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COMPUTATION OF DYNAMIC WAVES IN CHANNEL NETWORKS

by
IWASA, Y., Professor
and
GARG, A. K., Ph.D. Student
Department of Civil Engineering
KYOTO UNIVERSITY

1. INTRODUCTION

For subcritical flows in an open channel network, mutual backwater effects exist among the channel branches joining at a junction. Therefore, the branches can not be treated individually when a dynamic wave model is adopted to route floods in an open-channel network. Ideally, the entire network should be considered as a single unit and flow in all the channels and junctions should be solved simultaneously.

This paper presents an extension of our earlier work(ref.1) on four point implicit method. In this study four point implicit scheme for dynamic wave model to simulate the flood flow in channel network is presented. A sparse matrix algorithm is used to store and solve the linear set of non-banded, non-symmetric equations resulting from solving the complete propagation problem as a single unit.

2. DESCRIPTION OF IMPLICIT SCHEME USED IN NUMERICAL ANALYSIS

Gradually varied unsteady flow in open channels is mathematically described by a set of one dimensional shallow water equations commonly known as the Saint-Venant equations. These equations are

$$\partial A/\partial t+\partial Q/\partial x=0 \tag{1}$$

$$\partial Q/\partial t+\partial(\alpha Q^2/A)/\partial x+gA(\partial h/\partial x+S_f)=0 \tag{2}$$

Hydraulic conditions at a junction may be described by the continuity equation

$$Q_k=Q_o \tag{3}$$

and the dynamic equation

$$h_k=h_o \tag{4}$$

Where A is the flow area, Q the discharge, S_f the friction slope, t the time, h the water surface elevation above a reference horizontal datum, g the acceleration gravity. The subscript k stands for any one of the in-flowing channel and o represents the outflowing channel. α, momentum correction coefficient.

By using the four point implicit method, the eq.(1) and (2) are expressed as follows:

$$\frac{1}{2\Delta t}[(A_{i+1}^{n+1}+A_i^{n+1})-(A_{i+1}^n+A_i^n)]+\frac{1}{\Delta x}[\theta(Q_{i+1}^{n+1}-Q_i^{n+1})+(1-\theta)(Q_{i+1}^n-Q_i^n)]=0 \tag{5}$$

$$\frac{1}{2\Delta t}[(Q_{i+1}^{n+1}+Q_i^{n+1})-(Q_{i+1}^n+Q_i^n)]+\frac{\alpha}{\Delta x}[\theta\{(Q^2/A)_{i+1}^{n+1}-(Q^2/A)_i^{n+1}\}+(1-\theta)\{(Q^2/A)_{i+1}^n-(Q^2/A)_i^n\}]+\frac{g}{2}[\theta(A_{i+1}^{n+1}+A_i^{n+1})+(1$$

$$-\theta)(A_{i+1}^n+A_i^n)][\frac{1}{\Delta x}\{\theta(h_{i+1}^{n+1}-h_i^{n+1})+(1-\theta)(h_{i+1}^n-h_i^n)\}+1/2\{\theta(Sf_{i+1}^{n+1}+Sf_i^{n+1})+(1-\theta)(Sf_{i+1}+Sf_i)\}]=0 \tag{6}$$

Where θ is the weighting parameter on which the stability of solution depends. Kanda and Kitada (ref.4) have reported that the solutions are most favorable for θ=0.55~0.60. In this study 0.57 value was used for θ.

As can be observed in Fig.1, the channel reach has two confluences and the conditions at the confluence shown in Fig.2 are

$$h_1=h_2=h_3 \tag{7}$$

$$Q_3=Q_1+Q_2 \tag{8}$$

The Newton iteration method is used for the solution of this system.

3. INFORMATION USED IN NUMERICAL ANALYSIS

(i) The channel reaches subject to analysis are:

Downstream; Hirakata, 26.0 Km. from the estuary(The flood control project for the downstream Osaka metropolitan area provides the reference point of the project at Hirakata).

Upstream; Danmen 17, 50.2 Km. up the main stream(the Uji River), which is 2.0 Km. downstream from the Amagase reservoir

Kamo, 67.0 Km. the Yodo-Kizu and
Noso, 39.5 Km. up the Yodo-Katsura.

(ii) Channel Sections:

The survey results of 1974 is used for the simulation.

(iii) Channel roughness:

The Manning formula has been used for all the river channels. The roughness coefficients are

n=0.03 for the Uji and Kizu Rivers
n=0.04 for the Katsura River

(iv) Downstream boundary condition:

The stage-discharge curve at Hirakata, the reference point of the flood control project, is given.

(v) Upstream boundary condition:

Flood hydrographs resulting from heavy typhoon rainfalls in September 1953 are given for upstream boundary conditions, which are in Fig.3. The hydrograph for the Uji River shows a working behavior of flood control at the upstream Amagase Reservoir.

(vi) Initial condition:

Non-uniform flow was initially assumed throuhout all the channel reaches and the water stages of rivers have been computed by the Standard step method of analysis for gradually varied flows in open channel hydraulics.

4. CONCLUSION

A general numerical model based on four point implicit method for flood routing in non-prismatic channels have been formulated. Analytic differentiation is used to evaluate the partial derivative terms in the linear equations that are used to calculate the flow corrections. These partial derivative terms are stored and then solved using a sparse matrix storage technique. The use of these techniques has allowed significant saving in both the computer storage and computational effort required for simulations of flows within channel networks. The proposed model has been found to have the same convergence and stability characteristic as when applied to a single channel propagation problem. Simulations of flows in channel networks have shown the proposed model to require a much smaller quantity of computer memory, very less computational costs and accuracy and stability under a wide range of time increments. Because of the lacking of actual field data, the accuracy of the results were checked with the result of characteristic method calculated by Iwasa et. el. (ref.2) for the same flood. The results are shown in Fig.4-6. Fig.4 and Fig.5 shows the calculated stage and discharge hydrograph at Ingenbashi and Yawata, the two important downstream point in Uji River, respectively by the two method. Fig.6 shows the calculated stage and discharge hydrograph at Hirakata (a downstream end) by the two method. All the computations have been performed by use of FACOM M382 computer system at Kyoto university. CPU time for simulation of the flood in Yodo River was 37 sec. While with the Characteristic method it was found 1 min.15 sec.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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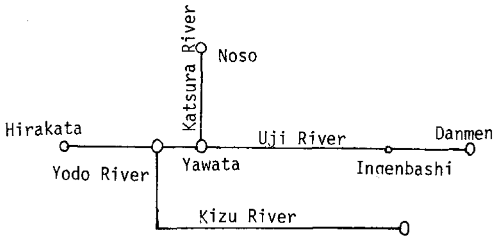

Fig.1 Network of Yodo River

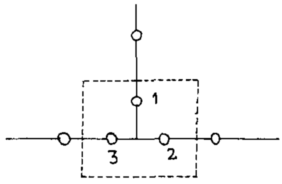

Fig.2 Confluence

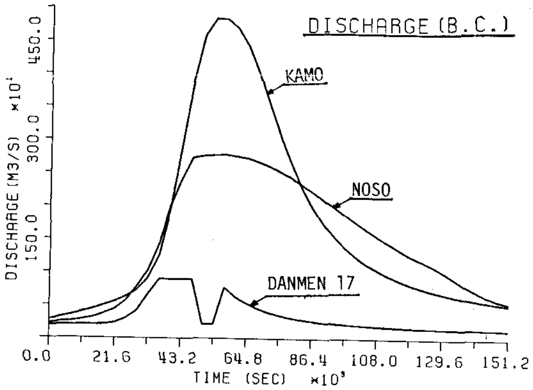

Fig.3 Discharge hydrograph at Upstream boundary ends

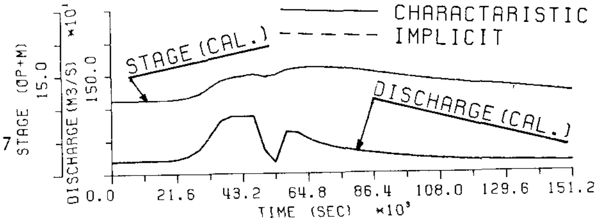

Fig.4 Stage and Discharge hydrographs at Ingenbashi

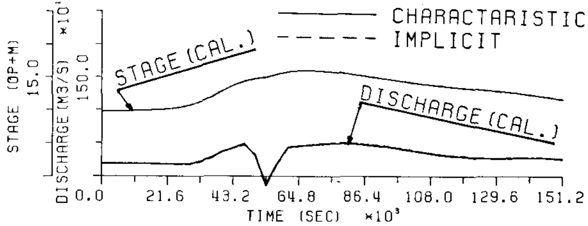

Fig.5 Stage and Discharge hydrographs at Yawata(Uji)

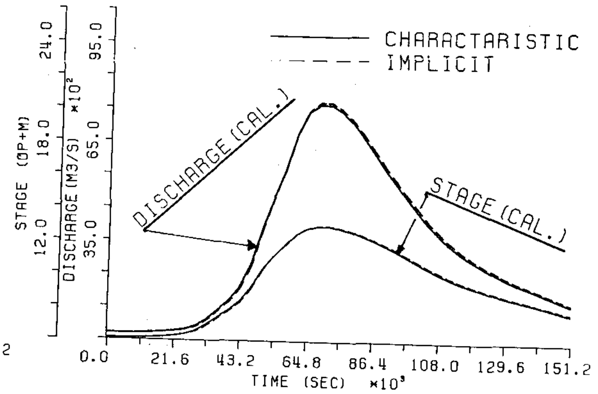

Fig.6 Stage and Discharge hydrographs at Hirakata(downstream point)