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Mathematical Model for Establishing the Overflow Spillway Discharges in the Flood Storage Ponds

An original method of euristic seeking of the overflow spillway discharge is presented. The model was drawn up for solving problems of economic designing of a network of water storage basins and for flood attenuating resulting from rain in the Transylvanian high plains. By establishing the overflow spillway discharge, the economic solution is being substantiated.

INTRODUCTION

The storage ponds are provided with a water discharge installation, called in brief overflow spillway.

The water discharges resulting from (Q) getting into the basin present a variation in time (Fig. 2a) according to a curve which has at least a maximum (point M); the overflow spillway discharges (Fig. 2a) also present a variation in time and a maximum (point N). The high water discharges are variabled on which, in general, we can act only sometimes and to a reduced extent (we shall not dwell on it, in this study).

According to equation (1), the overflow spillway discharge depends on two variables (the base and height of the overflow spillway wave) which we can modify in such a way as they should correspond to an economic minimum reflected in the size of the overflow spillway of the dam, such as earth works, concreting, etc.

$$QU = \mu w \sqrt{2gh} \tag{1}$$

where:

QU — represents the overflow spillway discharge [m³/s]
μ — the coefficient in keeping with the type and form of the overflow spillway (in this case 0.35);
w — section of the overflow spillway [m²], that is: base × the overfall wave
g — acceleration of gravitation
h — height of the overflow spillway water (Fig. 1)

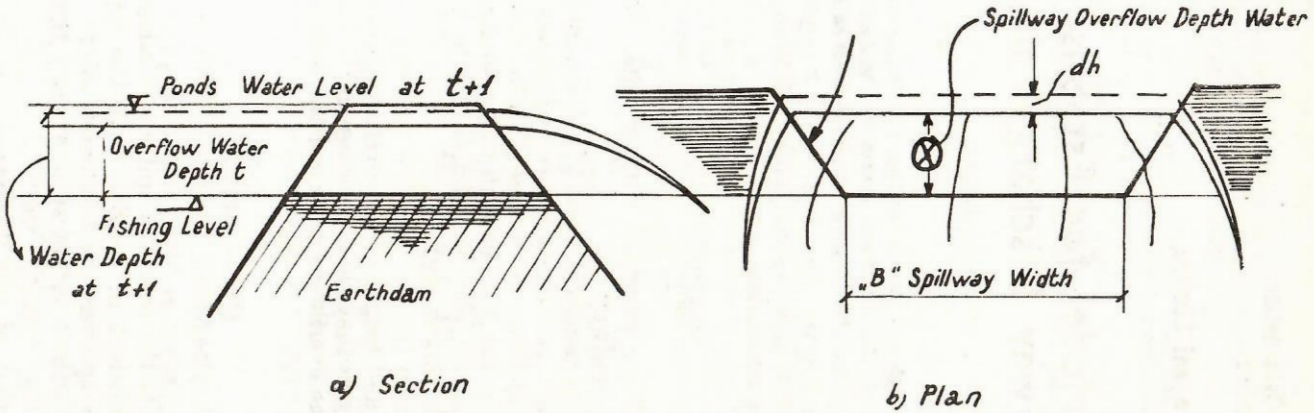


Fig. 1. PLAN SPILLWAY OVERFLOW CHARACTERISTICS

2. OBJECTIVE OF THE STUDY

It is requested o establish for a high water taking place in a zone and characterized by a succesion of flows $Q(i)$ $(i = 1,..., m)$ (Fig. 2a) arriving at times $T(i)$ $(i = 1,...,m$: 1) the overflow spillway maximum discharge QU in time (Fig. 2a) respectively point N) for a series k of overfall B_k, $k = 1,...mk$ widths and knowing the charcateristics of the attenuation basin (Fig. 2b), that is volumes $V_{(j)}$, $j = 1,...,n$ which can be stored at a various levels $H_{(j)}$, $j = 1,...,n$, n, being the number of levels for which we have values for the volumes storable in the basin.

A level called HPIS (fisheries control level) is sometimes used in the calculus, as a start.

3. THEORETICAL BASIS

The balance ratio of the basin lies at the basis of the calculus just as in any problem of stocks:

$$QU \cdot dt + S \cdot dh = W \tag{2}$$

where:

- QU — represents spillway discharge in an established time interval
- dt — the time interval studied from t to $t + 1$ (Fig. 1 a)
- S — the surface of the water in the basin at an established level
- dh — the increase or decrease in the height of the water in the basin, respectively of the overflow spillway water (fig. 1b) at the end of the analysed period.
- W — the variation of the quantity of water in the basin in the same time interval.

Expression Sdh — which corresponds to the volumes of water storage in the basin noted with V_j according to case may take positive and negative values. We mention that QU depends on dh.

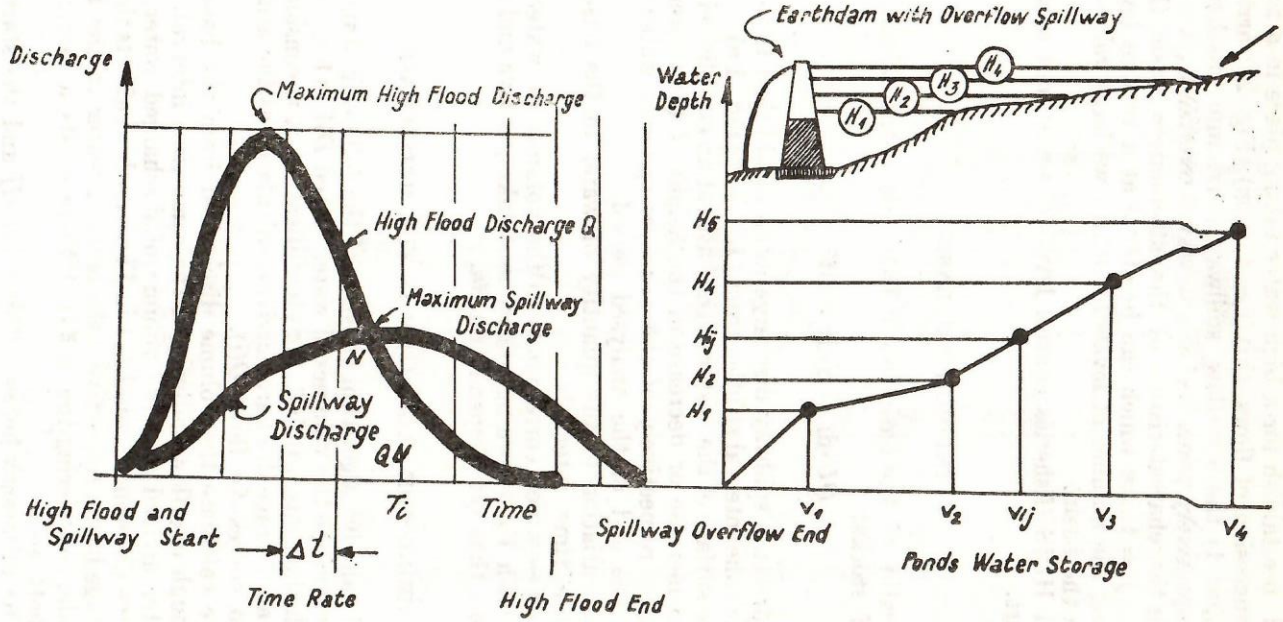
4. DESCRIBING THE ALGORITHM IN THE MAIN PHASES

The proposed calculus algorithm consists of the following stages:

Stage I: We calculate the volumes of water (noted DW in Fig. 3) arriving in the basin at each time interval DT. For simplification, it is considered that in a time interval, an average discharge arrives, calculated as the arithmetical mean between two successive flows $Q(i)$.

Stage II: We calculate the volume discharged from the basin (noted DU in Fig. 3) through overflow spillway in the same time interval. Between the volume of water arrived and the volume of discharged water, there is a positive or negative difference (noted DA in Fig. 3), which affects the volume of water in the storage basin, respectively the level of water in the basin Hj. The calculus is made, considering the fact that there exists a linear increase (a simplifying hypothesis).

Stage III: The difference between this level Hj and the starting level HPIS is considered to be the average height of the overflow spillway wave in the analysed period of time (a simplifying hypothesis). With this wave we



a) High Flood and Spillway Discharge

b) Storage Ponds Characteristics

Fig. 2 DATES FOR SPILLWAY OVERFLOW DISCHARGE COMPUTATION

calculate provisionally the adequate discharge of a spillway, QUC, with a B width of the wave. The calculus is considered to be sufficiently exact if the difference between QUC and QU is smaller than a given error. Considering the precision of establishing with an error of 0.000005, required by the designer, the overfall discharge (and, which reflects the correspondence between the quantity of water stored in the basin and that overflow spillway, fallen in a time interval) it was necessary to use the following seeking method: when the QUC flow does not correspond to discharge QU, the mean is made between the two flows and the calculus in the second stage is written with this new flow. If, in a given number of iterations, usually 100, the mentioned error was not attained, one passes to the next interval with the last mean. The program also envisages that in the zone where the maximum of the overflow spillway discharge takes place (and, each maximum separately) for determing it with greater precision — the time intervals should be automatically made more frequent with the adequate calculation of the high water discharges. Aftewards, each interval is covered until the high flood discharges Q_i are consumed. The calculus may be continued for establishing the overflow spillway flows until the wave becomes equal to zero.

Several overfall widths (B) can be checked automatically through the program.

Figure 3 presents a simplified logical scheme; the program was conceived in PL-1 and the run was made on IBM 360 and 370.

The table presents an example of the calculus made.

5. CONCLUSIONS

1. The calculus program establishes with high precision the overflow spillway maximum discharge, which is necessary for optimizing the execution economic solution.

2. The programme is part of a program deck with a view to optimizing the solution of the entire chain of accumulations.

MODELE MATHEMATIQUE POUR DETERMINER LES DEBITS DEVERSES PAR LES BASSINS D'AMORTISSEMENT DES HAUTES EAUX ORDINAIRES

On présente un procédé original de recherche euristique du débit déversé. Le modèle a été conçu pour résoudre certains problèmes de la projection économique d'une suite de bassins d'accumulation et d'amortissement des hautes eaux ordinaires, résultat des pluies sur le plateau de Transylvanie. En établissant le débit déversé on etaie la solution économique d'exécution.

МАТЕМАТИЧЕСКАЯ МОДЕЛЬ ОПРЕДЕЛЕНИЯ РАСХОДОВ ПЕРЕЛИВА ВОДЫ ИЗ БАССЕЙНОВ УМЕНЬШЕНИЯ ПАВОДКОВ

В настоящей статье представляется оригинальный способ эвристического изыскания расхода перелива воды. Модель была разработана для решения задач экономичного проектирования цепи бассейнов накопления и уменьшения паводков в результате дождей на плоскогорье Трансильвании. Путем установления расхода прелива воды обосновывается экономичное решение выполнения.

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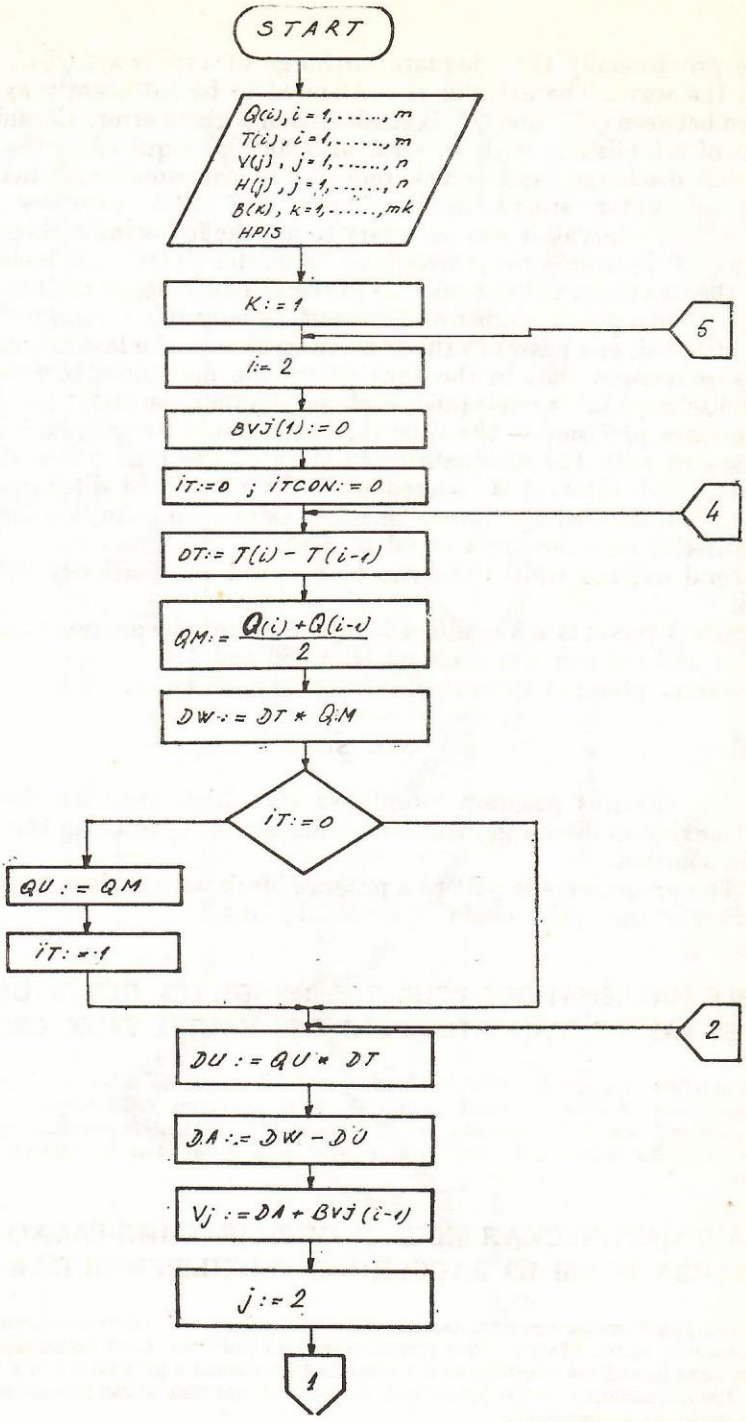

START
Q(i), i = 1, ..., m
T(i), i = 1, ..., m
V(j), j = 1, ..., n
H(j), j = 1, ..., n
B(K), K = 1, ..., mk
HPIS
K := 1
5
i := 2
BVJ(1) := 0
iT := 0 ; iTCON := 0
4
DT := T(i) - T(i-1)
QM := Q(i) + Q(i-1) / 2
DW := DT * QM
iT := 0
QU := QM
iT := 1
2
DU := QU * DT
DA := DW - DU
Vj := DA + BVJ(i-1)
j := 2
1

Fig. 3

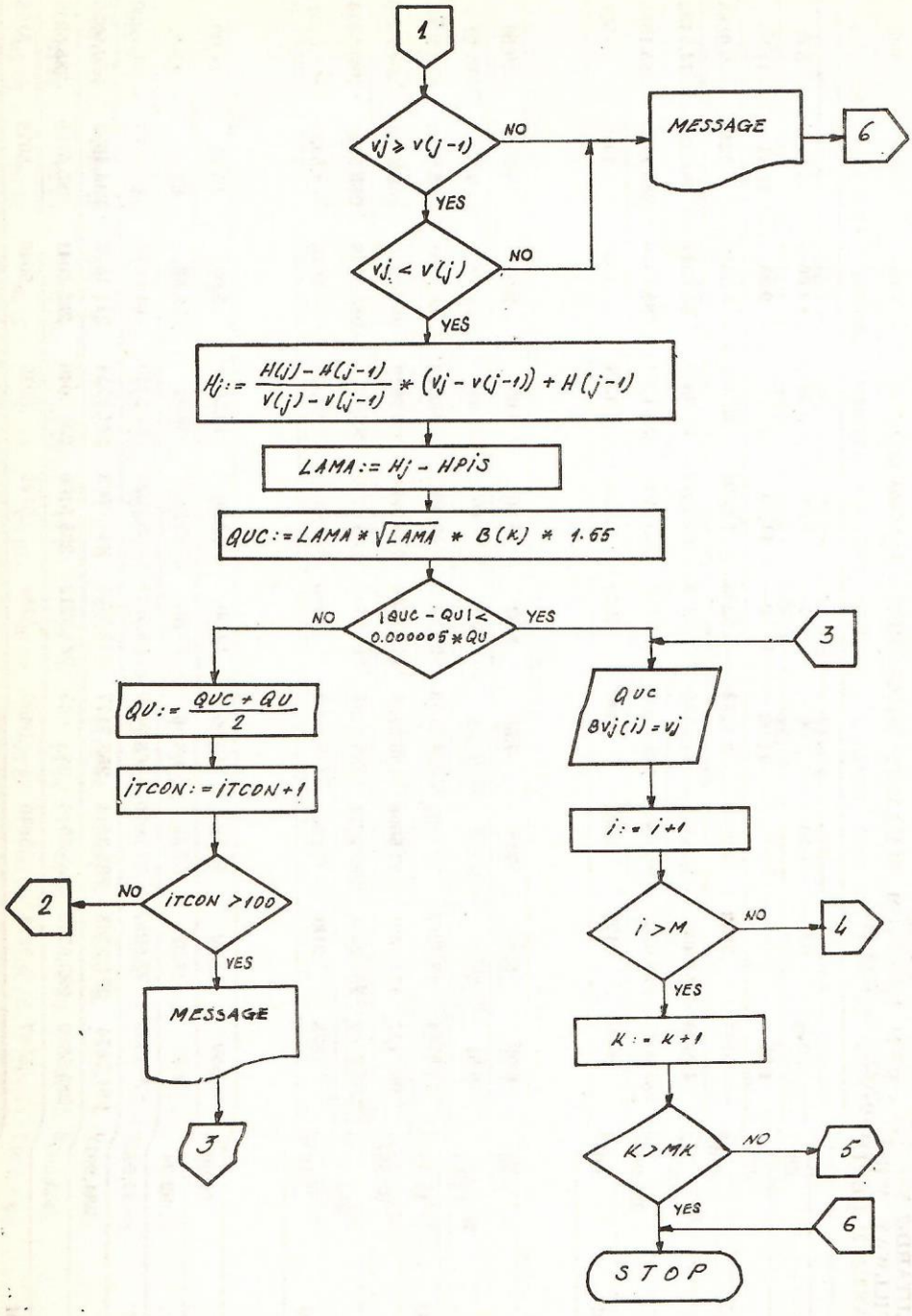


Fig. 3 (continued)

SCUTARD-2 Var. 10-g. ASIG 1% Storage
SPILLWAY WIDTH = 110 M MAXIMUM SPILLWAY DISCHARGE = 117.8694 MC/S
MAXIMUM DEPTH WATER = .7818 M

T	.00	.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00
Q	.00	1.25	2.50	6.75	11.02	17.09	11.78	10.25	9.33	10.31	11.96
QU	.0093	.0797	.3843	1.2693	3.1282	5.5268	7.2491	8.0483	8.5042	9.0249	9.9168
V	1.0916	4.2130	11.4081	23.9616	41.4386	55.3473	61.1517	63.8225	65.8347	69.0518	74.5492
H	285.0023	285.0088	285.0238	285.0501	285.0866	285.1157	285.1278	285.1334	285.1376	285.1443	285.1558
LM	.0014	.0060	.0172	.0381	.0696	.1017	.1218	.1306	.1355	.1410	.1501

T	5.50	6.00	6.50	7.00	7.50	8.00	8.50	9.00	9.50	10.00	10.50
Q	15.12	19.51	25.34	32.13	39.63	48.02	57.10	65.92	74.07	80.35	83.71
QU	11.4454	13.8784	17.4265	22.1833	28.1379	35.2428	43.3207	51.9723	60.5991	68.3910	74.3588
V	83.3874	96.1192	112.7401	132.5666	156.9128	179.1860	204.2850	228.7949	251.0976	269.2198	281.0456
H	285.1743	285.2009	285.2356	285.2771	285.3238	285.3745	285.4270	285.4782	285.5248	285.5627	285.5874
LM	.1652	.1878	.2186	.2568	.3009	.3496	.4012	.4529	.5018	.5439	.5751

T	11.00	11.50	12.00	12.50	13.00	13.50	14.00	14.50	15.00	15.50	16.00
Q	82.94	78.20	72.32	67.36	63.56	60.86	59.29	58.92	59.88	62.23	65.95
QU	77.5666	79.1889	75.5257	72.2090	68.7130	65.5811	63.1226	61.5440	61.0088	61.6447	63.5220
V	284.9919	281.7674	274.2788	265.3544	256.7177	249.3753	244.0003	241.1254	241.1876	244.4659	250.9820
H	285.5956	285.5889	285.5732	285.5546	285.5365	285.5212	285.5100	285.5040	285.5041	285.5109	285.5246
LM	.5915	.5997	.5811	.5640	.5456	.5289	.5156	.5070	.5040	.5075	.5178

T	16.50	17.00	17.50	18.00	18.50	19.00	19.50	20.00	20.50	21.00	21.50
Q	70.84	76.57	82.57	88.11	92.51	95.49	97.10	97.67	97.73	97.89	98.62
QU	66.6187	70.7829	75.6932	80.8607	85.7274	89.8263	92.9012	94.9468	96.1887	97.0060	97.8136
V	260.4187	272.0587	284.7620	297.1312	307.9022	316.2879	322.0823	325.6333	327.7217	329.3293	331.3631
H	285.5443	285.5686	285.5952	285.6210	285.6435	285.6610	285.6732	285.6806	285.6849	285.6883	285.6925
LM	.5345	.5565	.5820	.6081	.6323	.6523	.6671	.6769	.6828	.6866	.6904

T	22.00	22.50	23.00	23.50	24.00	24.50	25.00	25.50	26.00	26.50	27.00
Q	100.17	102.56	105.48	108.38	111.20	113.99	116.38	118.10	119.03	119.03	118.15
QU	98.9554	100.6224	102.7944	105.2957	107.9576	110.6475	113.1815	115.3391	116.9242	117.7902	117.8694
V	334.4587	338.8165	344.1099	349.8490	355.7565	361.5228	366.6688	370.7516	373.4130	374.4236	373.7484
H	285.6990	285.7081	285.7192	285.7312	285.7435	285.7556	285.7663	285.7749	285.7804	285.7825	285.7811
LM	.6958	.7036	.7137	.7252	.7374	.7496	.7610	.7706	.7777	.7815	.7818

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T	93.50	94.00	94.50	95.00	95.50	96.00	96.50	97.00	97.50	98.00	98.50
Q	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
QU	.3227	.2889	.2596	.2341	2.118	.1923	.1750	.1597	.1462	.1341	.1233
V	7.0445	6.5527	6.1098	5.7097	5.3472	5.0176	4.7172	4.4426	4.1910	3.9599	3.7472
H	285.0147	285.0137	285.0128	285.0119	285.0112	285.0105	285.0099	285.0093	285.0088	285.0083	285.0078
LM	.0153	.0142	.0132	.0124	.0116	.0108	.0102	.0096	.0090	.0085	.0081