FLOOD ROUTING A REVIEW OF NUMERICAL MODEL APPLICATIONS

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Abstract - Flood is a natural phenomenon and generally causes heavy damage to natural systems as well as human lives. Hence to avoid adverse effects and losses caused by flood, 'flood Routing' is necessary.. Traditional physics based methods require exogenous data and are generally time consuming whereas numerical model like: MIKE 11, can work with the available data with less time period along with improved accuracy. Therefore researchers tend towards the numerical models rather than the traditional ones. Considering this, present work aims in reviewing different applications of MIKE 11: a numerical model for flood routing. Though this type of review is not an innovation in research but certainly can provide a useful trail to upcoming research.

Keywords: Flood, flood routing, technique, numerical model, MIKE 11.

I. INTRODUCTION

Flood is a high stage in river, normally level at which river overflows its bank and inundates the adjoining area. Flood has caused many damages and losses to lives, properties, etc. There are some major floods which had occurred in India. Many people, properties, animals, etc. are adversely affected due to flood.

So, flood is a natural disaster which causes heavy damages. Flood cannot be avoided as it is a natural phenomenon. But we can avoid such damages caused by flood just by giving a prior warning about flood so that the people residing over there will evacuate the place as early as possible. This early warning can be given if we can route the flow which will be helpful o predict rise in water level and it will be possible to avoid such conditions. Thus flood routing is essential now days.

Flood routing is a technique of determining the flood hydrograph at a section of a river by utilising the data of flood flow at one or more upstream sections.the hydrologic analysis of problems such as flood forecasting, flood protection, reservoir design and spillway design invariably include flood routing. In these applications two broad categories of routing can be recognised:

1.Reservoir routing: In Reservoir routing, effect of flood wave entering a reservoir is studied.

2.Channel routing: In channel routing, change in shape of hydrograph as it travels down a channel is studied [4].

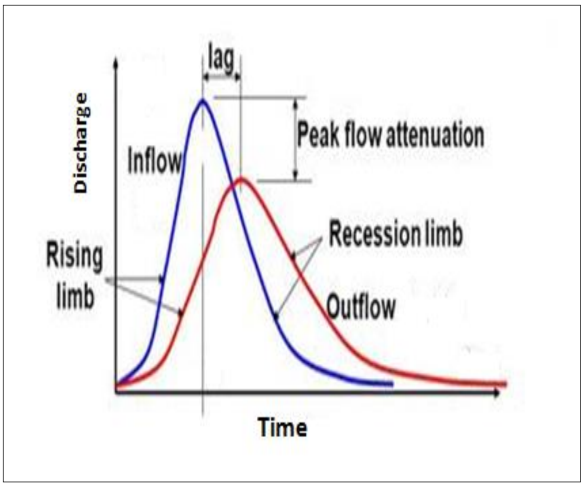

Fig No. 1: Flood routing hydrograph [4]

II. INTRODUCTION TO FLOOD ROUTING METHODS

A. Muskingum Method

$$S = K[x\,I + (1 - x)\,Q] \qquad (1)$$

This is Muskingum equation. In this, parameter x is known as weighting factor and takes value between 0 and 0.5 whereas the coefficient K is known as storage-time constant.

For a given channel reach by selecting a routing interval Δt and using the Muskingum equation, the change in storage is

$$S_2 - S_1 = K[x(I_2 - I_1)] + (1 - x)(Q_2 - Q_1) \qquad (2)$$

Where suffixes 1 and 2 refer to the conditions before and after the time intervalΔt.

The continuity equation for the reach is

$$S_2 - S_1 = \left(\frac{I_2 + I_1}{2}\right)\Delta t - \left(\frac{Q_2 + Q_1}{2}\right)\Delta t \qquad (3)$$

From above equations, Q_2 is evaluated as

$$Q_2 = C_0 I_2 + C_1 I_1 + C_2 Q_1 \qquad (4)$$

Where

$$C_0 = \frac{-Kx + 0.5\Delta t}{K - Kx + 0.5\Delta t} \qquad (5)$$

$$C_1 = \frac{Kx + 0.5\Delta t}{K - Kx + 0.5\Delta t} \qquad (6)$$

$$C_2 = \frac{K - Kx - 0.5\Delta t}{K - Kx + 0.5\Delta t} \qquad (7)$$

This equation is known as Muskingum Routing equation and provides the simple linear equation for channel routing. It has been found that for best results the routing interval Δt should be so chosen that K > Δt > 2Kx, the coefficient C_0 will be negative. Generally negative values of coefficient are avoided y choosing appropriate values of Δt [4].

To use Muskingum equation to route a given inflow hydrograph through a reach, the values of K and x for the reach and the values of outflow, Q_1, from the reach at the start are needed. The procedure is indeed simple.

- Knowing K and x, select an appropriate value of Δt.
- Calculate C_0, C_1 and C_2.
- Starting from the initial conditionsI_1, Q_1 and known I_2 at the end of first time step Δt calculate Q_2 by Muskingum equation.
- The outflow calculated in step (c) becomes the known initial outflow for the next step. Repeat the calculations for the entire inflow hydrograph.
  The calculations are best done row by row in tabular form. Spreadsheet such as MS Excel is ideally suited to perform the routing calculations and to view the inflow and outflow hydrographs [4].

B. A Numerical Method (Mike 11)

MIKE 11 is professional engineering software used for simulation of flows, water quality and sediment transport in estuaries, river, irrigation system, channels and other water bodies. MIKE 11 is a user friendly, fully dynamic, one dimensional modeling tool for the detailed analysis, design, management and operation of both simple and complex river channel system. With its exceptional flexibility, speed and user friendly environment, MIKE 11 provides a complete and effective design environment for engineering, water resource, water quality management and planning application [1].

The Hydrodynamic (HD) module is nucleus of MIKE 11 modeling system and forms the basis for most modules including flood forecasting, advection-dispersion, water quality and non-cohesive sediments transport module. The MIKE 11 HD module solves the vertically integrated equation for the conversion of continuity and momentum equation i.e. St. Venants equation [1].

Governing equations used (Shaikh Alfiya et al.2015):

Continuity equation

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \quad (8)$$

Momentum equation

$$\frac{\partial Q}{\partial t} + \frac{\partial\{\alpha\left(\frac{Q^2}{A}\right)\}}{\partial x} + gA\frac{\partial h}{\partial x} + \frac{gQ|Q|}{C^2\,AR} = 0 \quad (9)$$

Where, Q = Discharge, (m^3/s)

A = Flow area, (m^2)

q = Lateral inflow, ($m^3/m/s$)

h = Stage above datum, (m)

R = Hydraulic radius, (m)

C = Chezy's resistance coefficient

α = Momentum distribution coefficient

The four terms in the above momentum equation are local acceleration, convective acceleration, pressure and friction. In MIKE 11, a network configuration depicts the rivers and floodplains as a system of interconnected branches. Water-levels and discharges (h and Q) are calculated at alternative points along the river branches as a function of time as shown (Figure no.4.3.a). It operates on basic information from the river and floodplain topography to include manmade features and boundary conditions. The 6 point Abbott-Ionescu Finite Difference scheme for the dynamic, diffusive and kinematic wave approximation is used in MIKE11. The conservation of mass i.e. continuity equation is applied between elevation points and conservation of momentum is applied at discharge points [7].

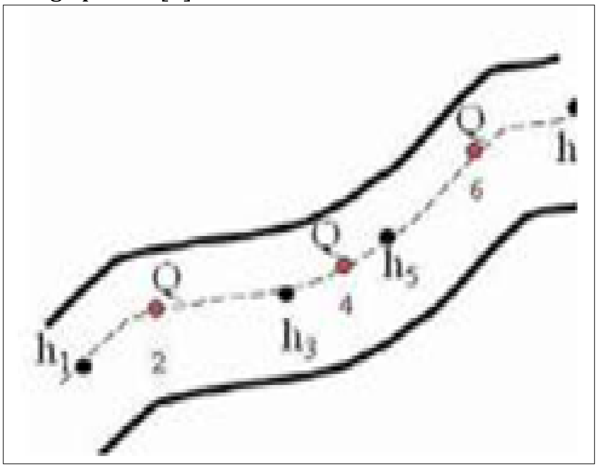

Fig No.2: Channel Section [7]

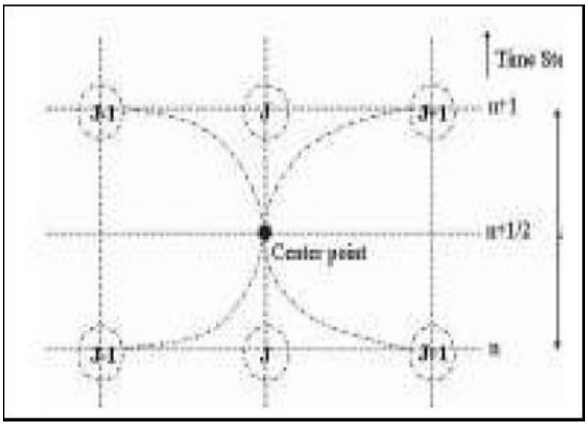

Fig No.3: Centered 6-point Abbott scheme [7]

C. Solution Scheme in MIKE 11

The finite difference scheme used in MIKE11 is 6-point Abbott scheme. A graphical view of this method is shown above (Figure no.1.3). As we can see at n+1/2 step the model bring data from steps n and n+1, so unknowns will obtain simultaneously for each time step. MIKE11model is fully implicit method to solve the problems and usually there is no limitation about computational steps[7].

D. Methodology for Model Setup

MIKE 11 includes multiple editors, each operating on different types of data. Where Data from these editors must be saved in separate editors, the integration and exchange of information between each of the individual data editors is achieved by use of the MIKE 11 Simulation editor. The Simulation Editor contains simulation and computation control parameters which are used to start the simulation as it provides a linkage between the graphical view of the network editor and the other MIKE 11 editors .The following steps have to be followed in order to setup the one-dimensional model [7].

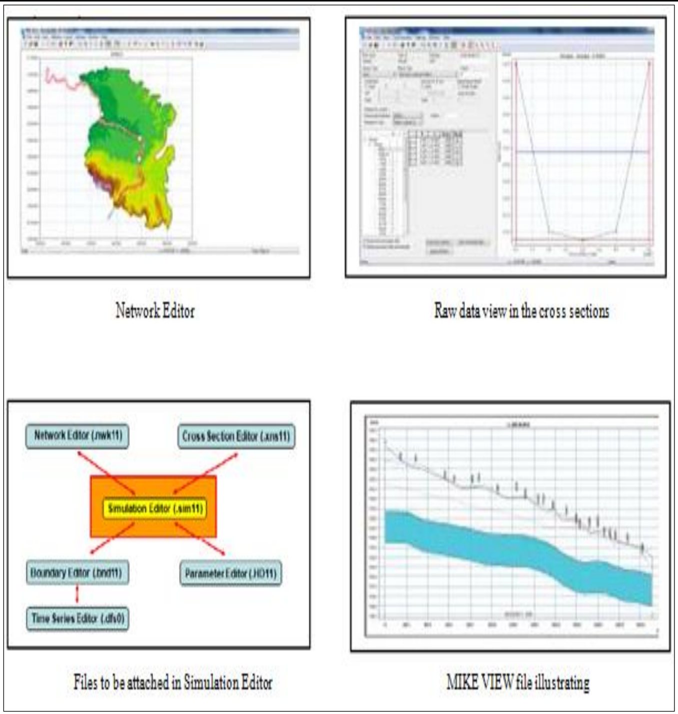

Fig No.4: Editors in MIKE 11 [7]

III. LITERATURE REVIEW

Since last decades or so many researchers have done application of MIKE 11 to route the flow and plethora of papers are available to study and which is a exhaustive task. Based on the hypothesis that a new advanced research at the latest time era in the same fields inherently covers the earlier basic concepts or sometimes obsolete the earlier concepts, only few major papers after 2007 (in last 10 years only) are reviewed in the present paper to study the applications of a numerical model (MIKE 11) to route the flow.

Kamel A. H. (2008) have done study on Application of A Hydrodynamic MIKE 11model for the Euphrates river in Iraq and concluded that that the MIKE 11 model gives a good simulation of the flow according to a comparison between the estimated and observed stage hydrograph and also the comparison between this model and the Uday model that was used for the same river explains that the MIKE 11 model give better simulation.

Ranaee E. et al. (2010) have done study on Sensitivity Analysis of River Flood Routing Model to Input Data, had concluded based on their study that this research is to offer a procedure to study the sensitivity of flood routing models to the input discharge statistics of different hourly time steps. In some case studies, it could be obvious that after calibration of river flood routing modeling; some of the first output statistics in ascending branch of output hydrograph are not acceptable. This error occurs because of the influence of flood volume which has been passed the upstream boundary cross section before the chosen initial time step for modeling; consequently, it could not been utilized as the boundary conditions definition for flood routing modeling software. Other words, it could be noticed that time range of initial and boundary conditions is larger than modeling one. During an innovative procedure; we used MIKE11 software as an acceptable river flood routing model; and also, different structures of artificial neural networks (ANNs) to compute the sensitivity of river flood routing to the number of previous time steps discharge which are effective in modeling accuracy.

Delphi M. (2011) have done study on Application of characteristics method for flood routing (case study : Karun River) and concluded that performance of MIKE 11 as numerical model is higher than characteristics method, because this model uses high order fully dynamic method for solving Saint-Venants equations.

Muku L. O et al. (2013) have done study on "River Flood Modeling with Mike 11: Case of Nzoia River (Budalangi) in Kenya" and concluded from their study that 1D hydrodynamic MIKE 11 model has been implemented for the lower part of the Nzoia river. The network file, cross-section file, boundary conditions file, and model parameter file has been created for this river. The components of MIKE 11 river hydrodynamic model were implemented efficiently for Nzoia River. For the MIKE 11 river model to be stable, specification of optimal time step and space step are required. The inappropriate selection of the time step normally leads to instabilities, depicted as warning and error reports after the simulation, which compromises the computed water levels in the river channel. This was noted especially when water level was calculated at a value less than the streambed elevation, the flow simulation crashes. Results from the scenarios investigations indicate that dykes breaching was the major cause of the 2008 Budalangi flood event. At the breached dykes, the water level was above the river embankment.

Timbadiya P.V. et al. (2014) have done study on "One-dimensional hydrodynamic modeling of flooding and stage hydrographs in the lower Tapi River in India" and concluded from their study that simulation of the floods during 2003 and 2006 was performed using MIKE 11 HD, and the results were validated for different gauging stations along the lower Tapi River. The present study addresses the simulation of floods for the years 2003 and 2006 and the development of stage–discharge relationship along the lower Tapi River in India. The MIKE 11 hydrodynamic model was calibrated for the 1998 flood using releases from the Ukai Dam (flood hydrograph) and the tidal water level in the Arabian Sea as the upstream and downstream boundary conditions respectively. The calibrated model was validated using low- and high-flood data of the years 2003 and 2006 respectively. The time series of the simulated flood levels were compared with the corresponding observed values at four intermediate gauging stations. The model performance was also evaluated using the standard performance index (i.e. root mean square error) and was found to be reasonably satisfactory for such a data-scarce region. The rating curves (i.e. stage–discharge relationship) were also developed from the aforesaid calibrated model which would be useful in flood forecasting and development of flood protection measures along the lower Tapi River.

Shaikh A. et al. (2015) have done study on "Application of MIKE 11 for flood forecasting (A Review)" and did a review on few major MIKE 11 applications specifically for flood forecasting which were done by earlier researchers in the last decade. In the present paper a detail review of MIKE 11 applications is presented through the different cases. It can be said that while the traditional and empirical methods requires huge data measurements and time consuming , the MIKE 11 which is completely based on theoretical Saint-Venant equations provides more accurate results within less time. MIKE 11. It is best simulation tool for flood forecasting which can be used effectively in the same field of interest and should be explored further in detail. Therefore it can be concluded that MIKE 11 is a powerful river modeling tool and its applications for flood forecasting proved to be efficient overall the entire world.

IV. CONCLUSION

In the present paper a detail review of few MIKE 11 applications (after 2007) is presented through the different cases which suffice the aim of the work. It can be said that while the traditional and empirical methods requires huge data measurements and comparatively greater consumption of time , the MIKE 11 which is completely based on theoretical Saint-Venant equations provides more accurate results within less time. It is clear from the above examples that when compared with the traditional methods MIKE 11 is proved its superiority. The inherent mathematical diffusion of Muskingum method shows a potential problem of under predictions whereas MIKE 11 overcomes this problem by providing more accurate and fast results. It is noticed that results generated by MIKE 11 can also be useful for generating the relationship among different hydrological variables. Also it is most useful technique for complex flood routing processes due to its powerful user-friendly river modeling toolbox with advanced features. It is evident from the earlier research that there is need of a technique which will work fast, give more accurate results along the reach which is successfully accomplished by MIKE 11. It can be said that MIKE 11 can effectively work as a simulation tool for flood routing and should be explored further in detail. Therefore it can be concluded that MIKE 11 can be a useful river modeling tool if explored further in depth.

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