"ECONOMIC-PRECISION" IN OPTIMIZING THE HYDROMETRICAL NETWORKS FOR THE HYDROLOGICAL FORECAST

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Abstract: In the hydrological forecast activity three sub-system interfere: the pluviometrical sub-system, the hydrometrical sub-system and the data transmission and hydrological forecasts elaboration sub-system. In present paper proposes a model of the type "Cost-Benefit", the so –called "Economic Precision", for the hydrometrical sub-systems and data transmission optimization
Key words: hydrological forecast, "Economic Precision", hydrometrical sub-system, data transmission sub-system.

"ÖKONOMISCHE PRÄZISION"IN DER OPTIMISIERUNG DER WASSERMESSNÄTZE FÜR DIE HYDROLOGISCHE VORHERSAGE

Kürzfassung: In der hydrologischen Voraussage-Unternemhmen kommenthe drei Unterabteilungen von: Nirderschlag-mess Unterabteilung, Hydrometrische Unterabteilung und Daten Sendung mit Hydrologischer Voraussage Herstellung Unterabteilung Die anwesende Vortragung achlägt ein Modell vom Muster "Kosten-Gewinn". um das Optimum für die Hydrometrische und Daten Sendrung Unterabteilungen zu finden vor, Modell "Ökonomische Präzision" genannt.
Schlüsselworte: hydrologische Voraussage, "Ökonomische Präzision", Hydrometrische Unterabteilung, Daten Sendung.

1. Introduction

By the hydrological forecast one controls the high flood formation on hydrographic basins from upstream to downstream, on the basis of the high flood produced on slopes and on hydrographic sub-basins. The precision of determining the flood hydrograph increases with time, once reduced the effective anticipation time. From the moment of setting up the forecasting tem and up to the end of the high flood at the level of the hydrographic basin, there is elaborated a great number of hydrological forecasts for a great number of sections.

Each hydrological forecast elaborated in every section is characterized by a forecast error and an effective anticipation time.

The effective anticipation time is defined, in the present paper, as the time between the moment in which the forecast reaches the beneficiary and the moment of the forecast event occurrence (e.g. the time between the maximum discharge production and the moment in which the forecast is received by the beneficiary).

In order to optimize the hydrometrical network in the analysis is necessary to use a single forecast moment. It is proposed that this moment schuld be the rain cessation moment.

This is a precise moment, independent of a forecast rain.

For optimizing the hydrometrical network for the high flood waves, it is also necessary to establish a number of sections as small as possible, in which the hydrological forecast is elaborated.

In addition, as auxiliary elements in taking the optimal decision, we propose, on the basis of some recorded high floods simulations, the achievement of forecast error-effective anticipation time curves in the following moments: initial forecast, forecast at the moment of the rain start, forecast at the middle of the mean increasing interval and forecast at the moment in which the maximum discharge is recorded (for the hydrographic basins for which the rain duration is shorter than the high flood increasing time).

As it can be noticed, in the hydrological forecast activity, after the rain has stopped, two sub-systems interfere:

- the hydrometrical sub-system;
- the data transmission and processing sub-system

2. Hydrometrical sub-system optimization

The hydrometrical sub-system is formed by gauging stations on rivers, channel and reservoirs.

The gauging stations within the hydrometrical sub-system can by classified in:

- gauging stations used for the surveillance of the deffluent discharges from the reservoirs and of discharges conveyed in transit through deviations in case of high waters. The hydrograph at these gauging stations represent inflow discharges in the runoff propagation schemes and play an important part in the runoff forecast in fitted regime;
- gauging stations on rivers representing closing sections for the warning basins (if forecasting methods with warning basins is applied) or inflow sections in the runoff schemes;
- gauging stations on rivers allowing, the generation of inflows in the propagation scheme, using the hydrological analogy method;
- gauging stations on rivers and reservoirs, representing propagation border sections;
- gauging stations on rivers used for the direct warning of different socio-economic objective; these ones are also used as sections for the gauging forecast validation at different T time steps.

The hydrometrical sub-system optimization passes through the following stages: the choice of the standard scenario, the choice of hydrometrical network scenarios, the mathematical model calibration, the economic calculation error, the choice of the optimal variant.

2.1. Standard scenario

To establish the standard hydrometrical network for the high flood waves forecast it is necessary to mention the following:

- the forecast moment, taken into account when calculating; with this respect, one proposes the cessation moment the moment in which the gauging stations are implicated in the forecast;
- the runoff propagation initial border with respect, there is proposed the gauging stations from which, up to first forecast section, T_E warning time is of minimum 3 hours;
- the applied mathematical models and the way of calculating the inflows in the propagation scheme, with this respect, there are proposed the warning basins method, in the case of hydrographic basins with an important role in the maximum runoff mitigation and mathematical models of the multimodel type, at present applied within NIMH. The above-mentioned mathematical model needs to be calibrated on the basis of 5-15 significant high floods for each analyzed hydrometrical network scenario, this aspect leads to the necessity of a fundamental limitation of the analyzed hydrometrical network scenarios.

2.2. Hydrometrical network scenarios

Once chosen the forecast method and the gauging sections in which the forecast is made, the forecast hydrometrical network scenarios establishment passes through the following stages:

- specifying the propagation scheme, the inflows and their calculation methods;
- pointing out the gauging stations within the optimal hydrometrical networks for reservoirs which can be used for the forecast elaboration; these ones will be compulsory including in all the forecast hydrometrical network scenarios.

In the case of the inflows in the propagation scheme, for which there can be used gauging stations within the above-mentioned hydrometrical network, there are not adapted another calculation solutions.

- the first scenario establishment it consists in the initially established standard scenario which is modified with respect to the gauging stations consideration in the optimal hydrometrical network for reservoirs;
- the establishment of the second up to maximum four scenarios is achieved on the basis of the first scenario in which there is partially modified the calculation method of one of the inflows; this aspect reverberates upon the number of gauging stations; there is proposed a difference of at least 10% of the existing gauging stations number.

The limitation of the hydrometrical network scenarios for forecast is a useful one, because of the great number of works necessary to calibrate the mathematical model for each scenario.

Application:

There is given in Fig. 1

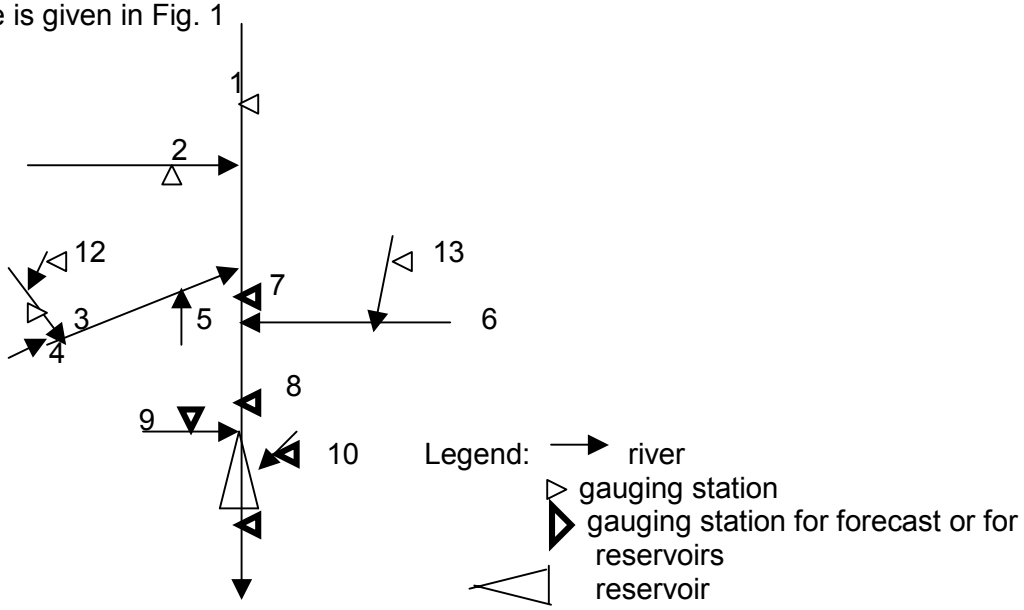

Figure 1. Hydrographical network scheme

- The forecast sections are 7,8,11.
- The sections in the optimal network for the affluent discharges determination in reservoirs are 8, 9, 10, 11.
- The inflows calculation method in the propagation scheme is

Table 1 Inflows calculation method in the propagation scheme

No. inflow	Inflow calculation method 0 – gauging station 1 – hydrological similitude 2 – unitary hydrograph	Observations
1	0	
2	0 ; 2	
3	0 ; 1 ; 2	similitude with the 12th gauging station
4	2 ; 1	similitude with the 3th gauging station
5	2	
6	2 ; 1	similitude with the 13th gauging station
14	2 ; 1	similitude with the 13th gauging station
9	0	
10	0	

On the basis of the above—mentioned table there are elaborated the following hydrometrical network scenarios for forecast:

Table 2 Hydrometrical scenarios for forecast

No. gauging station (inflow)/ No. scenarios	1	2	3	Inflow calculation methods in scenarios		
				10	2	3
1	x	x	x	0	0	0
2	x	x		0	0	2
3	x			0	1	2
4				1	0	0
5				2	2	2
6				1	0	0
7	x	x	x	0	0	0
8	x	x	x	0	0	0
9	x	x	x	0	0	0
10	x	x	x	0	0	0
11	x	x	x	0	0	0
12		x				
13	x					
14				1	2	2

2.3. Mathematical model calibration

The adopted mathematical model is calibrated out the basis of 5 up 15 previously recorded significant high foods for each scenario in the hydrometrical network.

It is pointed one the fact that by the model calibration, the resulted parameters do not totally reflect the reality, but they may include some particular measuring and method errors.

2.3.1. Error calculations

To evaluate the mean hydrological forecast error, there is proposed to take into consideration the following high flood wave element (fig. 2);

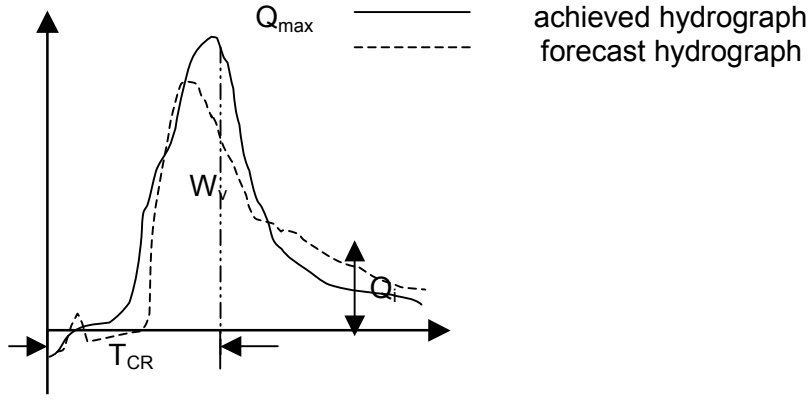

Figure 2 Forecast and achieved high flood wave elements

With this respect, there is proposed the use of the network suggested by P SERBAN for calibration of the unitary hydrograph type:

$$e_{vi}=0.3(\sum|Q_c-Q_o|)/nQ_{mo}+0.3(|Q_{maxc}-Q_{maxo}|/Q_{maxo}+0.4(|T_{crc}-T_{cro}|)/T_{cro} \quad (1)$$

where:
e_{vi} – the relation between the absolute errors and the calculated values mean (it is equivalent with the "i"
high flood forecast relative error)
Q_c – the high flood ordinates calculated, with the DT=T_{CR}/(3-5)h, time steps
Q_o – the achieved high flood ordinates
I I – the respective value modulo;
n – the high food ordinates number;
Q_{mo} – the mean value of the achieved (recorded) discharge in the high flood duration;
Q_{maxc}, , Q_{maxo} – the calculated (forecast) maximum discharge and respectively the recorded (achieved) one;
T_{CR}, T_{CRO} – the calculated (forecast) increasing time and respectively the recorde (achieved) increasing time.

There is considered the forecast relative error on a hydrographic basin:

$$e_{pg}=(\sum_{sh=1}^{j}\sum_{Nv}^{i} evi\ )(1/j.i) \qquad (2)$$

Application:
There is considered the achieved and forecast high flood in figure 3

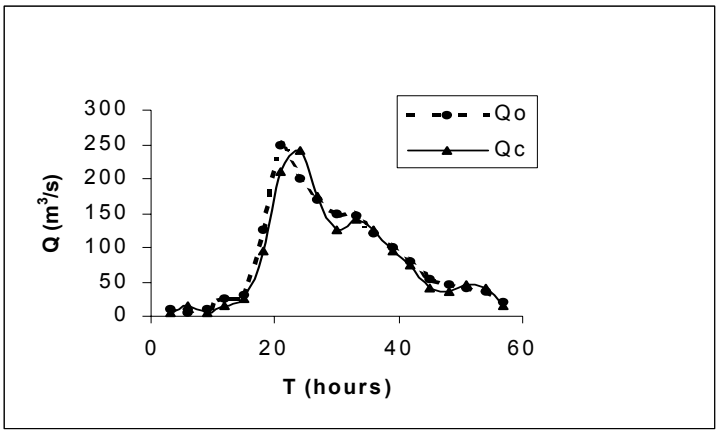

Figure 3. Forecast error calculation

By applying relation (2) one obtains:

e_{vi}=0.3(240.7/163.12)+0.3(10/250)+0.4(3/21)=0.113

2.3.2. Economic calculations

The economic calculations are performed in conformity with the previously exposed method.

Application

In the case in figure 1, in the conditions of the all gauging stations existence in the scheme presented on the analysis date, there result the following costs:

Scenario 1:
$C=C'_1+C'_2+C'_3+C'_7+C'_8+C'_9+C'_{10}+C'_{11}+M_{12}+C'_{13}$
Scenario 2:
$C=C'_1+R_2+R_3+C'_7+C'_8+C'_9+C'_{10}+C'_{11}+M_{12}+C'_{13}$
Scenario 3:
$C=C'_1+R_2+R_3+C'_7+C'_8+C'_9+C'_{10}+C'_{11}+M_{12}+M_{13}$

where C' – costs for exploitation and for the salaries of the exploitation personnel.

2.3.3. Establishment of the optimal scenario variant from the forecast precision point of view

The establishment of the optimal scenario variant from the forecast precision point of view is made on the basis of minimizing the $Z^*=C/(1-e)=min$.

3. Data transmission and processing sub-system

The data transmission and processing sub-system is represented by all the information transmission means (stationary and mobile phones, radio station, relay) on the measuring point – hydrological forecast beneficiary route, by all the data processing means and by the hydrological forecast elaboration.

On this route, there are defined the following times (time intervals):

- T_E – effective anticipation time, the time interval between the production moment of the forecast reception moment by the beneficiary and the forecast element;
- T_D – hydrological forecast dissemination time, the time interval between the forecast transmission and its reception by the beneficiary
- T_P – hydrological forecast elaboration time, the time interval from the moment of the full information reception from the hydrometrical network by the collection center up to the hydrological forecast achievement
- T_T – primary information transmission time to the hydrological forecast centers, the time interval between the information production moment at measuring points and this reception moment by the hydrological forecast centers
- T_S – total time, the time interval between the information production moment and the moment of the hydrological forecast reception by the beneficiary

Between these 5 above-mentioned times there by exists the following relation:

$$T_E=T_S-(T_D+T_p+T_T) \quad (3)$$

In the case of a manual or semi-automatic forecast system, the above-mentioned time values are assessed on the basis of the hydrological forecasters experience and of the analysis performed on previously occurred events.

By introducing the information circulation and data processing automatic systems, the time T_D, T_P, T_T are adequately modified.

On the basis of Walon Hydrological Service (SETHY) from Belgium, a country with an automatic real-time data collection and processing system (including an automatic system normality state surveillance equipment), it is estimated that:

- T_D – the information dissemination tome, in the case of the existence of a computers network, is reduced to about 15 minutes.
- T_P – the hydrological forecast elaboration time, in the case of the automatic data processing, is reduced to 15-30 minutes
- T_T – the information transmission time, in the case of the automatic transmission through the stationary phone network, is reduced to about 30 minutes for 100 collecting points.

3.1 Establishment of the optimal variant the help of transmission means

To choose the optimal scenario with data transmission, collection and processing means for the hydrological forecast, there is proposed the use of the Z^*_{tr} objective function:

$$Z^*_{tr}=C_{tr}/T_E \quad (4)$$

where:

C_{tr} – total expenses with the information measuring, collection, processing and dissemination means within the national hydrological system;

T_E – effective anticipation time.

The effective anticipation time differs from one station to another, mainly function of the T_S total time.

This is why, for the optimal scenario establishment there the adoption is proposed for the relation total time:

$$T_S = \sum_1^n Tsi \,/n \qquad (5)$$

where:
T_{si} – mean time corresponding to each forecast section;
n – number of hydrological forecast section.

For the hydrological forecast efficiency, it is considered necessary that the minimum effective anticipation time to last more than 3-6 hours; in the opposite case (effective anticipation time < 3 hours), it is considered necessary to apply the warning pluviometrical forecast method in the maximum anticipation and quantitative evaluation limits.

In the cases in which, by the warning pluviometrical forecast. there are not achieved effective anticipating times, lasting more then 3 hours, it is recommended only the population warning upon the imminent occurrence of rain falls producing high floods.

Application

There is given the scheme in fig. 1. As a result of technico-economic calculations, the second scenario proved to be optimal from the forecast precision point of view.

There are considered the following types of transmission means endowment.

Table 3 Types of transmission means endowment

No. gauging station.	Endowment with transmission means			Transmission means cost		
	variant 1	variant 2	variant 3	variant 1	variant 2	variant 3
1	RT	RT	T	200	200	100
2	automatic station	RT	T	0	200	100
12	automatic station	automatic station	automatic station	0	0	0
7	RT	T	T	200	100	100
8	RT	T	T	200	100	100
9	automatic station	RT	RT	0	200	200
10	automatic station	RT	RT	0	200	200
11	RT	RT	T	200	200	100
			Total:	800	1200	900

On the basis of the above mentioned table and of the calculations regarding the warning times, exposed in a previous chapter, there is considered to have obtained the following:

Table 4 Optimal scenario variant for transmission means

No. forecast section	Warning time in scenario		
	1	2	3
7	4	3	2
8	8	6	5
11	12	9	6
Mean value	8	6	4

From the table 4 analysis, there results the fact that variant 3 is unacceptable, because the minimum warning time is of 2 hours (the minimum admisible time is of 3 hours).

Results:

Z^*_{1tr}=100; Z^*_{2tr}=200, so the optimal variant is the first one.

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Being given the particular complexity of the hydrological network optimizing activity for the high flood waves forecast, especially due to the new forecast mathematical model and the computer products use, it is necessary that this operation should be performed by specialists in dynamic hydrology, assisted by system engineers, the last ones having the mission to ensure the optimal forecast scenario integration in the hydrometrical network scenarios for parameters.

In the case in which the optimal forecast scenario finally leads to total costs higher than the admissible maximum costs, the system engineer requires the specialists in dynamic hydrology other hydrometrical network scenarios supply for the high floods forecast, scenarios close to technical performance, complying with the maximum admissible cost conditions.

4. Conclusions

1. In the present period, when in the East and Central European countries, there are applied the market economy principles, it is necessary to apply technico-economic efficiency criteria in the hydrological activity.
2. With this respect, the present papers present an application proposal of an economic efficiency model for the hydrometrical network optimization in elaborating the high flood waves forecast.
3. The proposed model justifies, from the economic point of view, the hydrometrical network efficiency for the basis of the cost-forecast and cost precission-efective anticipation time ratios.

5. Reference

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