Application of BRAHMA hydrodynamic model for flood forecasting

D Devi1, K M Chaudhury2 and A K Sarma3

1PhD Research Scholar, Department of Civil Engineering, Indian Institute of Technology Guwahati, India
2Assistant Project Engineer, Department of Civil Engineering, Indian Institute of Technology Guwahati, India
3Professor, Department of Civil Engineering, Indian Institute of Technology Guwahati, India

Abstract. Flood forecasting models are of paramount importance to predict the flood and thereby warning the community living near the floodplains or the vulnerable areas. In the quest for understanding the complex processes of a river, scientist and researchers have given importance to river modeling both analytically and physically by conducting experiments in the laboratory. The numerical model which is basically a mathematical model has gained popularity in the last few decades. BRAHMA (Braided River Aid: Hydro-Morphological Analyzer) is a hydrodynamic model for simulating the spatial variation in water depth, flows, and velocities in the unsteady free surface flow. It is developed by IIT Guwahati in collaboration with Brahmaputra Board, Govt. of India. The BRAHMA 1-D model is capable of simulating both prismatic as well as non-prismatic channel reach. It is also capable of simulating channels with varying width and varying slope. In this paper, an attempt has been made to use the BRAHMA 1-D model for determining the water surface elevation at certain flood-prone areas of Ranganadi River which covers Assam and parts of Arunachal Pradesh, North-East India. The Ranganadi hydroelectric dam is situated in Arunachal Pradesh, India. In this study, the length of the river reach considered is 77.09 km from the Ranganadi Hydroelectric power project. The cross-sectional width of the river in different sections is extracted from Google Earth and depth was obtained by approximate field measurement. The peak release from the dam, the downstream water level and initial water levels are given as input to the model. The water levels at the particular sections of interest are computed as output from the model. From the generated output data set, it is possible to assess the vulnerable areas by the water levels which will be generated from the model.

1. Introduction

Flood is one of the acute problems that the whole world is facing. This catastrophic event not only affects the land and property but also creates a fear psychosis among mankind. Thus, there has been an urgent need for the scientific community to take some steps against this calamity. Flood forecasting is nowadays proved to be very important to predict the flood beforehand and thereby providing early warning to take some managerial activity [9]. Monitoring of river behaviour is an essential part of forecasting [3]. Nowadays integrated flood forecasting techniques are gaining more popularity as it consists of a hydrologic and a routing mechanism. Dams also play a very important roles in accelerating country’s economy and also provide sustainable development towards hydropower generation, irrigation, water allocation etc. One important aspect is the alteration of the natural
flood events which can create anomalies to the hydrologic cycle thereby causing severe consequence to the ecosystem. It is important to investigate the downstream impact due to dam release. Flood owing to the presence of dam not only depend on the release from the dam but also depends on the water level of the main channel at the confluence point [7]. Thus, the dam release, the initial water level and the downstream water level are the major parameters that can be attributed when hydrodynamically modelled.

2. BRAHMA MODEL

BRAHMA is a hydrodynamic model developed by IIT Guwahati in collaboration with the Brahmaputra Board, Govt. of India. BRAHMA stands for Braided River Aid: Hydro-Morphological Analyzer. It has both 1D and 2D versions and can be applied to compute different flow parameters. It is capable of simulating both prismatic as well as non-prismatic channels. Continuity and momentum equations of unsteady free surface flow in different forms are used in BRAHMA model and has scope of solving through different numerical schemes. The St. Venant’s Equations, which is the basic form of the governing equation can be written in the following conservative form:

2.1. Continuity Equation:

\[ \frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = 0 \]  

(1)

2.2. Momentum Equation:

\[ \frac{1}{A} \frac{\partial Q}{\partial t} + \frac{1}{A} \frac{\partial}{\partial x} \left( \frac{Q^2}{A} \right) + g \frac{\partial v}{\partial x} - g(S_0 - S_f) = 0 \]  

(2)

Where

Q=discharge ,

A=cross sectional area,

g=acceleration due to gravity,

S_0=Bed slope,

S_f=Friction slope

The numerical methods used in this model are Predictor-Corrector, Beam and Warming [2] and Lax Diffusive method [6]. The Predictor-Corrector and Lax Diffusive are explicit schemes whereas Beam and Warming is an implicit scheme. In our study, Predictor-Corrector method has been used.

3. Study Area

Ranganadi River originates from the Himalayan foothills of Arunachal Pradesh. Ranganadi River is a major tributary of Subansiri. It extends from 27°35’39.55”N-93°16’15.23”E to 27°01’04.58”N-
94°09’49.48”E. The total area of the basin is around 2468 sq.km. The flow of the Ranganadi River is regulated by Ranganadi Hydroelectric Power Project (405 MW) located at Yazali with a concrete gravity dam maintaining a drawdown level of 567 m.

4. Purpose of the study
The purpose of this study is to use the BRAHMA 1D (Version 1.0) hydrodynamic model to get the maximum water surface elevations in the flood prone reach so that it can be used to provide flood warnings and help in reducing the hazards of flood.

Figure 1 Ranganadi basin.
5. Methodology

In this study, the length of river reach considered is 77.09 km from the Ranganadi Hydroelectric Power project. The cross sectional widths of the river in different sections were extracted from Google Earth. The depths were obtained by approximate field measurement. **BRAHMA 1D** (Version 1.0) works under the principle of one dimensional St.Venant’s Equations. The model has been used in this study to compute the maximum water surface elevations using the discharge from the dam, the downstream water level (DWL) and the initial water level (IWL) as input parameters. Using various combinations of the above mentioned parameters, a set of data series has been obtained. Regression Analysis is performed in order to find the correlations among the variables and to make predictions. Regression models with one dependent and several independent variables constitute a multilinear regression model. In this analysis, several combinations among the variables are structured to get the possible scenarios. A multi linear regression model is then developed from the series of dataset generated using the Data Analysis tool in excel. The regression analysis tool performs linear regression analysis by using the Method of Least Squares. The multivariate regression model can be formulated using the relation as

\[ y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \ldots + \beta_n x_n \]  

where \( y \) = Dependent variable  
\( x_i \) = Independent variables  
\( \beta_i \) = Coefficients  
\( \beta_0 \) = intercept

The response variable, i.e. the maximum water surface elevation is computed based on the independent variables which are the peak discharge, downstream water level and initial water level.

![Figure 2 Joinpur (27°6'51''N 94°5'4.2''E). Source: Google Earth](image)
Figure 2 shows the flood prone reach where output water surface levels are needed to be calculated. The area of due consideration is Joinpur which is at a downstream of the catchment.

![Figure 2](image2.png)

**Figure 3** Water Surface Profile from Ranganadi Hydroelectric Power Project to downstream

Figure 3 shows the water surface profile and bathymetry of the Ranganadi River from the Ranganadi Hydroelectric Power Project to the downstream of confluence point with the main channel.

**6. Results and Discussions**

From the generated datasets, a multilinear regression model is developed in order to predict the correlations among the dependent variable and the independent variables. The independent variables are peak discharge \(x_1\), \(DWL\) \(x_2\) and \(IWL\) \(x_3\). The dependent variable is the maximum water level \(y\) that is generated from the model.

The equation of the regression model is found to be as follows

\[
y = 0.00394x_1 + 0.526x_2 + 0.477x_3 \tag{4}
\]
Figure 4 (a) Water Levels generated from BRAHMA and RM at Joinpur, 
(b) Water Levels generated from BRAHMA vs RM corresponding to DWL=85.09m and IWL=89.03m

Figure 5 (a) Water Levels generated from BRAHMA and RM at Joinpur, 
(b) Water Levels generated from BRAHMA vs RM corresponding to DWL=84.09m and IWL=89.03m

Figure 4(a) shows the water surface levels at Joinpur considering the different downstream level and initial water level. From several combinations of the variables, the maximum possible DWL and IWL from the model has been found to be as 85.09m and 89.03m respectively. Keeping these two parameters fixed the change in the water levels developed by hydrodynamic model BRAHMA and the regression model (RM). Figure 5(a) shows the water surface levels considering the downstream level and initial water level as 85.09m and 89.03m respectively. A similar analysis has been conducted considering the above mentioned parameters to compare the two models. From the comparative analysis of Figure 4(a) and 5(a) it can be seen that if the value of the DWL is less, then the two models gives similar result.

Figure 4(b) and 5(b) shows the comparison curve of the water levels generated by BRAHMA and RM.
7. Conclusion

BRAHMA model has been found to be quite useful as a routing tool. In this study BRAHMA model has been used to generate the waterlevel in the desired section of interest. Scope of generating the regression model for quick estimation of flood depth at a section based on discharge, initial water level and downstream water level has been explored and encouraging result has been found. A similar analysis can be implemented on other sections which are vulnerable to flood. From this exercise it is seen that the BRAHMA model helps in generating flood scenarios for different initial conditions and the regression model developed based on these simulation results found to be efficient for early warning thereby minimising the consequences.

8. References

[1] Barman D. and Sarma A.K. Applicability of Cartosat Stereo Dem for Understanding Flooding Genesis – A case study from Pagladia river watershed in lower Assam, India, International Journal of Earth Sciences and Engineering (IJEE); 2013, Vol. 6, Issue 6(01) ISSN0974-5904
[2] Beam R M and Warming R F 1976 “An Implicit Finite-Difference Algorithm for Hyperbolic Systems in Conservation –Law Form” Jour. Comp. Phys., vol.22, pp. 87-110.
[3] Bolshakov V 2013 “Regression-based Daugava River Flood Forecasting and Monitoring” Information Technology and Management Science doi: 10.2478/itms-2013-0021 2013/16
[4] Chaudhry M H 2008. “Open Channel Flow Second Edition” Springer ISBN 978-0-387-30174-7
[5] Jain S K, et. al, 2018 “A Brief review of flood forecasting techniques and their applications” International Journal of River Basin Management ISSN: 1571-5124 (Print) 1814-2060 (Online)
[6] Lax P D, 1954, “Weak Solutions for Nonlinear Hyperbolic Partial Differential Equations and their Numerical Computation.” Communications on Pure and Applied Mathematics, vol.7, pp. 159-163
[7] Report on “Flood of North Lakhimpur vis-à-vis Ranganadi Hydropower Project” by Indian Institute of Technology for Assam State Disaster Management Authority.
[8] Uyanik G K and Guller N, 2013 “A Study on Multilinear Regression Analysis” Procedia- Social and Behavioural Sciences 106 (2013 ) 234 – 240
[9] WMO, 2011b. Manual on flood forecasting and warning, WMO No. 1072. World Meteorological Organization, Geneva.

https://www.telegraphindia.com/states/north-east/ranganadi-floods-yet-again/cid/1436149

Acknowledgment

We acknowledge Brahmaputra Board, Ministry of Water Resources, Govt. of India for providing fund for the development of the hydrodynamic model BRAHMA.