t-1)
10	Slavonski Brod	Sava	-	-	-	ΔH(t,t-1)	-
11	Slavonski Samac	Sava	-	-	ΔH(t,t-1)	-	-
12	Sremska Mitrovica	Sava	ΔQ(t,t-1)	ΔH(t,t-1)	-	-	-
13	Doboj	Bosna	-	-	-	ΔH(t,t-1)	ΔH(t,t-1)
14	Trstenik	Zapadna Morava	-	-	-	ΔH(t,t-1)	-
15	Aleksinac	Juzna Morava	-	-	-	ΔH(t,t-1)	-
16	Varvarin	Velika Morava	-	-	ΔH(t,t-1)	-	-
17	Cuprija	Velika Morava	-	ΔH(t,t-1)	-	-	-
18	Ljubicevski Most	Velika Morava	ΔQ(t,t-1)	-	-	-	-

Legend: ΔQ(t,t-1), ΔH(t,t-1) - discharges and levels variations between the t and t-1 moments.

3. Multimodel procedure

The multimodel procedure (Newbold şi Granger, 1974) solves the problem regarding the taking of the decisions in real time when the forecast at one hydrometrical station is obtained using many models or methods. It consist in the automatically search of the best aggregation of the results obtains using all the operational models in view of minimised the variance of the forecast errors. The aggregation is made by giving different weigh for each model / method These weights are computed in function of the previous forecast errors.

The weight of each model can be computed with the formula:

$$W_{k,t-1} = \frac{\left(e_{t-1}^{2}(k)\right)^{-1}}{\sum_{j=1}^{m}\left(e_{t-1}^{2}(j)\right)^{-1}},$$

where: *k* is the number of the model, *t* - the forecast moment, *m* - the model number and $e_{t-1}(k)$ is the error of the *k* model at the *t*-1 moment computed using the formula:

$$e_{t-1}(k) = \frac{Q_{k,t-1}^{p} - Q_{t-1}^{m}}{Q_{t-1}^{m}},$$

where $Q_{k,t-1}^{p}$ is the forecasted discharge by the *k* model at the *t*-1 moment and Q_{t-1}^{m} is the measured discharge at the same moment.

The weights of all models must complete the condition:

$$\sum_{k=1}^{m} w_{k,t-1} = 1.$$

4. Automated forecast package software

On the basis of the automated multimodel procedure was achieved the MMODEL package software which allows the daily elaboration, with 7 days anticipation, of the discharge forecast at the inflow of the Portile de Fier I (Iron Gates I) reservoir. The package software includes the three forecast models mentioned before, namely: the non-linear mathematical model for runoff routing PROGRES, the discharge multiple linear correlation model VMEDZI and the PDF model.

The package software MMODEL consist of 11 programs (Figure 5):

- DATINA version 1.0 - allows the fill the input file necessary for all the forecast programs;
- PROG1TRA, VMED1TRA, PDFI1TRA - allow the automatically transfer of the input data in the forecast programs;
- PROGRES version 1.2, VMEDZI version 1.0, PDFI99 version 1.0 - forecast programs;
- PROG2TRA, VMED2TRA, PDFI2TRA - allow the automatically transfer of the output data from the forecast programs in the input files of the multimodel procedure;
- MMODEL - elaborates the discharge forecast at the inflow of the Portile de Fier I (Iron Gates I) reservoir using the multimodel procedure.

The MMODEL procedure is complete automatic, so that after the fill the data with the DATINA program the forecast programs executes automatically without the forecaster's intercession.

5. Validation of the multimodel procedure

The validation of the multimodel procedure yielded simulating the inflow discharges into the Iron Gates I reservoir over the period 1.01.1997 - 31.12.1998. In the Figures 6 and 7 are presented, in order to exemplify, the results of the simulation with the 3 and 7 days anticipation respectively using the multimodel procedure.

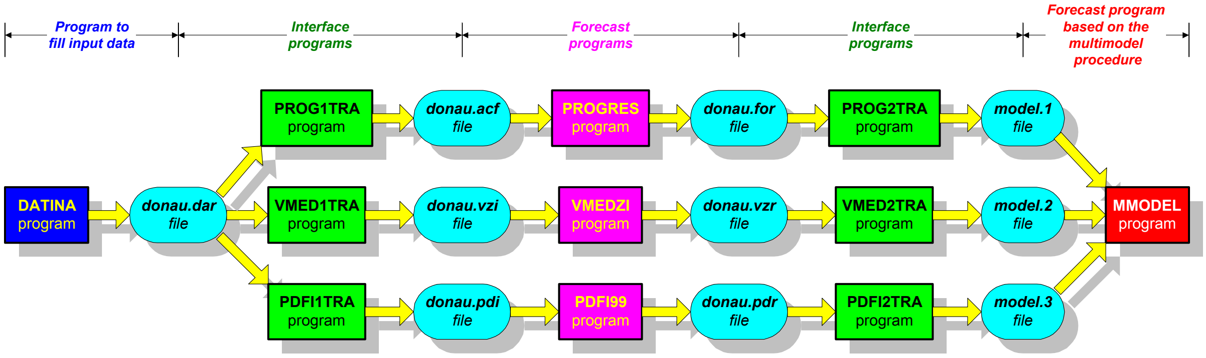

Figure 5. The package software MMODEL allows the elaboration of the discharges forecast at the inflow of the Portile de Fier I (Iron Gates I) reservoir on the basis of the multimodel procedure

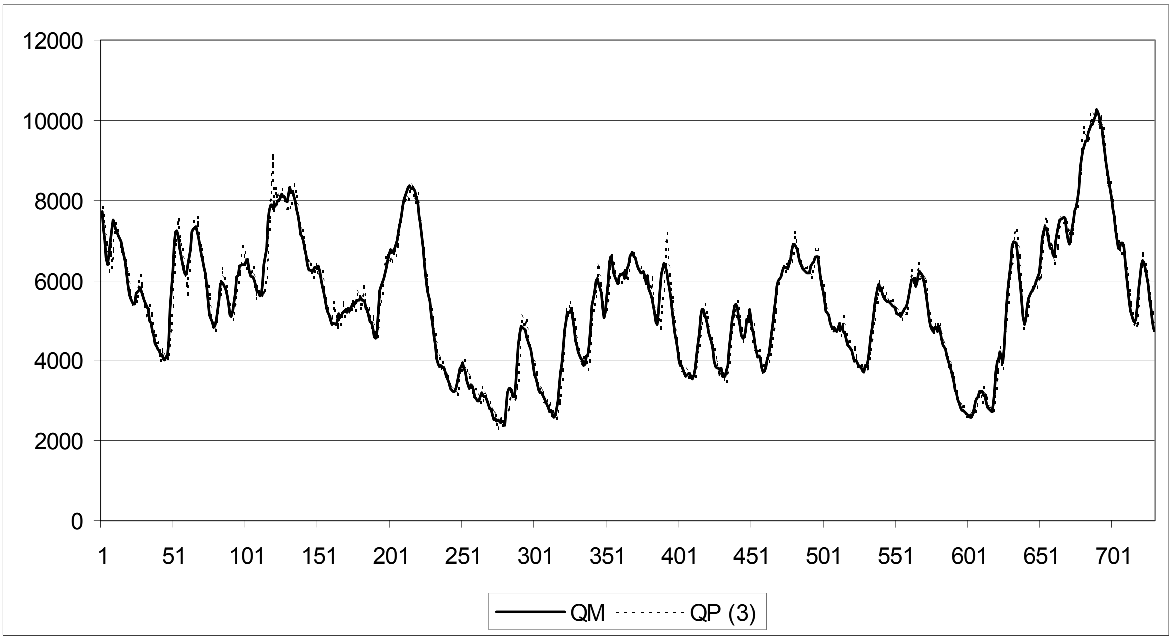

Figure 6. Measured (QM) and forecasted (QP(3)) inflow hydrograph in the Iron Gates I reservoir for 3 days time anticipation, over the period 1.01.1997 - 31.12.1998, using multimodel procedure

6. The evaluation of the forecast errors

The errors between the measured and forecasted discharges are estimated using the following numerical criteria:

- The mean relative error of the absolute deviation between the measured discharge (QM_i) and forecasted discharge (QP_i):

$$AMRE = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{|QP_i - QM_i|}{QM_i}\right)$$

- The frequency curve of the errors between the measured and simulated discharges, forecasted and updating ones.

In the table 3, the numerical values of the above mentioned criteria resulted after the forecasting, with 1 - 7 days anticipation, of the inflow discharges at the Iron Gates I reservoir, using the three selected models (PROGRES, VMEDZI şi PDF) and multimodel procedure, on the basis of the available data over the period 1.01.1997 - 31.12.1998 (730 values) are presented.

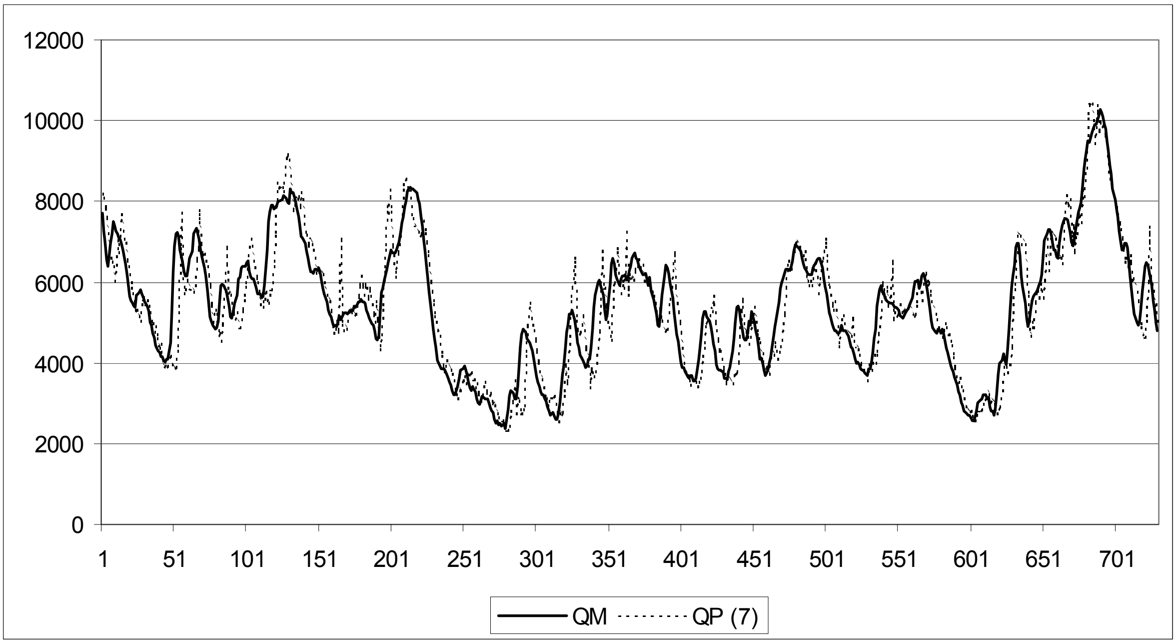

Figure 7. Measured (QM) and forecasted (QP(7)) inflow hydrograph in the Iron Gates I reservoir for 7 days time anticipation, over the period 1.01.1997 - 31.12.1998, using multimodel procedure

Table 3. The values of the criteria of estimating the errors between the measured and forecasted discharges with 1 - 7 days anticipation, at the Iron Gates I reservoir over the period 1.01.1997 - 31.12.1998, using the three forecast models and multimodel procedure

Anticipation (days)	Model	AMRE (%)	0-10 (%)	10-20 (%)	20-30 (%)	30-50 (%)	>50 (%)
1	PROGRES	1,590	99,589	0,411	0,000	0,000	0,000
	VMEDZI	1,514	99,726	0,274	0,000	0,000	0,000
	PDF	2,112	99,863	0,137	0,000	0,000	0,000
	Multimodel	1,555	99,863	0,137	0,000	0,000	0,000
2	PROGRES	2,795	97,945	2,055	0,000	0,000	0,000
	VMEDZI	2,110	98,904	1,096	0,000	0,000	0,000
	PDF	3,017	96,575	3,425	0,000	0,000	0,000
	Multimodel	2,146	98,767	1,233	0,000	0,000	0,000
3	PROGRES	4,261	92,192	6,849	0,959	0,000	0,000
	VMEDZI	3,016	97,397	2,603	0,000	0,000	0,000
	PDF	3,334	96,027	3,151	0,685	0.137	0,000
	Multimodel	2,922	97,671	2,192	0,137	0,000	0,000
4	PROGRES	5,842	83,333	13,223	3,168	0,275	0,000
	VMEDZI	4,347	91,873	7,300	0,826	0,000	0,000
	PDF	4,866	88,981	9,917	0,964	0,138	0,000
	Multimodel	4,032	93,113	6,061	0,826	0,000	0,000
5	PROGRES	5.673	79.878	16.463	3.049	0.610	0.000
	VMEDZI	6.549	88.415	11.585	0.000	0.000	0.000
	PDF	4.966	81.707	18.293	0.000	0.000	0.000
	Multimodel	4.462	89.634	10.366	0.000	0.000	0.000
6	PROGRES	9,433	64,932	22,877	9,178	3,014	0,000
	VMEDZI	7,553	71,781	24,110	3,288	0,822	0,000
	Multimodel	6,868	77,260	17,397	4,384	0,959	0,000
7	PROGRES	11,392	56,575	25,068	12,192	6,027	0,137
	VMEDZI	9,056	63,014	28,630	7,260	1,096	0,000
	Multimodel	8,611	67,397	24,247	6,849	1,507	0,000

7. Conclusions

From comparing the measured and forecast hydrographs, as well as from analysing the errors, it can be noticed that:

- The best performing model is VMEDZI.
- For one and two days of anticipation the multimodel procedure yields results slightly poorer than the best performing model, but anyway better than the other two models.
- For an anticipation of three days, the multimodel procedure yields results comparable with those supplied by the best performing model.
- For the rest of anticipation days (4 to 7), the multimodel procedure yields better results than those supplied by the best performing model.

8. References

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