LECTURE -6

KALININ-MILYUKOV METHOD OF FLOOD ROUTING

by

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INTRODUCTION

In a large number of techniques for solving a flood routing problem it is assumed that there is a single valued relationship between the river stage and discharge. It is well known that this is only an approximation and in reality the discharge is a function of the river stage as well as water surface slope which yields a looped rating curve. A more exact solution of the flood routing problem is obtained if a loop rating curve is considered instead of a single-valued rating curve.

A method of flood routing which takes into account the looped nature of the rating curve was presented by two Russian scientists — G.P. Kalinin and P.I. Milyukov. This approach is described here.

KALININ-MILYUKOV METHOD

The Kalinin-Milyukov method is a simple method of flood routing which takes into account the looped nature of the rating curve. Before discussing this method, the phenomenon of looped and steady state rating curve is being discussed.

It is well known that in a channel during a flood event, the maximum water surface slope occurs first, followed by maximum velocity, then maximum discharge and finally maximum stage. It is seen from the Fig. 1 that for a given discharge, there can be three different river stages corresponding to hydrograph rise, recession, and the steady state. It is clear that during the flood rise as well as recession, the river stage corresponding to the steady state will occur after a time Δt after the occurrence of the given discharge. Hence if the channel discharge measured at time t and stage measured at a time $(t+\Delta t)$ are used, one can obtain a single valued rating curve corresponding to the steady-state conditions. Based on this, one can also assume that discharge at the given site has a single valued relation with the river stage measured at a site located upstream at a distance for which the travel time of flood wave is Δt.

The Fig. 2 shows a reach of length Δx. Assume that there is a single valued relationship between the downstream discharge Q and the water stage z_s at the middle of the reach. Now the reach length Δx is to be determined.

Assume that uniform flow exists in the reach. The water surface is represented by ab whose slope is S_0. Now a perturbation is introduced such that the new water surface changes to a'b' but the discharge at section B, Q_B, is not changed, ie, $dQ_B = 0$. Since $Q=Q(z,S)$

$$dQ = (\partial Q/\partial z)dz + (\partial Q/\partial S)dS = 0$$

$$\text{or} \quad dz = (\partial Q/\partial S)dS \,/\, (\partial Q/\partial z) \tag{1}$$

consequent to above hypothesis, $dz_c = 0$ (see Fig. 2). If the water surface is a straight line, $dz = 0.5\Delta x * dS$. Hence the above equation becomes

$$\Delta x/2 = (\partial Q/\partial S)/(\partial Q/\partial z) \tag{2}$$

If the channel conveyance is denoted by K, $Q = K\sqrt{S}$ and the above equation can be written as

$$\Delta x/2 = K/(2\sqrt{S}\ \partial Q/\partial z) \tag{3}$$

Equation (3) can also be written as :

$$\Delta x/2 = Q/(2S\ \partial Q/\partial z) \tag{4}$$

With increase in Q, $\partial Q/\partial z$ also increases and hence Δx does not vary greatly with Q. The quantity Δx, also known as characteristic length, can be computed from equation (4) so that there is a single value relationship between the discharge at B and the river stage at point C. The time of propagation between points C and B corresponds to the time of arrival of discharge and the corresponding steady state river stage at B. Because of the above, this method requires that the computational grid points should be separated by a distance Δx.

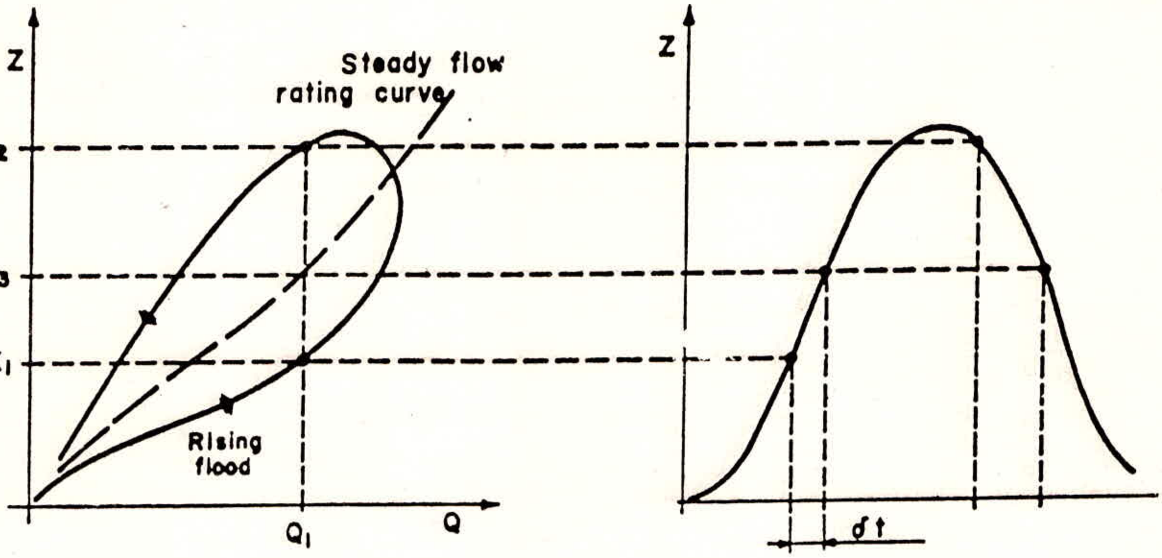

Figure 1. Variation of rive stage and discharge during a flood rise a recession.

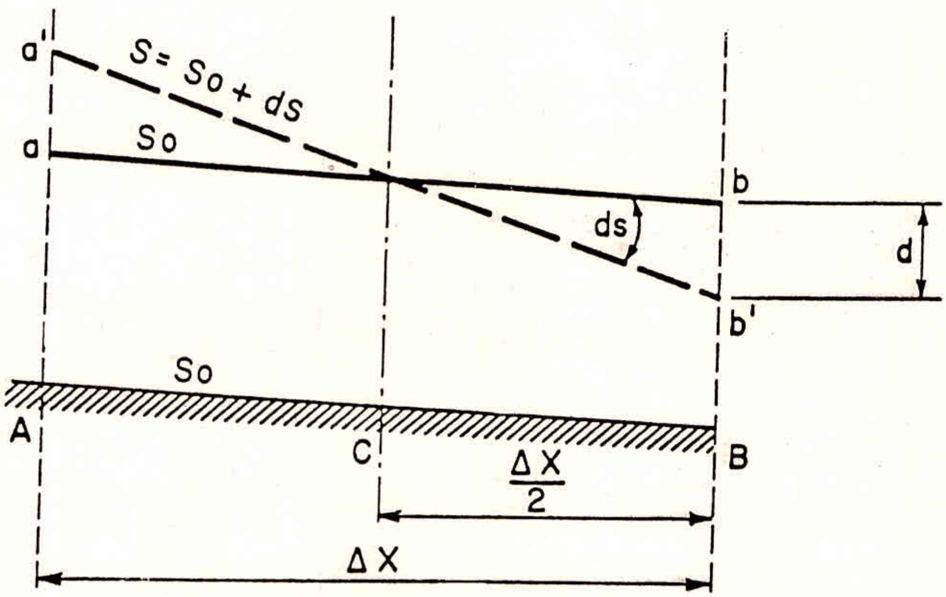

Figure 2. Illustration of the basic assumptions of th Kalinin-Miljukov method for a river reach.

It was pointed by Apollov et al(1970) that considerable underrating of the characteristic length of the river reach does not greatly affect the accuracy of the results. However, if this length is fixed many times smaller or larger than the actual length, the errors in the calculation of the maximum water discharge may become considerable.

The river stage in a channel reach is related to the water volume in that reach, $W_{\Delta x}$. Since the discharge at section B are single valued connected with the stage at section C, one can write

$$W_{\Delta x} = f(Q_B) \tag{5}$$

The flood routing computations can now be carried out as follows :

a) The river reach is divided into a number of sub-reaches of length Δx and the relationship given by eq. (5) is prepared for each one of them.

b) The outflows for each successive reach are calculated using the the above relationship and the water balance equation :

$$(I_t + I_{t+1})*\Delta t/2 - (Q_t + Q_{t+1})*\Delta t/2 = W_{t+1} - W_t \tag{6}$$

where Q_t and I_t are the discharges at the downstream and upstream ends of the channel reach and Δt is the length of the time period.

The Kalinin-Milyukov method can also be considered to be a variant of the well known Muskingum method of flood routing. We consider the continuity equation :

$$\partial A/\partial t + \partial Q/\partial x = 0 \tag{7}$$

or

$$(dA/dQ)_{x_0} \quad (\partial Q/\partial t) + \partial Q/\partial x = 0 \tag{8}$$

Discretizing the second term as :

$$\partial Q/\partial x \approx [\, Q_t - I_t]/ \Delta x \tag{9}$$

If $c = (\partial Q/\partial A)$ is the celerity of the wave carrying discharge Q, the eq. (8) can be written as :

$$\Delta x/c \;\; dQ/dt + Q(t) - I(t) = 0 \qquad (10)$$

If the time of propagation of a given discharge through the reach length, $\Delta x/c = \tau$ is constant, the reach length Δx becomes fixed.

Simplifying equation (10), one obtains

$$dQ/dt + Q_t/\tau = I_t/\tau \qquad (11)$$

Solution of this equation yields

$$Q_{t+1} = Q(t_{t+\Delta t}) = Q_t + (I_t - Q_t)k_1 + \Delta I K_2 \qquad (12)$$

where

$$k_1 = 1 - \exp(-\Delta t/\tau); \quad k_2 = 1 - \tau\, k_1/\Delta t; \quad \tau = \Delta x/c \qquad 13)$$

The equation (13) can be used to compute outflow hydrograph from a reach if the inflow is known.

ASSUMPTIONS OF KALININ-MILYUKOV METHOD

The main assumptions of the Kalinin-Milyukov method are :

a) The discharge is a function of flow depth and the slope of the water surface.

b) The loop rating curve at a section for unsteady flow can be reduced to a single valued curve by considering the discharge at that section and flow depth at that section observed after a known time interval(which depends on the flow velocity).

c) The steady flow regime in the channel reach is replaced by the unsteady flow regime in such a way that the discharge at the end of the reach does not change.

d) The new slope of the water surface under the unsteady conditions is constant throughout the reach.

COMPARISON OF KALININ-MILYUKOV AND MUSKINGUM METHOD

It may be mentioned that the Kalinin-Milyukov method is same as the Muskingum method of flood routing if in the Muskingum method, $K = \tau$ and $X=0$ and Δx is computed according to the equation (4). It has been reported that between the two, the Kalinin-Milyukov method is better because in this method Δx and τ are computed using a direct approach rather than through trial and error. Further, Miller and Cunge(1975) pointed out that the Kalinin-Milyukov method gives better results for water stages.

SOLUTION ALGORITHM OF KALININ-MILYUKOV METHOD

The problem of flood routing using the Kalinin-Milyukov method can be solved using the following steps :

1. For the reach for which the rating curve is available, obtain the value of Q, ΔQ, Δz, S from the rating curve. Assuming the flow to be steady state, find Δx as :

$$\Delta x = Q/(S\ \Delta Q/\Delta z)$$

An average of the Δx values obtained from the same rating curve as a function of Q should be used.

2. For every reach, plot the curve showing the relationship volume of reach vs water stage, $\beta=\beta(z)$. Using the rating curve, plot the curve of volume of reach vs discharge, $W = W(Q)$.

3. Compute for all reaches propagation time $\tau = \Delta W/\Delta Q$. There may be several values of τ for the same reach, varying with Q.

4. Choose a time step size Δt greater than τ. It will be preferable to use a constant Δt through the computations.

5. Compute the coefficients k_1 and k_2 using the eq. (13).

6. Now the outflow hydrograph ordinates corresponding to the ordinates of inflow hydrograph can be computed using the eq. (12).

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